Energy Storage Roadmap for Michigan

Prepared for the **Michigan Department of Environment, Great Lakes and Energy (EGLE)**

with Partners

michigan EIBC

5lakes energy
Clean Energy & Environmental Consultants

Annick Anctil
Associate Professor
Civil & Environmental Engineering
MICHIGAN STATE UNIVERSITY

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PROJECT TEAM

The **Michigan Department of Environment, Great Lakes and Energy (EGLE)** is committed to promoting healthy communities, economic growth, and environmental sustainability through Energy Efficiency (Energy Waste Reduction) and Renewable Energy. EGLE assists, educates, and encourages Michigan communities to advance conservation and efficient use of energy resources so they may provide for a healthier environment and achieve greater energy security for future generations.

The **Institute for Energy Innovation (IEI)** is a Michigan-based nonprofit organization that works to promote greater public understanding of advanced energy and its economic potential for Michigan, and to inform the policy and public discussions on Michigan's energy challenges and opportunities.

The **Michigan Energy Innovation Business Council (Michigan EIBC)** is a trade organization of more than 140 companies working in the advanced energy industry in Michigan whose mission is to grow Michigan's advanced energy economy by fostering opportunities for innovation and business growth and developing policy solutions to create a business-friendly environment for the advanced energy industry in Michigan.

5 Lakes Energy is a Michigan-based policy consulting firm dedicated to advancing policies and programs that promote clean energy policy for a resilient environment.

Dr. Annick Anctil is an Associate Professor in the Department of Civil and Environmental Engineering at Michigan State University. For several years, Dr. Anctil has conducted research into second life use of electric vehicle batteries for residential storage, grid integration, and electric vehicle charging.

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EXECUTIVE SUMMARY

Across the country, policy makers, regulators, utilities, developers, and customers are increasingly aware of and enabling a shift to greater use of renewable electricity, electrification of buildings and transportation, and two-way power flows on the electricity grid. As the costs of energy storage continue to decline, it is increasingly clear that energy storage enables these trends, all while ensuring grid reliability and customer resiliency. It is also clear that the growing energy storage and related electric mobility industries represent economic and job growth opportunities.

However, in many states, including Michigan, state policies lag behind industry trends because the policies were not established with energy storage in mind. To determine how best to enable the deployment and growth of energy storage in Michigan, the Institute for Energy Innovation (IEI) and partners, on behalf of the Michigan Department of Environment, Great Lakes and Energy (EGLE), developed this Energy Storage Roadmap for Michigan ("Roadmap") as a guide for policy makers. This Roadmap is divided into two sections: Part I provides background information on energy storage and the current deployment of energy storage and Part II provides an overview of state and federal policies, results from industry research and modeling, and policy recommendations for Michigan.

As described in detail throughout this Roadmap, energy storage can provide a variety of services, many of which can be provided simultaneously to different end users. However, current market structures and regulatory frameworks do not always include clear mechanisms to capture the full value of energy storage systems and sometimes explicitly prohibit storage from offering its various services.

The project team conducted both behind-the-meter (BTM) storage modeling and bulk electricity system modeling to determine under what future conditions customers and utilities should deploy storage systems. Based on current utility plans to retire fossil-fuel generation and deploy renewable energy, we estimate that at a minimum, Michigan will need to deploy 2,500 MW energy storage by 2030 and 4,000 MW by 2040 to ensure grid reliability and avoid curtailment of renewable energy generation.[1] To ensure adequate progress toward these targets, we recommend that the state sets a short-term target of 1,000 MW of energy storage by 2025.

To achieve the level of energy storage deployment necessary to support Michigan's future grid, supportive state policies are critical. This Roadmap includes immediate, short-term (1 to 5 years), and long-term (>5 years) policy recommendations for the Governor/executive branch agencies, Michigan Public Service Commission, and Michigan Legislature. It is important to note, however, that several of these recommendations could be accomplished through actions taken by multiple branches of government working in parallel.

Executive

- Establish a target to deploy 4,000 MW of front-of-the-meter (FTM) storage by 2040, with a short-term target of 1,000 MW of FTM storage by 2025 and a medium-term target of 2,500 MW of FTM storage by 2030.[2]
- Conduct a "value of storage" study to quantify the benefits that storage can provide.

[1] Storage is described both in terms of capacity and energy (see for example, https://www.nrel.gov/docs/fy19osti/74426.pdf). As described in Section X, the costs of energy storage additions were determined based on a 4-hour duration proxy system. The nameplate capacity stated in MW is the maximum rate of discharge in a single hour and total energy available is assumed to be four times the nameplate capacity. For example, a 4,000 MW addition of battery storage would have a total capacity of 16,000 MWh. Storage resources may discharge at a rate less than nameplate capacity for greater than four hours but cannot exceed the maximum discharge rate in a given hour.

[2] As described in Section X, the costs of energy storage additions were determined based on a 4-hour duration proxy system. The nameplate capacity stated in MW is the maximum rate of discharge in a single hour and total energy available is assumed to be four times the nameplate capacity. For example, a 4,000 MW addition of battery storage would have a total capacity of 16,000 MWh. Storage resources may discharge at a rate less than nameplate capacity for greater than four hours but cannot exceed the maximum discharge rate in a given hour.

- Conduct an economic gap analysis to quantify appropriate grant and rebate levels for residential and commercial and industrial (C&I) customers.
- "Lead by example" by committing to install behind-the-meter (BTM) storage at state buildings.
- Conduct public education on storage through Catalyst Communities or other similar programs.
- Amend Michigan's Uniform Energy Code and Residential Construction Code to include storage readiness requirements for new buildings and homes.
- Conduct a study to determine how best to increase the number of qualified personnel in the energy storage workforce.
- Provide financing for energy storage through Michigan's revolving loan fund for energy efficiency and renewable energy established via Public Act 242 of 2009.

Regulatory

- Conduct a "value of storage" study to quantify the benefits that storage can provide.
- Require utility IRPs to include an accurate evaluation of opportunities for storage resources and, at a minimum, meet any established storage target.
- Require competitive energy storage procurements that provide a level playing field for third-party ownership models.
- Support wholesale market opportunities for energy storage through implementation activities related to the Federal Energy Regulatory Commission's Orders 841 and 2222.
- Ensure state interconnection standards and utility procedures allow smooth integration of storage.
- Under current Commission authority, require Michigan's utilities to file on-bill financing pilot programs for which residential and C&I energy storage systems are eligible.
- Under current Commission authority, require Michigan's utilities to provide publicly available hosting capacity maps to provide sufficient detail to allow storage developers to identify the need for flexible generation or distribution alternatives.
- Require transparency and accessibility in rates for energy storage.
- Identify specific goals for energy storage pilots to address barriers to the efficient utilization of storage resources.

Legislative

- Pass new legislation to establish a target to deploy 4,000 MW of FTM storage by 2040, with a short-term target of 1,000 MW of FTM storage by 2025 and a medium-term target of 2,500 MW of FTM storage by 2030.
- Pass new legislation requiring utility IRPs to include an accurate evaluation of opportunities for storage resources and, at a minimum, meet any established storage target.
- Pass new legislation requiring Michigan's utilities to file on-bill financing pilot programs for which residential and C&I energy storage systems are eligible.
- Pass new legislation requiring Michigan's utilities to provide publicly available hosting capacity maps to provide sufficient detail to allow storage developers to identify the need for flexible generation or distribution alternatives.
- Pass new legislation eliminating the distributed generation cap.
- Pass new legislation to remove restrictions from the commercial Property Assessed Clean Energy statute.

SHORT-TERM ACTIONS (1-5 YEARS)

Executive

- Establish grants for solar plus storage projects at public schools to provide the benefits of storage and demonstrate the technology.
- Establish a rebate or grant program for BTM residential and C&I storage systems with a carve-out for low-income customers.
- Implement effective training programs to increase the number of qualified personnel to the energy storage workforce.
- Provide green bank funding for BTM C&I energy storage projects.
- Provide additional matching grants for commercial Property Assessed Clean Energy projects and for Michigan Saves loans that involve energy storage for multi-family properties.
- Appoint energy storage experts to boards and commissions.
- Encourage pilot EV fleet programs to allow fleets, including fleets of school buses, to provide storage benefits to the grid when not being used for transportation.

Regulatory

- Establish a rebate or grant program for BTM residential and C&I storage systems with a carve-out for low-income customers.
- Begin to implement performance-based ratemaking to incorporate resilience and reliability into principles to reward utilities for improvements toward policy goals.
- Establish appropriate benefit cost analysis framework for non-wires alternatives including storage such that storage is considered on an equal footing with other investments.
- Allow customers with existing self-generation who add storage resources to experience corresponding reductions in monthly demand charges and/or standby charges, including through waiver of an existing demand ratchet.
- Set default time-of-use (TOU) rates for BTM C&I storage customers to allow them to take advantage of the flexibility of storage for rate arbitrage and reliability.
- Time-varying rate designs should provide a clear price signal for BTM C&I storage customers to charge during periods when demand is low and discharge during periods when demand is high.
- Align demand charges with established cost allocation methods by reflecting coincident peak instead of a customer's non-coincident peak.
- Align rates for solar and storage to support pairing of these technologies and ensure that rates are transparent and accessible to customers.
- Rate designs applied to FTM energy storage projects connected to the distribution system should appropriately reflect cost of service through use of operational characteristics.
- Credit BTM storage in rates for grid reliability and resiliency values that benefit all ratepayers.
- Encourage pilot EV fleet programs to allow fleets, including fleets of school buses, to provide storage benefits to the grid when not being used for transportation.
- Encourage utilities to implement residential vehicle-to-grid pilot programs.
- Review utility interconnection procedures to ensure storage is being interconnected appropriately.

Legislative

- Pass new legislation establishing a rebate or grant program for BTM residential and C&I storage systems with a carve-out for low-income customers.
- Pass new legislation providing green bank funding for BTM C&I energy storage projects.
- Pass new legislation requiring implementation of performance-based ratemaking to incorporate resilience and reliability into principles to reward utilities for improvements toward policy goals.

LONG-TERM ACTIONS (>5 YEARS)

Executive

- Refresh this Energy Storage Roadmap.
- Reassess the energy storage target.

Regulatory

- Enable third-party aggregation of BTM storage resources.
- Eliminate demand charges in favor of time-varying rates.
- Establish sufficient differentiation within time-varying rates to allow for projects to be economic, even in the absence of demand charges.
- Exempt energy storage systems from standby charges, should they provide sufficient grid benefits to all ratepayers, pending the results of a Michigan-specific "value of storage" study.
- Continue to encourage customers to charge EVs at off-peak times using rate design by offering EV tariffs reflecting TOU rates and dynamic or real-time pricing.
- Revisit Michigan's interconnection rules to ensure that interconnection of storage is occurring in a timely manner.

Legislative

- Pass new legislation establishing tax incentives for BTM energy storage.

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PART I: THE CURRENT STATE OF STORAGE

I. Introduction

The electricity grid our parents and grandparents knew is changing, and the electricity grid of the future would likely be foreign to previous generations. Central station fossil fuel generators are retiring as they become more costly to operate and fuel price volatility continues. Renewable energy sources, including wind and solar, are not only the cheapest new forms of energy, but are now cost-competitive with existing coal and gas-combined cycle plants.[3] Power flows are no longer unidirectional – customers and businesses produce their own on-site electricity to power their homes, businesses, and electric vehicles (EVs). Customers, businesses, and electric generators interact with the grid in an increasingly complex manner to use power when it is most cost-effective, lower power consumption when it is beneficial, and store power for later using energy storage technologies.

These changes are happening across the globe and country, including in Michigan, where regulators, policymakers, utilities, and advanced energy companies are increasingly involved in the growing advanced energy economy. In October 2019, in an effort to set regulatory policy to maximize the benefits of grid modernization and the transition to renewable energy, the Michigan Public Service Commission (MPSC) launched the MI Power Grid initiative.[4] Michigan's utilities have set bold carbon reduction goals and determined, in large part, that renewable energy resources are the lowest-cost generators to meet future capacity needs. In 2019, DTE Energy set a goal to achieve net zero carbon emissions by 2050.[5] Similarly, in 2020, Consumers Energy announced their goal of achieving net zero carbon emissions by 2040.[6] More broadly, in September 2020, Governor Gretchen Whitmer issued Executive Directive 2020-10, which set a state goal of economy-wide carbon neutrality by 2050 and an interim goal to achieve a 28 percent reduction below 2005 greenhouse gas emission levels by 2025.[7]

Also underway is a shift toward home, business, and transportation electrification. Homeowners and businesses are moving toward electrifying their heating and cooking, with one in four U.S. homes now considered all electric – and this trend is expected to continue.[8] Michigan's automakers are also making major commitments toward and financial investments in an electrified future. General Motors has committed to selling only zero-emission vehicles by 2035,[9] while Ford Motor Company has vowed to invest $29 billion in EVs by 2025,[10] nearly tripling its previous investment plan. Globally, Wood Mackenzie predicts that annual EV sales will reach 45 million vehicles per year by 2040.[11]

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[3] Lazard. October 2020. "Lazard's Levelized Cost of Energy Analysis - Version 14.0." Available at: https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf.

[4] Michigan Public Service Commission. MI Power Grid. Available at: https://www.michigan.gov/mpsc/0,9535,7-395-93307_93312_93593---,00.html.

[5] DTE Energy. September 26, 2019. "Net Zero Carbon emissions goal announced by DTE Energy Electric Company." Available at: https://ir.dteenergy.com/news/press-release-details/2019/Net-Zero-Carbon-emissions-goal-announced-by-DTE-Energy-Electric-Company/default.aspx.

[6] Consumers Energy. February 24, 2020. "Consumers Energy Commits to Net Zero Carbon Emissions, Takes Stand for the Planet." Available at: https://www.consumersenergy.com/news-releases/news-release-details/2020/02/24/16/03/consumers-energy-commits-to-net-zero-carbon-emissions-takes-stand-for-the-planet.

[7] Governor Gretchen Whitmer. September 23, 2020. Executive Directive 2020-10. Available at: https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-540278--,00.html.

[8] U.S. Energy Information Administration. May 1, 2019. "Today in Energy." Available at: https://www.eia.gov/todayinenergy/detail.php?id=39293.

[9] Boudette, N. E. and Davenport, C. January 28, 2021. "G.M. will sell only zero-emission vehicles by 2035." The New York Times. Available at: https://www.nytimes.com/2021/01/28/business/gm-zero-emission-vehicles.html.

[10] Car and Driver. February 5, 2021. "Ford Makes $29 billion commitment to electric and self-driving cars." Available at: https://www.caranddriver.com/news/a35432253/ford-ev-commitment-announced/.

[11] Wood Mackenzie. August 19, 2020. "323 million electric vehicles will be on the roads by 2040." Available at: https://www.woodmac.com/press-releases/323-million-electric-vehicles-will-be-on-the-roads-by-2040/?utm_source=EV+Hub+Newsletter.

As the cost of energy storage has declined, it is increasingly clear that energy storage is central to achieving these goals and enabling these trends, all while ensuring reliability and resiliency.[12,13] According to a study by the U.S. Department of Energy, when renewable energy provides a high percentage of electricity generation (i.e., 40 to 50 percent), significant curtailment of those renewable resources occurs if energy storage is not available, thereby undermining the cost-effectiveness of those renewable investments.[14] Further, according to a study conducted by the University of California at Berkeley, if 90 percent of electricity across the U.S. was provided by clean energy by 2035, 150 GW of 4-hour duration energy storage would need to be deployed to maintain reliability.[15]

In addition to maintaining the reliability of the bulk grid, energy storage can increase reliability and resilience for customers, including those who have been historically underserved by our electric system. Ratepayers in Michigan currently experience the highest electricity rates in the Upper Midwest and experience some of the worst reliability and resiliency in the country.[16] Outages are particularly burdensome for low and moderate-income customers, as losses related to outages make up a higher percentage of income, and these customers spend a larger fraction of their annual expenditures on energy compared to higher-income customers.[17] By integrating energy storage technologies into Michigan's grid in an intentional manner with an equity lens, not only will reliability and resilience trend in the right direction, but also, the state can invest in equity.

With increasing reliance on renewable generating resources and changing loads due to electrification, it is essential that Michigan decision makers establish policies to support increased deployment of both behind-the-meter (BTM; i.e., storage located on the customer side of an electricity meter) and front-of-the-meter (FTM; i.e., on the grid side of a customer's electricity meter) energy storage. Michigan is already ahead of many other states with its pumped hydro storage facility in Ludington (hereafter called "Ludington"), which has a discharge energy of approximately 11,500 MWh and a discharge rate of 1,916 MW.[18]

Energy storage is measured in terms of capacity and energy. As described by the National Renewable Energy Laboratory, power capacity is the total possible instantaneous discharge capability (in MW), energy capacity is the maximum amount of stored energy (in MWh), and storage duration is the amount of time storage can discharge at its power capacity before depleting its energy capacity (in hours).

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[12] U.S. Department of Energy. National Renewable Energy Laboratory. 2012. "Renewable Electricity Futures Study." Available at: https://www.nrel.gov/analysis/re-futures.html.

[13] U.S. Department of Energy. National Renewable Energy Laboratory. 2016. "Energy Storage: Possibilities for Expanding Electric Grid Flexibility." Available at: https://www.nrel.gov/docs/fy16osti/64764.pdf.

[14] *Ibid.*

[15] Phadke, A. et. al. 2020. Goldman School of Public Policy, University of California Berkeley. "2035 The Report: Plummeting Solar, Wind, and Battery Costs can Accelerate our Clean Electricity Future." Available at: https://www.2035report.com/electricity/.

[16] Citizens Utility Board of Michigan. 2021. "Utility Performance Report." Available at: https://d3n8a8pro7vhmx.cloudfront.net/cubofmichigan/pages/1152/attachments/original/1602176971/CUB_of_MI_Utility_Performance_Report_2020_Edition.pdf?1602176971.

[17] Citizens Utility Board of Michigan. March 2020. "Utility Regulatory Measures to Improve Electric Reliability in Michigan." Available at: https://d3n8a8pro7vhmx.cloudfront.net/cubofmichigan/pages/105/attachments/original/1593548892/CUB_of_MI_Report_Utility_Regulatory_Measures_to_Improve_Electric_Reliability_in_Michigan_Final_3.30.2020_%281%29.pdf?1593548892.

[18] According to the U.S. Energy Information Administration, each of the six units at Ludington have a nameplate capacity of 329.8 MW (2019 Form EIA-860 Data - Schedule 3, 'Generator Data,' Operable Units Only. Available at: https://www.eia.gov/electricity/data/eia860/). Assuming each unit can discharge at nameplate capacity for six hours with a 3.15% forced outage rate, we calculate that Ludington has a discharge energy of 11,499 MWh and a discharge rate of 1,916 MW.

However, as Michigan's electricity mix shifts toward more renewables, the need for additional storage capacity will rise. Although Ludington can provide many benefits to the bulk energy system, it cannot provide important ancillary, transmission, distribution, or customer services that other forms of energy storage can provide. In addition, it would likely be very difficult to site, permit, finance, and build another pumped hydro storage facility like Ludington in Michigan.

As described in detail throughout this Roadmap, energy storage can provide a variety of values, many of which can be provided at the same time to different end users (called "value stacking"). For example, as the use of renewable energy continues to rise, storage can be used to hold energy from these low-cost intermittent resources and then provide that energy at times when system demand is higher. This allows for more efficient integration of renewable energy and decreased costs due to rapid ramping of fossil fuel generators. Storage can provide spinning and non-spinning reserves, which will become increasingly important as fossil fuel turbines are replaced by renewables like solar photovoltaics (PV). Storage can also be used for frequency regulation, voltage support, and black start capabilities. Under certain conditions, it can be used to defer transmission and distribution upgrades. Further, storage can increase resiliency and power quality by providing instantaneously available backup power. Customer-sited BTM energy storage resources can also be used as broader grid resources if they are installed in sufficient quantities and aggregated, which could benefit all ratepayers.[19]

In addition to these values, as the increasingly electrified automotive manufacturing capital of the country, Michigan's economy stands to benefit from increased demand for energy storage technologies, including for those energy storage technologies that can be used for both mobile and stationary applications. Michigan made early investments in battery manufacturing in the state, including in companies such as LG Chem and XALT Energy with facilities in Holland and Auburn Hills respectively.[20] There are currently 11,400 jobs in Michigan in transportation electrification, representing the largest transportation electrification workforce outside of California.[21] Putting policies in place to support energy storage deployment will serve to grow Michigan's supply chains in energy storage and transportation electrification — both of which promise to be large global markets.

Despite these benefits and the rapid growth of the energy storage market, there are challenges to the further development of energy storage. In essence, the electric system and the policies and regulations governing it were not designed with energy storage in mind. Energy storage is uniquely able to supply electricity, store electricity, and defer infrastructure investments, and can often switch among these roles. For a storage installation to make economic sense, it is often necessary to stack several of the values that storage can provide. However, current market structures and regulatory frameworks do not create clear mechanisms to capture the full value of energy storage systems and sometimes explicitly prohibit storage from offering its various services or fail to provide mechanisms to monetize services that are being provided by storage applications. Such policy constraints can lead to storage being used for something other than its highest and best use or make it uneconomical to pursue storage in the first place. It is essential that policy barriers are removed and price signals are established to accurately compensate storage systems for the services they provide. Michigan needs to prepare for and support the deployment and use of energy

[19] For example, in ISO New England, in 2019, Sunrun bid 20 MW of BTM energy storage into the Forward Capacity Market for 2022. See Clean Energy Group and Clean Energy States Alliance. August 2021. "Energy Storage Policy Best Practices from New England: Ten Lessons from Six States." Available at: https://cdn.cesa.org/wp-content/uploads/Energy-Storage-Best-Practices-from-New-England.pdf.

[20] Michigan Strategic Fund, State of Michigan. October 2020. "Michigan Economic Growth Authority FY 2020 Report to the Michigan Legislature." Available at: https://www.michiganbusiness.org/4aef81/globalassets/documents/reports/legislative-reports/fy2020-mega-annual-legislative-report.pdf.

[21] BW Research Partnership and Advanced Energy Economy. August 2021. "Electrifying Michigan: Economic Potential of Growing Electric Transportation." Available at: https://info.aee.net/hubfs/Michigan%20EV%20Supply%20Chain%20Fact%20Sheet.pdf.

storage at the level that will be necessary to support and balance our state's future electricity grid. This will require leadership, business innovation, appropriate incentive programs, regulatory changes, and new state laws.

To help Michigan chart a path forward, the Institute for Energy Innovation (IEI), along with partners the Michigan Energy Innovation Business Council (Michigan EIBC), 5 Lakes Energy, and Dr. Annick Anctil undertook a year-long study at the request of the Michigan Department of Environment, Great Lakes, and Energy (EGLE) to assess the challenges and opportunities for energy storage in Michigan and recommend policies to support future deployment of energy storage. Through strategic policy and regulatory actions, Michigan can position itself to build a strong in-state energy storage industry that provides customers with reliable, affordable, and clean electricity.

II. Services Provided by Energy Storage Systems

Most batteries deployed today are not fully utilized, usually because they are deployed to serve only single applications. For example, an energy storage system used only for demand charge reduction would only be utilized between 5 and 50 percent of the time.[22] Such a battery could be secondarily dispatched to serve another purpose, thereby making fuller use of its potential and providing additional value.

As shown in Figure 1, the services energy storage provides can be divided into different categories: bulk energy services, ancillary services, transmission services, distribution services, and customer services. Although it is useful to consider the potential values of storage individually, in many cases multiple values can be combined or "stacked." For example, customer-sited storage used as back-up power may also provide ancillary distribution grid services when it is not needed for back-up power by the customer. As detailed by MPSC Staff in a report on New Technologies and Business Models, "[valuing] the benefits in a way that the primary and secondary functions of a storage device are not conflicting will be important."[23]

It is also important to recognize that storage can provide important environmental and societal benefits that are often difficult to quantify and monetize. Because storage can increase the integration of renewable energy, decrease curtailment of renewable resources, and decrease the need for natural gas peaker plants, it can lead to reduced carbon emissions and improved air quality.

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[22] Rocky Mountain Institute. 2015. "The Economics of Battery Energy Storage: How Multi-Use, Customer-Sited Batteries Deliver the Most Services and Value to Customers and the Grid." Available at: https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf.

[23] Michigan Public Service Commission Staff Report. U-20898 MI Power Grid: New Technologies and Business Models Workgroup. December 1, 2021. "New Technologies, Business Models, and Staff Recommendations." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/0688y000001jEwjAAE. p. 87.

Category	Services	
Bulk Energy Services	Capacity Energy Arbitrage	Load Following Renewable Integration
Ancillary Services	Black Start Fast Frequency Response Frequency Regulation	Spinning/Non Spinning Resources Voltage/VAR Support
Transmission Services	Transmission Congestion Relief Transmission Upgrade Deferral	
Distribution Services	Virtual Power Plants Peak Shaving	Distribution Upgrade Deferral
Customer Services	Demand Response Bill Management Demand Charge Reduction	Microgrid Support Solar PV Self-Consumption Backup Power/Power Quality Support

Figure 1. Taxonomy of Energy Storage Services.

Bulk Energy Services

Services provided to the transmission-connected bulk electric power system.

Capacity: The potential to provide power when needed is capacity service. Michigan's electricity system in the Lower Peninsula is currently considered to be summer-peaking, as the highest energy consumption occurs in the summer months due to air conditioning needs. This peak summertime consumption currently drives capacity needs in Michigan. As electrification increases, along with more widespread use of heat pumps, there is a chance that the Lower Peninsula of Michigan may switch to be a winter-peaking system.[24] (The Upper Peninsula is already considered to be winter-peaking.[25]) In either case, energy storage systems integrated into the electric grid can ensure that there is power capacity to deploy at peak times, without needing to build new generation assets.

Energy arbitrage: Energy storage can be used to store energy when there is excess, lower-cost energy until such time when demand and/or prices are higher. This process of charging energy storage systems when energy prices are low and discharging the stored energy when prices are higher is called energy arbitrage. Because renewable resources have very low marginal costs, electricity produced by those resources is usually the cheapest available form of energy. However, because these low-cost renewable resources produce energy at times that do not always line up with demand, energy arbitrage using energy storage can enable the integration of additional renewable resources.

Load following: Load following is sometimes considered a subset of energy arbitrage. Load

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[24] Specian, M., C. Cohn, and D. York. 2021. "Demand-Side Solutions to Winter Peaks and Constraints." ACEEE. Available at: http://www.aceee.org/research-report/u2101. p. v.

[25] See Michigan Department of Environment, Great Lakes, and Energy. 2021. "Upper Peninsula Energy Task Force Committee Recommendations Part II – Energy Supply." Available at: https://www.michigan.gov/documents/egle/Report-UPETF-Phase-II_720856_7.pdf, pp. 28-29.

following means that energy storage can be used to manage the difference between scheduled generator output and predicted demand with actual generator output and actual demand.

Renewables integration: Michigan currently has approximately 3,300 MW of renewables installed.[26] Given the current commitments from DTE Energy and Consumers Energy, at least 7,000 MW more of solar and wind energy are expected to be installed in the state by 2040.[27] Despite the fact that the percentage of electricity currently generated by renewables is lower in the Midwest than in some other regions of the country, the Midcontinent Independent System Operator (MISO) has consistently had some of the highest curtailment rates for wind energy across all of the regional transmission organizations (RTOs).[28] With sufficient battery storage capacity, excess renewable energy can be stored and sent to the grid during times of peak load, avoiding these periods of curtailment. Additionally, battery storage systems can smooth variable output from renewable energy generators. This can reduce rapid ramping of fossil fuel and renewable generators, enabling more efficient integration of renewables.[29] Co-located storage and renewable generators can also contribute to reliability requirements and enable predictable management of power supplied to the grid.

> *Several interviewees indicated that storage-renewable hybrid projects are being considered by many developers, although not always with the storage directly co-located with the renewable asset and not always at the same point-of-interconnection.*

Ancillary Services

Services that support the transmission of electricity from generators to customers and/or maintain the usability of electricity throughout the system.

Black start: In the case of a grid outage or if an individual electricity generating unit goes down, it generally requires power to restart operations. Under these circumstances, energy storage can provide "black start" capability to enable energy generators to begin running without initial power from the grid. This can both resume power generation at an individual site or, in the case of a grid outage, can restart the power system to recover from a blackout.[30]

Fast frequency response: Sudden changes in generation or load can cause rapid changes in system frequency. When an electric grid is dominated by traditional turbines (powered by fossil

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[26] Michigan Public Service Commission. 2021. "Report on the Implementation and Cost-Effectiveness of the P.A. 295 Renewable Energy Standard." Available at: https://www.michigan.gov/documents/mpsc/2020_Renewable_Energy_Standard_Report_with_Appendices_716372_7.pdf.

[27] Commitments from DTE Energy and Consumers Energy in their most recently approved IRPs indicates that there will be increases in renewable installations over the next two decades. In June 2019, the Commission approved Consumers Energy's IRP wherein, the Company plans to procure over 4,500 MW of new solar resources by 2030 and 6,000 MW of solar by 2040 (see https://www.michigan.gov/documents/mpsc/CE_IRP_Issue_Brief_060719_657253_7.pdf). Additional commitments are expected upon approval of Consumers' next IRP, which was filed in June 2021. In March 2020, the MPSC approved DTE's IRP, in which the company committed to an additional 11 MW of solar plus storage pilots, 693 MW of wind, and between 465-715 MW's of Voluntary Green Pricing (VGP) program renewables between 2020 and 2024 (see https://www.michigan.gov/documents/mpsc/DTE_IRP_Issue_Brief_041520_687227_7.pdf).

[28] *Ibid*.

[29] National Renewable Energy Laboratory. 2016. "Energy Storage: Possibility for Expanding Electric Grid Flexibility." Available at: https://www.nrel.gov/docs/fy16osti/64764.pdf.

[30] National Renewable Energy Laboratory. "Black Start." Available at: https://www.nrel.gov/grid/black-start.html.

fuels), the immediate response to correct and stabilize frequency is maintained by the inertia in these rotating generators. However, as grids across the world, including in Michigan, shift from fossil fuels to renewable generators, the ability for generators to automatically provide this immediate frequency response is diminished. Energy storage can provide fast frequency response services to ensure the grid continues to operate reliably as less inertia becomes available from traditional generators.[31]

Frequency regulation: The standard frequency on the electricity grid in the United States is 60 Hz. If demand exceeds supply, the frequency will drop below 60 Hz and, in contrast, if supply exceeds demand, the frequency will exceed 60 Hz. Such frequency spikes or dips can create grid instability. Energy storage can provide frequency regulation by easily switching from charging to discharging and can detect and react to frequency changes automatically without additional input from grid operators.

Spinning/non-spinning reserves: In Michigan, MISO ensures that there are sufficient reserves available if a generator goes offline. Energy storage serving as a spinning reserve must respond quickly, be synchronized to the grid, and be available for a longer duration than the time it typically takes slower generators to ramp up (e.g., one hour or more). In contrast, non-spinning reserve, which storage can also provide, is generation capacity that can respond within a short period of time but is not synchronized to the grid.[32]

Voltage/VAR support: To maximize power and ensure power quality, a balance must be maintained between voltage and current on the grid. Energy storage can provide voltage support by dynamically re-aligning voltage and current (usually as a secondary service to its primary service). Energy storage can also provide Voltage Ampere Reactive power (VAR). In general, VAR is necessary to move electricity over long distances and to maintain system voltage within reliability limits. The farther electricity must travel, the higher the VAR required for the grid. Without adequate VAR support, it is more likely that voltage will fall outside of reliability limits. When this happens, it is more likely that customers, particularly industrial customers who require sufficient VAR levels to support their production processes, will experience service quality interruptions. Energy storage can provide VAR support by injecting or withdrawing reactive power from the grid to maintain reliability limits. This can be supplemental to or potentially replace current voltage management methods.[33] Traditionally, reactive power is generated and deployed from substations but with the advent of storage technologies, reactive power could be placed in different locations, potentially closer to the load, reducing the length real power has to travel, thus reducing energy loss during transfer, and lowering costs.[34] This is especially important in rural areas where load centers are located far from substations.

Transmission Services

Services that support the transmission system and transmission utilities.

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[31] Gonzalez-Inostroza, P., et al. 2021. "The Role of Fast Frequency Response of Energy Storage Systems and Renewables for Ensuring Frequency Stability in Future Low-Inertia Power Systems." Sustainability. Available at: https://www.mdpi.com/2071-1050/13/10/5656/pdf.

[32] Zhou, Z., Levin, T., and Conzelmann, G. Argonne National Laboratory. 2016. "Survey of U.S. Ancillary Services Markets." Available at: https://publications.anl.gov/anlpubs/2016/01/124217.pdf.

[33] Bialek, T., Bravo, R. J., and Robles, S. A. October 2014. Institute of Electrical and Electronic Engineers. "VAr support from solar PV inverters." Available at: https://ieeexplore.ieee.org/document/6925479/authors#authors.

[34] PJM. 2017. "Reactive Power." Available at: https://pjm.com/~/media/about-pjm/newsroom/fact-sheets/reactive-power-fact-sheet.ashx.

Transmission congestion relief: Energy storage can relieve congestion on transmission lines, especially during peak demand times, to reduce curtailments and potential outages. Such systems need to be sited proximate to the congested area and their duration must meet the length of the expected congestion.

Transmission upgrade deferral: Energy storage is a quick and less costly alternative to traditional transmission system upgrades. Storage resources can address persistent congestion issues, provide short-term infrastructure, or meet other grid needs quickly, given that they can be sited and come online more quickly than comparable solutions.

Distribution Services

Services provided in support of the distribution system and distribution utilities.

Distribution upgrade deferral: Like any infrastructure, the distribution grid is regularly undergoing upgrades to ensure reliability and power quality. Historically, issues related to upkeep or expansion of the distribution grid would have been solved with poles, wires, and substation upgrades. The nature of storage makes it a valuable alternative (known as a non-wires alternative, or NWA) capable of addressing power quality issues, mitigating voltage deviations, supporting load growth, enabling renewables integration, and providing load shifting. When peak loads and/or generation exceed the distribution grid's limits, utilities determine if energy storage or other NWAs may be a more cost-effective alternative to traditional poles and wires upgrades.[35] As of the winter of 2022, the MPSC has instructed Consumers Energy and DTE Energy to deploy NWA pilots, some of which include energy storage. To provide one example from those programs, DTE's 2021 Electric Distribution Grid Plan outlines a proposed $15 million substation upgrade in Port Austin which can be deferred by deploying a $4.5 million solar plus storage NWA, demonstrating substantial cost savings.[36]

Peak shaving: Distribution utilities can decrease their peak load requirements by using energy storage during peak hours.

Virtual power plants: Multiple distributed resources can be aggregated together to operate as a single unit to provide grid services traditionally offered by legacy fossil-fuel generators. Storage's ramping capability makes it an ideal aggregation asset as it can support intermittent resources like rooftop solar to be available when called upon. As described in Section VII, the Federal Energy Regulatory Commission's (FERC) Order 2222 will improve opportunities to utilize this value stream by allowing distributed aggregations to participate in wholesale markets.[37]

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[35] Smart Electric Power Alliance, Peak Load Management Alliance, and E4TheFuture. 2018. "Non-wires Alternatives: Case Studies From Leading U.S. Projects." Available at: https://sepapower.org/resource/non-wires-alternatives-case-studies-from-leading-u-s-projects/.

[36] DTE Energy. August 1, 2021. "2021 Distribution Grid Plan: Final Report." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000Uc0pkAAB.

[37] Federal Energy Regulatory Commission. September 17, 2020. Order No. 2222. "Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators." Available at: https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf.

Customer Services
Services provided to residential, commercial, and industrial customers.

Backup power/power quality support: Many commercial and industrial (C&I) and residential customers install energy storage systems to provide on-site back-up power. According to Lazard's "Levelized Cost of Storage Analysis," developers continue to move toward backup power applications given the increased focus on grid reliability and resiliency.[38] Michigan customers experience relatively low grid-level electricity reliability.[39] As a result, there are substantial opportunities for energy storage systems to provide backup power both for residential customers with critical loads and for C&I customers where even momentary power outages can cause material losses.

Energy storage can also provide critical power quality support for loads that cannot be interrupted, even for a millisecond. While many utilities offer interruptible rates in which they compensate customers for the ability to curtail service in times of economic or grid emergency, customers with critical loads suffer losses whenever their service goes down, and therefore elect to pay extra for firm or non-interruptible service. Non-interruptible service, however, is just a commitment to generate sufficient power except in emergency conditions and does not provide exceptional assurances against distribution grid outages. Customers that have some specific industrial, commercial, medical, or emergency load that cannot have a loss in power or a drop in power quality must procure some form of on-site backup power. Energy storage, when deployed on-site, can provide more reliability than an uninterruptible tariff.

Bill management: On-site energy storage can allow customers to take advantage of time-of-use (TOU) rates by allowing them to charge a battery when electricity rates are low and then use that stored energy on-site when electricity rates are higher. Depending on the differences in rates throughout the day, this can result in large cost savings.

Demand charge reduction: For C&I customers, demand charges represent a significant expense, and often fail to align with cost causation principles. Because demand charges are assessed based on an individual customer's maximum short-term consumption in a billing period, or a demand ratchet based on historical peak demand, these charges penalize customers for usage at times that do not impose especially high costs on the system, and incentivize customers to invest effort and money to shift loads away from their own maximum hour.[40] For example, in Michigan, under Consumers Energy's General Service Secondary Demand rate: "[the] Peak Demand shall be the Kilowatts (kW) supplied during the period of highest use in the billing month but not less than 60% of the highest Peak Demand created during the preceding billing months of June through September, nor less than 5 kW." [41] According to the Regulatory Assistance Project: "Traditional monthly demand charges provide an inaccurate price signal that is unrelated to high-cost periods for nearly all customers and which leads to inefficient customer efforts and investments in response

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[38] Lazard. 2021. "Lazard's Levelized Cost of Storage Analysis--Version 7.0". Available at: https://www.lazard.com/media/451882/lazards-levelized-cost-of-storage-version-70-vf.pdf.

[39] Michigan Citizens Utility Board. 2020. "Utility Performance Report: Ranking Michigan Amongst the States." Available at: https://d3n8a8pro7vhmx.cloudfront.net/cubofmichigan/pages/1152/attachments/original/1602176971/CUB_of_MI_Utility_Performance_Report_2020_Edition.pdf?1602176971.

[40] Regulatory Assistance Project. November 2020. "Demand Charges: What Are They Good For?" Available at: https://www.raponline.org/wp-content/uploads/2020/11/rap-lebel-weston-sandoval-demand-charges-what-are-they-good-for-2020-november.pdf. p. 4.

[41] Consumers Energy General Service Secondary Demand Rate GSD. Available at: https://www.consumersenergy.com/-/media/CE/Documents/rates/electric-rate-book.pdf.

to its incentives."[42] Further, "[e]ven in cases where a traditional demand charge could be justified, the sizing of demand charges to recover nearly all generation and delivery capacity costs reflects an outdated perspective of the engineering and economics of the electric system."[43]

Demand charges, as a component of standby rates, have been evaluated as a potential barrier to the deployment of distributed energy resources (DERs). As detailed in the Combined Heat and Power (CHP) Roadmap for Michigan, "[ideally], a decrease in electricity purchased from the utility would be commensurate with a decrease in monthly electric costs. However, many standby rates are created such that they increase capacity demand charges when a customer decreases energy consumption, thus negating much of the expected savings."[44] Despite these shortcomings, demand charges will remain a reality for C&I customers, at least in the near term. Energy storage can reduce demand charges by reducing monthly peak usage for C&I customers, which is used to calculate demand charges.

Demand response: Utility demand response programs incentivize customers to reduce their energy load during peak load times. These programs can be bolstered by on-site energy storage systems, especially for C&I customers.

Microgrid support: A microgrid is a property or group of properties with generation and loads that are interconnected to one another and to the distribution grid, and which can island from the distribution grid. Microgrids can provide a wide range of benefits including, but not limited to, improved reliability, resilience in the case of disaster, capacity and grid services to the broader electric grid, reductions in environmental impacts, and reductions in the need for additional grid infrastructure investments. Energy storage resources are increasingly integrated into microgrids because they enable easier integration of distributed renewables and improved load flexibility.

Solar PV self-consumption: Public Act 342 of 2016[45] required Michigan's utilities to transition from net metering (where customers receive a monthly credit at the retail rate for electricity exported from an on-site solar PV system) to new distributed generation tariffs. These tariffs reflect an "inflow/outflow" methodology wherein customers pay for all of the electricity they use from the grid ("inflow") and are credited for any electricity they export to the grid ("outflow") at a lower rate. Because the outflow credit is generally less than the charge for inflow, it is advantageous for customers with solar PV systems to use as much of the electricity generated by the solar system as possible on-site. As a result, many customers in Michigan are installing coupled solar PV and battery storage systems. For example, of the 887 residential customers who installed solar PV systems in DTE Energy's territory in 2020, 462 also installed lithium-ion battery storage systems.[46]

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[42] *Id*. p. 13.

[43] *Ibid*.

[44] Michigan Energy Office. February 2018. "CHP Roadmap for Michigan." Available at: https://www.michigan.gov/documents/energy/CHP_Roadmap_for_Michigan_Full_Report_final_628532_7.pdf. p. 102.

[45] Public Act 342 of 2016. December 21, 2016. Available at: https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

[46] DTE Energy. March 2021. MPSC Case No. U-15787. "2020 Annual Net Metering/Distributed Generation Report." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000MKx0pAAD.

III. Energy Storage Technologies

Often, the term "energy storage" is associated with certain battery technologies like lithium-ion or lead-acid, but there are many different viable energy storage technologies, each with its own characteristics and the ability to provide a distinct set of services. The policy recommendations in this Roadmap are designed to address barriers to energy storage in a technology neutral framework.

At their most fundamental level, as shown in Table 1, energy storage technologies can be divided into three basic categories: electrochemical storage, mechanical storage, and thermal storage. Note that the key characteristics and common services included in Table 1 are intended to be representative rather than exhaustive.

GROUP	TYPE	KEY CHARACTERISTICS	COMMON SERVICES PROVIDED BY EXISTING PROJECTS
Electrochemical storage	Lithium-ion	High energy density High cycle efficiency Fast response time Degradation after deep discharge Limited duration	Ancillary services Renewables integration Solar PV self-consumption Backup power/power quality Transmission upgrade deferral Distribution upgrade deferral Electric vehicles
	Lead-acid	Low cost Mature technology Low energy density Short cycle life Promising innovation	Small off-grid applications Microgrid support
	Sodium-based	Low degradation Chemical stability	Ancillary services Renewables integration
	Iron-air	Long duration Superior safety High energy density	Capacity Renewables integration Ancillary services Peak shaving Transmission upgrade deferral Distribution upgrade deferral
	Flow batteries	Long duration Quick recharge Minimum degradation	Energy arbitrage Voltage/VAR support Frequency regulation Behind-the-meter support
Mechanical storage	Pumped hydro	Bulk energy storage Long duration Site attributes requirements Large upfront costs	Capacity Peak shaving Renewables integration Ancillary services
	Compressed air	Bulk energy storage Long duration Site attributes requirements	Capacity Peak shaving Renewables integration Ancillary services
	Flywheel	Short duration Quick recharge Minimum degradation	Frequency regulation Voltage/VAR support
Thermal storage	Thermal storage	Long life Efficiency depends on storage medium	Bill management Demand charge reduction Heating and cooling

Table 1. Characteristics of energy storage technologies.

ELECTROCHEMICAL STORAGE TECHNOLOGIES

Lithium-Ion Batteries

Key characteristics: High energy density, high cycle efficiency, fast response time

Description: Lithium-ion batteries have high energy density and high cycle efficiency (minimal loss of energy between recharge and discharge).[47] The versatility of applications, flexibility of performance, and cost reductions achieved through advancements made for EV manufacturing have made lithium-ion systems very popular, especially for applications that require output durations of 4 hours or less. The use cases of lithium-ion batteries include grid services, EVs, residential/commercial resiliency, and portable electronics. However, lithium-ion systems designed for deep discharge (i.e., when a battery has been discharged to its full capacity) will exhibit greater performance degradation if they are cycled multiple times per day or used for applications such as frequency response.[48]

Example technology sub-types: Lithium Nickel Cobalt Aluminum (NCA) Battery, Lithium Nickel Manganese Cobalt (NMC) Battery, Lithium Iron Phosphate (LFP) Battery, Lithium Manganese Oxide (LMO) Battery

CASE STUDY

Alliant Energy Decorah Battery Storage

(Decorah, Iowa)[49]

This 2.5 MW/2.922 MWh battery is primarily used for increasing hosting capacity, which is the amount of DERs that can be added to a distribution system before system upgrades are required. With the local distribution grid circuit approaching its capacity and growing rooftop solar PV installations in the community, the Decorah battery storage project provides a less costly alternative to distribution system upgrades. The storage will also provide services such as voltage support and peak shaving.

CASE STUDY

Electric Vehicles

There are two major types of mobile energy storage systems: batteries which provide on-board power for EVs and module-based systems that can provide additional power for unique applications, but are simply transported via a vehicle and do not power the vehicle. In the case of EVs, the vehicles are essentially a mobile lithium-ion battery technology. There are many ways in which the integration of EV batteries and the grid can provide benefits to customers and the bulk power system, including through the provision of ancillary, transmission, and distribution services. Similar to any energy storage application, charging or discharging an EV battery at specific times functions in a similar manner to a stationary storage system. At the same time, EV storage applications require optimization that is different from stationary energy storage systems because the primary service provided is powering the vehicle. As described below, existing unidirectional vehicle-to-grid (called V1G) technology allows EVs to provide a number of customer services

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[47] University of Washington Clean Energy Institute. "Lithium-ion Battery." Available at: https://www.cei.washington.edu/education/science-of-solar/battery-technology/.

[48] Scroggin-Wicker, T. and McInerney, K. March 2, 2020. "Flow Batteries: Energy Storage Option for a Variety of Uses." Power Magazine. Available at: https://www.powermag.com/flow-batteries-energy-storage-option-for-a-variety-of-uses/.

[49] Clean Energy States Alliance. "Expanding Grid Capacity with Energy Storage in Decorah, Iowa." July 30, 2020. Available at: https://www.cesa.org/event/expanding-grid-capacity-with-energy-storage-in-decorah-iowa/.

including demand reduction, demand response, and back-up power. As bidirectional vehicle-to-grid (called V2G) technology evolves, EVs will likely be used for energy arbitrage, transmission and distribution deferrals, peak load reduction, and a variety of ancillary services.

Passive charging: EVs can be encouraged to charge at off-peak times using rate design, including TOU rates and dynamic or real-time pricing. For example, Consumers Energy and DTE Energy require recipients of Level 2 EV charging station rebates to sign-up for EV-specific tariffs. These tariffs have higher rates on-peak and lower rates off-peak to encourage customers, including those with automated vehicle charging, to charge during off-peak times. Such programs show that managed charging can make integration of EVs on the electric grid easier and can even provide services to the broader electric grid with the right regulatory and utility constructs. For example, after two years of the PowerMIDrive Pilot, Consumers Energy has found that weekday residential charging avoids times of peak load about 90 percent of the time.[50]

Vehicle-to-grid (V1G) active charging: V1G active charging is the control of the unidirectional power flow from the grid to the vehicle using smart charging technology. Through active management, charging can be increased, decreased, shifted across time horizons, or shifted across different charging ports. For example, BMW partnered with Pacific Gas and Electric on the ChargeForward pilot from 2015-2019.[51] The pilot found that smart charging can reduce greenhouse gas emissions by an additional 32 percent on average in northern California and produces $325 in annual grid savings per EV.[52]

Vehicle-to-grid (V2G) active charging: V2G active charging is the control of bidirectional power flows wherein grid operators can both charge and pull power from vehicle batteries based on the overall system needs. There are several ongoing pilot programs to test V2G technologies, many of which utilize fleets of electric school buses. For example, San Diego-based green energy tech company, Nuvve, and a manufacturer of school buses, Blue Bird, collaborated to develop V2G school buses.[53] Nuvve's solution enables electric buses, which are parked most hours of the day, to become mobile battery resources that can then be aggregated together to act as virtual power plants. At times of extreme grid stress, such as during a heat wave, electric buses can be deployed to provide the grid with additional energy capacity to prevent brownouts, blackouts, or even failure. In March 2021, Blue Bird delivered V2G buses to two school districts in Illinois.[54]

Lead-Acid Batteries

Key characteristics: Mature technology, low cost, small off-grid systems

Description: Traditional lead-acid battery storage is a mature technology that has the advantage of lower costs, but suffers from lower energy density and cycle life compared to lithium-ion batteries. These lead-acid batteries are typically bulkier and heavier than lithium-ion batteries and, as such, are less suitable for some applications like EVs. However, new developments such as advanced lead-carbon battery technology

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[50] Consumers Energy. 2021. "PowerMIDrive Program Annual Report 2021." Case No. U-20134. Available at: https://mi-psc.force.com/s/case/500t0000009fPPSAA2/in-the-matter-of-the-application-of-consumers-energy-company-for-authority-to-increase-its-rates-for-the-generation-and-distribution-of-electricity-and-for-other-relief.

[51] BMW. "BMW ChargeForward Electric Vehicle Smart Charging Program." Available at: https://www.bmwchargeforward.com/assets/pdfs/BMW-ChargeForward-Report.pdf.

[52] *Ibid.*

[53] Morris, C. 2021. "Blue Bird delivers electric school bus equipped with Nuvve V2G tech." Charged Electric Vehicles Magazine. Available at: blue-bird-delivers-electric-school-bus-equipped-with-nuvve-v2g-tech.

[54] *Ibid.*

and bipolar lead acid battery technology have resulted in improved energy density, decreased battery size, and decreased use of sulfate.[55,56] Lead-acid storage is most suitable for stationary grid applications and off-grid back-up power systems.[57] With technological advancements, lead-acid technologies may experience greater deployment in the future.

Example technology sub-types: Hybrid Lead-acid Battery/Electro-chemical capacitor, Lead Carbon Battery

CASE STUDY

Fort Bliss Microgrid Storage
(El Paso, Texas)[58]

This 300 kW/20 kWh lead-acid system was implemented in 2013 at the U.S. Army's Ft. Bliss to pair with renewable resources. The resulting microgrid reduces overall greenhouse gas emissions and energy costs while providing the capability to operate independently of the distribution grid when needed to provide energy security. When connected to the grid, the batteries also provide support services, including power factor correction and area frequency regulation, to the local electrical system operator.

Sodium-Based Batteries
Key characteristics: Long life cycle, large-scale applications

Description: Sodium-based battery storage is an established technology based on abundant materials with a long life cycle suitable for long-discharge applications.[59] These systems require high operating temperatures as they utilize molten sodium to operate (~300°C).[60] Sodium-based batteries are suitable for and can often compete with lithium-ion batteries for non-mobility applications because (1) sodium costs less than lithium; (2) the energy density for sodium-based batteries is typically lower than lithium-ion counterparts; (3) sodium-based batteries have a lower potential for structural degradation and, therefore, longer lifespan than lithium-ion counterparts.[61]

Example technology sub-types: Sodium-sulfur battery, Sodium-nickel-chloride battery, Sodium-air battery

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[55] Enos, D. G. Sandia National Laboratories. 2014. "Lead-Acid Batteries and Advanced Lead-Carbon Batteries." Available at: https://www.osti.gov/servlets/purl/1502636.

[56] Advanced Battery Concepts. "Greenseal® Technology." Available at: https://advancedbatteryconcepts.com/technology/.

[57] Vetter, M. and Rohr, L. 2014. "Lithium-Ion Batteries for Storage of Renewable Energies and Electric Grid Backup." Lithium-Ion Batteries: Advances and Applications. Ed. Pistoia, G. Available at: https://www.sciencedirect.com/science/article/pii/B9780444595133000133.

[58] Lockheed Martin. May 16, 2013. "U.S. Army and Lockheed Martin Commission Microgrid at Fort Bliss." Available at: https://news.lockheedmartin.com/2013-05-16-U-S-Army-and-Lockheed-Martin-Commission-Microgrid-at-Fort-Bliss.

[59] Energy Information Administration. 2020. "Battery Storage in the United States: An Update on Market Trends." Available at: https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf.

[60] *Ibid*.

[61] Jana, A., Paul, R., and Roy, A. K. 2019. "Architectural design and promises of carbon materials for energy conversion and storage: in laboratory and industry." Micro and Nano Technologies. Available at: https://www.sciencedirect.com/science/article/pii/B9780128140833000020.

CASE STUDY

Pacific Gas and Electric (PG&E) Yerba Buena Battery Energy Storage Pilot Project
(San Jose, California)[62]

This 4 MW sodium-sulfur battery storage project went online in May 2013. In the event of a power outage, the battery system can support a Silicon Valley storage technology company and neighbors of the company for up to seven hours. The system charges the four 1 MW batteries when demand is low and then sends stored power to the grid when demand grows. The batteries are projected to have a lifespan of 15 years. PG&E and the Electric Power Research Institute (EPRI) are also using this pilot to study how sodium-sulfur battery energy storage can support greater integration of intermittent renewable power.

Iron-Air Batteries

Key Characteristics: Multi-day duration, superior safety, globally scalable, utility-scale applications

Description: Iron-air batteries charge and discharge via a reversible rusting process. When discharging, the battery takes in oxygen from the air and converts iron metal into rust. When charging, an electrical current converts the rust back into metallic iron and "breathes" out oxygen. The active components in an iron-air battery are readily available, inexpensive, recyclable, and non-toxic. Each battery cell is filled with aqueous electrolye, contains an iron and air electrode, and has no fundamental risk of thermal runaway.[63, 64, 65] Iron-air batteries also boast potential for low-degradation and long-duration dispatch, potentially lasting for multiple days.[66, 67]

CASE STUDY

Form Energy Demonstration Project with Great River Energy
(Cambridge, Minnesota)[68]

Storage startup Form Energy is partnering with Minnesota utility Great River Energy to deploy a pilot project using Form Energy's iron-air battery system. The project will be a 1.5 MW grid-connected system capable of delivering its rated power continuously for 150 hours, far longer than other existing batteries. This pilot project will demonstrate the viability of iron-air battery technology and the company's scalable technology. Further, it will demonstrate how multi-day energy storage resources can meet emerging grid needs, provide energy during multi-day weather events, and effectively replicate the system functions of legacy fossil-fuel power plants on the Minnesota grid.

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62 Kligman, D. May 23, 2013. "Largest Battery Energy Storage System in California to Improve Electric Reliability for Customers." Currents. Available at: https://www.pgecurrents.com/2013/05/23/largest-battery-energy-storage-system-in-california-to-improve-electric-reliability-for-customers/.

63 "Thermal runaway can happen when an increase in temperature changes conditions in a way that leads to a further increase in temperature, a kind of feedback that can lead to catastrophe." National Renewable Energy Laboratory. July 8, 2010. "Building Better Batteries for Cars and Spacecraft." Available at: https://www.nrel.gov/news/features/2010/1477.html.

64 Li, Y. and Lu, J. 2017. "Metal-Air Batteries: Future Electrochemical Energy Storage of Choice?" Available at: https://www.osti.gov/pages/servlets/purl/1373737.

65 Form Energy. "Battery Technology: Enabling a 100% Renewable Grid." Available at: https://formenergy.com/technology/battery-technology/.

66 *Ibid*.

67 Narayanan, S.R. et al. 2012. "Materials challenges and technical approaches for realizing inexpensive and robust iron-air batteries for large-scale energy storage". Solid State Ionics. Vol. 216. Available at: https://www.sciencedirect.com/science/article/pii/S0167273811005820?via%3Dihub.

68 Form Energy. 2021. "Form Energy Announces Pilot with Great River Energy to Enable the Utility's Transition to an Affordable, Reliable and Renewable Electricity Grid." Available at: https://formenergy.com/wp-content/uploads/2020/05/Form-Energy_-GREPilotPress-Release.pdf.

Flow Batteries

Key characteristics: Long duration, quick recharge, minimum degradation, superior safety

Description: A flow battery system usually has one or more chemical components dissolved in liquid solution.[69] The chemical solutions are typically stored in tanks and separated by a membrane. For applications where multiple charge/discharge cycles are required each day, flow batteries are available within milliseconds as loads dictate and they can quickly recharge from a variety of available power sources. Flow batteries also experience minimal degradation.[70] This means that there are fewer limitations on use cases once the system is installed. With durations of six to eight hours or more and quick recharge capability, flow batteries can be most useful for energy arbitrage.[71] Other use cases of flow batteries include BTM support, voltage support, and renewables pairing.

Example technology sub-types: Zinc-bromine Flow Battery, Zinc-nickel Oxide Flow Battery, Vanadium Redox Flow Battery

CASE STUDY

San Diego Gas and Electric (SDG&E) and Sumitomo Electric (SEI) Substation Vanadium Redox Flow Battery
(San Miguel, California)[72]

This 2 MW/8 MWh pilot project was launched by SDG&E and SEI in 2017, with the support of Japan's New Energy and Industrial Technology Development Organization (NEDO) and the California Governor's Office of Business and Economic Development (GO-Biz). It began participating in the California Independent System Operator's (CAISO) wholesale electricity market in December 2018. This pilot project has supported research on power reliability, renewables integration, and ancillary services such as voltage and frequency regulation. In the summer of 2020, this battery also served to minimize the impact of rotating outages during a record heat wave.

MECHANICAL STORAGE TECHNOLOGIES

Pumped Hydro Storage

Key characteristics: Bulk energy storage, long duration, requires specific site attributes, large upfront costs

Description: Pumped hydro facilities typically use pumps to move water from a lower reservoir to an upper reservoir when excess electricity is available and then use gravity to release the stored water, generating electricity via a turbine. The round-trip efficiency of pumped storage facilities varies, from lower than 60 percent for some older systems to more than 80 percent.[73] As the dominant utility-scale energy storage

[69] Arabkoohsar, A. 2021. "Chapter One - Classification of energy storage systems." Mechanical Energy Storage Technologies. Available at: https://www.sciencedirect.com/science/article/pii/B9780128200230000018.

[70] Scroggin-Wicker, T. and McInerney, K. March 2, 2020. "Flow Batteries: Energy Storage Option for a Variety of Uses." Power Magazine. Available at: https://www.powermag.com/flow-batteries-energy-storage-option-for-a-variety-of-uses/.

[71] *Ibid*.

[72] SDG&E. January 22, 2021. "Groundbreaking Flow Battery Project Helping to Advance Clean Energy Microgrids." Available at: https://www.sdgenews.com/article/groundbreaking-flow-battery-project-helping-advance-clean-energy-microgrids.

[73] Yang, C.-J. 2016. "Pumped Hydroelectric Storage." Available at: https://books.google.co.uk/books?hl=en&lr=&id=TPReBwAAQBAJ&oi=fnd&pg=PA25&dq=info:1fSw0yVikpMJ:scholar.google.com&ots=nOV5mvjb3R&sig=-mVET6C_qQosE11doraPLlwi0e0&redir_esc=y#v=onepage&q&f=false.

technology, pumped hydro storage is regularly used to balance daily swings and seasonal differences in load, addressing issues such as evening ramps in net energy demand as solar energy production drops.[74] However, pumped hydro storage projects, due to their size and reliance on water, require specific site attributes that limit where they can be built and require large, upfront capital investments.

CASE STUDY

Ludington Pumped Storage Plant
(Ludington, Michigan)[75]

The Ludington Pumped Storage Plant on Lake Michigan, owned by Consumers Energy and DTE Energy, was the largest plant of its kind when built and consisted of six 312-MW units. It has been in operation since 1973, responding to the daily, weekly, and seasonal highs and lows of Michigan's energy demand. As of the fall of 2021, Ludington was close to finishing a major upgrade, which will add an extra 50 MW per unit.

CASE STUDY

Pumped Underground Storage Hydro
(Negaunee, Michigan)[76]

A team at the Michigan Technological University (MTU) is making progress on a new Pumped Underground Storage Hydro (PUSH) technology, combining the mature technology of pumped hydro storage and the innovation of utilizing abandoned underground mining sites. The storage is achieved by pumping the underground water up to the surface during periods of excess power generation and then allowing the water to drain back into the shaft to generate power during periods of demand. The MTU team has determined that the United States has between 137 and 285 GW of maximum cumulative national power capacities for partially underground and fully underground facilities of PUSH for daily storage. Among all the potential sites, the Upper Midwest is an attractive region for potential PUSH development, where most sites are concentrated in Michigan's Upper Peninsula.

Compressed Air Storage
Key characteristics: Bulk energy storage, long duration, requires specific site attributes

Description: Compressed air energy storage (CAES) is a bulk energy storage solution analogous to pumped hydro storage. In CAES systems, air is compressed using power drawn from the electric grid and stored under pressure in an underground cavern. When electricity is needed, the pressurized air is heated and expanded to drive a generator for power production.[77] Traditionally CAES technology uses underground geological

[74] U.S. Department of Energy. 2021. "Hydropower Value Study: Current Status and Future Opportunities." Available at: https://www.energy.gov/sites/prod/files/2021/01/f82/hydropower-value-study-v2.pdf.

[75] Consumers Energy. "Pumped Storage Hydro Electricity." Available at: https://www.consumersenergy.com/company/electric-generation/renewables/hydroelectric/pumped-storage-hydro-electricity.

[76] Michigan Technological University. "Researchers Investigate Pumped Storage in Retired Underground Mines." Available at: https://www.mtu.edu/news/stories/2020/march/researchers-investigate-pumped-storage-in-retired-underground-mines.html.

[77] Energy Storage Association. "Compressed Air Energy Storage (CAES)." Available at: https://energystorage.org/why-energy-storage/technologies/compressed-air-energy-storage-caes/.

formations, such as salt caverns, as reservoirs for compressed air. A newer approach with CAES uses chambers including pipelines and depleted natural gas fields.[78]

CASE STUDY

Bethel Energy Center Compressed Air Storage Facility
(Anderson, Texas)[79]

This 324 MW storage facility (with a planned expansion up to 487 MW) is expected to enter commercial operation in Fall 2022. When complete, the plant will provide power for over 300,000 homes, reduce carbon emissions and enable greater renewable energy integration. The 48-hour long-duration storage enables time-shifting of intermittent renewable energy production from low-demand to high-demand periods and provides low-cost ancillary services.

Flywheel Storage
Key characteristics: High energy density, fast response

Description: Flywheel energy storage is a mechanical system that converts kinetic energy to electricity in a spinning rotor. To reduce losses, the mass spins in a nearly frictionless enclosure.[80] A flywheel system can last more than 25 years and can be manufactured from 100 percent recyclable, nonhazardous materials.[81] These systems have high energy density and substantial durability which allows them to be cycled frequently with no impact to performance.[82] They also have very fast response and ramp rates.[83] Flywheels are well suited to applications that require high power and relatively low energy. They are especially attractive for applications requiring frequent cycling because these systems can undergo many partial and full charge-discharge cycles with limited wear per cycle.

CASE STUDY

Beacon Power 20 MW Flywheel Frequency Regulation Plant
(Hazle, Pennsylvania)[84]

This 20 MW flywheel system provides frequency regulation services to the PJM RTO. The flywheel system can respond nearly instantaneously to an independent system operator's control signal at a speed 100 times faster than traditional generation resources. The entire project consists of two hundred 100 kW flywheels that can fully respond in 4 seconds with no energy degradation over time.

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[78] *Ibid*.

[79] Apex CAES. "Bethel Energy Center." Available at: http://www.apexcaes.com/bethel-energy-center#:~:text=The%20Bethel%20Energy%20Center%20 is,fully%20permitted%20and%20construction%2Dready.

[80] Energy Storage Association. "Flywheel Energy Storage Systems (FESS)." Available at: https://energystorage.org/why-energy-storage/technologies/flywheel-energy-storage-systems-fess/.

[81] California Energy Commission. "Tracking Progress-Energy Storage." Available at: https://www.energy.ca.gov/sites/default/files/2019-12/energy_storage_ada.pdf.

[82] Energy Storage Association. "Flywheel Energy Storage Systems (FESS)." Available at: https://energystorage.org/why-energy-storage/technologies/flywheel-energy-storage-systems-fess/.

[83] *Ibid*.

[84] U.S. Department of Energy. Office of Electricity Delivery and Energy Reliability. August 2013. "Hazel Spindle, LLC: Beacon Power 20 MW Flywheel Frequency Regulation Plant." Available at: https://www.energy.gov/sites/default/files/2015/05/f22/Beacon-Power-Flywheel-Aug2013.pdf.

One interviewee indicated that as storage gains momentum, the ability to recycle/reuse battery components is going to become increasingly important.

THERMAL STORAGE TECHNOLOGIES

Thermal Energy Storage

Key characteristics: heating and cooling, long useful life, efficiency depends on storage medium

Description: Thermal energy storage (TES) technologies heat or cool a storage medium and, when needed, deliver the stored thermal energy to meet heating/cooling or power generation needs. Commercial and residential buildings, industrial processes, and district energy installations can benefit from TES because it can deliver stored thermal energy during peak demand periods, thereby reducing peak energy use.[85] TES systems are often integrated with electric or absorption chillers to reduce peak electricity costs and, in the case of new construction, to reduce capital costs by optimizing chiller size.[86]

Example technology sub-types: Ice (Latent Heat) Thermal Storage, Chilled Water (Sensible Heat) Thermal Storage, Hot Water Thermal Storage

CASE STUDY

TES Tank for Internet Service Provider
(Dulles, Virginia)[87]

DN Tanks, a private company, built a chilled water thermal storage for an internet service provider's data center in 2006. The thermal storage provides back-up to chillers which could experience unexpected downtime and result in overheating, leading to loss of information and other IT failures for the data center. Immediately upon shutting down the chillers, the thermal storage system is energized and chilled water from the storage tank becomes the sole source of cooling for the facility.

[85] U.S. Department of Energy. "Combined heat and power technology fact sheet series: thermal energy storage." Available at: www.energy.gov/sites/prod/files/2020/10/f79/Thermal%20Energy%20Storage_compliant.pdf.

[86] *Ibid*.

[87] DN Tanks. "TES Tank for Internet Service Provider in Dulles, VA." Available at: https://www.dntanks.com/projects/tes-tank-for-internet-service-provider-A-dulles-va/.

IV. Energy Storage Deployment

NATIONWIDE

Front-of-the-meter Storage versus Behind-the-meter Storage

In 2020, the U.S. deployed a record-setting 1.46 GW of storage in 2020, comprised of 1.1 GW of FTM storage and 0.36 GW of BTM storage.[88] Both FTM and BTM storage have an important role to play in Michigan's energy future. FTM storage typically provides services to utility-scale generation and transmission and distribution systems. On the other hand, BTM storage most often provides customer-level services, including supporting both on-site generation and microgrids. While the markets for specific energy storage technologies and specific applications of such technologies grow, policy must take a comprehensive approach that considers all storage technologies and use-cases. With so many use-cases for energy storage, it is important to recognize that market structures, regulations, and incentives need to be broadly applicable, while also specific enough to appropriately value the different services storage can provide.

Storage Deployment

While the energy storage market is characterized by innovation, energy storage has been deployed and used across the U.S. at scale for decades. The primary examples of historical storage deployment are the many pumped hydro facilities integrated across various state electricity grids. Pumped hydro storage still dominates existing storage deployment in the U.S., with more than 20 GW in rated capacity, which accounts for more than 90 percent of the total storage rated capacity (Figure 2).[89] The rest of existing storage is comprised of a variety of electrochemical storage technologies (3.0 percent), mechanical storage technologies (2.2 percent) including flywheels and compressed air storage, and thermal storage technologies (2.1 percent). As shown in Figure 3, lithium-ion batteries account for just over 90 percent of the total electrochemical battery energy storage system capacity. Lead-acid batteries, sodium-based batteries, and flywheel share the remaining 10 percent, while flow batteries account for less than 1 percent of operational capacity.

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[88] Wood Mackenzie. 2020. "US Energy Storage Monitor: 2020 year-in-review." Available at: https://www.woodmac.com/reports/power-markets-us-energy-storage-monitor-2020-year-in-review-474142.

[89] U.S. Department of Energy. "DOE Global Energy Storage Database." Available at: https://sandia.gov/ess-ssl/gesdb/public/. Note: This database was last updated in November 2020.

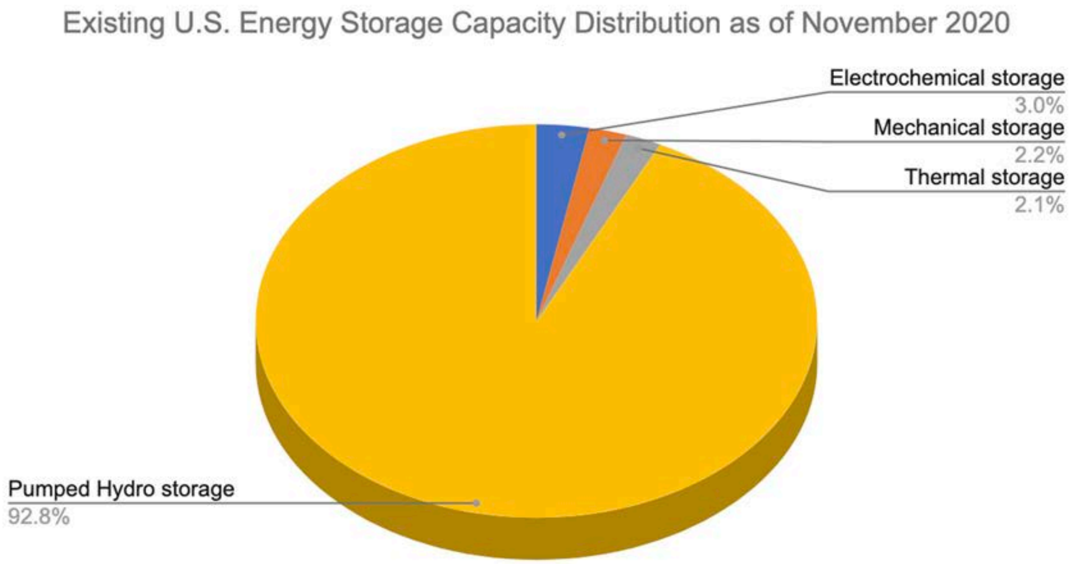

Figure 2. Existing storage deployment by storage technology.[90]

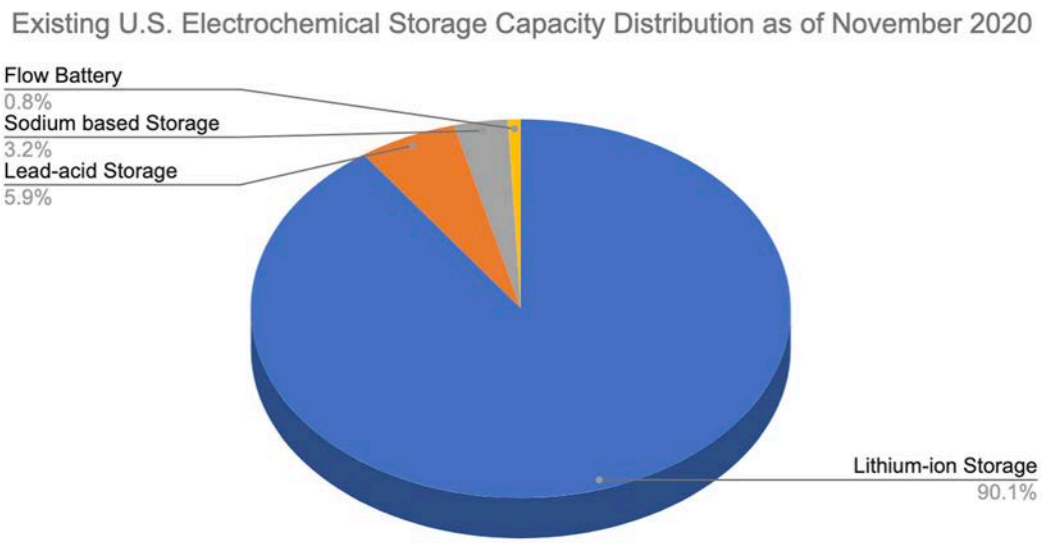

Figure 3. Existing electrochemical storage deployment by storage technology.[91]

Existing Storage Deployment by State

Given the dominance of pumped hydro facilities, it is instructive to omit pumped hydro facilities when examining recent deployment of other technologies. As such, in this section, the following discussion, figures, and tables, detail the deployment of energy storage technologies excluding pumped hydro facilities.

The total capacity and preferred technology type of deployed energy storage varies widely from state

[90] *Ibid*.

[91] *Ibid*.

to state. In the east, states including New York, Pennsylvania, New Jersey, and West Virginia all have considerable energy storage capacity installed. In the Midwest, Illinois and Ohio currently lead in storage deployment. On the west coast, existing storage projects are mainly concentrated in California and are primarily composed of lithium-ion systems. However, flywheel storage capacity surpasses lithium-ion battery capacity in both New York and Massachusetts. In Hawaii, paired lead-acid and renewables systems nearly match lithium-ion deployment despite being less common elsewhere in the country.[92]

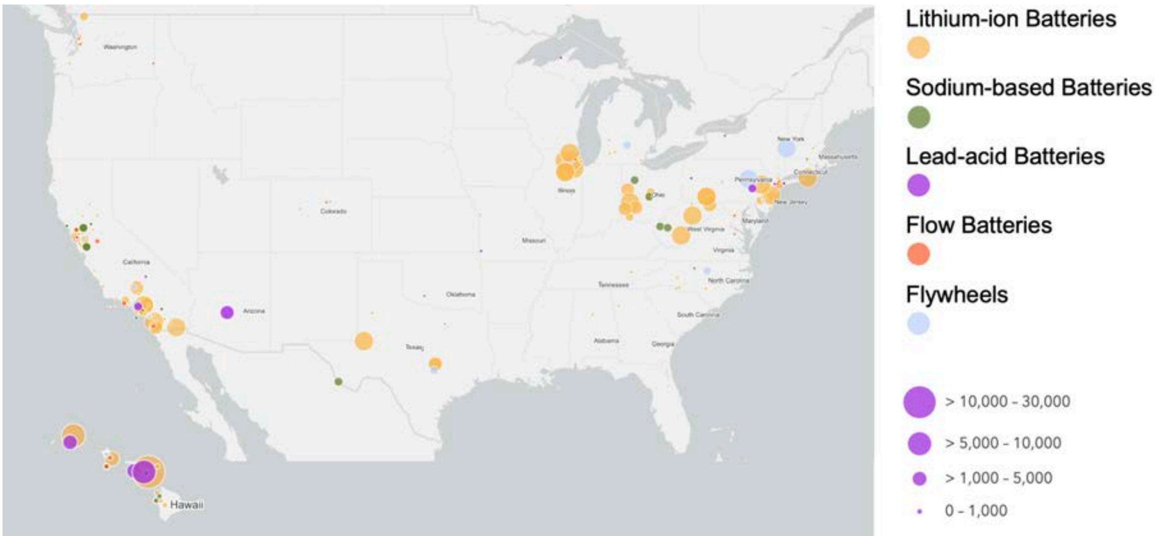

Figure 4. Map of energy storage deployment across the U.S. as of November 2020 (in kW; excludes pumped hydro storage and thermal storage).[93, 94]

	EXISTING STORAGE DEPLOYMENT CAPACITY BY TECHNOLOGY (kW)					
	Lithium-ion	Lead-acid	Sodium-based	Flywheel	Flow Battery	Others
AL	300	0	0	215	0	0
AZ	0	10000	0	600	25	0
CA	159067	5660	7695	2230	1130	4378
CO	30	0	0	0	20	325
GA	1000	0	0	0	0	20
HI	20466	17125	595	8	185	0
IL	143805	0	0	300	250	2800
MA	300	0	0	930	1000	0
MD	10540	0	0	0	0	0
MI	2850	100	0	1200	0	0
MO	1000	1100	0	0	0	0
NJ	46100	500	0	140	0	0
NY	18064	1558	1100	20000	190	0
NC	606	0	50	4000	0	2000

[92] Hawaii's lead-acid batteries are largely Xtreme Power batteries that are paired with renewable generation. After the 2021 Kahuku Wind Farm fire, Xtreme Power was acquired by a German company, Younicos, who has been replacing Xtreme's lead-acid batteries with lithium-ion batteries.

[93] U.S. Department of Energy. "DOE OE Global Energy Storage Database." Available at: https://sandia.gov/ess-ssl/gesdb/public/. Note: This database was last updated in November 2020.

[94] Figure 4 and Table 2 exclude thermal storage projects because a portion of these projects are used for heating and cooling purposes only.

OH	49200	0	4000	0	0	250
OK	0	0	0	0	250	0
PA	31350	3500	0	20000	0	0
TN	100	0	0	0	0	70
TX	57140	300	4900	5615	0	0
VA	0	0	0	0	73	0
WA	4055	0	0	0	2100	0
WV	63524	0	3200	0	0	0
Share of total	**82.2%**	**5.4%**	**2.9%**	**7.5%**	**0.7%**	**1.3%**

Table 2. Existing storage deployment across the U.S. as of November 2020 (in kW; excludes pumped hydro storage and thermal storage).[95]

MICHIGAN

Utility Front-of-the-meter Storage

As described previously, the majority of operational storage capacity in Michigan comes from Ludington, a pumped hydro facility co-owned by Consumers Energy and DTE Energy. Ludington provides system capacity, balances load and generation, enables the integration of renewable energy, and reduces price volatility.[96] Ludington also provides a valuable example of day-to-day operation on Michigan's grid, which can inform policies designed to capture the full value of energy storage and define a productive market participation model for such resources.

Unlike centralized pumped hydro storage, decentralized storage systems of many different technologies can be sited more flexibly. These facilities require less upfront investment and can meet specific locational needs on the distribution or transmission systems. Both Consumers Energy[97] and DTE Energy[98] have developed distributed storage projects in Michigan and have more planned projects. Many of these utility-developed projects are also pilot/demonstration programs that aim to inform future deployment.

In addition to these utility pilots, other distributed storage assets in Michigan include two microgrid

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[95] *Ibid*.

[96] Michigan Public Service Commission. March 2021. "New Technologies and Business Models Stakeholder Meeting 5: Storage." Available at: https://www.michigan.gov/documents/mpsc/MPGNewTech_Mtg_5_Storage_Slide_Deck_720192_7.pdf.

[97] In 2018 and 2019, Consumers Energy developed a 1 MW and a 500 kW lithium-ion battery respectively under its Parkview project and Circuit West project (see https://www.consumersenergy.com/news-releases/news-release-details/2019/01/23/consumers-energy-dedicates-first-ever-solar-battery-storage-systems-on-grand-rapids-west-side). The Parkview battery provides opportunities for Consumers Energy and Michigan State University to study the potential for battery storage use around the state. The Circuit West battery is collocated with 500 kW of solar generation at the Circuit West parking deck, offering valuable experience in smoothing renewable output and providing ancillary services (see https://www.michigan.gov/documents/energy/Energy_Storage_Session_4-Energy_Storage_in_the_Real_World_Washburn_652344_7.pdf). As of March 2021, Consumers Energy is also developing four additional storage projects (see https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000KlNuLAAX). These include another solar plus battery hybrid project in Cadillac, which is expected to be completed in 2022 and portable battery systems for substation capacity upgrade deferrals. The first portable system will be tested in the City of Standish. The third project involves a small long-duration battery that is capable of load transferring between distribution circuits with low capacity. The battery will be installed near the tie between two adjacent circuits, allowing both circuits to accept load transfers and enabling automatic voltage and VAR management. Finally, Consumers Energy is also in the process of designing a protection system with a battery that enables islanding during outages.

[98] For instance, in 2013 and 2014, DTE installed a 500 kW lithium-ion battery along with seventeen 25 kW/50 kWh distributed energy storage systems adjacent to a 500 kW solar PV system at Monroe County Community College. (see https://www.energy.gov/sites/prod/files/2017/01/f34/OE0000229_DTE_FinalRep_2016_03_16_0.pdf). This pilot project helped assess the storage system's ability to strengthen grid reliability and to store energy produced by renewable sources until it was needed. As of August 2021, DTE has 4 additional FTM storage-related pilot projects planned or under development. These include a 1 MW/1 MWh battery is scheduled to be co-located with the 2 MW O'Shea Solar Park in Detroit by early 2022, with the purpose of testing functions including, but not limited to, smoothing renewables output and wholesale market participation by responding to pricing signals implemented under the Federal Energy Regulatory Commission's (FERC) Order 841 (see Section VII; see https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000Uc0pkAAB). DTE is also planning to complete assembly of a portable 1 MW/4 MWh mobile battery trailer in 2021, with four more in the pipeline by 2025 depending on the first trailer's ability to replace traditional portable generators. These portable devices will be tasked with supporting system needs during shutdowns, and serve as components of several DTE's broader NWA projects (see see https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000Uc0pkAAB).

batteries located respectively at Fort Custer[99] and Isle Royale National Park,[100] a flywheel storage that serves Delta Dental Data Center,[101] and a thermal storage that supports Nissan Technical Center North America.[102]

Behind-the-meter Storage

As described previously, Public Act 342[103] of 2016 required the replacement of net metering with distributed generation tariffs. Under the new tariffs, it is more advantageous for customers with solar PV systems to use as much of the electricity generated by the solar system as possible on-site. As a result, many customers in Michigan are installing coupled solar PV and battery storage systems.

In 2020, Michigan's investor-owned utilities began reporting annually the number and capacity of BTM storage installations on their distribution systems. According to these reports, in DTE Energy's territory, as of December 2020, of the 887 customers who installed residential solar systems, 462 (52 percent) also installed battery storage systems for a total BTM storage capacity of 2,614 kW.[104] It is important to note that DTE Energy's distributed generation tariff was approved by the MPSC and went into effect on May 2, 2019.[105] In contrast, Consumers Energy's distributed generation tariff was not in effect until December 17, 2020.[106] Thus, it is not surprising that of the 1361 customers who installed residential solar systems in Consumers Energy's territory in 2020, only 147 (10.8 percent) also installed battery storage systems for a total BTM storage capacity of 757 kW.[107] The number and capacity of BTM battery storage systems is expected to increase in the future.

FUTURE STORAGE GROWTH: NATIONWIDE

Unprecedented growth is expected in the energy storage market throughout the next decade, both in the U.S. and around the world. According to a report from Wood Mackenzie and the U.S. Energy Storage Association (ESA), there was a 182 percent increase in deployment of new energy storage systems in Q4 of 2020 relative to Q3 of 2020.[108] In total, 2020 saw a 179 percent increase in MW of storage capacity relative to 2019, which set a new record for the industry.[109] This trend is expected to continue, as "the report estimates

[99] Go Electric. "Ft Custer Microgrid." Available at: https://goelectricinc.com/installations/534/.

[100] National Park Service. 2018. "Isle Royale National Park: Windigo Development Concept Plan Environmental Assessment." Available at: https://pubs.etic.nps.gov/eTIC/INTE-LACL/ISRO_139_147542_0001_of_0052.pdf.

[101] DOE Global Energy Storage Database. "Delta Dental Data Center VYCON (now Clanetix) Flywheels - 1200 kW." Available at: https://sandia.gov/ess-ssl/gesdb/public/projects.html#1217.

[102] Nissan Motor Corporation. 2014. "Nissan Technology Center North America (NTCNA) celebrates Earth Day 365 days a year." Available at: https://usa.nissannews.com/en-US/releases/release-4ae442cb46124590bab432c394408121-nissan-technology-center-north-america-ntcna-celebrates-earth-day-365-days-a-year.

[103] Public Act 342 of 2016. December 21, 2016. Available at: https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

[104] DTE Energy. March 29, 2021. "2020 Annual Net Metering/Distributed Generation Report." Case No. U-15787. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000MKx0pAAD.

[105] Commission Order. May 2, 2019. Case No. 20162. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000004SM3yAAG.

[106] Commission Order. December 17, 2020. Case No. 20697. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000004SM3yAAG.

[107] Consumers Energy. March 31, 2021. "Annual Net Metering Report for 2020." Case No. U-15787. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000MLTHwAAP.

[108] U.S. Energy Storage Association. "U.S. energy storage market shatters quarterly deployment record." March 3, 2021. Available at: https://energystorage.org/us-energy-storage-market-shatters-quarterly-deployment-record/.

[109] *Ibid*.

that the storage market will deploy five times more MW in 2025, with front-of the meter systems continuing to comprise a bulk of that growth."[110] The U.S. Energy Information Administration (EIA) suggests that there will be particularly accelerated growth in storage deployment in the coming years, estimating that 10,000 MW of storage will be added to the grid between 2021 and 2023, which is "10 times the capacity in 2019."[111] These predictions are echoed around the world and storage installations around the globe are expected to increase by 122-fold by 2040.[112]

The current and expected growth of the storage market is made possible in large part by the declining cost of storage and by the increasing penetration of renewables. According to EIA, average energy storage capital costs fell by 72 percent between 2015 and 2019.[113] In addition, EIA estimates that future energy storage systems are more likely to be co-located with solar generation projects. According to EIA, "if all currently announced projects from 2021 to 2023 become operational, the share of U.S. battery storage that is co-located with generation would increase from 30% to 60%."[114] ESA has stated that, though the current projections are already unprecedented, deployments of energy storage could exceed the projections "if clean energy policies boosted the penetration of wind and solar generation beyond the forecasted levels" because of co-location potential.[115]

Several interviewees indicated that it is important to be technology agnostic when setting policies to support energy storage deployment because the market and technologies are innovating so quickly.

FUTURE STORAGE GROWTH: MIDWEST

The MISO generator interconnection queue includes both stand-alone and hybrid energy storage resources (Figures 5 and 6).[116] As of January 30, 2022, approximately 14.2 GW of storage has been registered independently in the MISO queue, and another 13.2 GW of hybrid projects incorporate storage components.[117] In September of 2021, the number of applications to interconnect storage resources in MISO exceeded those for wind resources.[118]

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110 *Ibid*.

111 U.S. Energy Information Administration. August 2021. "Battery Storage in the United States: An Update on Market Trends." Available at: https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf.

112 Bloomberg NEF. July 31, 2019. "Energy to storage increase 122X by 2040." Available at: https://www.renewableenergyworld.com/storage/bnef-energy-storage-increase-122x-by-2040/#:%7E:text=BNEF%E2%80%99s%20Energy%20Storage%20Outlook%202019%2C%20published%20on%20July,different%20markets%20%E2%80%93%20stationary%20storage%20and%20electric%20vehicles.

113 U.S. Energy Information Administration. August 2021. "Battery Storage in the United States: An Update on Market Trends." Available at: https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf.

114 U.S. Energy Information Administration. August 2021. "Battery Storage in the United States: An Update on Market Trends." Available at: https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf.

115 Energy Storage Association. "100 x 30: Enabling the Clean Power Transformation." August 2020. Available at: https://energystorage.org/wp/wp-content/uploads/2020/08/100x30-Empowering-Clean-Power-Transformation-ESA-Vision.pdf.

116 MISO defines hybrid resources as a generator that combines more than one type of electric facility for the production and/or storage for later injection of electricity.

117 MISO. August 2021. "Generator Interconnection Queue-GI Interactive Queue." Available at: https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/gi-interactive-queue/.

118 MISO. September 15, 2021. "Storage project applications surpass wind for the first time." Available at: https://www.misoenergy.org/about/media-center/2021-generator-interconnection-queue-applications-set-new-record/.

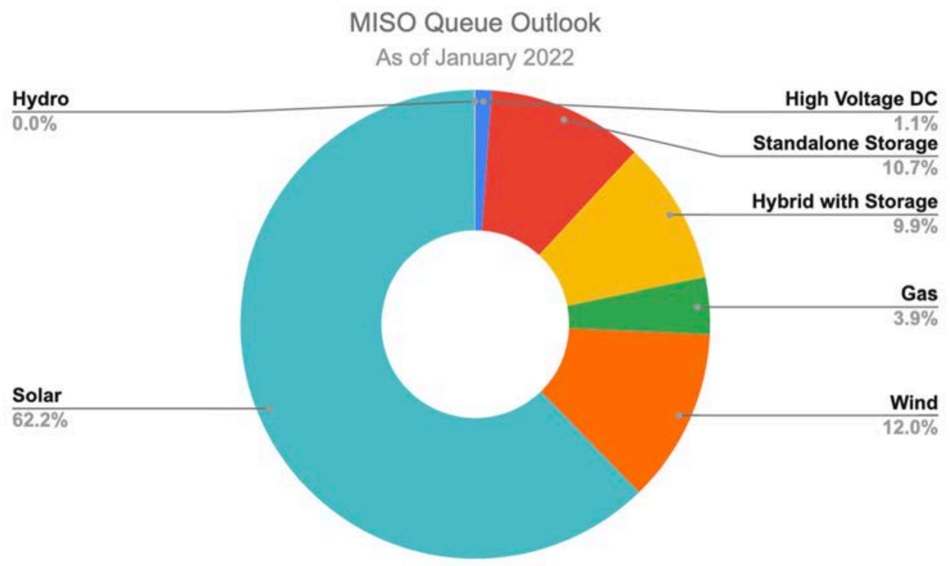

Figure 5. Resources in the MISO generator interconnection queue as of January 2022.[119]

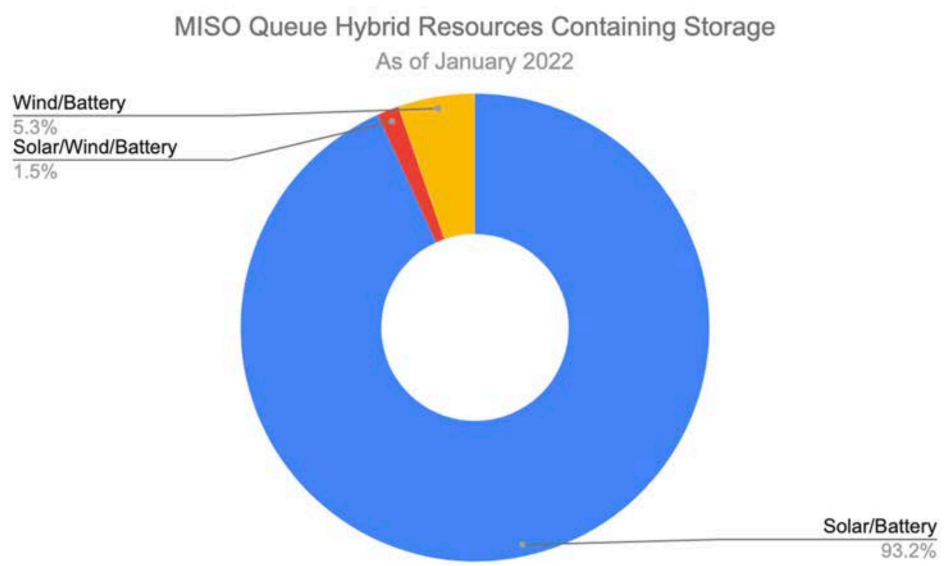

Figure 6. Hybrid storage resources in the MISO generator interconnection queue as of January 2022.[120]

In Michigan, as of January 2022, there are 2,020 MW of standalone storage projects in the MISO queue and 1,724 MW of solar-storage hybrid projects (Figure 7). These projects are spread across the state and vary in size from 20 MW to 400 MW (Table 3).

[119] *Ibid*.

[120] *Ibid*.

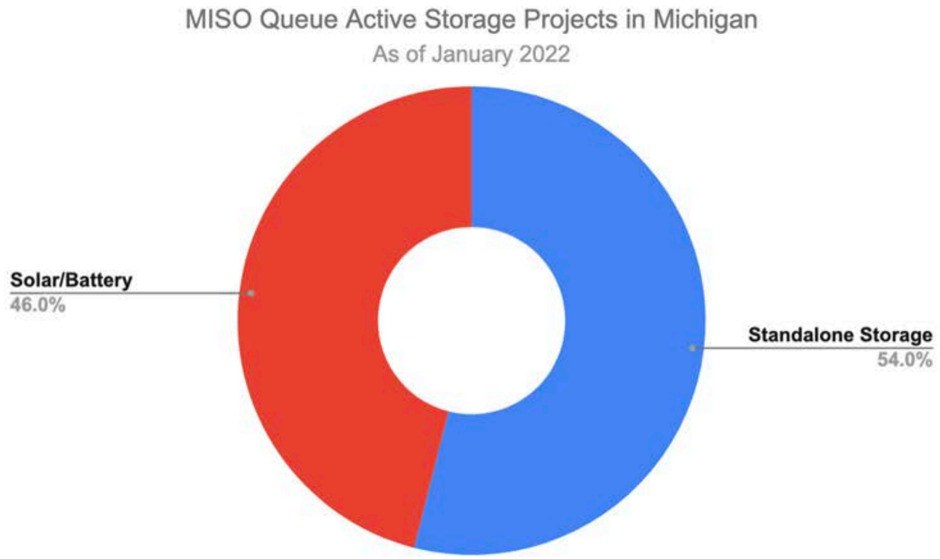

Figure 7. Michigan standalone and solar-storage hybrid resources in the MISO generator interconnection queue as of January 2022.[121]

QUEUE DATE	GENERATING FACILITY	CAPACITY (MW)	TRANSMISSION OWNER	COUNTY	STATE
4/29/19	Standalone Storage	20	ITC Transmission	Washtenaw County	MI
6/25/20	Standalone Storage	150	Michigan Electric Transmission Company LLC	Kent	MI
6/25/20	Solar/Battery	499	Michigan Electric Transmission Company LLC	Calhoun	MI
6/25/20	Standalone Storage	100	Michigan Electric Transmission Company LLC	Branch	MI
6/25/20	Standalone Storage	100	ITC Transmission	Washtenaw	MI
7/22/21	Standalone Storage	100	ITC Transmission	Washtenaw	MI
7/22/21	Standalone Storage	100	Michigan Electric Transmission Company LLC	Calhoun	MI
7/22/21	Standalone Storage	60	Michigan Electric Transmission Company LLC	Lenawee	MI
7/22/21	Standalone Storage	45	Michigan Electric Transmission Company LLC	Clinton	MI
7/22/21	Standalone Storage	60	Michigan Electric Transmission Company LLC	Otsego	MI
7/22/21	Standalone Storage	60	Michigan Electric Transmission Company LLC	Ottawa	MI
7/22/21	Standalone Storage	200	Michigan Electric Transmission Company LLC	Kalamazoo	MI
7/22/21	Standalone Storage	200	ITC Transmission	Wayne	MI
7/22/21	Standalone Storage	200	ITC Transmission	Wayne	MI
7/22/21	Standalone Storage	50	ITC Transmission	Monroe	MI
7/22/21	Standalone Storage	50	Michigan Electric Transmission Company LLC	Kent	MI
7/22/21	Standalone Storage	25	Michigan Electric Transmission Company LLC	Gladwin	MI
7/22/21	Standalone Storage	50	Michigan Electric Transmission Company LLC	Ottawa	MI
7/22/21	Standalone Storage	100	ITC Transmission	Gratiot	MI
7/22/21	Solar/Battery	200	Michigan Electric Transmission Company LLC	Lenawee	MI
7/22/21	Solar/Battery	100	Michigan Electric Transmission Company LLC	Montcalm	MI
7/22/21	Standalone Storage	100	Michigan Electric Transmission Company LLC	Jackson	MI

[121] *Ibid*.

7/22/21	Solar/Battery	100	ITC Transmission	Montcalm	MI
7/22/21	Standalone Storage	250	Michigan Electric Transmission Company LLC	Van Buren	MI
7/22/21	Solar/Battery	125	Michigan Electric Transmission Company LLC	Monroe	MI
7/22/21	Solar/Battery	50	ITC Transmission	Hillsdale	MI
7/22/21	Solar/Battery	150	Michigan Electric Transmission Company LLC	Allegan, Barry	MI
7/22/21	Solar/Battery	400	ITC Transmission	Livingston	MI
7/22/21	Solar/Battery	150	Michigan Electric Transmission Company LLC	Ionia	MI

Table 3. List of Michigan standalone and solar-storage hybrid projects in the MISO queue as of January 2022.[122]

Of course, the current MISO queue represents only storage projects able to deploy in the very near-term. The high quantity of storage resources in the queue, even in the presence of restrictive participation policies, indicates high potential for future deployment.

V. Quantifying the Value of Storage

In order to realize the true potential of an energy storage future, market rules need to accurately reflect the value of each distinct service provided by storage. The value of any particular service will vary depending on project characteristics like location, service provided, and availability of market opportunities. As such, policymakers must carefully consider appropriate compensation mechanisms via public and transparent processes. However, not all storage services are easily quantified (e.g., reduced renewables curtailment and the provision of back-up power).

Considerable work is already underway to monetize wholesale services provided by energy storage. FERC Orders 755 and 784 require wholesale market operators (like MISO and PJM) to compensate resources at a high level for frequency regulation services. As described in more detail in Section VII, FERC Order 841 (2018) directed regional system operators to revise wholesale market rules to allow energy storage to provide all available services and receive appropriate compensation. In 2020, FERC issued Order 2222 to allow the aggregation of DERs to offer energy, capacity, and ancillary services at the wholesale level.

At the retail level, much of this work remains to be done. This is the case in Michigan where, to date, pilots make up the majority of storage projects and the MPSC continues to direct utilities to propose new pilots to evaluate additional benefits.[123] For retail services, determining a methodology to monetize the services provided by energy storage may vary depending on the primary service provided. For instance, if a storage unit is installed to defer a distribution system upgrade, it will need to be available first to meet the needs of the distribution system and only offer other services when that service is not needed. However, there are some examples of monetization approaches that may serve as a foundation to build out a more comprehensive set of principles or rules to ensure that energy storage is appropriately compensated in Michigan. For example, the value of a deferred distribution investment is commonly the avoided cost of the traditional distribution project.

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[122] *Ibid*.

[123] Michigan Public Service Commission. August 11, 2021. Order U-21032. Available at: https://mi-psc.force.com/s/case/500t000000j0epIAAQ/in-the-matter-on-the-commissions-own-motion-to-request-comments-on-midcontinent-independent-system-operator-incs-implementation-of-federal-energy-regulatory-commission-order-no-841-regarding-energy-storage-resources.

A more comprehensive "value of storage" analysis could provide key insights into such a framework that is specific to Michigan. New York and Massachusetts have undertaken similar efforts to identify the dollar value that storage and other distributed resources provide to the electric system using different approaches. In 2016, as part of the $10 million Energy Storage Initiative launched by the Governor, Massachusetts undertook a study to determine the value of storage and under what conditions storage could be cost-effectively deployed. The resulting "State of Charge" report found that 1,766 MW of storage would deliver $2.3 billion in benefits to ratepayers, despite finding that only one third of the benefits of storage could be monetized under existing regulations and market designs.[124] In New York, after conducting a similar analysis of storage potential and benefits in the state, the state adopted a Value of Distributed Energy Resource (VDER) tariff[125] that provides bill credits to customers with distributed resources, including storage or storage paired with another resource type, based on a combination of the energy value, capacity value, environmental value, demand reduction value, and locational system relief value.[126]

VI. Barriers to Storage Deployment

While the global market for storage is poised for rapid growth and the need for energy storage is apparent as the electric grid evolves, the pace of energy storage deployment depends on future policy and market evolution. Despite notable FTM storage pilot projects and growing BTM storage projects, there is no certainty that Michigan will adopt energy storage at the necessary pace or be positioned to play a role in the global market for energy storage. Like any emerging market, energy storage deployment faces a variety of barriers, many of which can be addressed via public policy.

At a fundamental level, the integration of energy storage into the existing electric grid requires a paradigm shift. As described previously, laws and policies as well as various market signals are based on an electric grid using fossil-fuel generators, customer-driven loads, and traditional poles, wires, and substations. Many law, business, and regulatory constructs are not designed for a dynamic and responsive resource like energy storage. Energy storage deployment — and as a result, the demand for the manufacture and assembly of energy storage devices — is limited by regulatory and policy challenges that can largely be characterized into four categories: 1) outdated or ill-designed regulatory and policy frameworks at the state and regional levels; 2) economic cost and compensation limitations; 3) traditional utility business models that are not designed for energy storage; and 4) technological limitations.[127] Many of these challenges are interrelated and as such, any policy solutions that Michigan considers will need to work to address multiple challenges.

Outdated or Ill-Designed Regulatory and Policy Frameworks

RTO/ISO

While this Roadmap focuses on state regulatory and policy barriers and options to overcome those barriers, there remain broader barriers at the regional level that must be acknowledged. In MISO, energy

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[124] Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center. 2016. "State of Charge: Massachusetts Energy Storage Initiative Study." Available at: https://www.mass.gov/doc/state-of-charge-report/download.

[125] NYSERDA. "The Value Stack." Available at: https://www.nyserda.ny.gov/all-programs/programs/ny-sun/contractors/value-of-distributed-energy-resources.

[126] New York State Department of Public Services. Case No. 15-0751. Value of Distributed Energy Resources (VDER). Available at: https://www3.dps.ny.gov/W/PSCWeb.nsf/All/8A5F3592472A270C8525808800517BDD?OpenDocument.

[127] McNamara, W. July 31, 2020. "Energy Storage Policy Workshop." Sandia National Laboratories.

storage projects are often limited in their ability to be fully utilized and fairly compensated. For example, as described in Section VII, MISO has yet to implement Order 841 or Order 2222, which could both enable greater participation of FTM and BTM energy storage devices in regional markets. Energy storage developers also face complicated, unfavorable, and delayed interconnection procedures at the RTO level. For example, according to industry participants survey for this Roadmap (see Section IX), the interconnection study process for storage uses conservative dispatch assumptions unrealistic for storage injection and withdrawal in its peak and shoulder study cases. This, along with the limited transmission system capacity, leads to a high likelihood of unnecessarily expensive interconnection costs for storage projects.

Local and State Level

While energy storage will be critical in meeting key policy objectives related to reliability, affordability, and carbon reductions, the current policy and regulatory landscape presents hurdles to developing a robust energy storage market in Michigan. In some cases, energy storage is simply not contemplated in Michigan policy and regulatory frameworks, while in other cases, regulations and policies place actual limitations on how energy storage can best participate in the market for electricity. Some of these policies fail to consider energy storage in planning activities, limit access to the electric grid through procedural issues, restrict uses of energy storage, or fail to properly value and compensate energy storage.

A core challenge stemming from the lack of frameworks that account for energy storage is that energy storage does not fit into typical regulatory schemes because it can both supply and store electricity, or be deployed as a transmission or distribution asset, but it is often classified simply as generation. Rigidness in the functional classification of storage in policy serves to limit how energy storage can function and, in turn, hurts the economic case and the benefits that storage can provide to the grid and customers.[128] As such, planning processes, rules, and procedures may not allow energy storage to provide its full suite of benefits or may not provide compensation for such benefits.

Planning processes such as integrated resource planning and distribution system planning, as well as the traditional modelling underlying these processes, often fail to holistically evaluate and include energy storage. These processes often fail to identify and value all of the system-level services (see Section X), to account for specific services that may be unique to a given location, to account for the dynamic between competing and complementary uses of energy storage, or to capture the instantaneous services that energy storage offers.[129] Similarly, procedures, like interconnection standards, have typically been designed without broad future adoption of storage in mind. Without interconnection processes designed for energy storage, the risk of not gaining approval or of suffering delays can negatively impact the deployment of storage.

In many cases, rate design at the state level also fails to value the services that energy storage can provide, such as reducing peak loads and providing ancillary services. In addition, as described in Section VIII, rate design often also inappropriately penalizes storage. Better alignment between costs imposed (or saved) by operation of storage resources and rates charged to customers would be helpful in supporting the deployment of storage.

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[128] Bhatnager, D., et al. September 2013. "Market and Policy Barriers to Energy Storage Deployment." Sandia National Laboratory Report. Available at: https://www.sandia.gov/ess-ssl/publications/SAND2013-7606.pdf.

[129] Twitchell, J. 2019. "A Review of State-Level Policies on Electrical Energy Storage." Current Sustainable/Renewable Energy Reports. Vol. 6. Available at: https://link.springer.com/article/10.1007/s40518-019-00128-1.

Other local and state-level challenges exist for clean energy deployment broadly, such as siting and zoning, taxation, and more.[130] Siting challenges, similar to those faced by wind and solar projects, are anticipated as more hybrid and stand-alone storage systems are deployed.

Economic Cost and Compensation Limitations

The costs of energy storage projects have declined greatly over the last decade. For example, according to Bloomberg New Energy Finance, the costs of lithium-ion batteries have declined from $684/kWh in 2013 to $132/kWh in 2021.[131] However, while the costs of storage technologies have declined greatly, soft costs (e.g., siting, permitting, interconnection, etc.) continue to represent a large portion of system costs.[132] In addition to cost, the monetary value of the services an energy storage asset provides and the ability of the owner of that asset to be compensated for those services is equally important. Many of the services that storage can provide are not currently monetized in the wholesale market, are not currently compensated for at the retail level, or are indirect benefits that have been difficult to quantify such as reduced curtailment risk, reduced emissions, and increased grid resiliency and reliability. Michigan has not established a holistic valuation of energy storage and its services, but neighboring states like Minnesota have done so, factoring in energy and non-energy benefits.[133]

Business Models

Storage deployed both FTM and BTM may be owned by utilities, third-parties, customers, or some combination thereof. However, utilities and regulators are inherently risk-averse, including when it comes to the deployment and rate basing of new technologies. For FTM storage systems, one strategy to address this is to off-load that risk onto a third-party energy storage developer.[134] Third-party owners can take on risks associated with relatively new technologies, removing that risk burden from utilities and ratepayers. For BTM storage systems, customer-owned systems or third-party owned systems can be aggregated by third parties to provide grid services. Additional regulatory mechanisms may need to be developed to incentivize and enable customers to provide these benefits appropriately to the grid.[135]

In either case, ensuring third-party participation in the energy storage market will be important to reducing costs, deploying innovative technologies and allowing the many storage technologies to compete against one another. It is important to ensure that utilities and third-party developers have aligned incentives and objectives to encourage competition, growth, and innovation in the energy storage market.[136]

Technological Limitations

Technological innovation and the deployment necessary to gain lessons learned requires capital investments and creates risk. To continue to improve existing energy storage technical capabilities and to

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[130] E4TheFuture, PLMA, Smart Electric Power Alliance. November 2018. "Non-Wires Alternatives: Case Studies from Leading U.S. Projects." Available at: https://e4thefuture.org/wp-content/uploads/2018/11/2018-Non-Wires-Alternatives-Report_FINAL.pdf.

[131] Henze, V. BloombergNEF. November 30, 2021. "Battery Pack Prices Fall to an Average of $132/kWh, But Rising Commodity Prices Start to Bite." Available at: https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/.

[132] New York Department of Public Service. April 1, 2020. "State of Storage in New York." Available at: https://www.transmissionhub.com/wp-content/uploads/2020/04/NYdpsReportApr12020.pdf.

[133] Minnesota Commerce Department. 2020. "Minnesota Energy Storage Cost-Benefit Analysis." Available at: https://mn.gov/commerce/policy-data-reports/energy-data-reports/?id=17-415938.

[134] Bhatnager, D., et al. September 2013. "Market and Policy Barriers to Energy Storage Deployment." Sandia National Laboratory Report. Available at: https://www.sandia.gov/ess-ssl/publications/SAND2013-7606.pdf.

[135] Michigan Public Service Commission Staff Report. U-20898 MI Power Grid: New Technologies and Business Models Workgroup. December 1, 2021. "New Technologies, Business Models, and Staff Recommendations." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/0688y000001jEwjAAE. p. 90.

[136] McNamara, W. July 31, 2020. "Energy Storage Policy Workshop." Sandia National Laboratories.

drive new energy storage technologies, policies can be deployed to incentivize research and development, support new technologies as they move toward commercialization, and serve to minimize or mitigate risk.

PART II: ENABLING THE FUTURE OF STORAGE

VII. Federal and Regional Storage Policies

FEDERAL POLICIES

Federal Legislation

A number of technologies including solar PV, CHP, fuel cells, microturbines, and storage under certain circumstances are eligible for investment tax credits (ITC) under Sections 48[137] (commercial and utility-scale) and 25D[138] (residential) of the IRS tax code. These credits are based on the amount of the original investment. As of March of 2022, the ITC for commercial/utility-scale projects is set to phase down from its current 26 percent to 22 percent for projects that begin construction in 2023 and 10 percent for projects that begin construction in 2024 and thereafter. The ITC for residential projects similarly phases down to 22 percent in 2023 but phases out entirely at the end of 2023. Energy storage projects are currently eligible to access the ITC only when integrated with ITC-eligible solar resources.

Under the Build Back Better Act, which passed the U.S. House of Representatives on November 18, 2021, stand-alone energy storage projects would be added to the list of eligible technologies for the ITC. In this legislation, residential projects, including energy storage, would receive the full 30 percent Section 25D ITC through the end of 2031. The credit would then phase down to 26 percent in 2032 and 22 percent in 2033, expiring after the end of 2033. Commercial/utility-scale projects, including energy storage, would receive the full 30 percent ITC through the end of 2026 if prevailing wage requirements are followed. The bill also would make payments under Section 48 eligible for "direct pay," meaning that taxpayers can elect to treat the credit as a payment of tax instead of carrying forward credits to years with sufficient tax liability. The bill would allow taxpayers to choose a direct pay eligible ITC based on carbon emissions emitted per kWh generated, up to a maximum of 50 percent. These credits are set to phase out the latter of 2031 or over three years when the electricity sector emits 75 percent less carbon than 2021 levels. As of March of 2022, the future of this legislation and of these specific provisions is uncertain.[139]

Federal Environmental Justice Policies

Clean energy has been at the heart of recent debates in Congress on national infrastructure development and ensuring an equitable clean energy transition is a key priority of the Biden Administration. Energy storage can play an important role in such an equitable transition by shoring up reliability and resilience in historically underserved communities. According to the U.S. Department of Energy: "The benefits and costs

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[137] U.S. Internal Revenue Code. 26 U.S. Code § 48 - Energy credit. Available at: https://uscode.house.gov/view.xhtml?req=(title:26 section:48 edition:prelim).

[138] U.S. Internal Revenue Code. 26 U.S. Code § 25D – Residential energy efficient property. Available at: https://uscode.house.gov/view.xhtml?hl=false&edition=prelim&req=granuleid%3AUSC-prelim-title26-section25D&num=0&saved=%7CKHRpdGxlOjI2IHNlY3Rpb246NDggZWRpdGlvbjpwcmVsaW0p%7C%7C%7C0%7Cfalse%7Cprelim.

[139] As of March 14, 2022, the Build Back Better Act has not been brought to the U.S. Senate floor for a vote.

of the existing energy system have not been equitably distributed. Under-resourced communities (e.g., low-income communities, communities of color, communities facing near-term climate change risks) have borne disproportionately large shares of the costs of the existing system, have enjoyed fewer benefits, and have been largely shut out of energy system planning and procedures."[140]

To begin to address these historic injustices, in the summer of 2021, the Biden Administration announced the Justice40 initiative, an effort to deliver to disadvantaged communities at least 40 percent of the overall benefits from federal investments in clean energy and climate mitigation and adaptation activities.[141] The Infrastructure Investment and Jobs Act, which was signed into law by President Biden on November 15, 2021, includes more than $62 billion for the U.S. Department of Energy to deliver a more equitable clean energy future by: 1) investing in American manufacturing and workers; 2) expanding access to energy efficiency and clean energy for families, communities and businesses; and 3) delivering reliable, clean, and affordable power to more Americans.[142] The Act also includes the creation of a "Program Upgrading Our Electric Grid and Ensuring Reliability and Resiliency" to demonstrate, through implementation by the States and Tribal nations, innovative approaches to transmission, storage, and distribution infrastructure to harden and enhance resilience and reliability.[143] On November 15, 2021, President Biden issued his *Executive Order on Implementation of the Infrastructure Investment and Jobs Act* in which he identified as an implementation priority "investing public dollars equitably, including through the Justice40 Initiative, which is a Government-wide effort toward a goal that 40 percent of the overall benefits from Federal investments in climate and clean energy flow to disadvantaged communities."[144]

To support its focus on serving frontline environmental justice communities, the U.S. Environmental Protection Agency has developed a new environmental justice mapping and screening tool called EJSCREEN, "based on nationally consistent data and an approach that combines environmental and demographic indicators in maps and reports."[145] Going forward, the use of EJSCREEN and other similar screening tools may assist decision makers in ensuring that vulnerable communities have access to the reliability and resilience gains offered through energy storage installations.

REGIONAL REGULATION

Storage as Transmission-Only Asset

Storage as Transmission-Only Asset (SATOA), where storage is used as a substitute for transmission infrastructure, is an emerging line of potential business for storage developers. To date, only MISO has FERC-approved rules to govern consideration of SATOA in the transmission planning process, received in

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[140] U.S. Department of Energy. September 2021. "Solar Futures Study." Available at: https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf. p. 14.

[141] The White House Briefing Room. July 20, 2021. "The Path to Achieving Justice40." Available at: https://www.whitehouse.gov/omb/briefing-room/2021/07/20/the-path-to-achieving-justice40/.

[142] U.S. Department of Energy. November 9, 2021. "DOE Fact Sheet: The Bipartisan Infrastructure Deal Will Deliver For American Workers, Families and Usher in the Clean Energy Future." Available at: https://www.energy.gov/articles/doe-fact-sheet-bipartisan-infrastructure-deal-will-deliver-american-workers-families-and-0.

[143] Infrastructure Investment and Jobs Act of 2021. Section 40103. Available at: https://www.congress.gov/bill/117th-congress/house-bill/3684/text.

[144] The White House Briefing Room. November 15, 2021. "Executive Order on Implementation of the Infrastructure Investment and Jobs Act." Available at: https://www.whitehouse.gov/briefing-room/presidential-actions/2021/11/15/executive-order-on-implementation-of-the-infrastructure-investment-and-jobs-act/.

[145] U.S. Environmental Protection Agency. "EJSCREEN: Environmental Justice Screening and Mapping Tool." Available at: https://www.epa.gov/ejscreen.

August 2020.[146] However, stakeholders have identified a number of shortcomings in the MISO framework.[147] For instance, SATOA projects proposed by existing transmission owners do not have to be evaluated through the generator interconnection process, while those proposed by non-transmission owning members do. This process could take years and large financial investment to successfully navigate, substantially disadvantaging non-transmission owners. In addition, units identified in the transmission planning process as SATOAs (utility owned) are allowed to be oversized relative to the identified need. This serves to give the utility owners of such assets an advantage of having future capacity available that other units do not have. Notably, the MPSC filed an Answer with FERC supporting the position of stakeholders that the SATOA framework approved by FERC was indeed discriminatory in favor of transmission owners proposing SATOA.[148]

Recognizing the potential for energy storage to serve as a transmission asset is certainly a positive change for the storage industry, but allowing a resource to provide both transmission benefits and other market services is necessary to realize the full value that storage can provide.

FERC Order 841

Progress is underway to allow storage resources to provide the full suite of possible services in wholesale markets under the regulatory authority of FERC. On February 15, 2018, FERC issued Order 841[149] requiring RTOs/ISOs to adapt their market rules to remove barriers to participation of energy storage resources in wholesale energy, capacity, and ancillary services markets, provide compensation for all of the services provided, and recognize the unique physical and operational characteristics of energy storage. These rules specifically allow BTM storage 100 kW or larger to participate in the wholesale market.

Michigan utilities participate in either the MISO or PJM energy markets. Each of these regional entities has filed the required participation models with FERC and these models have been accepted with some compliance activities still under development. The effective date of the new model in MISO is not until June of 2022 while the effective date for PJM was December 2019 in part, with some elements phasing in through March 2024. These compliance filings are subject to input from stakeholders and require multiple iterations before receiving approval. Though most industry advocates generally support the approaches the RTOs have filed, the true impact will not be known until the rules are implemented and participants have sufficient actual experience.

One of the key issues not specifically required to be addressed in Order 841 but that will nonetheless impact opportunities for storage is the regulation of hybrid resources. As of fall 2021, discussions are underway in MISO and PJM on a potential path forward for hybrid resources, but the required stakeholder process and approval by FERC likely mean new rules are several years away.

FERC Order 2222

On September 17, 2020, FERC issued Order 2222,[150] a key policy change that will be beneficial to energy storage. Like Order 841, Order 2222 requires the RTO/ISOs to remove barriers to participation in wholesale

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[146] Midcontinent Independent System Operator, Inc. 172 FERC ¶ 61,132. August 10, 2020. Available at: https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20200810-3062&optimized=false.

[147] Docket No. ER20-588-000. September 9, 2020. "Request for Rehearing of the Joint MISO Stakeholder Section Participants." Available at: https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20200909-5184&optimized=false.

[148] Docket No. ER20-588-000. September 21, 2020. "The Michigan Public Service Commission's Motion for Leave to Answer Requests for Rehearing." Available at: https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20200921-5208&optimized=false.

[149] Federal Energy Regulatory Commission. Order No. 841. February 15, 2018. "Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators." Available at: https://ferc.gov/sites/default/files/2020-06/Order-841.pdf.

[150] Federal Energy Regulatory Commission. September 17, 2020. Order No. 2222. "Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators." Available at: https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf.

capacity, energy, and ancillary services markets. Unlike Order 841, this order applies to aggregated DERs that may include storage among a variety of other resources like rooftop solar PV, electric vehicles, demand response, and energy efficiency, including those connected to the distribution system or BTM. The deadline for submission of the proposed rules to govern Order 2222 implementation is February 2022 for PJM and April 2022 for MISO. As with Order 841, the compliance filings are likely to take several iterations of comments from stakeholders and required changes from FERC before they are final, which could also take a year or more.

It is important to note that Order 2222 definitively leaves the interconnection processes for distribution connected and BTM resources to state regulators and distribution utilities. The policies established in those proceedings, which will vary by state and could vary by utility within a state, will be key to the success of Order 2222 for energy storage and other distributed resources.

One interviewee indicated that policy changes at all regulatory levels (FERC, RTO, PUC) are critical to enabling the full benefits of energy storage.

VIII. State Storage Policies

Well-designed state policies can have an important impact on the deployment and operation of energy storage resources. According to the Interstate Renewable Energy Council (IREC), state policy actions on energy storage can be grouped into four categories:[151]

Investigate: Policies to consider storage and its values through workshops, studies, briefings, and investigations. These investigations most often result in actual policy changes when clear recommendations and next steps are established.

Clarify: Efforts to clarify existing rules to define how they apply to storage (e.g., interconnection rules, building codes, etc.).

Energize: Policies that encourage storage market growth (e.g., procurement targets, pilot projects, incentives).

Plan: Policies to integrate storage into regulatory planning processes such as Integrated Resource Plans (IRPs) and distribution system planning.

Many states have taken actions in each of these categories, which do not need to necessarily be viewed as sequential in nature.[152] For example, given expanding knowledge about the value, uses, and economics of energy storage, it is not always necessary for policy makers to wait for the results of a state-specific investigation to take immediate actions that set the stage for future storage deployment.

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[151] Stanfield, S., Petra, J. S., and Auck, S. B. Interstate Renewable Energy Council. April 2017. "Charging Ahead: An Energy Storage Guide for State Policymakers." Available at: https://irecusa.org/resources/charging-ahead-energy-storage-guide-for-policymakers/.

[152] Pacific Northwest National Laboratory. "Energy Storage Policy Database." Available at: https://energystorage.pnnl.gov/regulatoryactivities.asp.

As discussed throughout this Roadmap, policies that support the increased use of energy storage should include recognition of historic energy system inequities to intentionally deploy storage resources in a manner that shares the benefits to all communities.[153] This includes the equitable distribution of cost savings as energy storage adds value to the grid. In the fall of 2021, the U.S. Department of Energy launched the Energy Storage for Social Equity (ES4E) Initiative, a program to assist underserved and frontline communities in their efforts to leverage energy storage as a means of increasing resilience and lowering energy burdens.[154] Administered by the Pacific Northwest National Laboratory (PNNL), ES4E "is designed to empower urban, rural, and tribal disadvantaged communities to consider energy storage technologies and applications as a viable path towards community prosperity, well-being, and resilience."[155] At the state level, one way to focus on equity is to reserve a certain portion of available incentives for disadvantaged communities. For example, the California Self-Generation Incentive Program includes three categories focused on equity: residential equity systems, residential equity resiliency systems, and non-residential equity systems. The largest incentives ($1 per watt-hour), which are enough to almost cover the upfront cost of a residential solar plus storage system completely, are reserved for customers who are the most vulnerable to harm due to multiday outage events.[156]

Assessing the Value of Storage

As described previously, storage resources can be compensated for some services via wholesale market mechanisms. However, many services are not currently monetized in the wholesale market, are not currently valued at the retail level, or provide indirect benefits that have been difficult to quantify such as reduced curtailment risk, reduced emissions, and increased grid resiliency and reliability.

Public Act 286 of 2008, Sec 11 (1) requires that electric rates in Michigan reflect "cost of service."[157] Cost of service can consider actions of the customer and/or operations of a customer's system that provide value to all ratepayers, such as demand response programs and interruptible rates, which credit ratepayers for agreeing to curtail service when called upon to do so by the utility.[158] The costs and benefits of such programs/rates are generally evaluated in rate case proceedings. Such evaluation would be greatly aided by a Michigan-specific "value of storage" study.

It can be helpful for states to undertake detailed studies to understand the full value proposition for energy storage and provide clear metrics for utilities and stakeholders to evaluate when the value of storage to the grid, developers, end users, and ratepayers outweighs its costs. For example, in 2016, as part of the $10 million Energy Storage Initiative launched by the Governor, Massachusetts undertook a study to determine the value of storage and under what conditions storage could be cost-effectively deployed. The resulting "State of Charge" report found that 1,766 MW of storage would deliver $2.3 billion in benefits to ratepayers, despite finding that only one third of the benefits of storage could be monetized under existing regulations

[153] Tarekegne, B., O'Neil, R., and Twitchell, J. 2021. "Energy Storage as an Equity Asset." Current Sustainable/Renewable Energy Reports. Vol. 8. Available at: https://link.springer.com/article/10.1007/s40518-021-00184-6.

[154] U.S. Department of Energy. September 23, 2021. "DOE Invests $27 Million in Battery Storage Technology and to Increase Storage Access." Available at: https://www.energy.gov/articles/doe-invests-27-million-battery-storage-technology-and-increase-storage-access.

[155] Pacific Northwest National Laboratory. "Energy Storage for Social Equity Initiative." Available at: https://www.pnnl.gov/projects/energy-storage-social-equity-initiative.

[156] St John, J. January 21, 2020. "California Finalizes Plan Shifting Key Energy Storage Incentive Toward Blackout Resilience." Greentech Media. Available at: https://www.greentechmedia.com/articles/read/california-finalizes-plan-shifting-key-energy-storage-incentive-toward-blac.

[157] Public Act 286 of 2008. October 6, 2008. Available at: https://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0286.pdf.

[158] Michigan Public Service Commission. MI Power Grid Demand Response Working Group. "Michigan Interruptible Tariff Comparison." Available at: https://www.michigan.gov/-/media/Project/Websites/mpsc/workgroups/dr/Interruptible_Tariff_Comparison.pdf?rev=a2621594aa4840e3b7e2eaaa78b051a1.

and market designs.[159] Furthermore, these benefits to ratepayers dramatically outweighed the projected costs of deployment. According to the "State of Charge" report: "This optimized amount of storage is estimated to cost $970 million to $1.35 billion. Considering the Massachusetts ratepayer benefits alone of $2.3 billion, 1,766 MW of storage provides net benefits to ratepayers with a benefit-cost ratio ranging from 1.7 to 2.4."[160]

Storage Targets

One of the most prominent state energy storage policies is a requirement that a set amount of capacity or percentage of utility development be from storage resources. As detailed in Table 4, nine states, including California, Connecticut, Nevada, New York, Maine, Massachusetts, New Jersey, Oregon and Virginia have developed or are in the process of developing energy storage deployment goals, targets, or mandates.[161] A storage goal is a number without accountability measures, a target is a goal with defined measures for follow through, and a mandate is a goal with legal-liability for compliance.[162] Follow-through can be accomplished using accountability measures, direction to agencies and utilities to establish programs to support deployment, or, in the case of mandates, legal or financial penalties. Short-term "learning by doing" targets and interim targets can create check points and a clear path toward a longer-term goal. According to ESA, an appropriate short-term target would be 3 to 7 percent of peak demand within 2 to 3 years.[163]

Storage targets help focus regulators and policy makers to update rules enabling storage, provide a long-term signal and certainty to the industry, and accelerate learning-by-doing efforts.[164] For example, after the passage of directing legislation in 2010, California regulators set a deployment target of 1,325 MW of additional energy storage by 2020. That target was successfully achieved with more than 1,500 MW of storage operational and under contract, 24,000 MW of storage interconnection applications pending, and 16,000 people now working in the state's storage industry.[165] Similarly, in New York, after passage of a 2017 law, regulators set a target of 3,000 MW by 2030. As of April 2020, the state had 32 MW of storage operational, 706 MW under contract, 9,779 MW of storage interconnection applications pending, and 1,200 people working in the storage industry.[166]

STATE	YEAR	TARGET AMOUNT	SOURCE
California	**2013**	**1,325 MW to be procured by 2020 and implemented by 2024**	**CPUC Decision 13-10-040[167] (pursuant to AB 2514)**

[159] Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center. 2016. "State of Charge: Massachusetts Energy Storage Initiative Study." Available at: https://www.mass.gov/doc/state-of-charge-report/download.

[160] *Id*. p. xi.

[161] Synapse Energy Economics, Inc. Prepared for Iowa Economic Development Authority. 2020. "Energy Storage in Iowa: Market Analysis and Potential Economic Impact." Available at: https://energystorage.org/energy-storage-goals-targets-and-mandates-whats-the-difference/.

[162] Burwen, J. April 24, 2020. "Energy Storage Goals, Targets, Mandates: What's the Difference?" Energy Storage Association Blog. Available at: https://energystorage.org/energy-storage-goals-targets-and-mandates-whats-the-difference/.

[163] Energy Storage Association. 2021. "Policy Position on State-level Energy Storage Target Design." Available at: https://energystorage.org/wp/wp-content/uploads/2021/02/Final-Policy-Position-on-State-Level-Energy-Storage-Target-Design_clean-and-uploaded-3.pdf.

[164] *Ibid*.

[165] *Ibid*.

[166] New York Department of Public Service. April 1, 2020. "State of Storage in New York." Available at: https://www.transmissionhub.com/wp-content/uploads/2020/04/NYdpsReportApr12020.pdf.

[167] California Public Utilities Commission. October 21, 2013. "Decision Adopting Energy Storage Procurement Framework and Design Program." Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M079/K533/79533378.PDF.

Connecticut	2021	Implement 300 MW by 2024, 650 MW by 2027, 1 GW by 2030	SB 952[168]
Massachusetts	2018	1,000 MWh by 2025	An Act to Advance Clean Energy, Chapter 227 of the Acts of 2018[169]
Maine	2021	Implement 300 MW by 2025 and 400 MW by 2030	LD 528[170]
Nevada	2020	Procure 100 MW by 2020 and 1 GW by 2030	PUCN Order No. 44671[171] (pursuant to SB 204)
New Jersey	2018	600 MW by 2021 and 2 GW by 2030	AB 3723[172]/SB 2314[173]
New York	2018	1.5 GW by 2025 and 3 GW by 2030	NYPSC Energy Storage Order[174] (Case 18-E-0130 following the recommendation of Energy Storage Roadmap)
Oregon	2015	Portland General Electric and PacifiCorp each to procure at least 5 MWh by 2020	HB 2193[175]
Virginia	2020	American Electric Power to construct, acquire, or contract 400 MW, Dominion Energy Virginia to construct, acquire, or contract 2,700 MW by 2035. All systems must be competitively procured and 35% must be non-utility owned.	HB 1526[176]

Table 4. Existing state storage procurement targets.

Several interviewees indicated that energy storage targets or mandates have been established in many of the states that have larger amounts of storage deployed.

Renewable Energy Standard

Over the recent decades, many states have set Renewable Energy Standards (RES) or Renewable Portfolio Standards (RPS) that require utilities to procure a certain percentage of their generation from renewable sources by a certain date. These requirements tended to increase deployment of renewables, which, in turn, creates a greater need for the services that storage provides.

In some cases, RES can also drive storage deployment directly through direct inclusion in the RES or the use of "bonus" credits. For example, several states including Massachusetts have recently developed alternative

[168] Connecticut General Assembly. "Substitute for Raised S.B. No. 952 Session Year 2021." Available at: https://www.cga.ct.gov/asp/cgabillstatus/cgabillstatus.asp?selBillType=Bill&bill_num=SB-0952.

[169] The General Court of the Commonwealth of Massachusetts. 2018. "An Act to Advance Clean Energy." Available at: https://malegislature.gov/Laws/SessionLaws/Acts/2018/Chapter227.

[170] State of Maine Legislature. June 2021. "An Act to Advance Energy Storage in Maine." Available at: https://legislature.maine.gov/LawMakerWeb/summary.asp?ID=280078910.

[171] Public Utilities Commission of Nevada. March 2020. "Order Np. 44671." Available at: http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-7/44671.pdf.

[172] New Jersey Legislature. 2018. "Assembly No. 3723 State of New Jersey 218th Legislature." Available at: https://www.njleg.state.nj.us/2018/Bills/A4000/3723_I1.HTM.

[173] New Jersey Legislature. 2018. "Senate, No. 2314 State of New Jersey 218th Legislature." Available at: https://www.njleg.state.nj.us/2018/Bills/S2500/2314_I1.HTM.

[174] New York Public Service Commission. December 2018. "In the Matter of Energy Storage Deployment Program." Available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BFDE2C318-277F-4701-B7D6-C70FCE0C6266%7D.

[175] Oregon Legislative Information. June 2015. "78th Oregon Legislative Assembly 2015 Regular Session Enrolled House Bill 2193." Available at: https://olis.oregonlegislature.gov/liz/2015R1/Downloads/MeasureDocument/HB2193.

[176] Virginia's Legislative Information System. April 2021. "2020 Session HB1256 Electric Utility Regulation: Environmental Goals: Summary as Passed." Available at: https://lis.virginia.gov/cgi-bin/legp604.exe?201+sum+HB1526.

energy portfolio standards (APS), which explicitly include certain energy storage technologies.[177] Others, like Vermont, have amended their RES to require that a certain percentage of utility annual sales come from energy storage systems.[178] Others, like Michigan, provide utilities with bonus renewable energy credits (RECs) for using storage.[179]

Incentives

Incentives for energy storage can take many forms, including rebates, tax incentives, grants, and loans, and can spur early deployments and support market development as costs continue to decline and more of the values storage provides can be monetized. To optimize the use of resources, it is important that incentives are structured to adapt or even decline over time as regulations, markets, and policies evolve, reducing the need for incentives.

Rebates

Rebates, especially for BTM energy storage systems, can be provided based on system capacity (Table 5) or system costs (Table 6). According to ESA, rebates tend to be the most effective tool to overcome the upfront financing challenges that customers face when considering whether to install a BTM storage system.[180]

	CA	NV	AZ	MA	NY	NY
	Self-Generation Incentive Program (SGIP) Revisions (2020)[181]	Solar Energy Systems Incentive Program (2017)[182, 183]	Arizona Public Service Co. Residential Battery Storage Pilot Program (2020)[184]	Energy Efficiency Incentive[185]	Bridge Incentive Program: Retail (<= 5MW) Energy Storage Incentive Program[186]	Bridge Incentive Program: Bulk (>5 MW) Energy Storage Incentive Program[187]
Originating Source	Legislative & Regulatory (SB 700 - 2018)	Legislative (SB145 - 2017)	Regulatory (AZCC Docket No.	Regulatory (DPU 2019-2021 Three-Year Energy Efficiency Plans Order)	Regulatory (NYPSC energy storage order - 2018)	Regulatory (NYPSC energy storage order - 2018)

[177] Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center. "State of Charge: Massachusetts Energy Storage Initiative Study." 2016. Available at: https://www.mass.gov/doc/state-of-charge-report/download.

[178] Vermont General Assembly. June 11, 2015. "No. 56: An act relating to establishing a renewable energy standard, H.40." Available at: http://legislature.vermont.gov/assets/Documents/2016/Docs/ACTS/ACT056/ACT056%20As%20Enacted.pdf.

[179] Public Act 342 of 2016. December 21, 2016. Available at: https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

[180] Energy Storage Association. February 2019. "Energy Storage Incentive Programs." Available at: https://energystorage.org/thought-leadership/energy-storage-incentive-programs/.

[181] Lane, C. January 2, 2021. "What's new with California's SGIP battery rebate in 2021?" Solar Reviews. Available at: https://www.solarreviews.com/blog/california-sgip-battery-rebate#who-can-apply.

[182] Walton, R. June 2017. "Nevada Gov. Sandoval Signs Storage, Electric Vehicle Bills." Utility Dive. Available at: https://www.utilitydive.com/news/nevada-gov-sandoval-signs-storage-electric-vehicle-bills/444095/.

[183] Nevada Legislature. June 2017. "Senate Bill No. 145". Available at: https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/4981/Text.

[184] Arizona Corporation Commission. September 2020. "Commissioner Lea Márquez Peterson's Proposed Amendment No. 2." Available at: https://docket.images.azcc.gov/E000009162.pdf.

[185] Massachusetts Department of Public Utilities. "Three-year Energy Efficiency Plan." Available at: https://www.mass.gov/files/documents/2019/01/31/2019-2021%20Three-Year%20Energy%20Efficiency%20Plans%20Order_1.29.19.pdf.

[186] NYSERDA. July 2021. "Retail Energy Storage Incentive Program: Program Manual." Available at: https://www.nyserda.ny.gov/-/media/Files/Programs/Energy-Storage/Retail-Program-Manual.pdf.

[187] NYSERDA. "Bulk Storage Incentives". Available at: https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Storage/Developers-Contractors-and-Vendors/Bulk-Storage-Incentives.

Description	Upfront battery storage rebates up to $350/kWh for large-scale storage and up to $1,000/kWh for residential storage.	Incentive payments for utilities' customers' energy storage systems that have a nameplate capacity of at least 100 kW but not more than 1 MW. Eligible party must be a person who has installed on the property a solar energy system or energy storage system.	One-time incentive payment at $500/kW for customer-sited, behind-the-meter distributed energy storage, excluding payments to customers that have already installed batteries.	Customers installing storage can sign up for a five-year contract with their utility. They will be paid an incentive payment based on how much they reduced their load during peak hours: $100/kWh for a "targeted" dispatch program, and $200/kWh for a daily dispatch program.	Incentive based on the system's total MWh in the first 4 hours, 25% for hour five and six, no incentive for duration beyond six hours. Incentive level adjustable according to market factors.	For bulk energy storage projects that provide wholesale market energy, ancillary services, and/or capacity services, offers incentive payments at $90/kWh for projects 20 MW or less and up to $85/kWh for projects exceeding 20 MW.

Table 5. Example state rebate programs based on project capacity.

CASE STUDY

Rebates by Capacity: California Self-Generation Incentive Program (SGIP)[188, 189]

California utilities offer rebates for installing energy storage technologies at both residential and non-residential facilities through the Self-Generation Incentive Programs (SGIP). In order to qualify for SGIP, applicants must be either a commercial, industrial, agricultural, or residential customer of PG&E, SoCalGas, Southern California Edison (SCE), or SDG&E. The rebates vary from $200/kWh to $850/kWh for a residential storage project (<10 kW) depending on income eligibility criteria[190] and up to $350/kWh for a large-scale storage project (>10 kW). By the end of 2018, SGIP had provided incentives to 3,781 energy storage projects representing almost 111 MW of rebated capacity.[191]

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[188] California Public Utilities Commission. "Participating in Self-Generation Incentive Program." Available at: https://www.cpuc.ca.gov/sgipinfo/.

[189] Lane, C. January 2, 2021. "What's new with California's SGIP battery rebate in 2021?" Solar Reviews. Available at: https://www.solarreviews.com/blog/california-sgip-battery-rebate#who-can-apply.

[190] California Public Utilities Commission. "Self-Generation Incentive Program (SGIP)." Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpucwebsite/content/news_room/newsupdates/2020/sgip-factsheet-124020.pdf.

[191] Itron. 2020. "2018 SGIP Advanced Energy Storage Impact Evaluation." Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpuc_public_website/content/utilities_and_industries/energy/energy_programs/demand_side_management/customer_gen_and_storage/sgip-advanced-energy-storage-impact-evaluation.pdf.

	NJ	OR	TX	NY
	Renewable Energy Incentive Program (REIP) (2015)[192]	Oregon Solar + Storage Rebate Program[193]	New Technology Implementation Grant (NTIG) Program (last updated 2020)[194]	Affordable Solar and Storage Predevelopment and Technical Assistance (last updated 2020)[195]
Originating Source	Regulatory (NJBPU Docket No. QO14050489 - 2014)	Legislative & Regulatory (HB 2618 - 2019)	Regulatory (TCEQ Texas Emissions Reduction Plan - 2018)	NYSERDA Solar Program (NY-Sun) 2012
Description	Incentive payments no greater than $500,000 per project or 30% of the project's total installed cost. To receive an incentive payment, applicants will need to submit a Final As-Built packet once the project has been built.	Rebates may cover up to 40 percent of the net cost for a residential system installed for a regular customer, up to 60 percent of net cost for a low- or moderate-income customer, and up to 50 percent for a low-income service provider. A new phase of this program with an additional $10 million in funding was announced in September 2021.[196]	Offset the incremental cost of implementation for existing technologies that reduce the emission of pollutants from facilities and other stationary sources. Projects may be awarded a grant not to exceed 50% of the implementation costs.	Help low-to-moderate income (LMI) households living in rental housing, multifamily buildings, or other households not served by traditional onsite residential solar to install solar and storage. Approved projects receive contract awards based on costs, up to $200,000.

Table 6. Example state rebate programs based on project costs.

CASE STUDY

Rebates by Costs: New Jersey 2015 Renewable Energy Incentive Program (REIP)[197]

In Fiscal Year 2015, the New Jersey Board of Public Utilities approved a budget of $3 million for the Renewable Electric Storage Incentive. Under this program, applicants request the minimum incentive necessary to make their project economically feasible, which can be no greater than $500,000 per project or 30 percent of the project's total installed cost after deducting any other incentives, whichever is less. In addition to the maximum per-project incentive, there is also a maximum per-entity incentive. An entity may submit multiple projects, but the total incentive requested for those projects cannot exceed $750,000. An "entity" is defined as the business, corporation, non-profit, institution or public agency that is the site host for the energy storage project(s).

The program ended up offering $2.9 million for 13 energy storage projects that combine for a total of 8,750 kW of capacity.[198]

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192 Office of Clean Energy, New Jersey Board of Public Utilities. Fiscal Year 2015. "Renewable Energy Storage Incentive." Available at: https://www.njcleanenergy.com/files/file/Renewable_Programs/EnergyStorage/FY2015_Renewable_Electric_Storage_Solicitation_FINAL_%20with_Appendices_A-E_10_9_14.pdf.

193 Oregon Department of Energy. "Oregon Solar + Storage Rebate Program." Available at: https://www.oregon.gov/energy/Incentives/Pages/Solar-Storage-Rebate-Program.aspx.

194 Texas Commission on Environmental Quality (TCEQ). "Texas Emissions Reduction Plan (TERP) New Technology Implementation Grant (NTIG) Program Summary." Available at: https://www.tceq.texas.gov/assets/public/implementation/air/terp/ntig/FY20_NTIG_Summary_all_categories.pdf.

195 NYSERDA. "Affordable Solar Predevelopment and Technical Assistance." Available at: https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Communities-and-Local-Governments/Predevelopment-and-Technical-Assistance.

196 Oregon Department of Energy. "Oregon Department of Energy Re-launching Solar + Storage Rebate Program With Additional $10 Million in Funding." Available at: https://energyinfo.oregon.gov/blog/2021/9/13/oregon-department-of-energy-re-launching-solar-storage-rebate-program-with-additional-10-million-in-funding.

197 Office of Clean Energy, New Jersey Board of Public Utilities. Fiscal Year 2015. "Renewable Energy Storage Incentive." Available at: https://www.njcleanenergy.com/files/file/Renewable_Programs/EnergyStorage/FY2015_Renewable_Electric_Storage_Solicitation_FINAL_%20with_Appendices_A-E_10_9_14.pdf.

198 New Jersey Board of Public Utilities. 2015. "In the matter of the solicitation for energy storage incentives renewable energy incentive program-approvals." Available at: https://www.bpu.state.nj.us/bpu/pdf/boardorders/2015/20150318/3-18-15-8F.pdf.

Tax Incentives

Some states have established tax incentives for both BTM and FTM energy storage systems to reduce the tax burden associated with these systems (Table 7). Income tax credits may also be an option to encourage the deployment of energy storage systems.

	IA	MD	NH
	Property Tax Incentive (2012)[199]	Maryland Energy Storage Income Tax Credit Program (last updated 2021)[200]	Property Tax Exemption (2019)[201]
Originating Source	Legislative (Iowa Code 441.21 & SF 2342 - 2012)	Legislative & Regulatory (SB 758 - 2017)	Legislative (HB 464 - 2019)
Description	The market value added to a property by a solar energy system (including storage) is exempt from the state's property tax for 5 full assessment years.	Maryland Energy Administration may award a total of $750,000 in tax credit certificates to residential and commercial taxpayers who purchase or lease energy storage systems.	Updates the definitions of solar energy and wind-powered energy systems to include storage as an option in local property tax exemption.

Table 7. Example state tax incentives.

CASE STUDY

Tax Incentives: Maryland Energy Storage Income Tax Credit Program[202]

The Maryland Energy Storage Income Tax Credit Program is run by the Maryland Energy Administration (MEA) and aims to encourage the deployment of energy storage systems. The program is available to residential and commercial taxpayers who have installed an energy storage system on their property in Maryland. Under the enabling statute, MEA may award a total of $750,000 in tax credit certificates during a given tax year on a first come, first served basis. Current law authorizes MEA to offer the program for Tax Years 2018, 2019, 2020, 2021, and 2022.

In Tax Year 2019, the program issued 175 tax credit certificates for energy storage systems totaling over 2 MW and in Tax Year 2020, the program issued 121 tax credits certificates totaling 1.45 MW.[203, 204]

Grants

State sponsored grant programs come in various formats and with various requirements. The range in approaches allows these programs to incentivize energy storage deployment from a multitude of perspectives, from research and development, technical assistance, to workforce development. Multiple grant programs could potentially be combined to offer comprehensive assistance that can maximize the effects of incentives.

[199] Iowa Legislature. "Iowa Code 441.21 & SF 2342." Available at: https://www.legis.iowa.gov/docs/code/2020/441.21.pdf.

[200] Maryland Energy Administration. "Maryland Energy Storage Income Tax Credit - Tax Year 2021." Available at: https://energy.maryland.gov/business/Pages/EnergyStorage.aspx.

[201] Database of State Incentives for Renewable Energy (DSIRE). September 2021. "Local Option - Property Tax Exemption for Renewable Energy and Electrical Energy Storage." Available at: https://programs.dsireusa.org/system/program/detail/60.

[202] Maryland Energy Administration. "Maryland Energy Storage Income Tax Credit - Tax Year 2021." Available at: https://energy.maryland.gov/business/Pages/EnergyStorage.aspx.

[203] Maryland Energy Administration. 2020. "Maryland Launches Tax Year 2020 Energy Storage Income Tax Credit." Available at: https://news.maryland.gov/mea/2020/02/19/maryland-launches-tax-year-2020-energy-storage-income-tax-credit/.

[204] Maryland Energy Administration. 2021. "New Cycle of Maryland Energy Storage Income Tax Credit Now Open." Available at: https://news.maryland.gov/mea/2021/03/10/new-cycle-of-maryland-energy-storage-income-tax-credit-now-open/.

	CA	WA	NY	NY
	Electric Program Investment Charge (EPIC)[205]	Clean Energy Fund Smart Grid Grants (2014)[206]	Flexible Technical Assistance (FlexTech)[207]	P-12 Schools: Green and Clean Energy Solutions Program[208]
Originating Source	Regulatory (CPUC Decision 12-05-037)[209] (2011)	Legislative (SB 5035 - 2013)	Regulatory (NYSERDA Program Opportunity Notice 4192)	Regulatory (NYSERDA Program Opportunity Notice 4157)
Description	Overseen by CPUC, this program invests in R&D and other market facilitation activities, including market research, regulatory permitting and streamlining, and workforce development. Energy storage is one of the target technologies. In EPIC's 3 investment periods since 2012, more than $1 billion have been allocated to relevant projects.[210] The 4th period (2021-2025) will explore technology advancements that can make storage more cost-competitive and market ready.[211]	The Washington State Department of Finance provided $14 million grants to three smart-grid projects, as part of Governor Jay Inslee's Clean Energy Fund. The three smart-grid projects all include energy storage components, using lithium-ion, lithium iron phosphate, and vanadium flow battery technologies respectively. These projects will develop and validate use cases combining storage and information technology solutions.	Provides 50% cost-share for technical assistance services from a list of NYSERDA qualified FlexTech Consultants or an Independent Service Provider. The Consultant will identify, analyze and prioritize energy efficiency or carbon reduction recommendations (including energy storage), tailored to the customer's site and business needs.	Funding for eligible Pre-Kindergarten through Grade 12 (P-12) schools to reduce school energy loads and to convert to carbon free fuels. NYSERDA will provide a cost-share up to 75% for relevant projects, including battery storage.

Table 8. Example state grant programs.

CASE STUDY

Case study: Grant Programs: California Electric Program Investment Charge (EPIC)[212]

The Electric Program Investment Charge (EPIC) supports the development of new, emerging, and pre-commercialized clean energy technologies in California, including energy storage. These projects must be designed to produce ratepayer benefits in the form of increased reliability, improved safety, and/or reduced electricity costs. EPIC consists of three program areas shown in Table 9.

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205 California Energy Commission. July 20, 2021. "Electric Program Investment Charge 2021-2025 Investment Plan Scoping - Technology Advancements for Energy Storage." Available at: https://www.energy.ca.gov/event/workshop/2021-07/electric-program-investment-charge-2021-2025-investment-plan-scoping-2.

206 Washington Department of Commerce. January 2015. "Clean Energy Fund Update". Available at: https://www.commerce.wa.gov/wp-content/uploads/2016/06/Commerce-Clean-Energy-Fund-2014-updated.pdf.

207 NYSERDA. "Flexible Technical Assistance (FlexTech) Program Opportunity Notice (PON) 4912." Available at: https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00Pt000000R41QVEAZ.

208 NYSERDA. "P-12 Schools - Green & Clean Energy Solutions (PON 4157)." Available at: https://portal.nyserda.ny.gov/CORE_Solicitation_Detail_Page?SolicitationId=a0rt000000hcN0wAAE#:~:text=The%20P%2D12%20Schools%3A%20Green,conversion%20to%20carbon%20free%20fuels.

209 California Public Utilities Commission Decision 20-08-042. Rulemaking 19-10-005. "Decision Renewing the Electric Program Investment Charge." Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M346/K225/346225760.PDF.

210 California Public Utilities Commission. "Energy Research Development and Deployment." Available at: cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/energy-research-development-and-deployment.

211 California Energy Commission. July 20, 2021. "Electric Program Investment Charge 2021-2025 Investment Plan Scoping - Technology Advancements for Energy Storage." Available at: https://www.energy.ca.gov/event/workshop/2021-07/electric-program-investment-charge-2021-2025-investment-plan-scoping-2.

212 *Ibid*.

PROGRAM AREA	DESCRIPTION
Applied R&D	Investment in applied energy science and technology that provides public benefit but for which there is no current deployment of private capital
Technology Demonstration & Development	Investments in technology demonstrations at real-world scales and in real-world conditions to showcase emerging innovations and increase technology commercialization
Market Facilitation	Investments in market research, regulatory permitting and streamlining, and workforce development activities to address non-price barriers to clean technology adoption

Table 9. Program areas in California EPIC.[213]

There are four program administrators: the California Energy Commission (CEC), PG&E, SCE, and SDG&E. The CEC administers 80 percent of EPIC funds while the three large investor-owned utilities together administer 20 percent of the funds. Each administrator is required to submit an EPIC investment plan outlining their proposed projects for a given three-year investment period in the form of an application to the California Public Utilities Commission.

To date, EPIC's solicitations related to energy storage include developing computer models for optimal storage use cases as system components, developing advanced energy storage technologies and systems that can be demonstrated and deployed by the utilities, new and enhanced technologies to improve the cost and efficiency of thermal energy storage, and increasing the dispatchability of concentrated solar power systems.

Debt and Finance Instruments

As the energy storage economy grows, new business models and financing options will continue to emerge. With any new industry, government debt and finance instruments can catalyze private investment if designed with input from existing market actors, an emphasis on the leverage ratio between public dollars and private dollars, and an eye toward long-term obsolescence once the market or segments of the market matures. In the case that a financing need may be persistent in a market, there may be reason to provide favorable financing options indefinitely (e.g., to support BTM storage deployment in multifamily properties). Financing solutions can be used to catalyze both FTM and BTM energy storage deployments. A number of states across the U.S., including Michigan, are utilizing financing options through entities known as "green banks."

Direct Loans with Favorable Terms

Direct loans that have favorable terms, such lower interest rates, longer-terms, and/or more flexible qualifying and underwriting criteria, can increase deployment of BTM energy storage projects. Such direct loans can come in a variety of formats and may be designed to leverage other private resources or not. The primary debt instruments that may be used for energy storage deployments are loans, forgivable loans, revolving loan funds, and warehousing facilities.

Forgivable Loans

A forgivable loan can provide necessary capital to a possible BTM storage customer or to a FTM energy storage project while generating non-traditional returns for the lender. A forgivable loan may not expect monetary returns. Instead, the lender – which may be a governmental entity, a nonprofit, or a social impact investor – recognizes that the loan will likely be used to fund a project, such as an energy storage project, which infers a benefit to the entire community. Furthermore, while recipients are not required to make loan

[213] California Public Utilities Commission. "Energy Research Development and Deployment." Available at: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/energy-research-development-and-deployment.

repayments, they may be expected to give back to the community in the form of education, outreach, or economic stimuli. If the conditions of the lender are not met, the loan will need to be repaid.

Revolving Loan Funds

A revolving loan fund is a pool of capital that is loaned out and, upon repayment, is loaned out again. A fund operator may take some fee, but in general, most, if not all, of the capital is loaned out again or is used to cover anticipated expenses. A revolving loan fund is typically priced in a manner to ensure financial sustainability (i.e., perpetual operation), but not necessarily to make a profit. This generally results in a lower interest loan for the customer and a sustainable economic development tool for government programs. When applied to energy projects, a forgivable loan is often built on the premise that energy-cost savings or associated utility-cost savings will serve to repay the loan. In the case of energy storage, such an expectation is dependent on sufficient price signals including the monetization of all the services storage provides, appropriate rate design, and reduction of interconnection costs.

Warehousing Credit Facilities

Warehousing is analogous to a revolving loan fund in that funds are replenished, but rather than waiting for a loan to be repaid, the fund operator will sell the debt obligation and use the returns to lend again. Often, lenders or investors may not enter a new market like energy storage or even more specifically like energy storage in Michigan due to low volume of transactions in the market, a lack of familiarity with the market (geographic or otherwise), or insufficient transaction sizes. A warehousing facility helps alleviate these challenges for private lenders, while keeping costs reasonable for borrowers. However, there are additional risks with a warehouse structure given that loans need to be resold, requiring pricing and terms to be competitive in the market. Additionally, a warehouse facility is complicated to structure, requires resources and expertise to originate the loans, and requires relationships, expertise, and legal work to be able to securitize and sell into the capital markets.

Credit Enhancements[214]

According to the U.S. Department of Energy, a credit enhancement is anything that improves the chances that financing will be repaid.[215] Credit enhancements help capital providers reduce the risk of losing an investment and result in lower interest rates for the borrower, provide more flexible underwriting criteria to help borrowers better access financing, and encourage capital providers to enter unfamiliar markets. A growing market like energy storage — for both FTM and BTM applications — can benefit from credit enhancements provided by public institutions. Many credit enhancements are financial tools as described below, while others may be non-monetary enhancements, such as a special assessment agreement or an addition of financing to an existing utility bill (such as on-bill financing) and others may include internal transaction structures such as holding of a certain amount of capital in escrow by the property owner.

Loan Loss Reserves

To reduce risk for a lender – and thereby increase the availability of affordable capital for a borrower – the state, local, or federal government may provide a pool of funds (called a loan loss reserve) that is available to ensure repayment of a loan. In the case of nonpayment, a loan loss reserve can be drawn upon to limit losses for the lender. A loan loss reserve may cover all or a portion of losses. It can also be designed to exist in a first loss position, wherein the loan loss reserve is drawn on until it is expended and then the principal loan is drawn on, or to cover a percentage of the losses (e.g., 25% of any losses will be covered by the loan loss reserve). A loan loss reserve allows funders to have a greater impact per dollar spent and reduce risk to the lender.

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214 State and Local Energy Efficiency Action Network. U.S. Department of Energy/U.S. Environmental Protection Agency. January 2014. "Credit Enhancement Overview Guide." Available at: https://www.energy.gov/sites/prod/files/2014/06/f16/credit_enhancement_guide.pdf.

215 U.S. Office for Energy Efficiency and Renewable Energy. Available at: https://www.energy.gov/eere/slsc/credit-enhancements.

Loan Guarantees

Government entities can and do at times provide loan guarantees, to de-risk transactions for private market lenders and investors. A loan guarantee can be deployed on a specific energy storage project, to support an early technology or business, support manufacturing operations, and more. A loan guarantee is similar to a loan loss reserve, but typically covers the entire or a high percentage of the cost of a project and is typically a backing with the full faith and credit of the guaranteeing entity. Typically, a loan guarantee is provided by governmental entities, such as the U.S. Department of Energy or the U.S. Department of Agriculture. For example, the U.S. Department of Energy's Loan Programs Office has $40 billion in loan guarantee authority to use for a variety of energy projects, which could include energy storage. Due to the trustworthiness and financial resources of government institutions, they would not necessarily need to set aside funds as in a loan loss reserve arrangement.

On-Bill Repayment and On-Bill Tariffs

Some lenders will provide more favorable loan terms if the repayment of the loan is tied to a customer's utility bill, with the same recourse as a failure to pay an electric bill in the case of nonpayment (i.e., cancellation of service). On-bill repayment programs allow for the repayment of financing for a BTM energy project on the customers utility bill, using third-party financing (on-bill loan) or using the capital of the utility (on-bill tariff).

Co-Investment/Concessionary Debt

Co-investment and concessionary debt involve a subordinated/senior capital structure with two or more pools of capital. The senior capital is typically the private capital with higher return requirements and lower risk tolerance. The subordinated or concessionary capital is typically more flexible and is often provided by government, philanthropic funds, or impact investment funds. Subordinated capital can be designed to reduce interest rate, reduce risk, or both. Concessionary or subordinated debt will typically be structured to be in the first loss position. This means, typically, that the senior capital provider will not lose any money until the entirety of the subordinated debt has been lost. Concessionary or subordinated capital can also be offered at a lower interest rate. By offering the lower interest rate and blending the capital, the senior capital receives its required return while the borrower receives a lower interest rate. Such an approach can drive more capital into energy storage businesses, manufacturing and supply chain, and project deployment.

	CT	MA, CT, RI	NJ	NY
	Connecticut Green Bank Smart-E Battery (2014)[216]	National Grid and Eversource's ConnectedSolutions ("bring-your-own-battery") program[217]	Energy Resilience Greenbank (ERB)[218]	New York Green Bank RFP 13: Financing for Energy Storage Projects[219]
Originating Source	Connecticut Green Bank Smart-E Loan (2014)	Utility-run incentive program	Regulatory (NJBPU Docket No. 0014060626)	Regulatory (NYPSC energy storage order - 2018)
Description	Residential battery storage systems for solar PV are eligible for $500 to $40,000 loan amounts.[220] Rate/ Term options: 4.49% for 5 years; 4.99% for 7 years; 5.99% for 10 years (Minimum loan size $5,000); 6.99% for 12 years (Minimum loan size $5,000) at selected local lenders.[221]	Customers are eligible to apply for a HEAT Loan (0% interest) for the material and labor costs associated with installing a battery storage system.	ERB finances the design, acquisition, construction, and installation of DERs that will improve the energy resiliency at critical facilities. ERB financing will include both grant funding and longer term, low-interest loans with a portion of principal forgiven over time based on satisfying annual operational performance requirements.[222, 223]	Thermal and electric energy storage can participate in NY Green Bank's open investment solicitations.

Table 10. Example state financing and debt instrument programs.

CASE STUDY

New York Green Bank RFP 13-Financing for Energy Storage Projects[224]

Following the release of the New York State Energy Storage Roadmap in 2018, the New York Green Bank (NYGB) developed a Request for Proposals (RFP) entitled "Financing for Energy Storage Projects" to invite energy storage developers and other storage market participants targeting New York energy storage projects to propose transactions to NYGB that contemplate the financing of the purchase and ownership of energy storage projects. Through this RFP, NYGB sought to: 1) accelerate the deployment of energy storage projects; and 2) provide a financing framework that may be utilized in the future by equity investors and private sector lenders.

In the fiscal year that ended March 31, 2021, the NYGB issued a $2.3 million construction-to-term loan to support BQ Energy's 575 kW battery paired with solar and a $25 million commitment to a $420 million term loan for Nexamp's 50+ MWh battery paired with solar.[225]

[216] Connecticut Green Bank. "Smart-E Battery." Available at: https://www.ctgreenbank.com/smartebattery/.

[217] Eversource. "Demand Response for Home Battery Storage." Available at: https://www.eversource.com/content/ema-c/residential/save-money-energy/manage-energy-costs-usage/demand-response/battery-storage-demand-response.

[218] New Jersey Board of Public Utilities. July 2014. "Order in the Matter of the New Jersey Energy Resilience Bank-Initial Subrecipient Agreement Between the Board of Public Utilities and the Economic Development Authority." Available at: https://nj.gov/bpu/pdf/boardorders/2014/20140723/7-23-14-9A.pdf.

[219] NY Green Bank. "RFP 13: Financing for Energy Storage Projects." Available at: https://portal.greenbank.ny.gov/CORE_Solicitation_Detail_Page?SolicitationId=a0rt000000koxpAAAQ.

[220] Connecticut Green Bank. "Smart-E Battery." Available at: https://www.ctgreenbank.com/smartebattery/.

[221] Capital for Change. "Smart-E Loan." Available at: https://www.capitalforchange.org/homeowners/energy-efficiency-programs/smart-e-plan.

[222] Tweed, K. July 24, 2014. "New Jersey Launches $200M Energy Resilience Bank for Microgrids and Distributed Generation." Greentech Media. Available at: https://www.greentechmedia.com/articles/read/New-Jersey-Launches-200M-Energy-Resilience-Bank-For-Microgrids-and-Distrib.

[223] New Jersey Board of Public Utilities. July 2014. "Order in the Matter of the New Jersey Energy Resilience Bank-Initial Subrecipient Agreement Between the Board of Public Utilities and the Economic Development Authority." Available at: https://nj.gov/bpu/pdf/boardorders/2014/20140723/7-23-14-9A.pdf.

[224] NY Green Bank. November 2019. "Financing for Energy Storage Projects: Request for Proposals." Available at: https://portal.greenbank.ny.gov/servlet/servlet.FileDownload?file=00Pt000000HfPdaEAF.

[225] NY Green Bank. 2021. "NY Green Bank Impact Report For the Year Ended March 31, 2021." Available at: https://greenbank.ny.gov/-/media/greenbanknew/files/2020-21-NYGB-Impact-Report.pdf.

Other Incentives

In addition to the programs mentioned above, other incentives have been executed or are ongoing across the states that directly or indirectly support storage deployment. These incentives may not be designed specifically for the deployment of energy storage, but they are able to recognize the benefits provided by energy storage, such as clean energy pairing and new job opportunities.

	VT	IN	NY	NY
	Vermont Clean Energy Development Fund (CEDF)[226, 227]	Comprehensive Hoosier Option to Incentivize Cleaner Energy (Choice) Program (2012)[228]	Clean Energy Internship Program[229]	Building Operations and Maintenance Workforce Development and Training Program[230]
Originating Source	Legislative (S.52/Act 53 - 2017)	Legislative & Regulatory (SB 251 - 2011)	Regulatory (NYSERDA Program Opportunity Notice 4000)	Regulatory (NYSERDA Program Opportunity Notice 3715)
Description	Act 53 from 2017 authorizes CEDF to fund energy storage projects that support renewable resources.	Participating utilities are eligible for an increase in return on equity by as much as 50 basis points over its currently approved rate of return if the electricity they provide to their customers will include an average of 4% from renewable sources between 2013 and 2019, 7% between 2019 and 2024, 10% in 2025. Energy storage is specified as one of the technologies that can be used in the power mix and obtain "Clean Energy Credits," which can be used as part of utilities' clean energy portfolio standard.	With a budget up to $7.5 million, this program provides funding to eligible clean energy businesses, organizations, or local municipalities/ counties interested in hiring interns to perform meaningful work in the clean energy sector. Eligible businesses include those providing service in grid modernization and energy storage.	Provides employers and building owners with support to implement workforce development and training projects. Equipment-based skills training can target categories including chemical, thermal, or mechanical energy storage. NYSERDA will provide cost share of up to 50% with a cap of $400,000 per application.

Table 11. Examples of other state incentive programs.

STATE-LEVEL REGULATION

State-level regulatory activities will have an impact on the deployment and operation of energy storage. As discussed previously, there is a growing recognition that the benefits and costs of the clean energy transition, including the array of potential benefits provided by energy storage, will not necessarily be distributed equitably. State regulators should develop processes that thoughtfully incorporate equity considerations.

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[226] Vermont Department of Public Service. "Clean Energy Development Fund (CEDF)." Available at: https://publicservice.vermont.gov/renewable_energy/cedf.

[227] Vermont Legislature. May 2017. "S.52/Act 53." Available at: https://legislature.vermont.gov/Documents/2018/Docs/ACTS/ACT053/ACT053%20Act%20Summary.pdf.

[228] Indiana Office of Energy Development. "CHOICE Program FAQ." Available at: https://secure.iot.in.gov/oed/2650.htm.

[229] NYSERDA. "New York State Clean Energy Internship Program (PON 4000)." Available at: https://portal.nyserda.ny.gov/CORE_Solicitation_Detail_Page?SolicitationId=a0rt000000MdhViAAJ.

[230] NYSERDA. "Building Operations and Maintenance Workforce Development Training Program." Available at: https://www.nyserda.ny.gov/all-programs/programs/clean-energy-workforce-development/building-operations-and-maintenance-program.

Interconnection Standards

In recent years, FERC has issued a number of orders governing the interconnection of small electrical generators onto the grid. Although FERC does not have authority over intrastate electricity distribution, these orders were adopted by the FERC with the intent that each state would use the standards as a model to develop their own interconnection standards. Specifically, in 2013 and 2014, FERC issued Orders 792 and 792-A, which served as revisions to Order 2006. As a result of these Orders, many states including Iowa,[231] Illinois,[232] and Minnesota,[233] have undertaken processes to update their interconnection rules, including to add storage in the definition of "generator" and clarify how the output of electricity from an energy storage system will be defined/measured.

Resource Planning

Utilities and state public utility commissions across the country use IRPs to determine least-cost, best fit options to meet future energy and capacity requirements. There are a variety of ways storage can be considered as part of these planning processes. Some states, including California, Oregon, and Massachusetts require regulated utilities to procure energy storage.[234] It is more common for states to encourage or require utilities to include storage assets in the IRP process. For example, under Washington law, an IRP "must assess other distributed energy resources that may be installed by the utility or the utility's customers including, but not limited to, energy storage, electric vehicles, and photovoltaics. Any such assessment must include the effect of distributed energy resources on the utility's load and operations."[235] Similarly, Portland General Electric's 2016 IRP determined under what use cases the value of storage to the utility's system would exceed the cost of a battery system in 2021.[236] It is important when considering storage in an IRP context that a utility is able to fully assess the value of storage to the grid, the utility, and ratepayers, including by utilizing sub-hourly modeling. If accurate modeling of energy storage resources is not possible given model limitations, storage benefits can be incorporated into IRPs using a net-cost-of-capacity approach.[237] Under this method, operational benefits of storage that are difficult to represent accurately within the IRP model (e.g., the value of real-time energy arbitrage or ancillary services) can be estimated using a separate analysis outside the IRP model and credited to storage within the IRP model as a reduction in the installed cost of storage.

Energy storage can also be considered during a utility's distribution system planning process. In some cases, consideration of storage in a benefit-cost analysis can lead to the determination that a storage system can be a lower-cost solution as compared to traditional distribution investments. For example, in an area with increasing peak load, storage can be used to defer a costly substation upgrade. In these cases, it is critical that storage is considered whenever it might be able to serve as a non-wires alternative and that the utility is able to accurately represent the benefits and costs of storage versus a traditional investment.

[231] IAC. August 28, 2019. "Chapter 45. Electric Interconnection of Distributed Generation Facilities." Available at: https://www.legis.iowa.gov/docs/ACO/chapter/199.45.pdf.

[232] Joint Committee on Administrative Rules. Administrative Code. "Title 83: Public Utilities, Chapter 1: Illinois Commerce Commission, Subchapter c: Electric Utilities, Part 666 Electric Interconnection of Distributed Generation Facilities." Available at: https://www.ilga.gov/commission/jcar/admincode/083/08300466sections.html.

[233] Minnesota Public Utilities Commission. 2016. Docket No. E-999/CI-16-521. "In the Matter of Updating the Generic Standards for the Interconnection and Operation of Distributed Generation Facilities Established Under Minn. Stat. sec. 216B.1611." Available at: https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=eDocketsResult&userType=public#.

[234] Stanfield, S., Petra, J. S., and Auck, S. B. Interstate Renewable Energy Council. April 2017. "Charging Ahead: An Energy Storage Guide for State Policymakers." Available at: https://irecusa.org/resources/charging-ahead-energy-storage-guide-for-policymakers/.

[235] Washington Administrative Code 480-100-620. Available at: https://app.leg.wa.gov/WAC/default.aspx?cite=480-100-620.

[236] *Ibid*.

[237] Energy Storage Association. 2018. "Advanced Energy Storage in Integrated Resource Planning." Available at: https://energystorage.org/wp/wp-content/uploads/2019/09/esa_irp_primer_2018_final.pdf.

Further, new substations can be configured to be "storage ready" for later integration of storage as use of the distribution system evolves.

Storage can also provide location-specific value on the distribution system. As part of distribution planning, several utilities have adopted methodologies to identify DERs, like storage, that can be used to defer or avoid distribution investments in areas with the greatest need. For example, New York's Central Hudson Gas and Electric's Distribution System Implementation Plan applies probabilistic forecasting and planning methods to identify Locational System Relief Value (LSRV) projects and assigns value to non-wires alternatives in those areas based on avoided cost.[238, 239]

Finally, competitive procurements can enable fair competition for energy storage systems and cost reductions. This can be done using all-source or technology-neutral procurements or the explicit inclusion of energy storage (either as a stand-alone resource or as a hybrid system) as well as the fair consideration of third-party ownership models. It is important that all-source bidding processes reflect the full range of desired performance characteristics, services sought, and policy goals.

> *One interviewee described the importance of doing the correct modeling to ensure that storage is considered to solve hour-to-hour, day-to-day, and long-term seasonal load balancing challenges.*

Rate Design

Rate design is an important consideration for the deployment of storage technologies. Depending on the approach, electric rates create incentives and disincentives for customers considering the installation of storage applications. Empowering customers to make smarter energy decisions, including through the installation of BTM energy storage systems, will be key as customers increasingly demand more choices and more control over their energy solutions. Rate design also has a significant impact on the development of FTM energy storage projects. With this in mind, and to fairly reflect cost causation, rates assigned to storage should not unnecessarily assume that the resource will be operated in ways that will increase system costs. For FTM energy storage projects in particular, operational characteristics, or how the system operates at a particular site, may affect cost of service and thus should be considered. An example of this under existing rates would be reference to voltage level of service.

With clear price signals, customers will be enabled to operate their systems in ways that provide a net benefit to the grid. Combined with dispatchability, bidirectionality allows an energy storage system to act as both load and supply, depending on when it is most beneficial to the grid. Overall, storage systems are an asset, not a cost, to the system, which should be reflected in rates.

A key benefit of energy storage is that it "can store energy when prices are low and then release it when they are high."[240] As such, a major driver for adoption of both BTM and FTM storage is potential customer

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[238] Central Hudson Gas and Electric Corporation. September 21, 2020. "Central Hudson 2020 DSIP General Information Session." Available at: https://jointutilitiesofny.org/sites/default/files/Central%20Hudson%202020%20DSIP%20Filing%20General%20Information%20Session%20full%20deck%20final_0.pdf. p. 23.

[239] Central Hudson Gas and Electric Corporation. June 30, 2020. "Distributed System Implementation Plan." Case No. 16-M-0411 and Case No. 14-M-0101. Available at: https://jointutilitiesofny.org/sites/default/files/CH%202020%20DSIP.pdf. p. 282.

[240] Noffsinger, J., Rogers, M., and Wagner, A. April 26, 2018. "Why the future of commercial battery storage is bright." McKinsey & Company. Available at: https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/why-the-future-of-commercial-battery-storage-is-bright.

savings in energy charges and/or demand charges (if the customer is on a demand rate).

In addition to the structure of the rates themselves – i.e., whether and to what extent the rates include demand charges, and whether energy charges are tied to TOU – the transparency and accessibility of tariffs can have an impact of customers' ability to calculate estimated electricity costs and revenue, which can affect their willingness to embrace storage technology. In general, rates should be easy for customers to understand.

Demand Charges

A customer's demand refers to the quantity of power that they use in any given time interval. Demand charges are billed per kW and are often based on the customer's highest demand during each billing cycle. Demand charges can also be designed to correspond to a customer's highest demand during an on-peak period. The energy component of a customer's bill refers to the product of demand multiplied by the length of time it is used, usually measured in kilowatt-hours (kWh). The energy component of rates is based on actual consumption by the customer.[241]

Traditionally, the potential for reduction in demand charges on a customer's bill has been a main driver in making the installation of storage an attractive option. Demand charge savings from the installation of storage depends on the demand charge rate, whether demand charges are tied to the peak period, the timing and duration of the peak period, the interval for measuring the amount of billing demand, any seasonal variation in the demand charge rate, and whether there is a demand ratchet.[242] A demand ratchet is a minimum billing demand based on a customer's historical peak demand, generally over the course of the previous year. Because a demand ratchet is based on historical demand, rather than actual demand in a current month, it can serve as a disincentive for a customer to invest in resources that reduce on-site demand, such as distributed generation, energy efficiency and energy storage.

Additionally, given the synergies between storage and solar, rates for these technologies should link up seamlessly and be transparent and accessible for the customer (i.e., rates should be easy for customers to understand). According to the National Renewable Energy Laboratory: "Both solar and battery storage technologies have the potential to reduce demand charges. However, because demand charges are typically assessed based on a customer's maximum demand during the given month, a few clouds at the wrong time have the potential to mostly eliminate any solar-enabled demand reduction savings for an entire billing period. Storage, on the other hand, can more reliably deliver demand reductions throughout a billing cycle. In an integrated solar-plus-storage system, the technologies can often complement each other and increase demand charge savings through an effective demand-management strategy."[243] In fact, solar alone (without storage) is not all that effective in reducing demand charges for commercial customers. According to Lawrence Berkeley National Laboratory: "Under a basic, non-coincident demand charge design, commercial customers generally achieve low reductions in demand charges from solar. … rooftop solar reduces demand charges by just 7 percent in the median case…"[244] In this way, rate design efforts to increase deployment of storage may have a related impact on the deployment of solar for commercial customers.

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[241] Scripps, J. Hunterston Consulting for Great Plains Institute. March 2021. "Best Practices for Standby Rates for Combined Heat and Power." Available at: https://www.betterenergy.org/wp-content/uploads/2021/04/best-practices-for-standby-rates-for-combined-heat-and-power.pdf. p. 3.

[242] Darghouth, N., Barbose, G., and Mills, A. Lawrence Berkeley National Laboratory. August 2019. "Implications of Rate Design for the Customer-Economics of Behind-the-Meter Storage." Available at: https://eta-publications.lbl.gov/sites/default/files/darghouth_rate_design_storage_final.pdf.

[243] National Renewable Energy Laboratory. August 2017. "Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges." Available at: https://www.nrel.gov/docs/fy17osti/68963.pdf.

[244] Darghouth N., et. al. Lawrence Berkeley National Laboratory. 2017. "Exploring Demand Charge Savings from Commercial Solar." Available at: https://emp.lbl.gov/publications/exploring-demand-charge-savings-0.

Under traditional rate structures, there are two primary ways to save on demand charges: reduce customer demand in order to become eligible to move to a more favorable rate – or stay on the same rate and reduce billing demand.[245] Purely from a cost causation perspective, demand charges should eventually be eliminated completely, in favor of time-varying rates. To the extent demand charges continue to be used in the near term, they should align with established cost allocation methods by reflecting the coincident peak. According to the Regulatory Assistance Project: "Traditional monthly demand charges have always provided a perverse incentive that does not reflect cost causation for shared system costs. Individual customer non-coincident peaks (NCPs) do not reflect the coincident peaks that drive shared generation and delivery capacity costs."[246] The Regulatory Assistance Project further states: "Demand charges, of either the traditional monthly NCP or peak window variety, are not efficient, as a general matter, for shared system capacity costs because: 1) For the vast majority of customers, any peak reduction signal in a traditional monthly demand charge is weak and inaccurate; 2) Traditional calculations for demand charges have included far too many costs as demand-related. Ideally, utility commissions will adopt a new time-based classification and allocation framework for generation, transmission and shared distribution costs. Failing that, the numerous energy benefits from capacity investments should be properly accounted for — that is, reflected in energy, not demand, charges."[247] In this way, as we transition away from demand charges to time-varying rates, and to the extent demand charges continue to be used in the near term, reliance on cost allocation methods that reflect coincident peak would improve alignment with cost causation and remove a disincentive to deploy energy storage.

Energy Charges

Customers who install energy storage systems may also be able to save on their electric bills through energy price arbitrage. Time-varying or TOU rates can help customers with energy storage systems save money, since a storage system can charge during off-peak times and discharge during on-peak periods. "Energy storage can reduce TOU charges by charging when the energy cost is low (e.g., in the middle of the night) and discharging when the energy cost is high (e.g., late afternoon)."[248] In order to optimize the deployment and operation of energy storage, time-varying rates should become the default option for C&I energy storage customers, and should provide a clear price signal for these customers to charge during periods when demand is low and discharge during periods when demand is high. The more accurately rates reflect actual costs, the clearer the price signal to operate the customer's storage system in ways that are most beneficial for the grid.

Notably, the specific design of a TOU rate can have an impact on a customer's savings. On-peak vs. off-peak price variations, including both the price differential between on-peak vs. off-peak price periods and the duration of on-peak vs. off-peak price periods, can all have an impact on potential savings or profitability of an energy storage system.[249]

Additionally, the size of the battery storage installation matters more with energy charge arbitrage than with demand charge reductions. According to Lawrence Berkeley National Laboratory: "Arbitrage savings

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[245] Rocky Mountain Institute. 2015. "The Economics of Battery Energy Storage: How Multi-Use, Customer-Sited Batteries Deliver the Most Services and Value to Customers and the Grid." Available at: https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf.

[246] Regulatory Assistance Project. November 2020. "Demand Charges: What Are They Good For?" Available at: https://www.raponline.org/wp-content/uploads/2020/11/rap-lebel-weston-sandoval-demand-charges-what-are-they-good-for-2020-november.pdf. p. 4.

[247] *Id*. pp. 38-39.

[248] National Renewable Energy Laboratory. February 25, 2018. "When Does Energy Storage Make Sense? It Depends." Available at: https://www.nrel.gov/state-local-tribal/blog/posts/when-does-energy-storage-make-sense-it-depends.html.

[249] Carpinelli, G., et. al. May 26, 2014. "Battery Energy Storage Sizing When Time of Use Pricing Is Applied." The Scientific World Journal. Vol. 2014. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4177186/pdf/TSWJ2014-906284.pdf. pp. 7-8.

roughly scale with storage duration, whereas there are diminishing returns to demand charge reductions with increasing storage duration."[250]

Overall, while energy prices and demand charges both contribute to the economic viability of storage systems, as of now demand charges provide the primary revenue for BTM battery storage systems and, therefore, are the strongest predictor of economic viability.[251]

Standby Charges

One means of recovering revenue from customers with DERs making only partial use[252] of the grid is through the use of standby rates, which are intended to help the utility recover costs related to being ready to provide electricity during scheduled and unscheduled outages of a customer's on-site system. The reasonableness of standby rates, including their potential applicability to storage applications, depends on whether a utility's proposed approach follows accepted guidelines of utility rate design. The following three objectives of sound rate design are generally considered fundamental:

- Effectiveness in meeting the utility's revenue requirement;
- Fairness of the specific rates in the apportionment of total costs of services among the different consumers; and
- Encouraging optimum-use of utility services.[253]

For baseload technologies like CHP that only need infrequent backup and maintenance-related standby service from the utility, standby charges represent a way to prorate a customer's monthly bill to avoid full-service demand charges in months where the customer does not use standby service. Pro-ration can be particularly beneficial if there is normally a "demand ratchet" associated with the customer's full-service tariff. A demand ratchet is a minimum billing demand based on a customer's historical peak demand, generally over the course of the previous year. According to research by the Rocky Mountain Institute (RMI): "A Ratchet Mechanism can help stabilize utility revenue by locking in a floor at a certain level for the customer's demand bill, but the mechanism may remove customers' incentive to reduce peak load, depending on how the ratchet is designed."[254] According to a recent white paper from the Great Plains Institute on Best Practices in Standby Rates for CHP: "Demand ratchets in standby rates should be avoided where possible."[255]

If the customer is able to use storage to reduce its contribution to the system peak, from a cost causation perspective, the customer has done its part to reduce system costs during the peak period. Therefore, a resulting reduction in demand and/or energy charges is warranted. Any additional "standby charge" would remove the customer's incentive to help reduce system costs, and would over-recover costs from these customers, undermining fairness of rates in the apportionment of total costs of services among customers, and discouraging optimum use of utility services.

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[250] Darghouth, N., Barbose, G., and Mills, A. August 2019. Lawrence Berkeley National Laboratory. "Implications of Rate Design for the Customer Economics of Behind-the-Meter Storage." Available at: https://eta-publications.lbl.gov/sites/default/files/darghouth_rate_design_storage_final.pdf. slide 29.

[251] *Id*. slide 2.

[252] Here, partial use of the grid refers to self-generating customers' infrequent use of grid resources. This also includes customers' use of generation and distribution resources, which is also partial because these resources are shared with other ratepayers. However, we note that generation and distribution resources are shared differently and to varying degrees.

[253] Bonbright, J. C. 1960. "Principles of Public Utility Rates." Available at: http://www.raponline.org/wp-content/uploads/2016/05/powellgoldstein-bonbright-principlesofpublicutilityrates-1960-10-10.pdf.

[254] Rocky Mountain Institute. 2017. "A Review of Alternative Rate Designs." Available at: https://rmi.org/wp-content/uploads/2017/04/A-Review-of-Alternative-Rate-Designs-2016.pdf.

[255] Scripps, J. Hunterston Consulting for Great Plains Institute. March 2021. "Best Practices for Standby Rates for Combined Heat and Power." Available at: https://www.betterenergy.org/wp-content/uploads/2021/04/best-practices-for-standby-rates-for-combined-heat-and-power.pdf. p. 26.

One interviewee spoke about the interplay between rate design (e.g., demand charges) and the role that storage can play in tandem with EV fast charging to benefit customers and the grid.

CURRENT MICHIGAN POLICIES

A number of Michigan's current policies are supportive of energy storage. Broadly, as discussed previously, in terms of financing options, Michigan is home to Michigan Saves, a nonprofit green bank that operates as a loan loss reserve, using government and nonprofit resources to increase deployment a variety of technologies, including BTM energy storage projects.

Executive

On September 23, 2020, Governor Whitmer issued Executive Directive 2020-10, which set a goal of economy-wide carbon neutrality by 2050 and an interim goal of a 28 percent reduction in greenhouse gas emissions relative to 2005 by 2025.[256] This goal, in addition to cost declines and pressure from customers, will likely serve to shift electricity generation in Michigan toward greater percentages of renewables. As described previously, to avoid curtailment of this renewable energy and more efficiently and cost-effectively integrate the renewables into the grid, more energy storage capacity will be needed.

Regulatory

Interconnection Rules

Michigan has a number of regulatory policies and open dockets that support deployment of energy storage. In November 2018, the state began a process to update its interconnection rules. As noted in an MPSC Staff report, "[interconnection] standards and rate expectations can help provide certainty for storage developers to ensure that interconnection can happen at scale."[257] After a lengthy stakeholder process, the draft rules were sent to the Michigan Office of Administrative Hearings and Rules (MOAHR) on September 29, 2020 and regulatory impact statements were approved on July 21, 2021.[258] The draft standards were released in August 2021 and were subject to public comments. As of March of 2022, the new rules have not yet been finalized by the MPSC. The August 2021 draft standards include a definition of storage, the ability to add energy storage to a solar PV system without impacting the 10-year net metering grandfathering period and clarity that export of electricity from storage devices can be limited effectively. These are all important additions and will help to ensure that energy storage interconnecting to the distribution system is treated appropriately. However, the draft rules leave discretion to the utilities to determine how exactly to allow for and study behind-the-meter storage with appropriate limited export controls and front-of-the-meter storage with realistic operational characteristics (e.g., charging when excess power is available, not at peak load).

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[256] Governor Gretchen Whitmer. September 23, 2020. Executive Directive 2020-10. Available at: https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-540278--,00.html.

[257] Michigan Public Service Commission Staff Report. MI Power Grid: New Technologies and Business Models Workgroup. December 1, 2021. "New Technologies, Business Models, and Staff Recommendations." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/0688y000001jEwjAAE. p. 88.

[258] Michigan Public Service Commission. September 9, 2021. Order in Case No. 20890. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000TTCvjAAH.

One interviewee noted that for behind-the-meter storage, interconnection issues and rate design issues pose challenges.

Distribution Planning

Michigan instituted a requirement for the investor-owned utilities to file 5-year distribution system plans every 3 years.[259] These plans have increased in complexity and scope since the initial filings in 2018. As required by the MPSC, each utility has conducted NWA pilots, some of which include energy storage as described previously.

MI Power Grid

As part of the MI Power Grid initiative, the MPSC opened a stakeholder workgroup to consider the integration of transmission, generation, and distribution planning. These types of integrated planning processes could give storage resources an opportunity to provide supply-side and demand-side services through each aspect of the planning process. The MPSC is also revising Michigan's Integrated Resource Planning Parameters, providing another venue for the more accurate consideration of storage during utility planning processes. Finally, in 2021, the New Technologies and Business Models workgroup explored barriers and opportunities for a number of technologies including energy storage.

Rate Design

In general, electric utility rates in Michigan are designed to recover the utility's costs of providing electric service. Each utility provides a pricing structure in its tariff, which is a set schedule of fees determined by the utility and approved by regulators. There are special rates for some distributed generation technologies, designed to allow the customer to receive remuneration when their system's output exceeds their consumption. In Michigan, however, energy storage is not currently considered an eligible renewable energy technology under the utilities' distributed generation tariffs (though these tariffs may indirectly create incentives that affect storage deployment).[260] As a result, customers with storage are served on general full service electric rates, with the storage technology serving as a demand response resource, or a TOU resource, with the ability to lower the customer's electric bill through lower energy charges, or lower demand charges, or both. For example, for customers with rooftop solar who subscribe to the new distributed generation tariffs, there is an incentive to use as much of the power produced by the solar systems on site as possible to lower energy charges. This creates an economic incentive for customers with rooftop solar to also install BTM battery storage systems.

Standby charges are also an important rate design consideration for storage. In Michigan, standby rates were examined by the Staff Standby Rate Working Group of the Michigan Public Service Commission in 2016-2017. The impetus for the Standby Rate Working Group was "the burgeoning interest in these types of projects by potential self-generation customers and project developers," and a desire to develop "greater understanding of these complicated standby service tariffs."[261] Standby rates are not necessarily a bad thing, and in fact offer baseload technologies a pro-rated rate for receiving backup service from the utility. In this way, some level of standby charges may be appropriate for certain technology applications and loads, such as customers with CHP, and less appropriate in other situations, such as solar and storage. The Standby

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[259] Michigan Public Service Commission. November 21, 2018. Order in Case No. U-20147. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000003FSF2AAO.

[260] Michigan Public Service Commission. "Distributed Generation." Available at: https://www.michigan.gov/mpsc/0,9535,7-395-93308_93325_93423_93502_94989-506586--,00.html.

[261] Michigan Public Service Commission Staff. August 2016. "Standby Rate Working Group Report." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000001UMMNAA4. p. 2.

Rate Working Group found that standby rates were not necessary for non-residential solar, as long as the customer's full-service rate includes a delivery demand charge along with either TOU rates or a power supply demand charge.[262]

Mandatory standby charges should not apply to standalone storage applications unless cost justified. Similarly, for those customers adding a storage installation to an existing self-generation system, additional standby charges should not be assessed unless justified by a corresponding increase in the cost of serving that customer. Such an assessment should also consider any grid benefits (i.e., benefits to all ratepayers) provided by the storage system. To the extent that a customer's installation of storage resources reduces a customer's peak load, the customer should be permitted to experience a reduction in monthly standby charges, including through waiver of an existing demand ratchet.

Pending the results of a Michigan-specific "value of storage" study, policymakers may wish to consider exempting storage installations from monthly standby charges, should they be found to provide sufficient grid benefits (i.e., benefits to all ratepayers) to justify such an exemption.

Standby tariffs, in particular, can suffer from issues related to transparency and accessibility, and be difficult for customers to understand. This is particularly true for solar customers in Michigan, and due to the close relationship between solar and storage, is likely to affect storage customers, as well. "A lack of understanding of standby tariffs can contribute to confusion during the planning phases of self-generation projects. This may be particularly true for customers interested in solar projects, because Michigan has very few large solar self-generation projects. In some cases, non-utility solar project planners have not had the opportunities to develop expertise in complex utility rates. Without assistance from the utility, a solar project planner may find it difficult to calculate the potential utility bill reduction when analyzing the project economics."[263]

Legislative

In Michigan, energy storage has rarely been the subject of legislative discourse or action and is often left uncontemplated in adopted legislation. However, the real-world need for energy storage and the expanding market for storage means that existing laws are increasingly being examined for their implications on energy storage and policymakers are beginning to consider how to proactively support energy storage deployment by removing barriers or creating incentives.

The state's definition of energy storage is found in Public Act 592 of 2002, the Michigan Next Energy Authority Act. This law defines an "electricity storage device" as a "device, including a capacitor, that directly stores electrical energy without conversion to an intermediary medium" and defines an "electricity storage system" as "1 or more electricity storage devices and inverters or other power conditioning equipment."[264] Other than these definitions, energy storage is rarely considered in Michigan's key statutes.

Renewable Portfolio Standard and Renewable Energy Credits

Public Act 295 of 2008 established Michigan's RPS by setting a target of 10 percent renewable energy for

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[262] Scripps, J. Hunterston Consulting for Great Plains Institute. March 2021. "Best Practices for Standby Rates for Combined Heat and Power." Available at: https://www.betterenergy.org/wp-content/uploads/2021/04/best-practices-for-standby-rates-for-combined-heat-and-power.pdf. p. 26.

[263] *Id*. p. 21.

[264] Public Act 592 of 2002. October 17, 2002. Available at: https://www.legislature.mi.gov/(S(phzl3yax51qgr5d2q0xqwz4r))/documents/mcl/pdf/mcl-Act-593-of-2002.pdf.

each investor-owned utility by 2015.[265] Public Act 342 of 2016 increased that target to 15 percent by 2021 and established a goal of 35 percent by 2025.[266] By 2019 (two years early), all of Michigan's electric providers reached the 15 percent RPS targets.[267] By requiring utilities to increase the proportion of renewable energy in their generation portfolios, the RPS indirectly helped move Michigan toward an electric grid that has more need for energy storage.

To help track, validate, and in some cases aide in compliance with the state's RPS, Public Act 295 of 2008 established RECs and denoted how they are awarded based on generation. As a part of the REC accounting structure, a special consideration – awarding an additional 1/5 REC – is provided for renewable energy that is used to charge an energy storage device during off-peak hours and discharged during peak hours rather than being fed into the electric grid in real time.[268] Although this additional credit for storage set helpful precedent, it was primarily accessed an incentive to use existing storage provided by Ludington.

Performance-Based Regulation

Performance-based regulation (PBR) and its principles are included in a few provisions in Michigan law and may have applicability for energy storage. In particular, Public Act 3 of 1939 allows the MPSC to levy financial incentives and penalties upon any rate-regulated utility which exceeds or fails to meet service quality and reliability standards, thereby allowing for future performance-based constructs to incentivize energy storage in applications that deal with these outcomes in particular. While none of the existing applications of PBR are targeted toward energy storage or services that energy storage is particularly well-suited to provide, performance-based mechanisms have the potential to help accelerate energy storage adoption, for example by incenting demand management or peak demand reduction. Michigan has successfully implemented performance-based incentives, for example, to increase energy efficiency or energy waste reduction beyond what is otherwise required.[269]

Distributed Generation Program

As previously described, the distributed generation program was created by Public Act 342 of 2016 and replaced the previous net metering program.[270] The new distributed generation tariffs result in customers paying a standard rate for the electricity they consume (inflow) and being credited at a different – typically lower – rate for what they return to the electric grid. Such a tariff serves to incentivize onsite usage of distributed generation, which drives increased adoption of energy storage in tandem with solar PV systems. However, the limits on the size of systems that can qualify for the distributed generation program and limits on the overall enrollment in the program were retained in Public Act 342 of 2016, ultimately limiting the ability of this program to serve as a driver for BTM energy storage installations.

On-Bill Repayment and On-Bill Tariffs

On-bill repayment programs – referred to in Michigan law as "residential energy improvements" — for BTM energy projects are enabled in for rate-regulated utilities under Public Act 295 of 2008 as amended

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[265] Public Act 295 of 2008. October 6, 2008. Available at: http://www.legislature.mi.gov/(S(gczhrsktb1dwsowov03ay022))/mileg.aspx?page=getobject&objectName=mcl-Act-295-of-2008.

[266] Public Act 342 of 2016. December 21, 2016. Available at: https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

[267] Michigan Public Service Commission. February 2021. "Report on the Implementation and Cost-Effectiveness of the P.A. 295 Renewable Energy Standard." Available at: https://www.michigan.gov/mpsc/-/media/Project/Websites/mpsc/regulatory/reports/pa295-ren/2020_Renewable_Energy_Standard_Report_with_Appendices.pdf?rev=abf6a8f90b934d178f6e08e73bf970ca&hash=BA9BB458AD4441A78F357A5281B00206.

[268] Public Act 295 of 2008. October 6, 2008. Available at: http://www.legislature.mi.gov/(S(gczhrsktb1dwsowov03ay022))/mileg.aspx?page=getobject&objectName=mcl-Act-295-of-2008.

[269] *Id*. Section 75.

[270] Public Act 342 of 2016. December 21, 2016. Available at: https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

by Public Act 342 of 2016.[271] In the case of nonpayment, these programs can be enforced through utility shut off of a customer's electricity (as allowed by Public Act 3 of 1939).[272] Similarly, under Public Act 408 of 2014, municipal electric utilities in Michigan can establish what are termed to be "residential clean energy programs," which are a version of on-bill repayment or financing for residential energy projects.[273]

An investor-owned utility or municipal utility is able to offer on-bill financing for energy cost saving measures or for renewable energy projects. These programs could, therefore, be applied to energy storage under certain circumstances where energy storage is either combined with a renewable energy system or is deemed to generate utility-cost savings. There may be little incentive for utilities to offer such financing due to concerns over complicated start up hurdles and limited interest in providing capital for such customer-owned projects, as utilities can often earn better returns deploying capital toward utility-owned investments.

Commercial Property Assessed Clean Energy (PACE)
Under Public Act 270 of 2010,[274] commercial PACE loans are designed specifically to address energy- and water-related upgrades and can include BTM storage under the right conditions, though these loans are not well-suited for FTM storage. By tying loan repayments to a property owner's property taxes, the property owner can avoid all upfront costs for the PACE-eligible upgrades, and the property owner can also benefit from a loan term of up to 25 years. For the lender and investor, the project is effectively de-risked, allowing for more flexibility in the interest rate and the loan term. Furthermore, the loan is non-recourse, and therefore, repayment can be passed on to a future property owner should the property be sold. Finally, under certain conditions, the property owner may be able to benefit from "off balance sheet" treatment. This type of financing is enabled by local government policy, but state resources can still provide direct PACE loans, including with the State of Michigan's own investments.

Revolving Loan Fund for Energy Efficiency and Renewable Energy
Michigan has a revolving loan fund for energy efficiency and renewable energy housed in the Department of Treasury and administered by EGLE (established via Public Act 242 of 2009).[275] Although energy storage is not explicitly included, the fund could likely be used to support storage that is paired with solar PV systems.

Cost-Effective Governmental Energy Use Act
Through Public Act 625 of 2012, known as the Cost-Effective Governmental Energy Use Act, state government departments, agencies, and authorities may enter into energy performance contracting.[276] Energy performance contracting is an arrangement where a third-party executes an energy-saving or renewable energy generating project and guarantees that the savings will exceed the cost to pay for the project. Typically, such an arrangement will include financing, allowing the governmental unit the ability to reduce costs without using state resources. Under Public Act 625 of 2012, although energy storage is not explicitly mentioned, a project utilizing an energy performance contract could likely include energy storage as a measure that could be included if installed in tandem with a renewable energy measure, used to

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271 *Ibid*.

272 Public Act 3 of 1939. February 15, 1939. Available at: http://www.legislature.mi.gov/(S(qy252pu4pq4tonasbwwtep3k))/documents/mcl/pdf/mcl-Act-3-of-1939.pdf.

273 Public Act 408 of 2014. December 30, 2014. Available at: https://www.legislature.mi.gov/(S(phzl3yax51qgr5d2q0xqwz4r))/documents/mcl/pdf/mcl-Act-408-of-2014.pdf.

274 Public Act 270 of 2010. December 14, 2010. Available at: http://www.legislature.mi.gov/(S(ukexhpcbmoc1yrpshizq1o3a))/mileg.aspx?page=GetObject&objectname=mcl-Act-270-of-2010.

275 Public Act 242 of 2009. January 8, 2010. Available at: https://www.legislature.mi.gov/(S(phzl3yax51qgr5d2q0xqwz4r))/documents/mcl/pdf/mcl-Act-242-of-2009.pdf.

276 Public Act 625 of 2012. March 28, 2013. Available at: https://www.legislature.mi.gov/(S(phzl3yax51qgr5d2q0xqwz4r))/documents/mcl/pdf/mcl-Act-625-of-2012.pdf.

manage and reduce energy costs, or is deemed in some other way to reduce utility or operational costs for the unit of government.

Dialogue on Energy Storage
In 2018, the Michigan Legislature passed House Resolution 387[277] to support further discussion on energy storage by state government. In response, in March 2019, the MPSC, Michigan Agency for Energy (which later was reorganized under the Michigan Department of Environment, Great Lakes, and Energy), and a variety of private sector stakeholders including IEI and Michigan EIBC members convened and discussed energy storage in the Michigan market, highlighting major interest in the topic amongst regulators and other stakeholders.

IX. Stakeholder Engagement

STAKEHOLDER CONVENINGS

Michigan EIBC, as a partner to this project, hosted three virtual energy storage convenings with participating companies, individuals from state government, and members of the public in 2020 and 2021 and in-person convening on October 18, 2021, in Clare, Michigan. Each of these events drew more than 50 participants including state government officials, regulators, legislators, industry leaders, advocates, and interested members of the public.

The first convening was held virtually on July 8, 2020, and provided a general overview to attendees of existing storage markets as well as state and federal policies. It included speakers from the private sector, ESA, and others. The second convening was held virtually on October 5, 2020, and focused on BTM storage, including EVs, managing load and solar plus storage value stacking. This convening included presentations from industry partners and utilities. The third convening was held virtually on June 15, 2021, and focused on transmission and distribution connected storage. This convening included a panel of industry partners as well as a presentation from MPSC Commissioner Katherine Peretick. The final convening was held in-person at Advanced Battery Concepts' facility in Clare, MI. The event featured remarks from Dr. Annick Anctil and an industry panel focused on reuse and recycling of energy storage technologies.

INDUSTRY SURVEY AND INTERVIEWS

Methodology
Michigan EIBC conducted a survey of its members and a series of one-on-one interviews with advanced energy companies working on energy storage deployment. Questions in both the survey and interviews were tailored to probe preliminary conclusions gleaned from desk research and to better understand investments being made by the advanced energy industry in energy storage.

A 26-question survey (Appendix A) was sent to all Michigan EIBC members in March 2021 and members were given three weeks to complete the questions. Twenty-one Michigan EIBC member companies filed out

[277] House Resolution 387. 2018. Available at: https://www.legislature.mi.gov/(S(vrqjgb1ummxqm2ukrdp1koo3))/mileg.aspx?page=getObject&objectName=2018-HR-0387.

the survey including energy storage developers, renewable energy developers, rooftop solar/BTM storage installers, environmental consultants, and manufacturers.

Based on responses to the survey, 11 companies were selected for follow-up interviews. An effort was made to select companies from each of the represented industry sectors. These 30- to 60-minute surveys were conducted between May 25, 2021 and June 3, 2021. A set of standard questions was developed to guide the interviews including several follow-up questions to those asked in the survey. However, these questions were not strictly followed in each interview as it was determined that this information would be gathered in a primarily qualitative manner. Anecdotes and examples provided in these interviews are included throughout this report.

Survey Results

Of the 21 companies who completed the survey, six were residential/commercial solar and storage installers, four were renewable energy developers, two were storage developers, and two were manufacturers. The other companies were consultants or involved in other types of energy storage (e.g., mobile, water heating). The vast majority of the companies were either already currently operating in Michigan with storage projects completed (n = 10) or expecting to develop projects in Michigan in 1-3 years (n = 9). These current and planned storage projects were for a wide variety of different applications as shown in Figure 8.

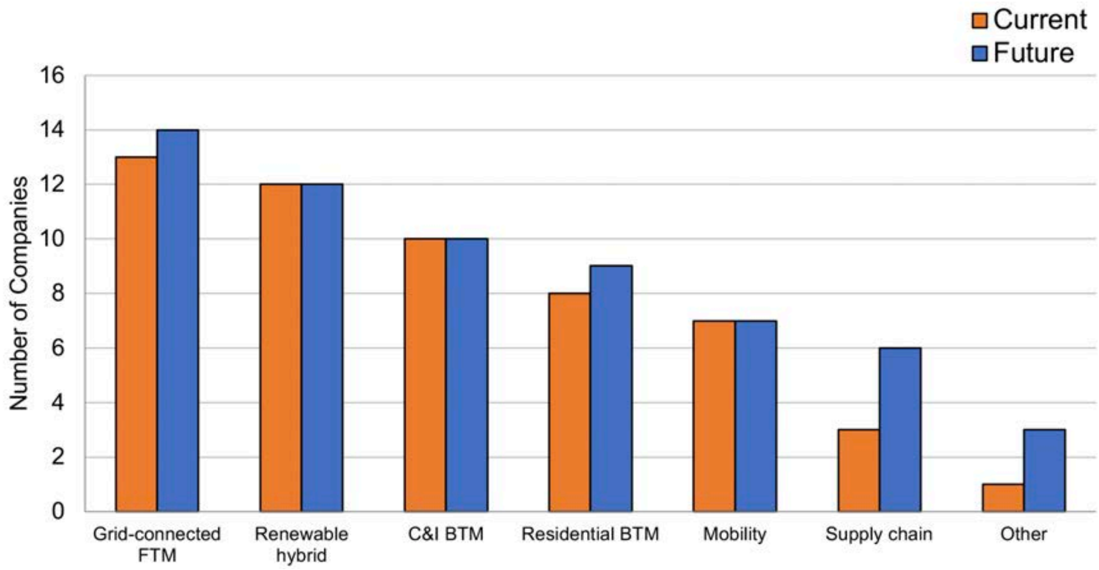

Figure 8. Number of surveyed companies (total n = 21) currently working on storage projects for different applications (orange) or planning to do so in the future (blue).

Most of the survey respondents indicated that their companies are working with lithium-ion batteries (n = 17), but a number are also working with other technologies as shown in Figure 9. Participants were allowed to select as many technologies as they wanted and although some companies are focused on one energy storage technology, several indicated that they are using multiple technologies.

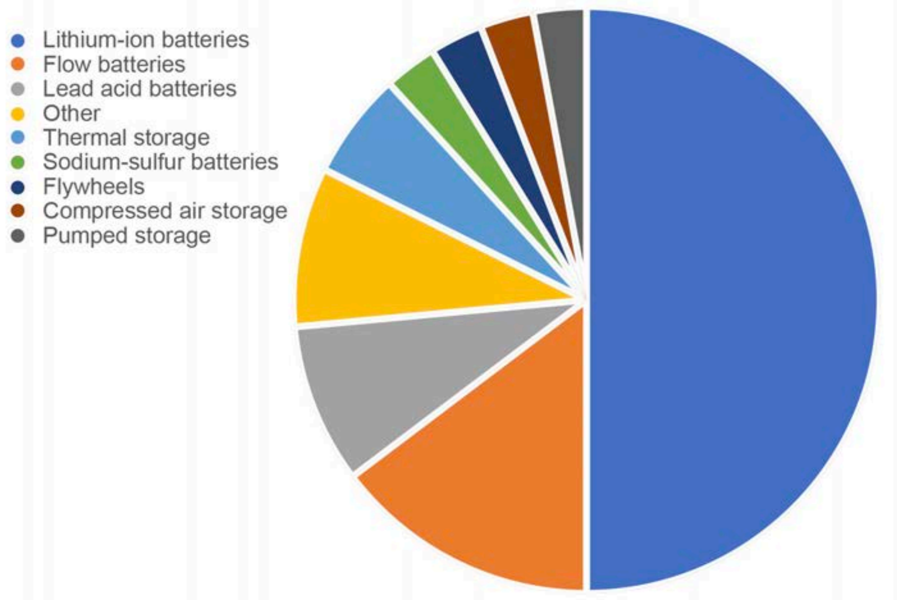

Figure 9. Types of energy storage technologies survey participants are deploying.

The survey respondents are also working on energy storage projects to provide a wide variety of services at the wholesale, distribution, and commercial/residential scales. At the wholesale level (Figure 10), the largest number of respondents indicated using energy storage to provide energy arbitrage benefits (n = 12), with a large number also indicating that demand response benefits (n = 10), frequency regulation (n = 9), and capacity markets (n = 8) were also important.

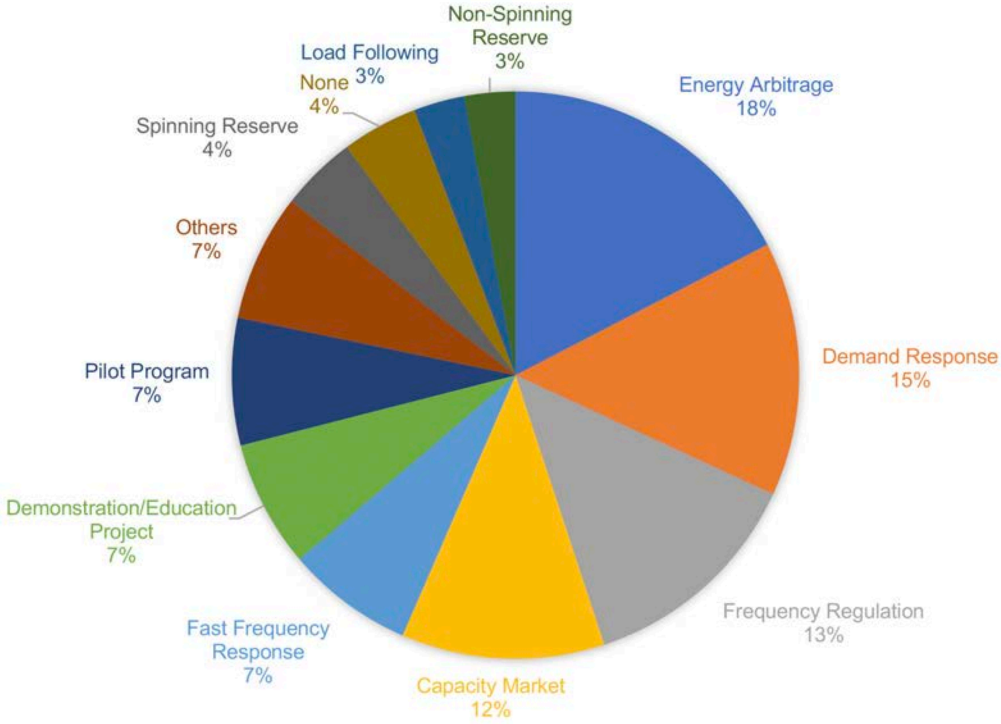

Figure 10. Wholesale services that survey paticipants indicated that they are providing.

At the distribution level, the greatest number of respondents indicated that they are using energy storage to provide renewables integration (n = 10; Figure 11). However, many respondents indicated that they are not providing any distribution system benefits (n = 7). This may be because a relatively large number of participants are engaged in either the BTM storage market or wholesale market (see Figure 8).

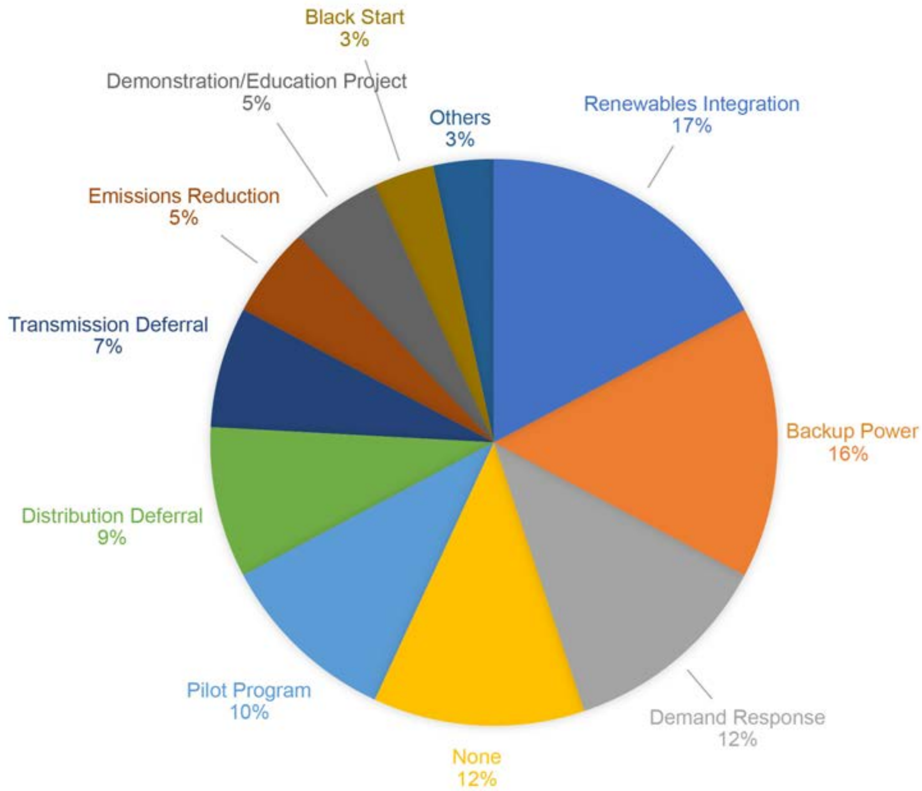

Figure 11. Distribution services that survey participants indicated that they are providing.

Finally, at the customer level (Figure 12), for BTM C&I and residential storage systems, most respondents indicated that they were providing backup power (n = 11), while many also indicated they were providing uninterrupted power supply (n = 7), customer bill management (n = 6) and power stability (n = 6). Again, given the dichotomy in types of companies, many respondents indicated that they are not working with commercial/residential customers (n = 8).

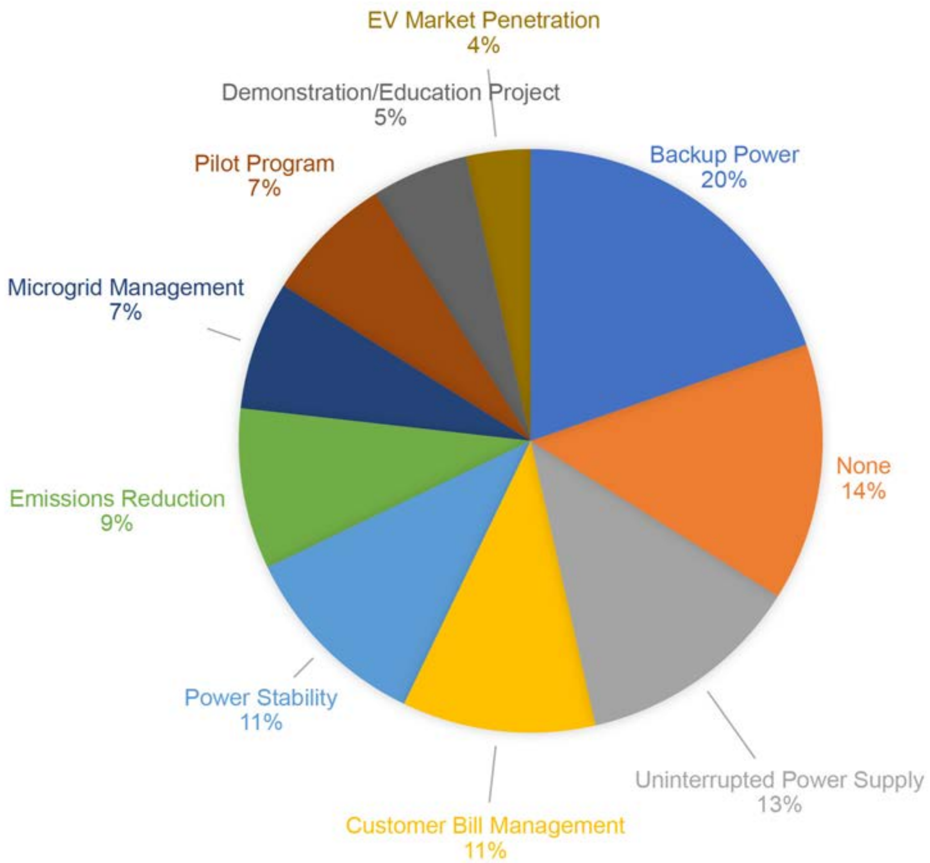

Figure 12. Customer services that survey participants indicated that they are providing.

Respondents were asked to indicate policies that supported energy storage such as state laws, administrative actions, RTO policies, and public utility commission (PUC) policies. Perhaps not surprisingly given the relatively nascent nature of the energy storage market in Michigan and the inherent lag between market dynamics and state policies, many respondents were not aware of laws (n = 8), administrative actions (n = 11), RTO policies (n = 7), or PUC policies (n = 11) that are supportive of energy storage. Many were also not aware of supportive policies in Michigan for energy storage (n = 8).

Similarly, when survey participants were asked about barriers to energy storage deployment in Michigan, again many were unsure (n = 8). However, a number indicated that utility-imposed barriers were an issue (n = 6), as well as the lack of additional incentives (n = 3), followed by a number of other identified barriers (Figure 13).

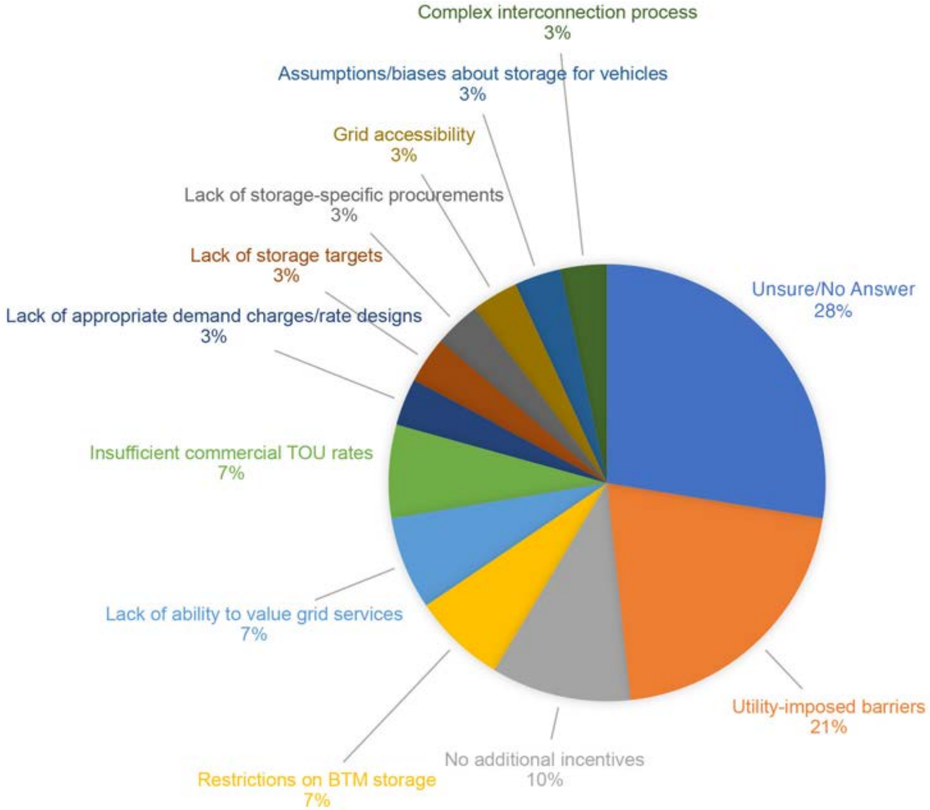

Figure 13. Barriers to storage deployment in Michigan identified by survey participants.

Looking to other states, respondents who were aware of supportive policies indicated that rebates/incentive programs (n = 8), tax credits (n = 5), and storage targets/mandates (n = 5) were important examples of supportive state laws. Respondents similarly indicated that storage targets/mandates (n = 4) and funding opportunities (n = 4) were important actions that a state administration could take. Finally, in terms of regulatory policies, at both the RTO and PUC levels, respondents highlighted the importance of appropriate interconnection rules (n = 7), appropriate rate design (n = 6), and appropriate benefit/cost analyses (n = 6).

X. Energy Storage Modeling

To clarify the opportunities and scope for storage in Michigan, the role of storage was modeled in two important contexts: commercial BTM storage operated to reduce the utility customer's bill and FTM as a bulk power system resource operated to minimize total power system costs. The bulk power system values included in our modeling correspond to the energy arbitrage, capacity, spinning reserve and non-spinning reserve value categories discussed earlier in this report. It is important to note that neither of these modeling contexts is intended to reflect the full value-stack for storage, as they do not include reliability and resilience benefits to customers, short-term ancillary services like frequency regulation, or avoided costs of transmission and distribution systems that are often customer-specific or location-specific.

The environmental impacts of energy storage were also assessed using life-cycle assessment (LCA). LCA is a method used to evaluate the environmental impact of a product, a system, or an activity over its entire life cycle. LCA includes all of the life-cycle stages of the energy storage system, from raw material extraction to manufacturing to use of the system. For this Roadmap, LCA was used to evaluate the environmental benefits of energy storage when deployed either FTM or BTM using the following impact categories:

Global Warming Potential (GWP): The global warming potential or lifecycle carbon footprint is a measure of the amount of energy absorbed over a given period (usually 100 years) by a particular gas relative to the energy absorbed by the unit weight of carbon dioxide (CO_2). The larger the GWP, the more that gas warms the Earth compared to CO_2. GWP provides a common unit that can be used to measure the global warming impacts of different gases.[278]

Photochemical oxidation potential (PCOP): The photochemical oxidation potential estimates the amount of secondary air pollution, also known as summer smog. It is formed by the reaction of sunlight in the upper atmosphere with different primary pollutants generated from fossil fuel combustion[279] including nitrogen oxides and volatile organic compounds.[280] Photochemical smog can lead to breathing problems and eye irritation in humans, in addition to damage to plant and animal life.[281] The reference unit for measuring PCOP is kilograms of ethylene (C_2H_4) equivalent.

Acidification potential (AP): The acidification potential evaluates the potential to cause acid rain (e.g., sulfur dioxide (SO_2), nitrogen oxides (NO_x), and reduced nitrogen).[282, 283] AP is measured in kilograms of SO_2 equivalent.

Abiotic Depletion Potential (ADP) – The abiotic depletion potential corresponds to the amount of consumed non-renewable minerals and resources such as copper and iron.[284] ADP is measured in kilograms of Antimony (Sb) equivalent.[285]

BTM MODELING

Methodology

To model the economics of BTM energy storage resources for commercial customers, we used Hybrid Optimization of Multiple Energy Resources (HOMER) Grid.[286] HOMER Grid is a commercially available software program designed to optimize the least-cost system to provide energy to a customer based on their load profile and other inputs and assumptions as described below. BTM modeling exercises in HOMER did not consider operation of the broader grid but solely focused on the economic benefits of BTM DERs to the individual commercial customer.

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[278] U.S. Environmental Protection Agency. "Understanding Global Warming Potentials." Available at: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

[279] Klöpffer, W. 2006. "The Hitch Hiker's Guide to LCA - An orientation in LCA methodology and application." International Journal of Life Cycle Assessment. Vol. 11.

[280] Manahan, S. 1994. "Fundamentals of Environmental Chemistry, Third Edition." Taylor and Francis.

[281] Adeeb, F. and Shooter, D. 2002. "Ozone highs and lows in Auckland." NIWA Water & Atmosphere. Vol. 10.

[282] Dincer, I. and Abu-Rayash, A. 2020. "Sustainability modeling." Energy Sustainability. Vol 119.

[283] Farinha, C., Brito, J. de, and Veiga, M. Do. 2021. "Life cycle assessment." Eco-Efficient Render Mortars. Vol. 205.

[284] Dincer, I. and Abu-Rayash, A. 2020. "Sustainability modeling." Energy Sustainability. Vol 119.

[285] Van Oers, L., et. al. 2016. "The Abiotic Depletion Potential: Background, Updates, and Future." Resources. Vol 5.

[286] An explanation of the limitations of this modeling program and suggestions for future modeling efforts is provided in Appendix B.

HOMER Grid has the ability to evaluate the economics of all possible combinations of multiple distributed generation components (e.g., solar PV, battery storage, inverters, etc.) with different characteristics, such as battery discharge rate and solar PV capacity, and grid purchases/power outflows under several rate schedules. In addition, the software allows the user to simultaneously evaluate multiple cost scenarios, where each component (and their replacements) can have a differing price-ratios vis-à-vis the base scenario.

For this Roadmap, HOMER Grid was used to quantify the economic benefits associated with investment in BTM storage at commercial buildings in Michigan over the 2020 to 2030 timeframe. The 2020 scenario was considered the baseline, providing a quantification of the current economics of commercial BTM storage, and consistency with which to evaluate the changes in storage economics in the future.

BTM storage was modeled using two core configurations: 1) stand-alone storage and 2) storage coupled with solar PV. The modeling also evaluated stand-alone solar PV as an option. All configurations were evaluated with respect to a base-case, whereby a commercial building continued being served as a traditional non-DER electric utility customer.

Load Profiles

The electrical load profile of an individual customer is a key consideration when developing a least-cost energy system. To model a diverse set of load profiles for commercial customers, we used the load profiles developed by the Open Energy Data Initiative with Department of Energy funding.[287, 288] This database consists of 16 unique load profiles that represent approximately 70 percent of commercial buildings in the U.S. according to the National Renewable Energy Laboratory (NREL).[289] Each load profile also has a representation across 16 different climate zones, of which the Midwest (Chicago) climate region is most representative for Michigan. As shown in Figure 14, the peak demand for the series of 16 commercial building types reflected nearly two orders of magnitude difference between the lowest peak-demand (small office, 20 kW) and highest peak-demand building (large hotel, 1,913 kW).

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[287] Open Energy Data Initiative. 2014. "Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States." Available at: https://data.openei.org/submissions/153.

[288] U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. "Commercial Reference Buildings." Available at: https://www.energy.gov/eere/buildings/commercial-reference-buildings.

[289] Deru, M. et al. National Renewable Energy Laboratory. 2011. "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock." Available at: https://www.nrel.gov/docs/fy11osti/46861.pdf.

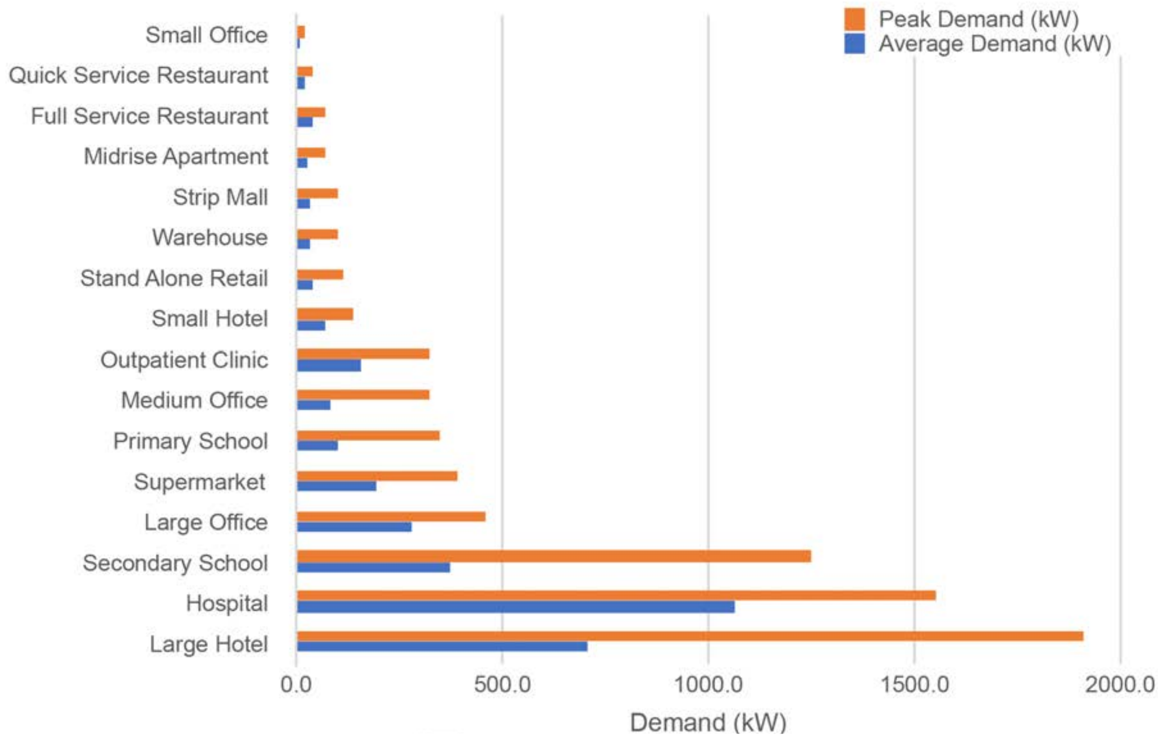

Figure 14. Peak and average demand (kW) for 16 commercial building types.[290]

Tariffs

Utility rates for the 2020 base year were those of DTE Electric[291] and Consumers Energy Electric[292] on file with the MPSC. Those rates were comprised of both secondary and primary service and have three core rate structures associated with each of the two service interconnections: traditional flat rates, demand-based rates, and for Consumers Energy, TOU rates. Rates were escalated using a uniform compound annual inflation factor of 2.44%.[293]

Modeling Scenarios

Scenarios were developed to model DER deployment at 5-year intervals from 2020 through 2030. For both solar PV and battery storage, the project lifetimes were assumed to be 25 years. Modeling exercises were conducted for both major utility territories in the state of Michigan: DTE Energy and Consumers Energy using representative locations (Ann Arbor, MI for DTE Energy and Grand Rapids, MI for Consumers Energy). Two general technology deployment scenarios were analyzed: 1) the first scenario allowed for only energy storage deployment and 2) the second allowed for both solar PV and energy storage deployment. The HOMER Grid software program allows these configurations to be modeled simultaneously, thus allowing both to be in economic competition with each other.

[290] Open Energy Data Initiative. 2014. “Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States.” Available at: https://data.openei.org/submissions/153.

[291] Michigan Public Service Commission. “MPSC-Approved DTE Electric Rate Books and Cancelled Sheets.” Available at: https://www.michigan.gov/mpsc/0,9535,7-395-93308_93325_93423_93501_93508_94515-504644--,00.html.

[292] Michigan Public Service Commission. “MPSC-Approved Consumers Energy Electric Rate Books and Cancelled Sheets.” Available at: https://www.michigan.gov/mpsc/0,9535,7-395-93308_93325_93423_93501_93508_94515-504646--,00.html.

[293] From 2009 to 2021, DTE Energy customers experienced 7 rate increases with an average overall percent increase of 4.88% (Cases U-15768, U-16472, U-17767, U-18014, U-18255, U-20162, and U-20561). Over the 12-year period, this represents an annual average rate increase of 2.44% per year.

Sensitivity Analyses

Technology Cost Projections

NREL's annual technology baseline (ATB) has three future cost scenarios.[294] The conservative scenario assumes historical investments come to market with continued industrial learning, while technology is similar to today. Both public and private research and development (R&D) decrease. The moderate scenario assumes innovations observed in today's marketplace become more widespread and innovations that are nearly market-ready today enter the marketplace. Public and private R&D investment continue at current levels. The advanced scenario assumes innovations that are far from market-ready today are successful and become widespread in the marketplace. Public and private R&D investment increases, while new technology architectures could look different from those observed today. To assess the impact of future technology costs on the deployment of said technologies, all three 2021 ATB scenarios were used in this analysis. However, the analysis described in this Roadmap is focused on the moderate (mid-cost) technology scenario.

Investment Tax Credit

As described previously, the federal ITC is available today for renewable energy technologies (solar PV and energy storage coupled with solar PV) at a rate of 26 percent of the initial capital investment.[295] As of December 10, 2021, the ITC for renewable energy projects is set to expire at the end of 2023. However, as described previously, it is likely that this tax credit will be extended and expanded. As such, sensitivity analyses were performed to assess if the tax credit has an impact on the speed and viability of energy technology deployment.

General Economic Assumptions

All costs in this Roadmap are expressed in 2019 dollars. Despite recent (likely temporary) increases in inflation, the Federal Open Market Committee estimates that an annual increase in inflation of 2 percent in the consumer price index is most consistent over the long-term.[296] Therefore, 2 percent inflation was used in the HOMER Grid modeling.

Discount rates for utility customers are best understood as the customer's opportunity cost of capital, which varies depending on customer class and individual financial circumstances. For commercial customers, a discount rate of 9.3 percent was used, in alignment with that developed for the New York State Energy Storage Roadmap.[297]

Energy Storage Technology Assumptions

Energy storage costs were developed following NREL's 2020 ATB cost curve for utility scale lithium-ion batteries.[298, 299] This cost curve was applied to current battery costs (estimated to be $248/kWh[300]) to project

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[294] National Renewable Energy Laboratory. "Annual Technology Baseline." Available at: https://atb.nrel.gov.

[295] U.S. Internal Revenue Code. 26 U.S. Code § 48 - Energy credit. Available at: https://uscode.house.gov/view.xhtml?req=(title:26 section:48 edition:prelim).

[296] Board of Governors of the Federal Reserve System. "What is inflation and how does the Federal Reserve evaluate changes in the rate of inflation?" Available at: https://www.federalreserve.gov/faqs/economy_14419.htm.

[297] New York Department of Public Service. 2018. "New York State Energy Storage Roadmap and Department of Public Service/New York State Energy Research and Development Authority Staff Recommendations." Available at: https://documents.dps.ny.gov/public/MatterManagement/MatterFilingItem.aspx?FilingSeq=209590&MatterSeq=55960.

[298] Although this Roadmap is not focused on any specific technology, it was necessary to choose a technology for this modeling effort. To best represent current BTM storage projects, we used the most common BTM storage technology, which is currently lithium-ion batteries.

[299] Cole, W. and Frazier, A. W. National Renewable Energy Laboratory. 2020 "Cost Projections for Utility-Scale Battery Storage: 2020 Update." Available at: https://www.nrel.gov/docs/fy20osti/75385.pdf.

[300] Bloomberg New Energy Finance (2019). "2019 Long-Term Energy Storage Outlook." https://www.bnef.com/core/insights/21113.

costs out to 2030. All other costs associated with battery installation and converters were based on residential battery costs from NREL's U.S. Solar PV and Energy Storage Cost Benchmark Report.[301]

HOMER Grid modeling considered a range of battery configurations when optimizing to a least-cost energy system including: ½ hour, 2 hour, 4 hour, 6 hour, and 8 hour duration (i.e., 2kW/1kWh; 0.125kW/kWh; 0.1667kw/1kWh; 0.25kW/1kWh; and 0.5kW/kWh). Each battery was assumed to have a 20 percent minimum state of charge and a 50 percent degradation limit. A "Modified Kinetic Battery Model" was used in HOMER Grid to determine battery life. Under this model, end of life is a function of both calendar degradation and cycle degradation. A wide range of battery lives were estimated for the various battery/solar PV system configurations and load characteristics of the 16 building types. In general, the model estimated battery lives between approximately 4 and 10 years. Replacements were made over the course of a 25-year project life with a range of 2 to 5 replacements over the project lifetime.

Solar PV Technology Assumptions

Commercial solar PV system costs were modeled based on a 200 kWDC system with a fixed-tilt (5°), roof-mounted system.[302] Capital expenditures are reported as $/kWDC with the cost of the necessary inverter included. Projections for the year 2030 were based on bottom-up cost modeling, with a straight-line change in cost in the intervening years. Solar PV panels were assumed to have a 25-year lifetime, 19 percent energy conversion efficiency,[303] and an 80 percent derating factor. The size of the solar PV array was constrained by the estimated roof area for each building type or by 150 kW limit for systems enrolled in the distributed generation program.[304]

Results

As a DER, BTM solar PV has a dominating effect on the resulting system configurations selected as most economic by the HOMER Grid model. Nearly all DER configurations associated with all commercial building types that were chosen first on a lifecycle net present cost (NPC) basis included a solar PV array, either on a stand-alone basis or coupled with battery storage. In fact, the modeling results indicate that by 2030 all commercial buildings in Michigan would find it economic (on a lifecycle NPC basis) to invest in DER resources – either a stand-alone solar PV system, coupled solar PV/battery storage system, or in limited cases, stand-alone battery storage. It is likely that these results were driven by assumptions regarding future costs of solar PV and BTM storage systems as well as assumptions regarding the continuation of federal tax credits.

Throughout the 10-year forecast period, in both DTE Energy's and Consumers Energy's territories, the best ranked (least-cost) systems on a lifecycle NPC basis are coupled solar/battery systems for the commercial building types with the largest energy usage – secondary schools, hospitals, and large hotels.[305] The next best systems for these large energy users based on lifecycle NPC are stand-alone solar PV systems. In contrast, the best ranked systems for small to medium-sized commercial buildings were stand-alone solar PV systems, with coupled solar/battery systems ranked second. However, it is important to note that the difference on an NPC basis between these solar and coupled solar/battery systems is typically very small

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[301] Feldman, D. et. al. National Renewable Energy Laboratory. 2020. "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020." Available at: https://www.nrel.gov/docs/fy21osti/77324.pdf.

[302] National Renewable Energy Laboratory. "Annual Technology Baseline." Available at: https://atb.nrel.gov.

[303] Barbose, G. et. al. Lawrence Berkeley National Laboratory. 2021. "Tracking the Sun." Available at: https://emp.lbl.gov/tracking-the-sun.

[304] Public Act 342 of 2016 established a limit of 150 kW of aggregate generation for a renewable energy system enrolled in a utility distributed generation system (see https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf). Although customers on demand tariffs do not have a PV size limit, we used a 150 kW limit for solar PV systems on all building types.

[305] Each of these building types had more than 1000 kW in peak demand.

(i.e., only a few thousand dollars over a 25-year project lifetime). Because this difference is within the margin of error and negligible relative to total project costs, and given the additional services that storage can provide, for the vast majority of the commercial building types examined, coupled solar PV/battery systems can be considered the best option based on cost and services provided.

For example, a full-service restaurant was modeled with a peak usage of 71 kW and an average usage of 37 kW. The least-cost option modeled for this building type was a coupled solar PV/battery storage system, which included a 37.2-kW solar PV system and a 4-hour battery with a capacity of 53 kWh. Although this building type could also choose to economically install a stand-alone battery storage system, the coupled solar PV/battery storage system could potentially allow for islanding of the building during a short-term utility outage. Given the combined benefits of the solar PV on-site generation and energy storage system and the lower lifecycle NPC, the coupled solar PV/battery storage system would be most effective for this building type.

Assuming, therefore, that coupled solar PV/battery systems are essentially economically equivalent to stand-alone solar PV for commercial buildings, the modeled battery capacity at baseline (2020), in 2025, and in 2030, associated with coupled solar/battery storage systems for the 16 commercial building types is shown in Figures 15 and 16.

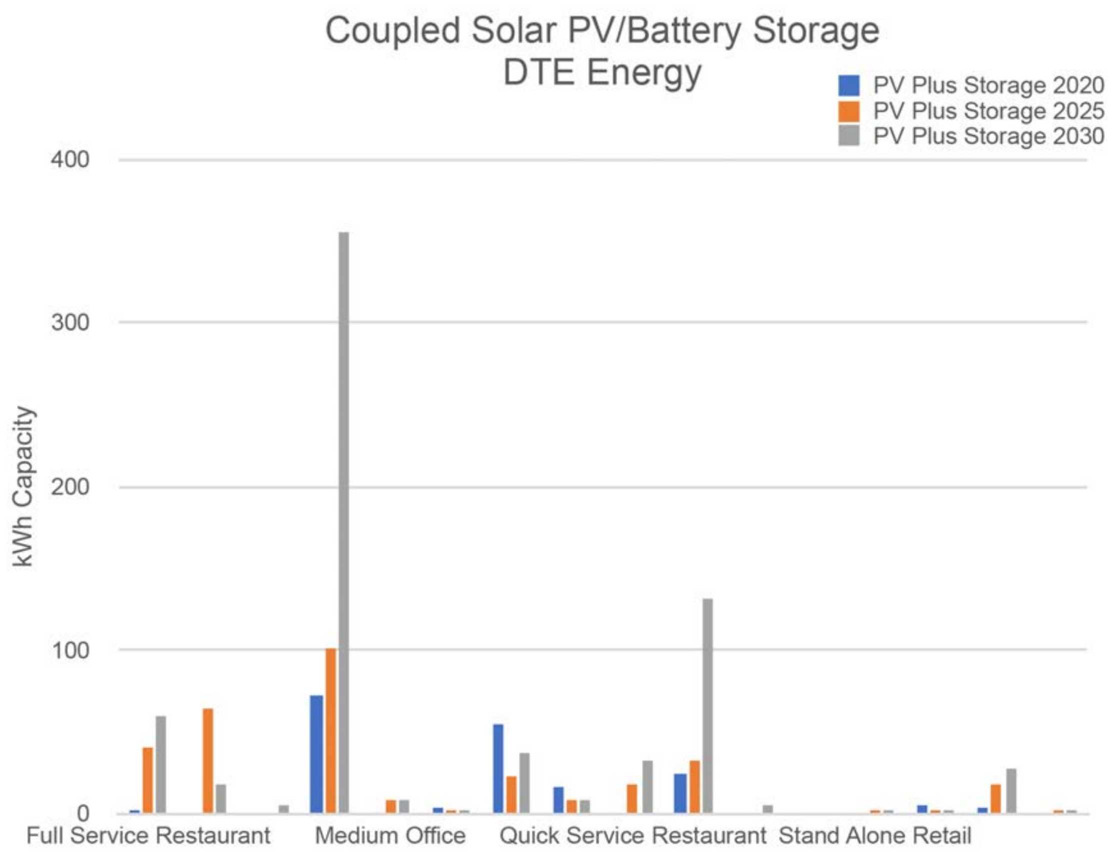

Figure 15. Modeled installed battery capacity (kWh, y-axis) of coupled solar PV/battery storage systems for 16 building types in DTE Energy's territory.

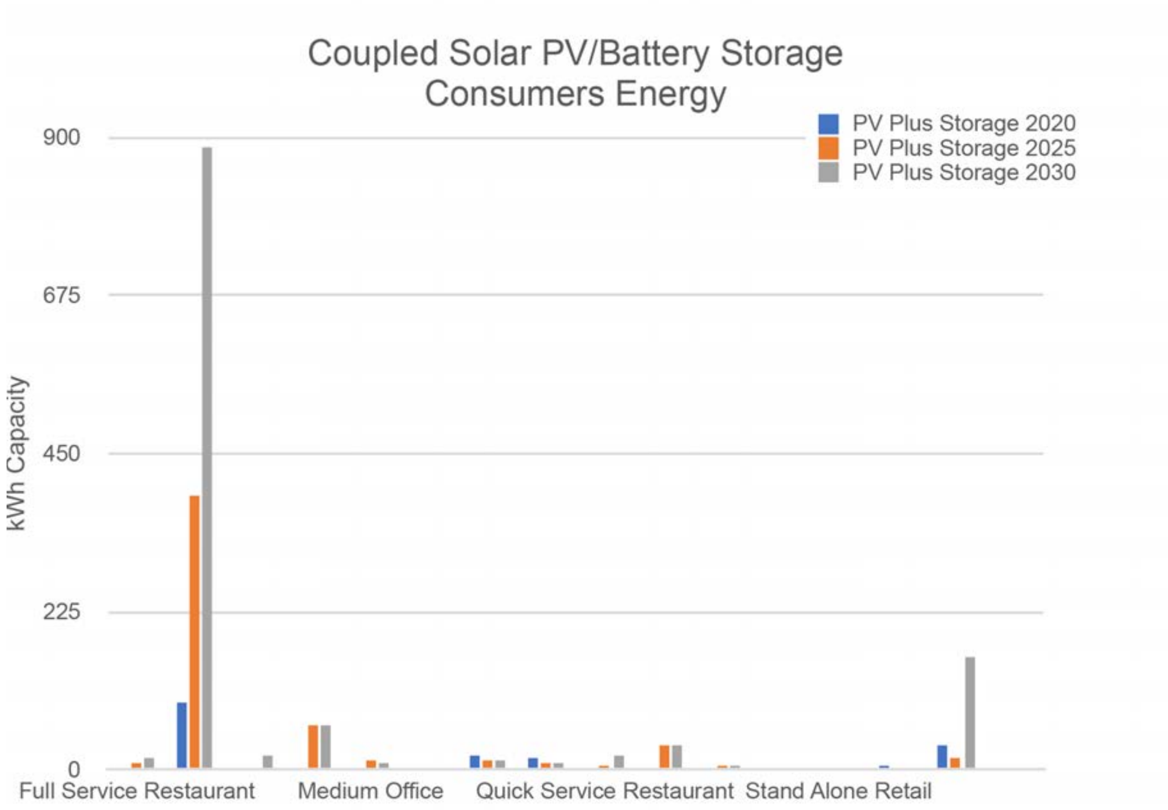

Figure 16. Modeled installed battery capacity (kWh, y-axis) of coupled solar PV/battery storage systems for 16 building types in Consumers Energy's territory. Note the difference in scale relative to Figure 15.

Impact of the Federal ITC

As described above, pending federal legislation could extend the ITC to stand-alone battery systems. As of March of 2022, the specifics of a future ITC for stand-along battery systems and the phase-down of any such credits were unknown. As such, an ITC of 26 percent was assumed for solar PV projects and stand-alone battery storage projects. Doing so resulted in limited uptake of stand-alone battery storage in commercial buildings in 2025 and 2030. However, likely because coupled solar PV/battery storage systems have the added benefit of providing onsite generation to serve load and reduce electricity costs (i.e., distribution charges), those coupled systems were still chosen more often, even with a federal ITC for stand-alone battery systems. The economic benefit associated with these coupled systems particularly holds for utility customers on TOU rate schedules.

Impact of Demand Charges

Only in the case of customers on demand-based rate schedules did the HOMER Grid model choose stand-alone battery storage over the non-DER base case configuration. For example, in the case of a quick service restaurant in DTE Energy's territory in 2030, the modeling selected as the least-cost option, a coupled solar PV/battery storage system with a solar PV capacity of 22.2 kWh and battery capacity of 33 kWh with a 4-hour duration. As the second lowest-cost option, the model selected a stand-alone battery system (37-kWh battery with a 6-hour duration). In either case, the hourly operation of the battery enabled a reduction in peak demand, and thus reductions in demand charges as shown in Figure 17 (coupled solar PV/battery storage) and Figure 18 (stand-alone battery storage). Given the ability to provide on-site generation to meet the restaurant's load, the coupled solar PV/battery storage system is able to decrease the net demand more (Figure 17) than the stand-alone battery storage system (Figure 18).

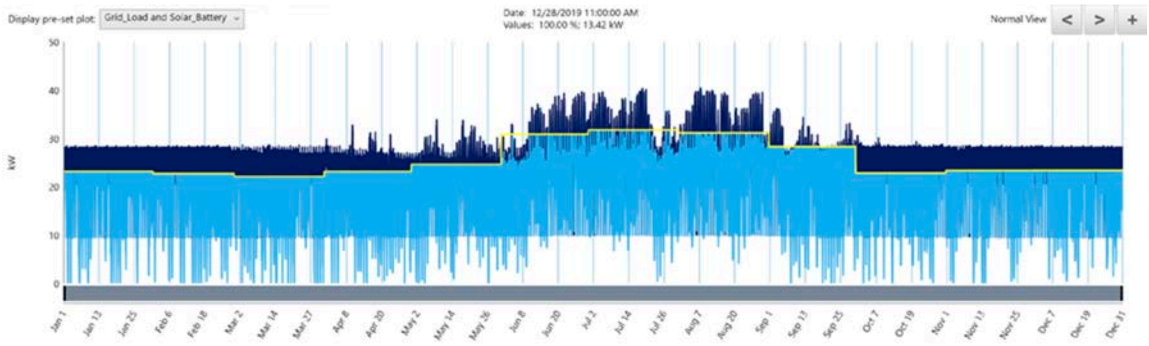

Figure 17. Demand charge reductions enabled at a quick service restaurant by the installation of a coupled solar PV/battery storage system (solar PV capacity of 22.2 kWh and battery capacity of 33 kWh with a 4-hour duration) in DTE Energy's territory in 2030. Dark blue lines represent the building's load, the light blue lines are electricity purchases from the grid, and the yellow line represents the demand limit achieved by virtue of the stand-alone battery.

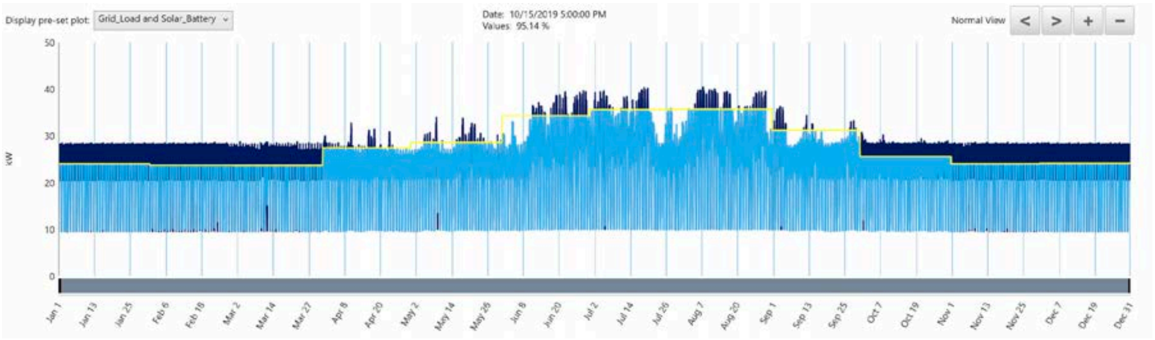

Figure 18. Demand charge reductions enabled at a quick service restaurant by the installation of a 37-kWh, 6-hour duration battery in DTE Energy's territory in 2030. Dark blue lines represent the building's load, the light blue lines are electricity purchases from the grid, and the yellow line represents the demand limit achieved by virtue of the stand-alone battery.

The economics of the coupled solar PV/battery storage and stand-alone battery storage configurations for the quick service restaurant are shown in Tables 12 and 13, respectively. All of the utility bill savings produced by the stand-alone battery system are derived from demand charge reductions. In contrast, for the coupled solar PV/battery storage system, 70 percent of the utility bill savings are related to demand reductions and 30 percent are related to energy reductions. Both demand charge savings and total utility bill savings are greater for the coupled solar PV/battery system than for the stand-alone battery storage system.

ANNUAL UTILITY BILL COMPARISON			
	Non-DER Base Case 2030	Solar PV/Battery 2030	Savings
Consumption Charge	$8,081.00	$6,960.00	$ 1,121.00
Demand Charge	$17,184.00	$ 13,507.00	$ 3,677.00
Demand Response	–	–	–
Fixed Rate	$164.00	$164.00	–
Minimum Rate	–	–	–
Taxes	–	–	–
Total	**$25,429.00**	**$20,631.00**	**$4,798.00**

Table 12. Utility bill comparisons for the quick service restaurant in DTE Energy's territory between the non-DER base case modeled in 2030 and a coupled solar PV/battery storage case modeled in 2030.

ANNUAL UTILITY BILL COMPARISON			
	NON-DER BASE CASE 2030	STAND-ALONE BATTERY 2030	SAVINGS
Consumption Charge	$8,081.00	$8,135.00	$(54.00)
Demand Charge	$17,184.00	$14,617.00	$2,567.00
Demand Response	–	–	–
Fixed Rate	$164.00	$164.00	–
Minimum Rate	–	–	–
Taxes	–	–	–
Total	**$25,429.00**	**$22,916.00**	**$2,513.00**

Table 13. Utility bill comparisons for the quick service restaurant in DTE Energy's territory between the non-DER base case modeled in 2030 and a stand-along battery storage case modeled in 2030.

Impact of TOU Rates

Modelling revealed a complex interplay between the magnitude of a commercial building's electric load, the load profile, and the availability of alternate rate structures. As is observed in practice, buildings with a peak electric load greater than 1000 kW always selected a primary voltage rate schedule as being the most economic. Those with a peak load between 100 kW and 1000 kW were allowed the choice in the HOMER Grid model between primary and secondary voltage rate schedules, whereas those buildings under 100 kW were modeled exclusively using secondary voltage rates.[306]

It was determined through the HOMER Grid modeling that load factor has a predominant influence on the utility pricing structure selected as economic for commercial BTM battery storage systems — either traditional flat rate, demand based or TOU rate structures. Commercial building load factor had a broad range between 26 and 68 percent for the 16 building types.

For buildings located in DTE Energy's territory, commercial buildings with a load factor of approximately 49 percent or greater always selected a demand-based rate schedule (either primary or secondary as appropriate). In contrast, commercial buildings with a load factor less than 49 percent generally selected a traditional flat rate-schedule, with two exceptions: (1) the large hotel and (2) the secondary school. These two buildings had high peak demand, but relatively low load-factors. Because DTE Electric does not yet offer a TOU primary rate-schedule, these building types with high peak demand are best served by choosing a demand-based primary rate.

For buildings located in Consumers Energy's territory, the results were more complex by virtue of the availability of both secondary and primary time-based rate schedules. In general, building types for which coupled solar PV/battery storage systems were selected also selected TOU rates if such rate structures were available. However, in some select cases (e.g., the large hotel with high peak load but a low load factor) still chose demand-based rates. Setting this exception aside, TOU rates are generally preferable because the time when on-site solar PV is generating the most electricity largely coincides with mid- and peak-period hours under TOU rate schedules, maximizing any credits and the coupling of solar PV with battery storage optimizes the availability of on-site generated solar energy for on-site use.

[306] 1000 kW was considered an approximate upper limit for secondary voltage interconnection, and 1/10 of that (100 kW) falls above any explicit peak demand minimums in either DTE Electric's or Consumers Energy Electric's primary rate-schedules available for commercial customers.

LCA: Behind-the-Meter Storage

LCA was used to calculate the reduction in the global warming potential (GWP), photochemical oxidation potential (PCOP), acidification potential (AP), and abiotic depletion potential (ADP) with the installation of solar plus storage systems for four commercial buildings in both Consumers Energy and DTE Energy territories (see Appendix C). These building types (quick-service restaurant, full-service restaurant, supermarket, and hospital) were selected because they have a wide range of peak and average electricity demand (see Figure 14). Additionally, these buildings differ considerably in occupancy per square meter of floor area, hours of operation per week, and building usage timings. Finally, out of the 16 building types analyzed using the HOMER model as described previously, these four buildings had the best or second-best net present cost associated with solar PV/battery storage systems for both utilities in 2020, 2025, and 2030.

The environmental impacts of installing a solar plus storage system for each utility were compared with the impacts of the baseline scenario (i.e., when no solar or storage systems were installed in the selected buildings). As shown in Figure 19, the GWP is always reduced compared to the baseline with the installation of solar PV/battery storage regardless of the reference year, building type or utility. These GWP benefits generally increase over time as the model predicts that higher capacity solar plus storage systems are installed.

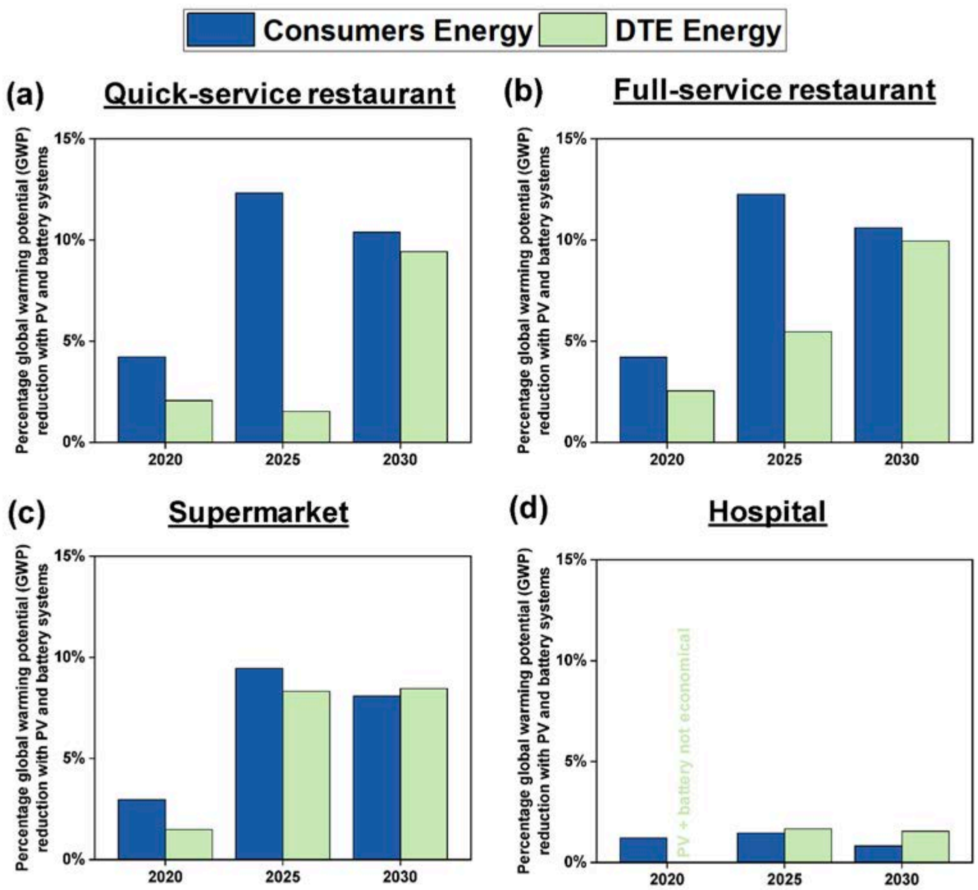

Figure 19. Percentage reduction in global warming potential (GWP) compared to baseline (no solar or storage system) when solar PV/battery storage systems were installed in the quick-service restaurant, full-service restaurant, supermarket, and hospital in Consumers Energy and DTE Energy territories in 2020, 2025 and 2030.

It is notable that the addition of solar PV/battery storage systems resulted in less than a 2 percent reduction in GWP compared to the baseline for hospitals. This is likely, as described above, because solar capacity was limited to 150 kW for any given building. Because hospitals have such high load requirements, the solar PV/battery storage systems were not able to significantly reduce grid purchases of electricity.

BULK SYSTEM MODELING

As a means of evaluating the current and future role of storage in the bulk power system, 5 Lakes Energy revised the State Tool for Electricity Planning (STEP) to provide a more sophisticated treatment of storage operations and capacity additions.[307] The updated version is referred to as STEP8760, reflecting that there are 8,760 hours in a typical year and that one of the changes necessary for storage modeling was to organize STEP8760 to represent a full year of hours in sequential order. STEP8760 is an open-access IRP tool in Microsoft Excel that can be provided free of charge. As with all such IRP tools, STEP8760 contains two major logical components. The annual production planning module calculates the optimal operation and associated costs to serve projected load given a fixed set of generation and demand reduction resources. The capacity additions module calculates the optimal addition of resources to meet demand given the way that existing and new resources would operate as described in the production planning module. In both modules, optimality is determined as the least-cost plan that satisfies all applicable constraints.

Although this modeling was conducted in a technology-neutral manner, it was not possible to fully capture emerging long-duration or multi-day storage resources. The costs of energy storage additions were determined based on a 4-hour duration proxy system. The nameplate capacity stated in MW is the maximum rate of discharge in a single hour and total energy available is assumed to be four times the nameplate capacity. For example, a 1,000 MW addition of battery storage would have a total capacity of 4,000 MWh. Storage resources may discharge at a rate less than nameplate capacity for greater than four hours but cannot exceed the maximum discharge rate in a given hour.

Methodology

The STEP8760 production planning module works as follows:

1. Hourly load for the entire year is constructed based on an historical hourly load profile with changes due to (potentially class and end-use specific) load changes.
2. Hourly hydropower, wind, and solar generation are projected for the entire year based on their historical production for the same year as the hourly historical load profile scaled from the historical capacity of these resources to the level assumed in the capacity plan. Solar resources are differentiated by major solar system configuration types, such as fixed tilt and single-axis tracking.
3. Hourly net load is computed as the difference between projected load and projected hydropower, wind, and solar generation. If hourly net load is negative, meaning that combined hydropower, wind, and solar generation exceed load, the amount of excess generation is considered curtailed but may be used to charge storage.
4. A dispatchable resource target is then computed for each hour as the sum of net load plus an operating reserve calculated as a percentage of gross load.
5. Fuel-based generation resources are ranked by their variable cost per MWh of generation. Variable costs include fuel, operations and maintenance that vary with use, and costs of emissions allowances and waste disposal. This ranking is commonly referred to as merit order. These resources are then calculated to be dispatched in merit order as far down the ranked list as is necessary to meet net load plus the operating reserve. The available capacity for dispatch is seasonal and reduced by the generation plant's expected failure or unavailability rate. The last plant in the list that is dispatched to meet load plus operating reserve margin is considered the marginal plant. The variable cost of operating the marginal plant is the marginal price of power, conceptually equivalent to the Locational Marginal Price (LMP) that is developed in wholesale power markets.
6. The marginal cost of power in a given hour is calculated as the sum of the LMP and the scarcity price.

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[307] A previous version of this model, the Michigan State Tool for Electricity Emissions Reduction (STEER) is available at: https://info.aee.net/steer-michigan.

7. Once the marginal cost of power is established for each hour based on the preliminary dispatch plan described above, the operations of available storage are calculated using a method called a model predictive controller. The model predictive controller calculates the optimum operation of storage for each hour in turn by looking forward a limited number of hours and calculating the best operation in the current hour based on that prediction of future operations. A similar calculation is then done for the next hour based on the storage operation in the previous hour and the optimum operation based on the same number of hours ahead. The model predictive controller recursively optimizes operations to a receding time horizon. This is a realistic depiction of operations for actual storage, where optimal operations depend on a forecast of future marginal costs of power that would be affected by things like weather. The model used a one-week time horizon, approximating the limits of usable weather forecasts.
8. Within the model predictive controller, the first decision in each hour was to charge, discharge, or do neither. Charging is the preferred decision if the storage is not currently fully charged, if the current price of power is low enough that there is a projected opportunity to profitably[308] discharge the charging power within the controller time horizon, and there is not opportunity to charge at an even lower cost before the profitable discharge opportunity. Discharging is the preferred decision if the storage is not currently empty and if similar logic says that it is profitable to discharge rather than wait. The amount of charging or discharging is limited by the lesser of the maximum power flow into or out of the storage system and the available energy storage capacity in the storage system.
9. Once the dispatch of storage was determined, energy used to charge storage was added to net load, energy discharged was subtracted from net load, and the generator dispatch process described above was applied to the resulting new load profile. Through this process, storage is used to reduce total operating costs of the power system by reducing the expected value of unserved energy[309] or the total variable cost of running generation plants.

The STEP8760 capacity planning module works as follows:

1. Planned resource retirements as determined by the model user are eliminated from use in the production planning process.
2. The production planning module is used to calculate the cost of serving projected load using the existing non-retired resources plus the value of unserved energy if the existing non-retired resources are insufficient to serve all projected load.
3. The levelized annual cost of ownership per unit of new capacity is calculated for the target year based on representative utility financial assumptions, tax policy, and project technology costs. Technology costs are selected by the user based on forecasts in the NREL ATB. For each technology that is considered, the economic value of incremental capacity is then calculated by recalculating the production planning module with the incremental capacity to determine if this lowers total system cost, including the cost of the new capacity, any changes in operating costs of the power system, and any changes in the expected value of unserved energy.
4. Incremental capacity is added as long as total cost of the power system, including the cost of unserved energy, is reduced by such additions. Incremental capacity additions may be wind, solar, battery storage, combined cycle natural gas, or combustion turbine.

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[308] Not all energy used to charge a battery energy storage system can be discharged back onto the grid. "Profitability," in this context, refers to a scenario in which the storage operator may discharge power at a market price high enough to overcome the losses incurred in a charge-discharge cycle. These energy losses are determined by the round trip efficiency (RTE) of the battery. To profitably charge and discharge the storage system, the market price of energy at the time of discharge must be equal to or greater than the market price of energy used for charging multiplied by 1/RTE. For example, if LMP is $25/MWh and RTE is 85%, a profitable market price to discharge while overcoming round-trip losses would be $25.00 * (1/0.85) = $29.40.

[309] The value of unserved energy is set to the MISO value ($3500) in the near-term scenario, ramping up to a price close to other RTOs' current value ($9000-$9500) in future scenarios. This reflects the fact that unserved load may be undervalued in MISO currently and will be more important in valuing reliability with higher penetration of RE. See https://cdn.misoenergy.org/20200910%20MSC%20Item%2005b%20RAN%20Value%20of%20Lost%20Load%20(IR071)472095.pdf and https://www.rtoinsider.com/articles/19750-miso-reevaluating-voll-as-monitor-pushes-10-000-mwh.

Based on the logic outlined above, STEP8760 will recommend additions of storage capacity if and only if the cost of capacity is covered by either improvements in resource adequacy as measured by reduced costs of unserved load or by the ability to save generation operating costs by running a plant that is cheaper to operate in order to charge the storage at a given time in order to discharge storage and avoid running a more expensive plant at another time.

The value of storage resources emerges in modeling analysis when time variation in power is fully represented (e.g., when storage charges from low-cost plants and discharges to displace high-cost plants.) IRP models that represent reasonably frequent charge-discharge cycles or high variation in hourly energy cost appropriately value energy storage. If it lacks these capabilities, an IRP model is unlikely to select high value storage resources.

Results

IRP Modeling

During initial testing of STEP8760, it was apparent that existing storage in Michigan at Ludington was predicted by STEP8760 to operate less than it actually economically operates. Examination of this behavior demonstrated that STEP8760 simulated less variation in the marginal cost of power than occurs in the actual wholesale market operated by MISO. A number of features were added to STEP8760 to increase the realism of its price variations. Although this was beneficial, as shown in Figure 20, the model nonetheless falls short of simulating the degree of price variation in the MISO market. In this example, additional storage would be economic in an IRP modelling scenario at 2025 storage costs if the actual market prices were used but would not be economic if the simulated prices were used.

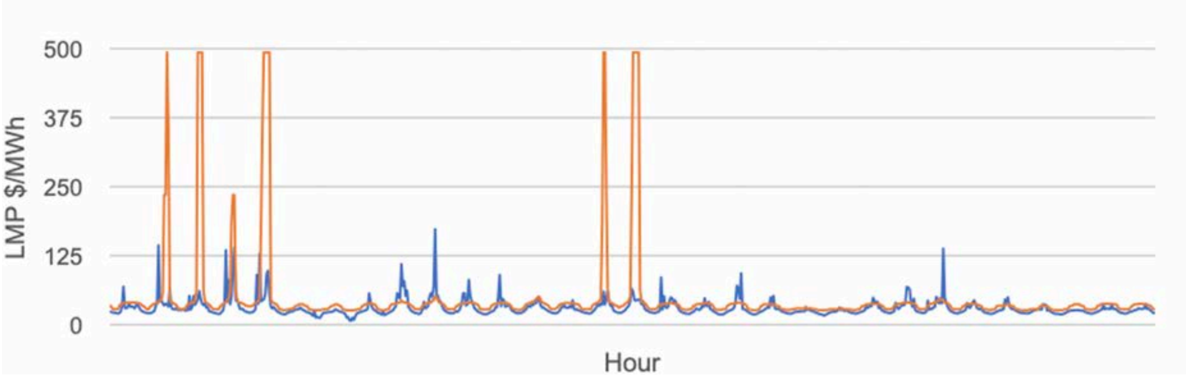

Figure 20. Graph of STEP8760 simulated (orange) and actual (blue) hourly LMP values for the month of June 2018.

Subsequent to our finding that STEP8760 does not provide sufficient price variation to match real-world conditions, several other researchers released similar findings. For example, Lawrence Berkeley National Laboratory (LBNL) released a paper showing that the Cambium model that they developed and use along with NREL has this same deficiency.[310] Because the researchers were unable to adequately adjust the Cambium model, they analyzed the effects of this problem on a variety of their projects. As shown in Figure 21, they illustrated the degree of mismatch between Cambium and actual markets, which is strikingly similar to the results from STEP8760 shown in Figure 20.

[310] Seel, J. and Mills, A. November 2021. "Integrating Cambium Marginal Costs into Electric-Sector Decisions." Lawrence Berkeley National Laboratory. Available at: https://eta-publications.lbl.gov/sites/default/files/berkeley_lab_2021.11-_integrating_cambium_prices_into_electric-sector_decisions.pdf.

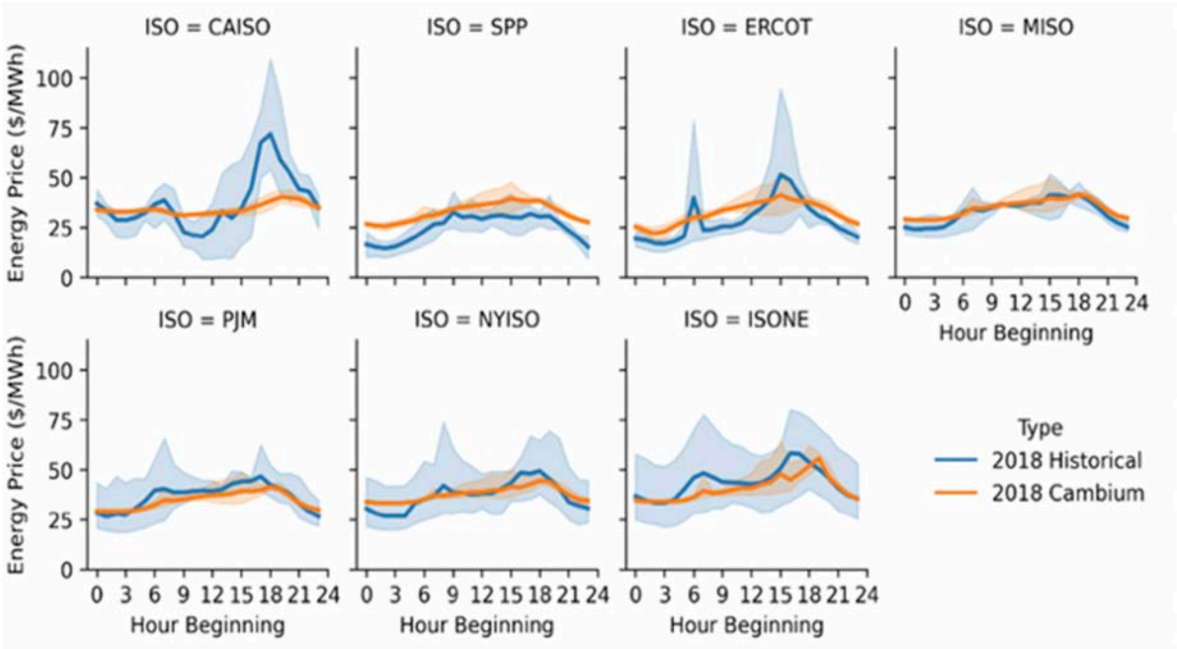

Figure 21. Figure 3-E from Seel and Mills, 2021.[311] Blue lines shows actual 2018 energy prices and orange lines show modeled energy prices for seven RTOs. The shaded areas around the blue and orange lines represent the seasonal range of average price profiles.

Researchers from LBNL and Pacific Northwest National Laboratory (PNNL) presented similar results to the fall 2021 conference of the National Association of Regulatory Utility Commissioners. They found that simplifying planning assumptions such as hourly planning resolution and the substitution of reserve margins for ancillary services "cause the flexibility and scalability benefits of energy storage to be undervalued."[312] The researchers also concluded that "there is no standard approach for modeling storage in IRPs, and storage is not fully integrated into the models that utilities currently use. More accurate inputs (e.g., up to date costs and forecasts) and improved modeling methods (e.g., assessing benefits for a wider range of grid services, incorporating behind-the-meter (BTM) applications) are needed to better integrate storage into planning processes."[313] We examined the analysis of storage in recent Michigan utility IRPs and found that they are typical in this regard.[314]

We conclude that IRP models systematically undervalue storage resources and that IRPs based on these models systematically select less storage than is actually optimal. Based on the STEP8760 modeling effort, these deficiencies in IRP models are primarily due to (1) the deterministic nature of these models which fail to capture the effects of unpredicted random changes in demand and in generation plant outages and outputs and (2) the loss of intra-hour detail in IRP models as compared to markets. Additional research is needed to develop abstractions of storage performance that will be tractable in an IRP model but also accurately represent the value of storage. The most likely approaches that would be tractable in IRP modeling will (1) incorporate the value of ancillary services and other values that are not well modeled in IRP modeling by reducing the net cost of storage resources in the IRP models to reflect those values (called

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[311] *Ibid*.

[312] Miller, C., Twitchell, J. and Schwartz, L. October 12, 2021. "State of the Art Practices for Modeling Storage in Integrated Resource Planning." Innovations in Electricity Modeling: Training for National Council on Electricity Policy. Available at: https://pubs.naruc.org/pub/CCBEFC58-1866-DAAC-99FB-3A405315FB9B.

[313] *Ibid*.

[314] The relevant information is in confidential materials obtained through discovery in those cases and is therefore unavailable for detailed explanation in this report.

the net-cost-of capacity approach[315]) or (2) credit storage for contributions to resource adequacy based on constructs similar to effective load carrying capacity.

Scenarios

Notwithstanding the limitations of IRP models generally and as reflected in STEP8760, STEP8760 was applied to determine (the minimum) role of storage in Michigan's future power system. Because the limitations of IRP models systematically undervalue storage and therefore select too little of it, our results should be viewed as likely understating the role of storage in the future power system and therefore represent minimums. Additional scenarios and modeling results are provided in Appendix D. Here, we discuss the role of storage in a single scenario that is both within utility planning horizons and reasonably likely. Retired coal generation (including existing retirements and announced retirements) is assumed to be replaced by already approved gas plant construction and a combination of energy efficiency, demand response, and renewables. This scenario reflects the conditions necessary to comply with Governor Whitmer's Executive Directive 2020-10,[316] which set a goal of economy-wide carbon neutrality by 2050 and an interim goal of a 28 percent reduction in greenhouse gas emissions relative to 2005 by 2025. However, instead of achieving the requisite carbon emission reductions at the beginning of the 2030s as ordered by the Governor, the scenario reflects the current public plans of Michigan utilities to meet these targets by approximately 2040.

We evaluated the amount of storage needed over and above Ludington that minimizes total power system cost in Michigan under the assumption that all regulated coal generation is retired. As described in Consumers Energy's IRP proposal in MPSC Case No. U-21090, we assume that Palisades nuclear plant will retire in 2022, the Karn 1 & 2 coal plants and the Karn 3 & 4 peaking units will retire in 2023, and that the Campbell 1, 2, and 3 coal units will retire in 2025.[317] We further assume that the Midland Cogeneration Plant is retired in 2030 at the end of its current Power Purchase Agreement with Consumers Energy. We assume as described in DTE Electric's approved IRP in MPSC Case No. U-20471 that the St. Clair, River Rouge, and Trenton Channel coal plants will all be retired by 2023.[318] We also assume as DTE recently announced, that the Belle River coal units will retire before 2028.[319]

As proposed in Consumers Energy's IRP in Case No. U-21090, under this scenario we assume that the existing Covert gas plant will be added to the MISO market area in lower Michigan in 2023 (from PJM) and that several existing CMS Enterprises gas plants will continue to operate. We also assume that DTE Electric's Bluewater Energy Center gas plant will become operational in 2022.[320] In addition, we assume that the Lansing Board of Water and Light's Erickson coal plant will retire by 2025 and that the Delta Energy Center gas plant will be operational in 2022.[321] In addition to these announced retirements and additions,

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[315] Energy Storage Association. 2018. "Advanced Energy Storage in Integrated Resource Planning." Available at: https://energystorage.org/wp/wp-content/uploads/2019/09/esa_irp_primer_2018_final.pdf.

[316] Governor Gretchen Whitmer. September 23, 2020. Executive Directive 2020-10. Available at: https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-540278--,00.html.

[317] Application of Consumers Energy Company in Case No. U-21090. Filed June 30, 2021. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000Nib8YAAR.

[318] Application of DTE Electric Company in Case No. U-20471. Filed March 29, 2019. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000004PqO4AAK.

[319] Grzelewski, J. October 13, 2021. "DTE to retire coal use at Belle River Power Plant in 2028, two years earlier than planned." The Detroit News. Available at: https://www.detroitnews.com/story/business/2021/10/13/dte-retire-coal-use-belle-river-power-plant-2028/8424435002/.

[320] DTE. "Blue Water Energy Center Information Hub." Available at: https://empoweringmichigan.com/bluewater/.

[321] Lansing Board of Water and Light. 2021. "Financial Report with Additional Information." Available at: https://www.lbwl.com/sites/default/files/documents/2021-10/bwl-financial-statements-final-6-30-2021.pdf.

we assumed in this scenario that DTE Energy's Monroe coal-fired power plant will be retired.[322] Although the announced retirement date for the Monroe Power Plant is not later than 2040, we believe the economics of power supply are likely to lead to this facility retiring not later than the middle-2030s.

We assumed that all additional generation resources other than those described above will be wind or solar, which created a total of approximately 9,100 MW of wind and 19,800 MW of solar. We then used STEP8760 to optimize the amount of storage to minimize total power system cost, including the cost of unserved energy, the costs of fuel and other variable costs of gas plants, and the costs of new wind, solar, and storage costs.

In this scenario, in which renewables provide approximately 52 percent of electricity supplied to lower Michigan, the optimum amount of storage in addition to Ludington is about 4000 MW of 4-hour storage by the time that the Monroe Power Plant is retired (i.e., prior to 2040). Assuming that substantial development of new storage has time lags such that the earliest major development will be in 2025, this implies an average annual storage development of 250 MW to 300 MW per year. The generation mix predicted in this scenario is shown more comprehensively below in Figures 22 and 23.

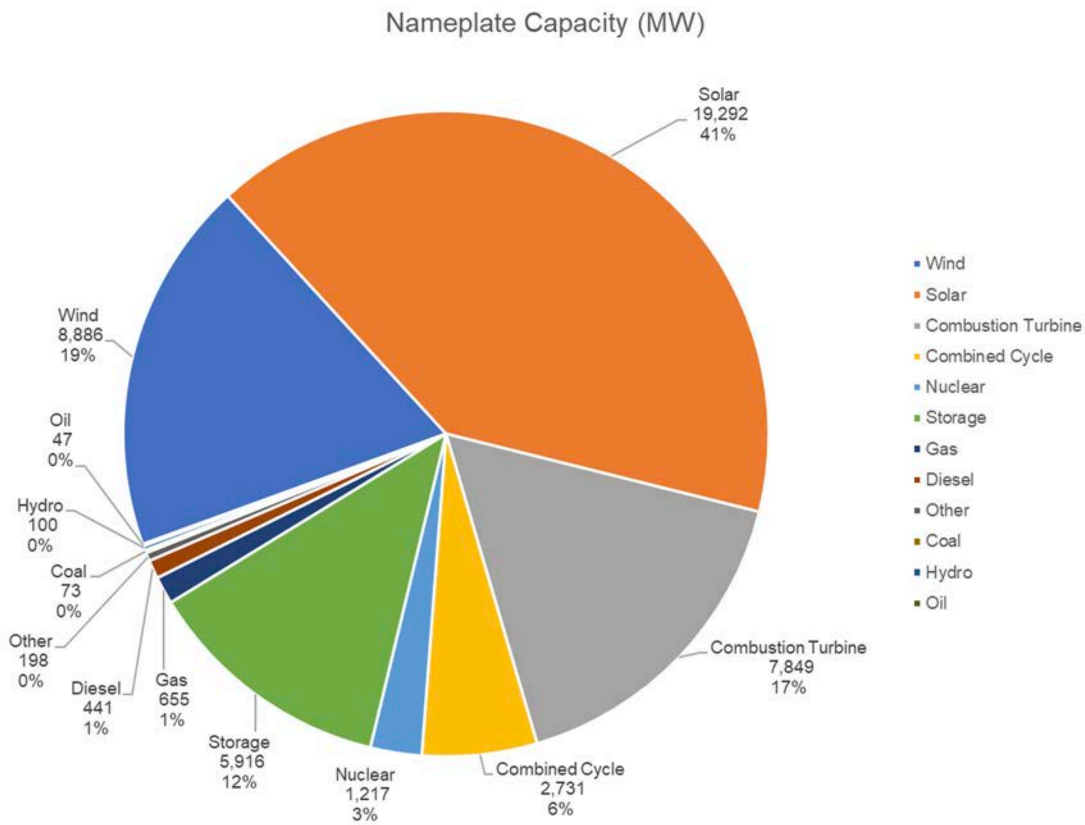

Figure 22. Nameplate capacity (MW) by generator type by 2040 under described scenario. Note that the nameplate capacity (1916 MW) of Ludington is included.

[322] Application of DTE Electric Company in Case No. U-20471. Filed March 29, 2019. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000004PqO4AAK.

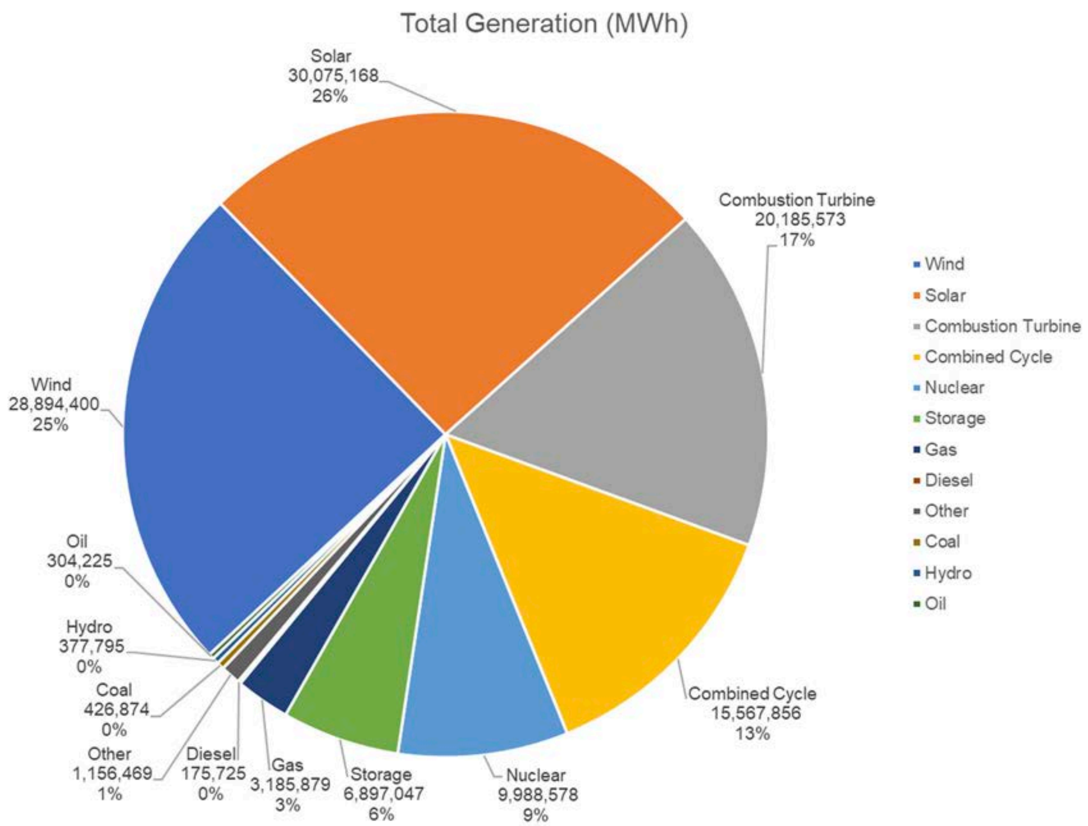

Figure 23. Total energy generation (MWh) by generator type by 2040 under described scenario. Note that the approximate total discharge energy (11,500 MWh) of Ludington is included.

With this generation mix, storage is fairly active. Figure 24 shows that storage is either charging or discharging during 6,971 hours or 80 percent of all hours annually. Figure 25 shows the total energy discharged onto the grid and the corresponding energy plus round trip losses needed to supply this energy. Thus, in the foreseeable future with significant use of renewable generation, storage plays a substantial role in providing reliability of power supply while making maximum use of the wind and solar generation that is available.

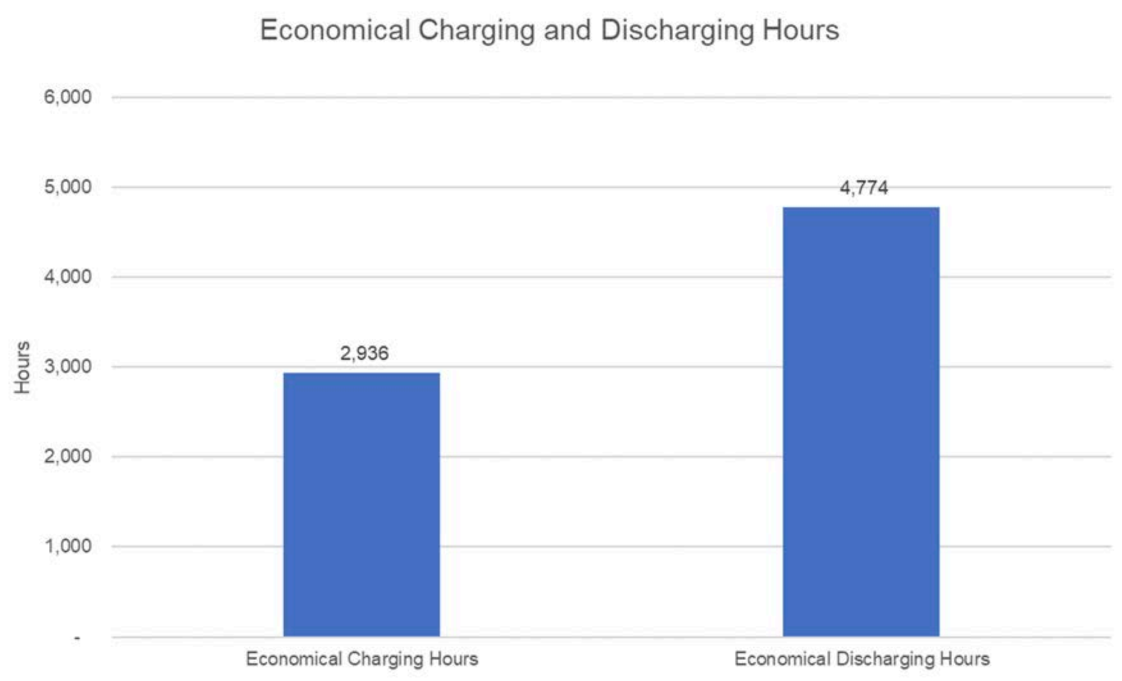

Figure 24. Number of hours for economical charging and discharging of storage under this scenario.

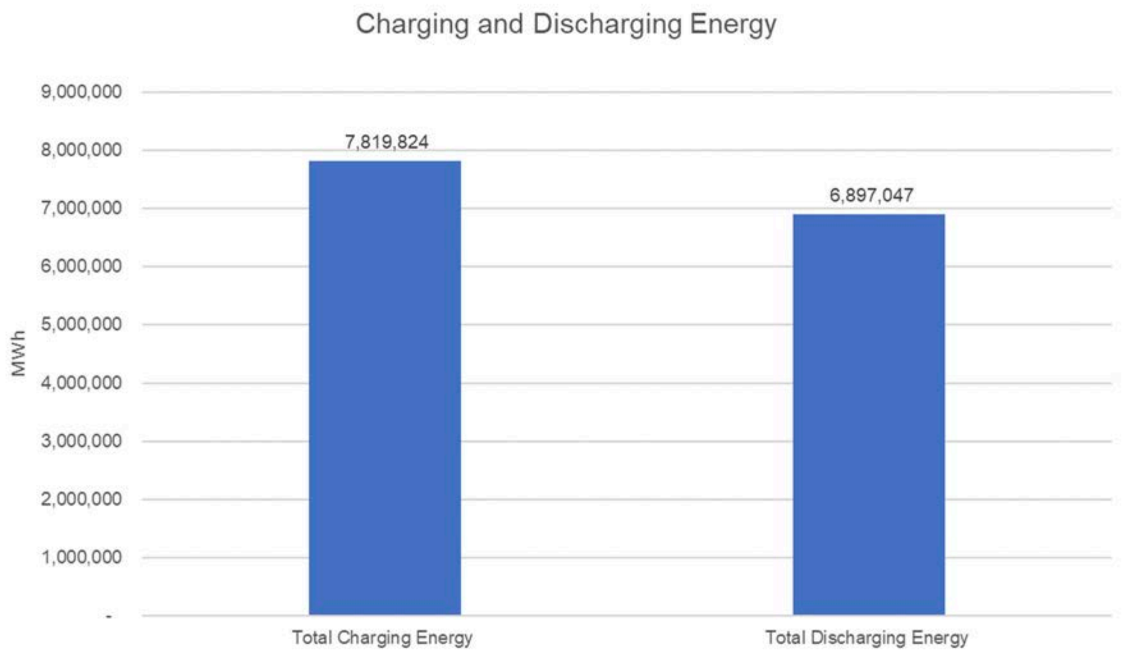

Figure 25. Total amount of energy (MWh) discharged and charged under this scenario.

LCA: Bulk Power System

Historically, some have expressed concerns that the addition of energy storage to the grid might lead to an increase in the life cycle impact of electricity production. This concern was driven by the common assumption that energy storage would be charged using the average mix of electricity on the grid and that the increase in carbon footprint would depend on the round trip efficiency of the energy storage system.[323] However, contrary to this assumption, the STEP8760 model data described in this Roadmap showed the opposite to be true. These data enabled an accurate comparison between the LCA impact estimated based on charging storage with average grid electricity and the more accurate LCA impact estimated based on charging storage using the actual hourly electricity data paired with storage charging/discharging data.

By combining the STEP8760 data with LCA, we were able to determine that the actual operation of FTM energy storage systems would result in lower GWP than storage charged with the average annual electricity on the grid (Figure 26 and Figure 27). For example, in 2030, the GWP of the average electric grid is 508 gCO_{2eq}/kWh, but the carbon footprint of the electricity used to charge energy storage is more than 20 percent lower (399 gCO_{2eq}/kWh). The electricity used to charge energy storage systems in 2040 and 2050 was more than 30 percent lower in carbon footprint than that of the average electricity grid (206 vs. 297 gCO_{2eq}/kWh in 2040 and 65 vs. 96 gCO_{2eq}/kWh in 2050).

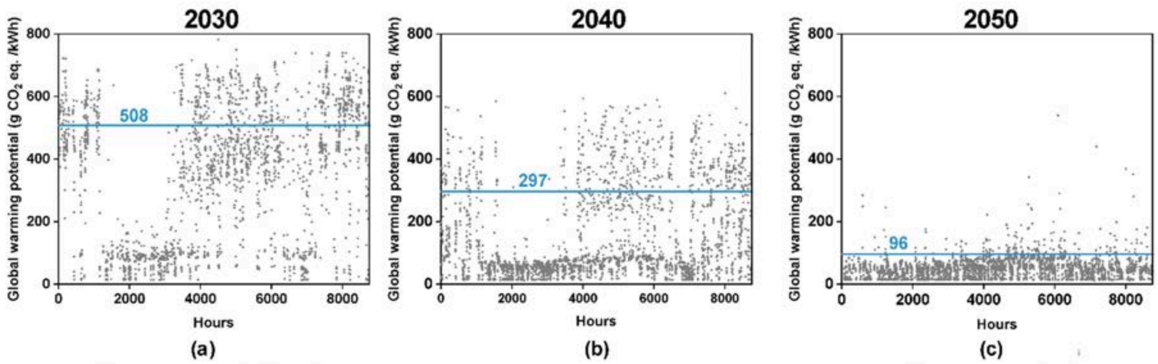

Figure 26. Carbon footprint of electricity used to charge energy storage system over a year period. The blue line indicates the average carbon footprint of the electric grid for that year and the individual points show the carbon footprint of the electricity used to charge energy storage systems for each charging event.

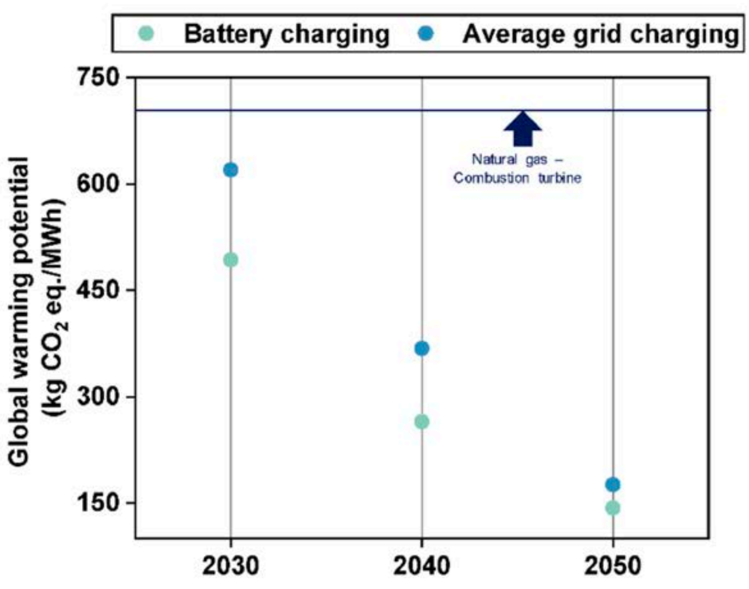

Figure 27. Life cycle carbon footprint of the average electric grid (dark blue dots) and of the electricity used to charge energy storage systems (light blue dots). The lifecycle carbon footprint for a natural gas combustion turbine is shown as a dark blue line for comparison.

[323] Kamath, D., et. al. 2020. "Evaluating the cost and carbon footprint of second-life electric vehicle batteries in residential and utility-level applications." Waste Management.

XI. Recommendations

It is important, as described throughout this Roadmap, to establish the proper policies to support deployment of energy storage systems to enhance grid reliability, integrate renewables, and support customer resiliency and equity among customers. This last consideration bears repeating: as decision makers consider establishing programs to incentivize the deployment of energy storage in Michigan, it is important to include consideration of and support for the state's most vulnerable populations. Energy storage is a tool that can be used to increase reliability and resilience for all customers, including those who have been historically least well-served by our electric system and experienced high numbers of outages.

It is also important, as stated previously, that the state approach policies to support energy storage from a technology neutral perspective. Although certain storage technologies may be a better fit for certain applications and the provision of certain services, state-level policies should not dictate preferred technologies and instead should allow the market to determine the best solutions for each given situation.

Although enabling future storage deployment will require actions at the federal and regional level, the recommendations described in this Roadmap focus primarily on actions that can be taken by the State of Michigan to complement federal and regional activities. No matter the speed with which the RTOs implement FERC Orders 841 and 2222, or the manner in which those orders are implemented, Michigan can take a number of steps to support the critical energy storage deployment that the state needs.

The recommendations in this section are organized both by timeline – immediate actions, short-term actions (1 to 5 years), and long-term actions (>5 years) – and by potential venue of change (i.e., executive, regulatory, legislative). It is important to note, however, that many of these recommendations could be accomplished through actions taken by multiple branches of government working in parallel and, as such, are listed more than once.

IMMEDIATE ACTIONS

Executive

Establish a target to deploy 4,000 MW of FTM storage by 2040, with a short-term target of 1,000 MW of FTM storage by 2025 and a medium-term target of 2,500 MW of FTM storage by 2030.[324]

- *Venue of change*: The Executive Office of the Governor or Michigan Legislature; with implementation by Michigan Public Service Commission
- *Background*: One of the most important policies that a state can adopt to actively support storage development is a requirement that a set amount of capacity be from storage resources (i.e., a storage target). Such a target should be established by the Governor through executive directive or by the Michigan Legislature through statute, with implementation coordinated by the MPSC. Based on the bulk system modeling conducted for this Roadmap, we estimate that Michigan will need a minimum of 4,000 MW of energy storage deployed by 2040 and 2,500 MW deployed by 2030 to ensure effective and cost-efficient integration of renewable resources as outlined in utility IRPs. In the near-term (before 2025), it will be valuable for the MPSC and Michigan's utilities to

[324] As described in Section X, the costs of energy storage additions were determined based on a 4-hour duration proxy system. The nameplate capacity stated in MW is the maximum rate of discharge in a single hour and total energy available is assumed to be four times the nameplate capacity. For example, a 4,000 MW addition of battery storage would have a total capacity of 16,000 MWh. Storage resources may discharge at a rate less than nameplate capacity for greater than four hours but cannot exceed the maximum discharge rate in a given hour.

gain additional experience with energy storage projects – both utility-owned and those owned by third parties. According to ESA, an appropriate short-term target would be 3 to 7 percent of peak demand within 2 to 3 years.[325] Based on current peak loads, this would equate to 330 MW to 770 MW for DTE Energy and 230 MW to 530 MW for Consumers Energy.[326] Given the need to begin installing storage and gaining learnings by doing so, it is reasonable to set a short-term target of 1,000 MW of storage by 2025.

- *Considerations*: It will be important when establishing these targets to identify accountable parties to report on progress (e.g., utilities, the MPSC, third-party developers, and transmission companies). In addition, as described further below, it will be critical to establish incentive programs and utility programs that support progress toward the target. The established energy storage target should aim to deploy a diversity of project sizes, types, and business models, including third-party ownership, to create a state storage market that provides the widest range of benefits. To that end, policymakers could consider providing a carve-out for long-duration (8+ hour dispatch) and/or multi-day (24+ hour dispatch) storage solutions, which provide additional benefits beyond existing short-duration storage systems.
- *Recommendations*: The Michigan Legislature should pass a law or Governor Whitmer should issue an executive order establishing a target to deploy 4,000 MW of FTM storage by 2040, with a short-term target of 1,000 MW of FTM storage by 2025 and a medium-term target of 2,500 MW of FTM storage by 2030. The MPSC should be charged with implementing this target, ensuring that Michigan's utilities are working with third-party developers to cost-effectively deploy storage on the grid where it is most effective and working with MISO to ensure that transmission-connected storage can effectively be deployed in Michigan.

Conduct a "value of storage" study to quantify the benefits that storage can provide.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy or Michigan Public Service Commission
- *Background*: Massachusetts conducted a value of storage study and found that the biggest challenge to achieving more storage deployment was the "lack of clear market mechanisms to transfer some portion of the system benefits created (e.g., cost savings to ratepayers) to the storage project developer."[327] Quantifying the value a storage resource can provide to customers and the grid enables the determined values to be used in developing innovative rate designs that offer credits to customers for the value of storage, even under a traditional cost of service paradigm, as well as appropriate compensation to third-party developers.[328]
- *Considerations*: The study should examine both the value a storage owner or developer can monetize through existing market mechanisms and the system benefits that accrue to Michigan's ratepayers through the deployment of storage, including resilience and locational values. This will require defining resilience, including from an individual customer's perspective and a grid planning perspective. Such a study should also include the location-specific and resilience value that storage can provide. Critical to such an effort is appropriately defining the grid need in Michigan, particularly by identifying past and potential future extreme weather or low renewable events.
- *Recommendation*: The MPSC should hire a third-party expert to conduct a value of storage study

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[325] Energy Storage Association. 2021. "Policy Position on State-level Energy Storage Target Design." Available at: https://energystorage.org/wp/wp-content/uploads/2021/02/Final-Policy-Position-on-State-Level-Energy-Storage-Target-Design_clean-and-uploaded-3.pdf.

[326] Energy Information Administration. Annual Electric Power Industry Report, Form EIA-861. 2020. Available at: https://www.eia.gov/electricity/data/eia861/.

[327] Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center. 2016. "State of Charge: Massachusetts Energy Storage Initiative Study." Available at: https://www.mass.gov/doc/state-of-charge-report/download.

[328] *Ibid*.

examining both the values a storage owner or developer can monetize through existing market mechanisms and the system benefits that accrue to Michigan's ratepayers through the deployment of storage. Such a study should include the location-specific and resilience value that storage can provide.

Conduct an economic gap analysis to quantify appropriate grant and rebate levels for residential and C&I customers.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy
- *Background*: To establish grant and rebate programs that will effectively enable residential and C&I customers to install energy storage systems, it is first necessary to determine what level of funding would most effectively enable increased deployment of storage while still allowing for the greatest possible number of recipients. It is important that incentives are large enough to make it possible for new adopters to deploy storage but small enough to enable sufficient access to the program. It is also important to consider through this analysis the appropriate level of incentives for low-income customers to ensure that any program carve-outs for those customers are effective. The appropriate funding levels could be determined through an economic gap analysis designed to understand the economics and currently monetizable services.
- *Considerations*: Grants and rebates should be set at a level to fill the gap between currently existing monetizable revenue streams and the total cost of the energy storage system with the caveat that incentives will likely need to be larger than this gap for low-income customers. An incentive that is too small will not increase storage deployment beyond the level that would already occur and an incentive that is unnecessarily large will limit the number of customers who can participate. According to ESA, an incentive gap analysis should account "for the state-specific average all-in installed costs and available revenue streams, rather than capping the incentive as a percent of project cost."[329]
- *Recommendation*: The Department of Environment, Great Lakes, and Energy should conduct an economic gap analysis to determine the appropriate level of funding for grants and rebates to effectively encourage deployment of energy storage by residential and C&I customers.

"Lead by example" by committing to install BTM storage at state buildings.

- *Venue of change*: Michigan Department of Technology, Management, and Budget; and Michigan Department of Environment, Great Lakes, and Energy; and Executive Office of the Governor
- *Background*: The Michigan Department of Technology, Management, and Budget currently manages over 6.7 million square feet of facility space,[330] meaning that there is ample opportunity for state government and state-managed buildings to commit to BTM storage. Making a state commitment to using storage in state buildings not only will benefit the state's economy and improve the resilience of state government, but also, it will be an opportunity for the state to lead by example for other building owners in Michigan. Additionally, when paired with BTM solar, storage then can provide state buildings with reduced energy costs and even greater reliability and resilience for the important work that government workers need to complete.
- *Considerations*: This recommendation may necessitate additional funding allocations of federal or state resources to enable the appropriate building upgrades, and therefore may need the support of the Legislature.

[329] Energy Storage Association. February 2019. "Energy Storage Incentive Programs." Available at: https://energystorage.org/wp/wp-content/uploads/2019/09/Incentive-Report_v7.pdf.

[330] Michigan Department of Technology, Management, and Budget. "State Facilities." Available at: https://www.michigan.gov/dtmb/0,5552,7-358-82551---,00.html.

- *Recommendations*: The administration should work together to set a BTM storage goal for state-operated buildings and consider pairing storage with solar for greater cost-reductions and resilience.

Conduct public education on storage through Catalyst Communities or other similar programs.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy
- *Background*: EGLE created the Catalyst Communities program to provide education, training, planning and technical resources to local public officials to help those officials prepare for the impacts of climate change on emergency response and public health.[331] The Catalyst Communities program includes resources, webinars, action plans, and examples from other communities related to energy demand management, renewable energy, and water. It represents an established program at EGLE and an effective line of communication with local communities across Michigan. Given that many local communities and public officials do not yet understand the value of energy storage, how to establish zoning requirements for energy storage, or how to enable residents to deploy energy storage, it would be valuable to provide educational opportunities on these topics through the Catalyst Communities program.
- *Considerations*: Given the complex nature of these topics and the breadth of issues that could be covered, it will be necessary to first identify what questions local communities most need answered prior to developing educational materials.
- *Recommendations*: The Office of Climate and Energy at EGLE should expand the Catalyst Communities program to provide education, training, and technical assistance to local officials and communities on both FTM and BTM energy storage systems.

Amend Michigan's Uniform Energy Code and Residential Construction Code to include storage readiness requirements for new buildings and homes.

- *Venue of change*: Michigan Department of Licensing and Regulatory Affairs
- *Background*: Michigan is currently in the process of updating its residential and commercial building codes, and there are opportunities to advance both residential and C&I access to energy storage by requiring energy storage readiness in new buildings. A building or home is considered "storage ready" if, at the time of construction or during extensive building upgrades, the building is ready to install energy storage without the need for a retrofit. An energy storage ready code requires commercial buildings to have the physical space, panel space, and equipment for a future energy storage system.
- *Considerations*: Storage readiness at the time of construction gives businesses and residents the option of installing energy storage systems in the future more easily and more cost-effectively. Storage readiness requirements will help to ensure homeowners and businesses are better equipped to improve their own reliability and resilience while keeping retrofit costs down as storage prices continue to decline. Although building for energy storage readiness does increase the cost of construction incrementally, these costs are much less than any retrofit costs that would be incurred in the future.
- *Recommendations*: The Michigan Department of Licensing and Regulatory Affairs and the Michigan Construction Code Commission should include amendments to the 2021 International Energy Conservation Code that require energy storage readiness in homes and commercial/multi-family buildings in the final revised codes.

[331] Michigan Department of Environment, Great Lakes, and Energy. Office of Climate and Energy. "Catalyst Communities." Available at: https://www.michigan.gov/climateandenergy/0,4580,7-364-98206_102852---,00.html.

Conduct a study to determine how best to increase the number of qualified personnel in the energy storage workforce.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy; and Michigan Department of Labor and Economic Opportunity
- *Background*: The 2021 Clean Jobs Midwest report identified workforce training as a key policy need in order to continue rebounding job growth in Michigan's clean energy industry.[332] As described previously, the energy storage and mobility industries are complementary. Given the importance of these industries and the automotive supply chain in Michigan, it is critical that the state has adequate training programs to ensure that Michigan workers are able to fill the mobility and storage jobs of the future. It is important, therefore, to determine how best to train workers in the production, installation, and maintenance of mobile and stationary energy storage systems. Further data is needed to determine how best to include storage technology in the training programs that already exist in the state, such as those that the Michigan Department of Environment, Great Lakes, and Energy and the Michigan Department of Labor and Economic Opportunity administer.
- *Considerations*: The federal government is investing in training workers at this nexus between electrified transportation and energy storage. For example, the U.S. Department of Energy recently partnered with Youngstown State University and Oak Ridge National Laboratory on a $1 million project to develop an Energy Storage Workforce Innovation Center to serve as a training center for the Midwest.[333]
- *Recommendations*: To better understand the scope of the workforce needs for both the advanced energy industry as a whole and the needs of the energy storage industry, the state should conduct a study to determine how best to improve existing workforce programs and deploy new programs.

Provide financing for energy storage through Michigan's revolving loan fund for energy efficiency and renewable energy established via Public Act 242 of 2009.

- *Venue of change*: Michigan Department of Environment, Great Lakes and Energy
- *Background*: Public Act 242 of 2009[334] established an energy efficiency and renewable energy revolving loan fund. Although energy storage is not explicitly included, the fund likely can be used to support storage that is paired with solar PV systems. The fund is administered by EGLE and housed in the Michigan Department of Treasury. The fund is able to receive monies from any sources, though it was originally established with the intention to channel federal funding from the American Recovery and Reinvestment Act and could likely be used as a similar vehicle for future federal funding made available to the State of Michigan.
- *Considerations*: For standalone storage or storage paired with solar, the revolving loan fund may likely be used for both FTM and BTM projects at the discretion of EGLE. In addition to expanding eligibility, clear guidance should be provided to stakeholders, including applicants wishing to pursue deployment of energy storage.
- *Recommendations*: EGLE should expressly expand eligibility for the energy efficiency and renewable energy revolving loan fund to include energy storage systems and provide clear application guidance to stakeholders.

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[332] Clean Jobs Midwest. 2021. "After a Rough Year, Clean Energy Jobs on the Upswing in Michigan." Available at: https://www.cleanjobsmidwest.com/state/michigan.

[333] U.S. Department of Energy. January 20, 2021. "Department of Energy Partners with Youngstown State University and Oak Ridge National Laboratory to Support Battery Manufacturing Workforce." Available at: https://www.energy.gov/articles/department-energy-partners-youngstown-state-university-and-oak-ridge-national-laboratory.

[334] Public Act 242 of 2009. January 8, 2010. Available at: https://www.legislature.mi.gov/(S(phzl3yax51qgr5d2q0xqwz4r))/documents/mcl/pdf/mcl-Act-242-of-2009.pdf.

Regulatory

Conduct a "value of storage" study to quantify the benefits that storage can provide.

See "Executive" recommendations above for details.

Require utility IRPs to include an accurate evaluation of opportunities for storage resources and, at a minimum, meet any established storage target.

- *Venue of change*: Michigan Public Service Commission or Michigan Legislature
- *Background*: A utility's IRP reflects its proposed plan for meeting forecasted demand through the use of supply-side and demand-side resources. When developing plans for future resource options, utilities should be required to meaningfully evaluate the full value of energy storage as a potential resource, both on the supply side and the demand side. However, as detailed in Section X, current IRP modeling practices fail to adequately or accurately model value of storage to decrease system costs. Specifically, these deficiencies in IRP models are primarily due to (1) the deterministic nature of these models which fail to capture the effects of unpredicted random changes in demand and in generation plant outages and outputs and (2) the loss of intra-hour detail in IRP models as compared to markets.
- *Considerations*: If, as recommended above, the Governor, the Legislature, or the MPSC establishes a storage target, the appropriate level of storage for each utility should be assumed as a baseline condition in utility IRP modeling. In addition, it is important that IRP modeling improves to utilize hourly and sub-hourly modeling and considers atypical weather events. This modeling should also consider both accurate energy arbitrage values as well as ancillary service values. If accurate modeling of storage is not possible given current model limitations, storage benefits can be incorporated into IRPs using a net-cost-of-capacity approach.[335] Under this method, operational benefits of storage that are difficult to represent accurately within the IRP model (e.g., the value of real-time energy arbitrage or ancillary services) can be estimated using a separate analysis outside the IRP model. Then, the estimated revenues generated by the storage project from those services can be credited to storage within the IRP model as a reduction in the installed cost of storage. This has the effect of more accurately making storage a more economic option for the IRP model to select by ensuring that the benefits storage that can provide are accounted for. In the long term, as IRP models evolve to better represent the value of energy storage and other emerging resources, utilities should be prepared to incorporate novel modeling techniques in each subsequent IRP.
- *Recommendations*: The Commission or the Michigan Legislature should require utility IRPs to include any established energy storage targets as a baseline and accurately model energy storage resources.

Require competitive energy storage procurements that provide a level playing field for third-party ownership models.

- *Venue of change*: Michigan Public Service Commission or Michigan Legislature
- *Background*: Energy storage is a unique asset class that has characteristics of distribution and transmission as well as generation. This has led to a diversity of ownership models in both restructured and vertically integrated states such as Michigan. In Michigan, Public Act 295 of 2008 included a provision commonly referred to as the "50/50 split,"[336] which required utilities to purchase a minimum of 50 percent of the renewable energy required to meet the Renewable Portfolio Standard from third-party developers using PPAs. The remaining 50 percent could be met

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[335] Energy Storage Association. 2018. "Advanced Energy Storage in Integrated Resource Planning." Available at: https://energystorage.org/wp/wp-content/uploads/2019/09/esa_irp_primer_2018_final.pdf.

[336] Public Act 295 of 2008. October 6, 2008. Available at: https://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0295.pdf.

using utility-owned resources. This provision was removed with the passage of Public Act 342 in 2016. Subsequently, the essence of this provision has been included in MPSC Orders, including a settlement of the 2018 Consumers IRP case (U-20165).[337] In the case of renewable generators, third-party ownership models have been shown to reduce costs for ratepayers[338] and similar trends likely exist for energy storage projects.

- *Considerations*: The MPSC established guidelines for competitive procurements in 2021 through Case No. U-20852.[339] These should be followed for any future storage competitive procurements, including those involving both utility-owned proposals and third-party owned proposals.
- *Recommendations*: As described above, through the IRP process, utilities should procure energy storage resources on a schedule that would achieve interim and long-term energy storage targets. The MPSC or the Legislature should require a percentage of those storage resources to be owned by non-utility third parties.

Support wholesale market opportunities for energy storage through implementation activities related to FERC Orders 841 and 2222.

- *Venue of change*: Michigan Public Service Commission
- *Background*: State utility regulators can influence the ease or burden with which distributed energy resources, like storage, are able to access the wholesale market. FERC Orders 841 and 2222 both contain provisions that recognize the role of states in the access of storage and other distributed energy resources to the wholesale market. In Order 841, FERC notes state's responsibility to, "among other things, retail services and matters related to the distribution system, including design, operations, power quality, reliability, and system costs."[340] Further, in Order 2222, states' roles, "may include, but are not limited to: developing interconnection agreements and rules; developing local rules to ensure distribution system safety and reliability, data sharing, and/or metering and telemetry requirements; overseeing distribution utility review of distributed energy resource participation in aggregations; establishing rules for multi-use applications; and resolving disputes between distributed energy resource aggregators and distribution utilities over issues such as access to individual distributed energy resource data."[341] In addition, state regulators play an important role at the RTOs by providing input and supporting the development of RTO policies that will enable storage deployment.
- *Considerations*: States and regulated utilities have a responsibility to maintain reliability and ensure fair distribution of costs among resources and customers. This can be approached in a way that focuses on the services provided by storage or it can be done in a way that makes it difficult technically and financially for those resources to provide value to both wholesale markets and retail services.
- *Recommendations*: (1) The MPSC should provide input in ongoing stakeholder activities at MISO that support maximizing the opportunities for FTM and BTM storage resources to provide all services possible and be compensated for their associated values; (2) the MPSC should focus

[337] Michigan Public Service Commission. Order in Case No. U-20165. June 7, 2019. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000005HSSrAAO.

[338] Michigan Public Service Commission. February 15, 2017. "Report on the Implementation and Cost Effectiveness of the PA 295 Renewable Energy Standard." Available at: https://www.michigan.gov/documents/lara/MPSC_PA295_Renewable_Energy_Report_Feb_2017_554530_7.pdf.

[339] Michigan Public Service Commission. September 9, 2021. Order in Case No. U-20852. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000TTDJAAA5.

[340] Federal Energy Regulatory Commission. February 15, 2018. Order No. 841. "Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators." Available at: https://ferc.gov/sites/default/files/2020-06/Order-841.pdf. p. 36.

[341] Federal Energy Regulatory Commission. September 17, 2020. Order No. 2222. "Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators." Available at: https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf. p. 324.

on realizing the appropriate value for storage through targeted stakeholder processes related to implementation of Orders 841 and 2222;[342] and (3) the MPSC should not maintain barriers to the participation of storage in wholesale or retail markets, including by removing the current prohibition on dual participation established in Case No. U-21032, while ensuring that provided services are not double-counted.[343]

Ensure state interconnection standards and utility procedures allow smooth integration of storage.

- *Venue of change*: Michigan Public Service Commission
- *Background*: In November 2018, the state began a process to update its interconnection rules in response to FERC Orders 792 (2013) and 792-A (2014). After a lengthy stakeholder process, the draft rules were sent to the Michigan Office of Administrative Hearings and Rules (MOAHR) in September of 2020 and regulatory impact statements were approved in July of 2021.[344] The draft standards were released in August of 2021 and were subject to public comments. The August 2021 draft rules include a definition of storage, the ability to add energy storage to a solar PV system without impacting the 10-year net metering grandfathering period and clarity that export of electricity from storage devices can be limited effectively. However, the draft rules leave discretion to the utilities to determine how exactly to allow for and study BTM storage with appropriate limited export controls and FTM storage with realistic operational characteristics (e.g., charging when excess power is available, not at peak load).
- *Considerations*: Ideally, the state interconnection standards would explicitly establish standards for the utilities to follow with respect to the study and interconnection of storage resources such as those outlined in the 2019 Model Interconnection Procedures established by the Interstate Renewable Energy Council (IREC).[345] If that is not possible, it is critical that these standards be established in utility procedures.
- *Recommendations*: The MPSC should update the state's interconnection standards to include specific rules for the study and interconnection of limited-export BTM storage systems and FTM storage systems using realistic operational characteristics. If not included in the state's interconnection standards, the MPSC should require the utilities to include specific rules for the study and interconnection of limited-export systems and realistic operation of storage systems in utility procedures.

Require Michigan's utilities to file on-bill financing pilot programs for which residential and C&I energy storage systems are eligible.

- *Venue of change*: Michigan Public Service Commission
- *Background*: On-bill financing or on-bill repayment programs have the ability to unlock financing for residential and C&I energy projects located BTM by providing more favorable rates and terms for borrowers. There are two types of on-bill financing or repayment programs: on-bill loans, which are funded by a third-party and on-tariff payments, which are funded by the utility. On-bill financing

[342] Michigan Public Service Commission. Case No. U-21032. Available at: https://mi-psc.force.com/s/case/500t000000j0epIAAQ/in-the-matter-on-the-commissions-own-motion-to-request-comments-on-midcontinent-independent-system-operator-incs-implementation-of-federal-energy-regulatory-commission-order-no-841-regarding-energy-storage-resources.

[343] Michigan Public Service Commission. August 11, 2021. Order U-21032. Available at: https://mi-psc.force.com/s/case/500t000000j0epIAAQ/in-the-matter-on-the-commissions-own-motion-to-request-comments-on-midcontinent-independent-system-operator-incs-implementation-of-federal-energy-regulatory-commission-order-no-841-regarding-energy-storage-resources.

[344] Michigan Public Service Commission. September 9, 2021. Order in Case No. 20890. Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000TTCvjAAH.

[345] Interstate Renewable Energy Council. 2019. "Model Interconnection Procedures." Available at: https://irecusa.org/resources/irec-model-interconnection-procedures-2019/.

is enabled in Michigan for investor-owned utilities under Public Act 295 of 2008[346] as amended by Public Act 342 of 2016.[347] On-bill loan pilots have been explored, but have not developed into broader programs in Michigan, with a lack of customer interest and billing system upgrade costs being cited as the reasons. In Michigan, as contemplated in Michigan law, on-bill financing can be provided by the investor-owned utility or by a third-party financier that is simply using the utility billing mechanism for repayment and added security. As part of the MPSC's MI Power Grid process, Commission staff recommended the pursuit of pilot programs for on-tariff payment programs.[348]

- *Considerations*: Any on-tariff repayment or on-bill financing pilot program should be proposed and considered as part of a contested utility rate case. BTM energy storage projects should qualify for these programs as long as the projects are considered a utility cost-savings measure or can be proven to save energy.
- *Recommendations*: The MPSC should require or encourage Michigan's investor-owned utilities to file on-bill financing pilot programs in any rate cases filed after April 1, 2022. These pilot programs should leverage third-party resources to provide on-bill loan options. To ensure that energy storage can qualify for the on-bill financing programs under existing law, the Commission should deem BTM energy storage a "utility cost-savings measure" as long as the BTM system can show savings, including avoided costs in the case of power outages or avoided costs of electricity supply disruptions.

Require Michigan's utilities to provide publicly available hosting capacity maps that that provide sufficient detail to allow storage developers to identify the need for flexible generation or distribution alternatives.

- *Venue of change*: Michigan Public Service Commission or Michigan Legislature
- *Background:* With a changing electric grid with more distributed energy resources and EVs, understanding grid capabilities and constraints can allow for appropriate investments and innovative solutions to increase grid reliability and customer resiliency and save ratepayers money. At the same time, energy storage and the varied services that it can provide have largely not been considered in utility planning processes and are difficult to model. To accommodate these needs and to identify places where the grid is constrained and what solutions best fit those constraints, an increasing number of states are developing comprehensive hosting capacity analyses, with the results often provided in the form of a publicly available hosting capacity map. According to IREC, "Hosting Capacity Analyses are an analytical tool that can help states and utilities plan for and build a cleaner electric grid that optimizes customer-driven distributed energy resources (DERs), such as rooftop solar, energy storage, or electric vehicle charging stations."[349] Such maps provide a "snapshot" of the distribution grid's ability to host additional distributed energy resources at a specific location across a utility's service territory. For energy storage, hosting capacity maps can help to identify where storage can more easily be added to the distribution grid and where there are constraints that energy storage may be able to relieve. Hosting capacity analysis and associated maps can uncover where energy storage will provide needed benefits in a cost-effective manner. For example, for a C&I customer, a hosting capacity analysis could help determine whether or not expensive distribution upgrades would be needed to enable the installation of a BTM solar plus storage

[346] Public Act 295 of 2008. October 6, 2008. Available at: http://www.legislature.mi.gov/(S(cpljvadawerqjxytmbwbh54k))/mileg.aspx?page=getobject&objectName=mcl-Act-295-of-2008.

[347] Public Act 342 of 2016. December 21, 2016. Available at: https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf.

[348] Michigan Public Service Commission Staff. December 1, 2021. "New Technologies, Business Models, and Staff Recommendations." Available at: https://www.michigan.gov/documents/mpsc/MPG_New_Technologies_Business_Models_and_Staff_Recommendations_742618_7.pdf.

[349] Interstate Renewable Energy Council. "Hosting Capacity Analysis." Available at: https://irecusa.org/our-work/hosting-capacity-analysis/.

project. Consumers Energy and DTE currently provide simple hosting capacity maps that are publicly available.

- *Considerations*: For hosting capacity analyses to be valuable, they need to provide accurate information about the grid that is transparent and accessible in a manner that is usable. To make sure that Michigan is gathering the right data to catalyze the market, inputs to hosting capacity analyses must be accurate, modeling should include valid assumptions, and the data should be validated.[350]
- *Recommendations*: Under existing Commission authority, the MPSC should require Michigan's investor-owned utilities to move more quickly to gather the data necessary to provide publicly available hosting capacity data in a phased manner starting with basic feeder/system data and moving to publicly available hosting capacity data at each node on the distribution system available in a map and spreadsheet format. Alternatively, the Michigan Legislature could pass legislation to require Michigan's utilities to gather and provide these data in a timely manner.

Require transparency and accessibility in rates for energy storage.

- *Venue of change*: Michigan Public Service Commission
- *Background*: In the MPSC's Staff Standby Rate Working Group Report, a lack of transparency and simplicity in tariffs was acknowledged as a potential challenge associated with the deployment of distributed energy resource projects.[351] With regard to electric rates, customers should have access to clear, accessible, understandable tariffs that they can readily navigate to make project investment decisions. Because of the close relationship between solar and storage, it will be important for rate structures for solar and storage applications to interact seamlessly and be transparent and accessible to customers. Therefore, it will be important for utility representatives to work closely with storage project developers and customers, to help these parties navigate potentially complicated tariff structures. Specific to FTM energy storage projects, utilities should be required to publish clear information indicating what delivery rates, if any, will be applied to the charging load of these projects.
- *Considerations*: Increased transparency alone does not address issues of complexity and navigability. Time-varying rates, in particular, may need to be nuanced in order to achieve optimal results. It is important to balance the need for complexity to achieve policy goals with the need for simplicity to ensure accessibility for customers.
- *Recommendation*: Tariffs should be transparent and should not be unduly complex. Utilities should provide outreach and educational tools to facilitate customers' understanding of how to apply published tariffs to potential energy storage projects. Specific to FTM energy storage projects, utilities should be required to publish clear information indicating what delivery rates, if any, will be applied to the charging load of these projects.

Identify specific goals for energy storage pilots to address barriers to the efficient utilization of storage resources.

- *Venue of change*: Michigan Public Service Commission
- *Background*: The MPSC began an inquiry into the need for energy storage pilots by Michigan

[350] Zakai, Y. Interstate Renewable Energy Council. June 13, 2020. "Validation is Critical to Making Hosting Capacity Analysis a Clean Energy Game-Changer." Available at: https://irecusa.org/blog/regulatory-engagement/validation-is-critical-to-making-hosting-capacity-analysis-a-clean-energy-game-changer/.

[351] Michigan Public Service Commission Staff. August 2016. "Standby Rate Working Group Report." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000001UMMNAA4. p. 21.

utilities in Case No. U-21032.[352] This case focused on the exploration of dual participation in the wholesale and retail markets. The Commission encouraged utilities to propose pilot programs that allowed for energy storage to participate in the retail and wholesale markets under different conditions.

- *Considerations*: The direction provided by the Commission to Michigan utilities in Case No. U-21032 is a good start, but it was established specifically in the context of dual wholesale and retail service participation. As a result, energy storage pilots established in response to this case may lack the full scope of information gathering that is necessary to fully integrate energy storage into utility planning and operations. For example, although storage can provide ancillary services like voltage/VAR support, often distribution utilities do not currently allow storage to provide those ancillary services or value those services.
- *Recommendations*: Either through Case No. U-21032, the MI Power Grid stakeholder process, or a new docket, the MPSC should establish a list of outstanding information that needs to be gathered through utility pilot programs to integrate energy storage systems into the grid more holistically. The utilities should then be encouraged to deploy pilot programs to gather the necessary data including timelines for completion and reporting. This effort should not delay greater utilization of beneficial energy storage where work is already underway or additional information is not necessary to utilize these resources.

Legislative

Establish a target to deploy 4,000 MW of FTM storage by 2040, with a short-term target of 1,000 MW of FTM storage by 2025 and a medium-term target of 2,500 MW of FTM storage by 2030.

See "Executive" recommendations above for details.

Require utility IRPs to include an accurate evaluation of opportunities for storage resources and, at a minimum, meet any established storage target.

See "Regulatory" recommendations above for details.

Require Michigan's utilities to file on-bill financing pilot programs for which residential and C&I energy storage systems are eligible.

See "Regulatory" recommendations above for details.

Require Michigan's utilities to provide publicly available hosting capacity maps that that provide sufficient detail to allow storage developers to identify the need for flexible generation or distribution alternatives.

See "Regulatory" recommendations above for details.

Eliminate the distributed generation cap.

- *Venue of change*: Michigan Legislature
- *Background*: Because the Legislature ended net metering in 2016 and moved to a cost of service based distributed generation tariff, customers save more money on their electricity bills if they use all of the electricity generated by a rooftop solar system on site. As a result, many customers are now installing BTM battery storage systems. However, there is a statutory cap (1 percent of average in-state load) on the capacity of each utility's distributed generation program. Once this cap is reached for each utility, there are no other customer-friendly options to allow customers to install solar or solar plus storage systems, and, in practice, any customer who wants to install a solar

[352] Michigan Public Service Commission. August 11, 2021. Order U-21032. Available at: https://mi-psc.force.com/s/case/500t000000j0eplAAQ/in-the-matter-on-the-commissions-own-motion-to-request-comments-on-midcontinent-independent-system-operator-incs-implementation-of-federal-energy-regulatory-commission-order-no-841-regarding-energy-storage-resources.

or solar plus storage system has been put on a waiting list. The Legislature needs to eliminate the distributed generation cap to allow customers who would like to gain the cost saving and back-up generation benefits of energy storage to continue to do so.

- *Considerations*: Based on data filed by the utilities with the MPSC, it is likely that Consumers Energy will hit its distributed generation caps in 2023 and DTE Energy will hit its caps in 2023 or 2024. Once that happens, no level of grants, rebates, or loans for residential or small business customers will enable customers to install solar plus storage systems.
- *Recommendation*: The Legislature should pass a bill to eliminate the distributed generation cap.

Remove restrictions from the commercial PACE statute.

- *Venue of change*: Michigan Legislature
- *Background*: Under Public Act 270 of 2010,[353] commercial PACE loans are designed specifically to address energy- and water-related upgrades and can include BTM storage projects. However, Michigan's commercial PACE statute requires all projects to provide positive cashflow in the first year. Such a requirement, given that many of the services of energy storage remain unrecognized, unmonetized, or underpriced in Michigan's regulatory framework, limits the ability of energy storage projects to qualify for commercial PACE financing.
- *Considerations*: Removing the restriction that all projects must provide positive cashflow in the first year and allowing property owners to waive this restriction would allow for more BTM storage projects to be financed for commercial, industrial, and multi-family properties.
- *Recommendations*: The Michigan Legislature should pass legislation to allow property owners to waive the savings-to-investment ratio guarantee, allowing more energy storage projects to qualify for commercial PACE financing.

SHORT-TERM ACTIONS (1-5 YEARS)

Executive

Establish grants for solar plus storage projects at public schools to provide the benefits of storage and demonstrate the technology.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy
- *Background*: The upfront capital costs of energy storage and solar plus storage projects may make them too expensive for public institutions like K-12 schools. However, deployment of these projects at schools could provide a number of benefits including increased resiliency and grid reliability, as well as decreased local air pollution for schools that currently rely on fossil fuel generators for back-up power. Energy storage will also lower monthly electricity bills for schools, leading to cost savings. In addition, by supporting energy storage projects at schools, the state can provide educational opportunities for children, parents, and communities.
- *Considerations*: It will be critical to ensure that schools take advantage of any available energy efficiency/energy management opportunities in addition to installing solar plus storage systems to gain the greatest cost and energy savings. These grants should be established at a high enough level to enable schools to undertake storage projects, but they also should include some amount of cost share. For example, in the case of the New York Green and Clean Energy Solutions Program,

[353] Public Act 270 of 2010. December 14, 2010. Available at: http://www.legislature.mi.gov/(S(ukexhpcbmoc1yrpshizq1o3a))/mileg.aspx?page=GetObject&objectname=mcl-Act-270-of-2010.

a 75 percent cost-share was provided to Pre K-12 schools.[354] It will also be important, depending on the size of the program, to ensure the funds are distributed across a diverse portfolio of schools to support and educate the greatest number and diversity of communities.

- *Recommendations*: EGLE should establish a grant program with a cost-share requirement to enable public schools to install solar plus storage projects. This program should include a carve out or higher incentive for schools located in low-income communities.

Establish a rebate or grant program for BTM residential and C&I storage systems with a carve-out for low-income customers.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy; or Michigan Public Service Commission; or Michigan Legislature
- *Background*: Energy storage solutions have the potential to provide backup power, support distributed solar solutions, and serve as cost-saving measures for customers. However, BTM energy storage systems may not be economically accessible for many ratepayers, particularly low-income households. In addition, certain types of public or private financing options may not be available for low-income customers. In addition to a grant program established by EGLE, the MPSC could encourage Michigan's utilities to work with stakeholders to establish similar "Bring Your Own Device" energy storage rebate programs for ratepayers and the Michigan Legislature could require Michigan's utilities to establish such rebate programs.
- *Considerations*: As described above, the state should first conduct a study to determine the appropriate levels of grants or rebates for residential customers, including low-income customers. It is important that incentives are large enough to make it possible for new adopters to deploy storage but small enough to enable large numbers of participants. To ensure uptake of these incentives among low-income customers, it may be valuable to create a carve-out for low-income customers and to structure incentives for these customers as up-front cash grants.

  Incentives should be established based on energy storage capacity in kWh, not on power rating in kW. This is because, for example, a 2 kW battery with a one hour duration (2 kWh) is cheaper than a 2 kW battery with a 2 hour duration (4 kWh). According to ESA, cash "rebates carry the greatest potential to reach the widest number and type of customers, and deploy the greatest number of systems by providing a solution to upfront financing challenges."[355]

  Finally, for any energy storage rebate program, it will be important to carefully consider ownership questions. If rebate programs are established by Michigan's utilities, ownership of the system should remain with the ratepayer or a third-party and the services provided to the utility should be properly valued.
- *Recommendations*: The state should establish a cash rebate/grant program for residential customers to install BTM storage systems where the level of the rebate is based on energy storage capacity as determined by the economic gap analysis. This program should include a carve-out for low-income households with a higher incentive level, potentially provided in the form of up-front cash grants.

Implement effective training programs to increase the number of qualified personnel in the energy storage workforce.

- *Venue of change*: Michigan Economic Development Corporation and Michigan Department of Environment, Great Lakes, and Energy
- *Background*: As described above, the state should first conduct a study to determine how best to

[354] NYSERDA. "P-12 Schools - Green & Clean Energy Solutions (PON 4157)." Available at: https://portal.nyserda.ny.gov/CORE_Solicitation_Detail_Page?SolicitationId=a0rt000000hcN0wAAE#:~:text=The%20P%2D12%20Schools%3A%20Green,conversion%20to%20carbon%20free%20fuels.

[355] Energy Storage Association. February 2019. "Energy Storage Incentive Programs." Available at: https://energystorage.org/wp/wp-content/uploads/2019/09/Incentive-Report_v7.pdf.

improve existing workforce programs for the energy storage industry and deploy new programs. Given the importance of addressing workforce needs for making advancements in the storage industry, it is critical that the state both understand the specific opportunities for improvement and implement the necessary programs.

- *Considerations*: The findings from the workforce development study may involve using existing state and federal resources and/or allocating new dollars into new and existing training programs. If new allocations are needed, the Legislature, administration, and stakeholders should work together to ensure adequate funds are available. Additionally, the state should consider how best to evaluate any new or improved programs considering the time that it may take to observe results.
- *Recommendations*: The state should improve existing programs and implement new clean energy and storage training programs to increase Michigan's energy storage workforce.

Provide green bank funding for BTM C&I energy storage projects.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy or Michigan Legislature
- *Background*: Some of the leading states for energy storage deployment have provided financing and grantmaking tools through a concept known as a "green bank" to catalyze the energy storage market while it is ramping up. Michigan is home to a nonprofit green bank in Michigan Saves, which has a track record of leveraging state funds, utility programs, and philanthropy to drive increased access to capital for BTM energy projects. The tools available to a green bank include a variety of debt instruments and credit enhancements, which are used to drive further investment from the private sector. Green banks have also been a key vehicle for providing capital to typically underserved communities to make sure everyone has access to advanced energy solutions.[356] Green bank tools are often geared toward BTM projects, but in states like New York, they have also been designed to drive FTM investments, including energy storage.[357]
- *Considerations*: To optimize benefits for customers, the electric grid, and the development of the energy storage market, a focus on BTM applications can leverage existing resources, relying on partners such as Michigan Saves to identify market gaps and how to develop specific products to serve the energy storage market. Often, BTM energy funding can be applied to any distributed energy resource. It is important, therefore, that innovative finance and grant tools provided by or funded by EGLE should be specifically for energy storage systems or solar systems that include energy storage. To ensure any funding modeled on green bank principles is optimized for driving market adoption, the success of the funds should be evaluated based on the amount of energy storage capacity deployed, the amount of private capital deployed per public dollar spent (leverage ratio), and the ability to ensure equitable access to the energy storage solutions.
- *Recommendations*: EGLE should partner with Michigan Saves to provide green bank financing to increase BTM applications of energy storage for residential and C&I properties in Michigan, with an emphasis on ensuring energy storage access in underserved communities.

Provide additional matching grants for commercial PACE projects and for Michigan Saves loans that involve energy storage for multi-family properties.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy
- *Background*: Commercial PACE financing is enabled in Michigan and has the potential to be used to unlock increased BTM energy storage applications for commercial businesses, including multi-

[356] Connecticut Green Bank. 2022. "Energy Storage Solutions for All." Available at: https://www.ctgreenbank.com/energy-storage-solutions/.

[357] NY Green Bank. November 2019. "Financing for Energy Storage Projects: Request for Proposals." Available at: https://portal.greenbank.ny.gov/servlet/servlet.FileDownload?file=00Pt000000HfPdaEAF.

family housing properties. Michigan's green bank, Michigan Saves, also provides loans that can be used for energy storage projects. Increasing the financing available through these programs can make energy storage cost effective by lengthening the term of the loan to 15-25 years. In addition, commercial PACE or Michigan Saves financed projects for C&I buildings typically include a variety of energy saving measures that, when paired with energy storage, can make energy storage investments more attractive economically.

- *Considerations*: Because energy storage is not explicitly enabled in Public Act 270 of 2010,[358] these projects must be deemed a utility-cost savings measure by the local government or the PACE program administrator. To gain this distinction, the energy storage device would need to operate in a manner that generated utility savings of some kind, whether through energy arbitrage, optimization of a solar system, or some other provision of services. It is also important to set the value of any matching grants to ensure that they are large enough to meet the financing gap but small enough to allow for a large number of participants. To ensure that the benefits of energy storage, including increased reliability and resilience are shared among all residents, including disadvantaged communities, it would be valuable to focus this matching grant program on multi-family housing properties.
- *Recommendations*: EGLE should establish a short-term matching grant program to incentivize increased installation of energy storage through commercial PACE financing and Michigan Saves for multi-family housing properties.

Appoint energy storage experts to boards and commissions.

- *Venue of change*: The Executive Office of the Governor
- *Background*: The Governor has the power to make appointments to boards and commissions each year, and there are a number of boards that would benefit from energy storage experts. Beyond just boards and commissions focused on energy and utilities, the state would benefit from appointing storage experts to boards focused on workforce development, economic development, finance, environment, engineering, buildings and construction, and others.
- *Considerations*: Appointments that are subject to Advice and Consent of the Senate will also need the Legislature's support.
- *Recommendations*: Given the industry growth that is occurring and expected to continue, the Governor's Office should ensure that energy storage experts are at the table on boards and commissions.

Encourage pilot EV fleet programs to allow fleets, including fleets of school buses, to provide storage benefits to the grid when not being used for transportation.

See "Regulatory" recommendations below for details.

Regulatory

Establish a rebate or grant program for BTM residential and C&I storage systems with a carve-out for low-income customers.

See "Executive" recommendations above for details.

[358] Public Act 270 of 2010. December 14, 2010. Available at: http://www.legislature.mi.gov/(S(ukexhpcbmoc1yrpshizq1o3a))/mileg.aspx?page=GetObject&objectname=mcl-Act-270-of-2010.

Begin to implement performance-based ratemaking to incorporate resilience and reliability into principles to reward utilities for improvements toward policy goals.

- *Venue of change*: Michigan Public Service Commission or Michigan Legislature
- *Background*: Performance-based regulation – also known as outcomes-based regulation – is a "regulatory framework designed to better align the financial interests and actions of regulated investor-owned utilities with public interest objectives and consumer benefits."[359] Such outcomes could include, for example, energy efficiency, decarbonization, operational reliability, reducing energy burden, market innovation, or deployment of DERs. In 2016, Michigan passed Public Acts 341 and 342, which enabled certain changes to Michigan's regulatory construct to incentivize certain public policy outcomes such as increasing energy efficiency through the energy waste reduction program. Additionally, Michigan utilities are enabled to establish financial incentives or penalties based on metrics including quality of service and reliability and are starting to do so through their distribution system planning processes.[360] Michigan has the tools to establish a performance-based incentive mechanism or other performance-based regulation tool that would compensate for the services that FTM and BTM energy storage can provide, such as improved reliability. Alternatively, the Michigan Legislature could establish additional policy goals to incentivize energy storage deployment through performance-based regulation.
- *Considerations*: Performance incentive mechanisms are often used to incentivize specific metrics or outcomes geared toward energy storage or the services that it provides. Such mechanisms can be designed to reward a utility for improved performance, penalize a utility for poor performance, or both. A variety of policy objectives could be incentivized through performance-based regulation that would help drive the energy storage market. For example, metrics around grid reliability and customer resiliency of the electric system, emergency response, cost efficient utility investments and operations, emissions reductions, renewable energy deployment, peak demand reductions, and timeliness of interconnection processes along with other metrics may be used.[361]
- *Recommendations*: The MPSC should develop or the Michigan Legislature should require establishment of a performance-incentive mechanism that rewards investor-owned utilities for a decrease in annual minutes of outage per customer, annual outages per customer, and average restoration time per outage, along with other key reliability metrics.

Establish appropriate benefit cost analysis framework for non-wires alternatives including storage such that storage is considered on an equal footing with other investments.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Depending on the circumstances, energy storage can be a cost-effective solution compared to traditional poles and wires investments to address increasing load on a circuit, expected future renewable growth, or reliability concerns. However, energy storage is not widely deployed by Michigan's utilities, and it can be difficult to ensure that storage solutions are appropriately evaluated and that the full benefits and costs of these solutions are included when utility investment decisions are made.
- *Considerations*: It is important that the Commission work with utilities and stakeholders to assess alternatives to conventional investments before those investments are selected, including developing a standardized benefit cost analysis (BCA) framework for utility distribution system

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[359] Advanced Energy Economy. June 5, 2018. "Performance-Based Regulation." Available at: https://info.aee.net/hubfs/PDF/PBR.pdf.

[360] Case No. U-20147. Available at: https://mi-psc.force.com/s/case/500t0000009gHerAAE/in-the-matter-on-the-commissions-own-motion-to-open-a-docket-for-certain-regulated-electric-utilities-to-file-their-distribution-investment-and-maintenance-plans-and-for-other-related-uncontested-matters.

[361] Littell, D. and Shipley, J. July 2017. "Performance-Based Regulation Options: White Paper for the Michigan Public Service Commission." Regulatory Assistance Project. Available at: https://www.michigan.gov/documents/mpsc/RAP_PBR_options_for_MI_PSC_7_14_17_579246_7.pdf.

planning that accurately considers energy storage. For example, as detailed in the MI Power Grid New Technologies and Business Models Draft Report, MPSC Staff recommends that "Benefit cost analysis, as detailed by the National Standard Practice Manual (NSPM) for Distributed Energy Resources, be required from the utilities when proposing and evaluating future pilots for new technologies and alternative business/ownership model pilots, and cost and benefits related to facets of "just" rates the Commission details be included in any benefit cost analysis."[362]

- *Recommendations*: The Commission should work with utilities and stakeholders to develop a standardized BCA framework for utility distribution plans. This BCA framework should utilize the BCA standards and best practices set forth in the NSPM for Distributed Energy Resources.

Allow customers with existing self-generation who add storage resources to experience corresponding reductions in monthly demand charges and/or standby charges, including through waiver of an existing demand ratchet.

- *Venue of change*: Michigan Public Service Commission
- *Background*: In Michigan, standby rates were examined by the Staff Standby Rate Working Group of the MPSC in 2016-2017. The impetus for the Standby Rate Working Group was "the burgeoning interest in these types of projects by potential self-generation customers and project developers," and a desire to develop "greater understanding of these complicated standby service tariffs."[363] Public Act 286 of 2008, Sec 11 (1) requires that electric rates in Michigan reflect "cost of service."[364] In Michigan, cost of service can consider actions of the customer and/or operations of a customer's system that provide value to all ratepayers, such as demand response programs and interruptible rates, which credit ratepayers for agreeing to curtail service when called upon to do so by the utility.[365]
- *Considerations*: If the customer is able to use storage to reduce its contribution to the system peak, from a cost causation perspective, the customer has done its part to reduce system costs during the peak period. Therefore, a resulting reduction in demand and/or energy charges is warranted. Any additional "standby charge" would remove the customer's incentive to help reduce system costs, and would over-recover costs from these customers, undermining the fairness of rates in the apportionment of total costs of services among customers, and discouraging optimum use of utility services. Similarly, if a customer installs storage resources and experiences a reduction in peak load, any existing demand ratchet should be waived to permit a corresponding reduction in monthly demand charges.
- *Recommendation*: Allow customers with existing self-generation who add storage resources to experience corresponding reductions in monthly demand charges and/or standby charges.

Set default TOU rates for BTM C&I storage customers to allow them to take advantage of the flexibility of storage for rate arbitrage and reliability.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Time-varying or TOU rates can help customers with energy storage systems save money, since a storage system can charge during off-peak times and discharge during on-peak periods. In fact, TOU rates are being embraced across rate classes and different technologies, and some believe that TOU rates should be the default for all customers.

[362] Michigan Public Service Commission Staff. Case No. U-20898. "MI Power Grid: New Technologies and Business Models Workgroup." p. vii. Available at: https://www.michigan.gov/documents/mpsc/MPG_New_Tech_Draft_Staff_Report_-_091521_735505_7.pdf.

[363] Michigan Public Service Commission Staff. August 2016. "Standby Rate Working Group Report." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000001UMMNAA4. p. 2.

[364] Public Act 286 of 2008. October 6, 2008. Available at: https://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0286.pdf.

[365] Michigan Public Service Commission. MI Power Grid Demand Response Working Group. "Michigan Interruptible Tariff Comparison." Available at: https://www.michigan.gov/-/media/Project/Websites/mpsc/workgroups/dr/Interruptible_Tariff_Comparison.pdf?rev=a2621594aa4840e3b7e2eaaa78b051a1.

- *Considerations*: The more accurately rates reflect actual costs, the clearer the price signal is to operate the customer's storage system in ways that are most beneficial for the grid.
- *Recommendation*: Time-varying rates should be set as the default rate option for BTM C&I storage customers, if not eventually for all customers.

Time-varying rate designs should provide a clear price signal for BTM C&I storage customers to charge during periods when demand is low and discharge during periods when demand is high.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Time-varying or TOU rates can help customers with energy storage systems save money, since a storage system can charge during off-peak times and discharge during on-peak periods.
- *Considerations*: The more accurately rates reflect actual costs, the clearer the price signal to operate the customer's storage system in ways that are most beneficial for the grid.
- *Recommendation*: Design time-varying rates to reflect a clear price signal to charge during periods when demand is low and discharge during periods when demand is high.

Align demand charges with established cost allocation methods by reflecting coincident peak instead of a customer's non-coincident peak.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Under current practice, distribution costs are often allocated with reference to coincident peak. In contrast, rates are designed with demand charges that do not reflect coincident peak, but instead reflect a customer's non-coincident peak. This is true even if the non-coincident peak occurs at a time (e.g., 2 am) when it is clearly not driving system costs.
- *Considerations*: This recommendation is intended to apply only to the extent that demand charges continue to be used in the near term.
- *Recommendation*: Where a rate design contains a demand charge, the MPSC should ensure that it is based on a customer's coincident peak instead of a customer's non-coincident peak. This change would support storage deployment in Michigan by ensuring better alignment between actual grid costs saved by timely use of storage and rates charged to customers.

Align rates for solar and storage to support pairing of these technologies and ensure that rates are transparent and accessible to customers.

- *Venue of change*: Michigan Public Service Commission
- *Background*: As a result of the distributed generation tariffs, customers are incentivized to use as much of the power produced by their solar systems on-site as possible. This creates an economic incentive for customers with rooftop solar to also install BTM energy storage systems.
- *Considerations*: Because of the close relationship between solar and storage, it will be important for rate structures for solar and storage applications to interact seamlessly and be transparent and accessible to customers.
- *Recommendation*: The MPSC should ensure that rates for solar and storage are transparent, accessible to customers, and well-aligned. Utility representatives should work closely with solar and storage project developers and customers to help these parties navigate potentially complicated tariff structures.

Rate designs applied to FTM energy storage projects connected to the distribution system should appropriately reflect cost of service through use of operational characteristics.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Public Act 286 of 2008, Sec 11 (1) requires that electric rates in Michigan reflect "cost

of service."[366] In Michigan, cost of service can consider actions of the customer and/or operations of a customer's system that provide value to all ratepayers, such as demand response programs and interruptible rates, which credit ratepayers for agreeing to curtail service when called upon to do so by the utility.[367] The costs and benefits of such programs/rates are generally evaluated in rate case proceedings. Additionally, in 2021, the MPSC and EGLE participated in the nationwide Task Force on Comprehensive Electricity Planning, a joint effort by NARUC and NASEO that sought greater alignment of resource and distribution system planning. A key benefit of comprehensive electricity planning is that it improves understanding of locational costs and benefits of resource deployment, which should be taken into account in rates.

- *Considerations*: Operational characteristics, or how the system operates at a particular site, may affect cost of service and thus should be taken into account in designing rates for FTM energy storage projects. An example of this under existing rates would be reference to voltage level of service.
- *Recommendation*: Utilities should be required to design rates for FTM energy storage projects to appropriately reflect cost of service through use of operational characteristics.

Credit BTM storage in rates for grid reliability and resiliency values that benefit all ratepayers.

- *Venue of change*: Michigan Public Service Commission
- *Background*: BTM storage systems can provide a number of services to the grid, including increased grid reliability and resilience, voltage support and frequency regulation, helping system operators to integrate increasing amounts of renewable energy onto the grid. These benefits go beyond customer resiliency to benefit the grid as a whole, providing value to all ratepayers. By helping to reduce the system peak load, BTM energy storage can also offset traditional grid investments. As described above, a value of storage study should first be conducted to examine both the values a storage owner or developer can monetize through existing market mechanisms and the system benefits that accrue to Michigan's ratepayers through the deployment of storage.
- *Considerations*: In the near term, pending the results of a value of storage study, the resilience value of energy storage can be equated to the economic loss customers would incur if a specified grid outage event were to occur.
- *Recommendation*: Based on the value of storage study and determined resilience value, customers with BTM storage systems should receive a credit for services provided to the grid, including grid reliability and resilience value.

Encourage pilot EV fleet programs to allow fleets, including fleets of school buses, to provide storage benefits to the grid when not being used for transportation.

- *Venue of change*: Michigan Public Service Commission, Michigan Department of Transportation, and Department of Environment, Great Lakes, and Energy
- *Background*: Electric vehicles have the potential to provide energy storage services to the electric grid if leveraged properly. Although transportation is the primary purpose for stored energy in these vehicles, there are opportunities to benefit the grid and provide new revenue streams for vehicle owners. As the proportion of EVs on the road in Michigan grow, the case for V2G applications will grow as charging and discharging patterns become more predictable. However, in the short term, it is more difficult to determine how to optimize individual vehicles for the provision of grid services without compromising the ability to provide the primary function of transportation. With that in mind, large commercial and public fleets represent the optimal opportunity to pilot and develop V2G applications. In particular, public school bus fleets are ideal

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[366] Public Act 286 of 2008. October 6, 2008. Available at: https://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0286.pdf.

[367] Michigan Public Service Commission. MI Power Grid Demand Response Working Group. "Michigan Interruptible Tariff Comparison." Available at: https://www.michigan.gov/-/media/Project/Websites/mpsc/workgroups/dr/Interruptible_Tariff_Comparison.pdf?rev=a2621594aa4840e3b7e2eaaa78b051a1.

for early stage V2G deployment. Electric school bus fleets are idle in the middle of the day, in the evening, and in the summer, and – in general – their total trip mileage is minimal. According to the World Resources Institute, electrifying the entirety of the U.S. school bus fleet alone can unlock 72 GWh of energy storage for utilities via V2G technologies.[368] Recently, a five-year electric bus pilot program funded by the Volkswagen settlement was launched by DTE Energy, which will include tests of electric bus V2G capabilities to provide backup power to buildings during emergencies.[369]

- *Considerations*: Any attempt at V2G deployment should develop and provide publicly an evaluation of grid capacity and constraints, the benefits to the grid and customers of energy storage, enabling interconnection processes, and appropriate tariff design. Additionally, pilots should also explore financing options and business models made possible by the added revenue available from the V2G services provided to the electric grid. It is generally accepted that the technology for V2G and vehicle-to-building applications is proven, so future pilots should focus on lessons learned to increase implementation, rather than to test technical capabilities.[370] Ensuring electric school and transit buses are accessible to low-income communities should also be a key consideration.
- *Recommendations*: The MPSC should encourage Michigan's investor-owned utilities to develop pilot programs to test third-party financing and innovative business model constructs for fleet applications of V2G technology and work with EGLE and Michigan DOT to build on existing school bus and transit fleet electrification efforts.

Encourage utilities to implement residential vehicle-to-grid pilot programs.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Like utility-scale wind, solar, and storage, EV technology is improving rapidly, and costs are declining. Even among the most conservative projections of EV adoption, the cumulative storage capacity contained in the batteries of Michigan drivers' personal EVs will quickly become relevant in comparison to existing utility-scale energy storage in the state. Tapping into a fraction of the storage capacity of personal EVs through V2G technology could have enormous benefits for an electric grid with high renewable penetration.
- *Considerations*: It is important to begin studying the technical and regulatory barriers and knowledge gaps to prepare for high EV adoption. V2G infrastructure, costs, or benefits are not well understood outside of few, controlled pilot programs and research projects. Studying EVs as a storage asset should occur concurrently with other regulatory developments that recognize third-party aggregation of storage assets, non-wires alternatives, and benefit cost improvements for energy storage.
- *Recommendations*: The MPSC should encourage Michigan's utilities to file residential V2G pilot programs to begin to understand the potential benefits and storage opportunities associated with residential EVs. The Commission should also convene stakeholders such as automakers, university researchers, advanced mobility companies, environmental justice groups, and the Office of Future Mobility and Electrification to study regulatory barriers, technical standards, consumer knowledge gaps, and opportunities for utility benefits associated with V2G applications.

Review utility interconnection procedures to ensure storage is being interconnected appropriately.

- *Venue of change*: Michigan Public Service Commission

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[368] World Resources Institute. "Electric School Bus Initiative." Available at: https://www.wri.org/initiatives/electric-school-bus-initiative.

[369] Proterra. September 12, 2019. "Proterra Powered Electric School Buses and Proterra Charging Systems Selected by Michigan Schools for Public Transportation and Vehicle-to-Grid Pilot Program." Available at: https://www.proterra.com/press-release/proterra-powered-electric-school-buses-and-proterra-charging-systems-selected-by-michigan-schools-for-vehicle-to-grid-pilot-program/.

[370] McCoy, K. June 23, 2021. "What 'vehicle-to-everything' electric vehicle pilots mean for the grid." Wood Mackenzie. Available at: https://www.woodmac.com/news/opinion/what-vehicle-to-everything-electric-vehicle-pilots-mean-for-the-grid/.

- *Background*: According to the April 2021 draft interconnection standards, Michigan's utilities are required to establish procedures to allow for limited-export generators (including energy storage) and for the accurate study of those generators, but the standards do not explicitly detail how that is to occur. As a result, it is essential that the Commission revisit the utility's interconnection procedures in the short-term to assess that the standards are being implemented successfully by each utility.
- *Considerations*: It is important that the Commission ensure, by review at a regular interval (e.g., every two years), that each utility's interconnection procedures are supporting the successful interconnection of distributed energy resources including energy storage.
- *Recommendations*: The Commission should engage stakeholders in a process to review the efficacy of utility interconnection procedures especially as they relate to energy storage systems.

Legislative

Establish a rebate or grant program for BTM residential and C&I storage systems with a carve-out for low-income customers.

See "Executive" recommendations above for details.

Provide green bank funding for BTM C&I energy storage projects.

See "Executive" recommendations above for details.

Begin to implement performance-based ratemaking to incorporate resilience and reliability into principles to reward utilities for improvements toward policy goals.

See "Regulatory" recommendations above for details.

LONG-TERM ACTIONS (>5 YEARS)

Executive

Refresh this Energy Storage Roadmap.

- *Venue of change*: Michigan Department of Environment, Great Lakes, and Energy
- *Background*: The technology and policy landscapes that impact energy storage resources are changing at an incredible pace. As such, the state policy approaches and recommendations based on what is known today may become stale and inhibit the full realization of the services provided by storage without a future reevaluation. The practice of updating storage roadmaps over time has been adopted in other states and would be beneficial for Michigan.
- *Considerations*: It will be important to consider any studies that have been conducted, including those recommended by this Roadmap, in any future roadmap updates.
- *Recommendations*: An update to the Energy Storage Roadmap for Michigan should be conducted in the fifth year after release of this report.

Reassess the energy storage target.

- *Venue of change*: Executive Office of the Governor or Michigan Legislature; with implementation by Michigan Public Service Commission
- *Background*: If established, any energy storage target should be routinely assessed to ensure that it appropriately addresses electric grid needs in the state of Michigan and reflects the current state

of available technology.

- *Considerations*: Any established energy storage target should aim to deploy a diversity of project sizes, types, and business models, including third-party ownership, to create a state storage market that provides the widest range of benefits. As such, the target should be reassessed and adjusted as the state of the storage industry in Michigan evolves.
- *Recommendations*: The Michigan Legislature should pass a law or Governor Whitmer should issue an executive order re-establishing a target to deploy FTM storage to reflect current best knowledge of the state's storage industry. The MPSC should be charged with adjusting and implementing this target.

Regulatory

Enable third-party aggregation of BTM storage resources.

- *Venue of change*: Michigan Public Service Commission
- *Background*: With the implementation of FERC Order 2222, there will be opportunities for BTM energy storage systems to provide services to the wholesale market through aggregation.
- *Considerations*: It is important to ensure that in addition to the utilities, third-parties are able to act as aggregators of BTM storage systems in Michigan. This is important to ensure the availability of multiple cost-effective options for customers.
- *Recommendations*: To be prepared for third-party aggregation of BTM storage resources, Michigan's utilities should conduct pilot programs with third-party partners to begin to gather the necessary data and experience to allow for smooth roll-out once FERC Order 2222 is fully implemented.

Eliminate demand charges in favor of time-varying rates.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Traditionally, the potential for reduction in demand charges on a customer's bill has been a main driver in making the installation of storage an attractive option.
- *Considerations*: Purely from a cost causation perspective, demand charges should eventually be eliminated completely, in favor of time-varying rates. According to the Regulatory Assistance Project: "Traditional monthly demand charges have always provided a perverse incentive that does not reflect cost causation for shared system costs. Individual customer non-coincident peaks (NCPs) do not reflect the coincident peaks that drive shared generation and delivery capacity costs."[371]
- *Recommendations*: The MPSC should encourage Michigan's investor-owned utilities to move toward elimination of demand charges in favor of time-varying rates. This change would support storage deployment in Michigan by ensuring better alignment between actual grid costs saved by timely use of storage and rates charges to customers.

Establish sufficient differentiation within time-varying rates to allow for projects to be economic, even in the absence of demand charges.

- *Venue of change*: Michigan Public Service Commission
- *Background*: As utilities move toward elimination of demand charges in favor of time-varying rates, it is important to recognize that historically, the potential for reduction in demand charges on a customer's bill has been a main driver in making the installation of storage an attractive option.
- *Considerations*: The specific design of a time-varying rate can have an important impact on a

[371] Regulatory Assistance Project. November 2020. "Demand Charges: What Are They Good For?" Available at: https://www.raponline.org/wp-content/uploads/2020/11/rap-lebel-weston-sandoval-demand-charges-what-are-they-good-for-2020-november.pdf. p. 4.

customer's savings. On-peak vs. off-peak price variations, including both the price differential between on-peak vs. off-peak price periods and the duration of on-peak vs. off-peak price periods, can all have an impact on potential savings or profitability of an energy storage system.[372]

- *Recommendations*: When designing time-varying rates, electric utilities should establish sufficient differentiation to allow for projects to be economic, even in the absence of demand charges. This change would support storage deployment in Michigan by ensuring better alignment between actual grid costs saved by timely use of storage and rates charges to customers.

Exempt energy storage systems from standby charges, should they provide sufficient grid benefits to all ratepayers, pending the results of a Michigan-specific "value of storage" study.

- *Venue of change*: Michigan Public Service Commission or Michigan Legislature
- *Background*: In Michigan, standby rates were examined by the Staff Standby Rate Working Group of the MPSC in 2016-2017. The impetus for the Standby Rate Working Group was "the burgeoning interest in these types of projects by potential self-generation customers and project developers," and a desire to develop "greater understanding of these complicated standby service tariffs."[373] Public Act 286 of 2008, Sec 11 (1) requires that electric rates in Michigan reflect "cost of service."[374] In Michigan, cost of service can consider actions of the customer and/or operations of a customer's system that provide value to all ratepayers, such as demand response programs and interruptible rates, which credit ratepayers for agreeing to curtail service when called upon to do so by the utility.[375]
- *Considerations*: If the customer is able to use storage to reduce its contribution to the system peak, from a cost causation perspective, the customer has done its part to reduce system costs during the peak period. Therefore, a resulting reduction in demand and/or energy charges is warranted. Any additional "standby charge" would remove the customer's incentive to help reduce system costs, and would over-recover costs from these customers, undermining the fairness of rates in the apportionment of total costs of services among customers, and discouraging optimum use of utility services.
- *Recommendation*: Pending the results of a Michigan-specific "value of storage" study, energy storage systems should be exempted from standby charges if they provide sufficient grid benefits (i.e., benefits to all ratepayers).

Continue to encourage customers to charge EVs at off-peak times using rate design by offering EV tariffs reflecting TOU rates and dynamic or real-time pricing.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Investor-owned utilities in Michigan, including Consumers Energy and DTE Energy, require recipients of Level 2 EV charging station rebates to sign-up for EV tariffs. These tariffs have higher rates on-peak and lower rates off-peak to encourage customers, including those with automated vehicle charging, to charge during off-peak times.
- *Considerations*: After two years of the PowerMIDrive Pilot, Consumers Energy has found that

[372] Carpinelli, G., et al. May 26, 2014. "Battery Energy Storage Sizing When Time of Use Pricing Is Applied." The Scientific World Journal. Volume 2014. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4177186/pdf/TSWJ2014-906284.pdf. pp. 7-8.

[373] Michigan Public Service Commission Staff. August 2016. "Standby Rate Working Group Report." Available at: https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000001UMMNAA4. p. 2.

[374] Public Act 286 of 2008. October 6, 2008. Available at: https://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0286.pdf.

[375] Michigan Public Service Commission. MI Power Grid Demand Response Working Group. "Michigan Interruptible Tariff Comparison." Available at: https://www.michigan.gov/-/media/Project/Websites/mpsc/workgroups/dr/Interruptible_Tariff_Comparison.pdf?rev=a2621594aa4840e3b7e2eaaa78b051a1.

weekday residential charging avoids the peak about 90 percent of the time.[376]

- *Recommendations*: Utilities should be required to continue to offer EV tariffs, through which customers are encouraged to charge EVs at off-peak times using rate design, including through use of TOU rates and dynamic or real-time pricing.

Revisit Michigan's interconnection rules to ensure that interconnection of storage is occurring in a timely manner.

- *Venue of change*: Michigan Public Service Commission
- *Background*: Although Michigan's revised interconnection rules took years to develop with large amounts of stakeholder input, given the pace of change in the electric grid, it is likely that after a few years of implementation, there may be issues, including those related to energy storage, that could be improved upon.
- *Considerations*: It is important that multiple stakeholders be brought into these discussions to ensure that issues experienced by customers, developers, and utilities are all fully explored. Specifically, as described above, it will be important to ensure that the interconnection timelines, standards, and study processes are accurate and effective for energy storage.
- *Recommendations*: The MPSC should convene stakeholders within three to five years after the interconnection standards are approved to explore any ongoing issues, determine if those can be addressed with changes to utility procedures, and, if not, open a rules process to update the interconnection rules.

Legislative

Establish tax incentives for BTM energy storage.

- *Venue of change*: Michigan Legislature
- *Background*: BTM energy storage applications for residential and C&I properties are becoming more affordable as the cost of energy storage declines, as business practices evolve, and as utilities become more familiar with energy storage technologies and their benefits. Tax incentives can move the BTM energy storage market forward and accelerate the deployment of more cost-effective solutions for customers. Federally, tax incentives have been used to support various advanced energy and EV technologies and, in Michigan, have been used to support other outcomes considered to be in the public good, transforming nascent markets into thriving industries. Several states have provided either property tax exemptions or tax credits for energy storage systems.[377]
- *Considerations*: A tax incentive could be structured as a state income tax credit or a property tax exemption and should be priced based on the ability to drive uptake. Size limitations and customer segments should be considered to ensure that the tax incentive is available for all customer classes. With that in mind, additional incentives such as utility rebate programs and state grants should be pursued in tandem to support energy storage deployment for customers that may not have the tax appetite to benefit from an income tax incentive.
- *Recommendations*: Establish a state energy storage income tax incentive of 30 percent of the total installed cost of the system for BTM energy storage installations, with specific limits to ensure opportunities to participate across all utility customer classes.

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[376] Consumers Energy. 2021. "PowerMIDrive Program Annual Report 2021." Case No. U-20134. Available at: https://mi-psc.force.com/s/case/500t0000009fPPSAA2/in-the-matter-of-the-application-of-consumers-energy-company-for-authority-to-increase-its-rates-for-the-generation-and-distribution-of-electricity-and-for-other-relief.

[377] As described in more detail in Section VIII, these states include Iowa, Maryland, and New Hampshire.

APPENDICES

APPENDIX A: INDUSTRY SURVEY QUESTIONS

1. **Company**
2. **Name**
3. **Is your company headquartered in Michigan?**
   a. Yes
   b. No
4. **Is your company operating in Michigan?**
   a. Yes
   b. No
   c. No, but may in the future
5. **Is your company currently working on any of the following? (Please choose as many as are applicable)**
   a. Grid-connected front-of-the-meter energy storage
   b. Residential behind-the-meter energy storage
   c. Commercial/industrial behind-the-meter energy storage
   d. Energy storage related to mobility/transportation
   e. Energy storage-renewable hybrid projects (with wind or solar)
   f. Energy storage supply chain
   g. Other
6. **In the future, does your company plan to work on any of the following? (Please choose as many as are applicable)**
   a. Grid-connected front-of-the-meter energy storage
   b. Residential behind-the-meter energy storage
   c. Commercial/industrial behind-the-meter energy storage
   d. Energy storage related to mobility/transportation
   e. Energy storage-renewable hybrid projects (with wind or solar)
   f. Energy storage supply chain
   g. Other
7. **What technologies is your company currently active with? (Please choose as many as are applicable)**
   a. Thermal storage
   b. Compressed air storage
   c. Pumped storage
   d. Flywheels
   e. Lithium-ion batteries
   f. Lead acid batteries
   g. Flow batteries
   h. Sodium-sulfur batteries
   i. Other
8. **In what states have you completed energy storage installations?**
9. **For what WHOLESALE reasons/use cases (values) has your company conducted energy storage installations? (Please choose as many as are applicable)**
   a. Demand response
   b. Energy arbitrage
   c. Capacity market
   d. Frequency regulation

e. Load following
f. Spinning reserve
g. Non-spinning reserve
h. Fast frequency response
i. Demonstration/education project
j. Pilot program
k. Others

10. For what UTILITY reasons/use cases (values) has your company conducted energy storage installations?
(Please choose as many as are applicable)
a. Demand response
b. Distribution deferral
c. Transmission deferral
d. Renewables integration
e. Emissions reduction
f. Black start
g. Backup power
h. Demonstration/education project
i. Pilot program
j. Others

11. For what COMMERCIAL/RESIDENTIAL reasons/use cases (values) has your company conducted energy storage installations?
(Please choose as many as are applicable)
a. Customer bill management
b. Emissions reduction
c. Backup power
d. Power stability
e. Microgrid management
f. Uninterrupted Power Supply (UPS)
g. EV market penetration
h. Demonstration/education project
i. Pilot program
j. Others

12. If you could request data from a utility, what data would you request to determine where energy storage is a potentially viable solution?
(Please choose as many as are applicable)
a. Substation capacity/load
b. Line/feeder capacity/load
c. Alternative upgrade costs
d. Frequency regulation challenges
e. Voltage regulation challenges
f. Localized load forecasts
g. Utility planned maintenance/upgrade schedules and costs
h. Localized customer characteristics
i. Density of non-interruptible loads
j. Other

13. If you selected "Other," please explain further.

14. What is the current status of your energy storage business efforts in Michigan?
a. Currently operating with projects completed

b. Currently operating with projects in development
c. Expect to develop projects in 1-3 years
d. Expect to develop projects in 3-5 years
e. Unsure if your company will develop projects in Michigan
f. Other

15. If you have completed any energy storage installations in Michigan, please list those projects including project name, location, technology, value provided to customer.

16. If you have worked in other states, what state laws have supported your deployment of energy storage?
(Please choose as many as are applicable)

a. R&D incentives
b. Storage targets/mandates
c. Tax credits
d. Rebates/incentive programs
e. Studies/demonstration opportunities
f. Grants/loans
g. Other

17. If you have worked in other states, what administrative actions (i.e., by the Governor) have supported your deployment of energy storage?
(Please choose as many as are applicable)

a. Storage targets/mandates
b. State-sponsored demonstration projects
c. Funding opportunities
d. Start-up support
e. Other

18. If you have worked in other states, what RTO policies have supported your deployment of energy storage?
(Please choose as many as are applicable)

a. Appropriate demand charges/rate designs
b. Time-varying pricing
c. Appropriate interconnection rules
d. Appropriate benefit/cost analysis
e. Appropriate market rules
f. Other

19. If you have worked in other states, what state regulatory policies have supported your deployment of energy storage?
(Please choose as many as are applicable)

a. Appropriate demand charges/rate designs
b. Time-varying pricing
c. Appropriate interconnection rules
d. Appropriate distribution planning processes/transparency
e. Storage targets/mandates
f. Appropriate benefit/cost analysis
g. Studies/demonstrations
h. Other

20. From your experience, which existing Michigan laws or policies are supportive of energy storage development
(Please choose as many as are applicable)

a. Utility non-wires alternatives pilot programs

b. Residential storage pilot programs
c. Integrated Resource Planning process
d. Distribution System Planning process
e. Governor's carbon neutrality executive directive
f. Grants/Loans
g. Other

21. If you selected "Other," please explain.

22. What policy barriers exist to energy storage deployment in Michigan?

23. Have you encountered any issues with local zoning related to energy storage? If so, please describe your experiences.

24. What are the [3] most important changes that need to be made to the policy landscape in Michigan to make it more supportive for energy storage?

25. Policies at many different levels influence the decision/ability to build new energy storage projects. Please rank the importance of policies set at these different levels to your decision/ability to build new energy storage projects: FERC, RTO, PSC/PUC, state legislature

26. What factors most influence your decision to enter a new market?

a. Electricity rates
b. State policies
c. Workforce
d. Proximity to supply chain and partners
e. Utility policies/programs
f. Customer demand

APPENDIX B: HOMER MODELING LIMITATIONS

There are a number of specific features of the HOMER Grid modeling that may have resulted in limitations of this BTM modeling as described below.

Solar PV Capacity

For all HOMER Grid modeling runs, solar PV capacity was limited to a 150-kW array, to enable participation in the utility distributed generation tariff programs. However, a number of commercial building types could economically, and potentially physically, accommodate larger solar PV arrays, and thus larger coupled energy storage systems. Modeling results showed that the smaller peak-load buildings selected solar PV arrays in the range of 35 to 75 kW, but the fact that mid-size and larger buildings almost universally selected a 150-kW solar PV system size was likely an artifact of the imposed solar PV capacity limit. Future analyses should explore enabling the model to choose larger solar PV systems, in conjunction with a detailed analysis of the physical constraints associated with locating solar PV arrays on the commercial building sites.

Use of Hourly Load Data

HOMER models developed for the study relied on 8,760-hour synthetic building load profiles. The use of hourly loads, as opposed to sub-hourly data, may have limited the accuracy of the modeling results. For example, utility rate schedules typically set demand charges based on a 15-minute integrated peak load. Models relying on an hourly average demand will necessarily understate the true peak-demand and thus underestimate demand charges. This, in turn, may have artificially decreased the benefits of both coupled solar PV/battery storage systems and stand-alone battery storage systems.

In addition, the use of hourly load data necessitated the use of hourly solar PV generation data. This may have understated the true level of power inflows (retail purchases) and power outflows (grid sales) and consequently understated the true value of energy storage in managing power flows to reduce utility bills.

Finally, the synthetic load profiles used in this study were generated by combining data from multiple buildings (in some cases, thousands of buildings). This averaging methodology results in a smoothing of load data and ultimately results in an artificial reduction in the natural variability associated with real buildings. This reduction in natural variability likely resulted in an underestimate of the value of energy arbitrage provided by BTM storage. NREL is in the process of publishing a publicly available sub-hourly synthetic commercial building load database that features 15-minute data. Future studies should use sub-hourly data to estimate economic levels of commercial BTM energy storage.

Rate Increases

Utilizing forecasted bulk power prices and forecasted retail electric rates would likely provide a more accurate approach to model storage uptake beyond 2030 than the simple approach used in this Roadmap of using a fixed compound annual rate increase. Long-term retail rate forecasts (beyond the 2030 timeframe) would be needed to integrate BTM modeling of energy storage with bulk power system modeling. As wholesale rates flow into retail rates, a connection of the two markets in future studies will provide a holistic basis for long-term policy direction in advancing decarbonization in electric energy production, transmission, distribution, and finally retail consumption.

APPENDIX C: LIFE-CYCLE ASSESSMENT OF BTM STORAGE

Methodology

LCA was conducted using the CML-IA baseline v3.06 method in SimaPro v9.1 software.[378] The selected environmental impact categories were: 1) Global warming potential, 2) Abiotic depletion potential, 3) Photochemical oxidation potential (smog), 4) Acidification potential. The inventory data for the manufacturing of lithium-ion batteries[379] was modified for different battery chemistries as described below.[380] The life-cycle inventories for all energy generators were from the Ecoinvent 3.6 database.[381]

For the BTM assessment, four buildings (quick-service restaurant, full-service restaurant, supermarket, and hospital) were considered based on the 2020, 2025, and 2030 for electricity rate schedules of both Consumers Energy Electric and DTE Electric with a project lifetime of 25 years. The storage was assumed to be Li-ion batteries with nickel-manganese-cobalt (NMC) cathodes. The annual change in battery chemistry was taken from a Bloomberg New Energy Finance report.[382] The functional unit was the delivery of electricity to meet the demand of behind-the-meter scenarios for 25 years.

As shown in Table 14, solar PV capacity, inverter capacity, and battery capacities varied across these four building types.

			PV CAPACITY (KW)	INVERTER CAPACITY (KW)	BATTERY CAPACITY (KWH)	BATTERY
2020	Consumers Energy	Quick-service restaurant	7.4	0.4	1.0	1
		Full-service restaurant	12.2	0.8	2.0	2
		Supermarket	46.1	14.9	33.0	2
		Hospital	105.0	45.7	95.0	2
	DTE Energy	Quick-service restaurant	4.1	2.6	11.0	2
		Full-service restaurant	8.3	5.0	22.0	2
		Supermarket	23.2	4.7	4.0	2
		Hospital	NA	NA	NA	NA
2025	Consumers Energy	Quick-service restaurant	22.5	2.5	5.0	1
		Full-service restaurant	37.2	6.3	1.0	1
		Supermarket	150.0	11.8	17.0	4
		Hospital	149.0	89.0	392.0	2
	DTE Energy	Quick-service restaurant	4.3	3.9	17.0	3
		Full-service restaurant	19.0	9.0	40.0	2
		Supermarket	133.0	12.9	18.0	1
		Hospital	146.0	39.4	65.0	1

[378] Simapro from PreSustainability. Available at: https://simapro.com/about/.

[379] Kim, H.C., et al. 2016. "Cradle-to-Gate Emissions from a Commercial Electric Vehicle Li-Ion Battery: A Comparative Analysis." Environmental Science and Technology. Vol. 50.

[380] Accardo, A., et al. 2021. "Life cycle assessment of an NMC battery for application to electric light-duty commercial vehicles and comparison with a sodium-nickel-chloride battery." Applied Science. Vol 11.

[381] Wernet, G., et al. 2016. "The ecoinvent database version 3 (part I): overview and methodology." International Journal of Life Cycle Assessment.

[382] Bloomberg New Energy Finance. 2019. "Lithium-Ion Battery Recycling: 2 Million Tons by 2030."

2030	Consumers Energy	Quick-service restaurant	22.5	5.6	25.0	2
		Full-service restaurant	37.2	8.7	37.0	2
		Supermarket	150.0	35.2	160.0	2
		Hospital	148.0	139.0	885.0	2
	DTE Energy	Quick-service restaurant	22.2	7.1	33.0	1
		Full-service restaurant	37.2	12.0	53.0	2
		Supermarket	150.0	14.0	28.0	4
		Hospital	149.0	39.4	18.0	4

Table 14. Solar PV, inverter, and battery capacities for solar plus storage scenarios for four selected buildings in Consumers Energy and DTE's territories in 2020, 2025, and 2030.

Results

The PCOP, AP, and ADP impacts of the quick-service restaurant and full-service restaurant are shown in Figure 28. For these buildings, solar plus storage systems reduced PCOP and AP impacts compared to baseline in both the utility territories for all reference years. The reduction in PCOP and AP impacts with solar plus storage systems is marginally higher (up to 9 percent) in Consumers Energy locations than DTE Energy locations in 2020 and 2025 due to higher system capacities. However, the PCOP and AP benefits were similar in both the utilities by 2030 due to similar optimized system capacities.

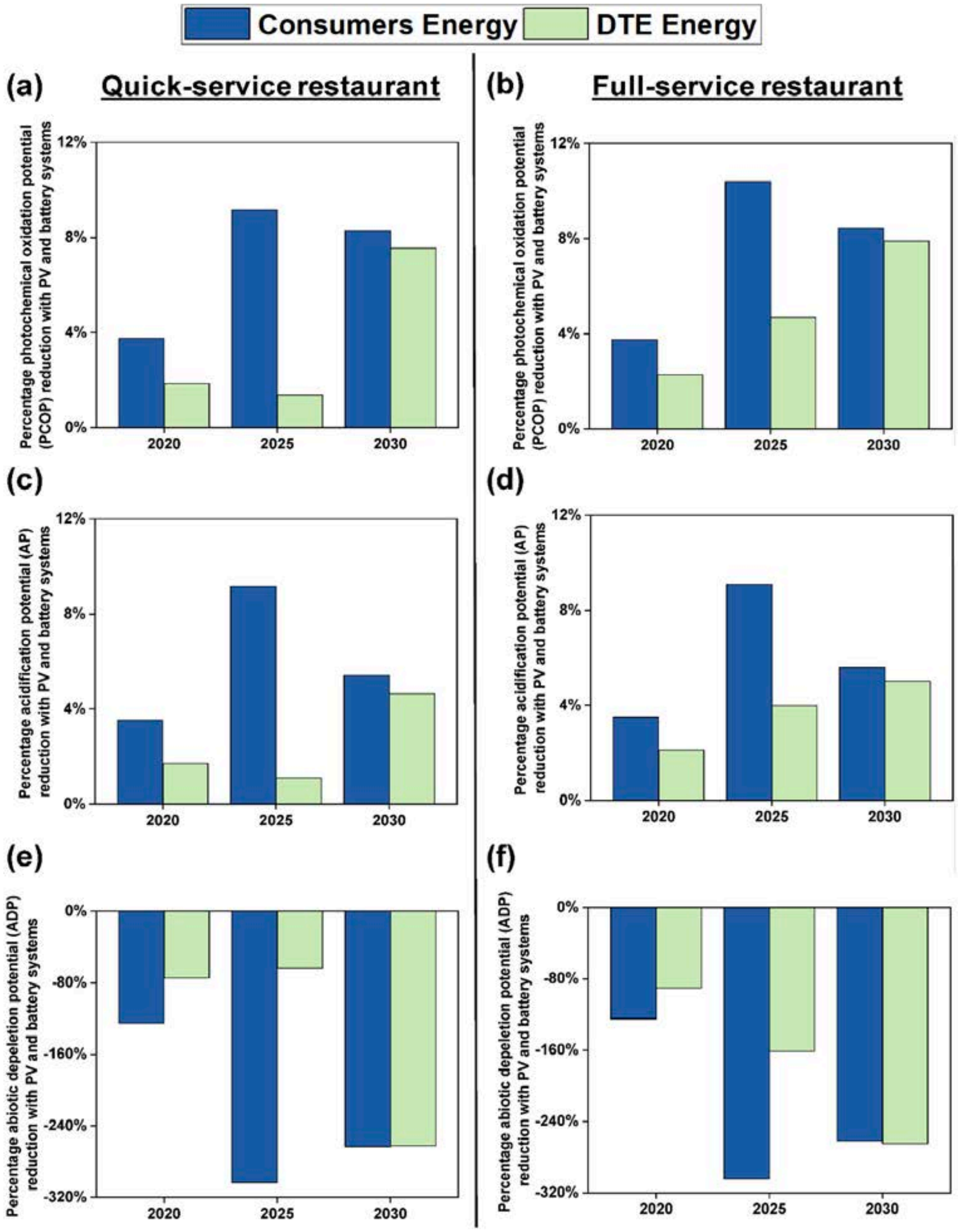

Figure 28. Percentage reduction in photochemical oxidation potential (PCOP) ((a) and (b)), acidification potential (AP) ((c) and (d)), and abiotic depletion potential (ADP) ((e) and (f)) compared to the baseline (no solar or storage) when solar plus storage systems were installed in the quick-service restaurant and full-service restaurant building types in Consumers Energy and DTE Energy territories in the years 2020, 2025 and 2030.

Similarly, for supermarkets and hospitals, the installation of solar plus storage systems reduced the PCOP and AP impacts (Figure 29). In addition, the impact reduction was higher in the Consumers Energy locations compared to DTE Energy locations due to higher system capacities in 2020 and 2025.

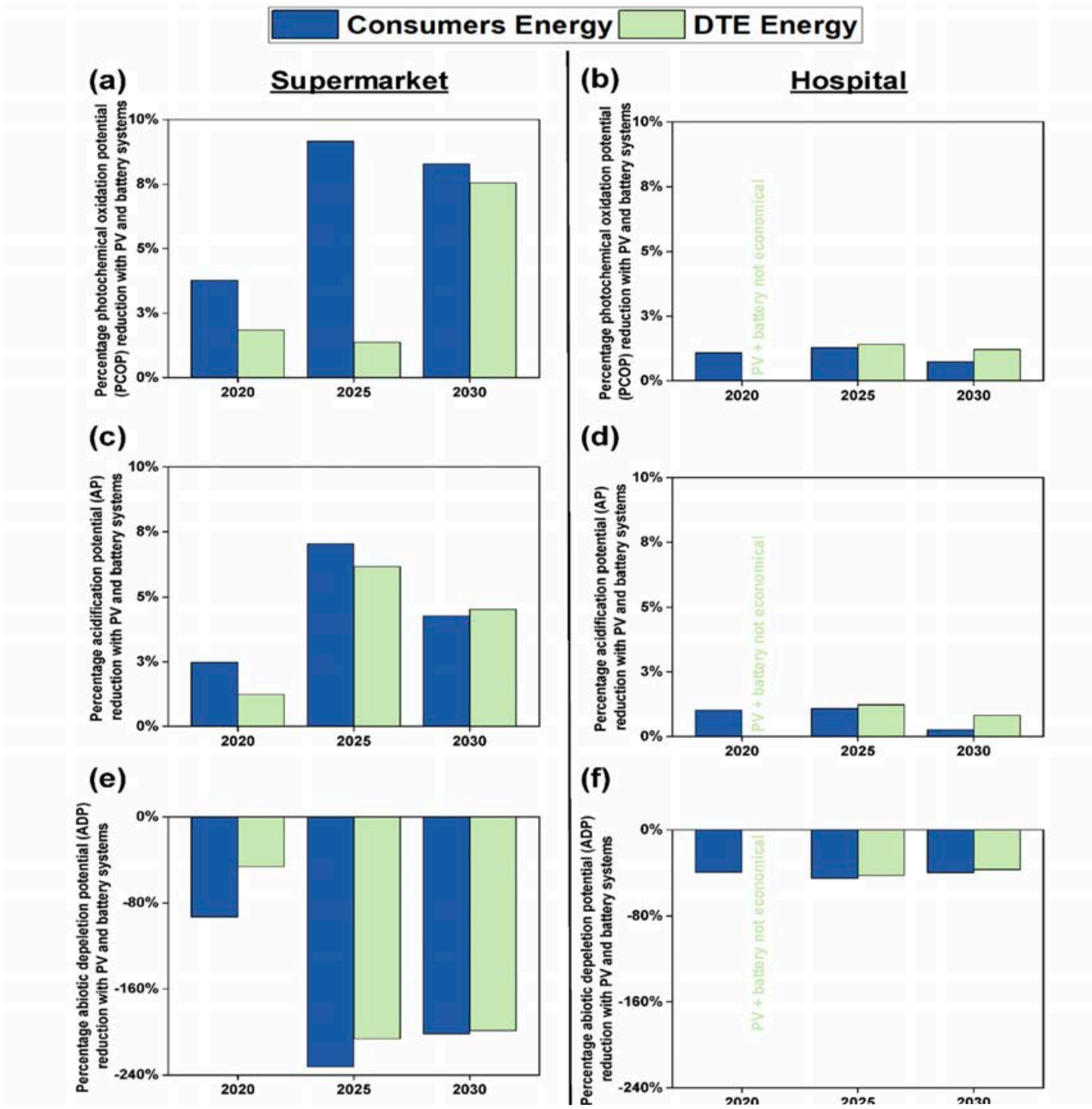

Figure 29. Percentage reduction in photochemical oxidation potential (PCOP) ((a) and (b)), acidification potential (AP) ((c) and (d)), and abiotic depletion potential (ADP) ((e) and (f)), compared to baseline (no solar or storage) when solar plus storage systems were installed in the supermarket and hospital building types in Consumers Energy and DTE Energy territories in the years 2020, 2025 and 2030.

Figures 28 and 29 show that all four buildings had an increase in the ADP (0.4 to 3 times) compared to the baseline due to the addition of solar plus storage systems because non-renewable resources are required to build these systems. In addition, the ADP of grid electricity also increased by 46 percent from 2020 to 2030 because a higher percentage of electricity will come from solar and wind energy in 2030.

APPENDIX C: STEP MODELING

Assumptions

- Fossil fuel prices are based on the Reference Case scenario in the Annual Energy Outlook published by EIA. To capture seasonal volatility, natural gas and coal monthly fuel prices are averaged from 2018 and 2020 delivered fuel prices for the electric power industry, then indexed based on the price differentials per MMBtu between years in the Annual Energy Outlook.
- Fixed and variable costs for new and existing resources are taken from the NREL Annual Technology Baseline moderate scenario.
- The roundtrip efficiency of energy storage is assumed to be 85 percent in 2025, 86 percent in 2030, 88 percent in 2040, and 90 percent in 2050.

2025 Scenario: Current Utility IRP Pathway

The 2025 model run replicates the publicly announced, near-term retirements and capacity expansion commitments made by DTE and Consumers Energy in their most recent IRPs.

Retirements

The 2025 model run retires Dan E Karn Unit 3 and Unit 4 in 2023. Units 3 and 4 are natural gas-fired generators with nameplate capacities of 693 MW and 710 MW, respectively. Unit 3 has a summer capacity of 593 MW and a winter capacity of 618 MW. Unit 4 has a summer capacity of 465 MW and a winter capacity of 531 MW. The retirement of Units 3 and 4 are in addition to the previously announced retirement of Units 1A, 1B, 2A, and 2B. These four generators are subbituminous coal-fired generators with nameplate capacities of 136 MW each. Collectively, the retirement of all six Dan E Karn generators represents 1,946 MW of nameplate capacity, 1,566 MW of summer capacity, and 1,662 MW of winter capacity.

In 2021, Consumers Energy also announced the accelerated retirement of all three coal-fired generating units at J.H. Campbell Generating Plant by 2025. Unit 1 has a nameplate capacity of 265 MW, a summer capacity of 260 MW, and a winter capacity of 260 MW. Unit 2 has a nameplate capacity of 379 MW, a summer capacity of 334 MW, and a winter capacity of 360 MW. Unit 3, the largest and newest unit, completed in 1980 has a nameplate capacity of 917 MW, a summer capacity of 841 MW, and a winter capacity of 842 MW. Combined, the retirement of J.H. Campbell units 1, 2, and 3 represent 1,561 MW of nameplate capacity, 1,435 MW of summer capacity, and 1,462 MW of winter capacity.

DTE Electric Company announced the retirement of several coal-fired power plants by 2022, including St. Clair units 2, 3, 6, and 7, Trenton Channel, and River Rouge. St. Clair Units 2 and 3 each have a nameplate capacity of 156 MW. Units 6 and 7 have a nameplate capacity of 353 MW and 545 MW, respectively. Combined, St. Clair units account for 1,210 MW of nameplate capacity, 1,065 MW of summer capacity, and 1,100 MW of winter capacity. St. Clair Units 11, 12A, and 12B will remain operational and operate on oil and natural gas. The closure of Trenton Channel, a subbituminous coal-fired plant with one generating unit, will retire 536 MW of nameplate capacity, 495 MW of summer capacity, and 495 MW of winter capacity. Finally, River Rouge Unit 3 will retire 358 MW of nameplate capacity, 272 MW of summer capacity, and 280 MW of winter capacity.

Other notable retirements include Palisades Nuclear Plant, owned by Entergy Nuclear Palisades LLC, in 2022, representing 812 MW of nameplate capacity. Lansing Board of Water & Light retired coal-fired Eckert Station Units 4, 5, and 6 in 2020 combining for 240 MW of nameplate capacity, while Erickson Station, a 155 MW coal-fired plant is scheduled for retirement in 2025. The City of Grand Haven retired both their 7 MW diesel plant and 80 MW coal-fired power station, J.B. Sims in 2020.

Completed or planned retirements by 2025 account for 6,909 MW of nameplate capacity, 6,031 MW of summer capacity, and 6,252 MW of winter capacity in MISO Zone 7. Fossil plant retirements occurring in or before 2025 were assumed to be unavailable for the entirety of the 2025 model scenario.

Total capacity of retirements by fuel source:
- Nuclear: 812 MW
- Natural Gas: 1,413 MW
- Coal: 4,683 MW

Additions
According to the operable and proposed generator list from EIA-860, capacity of solar in 2025 is 294 MW and capacity of wind is 2,194 MW. This does not include all proposed, planned, or approved capacity additions. It only includes projects close enough to operation to be included in the proposed generator list from 2019. Other projects with a shorter construction time will be built by 2025.

Additional capacity of wind and solar is modeled for 2025 using utilities' public IRPs. Michigan's two large investor-owned utilities, DTE and Consumers Energy, have committed to significant renewable energy additions over the next three decades. While the rate of renewable project completion relative to public commitments is somewhat uncertain, the following renewable capacity additions have been announced. By 2025, Consumers Energy accumulates 2,100 MW of additional solar capacity and 230 MW of wind capacity over 2020 levels. DTE Electric Company accumulates 800 MW of solar capacity and 225 MW of wind capacity over 2020 amounts. In the 2025 modeling scenario, the capacity factors for existing solar and wind resources are 13 and 33 percent, respectively. These capacity factors are calculated from actual 2018 hourly generation profiles from the respective utilities. New wind and solar resources are modeled with higher, regionally appropriate capacity factors, primarily attributable to technological improvements. New solar projects are modeled using a capacity factor of 18 percent due to the strong trend toward single-axis tracking rather than fixed tilt solar projects in the upper Midwest region.[383] New wind projects are modeled using a 39 percent capacity factor due to the trend toward higher hub heights, larger turbine sizes, and more efficient operation.[384]

In 2023, Consumers Energy plans to purchase the New Covert Generating Facility. The plant, which currently operates in the PJM wholesale market, will be transferred to the MISO market. New Covert Generating Facility is comprised of three combined cycle generators, each with a nameplate capacity of 147 MW, and three combustion turbine generators, each with a nameplate capacity of 245 MW. Combined nameplate capacity at New Covert is 1,176 MW, with a summer capacity of 1,077 MW and a winter capacity of 1,164 MW.

Total capacity of additions by fuel source:
- Natural Gas: 1,176 MW
- Solar PV: 2,900 MW
- Wind: 455 MW

[383] According to Lawrence Berkeley National Laboratory, Michigan's weighted average capacity factor for utility-scale solar PV was 17.1% through 2020. See https://emp.lbl.gov/pv-capacity-factors.

[384] According to Lawrence Berkeley National Laboratory, Michigan's weighted average capacity factor for utility-scale wind was 33% through 2020 with capacity factors as high as 42%. See https://emp.lbl.gov/wind-power-performance.

Results

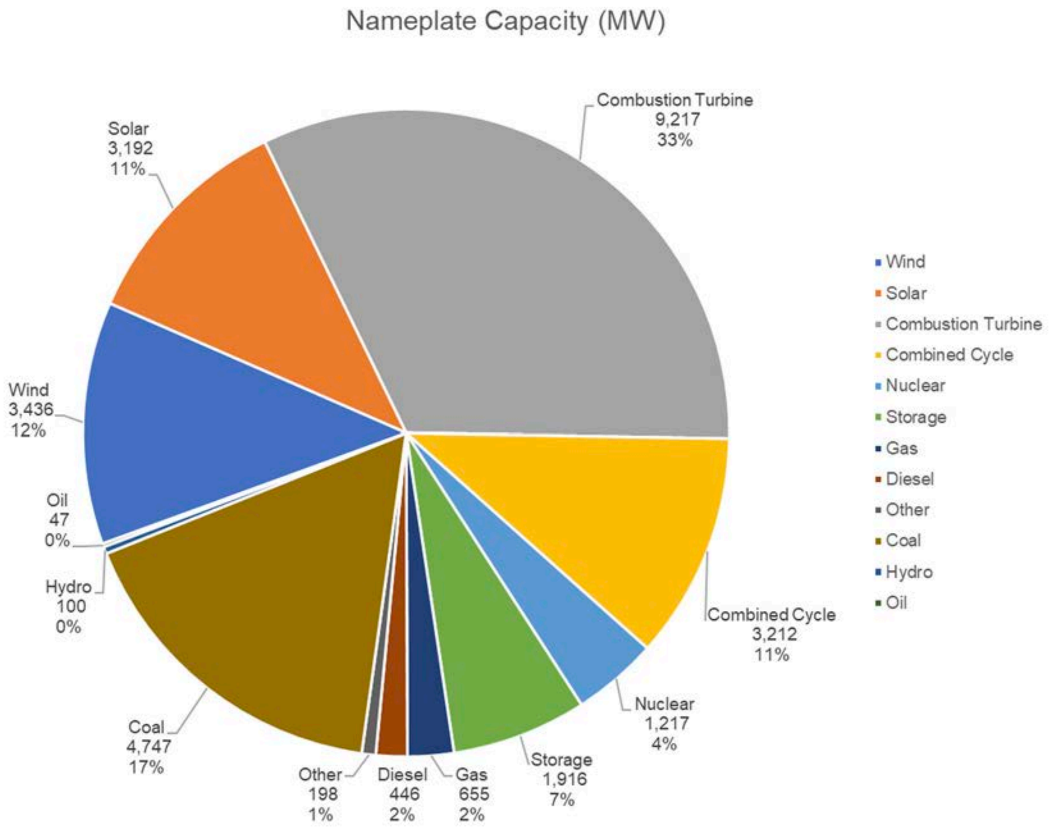

Figure 30. Percent nameplate capacity (MW) by generator type under the 2025 scenario. Note that the nameplate capacity (1916 MW) of Ludington is included.

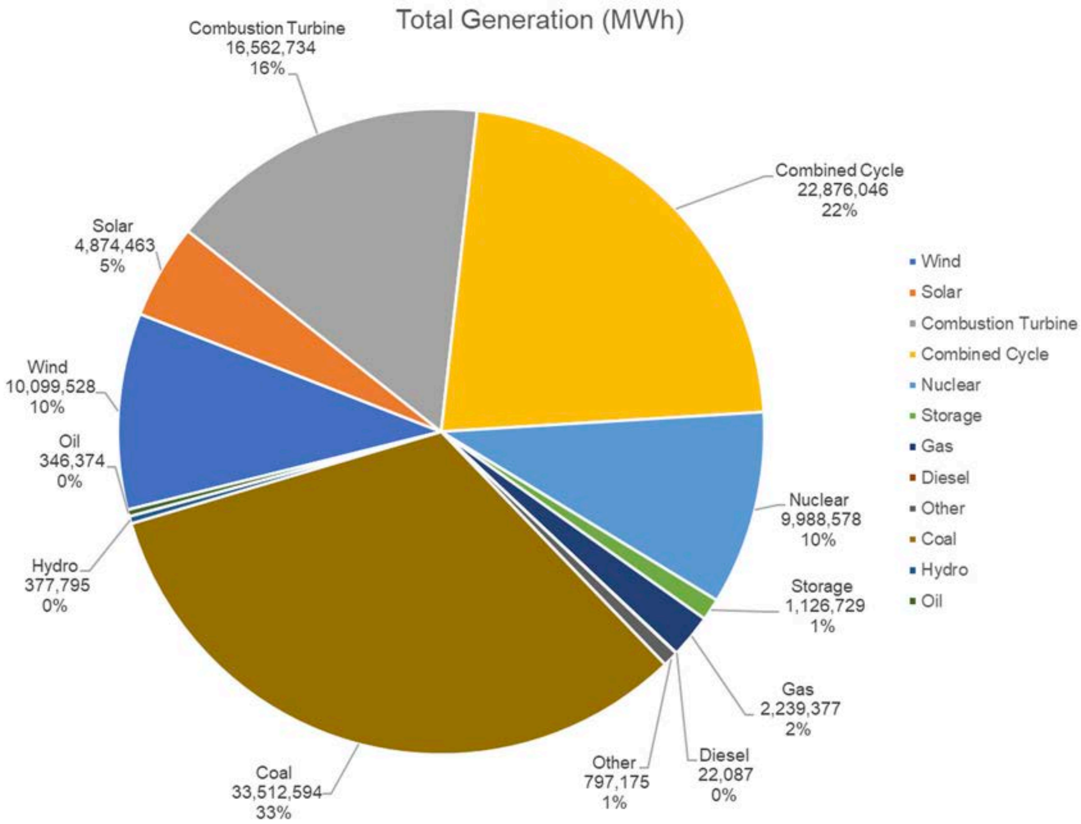

Figure 31. Total energy generation (MWh) by generator type under the 2025 scenario. Note that the approximate total discharge energy (11,500 MWh) of Ludington is included.

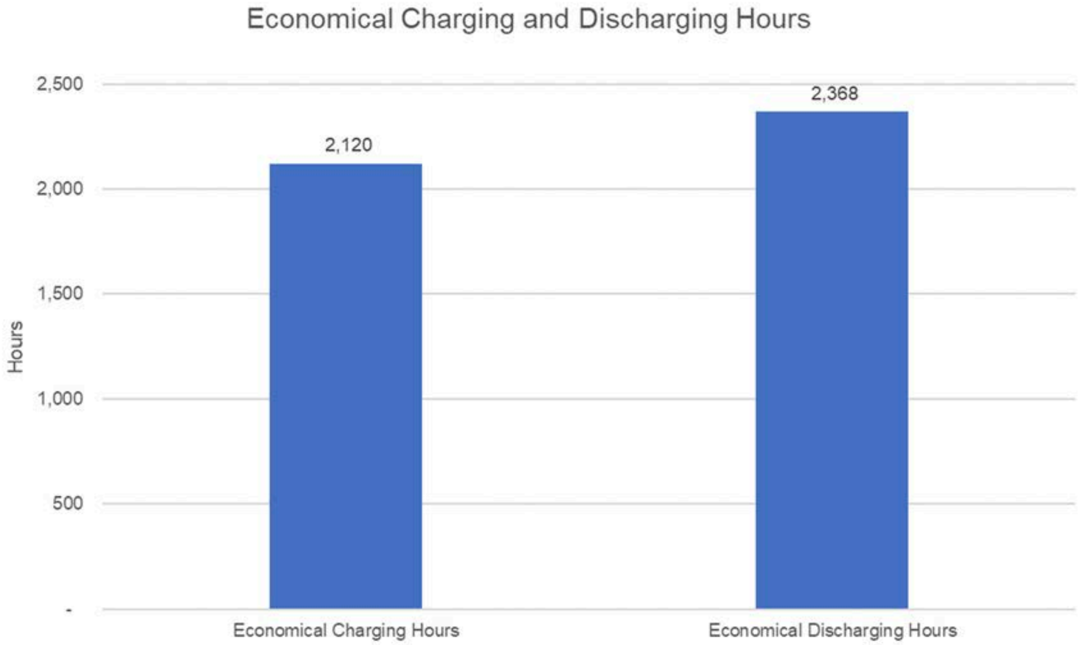

Figure 32. Number of hours for economical charging and discharging of storage under the 2025 scenario.

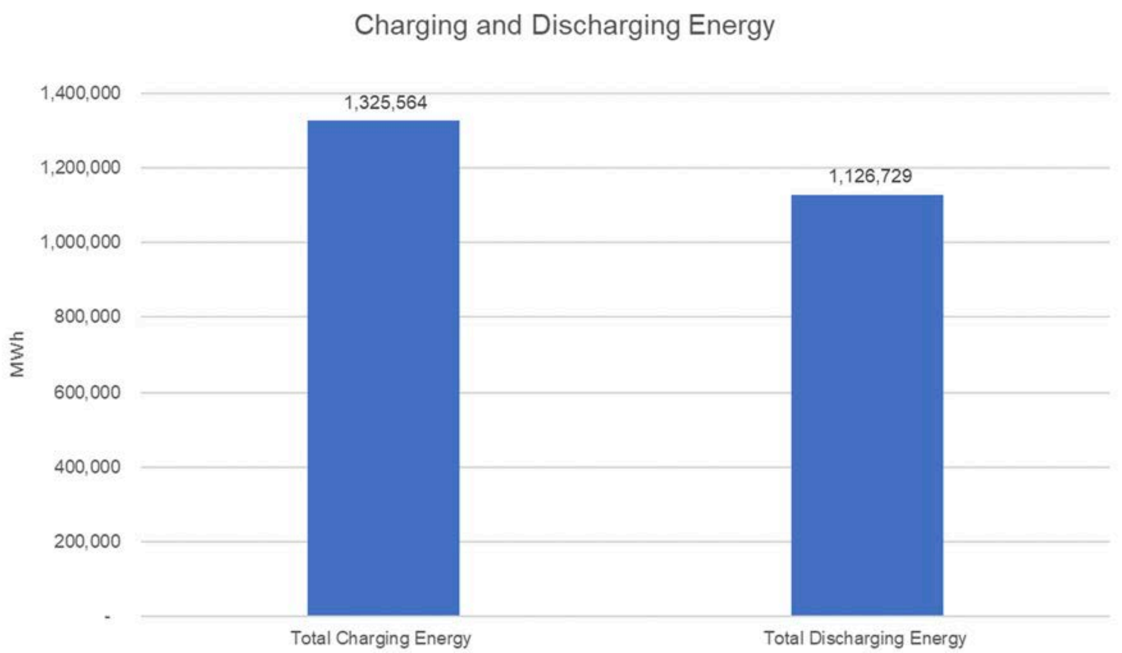

Figure 33. Total amount of energy (MWh) discharged and charged under the 2025 scenario.

In the 2020 modeling scenario, energy storage operated during summer months on near daily cycles due to arbitrage opportunities resulting from load ramping, but intermittently during spring, fall, and winter months. In contrast, the 2025 modeling scenario shows that fossil fuel plant retirements and increasing penetration of renewable energy induce much more consistent energy storage operation throughout the year. With more than 4,400 hours of charging or discharging hours, storage operates more than half of the year's 8,760 hours.

Despite frequent cycling of storage, the 2025 capacity of the modeled fleet of generators is unable to serve load for 35 summer hours of the year. Cumulative unserved load is modest, at 22,042 MWh. Because storage operates during limited economic hours, additional energy storage does little to serve unmet load. In other words, the hours with a generation shortage are not economical hours in which to discharge storage, so increasing storage capacity does not serve unmet load. Additional 4-hour energy storage in increments of 250 MW were modeled with no tangible system reliability benefits at small or large amounts. With the renewable energy additions, the 2025 scenario shows no curtailment, which could be used to charge energy storage even in the absence of arbitrage opportunities. It is assumed that unserved load in 2025 would be served by energy imports in this scenario.

2030 Scenario: Augmented Utility IRP Pathway

The 2030 model run carries out publicly announced retirements and capacity expansions, as well as the retirement of Belle River and Midland Cogeneration Venture, and replacement of Belle River with equivalent generation from new wind and solar resources. Energy storage is also added based on system cost and reliability model results.

Retirements

The 2030 modeling scenario continues the trend of coal plant retirements. DTE retires Belle River Units 1 and 2 in 2027. Belle River Units 1 and 2 are coal-fired steam turbines, each with a nameplate capacity of 698 MW and summer and winter capacities of 635 MW each.

Midland Cogeneration Venture is also retired in the 2030 modeling scenario. While the retirement of this facility is not currently scheduled, its future involvement in the wholesale electricity market is uncertain and Consumers Energy's power purchase agreement with Midland Cogeneration Venture currently ends in 2030. One of the largest cogeneration facilities in the country, Midland Cogeneration Venture is comprised of two large steam turbines, twelve combustion turbines, and two other small generating units. Unit 1 has a nameplate capacity of 410 MW, Unit 2 has a nameplate capacity of 380 MW, and the remaining combustion turbines combine for 1,045 MW.

Total capacity of retirements by fuel source relative to 2025:

- Natural Gas: 1,792 MW
- Coal: 1,396 MW

Additions

By 2030, Consumers Energy adds an additional 5,900 MW of solar to satisfy the remainder of its 8,000 MW solar energy commitment.

A roughly equal amount of additional wind and solar is built to replace the energy generated from Belle River Units 1 and 2. In the 2025 modeling run, Belle River Units 1 and 2 operate at around a 75 percent capacity factor, generating roughly 9,300,000 MWh. To replace roughly half of Belle River's generation, 1,350 MW of additional wind capacity is needed when operating at a 39 percent capacity factor. To replace the other half of Belle River's generation, roughly 3,000 MW of solar PV operating at an 18 percent capacity factor is built.

Total capacity of additions by fuel source relative to 2025:

- Natural Gas: 1,176 MW
- Solar PV: 8,900 MW
- Wind: 1,350 MW
- Storage 2,500 MW

Results

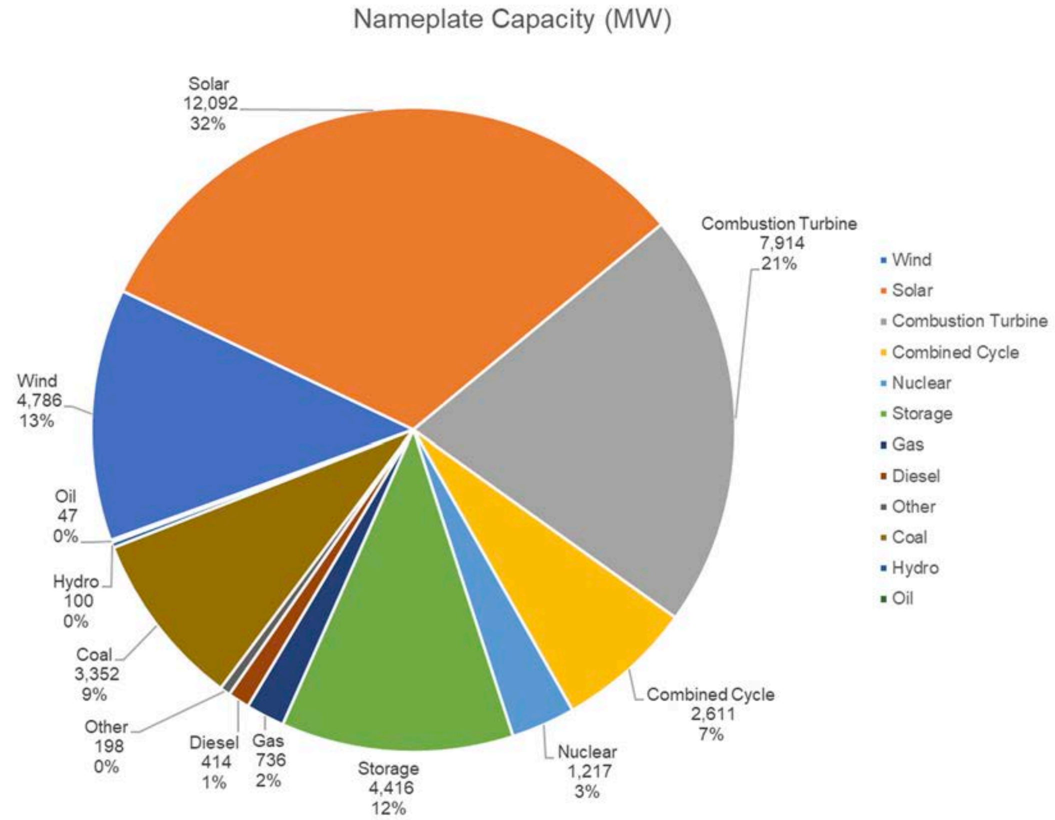

Figure 34. Percent nameplate capacity (MW) by generator type under the 2030 scenario. Note that the nameplate capacity (1916 MW) of Ludington is included.

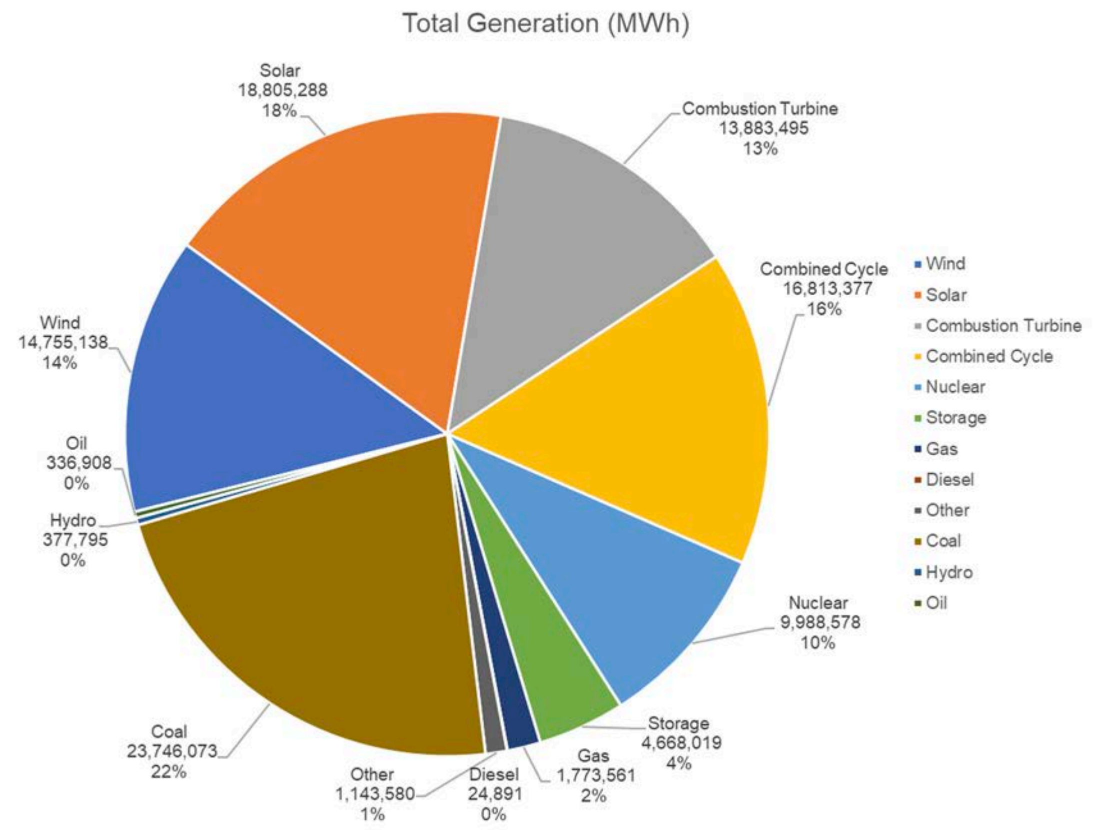

Figure 35. Total energy generation (MWh) by generator type under the 2030 scenario. Note that the approximate total discharge energy (11,500 MWh) of Ludington is included.

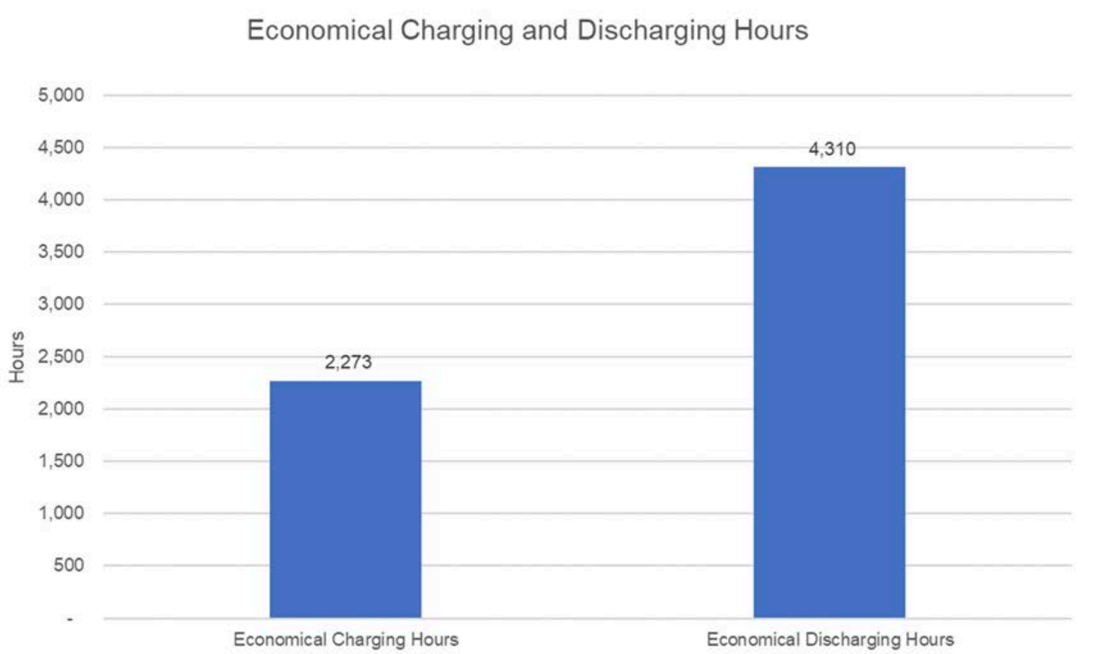

Figure 36. Number of hours for economical charging and discharging of storage under the 2030 scenario.

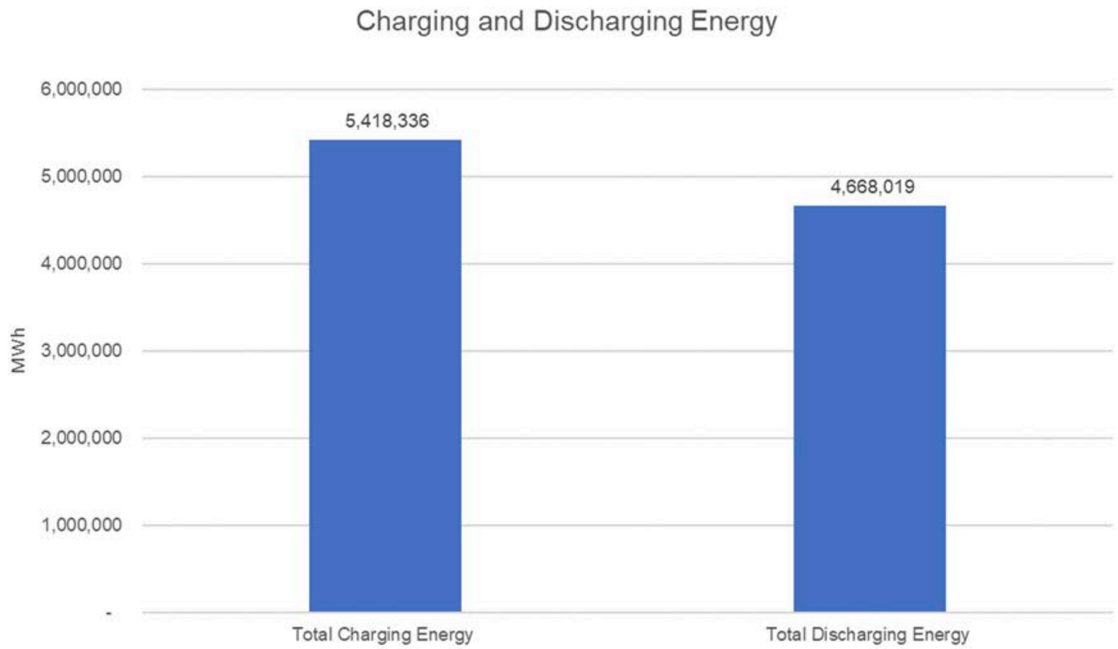

Figure 37. Total amount of energy (MWh) discharged and charged under the 2030 scenario.

The 2030 modeling scenario demonstrates an increase in hours with unserved load relative to the 2025 scenario. With the retirements and additions above, but without additional energy storage built, the 2030 scenario results in 151 hours of unserved load with a cumulative 211,500 MWh of unserved load. With scarcity pricing in the MISO market assumed to rise to $9,000/MWh of unserved load, mirroring other RTOs, additional storage becomes economical to both decrease cumulative unserved load and displace more expensive fossil fuel generation. As LMP variability increases, storage finds more hours in which it is economical to discharge, therefore load shortages decrease as storage capacity increases. When tested in 250 MW increments, the model builds 2,500 MW of additional 4-hour storage above the capacity of Ludington to optimize system reliability while minimizing total system cost. Even with 2,500 MW of additional storage and the prior capacity additions, the 2030 scenario results in 66 hours of unserved and a cumulative 66,000 MWh of unserved load that must be met by a combination of demand response, energy efficiency, or imports.

2040 Scenario: Retirements and Storage

Retirements

With most coal units retired before 2030, there are few foreseeable retirements between 2030 and 2040. By 2040, Monroe will be the last large coal plant in Michigan. In the 2040 scenario, DTE retires Monroe Units 1, 2, 3, and 4. Its four units have a combined nameplate capacity of 3,280 MW. In the 2030 modeling scenario, Monroe's four units operated at a roughly 86% capacity factor and generated a total of 25,000,000 MWh over the year.

Total capacity of retirements by fuel source relative to the 2030 scenario:

- Coal: 3,280 MW

Additions

Although 2040 is beyond the planning period addressed in the major utilities' IRPs, it is assumed that wind and solar will continue to be built to satisfy load. By 2040, enough wind and solar capacity is built to replace the roughly 25,000,000 MWh generated by Monroe. New wind resources built by 2040 total 4,100 MW above 2030 levels. New solar resources built by 2040 total 7,200 MW above 2030 levels.

Total capacity of additions by fuel source relative to 2030 scenario:

- Solar PV: 7,200 MW
- Wind: 4,100 MW
- Storage: 1,500 MW

Results

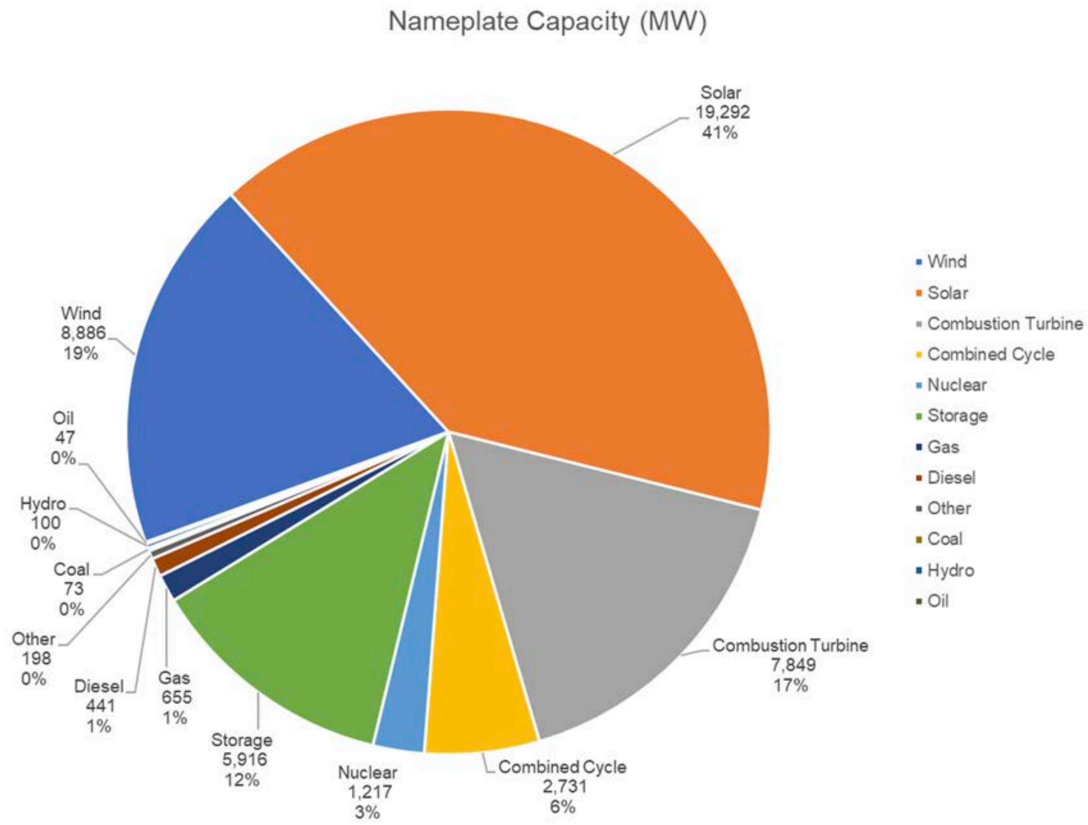

Figure 38. Percent nameplate capacity (MW) by generator type under the 2040 scenario. Note that the nameplate capacity (1916 MW) of Ludington is included.

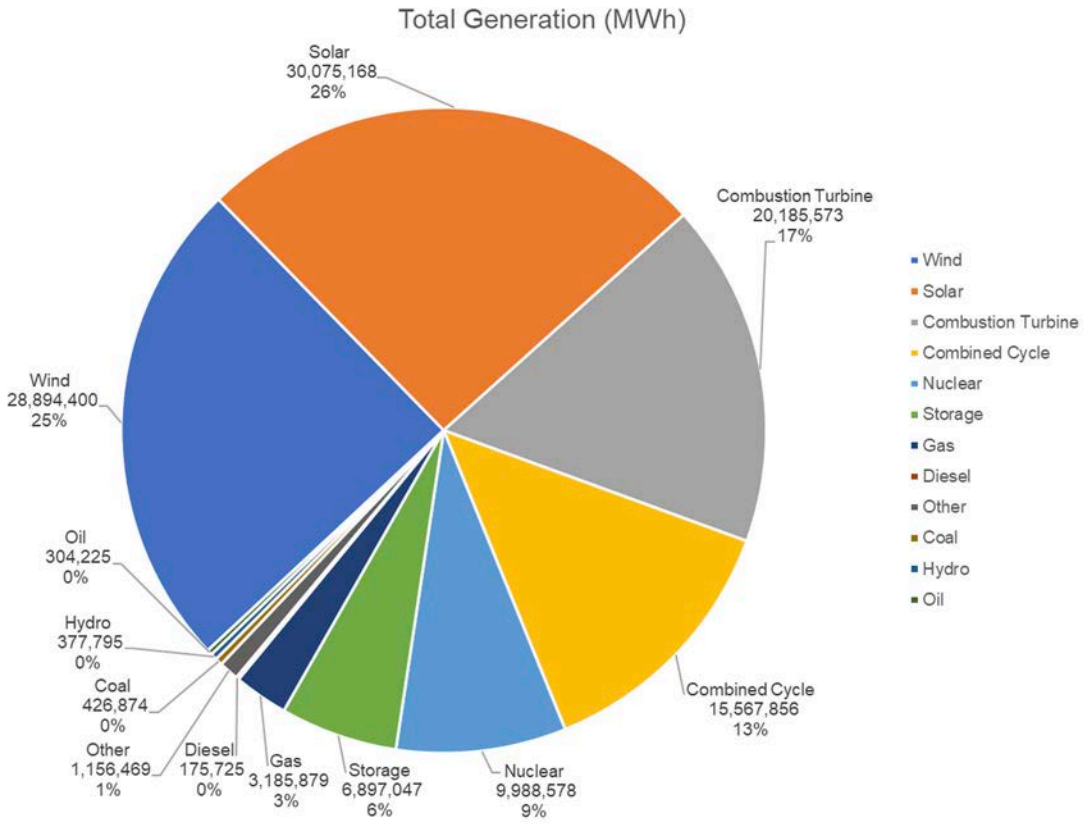

Figure 39. Total energy generation (MWh) by generator type under the 2040 scenario. Note that the approximate total discharge energy (11,500 MWh) of Ludington is included

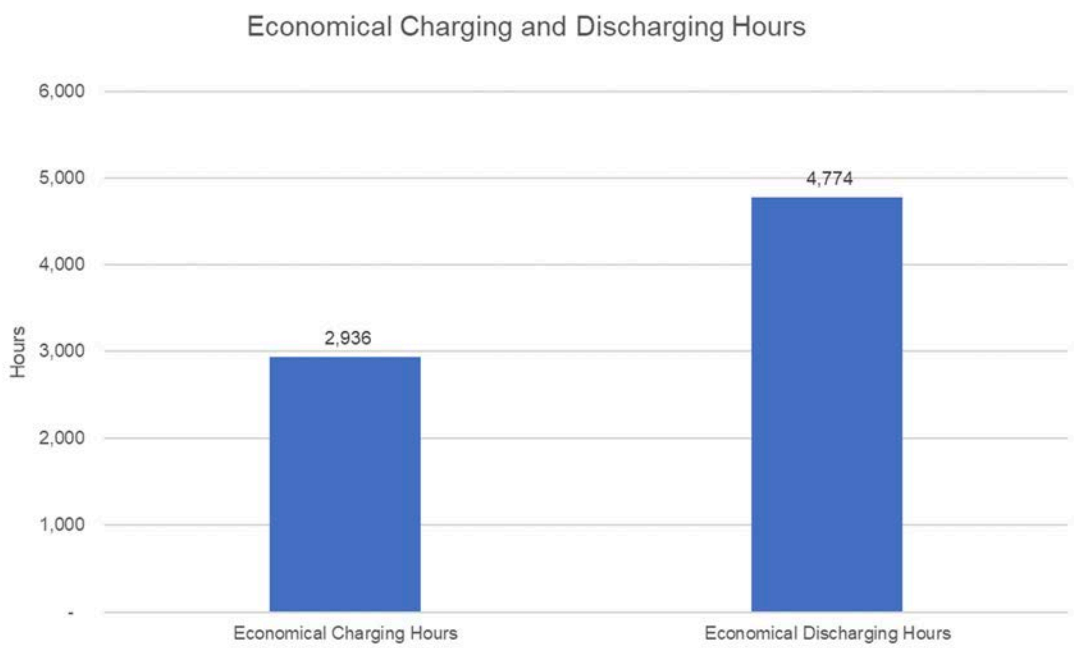

Figure 40. Number of hours for economical charging and discharging of storage under the 2040 scenario.

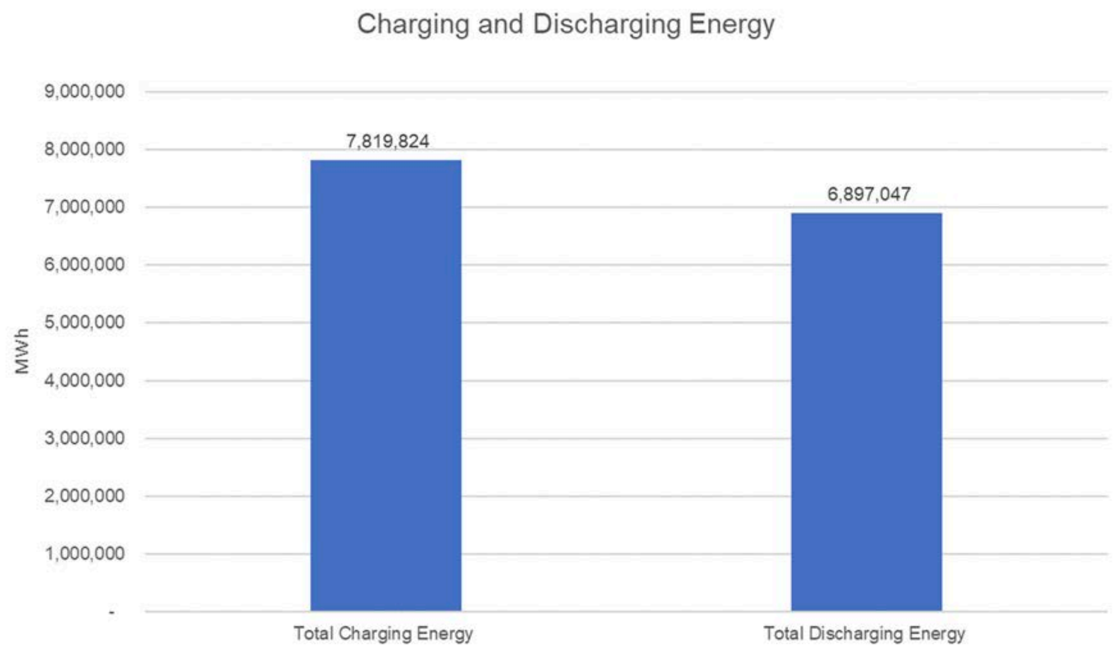

Figure 41. Total amount of energy (MWh) discharged and charged under the 2040 scenario.

By 2040, all baseload coal plants are retired, and system load net of renewable energy shows a high level of volatility and increased unserved load. Storage is economic to charge or discharge in nearly every hour of the year and cycles almost daily, even in shoulder seasons. The number of hours with curtailment increases to 1,067 and storage charges from curtailed energy in hours in which it would be otherwise uneconomic to charge. Excess renewable generation and curtailment allows for energy storage to charge at zero cost. Thus, energy storage maintains a higher state of charge entering discharge periods relative to previous scenarios in which storage did not have a charging opportunity between discharge periods. Given the additions and retirements for the 2040 scenario, system reliability and cost are optimized with 4,000 MW of 4-hour storage above the capacity of Ludington, a 1,500 MW increase relative to the 2030 scenario. Even with this amount of storage, the system has reliability issues. There are 315 hours in which load is unserved and 405,274 MWh of cumulative unserved load.

2050 Scenario: Carbon-free Bulk Power System

The 2050 scenario models a nearly carbon-free bulk power system. Carbon emissions are constrained to 5 million metric tons.

Retirements

In the 2050 modeling scenario, Fermi nuclear plant is the only additional retirement with a nameplate capacity of 1,217 MW.

Additions

In 2050, wind, solar, and storage make up the majority of capacity and generation.

Total capacity of additions by fuel source relative to 2040 scenario:

- Solar PV: 16,500 MW
- Wind: 12,595 MW
- Storage: 13,000 MW

Results

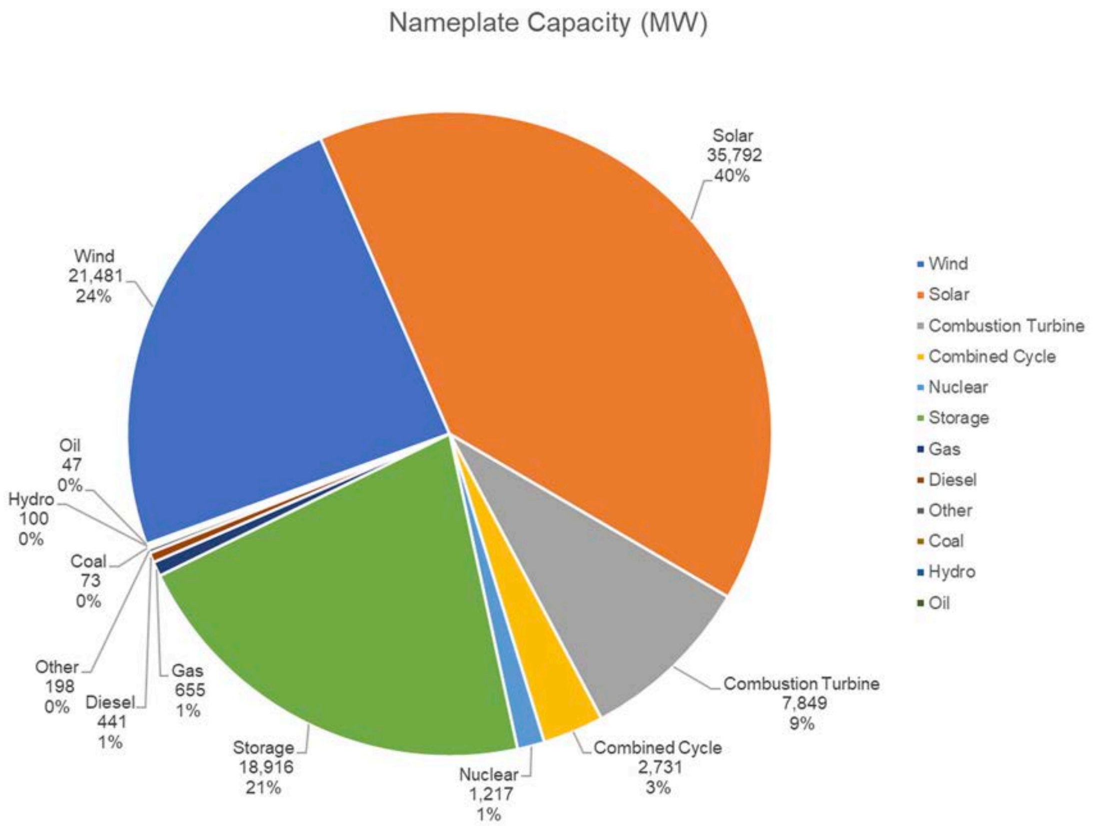

Figure 42. Percent nameplate capacity (MW) by generator type under the carbon-free scenario. Note that the nameplate capacity (1916 MW) of Ludington is included.

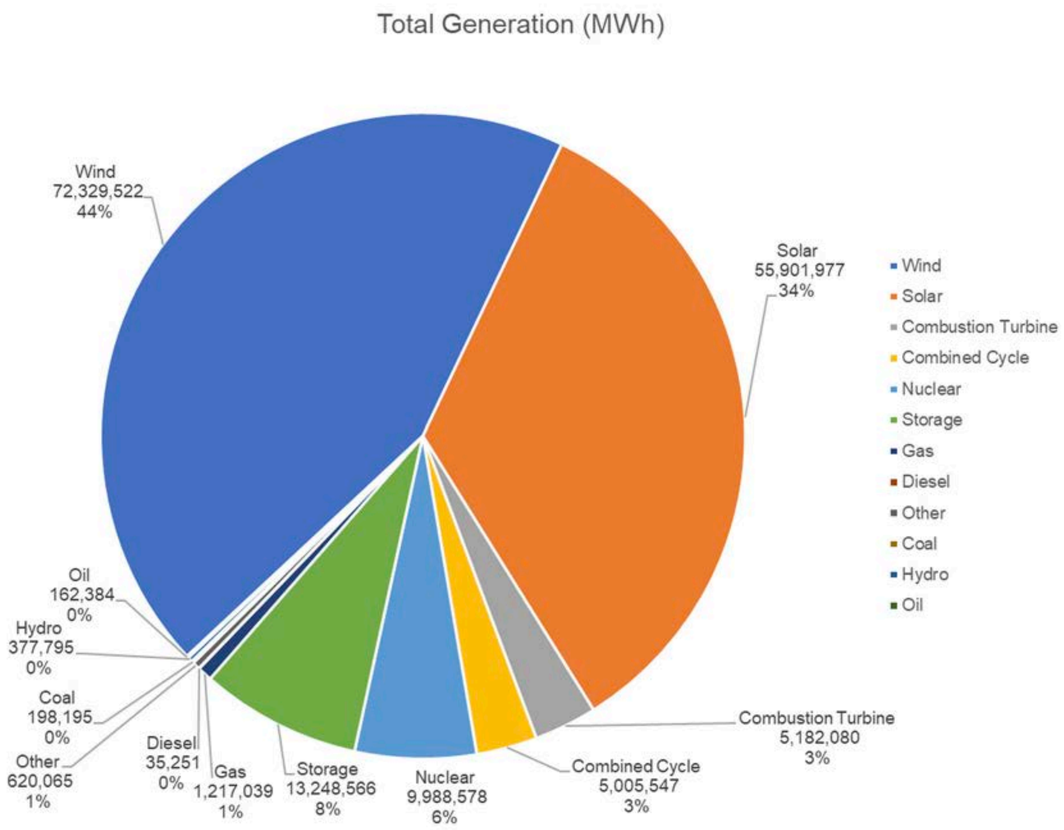

Figure 43. Total energy generation (MWh) by generator type under the carbon-free scenario. Note that the approximate total discharge energy (11,500 MWh) of Ludington is included.

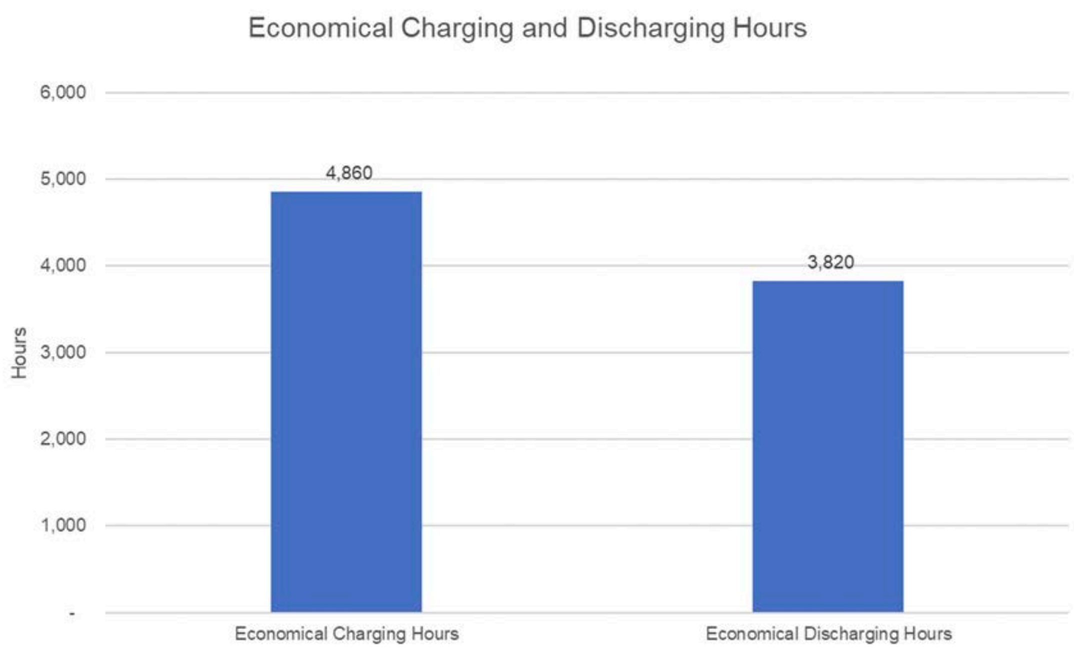

Figure 44. Number of hours for economical charging and discharging of storage under the carbon-free scenario.

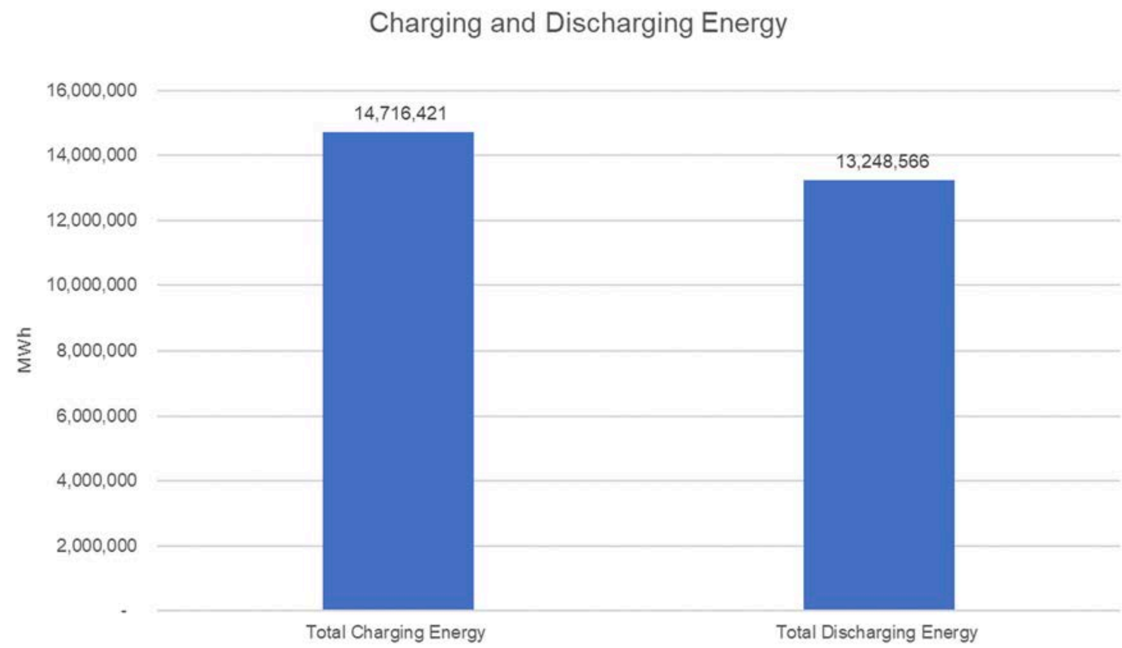

Figure 45. Total amount of energy (MWh) discharged and charged under the carbon-free scenario.

In the 2050 scenario, renewables generate energy in excess of load (curtailment) in more than 4,900 hours of the year. More than 99 percent of the 14.7 million MWh of energy used to charge storage is free, excess renewable generation rather than energy from fossil fuel generators.

The system is unable to meet load in only 55 hours. In all hours in which there is unserved load, storage is actively discharging. With the repeated qualifier that our load shape did not simulate flexible load from demand response, heating electrification, vehicle-to-grid storage, critical peak pricing, or imports, this finding suggests that additional storage could further improve grid reliability, though these load modifiers could likely prevent reliability issues in the first place. Increasing storage, either duration or capacity, would also displace much of the remaining energy from fossil fuel generation, further lowering carbon emissions.

While the capacity of wind, solar, and storage additions are large, it is important to understand that this modeling exercise assumes a largely unmodified load shape based on to 2018. With the committed capacity additions of solar by Consumers Energy and DTE's public carbon reduction commitments, it is not unreasonable to assume DTE matches or exceeds the amount of new solar built by Consumers. Remaining solar capacity could feasibly be installed on rooftops. Emerging technologies and cost declines in existing technology, such as residential battery storage, can shift and smooth residential load profiles. Assuming a highly electrified vehicle fleet opens opportunity for vehicle-to-grid storage to serve and smooth load, lessening the need for such large capacity investments.

APPENDIX E: LIFE-CYCLE ASSESSMENT OF FTM STORAGE

Methodology

The life cycle carbon footprint of electricity was calculated for each type of power plant by adding the direct carbon emissions from the individual generators calculated by the STEP8760 model to the upstream life cycle impact based on life cycle inventory model. For example, the upstream impacts for coal correspond to the emissions during mining and transportation to the power plant. Wind and solar energy do not have direct carbon emissions but have upstream emissions associated with their manufacturing and transport. An example of these data is shown in Figure 46 for 2025.

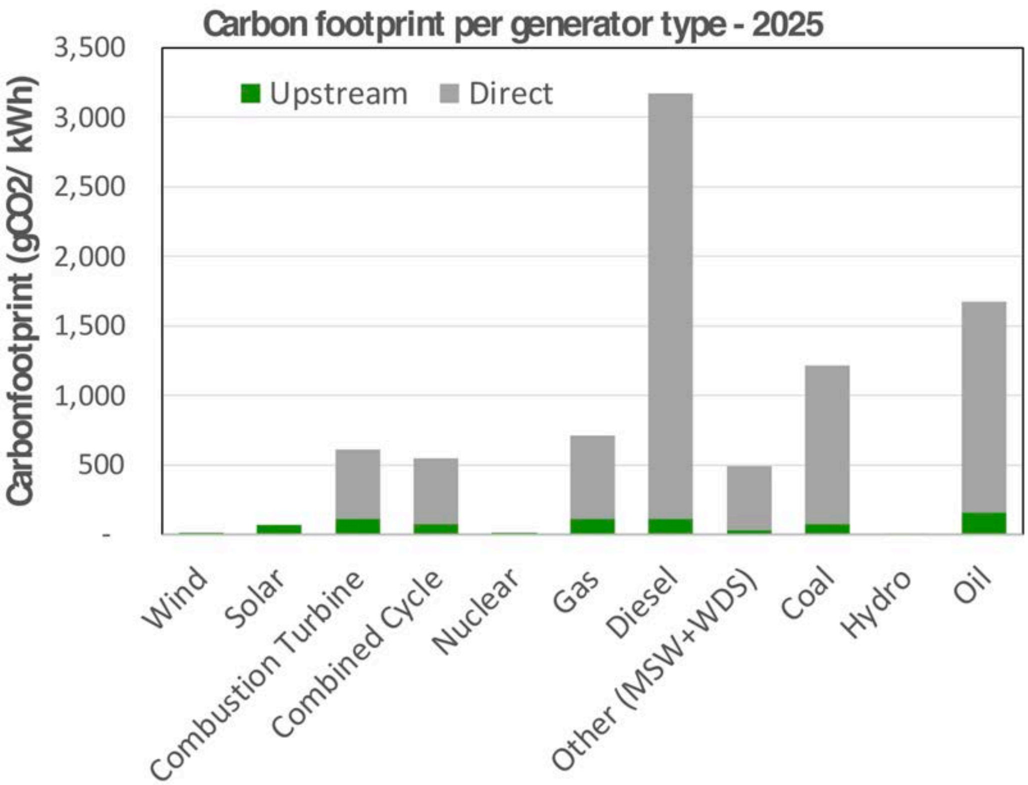

Figure 46. Direct and upstream carbon footprint of various generators for 2025.