Energy Storage in Iowa

Market Analysis and Potential Economic Impact

Prepared for Iowa Economic Development Authority

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EXECUTIVE SUMMARY

The State of Iowa's interest in energy storage began as part of stakeholder discussion in the formation of the 2016 Iowa Energy Plan. Energy storage intersects with several of the seven key areas of the plan including:

- Technology-Based Research and Development
- Workforce Development
- Electric Grid Modernization
- Alternative Fuel Vehicles[1]

In early 2018, the Iowa Energy Office[2] convened the Iowa Energy Storage Committee and invited a diverse group of industry stakeholders to participate. The 2019 Energy Storage Action Plan called for a study to fully analyze the benefits of storage and the barriers to the sustainable growth of the storage industry in Iowa. Synapse Energy Economics, Inc. partnered with SlipStream, Inc. to produce this final report that contains a comprehensive analysis of energy storage technologies and an assessment of the industry's economic development potential in Iowa. The report provides answers to the following four key questions:

1. What is the state of energy storage technologies today?
2. What services can energy storage provide to reduce energy costs and improve reliability?
3. What is the potential size of energy storage deployments and the potential economic impacts in Iowa over the next 15 years?
4. What are the barriers to and best practices for the development of sustainable market opportunities for energy storage in Iowa?

What is the state of energy storage technologies today?

Energy storage is ubiquitous in our modern world, from the small rechargeable batteries that power our cell phones to the hot water stored in a tank for washing dishes and showering. Today, however, there is limited energy storage used in conjunction with the electric power grid. All energy storage systems used in conjunction with the power grid represent a demand for electricity when charging and a supply of electricity when discharging. Energy storage systems are scalable and can be engineered to serve many

[1] Iowa Economic Development Authority and the Iowa Department of Transportation. December 2016. Iowa Energy Plan: Executive Summary. Available at http://www.iowaenergyplan.org/docs/IEPExecutiveSummary.pdf.

[2] The Iowa Energy Office is housed within the Iowa Economic Development Authority and is responsible for managing a diverse mix of state, federal and utility-funded programs and initiatives that provide energy-economic benefits for Iowa's citizens, businesses and organizations.

different applications. Table ES-1 list the various energy storage systems that can be deployed to potentially reduce energy costs and improve reliability.

Table ES-1. Energy storage technology types

Storage Type	Description
Batteries	Battery storage, also referred to as electrochemical energy storage, stores electricity as chemical energy in its active materials. A battery consists of two electrodes (electrical terminals) and a chemical called an electrolyte in between them. The electricity is released from a battery when a circuit is created between the positive and negative electrodes. Electric vehicles use lithium-ion batteries and can be used as a grid resource using vehicle-to-grid systems.
Hydrogen	While most hydrogen today is produced through steam-methane reforming using natural gas as the source of methane, electricity can be used to power an electrolyzer which will separate hydrogen (H_2) from water (H_2O) in a process called electrolysis. The hydrogen can be used as a fuel for a variety of applications. One application is to use hydrogen in a fuel cell to generate electricity.
Thermal	Thermal storage involves heating or cooling any type of material with high specific heat and discharging the medium at a later time. The most basic (and ubiquitous) example is a residential storage hot water heater, which can be controlled to take advantage of its inherent storage potential. Thermal energy storage systems have been in use for decades in buildings, yet this approach is still under development for electric grid applications.
Mechanical	Mechanical storage uses physical-mechanical processes to store energy. Pumped hydro storage (PHS) is an example of this approach. PHS has the most installed capacity of any storage technology on the market. As of 2018, the United States had 22.9 GW of installed PHS capacity. PHS requires specific geological features including large elevation differences over a short horizontal distance, which is not common in Iowa. Another form of mechanical energy storage uses electricity to spin up a small turbine, called a flywheel, that releases energy in short bursts when needed.
Compressed Air	Compressed air energy storage (CAES) technology uses compressors powered by electricity to compress air until it is ready to be injected and stored in underground reservoirs. When the compressed air is released, it can spin a turbine to generate electricity. One of the major limitations of CAES is that it relies on existing geological formations such as exhausted salt mines or some other natural reservoir to hold the compressed air before it is released.

This report focuses on battery energy storage systems. Lithium-ion batteries are the fastest-growing storage technology in the world. Large format lithium-ion batteries are used in a variety of applications such as electric vehicles, stationary systems used in homes and businesses, and increasingly by electric utilities as part of modernizing the electric grid. Lithium-ion battery system costs have decreased drastically over the past few years and continue to decrease rapidly. This cost decrease is mostly driven by economies of scale in manufacturing to meet the demand for batteries from the electric vehicle market. In less than a decade, Lithium-ion batteries experienced an 87 percent decrease in costs.[3] Costs

[3] Bandyk, M. December 2019. "Battery prices fall nearly 50% in 3 years, spurring more electrification: BNEF." *Utility Dive*. Retrieved from https://www.utilitydive.com/news/battery-prices-fall-nearly-50-in-3-years-spurring-more-electrification-b/568363/.

continue to fall for every component that goes into a complete battery system. This includes cells, modules, and balance of system components.[4]

What services can energy storage provide to reduce energy costs and improve reliability?

Front-of-the-meter (FTM) energy storage applications refer to systems that are located on the utility side of the meter. These systems are typically owned and operated to provide grid-level services and can be hundreds or tens of thousands of kilowatts (kW) in size with durations from 1–4 hours.

Grid operators require a suite of services from generators to help maintain reliability and the power quality of the grid. These services are commonly referred to as ancillary services. Ancillary services include frequency regulation, voltage support, black start services, reserves, and reactive power support. Many storage technologies can provide grid operators with these services. Lithium-ion batteries have proven to be capable of meeting all the technical requirements to provide these services.

Grid operators must make sure that sufficient generation, transmission, and distribution capacity is available to serve customers and provide a reserve margin in case some part of the system fails. Investments in FTM storage systems can provide capacity for grid operators, thereby avoiding investments in traditional grid technologies that provide the needed capacity.

As electric grids integrate more and more variable forms of renewable energy, energy storage will almost certainly play an important role. FTM energy storage systems can help to manage the intermittent production of wind and solar to ensure that energy is available when it is needed. This is a potentially important role for storage in Iowa given the large amount of wind generation that currently exists in the state. Each year, a fraction of the wind power generated in Iowa is not delivered to the grid or "curtailed" due to constraints on the grid. If this energy could be stored and sold at a later time, we estimate that this could results in $25.6 million annually in increased revenue to wind plant owners.

FTM energy storage systems can provide many additional benefits. Energy storage can be used to store low-cost energy and then discharge that energy during high price periods. This is referred to as energy arbitrage. FTM energy storage systems can also provide resilience benefits if integrated with larger microgrids that can support city blocks or neighborhoods during prolonged power outages.

Battery storage systems that are sited in a home or business are referred to as behind-the-meter (BTM) systems. This means that the battery system is on the customer-side of the meter providing benefits primarily to homeowners and businesses themselves. BTM system owners charge the battery by purchasing electricity from their local power company and then use the stored energy to provide economic or resilience benefits. Residential battery storage systems are typically in 5–10 kW in size with

[4] Balance of system includes the container, the inverter that converts AC electricity to DC electricity, and other power electronics to manage charging and discharging of the battery system.

3- to 4-hour durations. Battery storage systems for a commercial or industrial business can be as big as 200 kW or more with 2- to 4-hour durations.

For commercial and industrial (C&I) customers, electric bills may contain a demand charge component. Utility demand charges are stated in $/kW and are applied to the peak usage of a facility. For example, a building with peak energy use of 100 kW under a utility with a demand charge of $20/kW would see demand charges totaling $2,000 per month.[5] Battery storage systems can be used to reduce the peak use of a building, thus reducing demand charges. In this case, a 50-kW battery used to shave a building's peak demand would save $1,000 per month. This opportunity is the main factor driving interest in BTM systems within the C&I sectors.

Another use of BTM battery storage is to reduce overall energy costs by storing low-cost energy for use during periods when the price of energy is higher. This is made possible by electricity rate structures that vary the price of energy throughout the day, so-called time of use (TOU) rates or dynamic pricing. Today, however, most residential customers pay the same price per kWh regardless of the time of day.

Adding a battery to a solar energy system allows the system owner to store solar energy produced during the day for later use. This is particularly valuable when net energy metering is not available. Net energy metering allows a solar customer to spin their meter backward when energy production is greater than energy use. This results in bill credits that can be used during the evening and on cloudy days when solar production is low. Net energy metering is not available in some Iowa utility service territories and thus solar paired with storage could emerge as an important BTM application.

One of the primary values of BTM battery storage is for increased reliability and resilience. During a power failure, stored energy from the battery can be used to power critical loads such as home heating and cooling systems or a refrigerator. Businesses benefit from having an emergency source of back-up power by avoiding lost productivity due to a power outage. In larger regional outages, an emergency shelter powered with a battery can provide critical emergency services. In the event of a long-duration power outage, a micro-grid combining energy storage with a source of generation including solar or a gas-fired generator can provide emergency power for days or months as needed.

Some utilities have been experimenting with aggregating individual BTM battery storage systems for use in applications that are typically served with FTM systems. These systems are referred to as "virtual power plants" that rely on software controls and communication systems managed by the utility to aggregate and control hundreds or thousands of devices.

What is the potential size of energy storage deployments and the potential economic impacts in Iowa over the next 15 years?

[5] This is a simplified example for illustrative purposes. A battery energy storage may not perfectly offset demand and demand charges based on the rated capacity of the system. Also, the effect on the demand charges can vary depending upon, among other considerations, the specific tariff structure that the customer is under.

To evaluate the economic development impacts of a growing battery storage system industry in Iowa, we developed projections for low and high deployments between 2020 and 2035. Data from a 2019 study of the energy storage potential in Colorado were adapted for Iowa. Table ES-2 provides the estimated deployments for the low and high scenarios. Energy storage deployments are projected to range from just over 1 GW in 2035 to over 2 GW. We project that over 90 percent of energy storage systems will be deployed in utility-scale FTM applications. Without future price declines or supportive policies and regulations, actual energy storage deployments in Iowa in 2035 could be less than the low scenario.

The scale and pace of energy storage deployments in Iowa, however, will depend on many factors. This includes future capital and maintenance costs for battery storage systems. Reforms within Midcontinent Independent System Operator (MISO) wholesale energy markets that impact the ability of storage to generate revenue providing grid services will also impact the rate of energy storage deployments. The degree to which state regulators incentivize utilities to consider storage as an alternative to traditional utility investments is also a factor. Finally, the degree to which energy planning in Iowa considers the importance reducing carbon emissions and the value of resilience will impact the battery storage market in the coming decade.

Table ES-2. Estimated low and high deployment scenarios for energy storage in Iowa

Scenario	Projected Storage Capacity (MW)				Projected Storage Energy (MWh)			
	2020	2025	2030	2035	2020	2025	2030	2035
High (Storage Generation + BTM)	1	60	1,900	2,130	3	220	7,510	8,320
Low (Load + BTM)	1	240	1,090	1,260	3	940	4,290	4,810

Today, the battery storage supply chain in Iowa is rather limited. The state economic impacts of a growing battery storage industry are estimated to be limited, but positive. We find net job impacts ranging from 298 to 595 full time equivalent jobs and state gross domestic product impacts from $13 million to $24 million per year. This could change, however, if Iowa attracts new businesses to the state that are part of the battery storage supply chain. In addition, the overall economic impact on the state could be much greater when battery storage systems are used to enable other opportunities. This includes expanding the use of wind and solar generation in the state. This also includes the potential role that battery energy storage systems can play in enabling the use of in-state generation to displace imported fuels.

What are the barriers and best practices to the development of sustainable market opportunities for energy storage in Iowa?

Stakeholder interviews revealed common concerns about barriers to battery storage deployments in Iowa. A key challenge for FTM energy storage deployment in Iowa is the inability of owners to capture the various value streams that storage can provide. Optimizing value streams takes effort in any storage project, but it is exacerbated in Iowa by lack of alignment between MISO and the multiple market participants, as well as a lack of regulatory clarity in general. In addition to the difficulty in capturing the value energy storage provides, the high upfront cost of battery energy storage serves as a barrier to installations in the state. While the cost has been falling in recent years, the current cost continues to be an obstacle to the widespread deployment of energy storage.

The initial cost is also a barrier for BTM installations. Stakeholders stated that batteries are not currently economical as a back-up source of power when compared to fuel-powered generators and that energy rates are typically not high enough to justify the installation of BTM storage. Specifically, utilities mentioned that energy rates are not high enough in their territory for solar-plus-energy storage to save enough money to offset the cost. Battery energy storage is still viewed as a relatively new technology, especially when compared to traditional generation or transmission solutions. The infancy of the technology serves as an additional barrier to widespread adoption—both due to uncertainty about the technology's performance and uncertainty about how market and regulatory frameworks may change in the future.

Because of the broad range of capabilities of energy storage systems, regulatory bodies have struggled to clearly and consistently apply existing policies. As a result, states have begun developing new policies (and policy reforms) specifically targeting electrical energy storage systems. Table ES-3 presents the range of policy and market reforms that various states have pursued to address the barriers to battery storage investments.

Table ES-3. State policy and market reforms to address battery storage investment barriers

Policy type	Brief description	States with this and other policies	States with this policy only	Total
Procurement targets	Requires utilities to install specific amounts of energy storage	CA, CO, MA, NJ, NV, NY, OR		7
Regulatory requirements	Varying requirements for utilities to evaluate and/or plan for energy storage installations, among others	AZ, CA, CO, HI, MA, MD, MO, NJ, OR, VA, VT, WA	CT, ME, MN, NC, NM, TX	18
Demonstration programs	Funding for, state-led pilots of, or regulatory allowance for, individual storage projects	MA, MD, NH, NY, VA, WA	UT	7
Financial incentives	Establishment of discount rates, net metering allowances, tax rebates, or cash payments for BTM storage installations	AZ, CA, HI, MA, MD, MO, NH, NV, NY, OR, VA, VT	SC	13
Consumer protection	Provides interim allowance for BTM energy systems while standards are being developed	CO, NV		2

Source: Pacific Northwest National Laboratory. Energy Storage Policy Database.

This report identified three key barriers to broader implementation of storage in Iowa. These include:

1. Lack of current alignment between storage value and markets

2. The relatively high capital cost of battery systems
3. Uncertainty in the future (for markets, regulation, and battery technology)

Each of the five policy types described in Table ES-3 could be used to address these barriers to some extent. However, the most successful and widespread approaches seen in other states have been **regulatory requirements** and **financial incentives**.

Iowa is home to several top-tier university research centers that could play an important role in evaluating the most promising opportunities to realize the full potential that battery energy storage offers to the state. The existing Iowa Energy Storage Committee provides an excellent mechanism to take the next step to support the development of energy storage in the state to maximize the economic and reliability benefits that battery energy storage can provide. The Committee could expand its stakeholder process to address the three key barriers to energy storage in Iowa identified in this report. This could include convening workshops or a conference to evaluate the efforts that other states have taken discussed in this report within the Iowa context to support the development of the energy storage industry. This could also include engaging with wind and solar industry stakeholders to explore the role that energy storage can play in Iowa to reduce wind curtailments and support the growth of solar energy installations. Greater use of in-state renewable energy sources through electrification of the transportation, buildings, and agricultural sectors could support regional economic development while reducing the environmental impacts of energy consumption.

1. INTRODUCTION

In many ways, Iowa leads the nation in energy innovations. Iowa has decades of experience with wind power and a long history of being a leading producer of wind energy in the nation. Based on data from the U.S. Energy Information Administration, in 2019 wind energy produced over 40 percent of the net electricity generated in the state.[6] The state has nearly 5,100 wind turbines scattered across the gently rolling plains for which the state is known. In addition, Iowa is the leading ethanol-producing state in the nation and is home to one-fourth of U.S. fuel ethanol production capacity, which collectively can produce nearly 4.5 billion gallons of corn-based ethanol each year.[7]

Iowa has identified energy storage as an opportunity to continue its tradition of energy innovation. Specifically, the Iowa Economic Development Authority (IEDA) recognizes energy storage's potential benefits for the state's economy, utilities, building owners, and the regional grid.[8] A 17-member Iowa Energy Storage Committee was formed in 2018 to guide the state's effort to assess the energy storage opportunity, and some investments in energy storage pilots have already been made.[9] The Committee identified a need for a full analysis of the benefits of storage and the barriers to the sustainable growth of the storage industry in Iowa. Synapse Energy Economics, Inc. (Synapse) partnered with SlipStream, Inc. to produce this final report that contains a comprehensive analysis of energy storage technologies and an assessment of the industry's economic development potential in Iowa.

Energy storage is ubiquitous in our modern world, from the small rechargeable batteries that power our cell phones to the hot water stored in a tank for washing dishes and showering. Today, however, there is limited energy storage used in conjunction with the electric power grid.[10] The current electric grid is managed such that the production of electricity is timed precisely with when it is being consumed. It is widely recognized, however, that energy storage will become increasingly important for operating a modern grid. As more and more low-cost renewable resources such as solar and wind are used to produce electricity, many anticipate energy storage will play a central role in managing the variable output of these renewable sources of generation.

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[6] U.S. Energy Information Administration. May 2020. "Iowa State Energy Profile." Available at https://www.eia.gov/state/print.php?sid=IA.

[7] *Ibid.*

[8] Iowa Economic Development Authority, Iowa Energy Office. May 2019. *Energy Storage Action Plan*.

[9] MiEnergy, Iowa State University, and Ideal Energy. November 2019. *Battery Storage in an Energy Efficient Iowa*. 2019 Iowa Energy Summit.

[10] The largest and most established energy storage systems today are pumped hydro facilities that use electricity during periods of low demand or low prices to pump water up to a reservoir at a higher elevation. When the demand for energy is high, the water flows downhill to turn a turbine and generate electricity.

There are numerous energy storage technologies that can enhance electricity production and distribution systems. This report discusses several of these energy storage technologies but primarily focuses on battery energy storage systems.

According to Bloomberg New Energy Finance's (BNEF) latest forecast, global battery storage deployments are poised to expand from 9 gigawatts (GW) as of 2018 to 1,095 GW by 2040. BNEF further projects that the anticipated 122-fold growth in battery energy storage over the next two decades will require $662 billion in new investment.[11] At the same time, analysts are projecting exponential growth in battery electric vehicle (EV) adoption. In 2018 the global EV fleet totaled 5 million and is expected to grow 25 times larger by 2030.[12] EVs of all types reduce our dependence on petroleum-based fuels.

Battery energy storage can provide many benefits to Iowa in stationary applications, in addition to transportation:

- Energy storage can be used to reduce the investments in new generation, transmission, and distribution by shifting energy use from peak demand periods to low demand periods.
- Storage can play an important role in integrating additional wind and solar energy by addressing the challenges associated with fluctuations in production.
- Homeowners, businesses, and critical facilities can use energy storage to reduce electric bills and provide resilience benefits when the larger power grid fails.
- Large systems operated by electric utility companies can be used to provide valuable services to the regional grid through participation in wholesale energy markets.
- Electric vehicles and agricultural equipment can reduce imported fuels with electricity generated within the state.

Today, there are a small number of battery storage systems deployed across Iowa that were developed as research, development, and demonstration projects. Looking forward, rapidly falling prices for battery storage systems and the ability to capture multiple value streams will create growing market opportunities for energy storage in Iowa in the coming decades. Iowa can prepare for these opportunities by examining policies and regulations adopted in other states to support the nascent energy storage industry.

This report assesses potential storage benefits for Iowa and delves into likely barriers to the industry's growth. Section 2 provides an overview of each major energy storage system type. The section also

[11] *Bloomberg New Energy Finance (BNEF)*. July 2019. "Energy Storage Investments Boom As Battery Costs Halve in the Next Decade." Available at https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/.

[12] International Energy Agency. May 2019. Global EV Outlook. Available at https://www.iea.org/publications/reports/globalevoutlook2019/.

provides a brief discussion of the two broad categories of energy storage applications (behind the customer meter and in front of the meter). Section 3 provides a detailed discussion of battery storage market opportunities in Iowa. In Section 4, we present two possible future energy storage deployment scenarios in Iowa. These low and high scenarios are used to assess the potential economic development impacts that Iowa might experience from expanding the use of energy storage in the state. Section 5 discusses energy storage policies to overcome barriers, create incentives, and support best practices. Finally, Section 6 presents our primary conclusions.

2. Energy Storage: Technology Overview

In this section, we provide an overview of energy storage technologies that can be used to store electricity from the grid for future use. This includes an assessment of the technologies' commercial status and costs. We introduce the two key application contexts for battery storage technologies: behind-the-meter (BTM) and in-front-of-the-meter (FTM) systems, which are discussed in greater depth in Section 3.

2.1. Storage Technologies Overview, Commercial Status, and Costs

All energy storage systems represent a demand for electricity when charging and a supply of electricity when discharging. Energy storage systems are scalable and can be engineered to serve many different applications. Energy systems are characterized based on the power rating in kilowatt (kW) or megawatt (MW) and energy storage capacity in kilowatt-hours (kWh) or megawatt-hours (MWh).[13] The power rating determines the rate at which the battery can be charged and discharged. The energy storage capacity determines the storage duration. For example, a 1 kW battery system with 1 kWh capacity has a one-hour duration. If the energy is released at a rate of 0.5 kW the battery would last for two hours before needing to be recharged. It is important to note that energy is lost in the process of charging and discharging a battery, referred to as round trip losses.

Battery storage

Battery storage, also referred to as electrochemical energy storage, stores electricity as chemical energy in its active materials. A battery consists of two electrodes (electrical terminals) and a chemical called an electrolyte in between them. The electricity is released from a battery when a circuit is created between the positive and negative electrodes.[14] As an example, the switch on a flashlight completes the circuit

[13] In terms of power ratings 1 kW is 1,000 watts and 1 MW is equal to 1,000 kW. Similarly, for energy capacity 1 kWh is equal to 1,000 watt-hours and 1 MWh is equal to 1,000 kWh.

[14] Krivik, P., & Bac, P. 2013. Electrochemical Energy Storage. Energy Storage - Technologies and Applications. doi: 10.5772/5222. Available at: https://www.intechopen.com/books/energy-storage-technologies-and-applications/electrochemical_energy_storage.

and delivers the energy stored in the battery to power the bulb. Similarly, when you step on the "gas" pedal of an EV, a circuit is formed, and stored electricity in the onboard battery pack is released to power the vehicle's electric motor.

Though there are numerous different chemical combinations used in modern rechargeable batteries, there are six main types of battery storage technologies on the market today. These include sodium-sulfur batteries, lithium-ion batteries, lead-acid batteries, sodium metal halide batteries, zinc-hybrid cathode batteries, and redox flow batteries. There are further variations within each of these categories that serve many different applications.

Common battery technology

Lithium-ion batteries are the fastest-growing storage technology in the world.[15] The technology is anticipated to reach 158 gigawatt-hours[16] (GWh) installed worldwide by 2024 from just 12 GWh in 2018.[17] As discussed later in this report, large format lithium-ion batteries are used in a variety of applications such as EVs, stationary systems used in homes and businesses, and increasingly by electric utilities as part of modernizing the electric grid.

Figure 1 illustrates how lithium-ion batteries charge and discharge electricity. Electricity is the flow of electrons through a conductor such as a copper wire. As batteries charge, electrons are pushed from the cathode to the anode. To discharge, electrons are released from the anode back to the cathode when a circuit is created.

Battery systems vary greatly in size, ranging from 1 kW to 100 MW.[18] Lithium-ion batteries may also have energy storage capacities of up to 200 MWh or more depending on the application.[19] This large range in power and duration capabilities makes lithium-ion batteries a good option for a variety of applications, including those that require either short duration/high power or long duration/low power. Generally, these types of batteries will last longer if they are operated under the manufacturer's suggested parameters. One important parameter is how low the batteries are drawn down before

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[15] *T&D World*. "Lithium Ion Batteries to Top Energy Storage Tech: Study." 2020. Available at: https://www.tdworld.com/distributed-energy-resources/article/21125807/lithium-ion-batteries-to-top-energy-storage-tech-study#:~:text=Lithium%20ion%20batteries%20will%20be,to%20analysis%20by%20Navigant%20Research.

[16] A gigawatt-hour is a measure of energy and represents 1,000,000 kWh. A typical U.S. household consumes approximately 1,000 kWh per month.

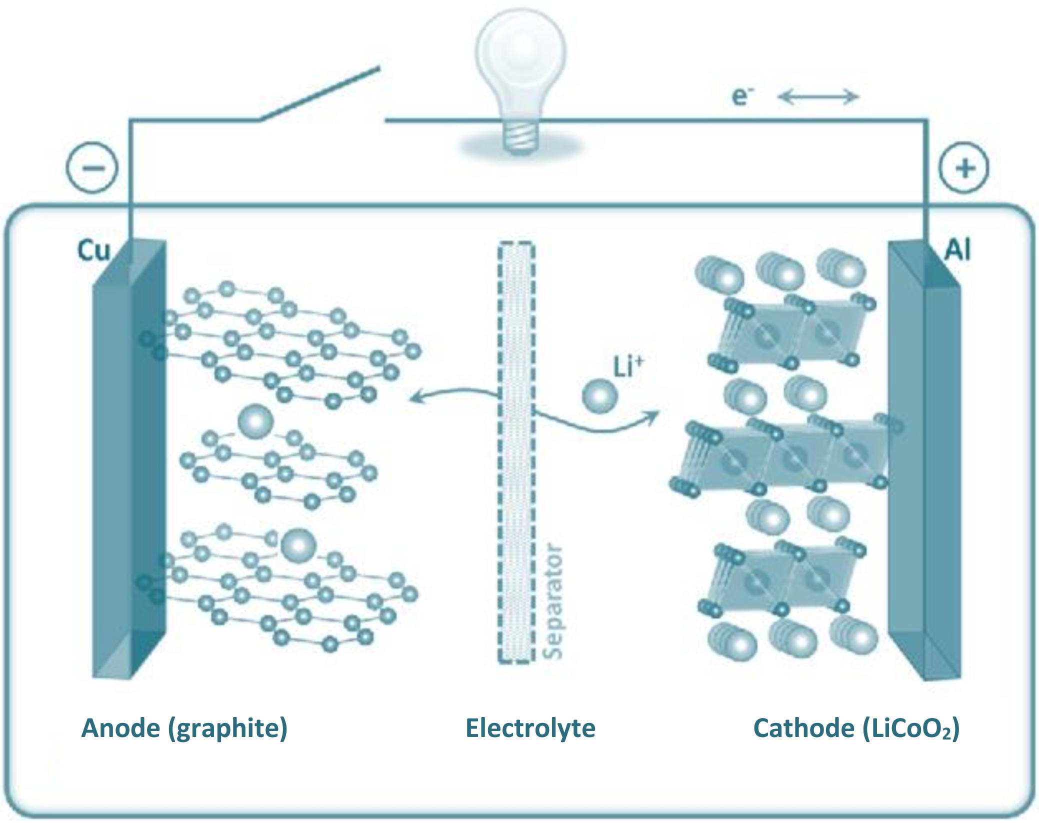
[17] John, J. S. October 2019. "Global Energy Storage to Hit 158 Gigawatt-Hours by 2024, Led by US and China." *GreenTech Media*. Retrieved from https://www.greentechmedia.com/articles/read/global-energy-storage-to-hit-158-gigawatt-hours-by-2024-with-u-s-and-china.

[18] 1 MW is equal to 1,000 kW.

[19] Longer duration storage is still being researched and developed by many companies but is not yet widely commercially available.

recharging (referred to as depth of discharge). Manufacturers often guarantee a certain number of cycles based on a specified depth of discharge.

Figure 1. Lithium-ion charging and discharging mechanics



Source: Goodenough, J. B. and K. Park. 2013. "The Li-ion rechargeable battery: a perspective." Journal of the American Chemical Society. Accessed via https://www.semanticscholar.org/paper/The-Li-ion-rechargeable-battery%3A-a-perspective.-Goodenough-Park/42e965ce07774bc11bf7b270b6249bda7c510fc9.

Other battery types

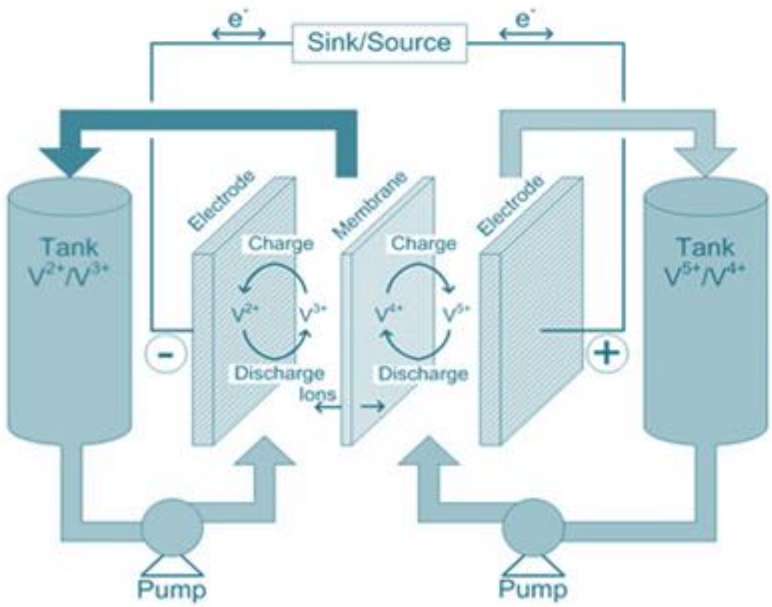
While lithium-ion batteries are the fastest-growing battery technology on the market today, other types of battery storage technologies are at different stages of commercial development. For certain electric grid applications, redox flow batteries are projected to become increasingly cost-competitive in the coming decades.[20] Flow batteries are attractive for their inherent safety features, ability to easily scale, and use for long-duration storage applications.[21] Unlike lithium-ion batteries, flow batteries are able to

[20] Camp, Erin, et al. 2019. *The Future of Energy Storage in Colorado*. Synapse Energy Economics. Available at: https://www.synapse-energy.com/sites/default/files/The-Future-of-Energy-Storage-in-Colorado-19-025.pdf.

[21] Solid Electrode Battery Technology: Energy Storage Association. (n.d.). Retrieved from https://energystorage.org/why-energy-storage/technologies/solid-electrode-batteries/

fully charge and fully discharge safely without fear of degradation.[22] As shown in Figure 2, flow batteries utilize a liquid electrolyte that flows through a membrane between two different tanks to store and release energy. The tanks require more physical space than lithium-ion batteries and the active pumps and other battery components use a noticeable amount of energy to charge and maintain charge.[23] However, as technology continues to advance for flow batteries, this battery is anticipated to become increasingly popular given the technical advantages referenced above over lithium-ion batteries.

Figure 2. Flow battery schematic



Source: Battery University/https://batteryuniversity.com/learn/article/bu_210b_flow_battery.

Electric vehicles as storage

EV passenger vehicle sales are projected to reach 10 percent of global car sales by 2025.[24] As the adoption rate of all-electric and plug-in hybrid vehicles (collectively referred to as EVs) continues to increase, many studies have evaluated the utilization of stored energy in EVs for various purposes.[25,26]

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22 Battery performance tends to decline with use, which is referred to as degradation.

23 This has an impact on the system efficiency, which is characterized as the round-trip losses or how much energy is lost as it cycles from the grid to the battery and back to the grid.

24 McKerracher, Colin, et al. 2020. "Electric Vehicle Outlook 2020." *BNEF*. Available at: https://about.bnef.com/electric-vehicle-outlook/.

25 Steward, Darlene. September 2017. *Critical Elements of Vehicle-to-Grid (V@G) Economics*. National Renewable Energy Laboratory (NREL). Available at: https://www.nrel.gov/docs/fy17osti/69017.pdf.

26 Massachusetts Department of Energy Resources (DOER). February 2020. *Mobile Energy Storage Study*. Available at: https://www.mass.gov/doc/mobile-energy-storage-study/download.

This application is referred to as vehicle-to-grid (V2G), and although not a commercial application today, many pilot projects around the world demonstrate its viability.[27,28] This includes multiple ongoing V2G pilot projects by major automobile manufacturers and technology partners to demonstrate the concept.[29]

EVs come in many different platforms, from passenger vehicles to transit and school buses. This includes growing interest in electric agricultural machinery. The leading global tractor supplier John Deere has announced plans to develop all-electric tractors with autonomous operation.[30] When EVs are not in use for transportation, the batteries in these systems can provide V2G services, thereby increasing the use of the equipment and generating a new revenue stream. As EV adoption expands, V2G applications using the battery systems in EVs may become increasingly viable for a variety of applications.

Hydrogen storage

Electricity can be used to produce hydrogen, which is a fuel that can be used for a variety of applications. One application is to use hydrogen in a fuel cell to generate electricity. A fuel cell is like a battery in that it uses an electrochemical process to produce electricity—in this case from hydrogen. Electricity powers an electrolyzer which separates hydrogen (H_2) from water (H_2O) in a process called electrolysis. That hydrogen can then be stored as pressurized gas in a tank for long periods of time.[31] While hydrogen production today is costly, it does offer the advantage of storing energy over much longer time periods than the battery systems discussed above. Rather than storing energy for hours or days, hydrogen can store energy over months. Solar energy in the summer could produce hydrogen that can be used in the winter months as a fuel for producing electricity or heating buildings. Grid operators and other stakeholders are also beginning to explore converting retired fossil-fuel plants into hydrogen facilities.[32] Hydrogen storage technologies are still developing, but this storage option may play an important role in the future for the electric grid and the transportation sector.

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[27] Lawrence Berkeley National Lab (LBNL). *Los Angeles Air Force Base Vehicle to Grid and Building Integration Project*. Available at: https://building-microgrid.lbl.gov/projects/los-angeles-air-force-base-vehicle-grid.

[28] University of Delaware. May 2011. *Vehicle to Grid Demonstration Project*. Available at: https://www.osti.gov/servlets/purl/1053603.

[29] Green Car Congress. November 28, 2018. “Nissan LEAF helps power company's NA facilities with V2G; Nissan Energy.” Retrieved from https://www.greencarcongress.com/2018/11/20181128-nissan.html.

[30] *Future Farming*. March 2020. “John Deere: ‘We believe in electric tractors. 100%’.” Available at https://www.futurefarming.com/Machinery/Articles/2020/3/John-Deere-We-believe-in-electric-tractors-100-552869E/.

[31] U.S. Department of Energy. n.d. “Hydrogen Storage.” Retrieved from https://www.energy.gov/eere/fuelcells/hydrogen-storage.

[32] Plan advances to convert Utah coal-fired power plant to run on 100% hydrogen with storage. (2020, March 10). Retrieved from https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/031020-plan-advances-to-convert-utah-coal-fired-power-plant-to-run-on-100-hydrogen-with-storage.

Thermal storage

Thermal storage involves heating or cooling any type of material for use at a later time. The most basic (and ubiquitous) example is a residential storage hot water heater, which can be controlled to take advantage of its inherent storage potential. Thermal energy storage systems have been in use for decades in buildings, yet this approach is still under development for electric grid applications.

Thermal storage systems used in buildings are often cost-effective when they use low-cost off-peak electricity to avoid using high-cost electricity during periods of peak use. Several thermal storage options for buildings include:

- **Ice storage.** Conventional chillers or DX cooling units are used to freeze water in insulated tanks in off-peak hours. The ice is later melted to provide space cooling.
- **HVAC chilled water storage.** Chilled water, which is already commonly used for space cooling, is stored directly. This requires more space than ice to meet the same load (not having the benefit of a material phase change) but is less complicated and can have better round-trip efficiency.
- **Phase-change materials (PCMs).** PCMs are specially engineered materials that change from solid to liquid at specific, tunable temperatures. Packets with these materials can be installed in a variety of building systems. They can be installed passively, near the ceiling (typically) of new or existing buildings. With advanced temperature controls, small changes in space temperature can be used to melt or freeze the PCM, providing heating or cooling to the space. PCM systems do not generally require additional mechanical equipment beyond what is typical of spaces where they are used. They can be especially impactful in refrigerated spaces like walk-in freezers and cold storage warehouses. Systems are being commercialized that also use PCMs actively in configurations similar to the ice storage discussed above.
- **Hot water.** Advanced hot water heaters with controls, higher insulation values, and higher temperature ranges, can be used to produce and store hot water for longer durations than conventional hot water heaters, allowing a greater span in time between when hot water is produced and when it is needed.

In contrast to these thermal storage systems used in buildings, **molten-salt thermal energy storage** is being used for grid-level applications. This technology is often paired with large solar thermal systems that use mirrors to concentrate the sun's energy to achieve very high temperatures. There are currently three molten salt systems operation in the United States, one each in Arizona, Nevada, and New Mexico,[33] where they are paired with concentrated solar power systems. Given this typical application, they are unlikely to be applicable in Iowa.

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[33] U.S. Department of Energy. Updated 2/18/2020. "DOE Office of Electricity Global Energy Storage Database." Available: https://www.sandia.gov/ess-ssl/global-energy-storage-database-home/.

Flywheels and other mechanical storage systems

Mechanical storage uses physical-mechanical processes to store energy. Pumped hydro, discussed above, is an example of this approach. Alternative mechanical systems can use electricity to spin up a small turbine, called a flywheel, that releases energy in short bursts when needed. Pumped hydro storage (PHS) has the most installed capacity of any storage technology on the market. As of 2018, the United States had 22.9 GW of installed PHS capacity. The market for new PHS has decreased as battery technology has advanced and because suitable sites for developing pumped hydro facilities are scarce, particularly in Iowa. PHS is often used for long-duration storage but is limited by the large land area requirements. Alternatively, flywheels are suitable for short duration storage applications. Flywheels held a higher market share when battery costs were high, but as battery technologies have improved, short-duration storage needs have largely been met with the advanced battery systems described above.

Compressed air energy storage

Energy can also be stored as compressed air. Compressed air energy storage (CAES) technology uses compressors powered by electricity to compress air until it is ready to be injected and stored in underground reservoirs. CAES is similar to hydrogen storage in that it is only economically viable to use when energy prices are low, and it can provide long-duration storage capabilities. One of the major limitations of CAES is that it relies on existing geological formations such as exhausted salt mines or some other natural reservoir to hold the compressed air before it is released to turn a turbine to produce electricity. In 2012, a proposed 270 MW CAES project in Iowa was abandoned because the barriers to implementation for this technology were too high to overcome.[34]

2.2. Storage Cost and Capacity Comparison

The U.S. Department of Energy's *Storage Cost and Performance Report* analyzed different storage technologies and assessed their costs, technology maturity, and market maturity.[35] The report found that PHS, CAES, and flywheels have reached technological maturity and are unlikely to experience much market growth. That same report found that large-format battery storage systems have the potential for significant technological advancements and expanding market opportunities.

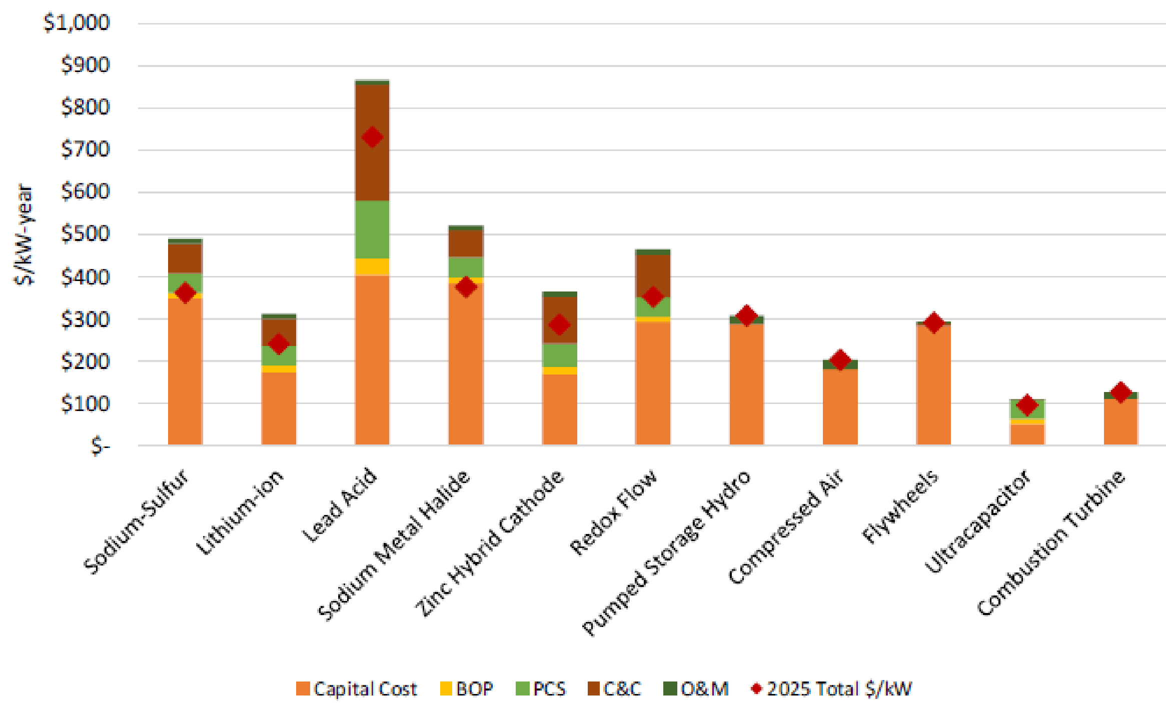
Given the technology's use in a broad number of applications, lithium-ion batteries are the most cost-competitive storage solution for short-duration (4 hours or less) applications. While PHS and CAES are not cost-competitive for short-duration storage applications, these technologies offer a cost-effective

[34] Iowa Energy Office. May 2019. *Energy Storage Action Plan*, page 7. Available at: https://www.iowaeconomicdevelopment.com/UserDocs/news/IEDA_EneryStorage_2019.pdf.

[35] Mongrid, K, et al. July 2019. Energy Storage Technology Cost Characterization Report. US Department of Energy (DOE). Available at: https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

solution for longer-duration (16 hours or more) applications.[36] Figure 3 provides details on the cost breakdown for each storage technology analyzed and the projected cost in 2025. Figure 4 is a visualization of the power and duration capabilities of each storage technology considered above.

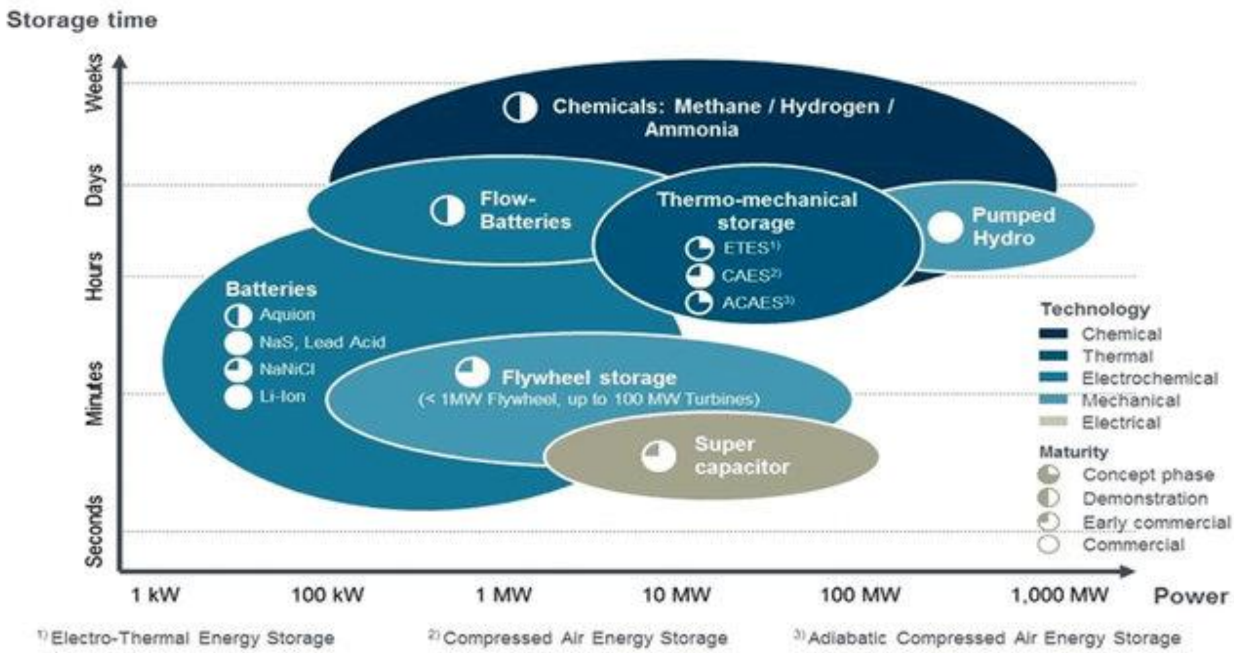
Figure 3. Annualized $/kW-year of storage technologies



Source: DOE Storage Cost and Performance Characterization Report.

[36] Monogrid, K. et al. July 2019. *Energy Storage Technology and Cost Characterization Report*. Department of Energy (DOE).

Figure 4. Duration and power capabilities of each storage technology



Source: Valera-Medina, A, et al. Ammonia for power. Journal for Progress in Energy and Combustion Science. July 2018.

Lithium-ion batteries represent a relatively low-cost form of energy storage to provide storage over multiple hours within a day or over a few days. Today, however, it is less clear what the most cost-effective energy storage solution is for applications that require energy to be stored over multiple days or weeks.

3. Battery Storage System Markets and Costs

There are many market opportunities for energy storage technologies, based on the value storage provides. Most of these market segments represent existing value streams for storage, yet others are newly emerging market opportunities that are likely to become larger value streams for storage in the near future. This section discusses the market services that storage provides and the market landscape for each service within Iowa. This section concludes with an exploration of battery energy storage cost trends.

We separate the types of services into those provided by high-capacity utility-scale FTM storage and those provided by smaller-capacity BTM storage systems.

FTM energy storage applications refer to systems that are located on the utility side of the meter. These systems are typically owned and operated by the utility to provide grid-level services and can be hundreds or tens of thousands of kW in size with durations from 1–4 hours.

BTM battery systems are located on the customer-side of the meter providing benefits primarily to homeowners and businesses. BTM battery system owners charge the battery by purchasing electricity from their electric utility company and then use the stored energy to provide economic or resilience benefits for themselves.[37] Residential BTM systems are typically 5–10 kW in size with 3- to 4-hour durations. BTM systems for a commercial or industrial business can be as big as two hundred kW or more with 2- to 4-hour durations.

3.1. Utility-Scale Energy Storage Markets

Utility-scale FTM storage systems are operated to optimize the grid's operation, reliability, and costs. Because Iowa is part of both the Midcontinent Independent System Operator (MISO) and Southwest Power Pool (SPP) wholesale markets, utility-scale storage in Iowa also has the potential to reduce system costs. The following sections are separated into the services that utility-scale storage can provide to the wholesale market and those that storage can provide to utility operations. For each category of services, we note whether energy storage can currently benefit substantially from the value that it provides in the current MISO context. [38]

Wholesale market services

The following service types are those that energy storage can provide to Iowa's wholesale markets through MISO: energy arbitrage, reserves, capacity, frequency regulation, voltage support, and black start. Each service type is described below.

Energy arbitrage

In a wholesale market, grid operators typically use a least-cost dispatch model in which resources are used in order of increasing marginal costs. Resources with the lowest marginal cost (e.g., hydroelectric, wind, and solar) are dispatched first, followed by nuclear generators and then fuel-based resources (whose marginal costs depend on their fuel costs and efficiency). Some of the lowest-cost energy resources (i.e., wind and solar) are intermittent, and their generation does not always align with demand. Energy storage can store intermittent, low-cost resources until a time when there is higher demand. For example, a storage resource can charge at night when wind energy generation tends to be high, but demand is low. The storage resource can then discharge that energy during the following day

[37] BTM storage system can also be charged using a rooftop solar energy system and does not necessarily require electricity purchased from the local supplier.

[38] We focus our discussion of wholesale markets on MISO, given the vast majority of Iowa load is served through MISO operated wholesale markets. Data from the Energy Information Administration on U.S. electric sales by state and balancing authority shows that, in 2018, 93% of electricity sales in Iowa were from utilities that participate in MISO's wholesale energy markets. See EIA Annual Electric Power Industry Report, Form EIA-861 detailed data file, available at https://www.eia.gov/electricity/data/eia861/.

once demand has increased. This example is particularly relevant for a state like Iowa, where there is a large amount of installed wind capacity.

The process of charging when energy prices are low and discharging when prices are high is called energy arbitrage. Energy arbitrage exploits the difference between periods of high prices and periods of low prices, which may not necessarily involve renewable sources of generation. A consequence of energy arbitrage is that some of the higher-cost generators are avoided, thus reducing overall system costs and hence the costs passed on to ratepayers. Operators of energy storage can currently benefit from providing this service in Iowa—in the form of the revenue earned when selling energy at a higher price than the purchase price.

Reserves

Reserves are resources that can provide power to the grid on short notice in case generators or transmission lines go offline. Reserves are typically classified as either spinning or non-spinning. Spinning reserves must be available nearly instantaneously, whereas non-spinning reserves must be able to respond within 10 minutes. Energy storage can respond very quickly; therefore, it can serve as a spinning reserve resource. A storage system can provide spinning reserves if its duration exceeds the time it takes for slower generators to respond (i.e., ramp) or the offline generator to be restored. Ramping of slower generators is typically around a half-hour, so energy storage designed to provide spinning reserves would need to have a duration of an hour or more.

In Iowa, MISO is responsible for maintaining sufficient reserves for reliability purposes if a power plant or transmission facility trips offline. MISO determines reserve requirements on both a system-wide and a zonal level, based on its seven reserve zones. Iowa is split between MISO's first and fifth reserve zone.[39] In MISO, there are three different types of reserves: regulation reserves (see the section on frequency regulation below), spinning reserves, and supplemental reserves. Spinning reserves in MISO must be synchronized to the grid and able to adjust their output within 10 minutes of receiving a signal from MISO; supplemental reserves do not need to be synchronized with the grid but must be able to initiate generation and adjust output within 10 minutes of receiving a signal from MISO. Storage currently cannot participate as spinning or supplemental reserves in MISO; however, this is likely to change following MISO's compliance filing in response to the Federal Energy Regulatory Commission's (FERC's) Order 841,[40] which is discussed in more detail in Section 5.2.

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[39] Argonne National Library. 2016. Survey of U.S. Ancillary Services Markets. Pages 13-14. Available at: https://publications.anl.gov/anlpubs/2016/01/124217.pdf.

[40] FERC's landmark, unanimous, bipartisan Order 841 on February 15, 2018, which directed regional grid operators to remove barriers to the participation of electric storage in wholesale markets. For more information see Energy Storage Association, Issues Briefs available at https://energystorage.org/policy-statement/overview-of-ferc-order-841/.

Capacity

Capacity service provides the power needed to meet peak loads in a given area.[41] Typically, these peaks are driven by heating or cooling demands and therefore occur on the coldest winter days or hottest summer days. In Iowa, the highest peak of the year is experienced during the summer.

In MISO, capacity planning is done through its annual Planning Resource Auction (PRA) for each of its Load Resource Zones. Capacity resources must be able to provide power to the grid for the duration of the peak event, which is generally a few hours long. Traditionally, capacity-focused generation resources are combustion turbines or reciprocating engines—systems with relatively low capital costs that can sit idle and wait to deliver electricity during peak times. Energy storage can also help to meet capacity needs by committing to be charged and ready to deliver during peak events. In MISO, energy storage can participate in the PRA if it has a capacity of 100 kW or larger and has the necessary metering equipment installed.[42]

This service will become increasingly important as Iowa increases the amount of variable renewable resources on its electricity grid and as new energy end-uses become electrified (e.g., transportation and heating).

Frequency regulation

To ensure stability on the grid, supply and demand must be matched on a moment-to-moment basis. If demand exceeds supply, the frequency drops below 60 Hz—its standard value in the United States. If supply exceeds demand, frequency exceeds 60 Hz. Maintaining a 60 Hz frequency on the grid is called frequency regulation, and it is critically important for operating a stable grid. Generation resources can provide frequency regulation service by rapidly changing their output in response to a signal from the grid operator (i.e., MISO in the case of Iowa). Because energy storage can change its operation direction (charge versus discharge), it is particularly well-suited to providing frequency regulation service to the grid. Some energy storage technologies can provide this service by detecting and reacting to frequency changes without requiring a signal from the grid operator. Storage with either a short or long duration can provide frequency regulation service, though a storage system designed specifically for frequency regulation might have a duration of about 15 minutes at peak output.

MISO does compensate resources for providing frequency regulation through its Regulation Reserve market. Regulation Reserves can be provided by both generation-based resources and energy storage resources. For both categories, resources must be able to adjust their power output within five minutes

[41] There is a summary of capacity service and how U.S. wholesale capacity markets are designed at https://business.directenergy.com/understanding-energy/managing-energy-costs/deregulation-and-energy-pricing/capacity-markets.

[42] *Midcontinent Independent System Operator, Inc.'s Filing to Revise Tariff as Necessary in Compliance with Order No. 841,* Docket No. ER19. December 2018. Page 4-5. Available at: https://cdn.misoenergy.org/2018-12-03%20Docket%20No.%20ER19-465-000298849.pdf.

of receiving a signal from MISO.[43] Currently, energy storage resources can participate in the Regulation Reserve market in MISO, though details of that participation model may change as a result of Order 841.

Voltage support

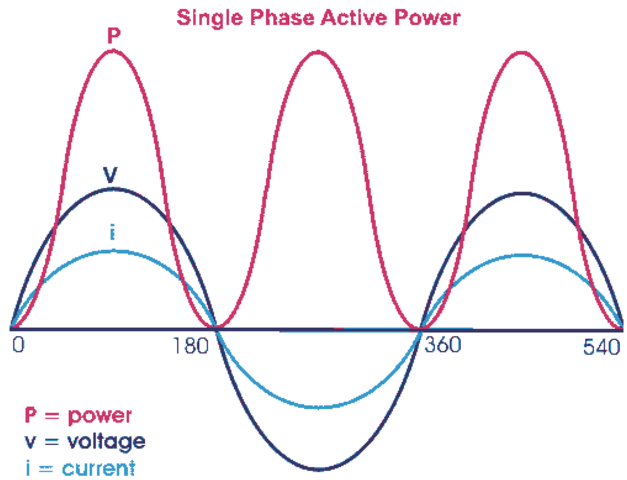
In addition to maintaining frequency, grid operators must also balance voltage and current to maximize power on the grid. When the voltage and current are aligned, power is maximized (Figure 5). If voltage and current are out of alignment, the grid operator can make static adjustments to re-align them.[44] However, static adjustments are inadequate if the misalignment is caused by dynamic load shifts. Energy storage systems include components that can re-align voltage and current dynamically, making them important contributors to maximizing power on a grid. In MISO, compensation for voltage support is provided directly to generators as a non-market service (i.e., there is no market-clearing price, so compensation is relatively constant). Energy storage will be able to be compensated for voltage support as a result of Order 841.

Because voltage alignment conditions are highly localized near load centers, they are difficult to address with resources located at substations or further upstream from customers' loads. Long distribution feeders, which commonly exist in rural areas across the country, often require voltage support—especially if the feeders host variable distributed generation resources. Energy storage that is located on distribution feeders can provide voltage support in real-time to improve power quality. Energy storage is not usually designed specifically for voltage support, but energy storage systems of any duration can provide this service (in addition to the primary service(s) of the storage) if they are located in a place where voltage support is valuable.

[43] Argonne National Library. 2016. Survey of U.S. Ancillary Services Markets. Pages 13-14. Available at: https://publications.anl.gov/anlpubs/2016/01/124217.pdf.

[44] Voltage and current can get out of alignment due to inductive loads (e.g., from motors, which cause the current to lag the voltage) or capacitive loads (e.g., from long cable runs, which cause the voltage to lag the current).

Figure 5. The waveform of alternating current, showing optimal alignment between voltage (v) and current (i), leading to maximized power (P)



Source: "Electric Power Single and Three Phase Power Active Reactive Apparent" from Electrical 4 U, available at https://www.electrical4u.com/electric-power-single-and-three-phase/.

Black start

During normal grid operations, generating stations consume a portion of the electricity from their on-site generators to run the plant. If their generators are not operating, the power plant requires power from the grid to begin operations. In the event of a wide-area power outage, the generators cannot draw power from the grid to begin operation. Generators that can initiate operation without drawing power from the grid can provide a "black start," thereby helping to restart the power grid into full service. In MISO, compensation for black start service is provided directly to generators as a non-market service (i.e., there is no market clearing price, so compensation is relatively constant). Energy storage will be able to be compensated for black start service as a result of Order 841.

Utility services

The following services (peak shaving, deferral of transmission and distribution investments, and congestion relief) are those that do not provide value directly to MISO's wholesale markets. Instead, they are services from which distribution utilities or transmission owners within Iowa would benefit.

Peak shaving

Distribution utilities in MISO can reduce their peak load requirement by installing storage as a distribution-level solution for peak shaving. Energy storage operated in this manner would need to have a duration long enough to shave the full length of the peak (e.g., 4-hour duration for a typical 4-hour peak). Furthermore, energy storage designed for peak shaving would receive a signal to charge from the utility before a day in which a peak is expected to occur.

Transmission and distribution investment deferral

Transmission and distribution lines are built to transmit a certain capacity of electricity from one point to another on the grid. Sometimes peak loads increase to the level that causes wires to reach their reliability limits. When this happens, utilities make plans to invest in assets that will increase the capacity to meet the future load. The higher cost of transmission upgrades relative to distribution upgrades may create more cost-effective opportunities for energy storage to defer transmission projects.

Implementing energy storage, energy efficiency, demand response, or distributed generation located in the area with a growing load can reduce the need for energy to flow during times of high demand which increases local resilience or redundancy. Doing so can help to avoid or defer a more expensive wires-based solution.[45] The duration of energy storage required to be a part of these "non-wires alternatives" (NWA) depends on the other resources deployed as part of the solution and the shape of the peak load. The required duration of such storage systems can extend to up to half a day if the systems are asked to meet a large portion of the load.

Congestion relief

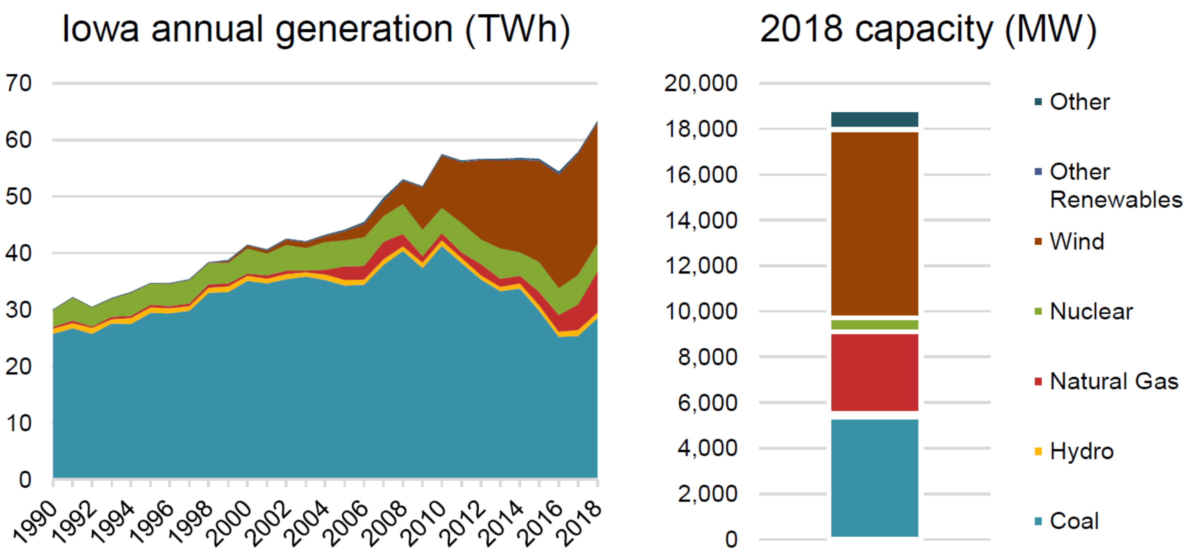
Transmission corridors can sometimes become "congested" during high-demand parts of the day, causing wires to reach their reliability limits for a short period of time. Energy storage that is sited downstream of the congested transmission line can alleviate the congestion by proactively storing electricity prior to peak hours and discharging it in the location it is needed. Energy storage systems designed to relieve congestion must have a duration that meets or exceeds the length of the expected congestion.

Renewable energy integration

While still an emerging application, energy storage is widely viewed as a necessary technology to allow for the integration of variable sources of renewable generation including wind and solar. The current grid generation in Iowa from 1990 to 2018 is shown in Figure 6.

[45] The Smart Electric Power Alliance. *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/, summarizes the different resources that are being used as part of real-world NWAs.

Figure 6. Iowa electricity generation by year 1990–2018 and 2018 capacity by resource type



Source: Energy Information Agency, 2018. EIA Form 923 (https://www.eia.gov/electricity/data/eia923/).

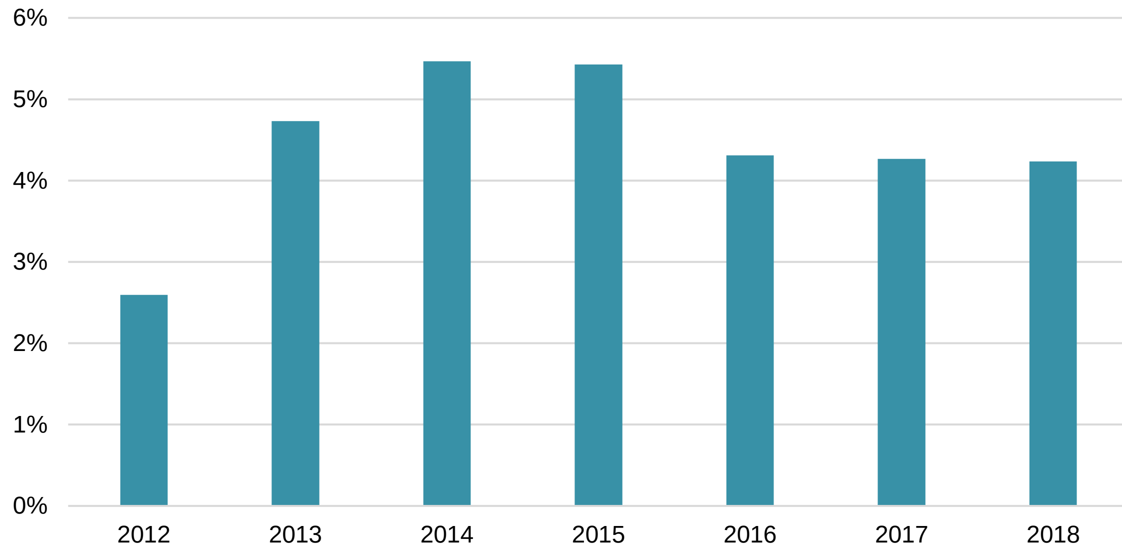
The most significant trends are the growth in wind generation and the decline in coal-fired generation. In many regions of the United States, declines in coal generation have been replaced with flexible natural gas-fired capacity. However, Iowa, with its rich wind resource, has seen tremendous growth in wind capacity, reaching 44 percent of total capacity in 2018. Iowa has over 10 GW of wind currently installed and an estimated 279 GW of total potential.[46] Given the continued declines in wind energy cost, Iowa is expected to continue to see significant growth in wind energy installations.

This growth in wind capacity in Iowa and across the Midwest has led to wind energy curtailment. Curtailment occurs at times when the grid is congested, or over-supplied and excess wind generation cannot be used. While data specific to Iowa is not readily available, Figure 7 below shows the wind curtailment rate across MISO, which is the highest among the major RTOs/ISOs in the United States.[47] Energy storage systems can store the excess wind energy and then sell that energy when the grid is no longer congested or over-supplied. This is a variant of the energy arbitrate opportunity discussed above.

[46] American Wind Energy Association. 2019. Wind Energy in Iowa. Available at https://www.awea.org/Awea/media/Resources/StateFactSheets/Iowa.pdf

[47] U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. 2018 Renewable Energy Grid Integration Data Book. Available at https://www.nrel.gov/docs/fy20osti/74823.pdf.

Figure 7. MISO wind curtailment rate



Source: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. 2018 Renewable Energy Grid Integration Data Book. Available at https://www.nrel.gov/docs/fy20osti/74823.pdf.

Notably, while 42 percent[48] of total annual generation in Iowa is provided by wind, the MISO total is just 9 percent, meaning that curtailments affect Iowa to a much greater extent than other MISO states.,[49] High wind penetration and curtailment create an opportunity for storage to support the grid and generate revenue through energy arbitrage. In times of low renewable generation (e.g. less wind) energy and capacity costs increase substantially. In other areas, flexible and low-cost natural gas generators can respond to fluctuating load and supply more cost-effectively than coal. The relatively small share of natural gas capacity in Iowa presents an opportunity for energy storage systems to serve this function. A more flexible grid will be necessary in the future to handle these grid fluctuations and provide financial benefit to the state.

We estimate that in 2019 approximately 1,115 GWh of wind energy in Iowa was curtailed.[50] This curtailed wind represents lost revenues to the owners of these wind energy plants. With sufficient utility-scale battery storage, this curtailed energy could be stored and sold into the MISO market when

[48] Energy Information Administration. May 2020. State Profiles and Energy Estimates: Iowa. Available at https://www.eia.gov/state/analysis.php?sid=IA#23.

[49] Potomac Economics. June 2020. 2019 State of the Market Report for the MISO Electricity Market. Available at https://www.potomaceconomics.com/wp-content/uploads/2020/06/2019-MISO-SOM_Report_Final_6-16-20r1.pdf.

50 This is a conservative estimate of the wind energy curtailed in Iowa in 2019. It is based on total wind production in 2019 of 26,558 GWh from the Energy Information Administration's Electricity Data Browser and the MISO-wide wind curtailment rate for 2018 of 4.2% (see Figure 7). It is likely that the curtailment rate in Iowa is higher, but that data is not currently available for each state within MISO.

prices increase. Given the average price of wholesale energy in MISO in 2019 of $26.76/MWh[51] and battery system round trip losses of 14 percent[52] the stored curtailed wind energy in Iowa could potentially be sold generating revenue of $25.6 million. Furthermore, wind power that is not used does not qualify for the federal production tax credit (PTC). The PTC provides a tax credit of $0.01/kWh–$0.02/kWh for the first 10 years of electricity generation for utility-scale wind.

Wind seasonal fluctuations are more predictable than daily fluctuations, whereas for solar, daily fluctuations are more predictable and perhaps better suited for shorter duration battery storage systems. Although solar PV installations are rather limited in Iowa, solar PV installations are expected to grow rapidly in the coming decade.[53] Battery energy storage systems can play a role in addressing the variable output of large-scale solar systems. Studies have found that solar increases the need to ramp generation units down quickly in the morning hours as solar energy production increases. Conversely, at the end of the day as solar energy production is decreasing, traditional generation units must rapidly ramp up, which is costly and inefficient. Battery energy storage are well suited to provide ramping services that allow traditional sources of generation to operate more efficiently.[54]

3.2. Customer-Sited Energy Storage Markets

Customer-sited BTM energy storage systems provide value to the host customers helping to manage energy use to reduce costs and to provide resilience. Resilience is difficult to place a dollar value on but is understood to be an important benefit provided by battery storage systems.

In addition, customer sited BTM systems can be aggregated to provide the services discussed above in Section 3.1. There is growing interest in aggregating hundreds or thousands of BTM system in what is referred to in the industry as a “virtual power plant” to provide the number utility-scale services referenced above. This requires the deployment of distributed energy resource management systems that allows the aggregator to communicate with grid operators and manage the operation of customer-sited BTM storage systems.

Demand limiting and demand response

One of the greatest benefits of BTM storage for large commercial and industrial (C&I) customers in Iowa is avoided demand charges. Utility demand charges are stated in $/kW and are applied to the peak

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[51] Potomac Economics. June 2020. 2019 State of the Market Report for the MISO Electricity Market. Available at https://www.potomaceconomics.com/wp-content/uploads/2020/06/2019-MISO-SOM_Report_Final_6-16-20r1.pdf

[52] U.S. Department of Energy. July 2019. Energy Storage Technology and Cost Characterization Report. Available at https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

[53] Solar Energy Industry Association. June 2020. State Solar Spotlight: Iowa. Available at https://www.seia.org/sites/default/files/2020-06/Iowa_1.pdf.

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

usage of a facility. Storage helps C&I customers lower demand charges by reducing their monthly peak usage. For example, a building with peak energy use of 100 kW under a utility with a demand charge of $20/kW would see demand charges totaling $2,000 per month. Battery storage systems can be used to reduce the peak use of a building, thus reducing demand charges. In this case, a 50-kW battery used to shave a building's peak demand would save $1,000 per month.[55]

A 2017 study by the National Renewable Energy Laboratory (NREL) found that Iowa was one of the top 10 states for the number of commercial clients operating in a utility territory with demand rates greater than $20 per kW.[56] This was identified as a significant indicator of storage adoption potential. The table below supplements the NREL data with additional distinctions about utility types and rate structures for C&I customers in Iowa.

Table 1. Rate structures for commercial and industrial customers in Iowa ($/kW-month)

Type	Utilities	Customers	MWh Sales	Sector	Avg Demand Charge	Min Demand Charge	Max Demand Charge
Co-op	43	1,179,601	38,377,063	Commercial	4.6	0.0	77.8
				Industrial	9.0	0.0	27.2
Municipal Utility	136	219,728	5,531,854	Commercial	6.2	0.0	23.6
				Industrial	7.2	3.5	16.4
Investor Owned Utility	2	233,176	7,293,966	Commercial	2.4	0.0	33.0
				Industrial	7.7	0.0	22.3

Source: Utility Rate Database, https://openei.org/wiki/Utility_Rate_Database.

Consistent with NREL's analysis, in our interviews with several different stakeholder types in Iowa, the ability of an energy storage system to reduce demand charges was consistently identified as driving demand for such systems.

Demand response (also known as load shedding) is another significant benefit of BTM storage for C&I customers in Iowa. There are a variety of demand response programs offered by all types of utilities in Iowa that provide financial rewards to customers in return for agreeing to limit their usage on a handful of event dates each year (generally at times of grid congestion). The economic parameters vary significantly by utility. As of 2018, there were 1,854 C&I customers enrolled in these programs and those

55 This is a simplified example for illustrative purposes. A battery energy storage may not perfectly offset demand and demand charges based on the rated capacity of the system. Also, the effect on the demand charges can vary depending upon, among other considerations, the specific tariff structure that the customer is under.

56 McLaren, Joyce, Seth Mullendore, Nicholas Laws, and Kate Anderson. 2017. "Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges," August 7.

customers were paid a total of $35 million for their participation that year.[57] The share of that load flexibility provided by storage is currently negligible, but battery energy storage systems are likely to increase in use as demand response resources.

Managed EV charging

While discussion of BTM energy storage often focuses on stand-alone batteries, managed EV charging functions similar to energy storage in that it also allows for demand limiting and load-shedding capabilities. This technology has potential in all sectors—not just C&I— but is driven by similar economic drivers: namely demand charges and time-of-use or real-time rates. Managed EV charging is an emerging energy management strategy that is not yet widely available in Iowa or other parts of the country. As EV adoption increases in the coming decade, managed EV charging will represent a significant new form of flexible load.

Solar plus storage

The use of storage and solar in the same facility can significantly improve the cost-effectiveness of both technologies. Storage systems paired with solar are eligible for the federal investment tax credit (ITC).[58] The amount of the full credit that a given storage system is eligible for is scaled by how much of the time it is charged from the renewable resource, with a 75 percent minimum. For example, a battery charged 95 percent of the time from solar would be eligible for 95 percent of the incentive currently available, which is 26 percent of the total capital cost through the end of 2020.[59] The incentive drops to 22 percent in 2021, then 10 percent for 2022 and future years for C&I customers.

A study by California utility San Diego Gas and Electric (SDG&E) found that, for commercial customers, adding storage to an existing solar photovoltaic (PV) system provided the fastest payback compared to new solar, new solar plus storage, or storage alone.[60] In addition to the opportunity of such a system to take advantage of the ITC, the main reason for this faster payback was the ability of customer systems to use solar during the day to offset high demand charges and time-of-use rates and extend the flexibility of the battery to offset these charges later into the day. This is particularly valuable in areas with high solar penetration whereby the peak demand shifts to later in the afternoon when the solar resource begins to decline. This shift in peak demand will also be reflected in wholesale market prices. While solar

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[57] Energy Information Agency. 2019. “Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files.” https://www.eia.gov/electricity/data/eia861/.

[58] Pairings with other renewable sources are also eligible, but solar is the most common and has the highest incentive rate. Other qualifying technologies include fuel cells, small wind turbines, geothermal, microturbines, and combined heat and power. See DSIRE, Business Energy Investment Tax Credit (ITC), available https://programs.dsireusa.org/system/program/detail/658

[59] Elgqvist, Emma, Kate Anderson, and Edward Settle. 2018. “Federal Tax Incentives for Energy Storage Systems.”

[60] E Source Companies, LLC. 2020. “Behind-the-Meter Battery Market Study.” DR19SDG0002. Emerging Technology Program. SDGE.

resources are not as favorable in Iowa as they are in California, the same strategy may still be viable to a lesser extent given the current low penetration rates for solar in the state.

Another synergy between solar and storage exists for customers in municipal and electric cooperative utility territories. Currently in Iowa, several of these utilities do not have net energy metering.[61] For customers in these territories that have solar systems, batteries present an opportunity to increase self-consumption and thus increase the value from solar installations. This does not apply in the case of utilities which have net metering policies.

Emergency back-up power

In Iowa, the main reason cited by residential consumers for installing battery systems is to provide back-up power. This finding matches the SDG&E study. However, using an energy storage system as back-up power currently represents an expensive niche option, pursued by technology-savvy early adopters. The market for back-up power for residential customers is not large, and engine-based generators still represent a more economical solution. Increased interest in electrification and state decarbonization goals, however, if coupled with strong enough programs or policies, could have the potential to change this in the medium to long term.

For commercial clients, battery systems are typically sized with sufficient power (kW) to offset demand charges. Because these charges are applied based on a continuous 15-minute period, energy capacity (or battery duration, measured in kWh) is a less significant concern. To be cost-effective, limiting the energy to focus on power makes sense. As a result, most commercial systems would not be able to meet back-up power requirements for more than a few hours. Some commercial customers are beginning to consider hybrid back-up systems that include both batteries and engine-based generators. This is one possible market for the foreseeable future. Such systems share many characteristics with microgrids, as described below.

Microgrids

An additional market niche where BTM batteries can be employed for emergency back-up is integration in resilient microgrids. In mission-critical applications, engine-based back-up power systems are generally paired with a UPS (uninterruptible power supply). A UPS provides power to critical loads upon detection of a grid fault while a generator goes through its startup sequence. As a UPS is essentially a single-purpose battery, a battery energy storage system with proper control capabilities can easily fill this role.

[61] Stakeholders interviewed in Iowa stated that several electric cooperatives and municipal utilities in the state do not offer net metering options at this time. Additionally, Docket No. NOI-2014-0001, "Order Soliciting Additional Comments and Scheduling Workshop" states that the Iowa Utility Board estimates that 89 percent of residential customers have access to net metering in the state.

A microgrid consisting of a generator for back-up power, a battery energy storage system(BESS) capable of operating as a UPS, and a PV array to charge the BESS would allow a client to have continuous back-up power while also taking advantage of demand charge reductions, demand response programs, and the federal ITC. Furthermore, stand-alone PV arrays are generally integrated with inverters that are incapable of providing back-up power; but when arranged in a microgrid as described above, energy from the PV array could be used to supplement the generator. This would lower fuel costs and/or extend the amount of time the facility could serve loads during a grid outage. While such a combination would improve the payback of a BESS, the upfront cost of batteries will need to continue to decline before such a system is financially viable for most commercial clients in Iowa.

Microgrids are a newer application than the others above, and more difficult to project. Research indicates that there are not currently any microgrids operational in Iowa. However, the University of Iowa recently signed a contract with the energy company Engie for utility management which includes the possibility of adding a microgrid.[62]

3.3. Emerging Storage Opportunities

Value stacking revenue streams

As discussed in the sections above, battery storage systems can provide many different services to grid operators, electric utilities, and BTM customers. As this technology continues to be deployed, battery owners are exploring opportunities for stacking value streams associated with the various services battery storage can provide. The ability to stack several value streams can have a significant positive impact on battery utilization and economics. For example, a battery could be located at a constrained substation to provide support to the transmission and distribution lines. The main benefit this battery provides is the ability to avoid or defer investments in traditional transmission and distribution equipment. The same battery could be used to provide additional grid benefits through voltage support or frequency regulation. Adding this service to the battery’s value stack improves the economics, but it will also increase the rate at which the battery degrades. Battery storage has limited cycles and can degrade more quickly depending on how the battery is operated.

Battery operators are still working to understand how to best stack these services to optimize both projected revenue and battery lifetime. Furthermore, each state has different rules and regulations that govern how energy storage systems can contribute to the electric grid. Many jurisdictions are considering regulations that allow for more flexibility in the services that can be provided by a single battery asset.

62 Microgrid Knowledge (blog). 2019. “Microgrid Possible under Deal between University of Iowa, Engie, Meridiam.” https://microgridknowledge.com/microgrid-engie-university-of-iowa/

Vehicle-to-grid

The steady reduction in battery costs over the past decade (described in the next section) is the result of the increased demand for EVs. EVs use energy stored in lithium-ion batteries to power a vehicle's drivetrain, instead of using gasoline. EV batteries are designed to achieve maximum capacity while minimizing space needs and battery weight to create an energy efficient EV. EV adoption rates are expected to increase exponentially over the next few decades.[63] As the adoption of EVs increases, more EV battery capacity will become available for V2G applications. Using V2G systems, EVs can act as a flexible supply and demand resource to BTM customers, electric utilities, and grid operators. V2G also allows EV or EV fleet owners to utilize their vehicles' batteries for non-mobility services, including many of the services described earlier in this section. This can expand the value streams that can be realized by EVs as well as better utilize existing batteries rather than manufacturing new ones. Most V2G programs are still in a pilot phase. For V2G application, EVs and charging infrastructure must be equipped with bi-directional charging to allow for flexible use of the EV battery. As of mid-2020, some major automobile manufacturers and several startups are manufacturing EVs capable of supporting V2G application.[64] In addition, several technology companies are building software solutions that integrate EVs into distributed energy resource management systems.[65]

Battery reuse and recycling

EV batteries are typically no longer usable for mobility purposes once the battery has reached 70 percent state of health (i.e., the battery's total capacity has degraded by 30 percent).[66] However, batteries at 70 percent state of health can still be used for stationary storage applications. Once batteries are retired from EVs, they can then be repurposed for stationary applications (i.e., "second life batteries"). These lightly used batteries can be commercialized at a much lower cost than newly manufactured batteries. Furthermore, this reuse of batteries extends the total useful life of a single battery and enables the battery industry to be more environmentally sustainable. To incorporate more environmental sustainability into the battery industry, batteries should be recycled at the end of life. Battery recycling can minimize the amount of new lithium that needs to be mined to keep up with battery demand. The Lithium ion battery recycling industry is still in its infancy with some uncertainty regarding how much of the materials can be recovered and the most efficient methods. The economic

[63] Bloomberg New Energy Finance. 2020. Electric Vehicle Outlook. Available at: https://about.bnef.com/electric-vehicle-outlook/.

[64] Parnell, John. September 2019. "Vehicle-to-Grid Technology Puts Businesses in Driver's Seat of EV Revolution." *GreenTech Media*. Available at: https://www.greentechmedia.com/articles/read/vehicle-to-grid-technology-puts-businesses-in-drivers-seat-of-ev-revolution.

[65] See Nuvve (https://nuvve.com/) and Peak Power (https://www.peakpowerenergy.com/)

[66] Roberson, Bill. September 2019. *The Clock Is Ticking On Electric Car Batteries – And How Long Will They Last*. Forbes. Available at: https://www.forbes.com/sites/billroberson/2019/09/30/the-clock-is-ticking-on-electric-car-batteriesand-how-long-they-will-last/#70d0176521d9

feasibility of battery recycling is still up for debate, but most recyclers claim that recycling can be very effective at obtaining the necessary active components to make lithium-ion batteries.[67]

3.4. Battery System Costs

Battery system costs have decreased drastically over the past few years and continue to decrease rapidly. This cost decrease is mostly driven by economies of scale in manufacturing to meet the demand for batteries from the EV market. In less than a decade, Li-ion batteries experienced an 87 percent decrease in costs.[68] Costs continue to fall for every component that goes into a complete battery system. This includes cells, modules, and balance of system components.[69] These lower costs continue to enable increased deployment of energy storage.

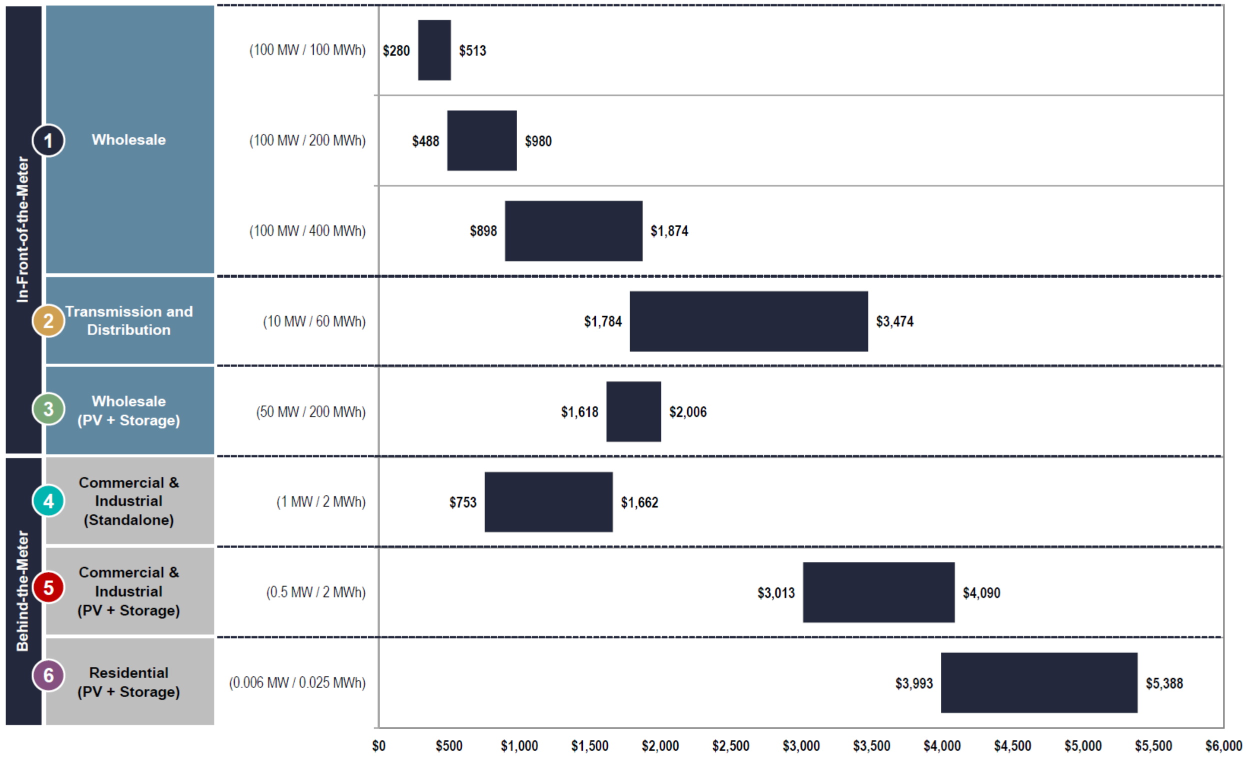
Battery prices are often quoted based on power rating ($/kW) or energy rating ($/kWh). Longer duration batteries have a higher $/kW cost relative to shorter duration battery systems and lower $/kWh cost. In contrast, shorter duration batteries have a higher $/kW cost and lower $/kWh cost. Figure 8 and Figure 9 present estimates by the research firm Lazard on the capital cost for battery storage systems based on different applications. In Iowa, energy storage may be particularly useful in reducing wind curtailment. This type of storage would be large-scale at the wholesale or transmissions and distribution levels and would be among the lower cost storage applications as illustrated in Figures 6 and 7 below.

67 Jacoby, Mitch. July 2019. *It's time to get serious about recycling lithium-ion batteries*. Chemical and Engineering News. Available at: https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28

68 Bandyk, M. December 2019. Battery prices fall nearly 50% in 3 years, spurring more electrification: BNEF. Retrieved from https://www.utilitydive.com/news/battery-prices-fall-nearly-50-in-3-years-spurring-more-electrification-b/568363/

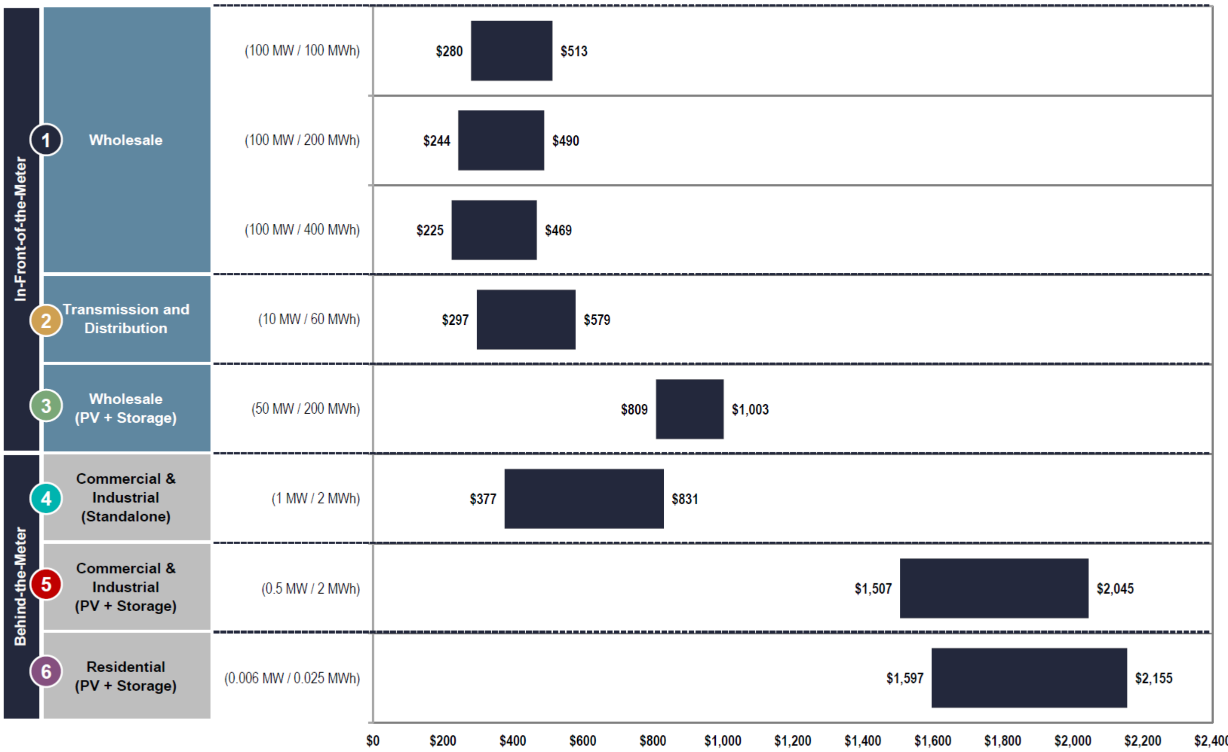
69 Balance of system includes the container, the inverter that converts AC electricity to DC electricity, and other power electronics to manage charging and discharging of the battery system.

Figure 8. Capital costs comparison (nameplate capacity) of battery storage systems by application ($/kW)



Source: Lazard's Levelized Cost of Storage Analysis – Version 5.0. November 2019. Available at https://www.lazard.com/media/451087/lazards-levelized-cost-of-storage-version-50-vf.pdf.

Figure 9. Capital costs comparison (nameplate capacity) of battery storage systems by application ($/kWh)



Source: Lazard's Levelized Cost of Storage Analysis – Version 5.0. November 2019. Available at https://www.lazard.com/media/451087/lazards-levelized-cost-of-storage-version-50-vf.pdf.

4. Economic Impacts of Future Battery Storage in Iowa

This section provides an analysis of the potential for energy storage deployments in Iowa and the associated economic development impacts. The goal of this analysis is to understand the economic benefits of future installations of energy storage specifically in the state of Iowa. To quantify the potential economic benefits associated with an expanding energy storage supply chain in Iowa, the first step is to estimate how much energy storage will be deployed in the state. For this analysis, our projections extend from 2020 through 2035 and include both large utility-scale storage and BTM (residential and commercial/industrial) energy storage systems. We used the results of the scenario analysis as inputs to an economic input-output model (IMPLAN),[70] which calculates the employment and GDP impacts from increased storage deployment in Iowa. The sections below describe in detail our methodology and results for both the scenario analysis and economic impact analysis.

4.1. Deployment Scenarios Approach

As mentioned above, the scenario analysis is separated into two market categories: utility-scale and BTM storage. For the utility-scale market segment, we developed four possible future scenarios. For the BTM market segment, we developed two intermediate adoption scenarios: one for residential customers and one for C&I customers. Given the uncertainty of the energy storage landscape more than a decade in the future, largely due to unforeseen policies and changes in storage equipment and installation costs, these scenarios are intended to provide a range of realistic future storage deployments in Iowa. The sections below describe the approach used in developing each scenario option as well as how the utility-scale and BTM scenarios were merged into a single set of scenarios for the economic impact analysis.

Utility-scale storage

We used several approaches to develop projections for utility-scale storage deployment that rely on the *Reference Case* results from Synapse's recent energy storage study for the state of Colorado.[71] These approaches involve applying different ratios from the results of the Colorado study to Iowa's projected energy demand in each year out to 2035.[72] The Colorado study was adapted for Iowa based on the similarities in term of total energy demand, load, and renewable energy penetration. That study used a

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[70] IMPLAN is an industry-standard input-output model for assessing the macroeconomic impacts of structural changes to a regional economy, see https://www.implan.com/.

[71] Synapse Energy Economics. June 2019. The Future of Energy Storage in Colorado: Opportunities, Barriers, Analysis, and Policy Recommendations Prepared for the Colorado Energy Office. Available at https://www.synapse-energy.com/sites/default/files/The-Future-of-Energy-Storage-in-Colorado-19-025.pdf. The Reference Case represents "Business as Usual" in Colorado, but without the 2019 Sunset Bill, which requires all regulated utilities to include a carbon price in their resource planning. We use this scenario because Iowa does not have a comparable regulation to the Sunset Bill.

[72] We utilize Iowa's generation forecast from the Independent MISO load forecast done by Purdue University. https://www.purdue.edu/discoverypark/sufg/docs/publications/MISO/MISO%20forecast%20report%202019.pdf.

capacity and expansion modeling tool that was beyond the scope of this project. For each option, we provided estimates of how much installed storage capacity (MW/MWh) would be deployed from 2020 through to 2035. We projected both installed capacity of the storage (in MW) as well as the total energy the system can store (in MWh). [73] Figure below illustrates the full storage trajectory for each ratio approach described below. The different approaches include:

1. **Total Generation**: Ratio of installed storage capacity in Colorado to total energy generation (i.e., how much energy is produced each year, including any energy losses during transmission and distribution) in Colorado, applied to the Iowa load forecast. This ratio implies a focus on the power availability of the storage; therefore, this might be a good approach where peak shifting is the dominant application. This method results in 1.4 GW/5.6 GWh of installed storage in 2035.

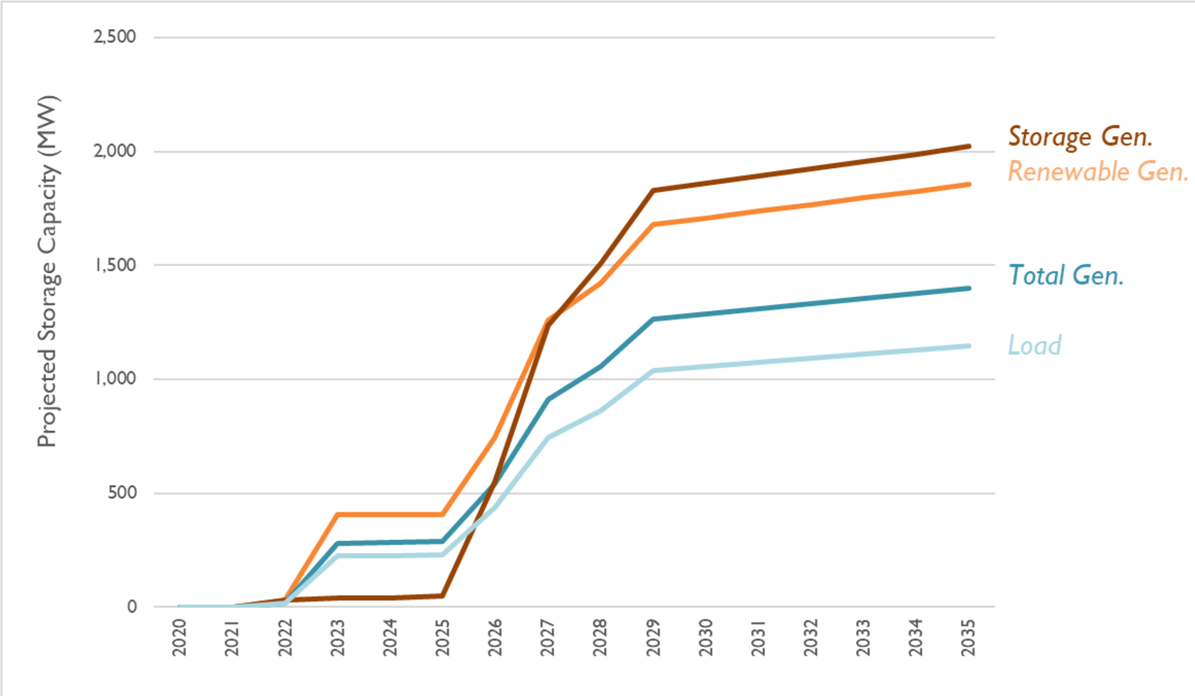
2. **Renewable Generation**: Ratio of installed storage capacity to variable renewable resource generation (e.g., solar PV and wind), applied to the Iowa load forecast. This ratio implies a focus on using energy storage to support the generation of intermittent resources; therefore, this is a good approach where reducing curtailment of variable resources is concerned. This approach requires assumptions relating to what share of Iowa's future generation is from wind resources. Given the assumption that wind generation grows at the same rate as Iowa's projected total energy generation, this method results in about 1.9 GW/7.4 GWh of storage in 2035.

3. **Storage Generation**: Ratio of storage "generation" (i.e., storage dispatch) to total generation, applied to the Iowa load forecast. This ratio implies a focus on the energy availability of the storage; therefore, this might be a good approach where reliability and reserves are concerned. This method results in 2.0 GW/8.0 GWh storage in 2035. Though this scenario results in the greatest amount of storage by 2035, it has the slowest near-term growth (through 2027) because storage generation in the early years of our Colorado model increases slowly.

4. **Load**: Ratio of installed storage capacity to total energy consumption (i.e., how much energy is used, excluding energy lost during transmission and distribution) in Colorado, applied to the forecasted energy consumption (i.e., retail sales) in Iowa. Currently, Colorado and Iowa are similar in load, so this approach has a solid foundation, assuming that future load growth in the two states is relatively similar. This approach results in about 1.1 GW/4.6 GWh of storage in 2035.

[73] We assume utility-scale batteries are four hours in duration.

Figure 10. Estimated utility-scale storage capacity projections for each ratio approach from the Colorado study



Source: Synapse Energy Economics, Inc.

Table 2. Summary of utility-scale storage deployment (MW/MWh) in 2020, 2025, 2030, and 2035

Scenario	Battery Specification	2020	2025	2030	2035
Storage Generation	MW	0	50	1,860	2,020
	MWh	0	200	7,440	8,090
Renewable Generation	MW	0	410	1,710	1,860
	MWh	0	1,630	6,840	7,430
Total Generation	MW	0	290	1,290	1,400
	MWh	0	1,150	5,150	5,600
Load	MW	0	230	1,060	1,150
	MWh	0	920	4,220	4,590

The Load scenario projects the smallest amount of utility-scale storage in Iowa by 2035 (1,150 MW), and the Storage Generation scenario projects the greatest amount of utility-scale storage in Iowa by 2035 (2,020). To demonstrate the full range of possible storage adoption scenarios in Iowa's future, we retained these two scenarios for integration with the BTM scenario results (described in the next section), to be used as inputs for the economic analysis.

Behind-the-meter storage

Developing storage projection scenarios for BTM storage is challenging for several reasons. First, there are limited projections for this type of storage application to date. Second, the regulatory landscape is diverse, changing rapidly, and remains unclear in many cases in the United States. Fortunately, Iowa has been forward-thinking in explicitly including energy storage within the definition of distributed energy resources.[74] Third, the benefit of BTM storage can vary greatly depending on the jurisdiction and the customer class using the storage. For example, one of the greatest benefits of BTM storage for large C&I customers in Iowa is avoided demand charges, because storage helps those customers shave their monthly peak usage.[75] Residential customers, however, are not typically on demand charge tariffs; therefore, the economics of storage for residential customers is very different than for C&I customers.

For this reason, we separate Iowa's BTM storage projection into two unique projections: one for residential customer BTM storage and another for C&I customer BTM storage. Further, given the relatively small scale of BTM storage compared to utility-scale storage in Iowa's energy landscape, we use a single intermediate adoption scenario for each, rather than a low and high scenario for each. In other words, a low and high sensitivity on the projection is less important given the small contribution of BTM storage in Iowa. Together, residential and C&I BTM storage are projected to reach 114 MW (227 MWh) of capacity in 2035.

Residential

Most residential BTM storage systems in the United States have been installed through utility-funded pilot programs, which have only existed for a few years.[76] Iowa's rural electric cooperative, MiEnergy, recently implemented a small-scale pilot program for residential energy storage. Four residential customers received battery energy storage systems, which are controlled by MiEnergy, to test the potential customer savings associated with experimental time-of-use rates. The cooperative has no near-term plans to expand this program, given the cost of batteries relative to the potential customer savings at this time. However, they did express an interest in expanding the pilot if the cost of energy storage declines in the coming years. We are not currently aware of other Iowa utilities investigating BTM storage programs for residential customers.

To project the amount of residential BTM storage likely to be installed in Iowa through 2035, we applied a realistic compounded annual growth rate (CAGR) to the amount of currently installed residential storage of which we are aware. A market research report from April 2019 projects that the global

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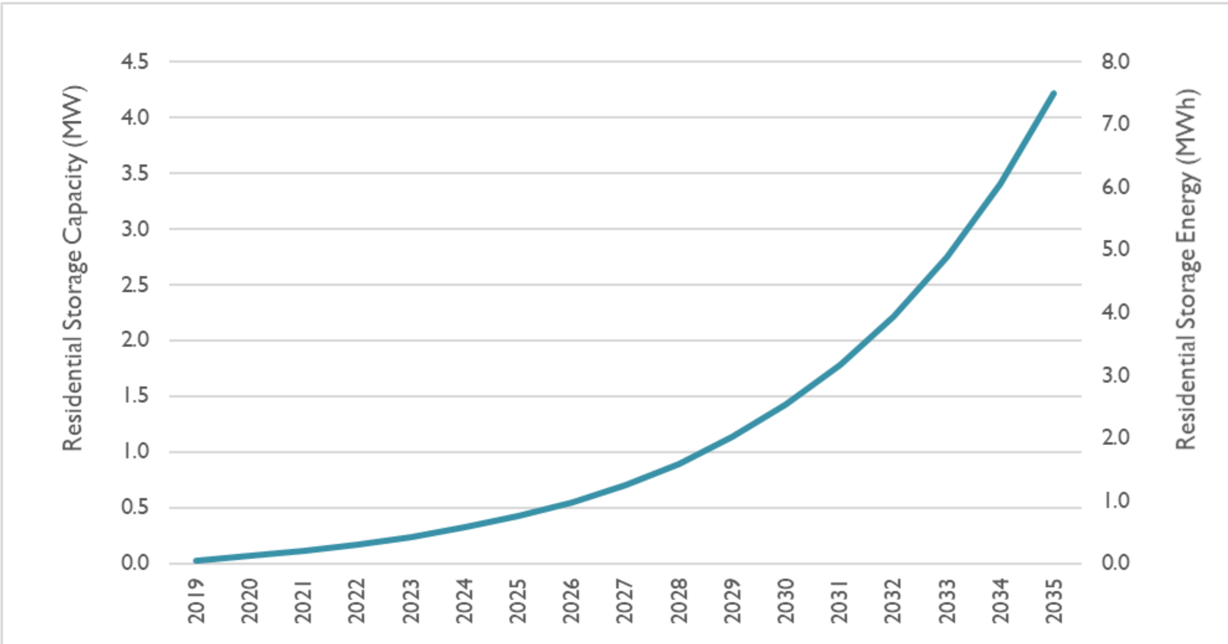
[74] *Utilities Board. n.d. Rule Making Related to Interconnection Standards. Iowa Administrative Code*. Vol. ARC 4645C. Accessed April 8, 2020. https://www.legis.iowa.gov/docs/iac/chapter/199.45.pdf.

[75] National Renewable Energy Laboratory. 2017. Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges.

[76] See Liberty Utilities and Green Mountain Power. Available at: https://new-hampshire.libertyutilities.com/grafton/residential/smart-energy-use/electric/battery-storage.htmlhttps://greenmountainpower.com/product/powerwall/.

residential energy storage market for new installations is likely to increase at a CAGR of 22.88 percent from 2019 through 2024.[77] We apply this rate to the 30 kW (52 kWh) of known residential storage in the MiEnergy service territory.[78] This growth rate leads to 4.2 MW (7.32 MWh) of residential BTM storage in 2035 (Figure 10).

Figure 10. Residential BTM storage projection



Commercial and industrial (C&I)

Our approach for the C&I BTM storage scenario uses demand charges as a proxy for BTM storage deployment.[79] Our recent interview with Ideal Energy, a solar and storage installer in Iowa, revealed that storage solutions are typically only economical for large C&I customers who are on tariffs with demand charges over $15 per kW. Ideal Energy also noted that, unless an investment tax credit for stand-alone storage is created at the federal or state level, only paired solar-plus-storage solutions are likely to be economical in the short term.[80]

[77] Markets and Markets, April 2019. Residential Energy Storage Market. Available at: https://www.marketsandmarkets.com/Market-Reports/residential-energy-storage-market-153284325.html

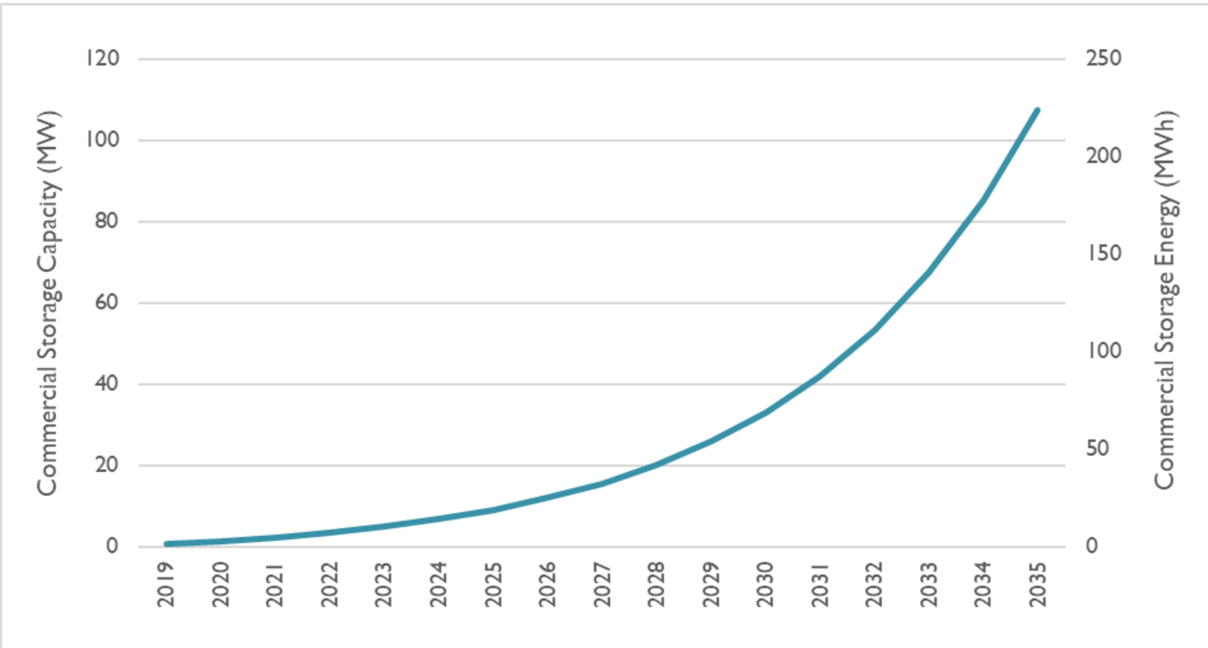
[78] Though we do not know of other residential storage systems installed in Iowa, there may be others not accounted for in this analysis.

[79] Matthew Long, Travis Simpkins, Dylan Cutler, and Katie Anderson. 2016. A Statistical Analysis of the Economic Drivers of Battery Energy Storage in Commercial Buildings. A report by the National Renewable Energy Laboratory. Available at https://www.nrel.gov/docs/fy17osti/66832.pdf

[80] This tax credit is currently 30 percent but declines to 10 percent starting in 2022. The ITC is proportional to the percentage of time that the storage system is charged by the solar array, with a minimum of 75 percent.

Given that high demand charges are a primary driver of C&I BTM storage, we developed a growth curve using an estimate of how many large C&I customers are on high demand charges in Iowa, as well as their associated non-coincident peaks. Using data from a recent rate case in Iowa, we estimate there are at least 3,000 customers on a large General Service tariff, with a combined secondary non-coincident peak of 1,100 MW.[81] If we assume that about 10 percent of those customers (about 450) will have installed energy storage solutions by 2035 to shave their peak demand, Iowa will see about 110 MW (220 MWh) of C&I BTM storage.[82] Figure 11 illustrates a compound growth trajectory for 2019–2035, starting with about 0.6 MW (1.5 MWh) of C&I BTM storage installed in 2019. This growth would imply a CAGR of about 26 percent through the study period.

Figure 11. Commercial and industrial BTM storage projection



4.2. Deployment Scenarios Results

Using the approaches listed above, utility-scale storage is projected to be about 95 percent of the total installed storage capacity in 2035. Of the BTM forecast, C&I is projected to comprise about 99 percent of the total installed BTM storage capacity in 2035. Table 3 shows the range of projected storage capacity for the low and high scenarios. Integrating the projections for utility-scale and BTM storage, we estimate that battery adoption could reach between 1.3 to 2.1 GW (with 4.8 to 8.3 GWh of storage) by 2035. These scenarios provide a reasonable range for purposes of this study to estimate the economic

81 We use data from the Cost of Service Study associated with rate case RPU-2019-0001.

82 We assume that large C&I customers would have storage solutions with an average duration of 2 hours, based on the median duration of the three installations that Ideal Energy has conducted (2, 2, and 3-hour durations)

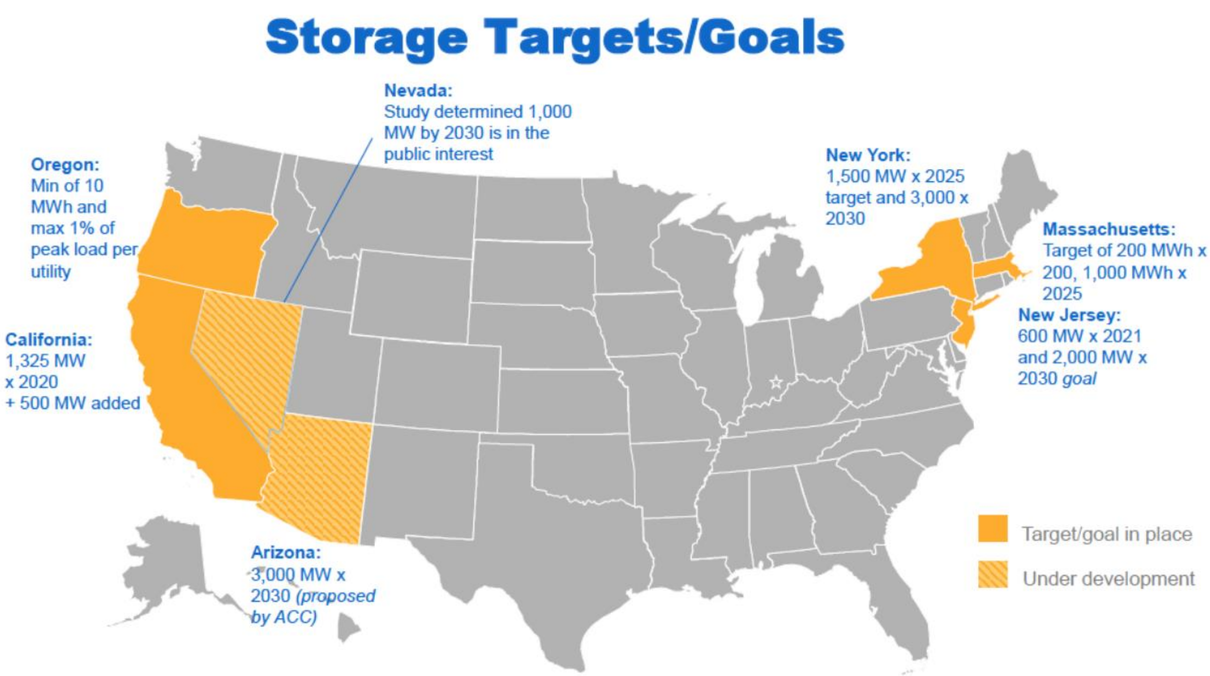
development impacts from a growing energy storage industry in Iowa. However, actual energy storage deployments over the next 15 years could be higher or lower depending on numerous factors. This includes the pace and level of future battery storage price declines and whether favorable MISO market rules or policies are adopted among other factors.

As a point of comparison to the storage deployment scenarios used to estimate the economic development impacts in Iowa, Figure 12 presents the energy storage targets that several states have adopted in recent years. California has a target to reach 1.8 GW of storage by 2020, New York has a target to reach 3 GW of storage by 2030, and New Jersey has a goal of 2 GW of storage by 2030. Given that Iowa has a smaller population and supply chain than these three larger states, our battery projections for Iowa are appropriately lower than these example state goals. The scenarios presented in Table 3 are utilized in the economic impacts analysis described in sections 4.3 and 4.4.

Table 3. Projected storage capacity by scenario for years 2020, 2025, 2030, and 2035 (MW)

Scenario	Projected Storage Capacity (MW)				Projected Storage Energy (MWh)			
	2020	2025	2030	2035	2020	2025	2030	2035
High (Storage Generation + BTM)	1	60	1,900	2,130	3	220	7,510	8,320
Low (Load + BTM)	1	240	1,090	1,260	3	940	4,290	4,810

Figure 12. State energy storage targets



Source: Energy Storage News. March 2020. "Forward-thinking US states charge ahead on energy storage." Available at https://www.energy-storage.news/blogs/forward-thinking-us-states-charge-ahead-on-energy-storage.

4.3. Economic Impacts Approach

New spending on storage will impact the Iowa state economy through several different channels. New jobs in the storage sector can reduce jobs in other energy sectors. To account for this potential job loss, this study has assessed the net results of the key impacts to provide an overall picture of the state gross domestic product (GDP), employment, and income changes that can be expected from new investment in energy storage. An overview of the different economic effects is provided below.

Impacts of new utility-system spending

The first effect considered is the benefits to the state economy provided by spending on new utility-scale and BTM storage installations. This new spending on storage in Iowa is expected to impact the economy in several ways. Capital investment in new storage assets benefits the manufacturing supply chain. To the extent that there are Iowa companies involved in this manufacturing (even if not directly involved in assembly of completed batteries), new BTM and utility-scale BESS procured for Iowa translates into employment, income, and GDP boosts for the state. As noted above, installation and servicing of storage also produces new revenues for Iowa companies and workers.[83]

Impacts of displaced grid investments

The second key effect evaluated is the displacement of other grid investments that will result from investment in storage. This analysis has taken a conservative approach to estimating these impacts and does not assume that utility-scale storage capacity substitutes one-for-one with traditional utility alternatives.[84,85]

Utilizing the Colorado study as a proxy to determine new storage impacts in Iowa, storage is expected to displace:

- 377 MW of natural gas generation capacity in each of the scenarios;

[83] These impacts are separated into three categories in IMPLAN. Direct impacts include changes in employment, GDP, and income associated with shifts in production in directly affected industries. Indirect impacts are those that cascade down through the supply chains of directly affected industries. Finally, induced impacts are the result of re-spending of employee wages and consumer energy savings in the wider economy.

[84] These projections were limited by the requirement that only natural gas combustion turbine units with retirement dates prior to 2035 be closed, and the assumption that storage capacity could only avoid transmission and distribution capacity at a 2:1 ratio.

[85] The two storage scenarios evaluated in this analysis represent alternatives to an unknown future, which is conceptualized as the study baseline or "base case." Due to data limitations and study scope, Synapse did not conduct power sector modeling to specify the complete characteristics of this base case but did estimate the energy and capacity displacements that would result from new storage.

- 630 MW of transmission and distribution capacity in the Low scenario and 1,068 MW of transmission and distribution capacity in the High scenario;
- 33,373 MWh of energy imports in the Low scenario and 48,037 MWh of energy imports in the High scenario.

These displacements represent money that *is not spent*, and as a result, indicate reductions in employment, income, and GDP for the state.

Changes in electricity rates and bills

The final effect considered is the change in customers' electricity rates and bills that result from the first two effects. Spending on new utility-scale storage will raise rates and bills for all customers, all else equal, while utility-system displacements *reduce* rates and bills. In sum, this final effect may be either positive or negative.

Summary of spending changes

Synapse estimated changes in spending associated with each of the three effects discussed above for every year of the analysis. These changes in spending were then used as inputs in the macroeconomic model to determine the ultimate impacts to GDP, jobs, and income. Table 4 and Table 5 below summarize these spending changes, with aggregate changes in spending provided for three study periods, 2020–2024, 2025–2030, and 2031–2035.

Table 4. Low scenario projected spending changes for three study periods (2019$ Million)

Spending Change	2020–2024	2025–2030	2031–2035
Utility-Scale Storage	$319	$1,170	$130
BTM Storage	$10	$39	$109
Natural Gas Generation Capacity	-$17	-$53	-$22
Transmission and Distribution Capacity	-$7	-$25	-$5
Energy Imports	$0	-$1	-$1
Electricity Rates and Bills	$305	$1,129	$211

Table 5. High scenario projected spending changes for three study periods (2019$ Million)

Spending Change	2020–2024	2025–2030	2031–2035
Utility-Scale Storage	$57	$2,567	$230
BTM Storage	$10	$39	$109
Natural Gas CT	-$4	-$58	-$13
Transmission and Distribution Wires	-$1	-$54	-$7
Energy Imports	$0	-$1	-$1
Electricity Rates and Bills	$62	$2,493	$318

4.4. Economic Impacts Results

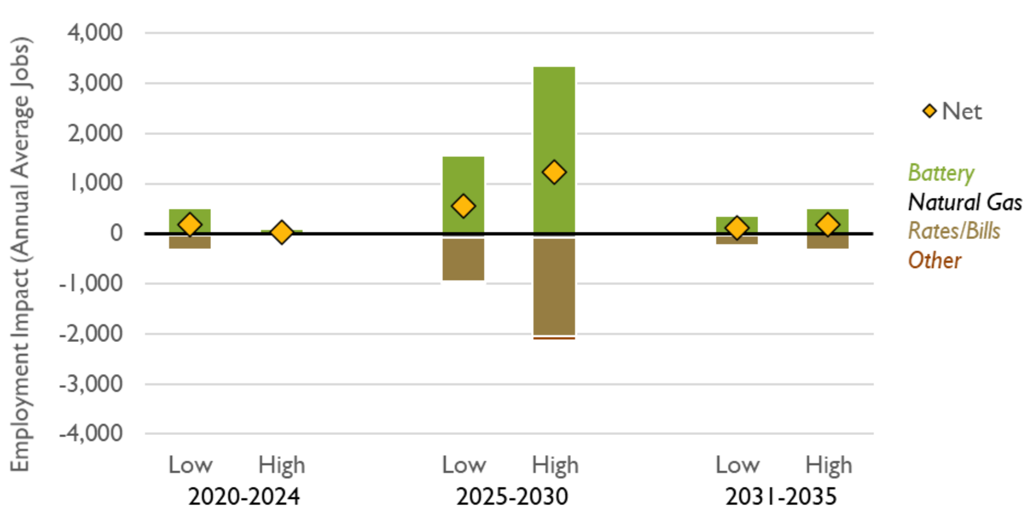
Overall, we found that both scenarios would deliver economic benefits to the state of Iowa. Over the entire study period, the Low scenario results in an average of 298 more full-time employed workers for the study period (full-time equivalents or FTEs), an additional $17 million dollars in annual income, and a $13 million boost to state GDP per year. The High scenario is associated with an average of 525 more jobs annually, $30 million in additional income per year, and annual GDP growth of $24 million.

While the storage supply chain is situated almost entirely outside of Iowa, with little related manufacturing occurring in state, investments in both utility-scale and BTM storage projects are expected to boost the local economy by increasing employment of technicians and other professionals. These investments will also provide stimulus to related businesses including engineering, construction, and legal service firms. Overall, the stimulating effects of new investment in storage outweigh the downward pressure reductions in other utility-system spending and increased electricity rates and bills.

Employment impacts

Figure 13 displays the average annual Iowa employment impacts for the Low and High scenarios relative to baseline. The results indicate small net positive employment impacts under both BESS deployment scenarios. In both cases, two primary effects can be seen to act in opposition: positive employment impacts result from the new investment in storage resources, while negative impacts result from reductions in consumer spending and business investment. This is a consequence of higher utility bills and greater private spending on BTM storage. Positive impacts outweigh negative ones. Over the full period, the Low scenario averages about 298 more jobs or FTEs than the baseline, while the High scenario average about 525 more FTEs than baseline.

Figure 13. Average annual employment impacts of Low and High scenarios

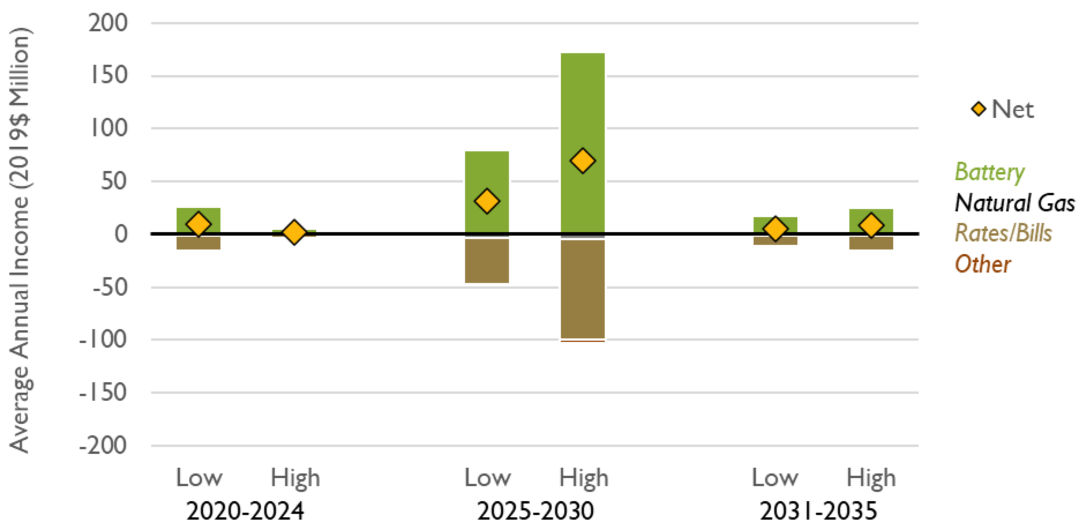


Source: Synapse calculations.

Income impacts

Figure 14 presents findings regarding income impacts in Iowa. Income impacts are the net change in disposable income of any person impacted by the storage industry in Iowa. This study found small positive net impacts under the Low and High scenarios. Over the full study period, net average annual income impacts were found to be about $17 million under the Low scenario and $30 million under the High scenario.

Figure 14. Average annual income impacts of Low and High scenarios

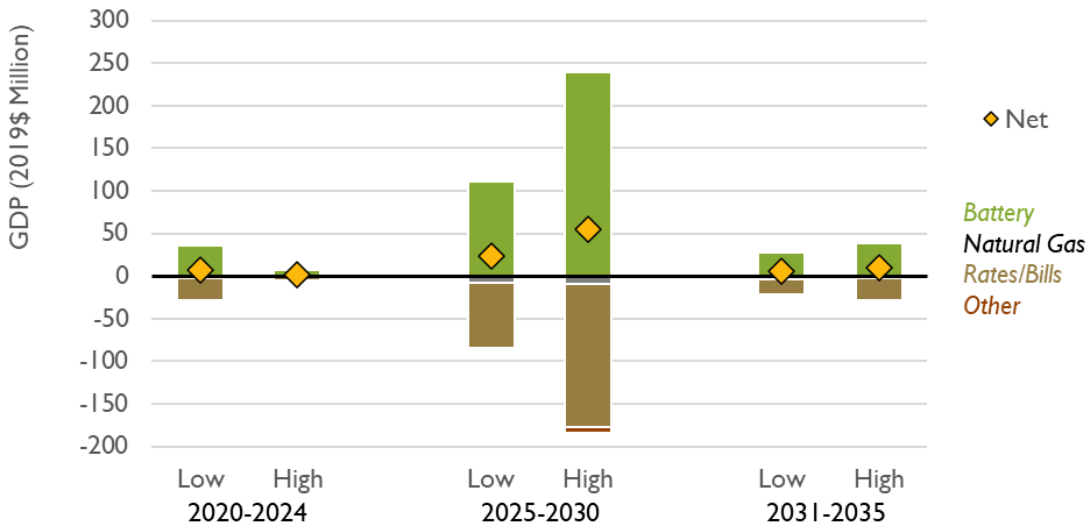


Source: Synapse calculations.

GDP impacts

Figure 15 displays net GDP results. This study found small positive net impacts under the Low and High scenarios. Over the full study period, expected net average annual GDP impacts are approximately $13 million under the Low scenario and $24 million under the High scenario.

Figure 15. Average annual GDP impacts of Low and High scenarios



Source: Synapse calculations.

The analysis of the macroeconomic impacts of a growing energy storage industry in Iowa demonstrate modest but positive impacts on jobs and GDP. The analysis, however, did not consider the cross-sector impacts of storage serving as a transformational technology. For example, energy storage could play a role in helping to better use the state's existing wind resources plus support the expansion of wind and solar as low carbon, low-cost forms of energy generation. Nor does the analysis capture the state-wide benefits of energy storage enabling deep electrification of the transportation, buildings, and agricultural sectors. Displacing imported fuels used in these sectors with in-state wind and solar generation would stimulate the Iowa economy well beyond what this report forecasts. The analysis represents a conservative approach to assessing the likely future macroeconomic impacts of energy storage deployments in the state.

5. STORAGE POLICIES: BARRIERS, INCENTIVES, AND BEST PRACTICES

As discussed above, energy storage provides many benefits to consumers and electric utilities. Energy storage can provide a variety of valuable services in the regional wholesale energy markets. However, energy storage is unique in serving as both a supply of energy when discharging and demand for energy when charging. As a result, policy and regulation need to be explicit for owners to capture those benefits. New technologies often require policy and regulatory support during the early stages of market development. While there are limited programs available at the federal level, many states have put in place programs and market reforms designed to support the adoption of energy storage technologies. It is also important that the rules and regulations that govern how energy storage systems are designed and operated address safety concerns while maximizing the value that energy storage can provide. This section begins with a description of the Iowa battery storage supply chain and then reviews barriers to widespread adoption of storage and the program and incentives being used to overcome these barriers.

5.1. Battery Storage Supply Chain and Industry in Iowa

Energy storage installations in Iowa currently rely primarily on in-state labor and out-of-state materials and manufacturing. This stems directly from the lack of lithium-ion manufacturing in the state as of now. Iowa does have several companies that manufacture lead-acid batteries, such as for cars, but none of these companies currently manufacture the materials needed for an energy storage installation.

Each of the Iowa stakeholders interviewed stated that they are unaware of any companies in the state that manufacture batteries or any other component of an energy storage system. The stakeholders who had installed an energy storage system stated that they relied on materials from other regions of the United States or other countries. For example, a utility representative in the state mentioned that they primarily receive bids from out-of-state or overseas companies when they request quotes. Another firm in the state mentioned that it received a number of parts for both large commercial projects and residential projects from Tesla. These companies work directly with the manufacturers rather than through distributor or sales networks.

Although there currently is no direct energy-storage-related manufacturing in Iowa, the state does have energy storage integrators. These are single multipurpose firms that will handle the procurement, design, and installation of energy storage projects. The integrator firm we interviewed stated that it handles everything from the permitting and fees to the installation and ongoing maintenance of the energy storage systems.

Stakeholders also stated that they rely primarily on in-state labor for the installation and maintenance of energy storage systems. The integrator firm we interviewed uses in-house designers and electricians and hires installer crews from within the state for most of its projects. The integrator stated that maintenance is typically done in-house as well. The utility uses a similar structure and relies on an in-house or local electrician for ongoing maintenance as well.

5.2. Federal Storage Support Landscape

On a federal level, there is limited support for energy storage. However, there are several programs that indirectly incentivize energy storage. In addition, the U.S. Department of Energy (DOE) released the *Draft Roadmap for the Energy Storage Grand Challenge* in July 2020. This roadmap provides an overarching strategy for strategic investments by the federal government. The *Energy Storage Grand Challenge* is a comprehensive program to accelerate the development, commercialization, and utilization of next-generation energy storage technologies and promote U.S. global leadership in energy storage.[86] The roadmap focuses on the following five tracks:

1. The Technology Development Track will focus DOE's ongoing and future energy storage R&D around user-centric goals and long-term leadership.
2. The Manufacturing and Supply Chain Track will develop technologies, approaches, and strategies for U.S. manufacturing that support and strengthen U.S. leadership in innovation and continued at-scale manufacturing.
3. The Technology Transition Track will work to ensure that DOE's R&D transitions to domestic markets through field validation, demonstration projects, public private partnerships, bankable business model development, and the dissemination of high-quality market data.
4. The Policy and Valuation Track will provide data, tools, and analysis to support policy decisions and maximize the value of energy storage.
5. The Workforce Development Track will educate the workforce, who can then research, develop, design, manufacture, and operate energy storage systems.[87]

Federal Energy Regulatory Commission and MISO's and SPP's responses to Order 841

The FERC issued Order 841 in 2018 to reduce wholesale energy market barriers for energy storage resources. This Order required all regional transmission organizations (RTO) and independent system operators (ISO) to submit a compliance filing. The filings must include reforms to existing wholesale market rules that remove barriers to energy storage participation in wholesale energy markets.

MISO submitted its compliance plan in December of 2018 to the FERC. This proposal was partially accepted by FERC in November of 2019, subject to further revisions. The FERC rejected MISO's proposal on metering implementation and accounting practices. The FERC further specified that the compliance

[86] U.S. Department of Energy (DOE). July 2020. *Energy Storage Grand Challenge: Draft Roadmap*. Available at: https://www.energy.gov/sites/prod/files/2020/07/f76/ESGC%20Draft%20Roadmap_2.pdf.

[87] *Ibid*.

plan must allow energy storage resources to both buy from the market and sell to the market. Furthermore, the FERC articulated that storage should be able to participate in both wholesale and retail energy markets without being charged twice for energy.[88] MISO's final FERC 841 compliance plan is not anticipated to be in place until 2021 or mid-2022.

SPP submitted its Order 841 compliance filing in December 2018, which was subsequently amended in February 2019. Like MISO, in October 2019 the FERC gave partial approval of SPP's compliance filing, subject to further revisions. The FERC ordered SPP to submit a second compliance filing to address several issues including a request to clarify mechanisms to prevent conflicting supply offers and demand bids among others.[89] In response, SPP submitted a second compliance filing in December 2019, which was approved by FERC for implementation effective August 2021.

Several stakeholders have expressed concern about some of the requirements in FERC's Order 841. Distribution companies and other stakeholders are claiming it is beyond the FERC's jurisdiction to dictate how storage must participate at the distribution level, as Order 841 does.[90] However, on July 10, 2020, the Federal Court of Appeals decided in favor of FERC Order 841.[91] This ruling was supported by many energy storage stakeholders and advocates but was opposed by many state public utility regulators and utilities.[92] This ruling ends years of dispute over the Order, paving the way for the Order to be finalized in regions where concerns had been raised. The integration of energy storage in wholesale energy markets will take time as each RTO/ISO implements the necessary market reforms to comply with FERC Order 841.

Federal tax policy

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[88] O'Konski, Katherine, Kooistra, Russel. November 2019. FERC Conditionally Accepts CAISO, MISO, and ISO-NE Order No. 841 Energy Storage Participation Proposals. Washington Energy Report. Available at: https://www.troutmanenergyreport.com/2019/11/ferc-conditionally-accepts-caiso-miso-and-iso-ne-order-no-841-energy-storage-participation-proposals/

[89] FERC. July 16, 2020. Southwest Power Pool, Inc. Docket No. ER19-460-005, ORDER ON COMPLIANCE FILING. Available at https://www.spp.org/documents/62613/20200716_order%20on%20compliance%20filing%20-%20order%20no.%20841%20compliance%20filing_er19-460-005.pdf.

[90] O'Konski, Katherine, Kooistra, Russel. November 2019. FERC Conditionally Accepts CAISO, MISO, and ISO-NE Order No. 841 Energy Storage Participation Proposals. Washington Energy Report. Available at: https://www.troutmanenergyreport.com/2019/11/ferc-conditionally-accepts-caiso-miso-and-iso-ne-order-no-841-energy-storage-participation-proposals/

[91] United States Court of Appeals. July 2020. No. 19-1142: National Association of Regulatory Utility Commissioners (NARUC) v. Federal Energy Regulatory Commission (FERC). Available at: https://www.cadc.uscourts.gov/internet/opinions.nsf/E12B1903B0477E21852585A1005264D7/%24file/19-1142-1851001.pdf

[92] St. John, Jeff. 'Enormous Step' for Energy Storage as Court Upholds FERC Order 841, Opening Wholesale Markets. Green Tech Media. July 2020. Available at: https://www.greentechmedia.com/articles/read/court-upholds-ferc-order-841-opening-wholesale-markets-to-energy-storage#:~:text=In%20a%20victory%20for%20the,the%20distribution%20grid%20or%20behind

The federal government provides an ITC to homeowners and businesses that invest in a solar PV system. The solar ITC also applies to energy storage systems coupled with solar. The exact credit varies based on what percent of the battery is charged by the qualifying solar facility. The ITC for storage systems increases as the percentage of energy sourced from solar increases. However, the ITC is being phased out and was reduced from the prior rate of 30 percent to 26 percent in 2020. It will be further reduced in 2021 to 22 percent. After 2021, the residential credit drops to zero while the commercial credit drops to a permanent 10 percent.

Beyond the existing ITC, the U.S. House of Representatives has proposed *The Energy Storage Tax Incentive and Deployment Act*. This act aims to incentivize stand-alone energy storage in the same way the ITC does for stand-alone solar. This proposed legislation mimics the solar ITC's ramp down rate of 26 percent in 2020 and 22 percent in 2021.[93] While this legislation is not likely to pass both houses of Congress, a stand-alone energy storage incentive at the federal level could help support the sustainable growth of the energy storage industry at some point in the future.

5.3. Barriers in Iowa

With limited federal support for energy storage investments, most support is found at the state level. In Iowa, however, there has not been the level of support seen in other states. The main existing barriers affecting the growth of energy storage in Iowa include the relatively high capital cost of battery systems, a lack of current alignment between storage value and markets, and uncertainty in the future (for markets, regulation, and battery technology). These barriers are discussed in detail below.

Capital cost

The current high upfront cost of battery energy storage serves as a barrier to installations in the state. While the cost has been falling in recent years, the current cost continues to be an obstacle to the widespread deployment of energy storage. Some utilities interviewed expressed concern about the high upfront cost and the need to find multiple value streams in order to make their investment economical. Utilities mentioned that the current cost of a battery does not position it as the lowest cost option for any of its benefits, including for frequency regulation, as a capacity resource, or for transmission and distribution deferral. Furthermore, utilities noted that they expect the cost to continue to fall and do not want to invest now and end up with an expensive asset that is losing value in the future.

This barrier also exists for BTM installations. Stakeholders stated that batteries are not currently economical as a back-up source of power when compared to fuel-powered generators and that energy rates are typically not high enough to justify the installation of BTM storage. Specifically, utilities mentioned that energy rates are not high enough in their territory for solar-plus-energy storage to save enough money to offset the cost. It is difficult to offset the current high upfront costs of a battery

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[93] St. John, Jeff. April 2019. US House Introduces Energy Storage Tax Credit Bill. Green Tech Media. Available at: https://www.greentechmedia.com/articles/read/congress-introduces-energy-storage-tax-credit-bill

energy storage system given the lack of time-of-use rates offered by Iowa utilities and the availability of net energy metering (which eliminates the potential to save money with energy storage through increased self-consumption) for all investor-owned utilities.

Lack of current alignment between storage value and markets

In addition to the current high cost of energy storage, a key challenge for energy storage deployment in Iowa is the inability of owners to capture the various value streams that storage can provide. Optimizing value streams takes effort in any storage project, but it is exacerbated in Iowa by lack of alignment between MISO and the multiple market participants, as well as a lack of regulatory clarity in general. In interviews with Iowa stakeholders, MISO policy was consistently mentioned as a deterrent to energy storage. Stakeholders stated that MISO is still developing policy on how the market will value energy storage and that it is currently unclear how energy storage will be compensated in the market. This makes it difficult for Iowa stakeholders to capture the benefits that energy storage can provide.

For example, an investor-owned utility mentioned the need to clarify when to charge and when to discharge in order to properly optimize the use of a battery in MISO's wholesale energy market. Furthermore, others mentioned the need to clarify how batteries could provide value as a non-wire alternative that could allow utilities to offset transmission upgrades.

Energy storage stakeholders in Iowa could play a role in influencing the ways in which MISO responds to FERC Order 841. The MISO governance structure allows for significant stakeholder engagement. The Iowa Storage Committee could develop a position statement on the necessary wholesale market reforms that would support the expansion of energy storage in Iowa. Iowa energy storage interests could use the Committee's position statement to actively engage in stakeholder discussion taking place through the MISO governance process.

The Energy Storage Committee could also play a role in determining how energy storage could be integrated into current distribution utility planning activities through regulatory requirements discussed below. Some states explicitly require distribution utilities to explicitly consider non-wires alternatives to traditional investments in distribution infrastructure. As discussed above, energy storage systems can be a cost-effective alternative to address constraints within the distribution and transmission systems.

In addition to a lack of clarity from MISO, stakeholders also mentioned that the current market structure makes it difficult to capture other benefits often associated with energy storage. The state of Iowa currently has substantial wind energy generation relative to its solar generation. The wind resource is both less predictable than solar and has a stronger seasonal pattern than a daily pattern, making energy arbitrage difficult in the current market. Finally, stakeholders mentioned that the MISO market is currently oversupplied with capacity, decreasing the value utilities can receive for energy storage capacity additions.

Uncertainty in the future: For markets, regulation, and battery technology

Energy storage, particularly batteries, is still viewed as a new technology relative to traditional generation or transmission solutions. The infancy of the technology serves as an additional barrier to widespread adoption—both due to uncertainty about the technology's performance and uncertainty about how market and regulatory frameworks may change in the future. Given that battery storage systems create both retail and wholesale value that are not mutually exclusive, there is uncertainty about how markets and regulations will evolve to support value stacking discussed above in Section 3.3

The performance of the technology is still a concern for many Iowa stakeholders. Stakeholders mentioned concerns about the reliability of the technology as well as the expected lifetime and rate of degradation of the technology. For example, one investor-owned utility mentioned that its current installation has required more maintenance than expected, with batteries going out of service more frequently than anticipated. Furthermore, utilities expressed concern about the potential for other technologies to enter the market and provide the same benefits at a better value.

The other risk Iowa stakeholders noted was the uncertainty around regulatory decisions and utility rates, both of which have significant influence over the value of energy storage. The possibility that less favorable utility rates for energy storage may be passed in the future deters the installation of commercial or residential energy storage. For FTM installations, the lack of clarity around how MISO will value batteries in the future makes it difficult for utilities to guarantee that an energy storage installation will recover its cost over its lifetime.

As discussed below, many states are supporting battery storage pilot projects to gain experience and learnings that help to decrease the perceived risks of energy storage and share knowledge on how to optimize the value that energy storage provides.

5.4. Policies and Incentives: Best Practices

Because of the broad range of capabilities of energy storage systems, regulatory bodies have struggled to clearly and consistently apply existing policies. As a result, states have begun developing new policies (and policy reforms) specifically targeting electrical energy storage systems.

The Pacific Northwest National Laboratory (PNNL) maintains a frequently updated database of state-level policies related to energy storage around the United States.[94] The table below categorizes the different types of policies and the states which have each policy type in place. In all, 23 states have some form of policy related to energy storage. The sections following the table discuss these categories of policy in more detail, with examples of successful policy initiatives in a few states.

[94] PNNL. 2020. "Energy Storage Policy Database." Energy Storage. March 2020. https://energystorage.pnnl.gov/regulatoryactivities.asp.

Table 6: Types of policies supporting energy storage and states that have implemented them

Policy type	Brief description	States with this and other policies	States with this policy only	Total
Procurement targets	Requires utilities to install specific amounts of energy storage	CA, CO, MA, NJ, NV, NY, OR		7
Regulatory requirements	Varying requirements for utilities to evaluate and/or plan for energy storage installations, among others	AZ, CA, CO, HI, MA, MD, MO, NJ, OR, VA, VT, WA	CT, ME, MN, NC, NM, TX	18
Demonstration programs	Funding for, state-led pilots of, or regulatory allowance for, individual storage projects	MA, MD, NH, NY, VA, WA	UT	7
Financial incentives	Establishment of discount rates, net metering allowances, tax rebates, or cash payments for BTM storage installations	AZ, CA, HI, MA, MD, MO, NH, NV, NY, OR, VA, VT	SC	13
Consumer protection	Provides interim allowance for BTM energy systems while standards are being developed	CO, NV		2

Source: Pacific Northwest National Laboratory - Energy Storage Policy Database.

Procurement targets

To date, seven states have established storage procurement targets through several mechanisms (executive orders, utility commission decisions, or legislation).

Table 7: Energy storage procurement targets by state

State	Target	Mechanism
CA	1,325 MW total, 500 MW connected at distribution level	Assembly Bills 2514 and 2868
CO	The PUC has established mechanisms for utilities to procure ESS	House Bill 18-1270
MA	200 MW by 2020, 1 GW by 2025	House Bill 4857
NJ	600 MW by 2021, 2 GW by 2030	Assembly Bill 3723
NV	The PUC has proposed regulations for setting and reviewing targets	Senate Bill 204
NY	1,500 MW by 2025, 3,000 MW by 2030	PSC Case 18-E-0130
OR	The two large IOUs must install 5 MWh each by 2020	House Bill 2193

Source: Pacific Northwest National Laboratory. Energy Storage Policy Database.

In each case, the target is paired with one or two other strategies to drive installation of energy storage. Several of these states have established a target with a specific grid benefit in mind. California's CPUC established specific targets for renewable integration, reduction in use of fossil fuels, and NWAs to defer transmission and distribution upgrades[95]. In contrast, New Jersey's target was mandated to address resiliency by using energy storage to avoid the loss of power to critical loads.

Regulatory requirements

Regulatory requirements are the most common method by which states have sought to encourage the development of energy storage resources. In most cases, these requirements seek to update or amend existing regulatory processes in ways that increase the ability for energy storage systems to become cost-competitive relative to other resource types. Five of the seven states with specific targets also have regulatory measures in place to facilitate the process of meeting those targets. The exceptions are Nevada, where a specific target is still pending, giving time for regulatory reform; and New York, Massachusetts, and New Jersey where being deregulated and within FERC jurisdiction means there is less need for PUC-issued regulatory reform.

In general, regulatory reform involves some combination of updating utility planning requirements (such as the IRP process) and revising ratemaking regulations. These reforms often consider existing RPS requirements, as storage is recognized as a technology that enables higher renewable penetration. Of the 18 states that have instituted regulatory reform, all have mandatory renewable portfolio standards, and 10 have a requirement of 30 percent or greater.[96]

Other significant factors influencing the genesis of regulatory requirements have varied by state:[97]

- Washington implemented changes to incorporate lessons learned from demonstration projects.
- California's reforms aimed to improve market compensation for resources brought online to meet previously established targets.
- Hawaii focused on reforms that would incentivize co-location and coordination of renewables and storage.
- Arizona had a need to expand demand response, so focused on load management capabilities of storage in regulations.

Massachusetts has taken an innovative approach to regulatory changes by opting to include energy storage in the state energy efficiency program.[98] Traditionally, state-regulated utility energy efficiency

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[95] Twitchell, Jeremy. 2019. "A Review of State-Level Policies on Electrical Energy Storage." Current Sustainable/Renewable Energy Reports 6 (2): 35–41. https://doi.org/10.1007/s40518-019-00128-1

[96] National Conference of State Legislators. 2020. "State Renewable Portfolio Standards and Goals." Available at: https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx

[97] Twitchell, Jeremy. 2019. "A Review of State-Level Policies on Electrical Energy Storage." Current Sustainable/Renewable Energy Reports 6 (2): 35–41. https://doi.org/10.1007/s40518-019-00128-1.

[98] Todd Olinsky-Paul. 2019. "Energy Storage: The New Efficiency." Clean Energy Group. https://www.cleanegroup.org/wp-content/uploads/energy-storage-the-new-efficiency.pdf.

programs have channeled funding into measures which performed the same end-use tasks with less energy; LED lightbulbs, low-flow plumbing fixtures, weatherization, etc. After years of funding such programs, however, Massachusetts made a troubling observation, explained in the 2016 *State of Charge* report: while annual energy usage has been in decline, summer peak demand has been growing.[99] The report went on to argue that because Massachusetts' 2008 *Green Communities Act* had included demand reduction within the definition of energy efficiency for the state program, energy storage should be explicitly included because of its ability to reduce peak demand. On this recommendation, the 2018 *Act to Advance Clean Energy* added active demand management technologies, including energy storage, to the list of eligible technologies within the energy efficiency program.[100]

Demonstration programs

As part of the 2009 American Recovery and Reinvestment Act (ARRA), 15 energy storage demonstration projects were funded around the United States, all of which were completed by 2015.[101] Sandia National Laboratories, in reviewing these projects, found that in each case project stakeholders benefited from the ability to determine first-hand the logistical, regulatory, and operational challenges associated with each project. In 2019, the Maryland General Assembly passed Senate Bill 573, known as the *Energy Storage Pilot Program Act*. Subsequently, the Maryland Public Service Commission established an Energy Storage Pilot Program requiring each Maryland investor-owned electric distribution company to solicit offers to develop energy storage projects and to submit at least two energy storage proposals for the Commission's consideration.[102] The total capacity for the combined storage projects across all utilities included in the Energy Storage Pilot Program is not to exceed 10 MW of capacity. States with energy storage demonstration projects typically have the same general goals in mind for demonstration projects. There are varying ways to accomplish these goals, which can generally be divided into three models:[103]

- Guaranteed funding: providing funding through grants or other means specifically for energy storage projects
- Special authorization: allowing utilities to pursue storage projects which would otherwise not be possible due to existing regulation

[99] Massachusetts Department of Energy Resources (DOER) and Massachusetts Clean Energy Center (MassCEC). 2016. "State of Charge: A Comprehensive Study of Energy Storage in Massachusetts."

[100] An Act to Advance Clean Energy. 2018. Vol. Acts of 2018. https://malegislature.gov/Bills/190/H4857.

[101] Bender, Donald Arthur, Raymond Harry Byrne, and Daniel R. Borneo. 2015. "ARRA Energy Storage Demonstration Projects: Lessons Learned and Recommendations." SAND-2015-5242. Sandia National Lab. (SNL-NM), Albuquerque, NM (United States); Sandia National Lab. (SNL-CA), Livermore, CA (United States). https://doi.org/10.2172/1504840.

[102] Maryland Public Utilities Commission. August 2019. Order Establishing an Energy Storage Pilot Program, Order #89420. Available at https://www.psc.state.md.us/wp-content/uploads/Order-No.-89240-Case-No.-9619-Order-Establishing-an-Energy-Storage-Pilot-Program.pdf.

[103] Twitchell, Jeremy. 2019. "A Review of State-Level Policies on Electrical Energy Storage." Current Sustainable/Renewable Energy Reports 6 (2): 35–41. https://doi.org/10.1007/s40518-019-00128-1.

- Other assistance: similar to special authorization, but with some roles of the program, such as developing and evaluating projects, being performed by the state.

Financial incentives

While capital costs for energy storage systems continue to fall, several states have elected to provide financial incentives for the development of projects to speed development. Funding approaches include rebates, incentive payments, and tax credits on capital expenditures (California, Nevada, New York, and Oregon); net metering allowances and other rate-based incentives (California, Massachusetts, New York, and South Carolina); eligibility for existing financing mechanisms (Virginia and Vermont); tax exemptions (New Hampshire); and demand response payments specific to storage (Arizona).[104] In general, the design of financial incentives depends on existing compensation methods for other grid technologies.

Consumer protection

The final category includes laws passed in Colorado and Nevada intended to ensure that utility customers are not prevented from installing and connecting BTM energy storage systems in those two states. In both cases, these laws seem to be intended as stopgap measures while other, more comprehensive regulation is developed and put in place.[105]

5.5. Applying Best Practices in Iowa

Section 5.3 identified three key barriers to broader implementation of storage in Iowa:

- Lack of current alignment between storage value and markets
- The relatively high capital cost of battery systems
- Uncertainty in the future (for markets, regulation, and battery technology)

Each of the five policy types described in Section 5.4 could be used to address these barriers to some extent. However, the most successful and widespread approaches seen in other states have been **regulatory requirements** and **financial incentives**.

Developing new or updated regulatory requirements serves a critical role in reducing uncertainty for utilities and other storage project stakeholders. The example of Massachusetts' Act to Advance clean energy is also instructive – expanding existing regulations, programs, and incentives in the state to explicitly include energy storage systems creates opportunities and programs that utilities and other

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[104] PNNL. 2020. "Energy Storage Policy Database." Energy Storage. March 2020. https://energystorage.pnnl.gov/regulatoryactivities.asp

[105] Twitchell, Jeremy. 2019. "A Review of State-Level Policies on Electrical Energy Storage." Current Sustainable/Renewable Energy Reports 6 (2): 35–41. https://doi.org/10.1007/s40518-019-00128-1

stakeholders are already familiar with. It also allows the state to build on lessons learned through these existing regulations and programs.

Financial incentives, of varying types, allow the state to increase alignment between storage value and markets, while also defraying capital costs. Again, this can often be as straightforward as broadening existing incentive programs, financing programs, net metering policies, or tax rebates to include storage. When considering tax-based incentives, however, care should be taken to understand the implications for non-profit utilities such as municipal utilities and cooperatives, given their extent in Iowa.

6. CONCLUSIONS

Battery energy storage is a relatively new technology that offers significant potential as part of an overall effort to modernize the nation's electric grid.

Utility-scale FTM applications can defer or reduce investments in traditional utility infrastructure, generate revenues providing wholesale market services, and increase resilience as part of microgrid systems. We estimate that the utility-scale FTM potential in Iowa is between 1 GW and 2 GW over the next 15 years. The scale and pace of energy storage deployments in Iowa, however, will depend on many other factors even with new energy policies. This includes reforms within MISO wholesale energy markets that impact the ability of storage to generate revenue providing grid services. The degree to which state regulators incentivize utilities to consider storage as an alternative to traditional utility investments is also a factor. Finally, the degree to which energy planning in Iowa considers the importance and value of resilience will impact the battery storage market in the coming decade.

Perhaps one of the most important roles that energy storage can play in Iowa is to support the expansion of renewable energy generation. Battery energy storage systems can help to manage the variable production of wind and solar generation. Battery energy storage systems can be charged from wind farms in Iowa during period when the wind generation would otherwise be curtailed due to constraints on the regional grid. We estimated that this stored energy could be sold at a later time increasing revenues to wind farm owners of approximately $25.6 million each year. This is a one form of energy arbitrage, whereby a battery storage system charged during low-cost/no cost periods and then discharging back to the grid during high-price periods.

Although solar installations are rather limited in Iowa today, declining cost make solar a cost-effective resource alternative to traditional sources of generation. Again, if solar production increases significantly in Iowa, battery energy storage systems can help support increased solar deployments by managing the variable production, particularly during the morning and evening hours as the sun is rising and setting, which requires traditional sources of generation to ramp up and down respectively.

For households and businesses in Iowa, energy storage provides opportunities to manage energy use and provide resilience during major grid failures. In utility service territories without net energy metering, pairing solar with energy storage offers benefits. Stand-alone energy storage or energy storage incorporated into a microgrid can offer resilience benefits that are valuable but often difficult to quantify. We project that BTM market opportunities are more limited than those for FTM systems. Based largely on the market opportunity for demand charge reduction for C&I customers, the BTM energy storage market could reach 114 MW by 2035. This is based on projections on the annual growth rate for BTM systems.

Today, the battery storage supply chain in Iowa is rather limited. The state economic impacts of a growing battery storage industry are estimated to be limited, but positive. This could change, however, if Iowa attracts new businesses to the state that are part of the battery storage supply chain. In addition, the overall economic impact on the state could be much greater when battery storage systems are used to enable other opportunities. This includes expanding the use of wind and solar generation in the state. This also includes the potential role that battery energy storage systems can play in enabling the use of in-state generation to reduce imported fuels.

There is no oil or gas production in Iowa due to limited crude oil and natural gas reserves. However, in 2018 Iowa was the fourth-largest consumer of hydrocarbon gas liquids, mostly propane. The propane is used for drying the state's large harvested corn crop and for heating one in eight Iowa households.[106] Energy storage paired with the state's abundant renewable resources offers a pathway to electrify the state's transportation, buildings, industrial, and agricultural sectors. Using in-state, low carbon energy generation to reduce imported fuels used in these sectors could have a significant impact on the state's overall economy.

It is worth considering the relatively large share of energy flow in Iowa that is ethanol. Using electric agricultural machinery to reduce fossil fuel resources in the production of corn-based ethanol could also serve to improve the energy balance of this renewable source of motor vehicle fuel. The opportunity to reduce petroleum fuels in this process with renewable energy paired with energy storage provides an opportunity to make ethanol an even more environmentally superior fuel relative to gasoline. Furthermore, electrification of agricultural machinery with large battery packs could provide V2G services when not in use for farming.

Iowa is home to several top-tier university research centers that could play an important role in evaluating the most promising opportunities to realize the full potential that battery energy storage offers to the state. The existing Iowa Energy Storage Committee provides an excellent mechanism to take the next step to support the development of energy storage in the state to maximize the economic and reliability benefits that battery energy storage can provide. The Committee could expand its stakeholder process to address the three key barriers to energy storage in Iowa identified in this report. This could include convening workshops or a conference to evaluate the efforts that other states have

[106] U.S. Energy Information Administration. 2019. Iowa State Profile and Energy Estimates. Available at https://www.eia.gov/state/?sid=IA.

taken discussed in this report within the Iowa context to support the development of the energy storage industry. This could also include engaging with wind and solar industry stakeholders to explore the role that energy storage can play in Iowa to reduce wind curtailments and support the growth of solar energy installations. Greater use of in-state renewable energy sources through electrification of the transportation, buildings, and agricultural sectors could support regional economic development while reducing the environmental impacts of energy consumption.

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