HOOSIER ENERGY FULLY CHARGED

AN OUTLOOK OF INFLUENTIAL POLICIES AND TECHNOLOGIES FOR ENERGY STORAGE

FINAL REPORT

PREPARED FOR:

HOOSIER ENERGY RURAL ELECTRIC COOPERATIVE, INC.

PREPARED BY:

V600 ENERGY STORAGE CAPSTONE

DECEMBER 11, 2019

O'NEILL
School of Public and Environmental Affairs
Indiana University

HOOSIER ENERGY
FULLY CHARGED

An Outlook of Influential Policies and Technologies for Energy Storage

Final Report

Prepared for: Hoosier Energy Inc.
Josh Cisney

Prepared by: SPEA-V600 Fall 2019
Reena Azlan, Bronson Bast, Tianyu Chen, Sean Chung, Kenneth Hagen, Madeline Mohrman, Patricia Murphy-Geiss, Gabriela Scott, Quintin Thompson, Ruurd van der Heide, and Jin An Yi

Faculty Advisor:
John A. Rupp

V600 Capstone Course
O'Neill School of Public and Environmental Affairs
Indiana University

Submitted: December 11, 2019

TABLE OF CONTENTS

GLOSSARY

BESS	Battery Energy Storage System
BOS	Balance of System
BTM	Behind the Meter
CAISO	California Independent System Operators
DRR	Demand Response Resource
DER	Distributed Energy Resource
EECLP	Energy Efficiency and Conservation Loan Program
EE	Energy Efficiency
ESR	Electric Storage Resource
EV	Electric Vehicles
FERC	Federal Energy Regulatory Commission
FTM	Front of the Meter
HVAC	Heating, Cooling, Air Conditioning
IRP	Integrated Resource Planning
ISO	Independent System Operator
IPL	Indianapolis Power and Light Company
ITC	Federal Investment Tax Credit
LCOE	Levelized Cost of Electricity
LCOS	Levelized Cost of Storage
LMP	Locational Marginal Pricing
MISO	Midcontinent Independent System Operator
NERC	North American Electric Reliability Corporation
NIPSCO	Northern Indiana Public Service Company
PJM	Pennsylvania, Jersey, Maryland Power Pool
PPA	Power Purchase Agreements
PHES	Pumped Hydroelectric Storage
RESP	Rural Energy Savings Program
RTO	Regional Transmission Organization
RPS	Renewable Energy Portfolio Standards
SER	Storage Energy Resources
SGIP	Self- Generation Incentive Program
Tariff	Opening Access Transmission, Energy and Operating Reserve Markets Tariff

INTRODUCTION

Opportunities for using energy storage technologies have expanded significantly in the last few years. This trend is a result of a combination of factors - from recent cost declines and increased capabilities in the technologies to the implementation of state energy policies and a surge in recognition of energy storage services. As these trends and others continue - including increased penetration of renewable generation assets, distributed energy resources (DERs), and the rise of electric vehicle (EV) use - the potential role that energy storage is expected to play in the overall transformation of energy generation will likely increase exponentially. As the energy landscape changes, Hoosier Energy should consider how energy storage can serve as a cost-effective solution to arising challenges. Energy storage can allow for renewable grid integration and provide a number of traditional services. When combined, energy storage can facilitate a positive return on investment as well as improve the return on past investments of currently installed solar installations.

Deciding when and how to deploy energy storage as a prudent investment presents a new challenge to Hoosier Energy. To address decision challenges, this assessment evaluates relevant factors that significantly impact deployment decisions regarding storage assets. This report was prepared by a V600 capstone course comprised of graduate students of the O’Neill School of Public and Environmental Affairs at Indiana University, Bloomington. Students assessed the risks and rewards of energy storage for Hoosier Energy, considered the technological and policy aspects, and then assessed these dimensions in research teams. The technology team examined the operational aspects and costs associated with the application of select storage technologies and the services these applications can provide. The policy team examined policy and institutional influences on the valuation of energy storage services.

The report is guided by a fundamental research question: "What are the key policy related factors that will either inhibit or promote the effective integration of energy storage into Hoosier Energy's portfolio?" This report is designed to aid Hoosier Energy in the decision-making process for investing in energy storage. The report contains: a background section and overview of energy storage, an analysis of four key factors that will affect energy storage in the short and long-term, a decision making framework to help design a project, and a set of recommendations to consider in the next decade. As this assessment is prepared by graduate students in a public policy program, it has a greater emphasis on policy-centric factors over the technical or business considerations. The research approach is described in more detail in the following section.

RESEARCH APPROACH

To effectively evaluate the policy and related factors that will influence the deployment of storage assets into Hoosier energy's system, the context of energy storage in general was investigated, those factors that were found to be influential to its use identified, the most influential ones determined and their influence prioritized. The potential relationships between factors and probability of occurrence of each factor was evaluated using existing models and forecasts generated by various utilities and organizations. Based on these four factors, a decision making tree was created to help guide a project planning process. Finally, recommendations were formulated for the coming years.

BACKGROUND RESEARCH

Background research was completed to provide a base of knowledge necessary to consider energy storage opportunities. This research was undertaken by two separate work groups, one focusing on technologies and the other policy factors.

TECHNOLOGY

Energy Storage technology has important considerations for the transmission grid, distribution grid, and behind the meter (BTM) systems. The transmission and distribution research was grouped together and evaluated as front of the meter (FTM) applications, because storage technologies in these systems are capable of providing many of the same services.

Storage technologies were assessed to determine which were best suited for each storage system. To summarize the possibilities for Hoosier Energy, a series of relevant case studies were reviewed to determine the most promising technologies at each level of application. The technology team began by conducting background research and applications of energy storage.

TECHNOLOGY TASK 1: BACKGROUND RESEARCH

Background research was completed on a select group of promising storage technologies. This included research on costs, current trends, and technological limitations of each technology given its scale of application.

TECHNOLOGY TASK 2: ANALYSIS OF ENERGY STORAGE TECHNOLOGY APPLICATIONS

Technologies were analyzed in the context of their application and the benefits they could offer. These technologies were analyzed with their respective ability to: participate in energy, capacity and ancillary service markets; defer transmission and distribution infrastructure, benefit customers by reducing demand charges and/or time of use charges, increase reliability; and support microgrids.

POLICY

Policies and their potential influences on energy storage adoption were analyzed to determine which policies will be most influential and which will be contingent on other events occurring.

POLICY TASK 1: MISO'S STORAGE PARTICIPATION PLAN TO COMPLY WITH FERC ORDER 841

Federal Energy Regulatory Commission Order (FERC) No. 841, attempts to remove barriers to participation of energy storage resources in power markets operated by Regional Transmission Organizations or Independent System Operators (RTOs/ISOs). In conjunction with this analysis, MISO's proposed policies for compliance with FERC Order No. 841, which governs bidding parameters and tariffs for energy storage resources, were examined.

POLICY TASK 2: OUTLOOK OF STATE AND FEDERAL POLICIES

Policies that regulate emissions and/or incentivize energy storage in comparator states were analyzed. Furthermore, current federal incentives for storage and any relevant legislation proposed both in Indiana and at the federal level regarding energy storage may indicate a shift towards greater public interest in energy storage and increase incentive options. This research provides the background information necessary to determine the relevant technical and policy factors impacting the viability of energy storage in Hoosier Energy's future.

FACTOR IDENTIFICATION

After completing this initial research, key factors driving the potential for energy storage were identified and internally discussed. These factors were then diagramed on concept maps to illustrate their relative importance in relation to one another. Through this process, four key factors were selected: technological innovation, renewable energy penetration, DER aggregation, and energy policy. These factors are the primary determinants affecting energy storage opportunities in the future. Two opposing scenarios were summarized for each factor. These scenarios are: incremental technological innovation and disruptive technological innovation, high and low renewable energy penetration, recognition of distributed resource aggregation and no recognition, and energy policy implementation and no energy policy. Finally, specific recommendations were formulated for the coming years. Because this research effort is dominantly a policy assessment, techno-economic and business aspects of energy storage deployment were only examined and integrated into the evaluation to the extent needed to make the assessment.

ANALYSIS OF IMPACTS AND FACTOR INTERACTIONS

The impact of a given factor on the deployment of storage was examined in conjunction with a qualitative assessment of possible interactions it may have among the four factors. Understanding that there are a myriad of possible combinations and degrees of influence resulting from the interaction of these factors, this process was simplified by using scenarios. These scenarios pushed each factor to a hypothetical extreme on the continuum of possible outcomes and focusing on outcomes that were the most likely. Each factor was analyzed in relation to the other scenarios in each of the other three factors (e.g. what would happen to renewable penetration if technology improves significantly versus incrementally, if aggregation is recognized versus not recognized, and if energy policies are enacted verses not enacted). This research included an assessment of models done by utilities to project the costs of various projects under different scenarios, evaluation of predictions of market changes for various technologies, and consideration of models of renewable penetration.

ASSESSMENT OF PROBABILITY AND RELATIVE IMPORTANCE

The probability of each scenario occurring was determined through an analysis of various predictions, models, and forecasts. Price forecasts for energy storage technologies, natural gas, coal, and renewables were used to predict the likelihood of technological innovation and the possible extent of renewable penetration. Prioritization of factors and the qualitative assessment of their likelihood was informed by the background research, which identified the primary factors currently driving energy storage technologies alongside future projections and predictions of how these dynamics will change in the future. The likelihood of DER aggregation recognition was determined from FERC's interaction with the California Independent System Operator (CAISO) in allowing aggregation to enter the market in California. Indiana was compared to other states to determine the likelihood of emissions policies being enacted in Indiana. Various case studies were used to explore how these factors are impacting energy storage opportunities for other utilities in the Midcontinent Independent System Operator (MISO) region.

FORMATION OF A DECISION MAKING FRAMEWORK

Based on the most likely scenarios occurring for each factor, a decision making framework was created to guide Hoosier Energy through the process of planning future energy storage projects. The framework begins by providing a choice between approaching a potential energy storage project as a solution to a problem or as an economic opportunity in and of itself. It then guides Hoosier in the identification and prioritization of services that a potential storage project could provide, an analysis of technologies that can provide these services, the identification of costs and benefits involved in the potential project, the identification of energy policy that can be utilized to finance and support the project, and the formation of a detailed business case.

GENERATION CONCLUSIONS AND ASSOCIATED RECOMMENDATIONS

Conclusions were generated based on the most likely scenarios for the four key factors. These conclusions, along with the overall evaluation, were used to generate a set of recommendations that Hoosier could consider implementing within the next decade. The recommendations are dominantly based on a preliminary utilization of the decision making framework and the most likely combination of the four factors occurring.

BACKGROUND

Energy storage will play an important role in the coming years because of its ability to provide a variety of services. However, energy storage does not fit the categories that utilities typically use. Market rules in many regions do not allow projects to take full advantage of the potential energy storage benefits. FERC is now addressing some of the barriers to energy storage participation with FERC Order 841. Additionally, federal and state governments are considering and passing energy policy that can either incentivize renewables and storage, or regulate more traditional technologies like coal and natural gas. The landscape for energy storage is changing dramatically and quickly. The following sections outline the services energy storage can provide, FERC's actions addressing the barriers to storage, current and promising technologies, and energy policy.

ENERGY STORAGE SERVICES

Power systems operation is a balancing act of matching electricity supply with demand. As the supply of electricity becomes more intermittent, unpredictable, and less flexible, there will be a greater need for services that balance supply and demand. Energy storage can shift energy through time to meet this challenge. Energy storage technologies can often provide multiple services, referred to as “stacking.” The challenge then is considering the current and future value of services, how well energy storage technologies are positioned to provide these services, and what combination of services they could provide. Aligned with the Rocky Mountain Institute’s categorization, these services are divided below into (I) RTO/ISO services, (II) Utility services, and (III) Member-consumer services.[1] This categorization defines who benefits from the services provided. A summary of these services is provided in table 1 with further detail below.

---

[1] Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. The Economics of Battery Energy Storage:How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. Rocky Mountain Institute, (2015). https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

Table 1. A summary of the services energy storage can provide

Benefiting Party	**Service**	**Sub-Service**	**Definition**
RTO/ISO	Peak Shaving		Reducing the amount of energy purchased from the utility company during peak demand hours[2]
	Energy Arbitrage		Storing energy when prices are low and discharging when prices are high
	Ancillary Services	Operating Reserve	Surplus operating capacity that can instantly respond to a sudden increase in the electric load or a sudden decrease in the renewable power output[3]
		Voltage Support	Producing or absorbing reactive power to maintain a certain amount of voltage
		Black Start	Providing the energy needed to restart the grid in the case of a blackout
Utility Services	Resource Adequacy		Ensuring the grid system can support the peak demand of electricity over a given year
	Transmission Congestion Relief		Storing energy downstream from congested transmission assets
	Transmission Deferral and Distribution Deferral		Accommodating changes in demand for transmission and distribution services throughout the grid
Member-Consumer Services	Time-of-Use Bill Management		Allowing member-consumers to shift energy demand through time
	Demand Charge Reduction		Shifting demand peaks
	Increased PV Self-Consumption		Storing electricity to be used later
	Backup Power		Providing power in the case of power disruption

RTO/ISO Services

Peak Shaving and Energy Arbitrage

RTO/ISOs use a supply stack to set wholesale electricity rates every five minutes. Generators bid into the wholesale electricity market at their marginal cost of generation. The RTO/ISO will then call upon the least-cost generation assets until demand is met. The price of electricity in the market is set by the last unit of generation to clear the market (figure 2). Consequently, the wholesale

---

[2] Clifford Power, “Peak Shaving with Generators” *Case Studies*, (May 24, 2018) http://www.cliffordpower.com/peak-shaving-with-generators-1

[3] Homer Energy, “Operating Reserve,” *Glossary of Terms*. (2018) https://www.homerenergy.com/products/pro/docs/latest/glossary.html

market price reflects the cost of producing the last unit of electricity in the market and is therefore higher during peak demand when less efficient and more costly peaking assets are participating. The clearing price for electricity varies based on several factors, including: consumer demand, fuel costs, and transmission constraints.[4] Part of the rationale for creating RTOs/ISOs was to operate wholesale electricity markets where electricity can be purchased and sold with minimal administrative and information burdens.

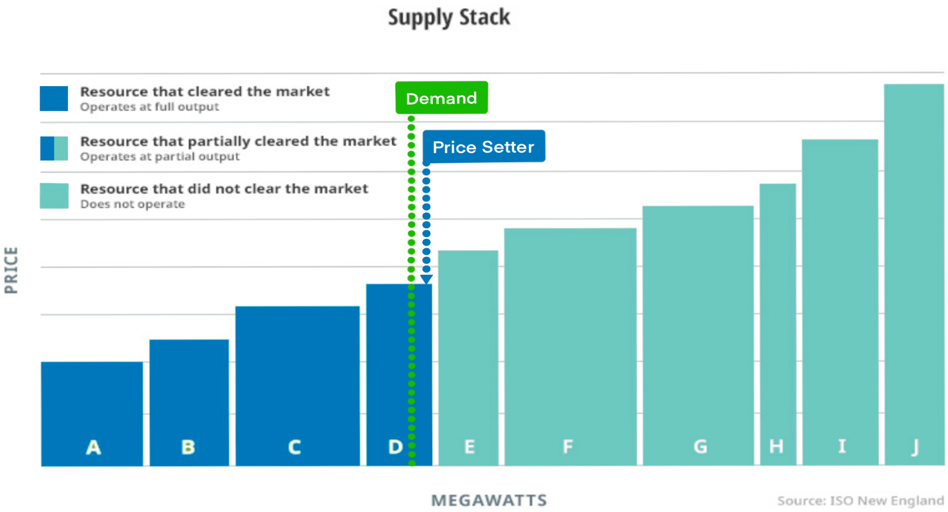


Figure 1. Opportunities for energy arbitrage as a result of variable energy prices
Source: How Resources are Selected and Prices are Set in Wholesale Electricity Markets NE ISO (2019) https://www.iso-ne.com/about/what-we-do/in-depth/how-resources-are-selected-and-prices-are-set

Demand for electricity changes throughout the day; beginning with peak demand occurring in the early evening on weekdays.[5] High demand periods are traditionally met with peaking natural gas or oil assets that can flexibly increase production for short periods of time more effectively than traditional base load assets (e.g. coal and nuclear assets). These peaking assets are, however, costly to operate and lead to higher market clearing prices when they are used.[6]

---

[4] NE ISO "Wholesale vs. Retail Electricity Costs" (2019) https://www.iso-ne.com/about/what-we-do/in-depth/wholesale-vs-retail-electricity-costs

[5] EIA, "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *Demand for Electricity Changes through the Day - Today in Energy - U.S. Energy Information Administration (EIA)*, (2011) https://www.eia.gov/todayinenergy/detail.php?id=830.

[6] EIA, "U.S. Energy Information Administration." *Demand for Electricity Changes through the Day*, (2011)

Energy storage technologies can provide a similar service by storing energy when prices are low and discharging when prices are higher. This is referred to as energy arbitrage. The revenue from this process is the difference between the prices when the electricity was purchased and then sold, meaning the absolute prices of electricity are less important for energy storage than the variability of energy prices throughout the day. The length and number of peak periods throughout the day are also important for energy storage considerations. For example, one long energy peak period during the day would allow a single opportunity to participate in peak shaving; whereas, multiple shorter peak periods would allow for storage to participate several times (figure 2).

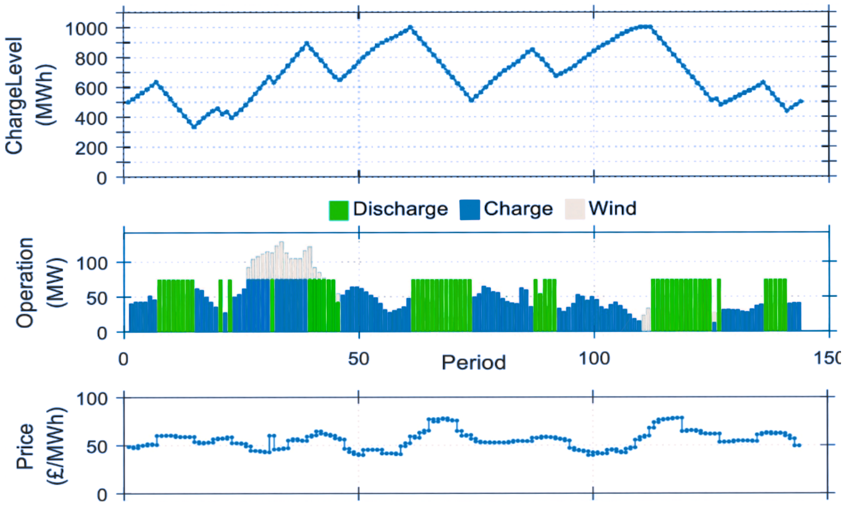


Figure 2. Opportunities for energy arbitrage as a result of variable energy prices
Source: Staffell, Iain, and Mazda Rustomji. "Maximizing the Value of Electricity Storage." *Journal of Energy Storage* 8 (2016): 212–25. https://doi.org/10.1016/j.est.2016.08.010.

Storage technologies, such as batteries can quickly respond to short-term changes in wholesale electricity prices and quickly discharge when engaging in energy arbitrage. Currently, in MISO's wholesale markets, these differences are not profitable enough to provide sufficient revenue to support energy storage alone.[7] However, participating in energy arbitrage is possible while also

---

[7] Nguyen, Tu A., Raymond H. Byrne, Ricky J. Concepcion, and Imre Gyuk. "Maximizing Revenue from Electrical Energy Storage in MISO Energy & Frequency Regulation Markets." *2017 IEEE Power & Energy Society General Meeting*, 2017. https://doi.org/10.1109/pesgm.2017.8274348.

providing other services.[8] Higher penetrations of renewable energy are expected to result in higher variations in prices throughout the day. Notably, in places like Hawaii and California, high renewable penetration has even resulted in negative prices as there is a cost to curtail production as well as subsidies available for wind production. Wind and solar renewable energy without storage capability is non-dispatchable, meaning it is inflexible and unable to ramp-up to meet certain demand periods. When these generation sources are not producing, there could be relatively high marginal costs of production, resulting in higher wholesale electricity rates. Variability and uncertainty in renewable energy generation may produce a load profile where there are multiple, shorter peak periods allowing for storage to participate in the markets more often.

ANCILLARY SERVICES

Ancillary services primarily support the optimal functioning and reliability of an electrical grid.[9] Ancillary services typically include frequency regulation, spinning reserves, non-spinning reserves, voltage support, and black start. The definition of each service depends upon governing market participation rules, which vary between each RTO/ISO and country regulations. RTO/ISOs have slightly different rules for what qualifies for each type of service and often have different names for similar services.[10]

---

[8] Denholm, Paul "Greening the Grid" NREL, (2019) https://cleanenergysolutions.org/sites/default/files/documents/battery-storage-webinar-feb-27-final.pdf

[9] Staffell, Iain, and Mazda Rustomji. "Maximising the Value of Electricity Storage." *Journal of Energy Storage* 8 (2016): 212–25. https://doi.org/10.1016/j.est.2016.08.010.

[10] Short-term reserve markets refer to the provision of energy to the grid on short notice for a period of time that is less than 30 minutes

OPERATING RESERVE

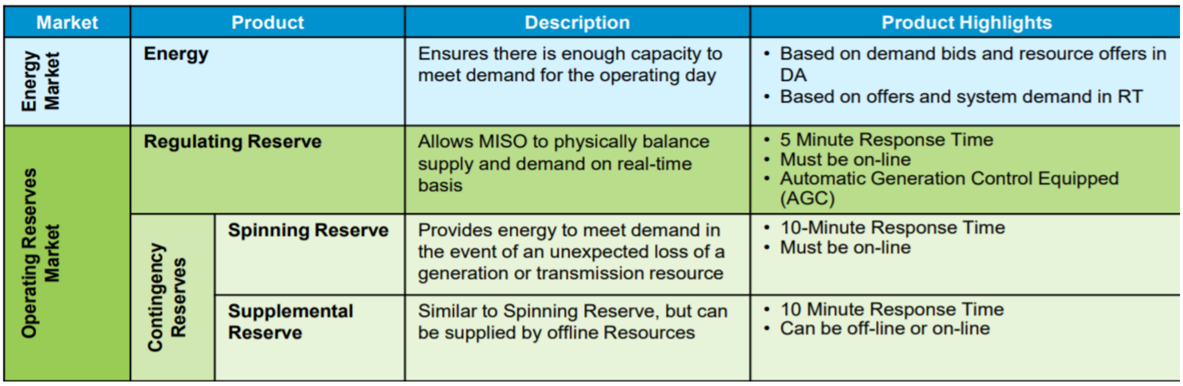
The primary ancillary service market in most RTO/ISOs are the regulating reserve and operating reserve markets.[11] The North American Electric Reliability Corporation (NERC) defines the operating reserve market as: "That capability above firm system demand required to provide for regulation, load forecasting error, equipment forced and scheduled outages and local area protection. It consists of spinning and non-spinning reserve." And regulating reserve as "An amount of reserve responsive to Automatic Generation Control, which is sufficient to provide normal regulating margin"[12] MISO operates their regulating reserve within their operating reserve market (figure 2). These markets ensure that the supply and demand of electricity loaded on the grid is closely matched with off-loading, ensuring that the grid maintains a frequency of 60 hertz, which is essential for grid reliability. Regulating reserves match smaller fluctuations in energy on a short time scale (usually under five minutes) while contingency reserves match larger fluctuations in energy on a slightly longer time scale of 10 minutes.

Operating reserves are compensated under three separate markets including regulating reserve, spinning reserve, and supplemental reserve (figure 4). Each of these markets have separate rules for participation. To participate in one of these markets, an asset must submit parameters that are consistent with the participation model detailing how they intend to participate in the market. MISO will then call upon assets to provide services based on prioritization parameters and compensate them for the amount of regulation they provide.

---

[11] Staffell, Iain, and Mazda Rustomji. "Maximising the Value of Electricity Storage." *Journal of Energy Storage* 8 (2016): 212–25. https://doi.org/10.1016/j.est.2016.08.010.

[12] "NERC Glossary of Terms" NERC. (2019) https://www.nerc.com/files/glossary_of_terms.pdf



Market	Product		Description	Product Highlights
Energy Market	**Energy**		Ensures there is enough capacity to meet demand for the operating day	• Based on demand bids and resource offers in DA • Based on offers and system demand in RT
Operating Reserves Market	**Regulating Reserve**		Allows MISO to physically balance supply and demand on real-time basis	• 5 Minute Response Time • Must be on-line • Automatic Generation Control Equipped (AGC)
	Contingency Reserves	**Spinning Reserve**	Provides energy to meet demand in the event of an unexpected loss of a generation or transmission resource	• 10-Minute Response Time • Must be on-line
		Supplemental Reserve	Similar to Spinning Reserve, but can be supplied by offline Resources	• 10 Minute Response Time • Can be off-line or on-line

Figure 4. MISO's energy and operating reserve market descriptions
Source: Centralized Energy and Operating Reserve Markets: A MISO Perspective, MISO, November 2018
http://integrationworkshops.org/2019/wp-content/uploads/sites/14/2017/09/8C_2_GIZ17_xxx-presentation_Durgesh_Manjure.pdf

In MISO, energy storage assets have separate rules and requirements for participating in these markets and includes details such as how much an asset is willing to charge or discharge as well as how quickly an asset can charge or discharge in response to an event.

Energy storage technology, particularly batteries, are well-suited to provide operating reserve services as they can quickly and accurately charge and discharge electricity to the grid at almost any time.[13] In contrast, renewable energy generation assets have near zero marginal costs and therefore typically run at their available capacity and therefore cannot increase their production. Wind assets can decrease their production by curtailment, but at the opportunity cost of generating electricity. Baseload assets such as coal and nuclear plants tend to run at optimal efficiencies at constant power production and therefore do not provide operating reserves.[14] Natural gas peaking plants can potentially provide some operating reserves, but are often not running, and therefore cannot increase or decrease their production. Because of this limitation, peaking assets typically respond after a disruption event, which increases demand, by responding to the increase in

---

[13] Tyson, Madeline, Charlie Bloch. Breakthrough Batteries: Powering the Era of Clean Electrification. Rocky Mountain Institute, 2019. http://www.rmi.org/breakthrough-batteries

[14] Erik Ela, Michael Milligan, and Brendan Kirby "Operating Reserves and Variable Generation" NREL (2019)

prices on the wholesale electricity market. In the context of frequency regulation, this is known as economic dispatch (figure 5).[15]

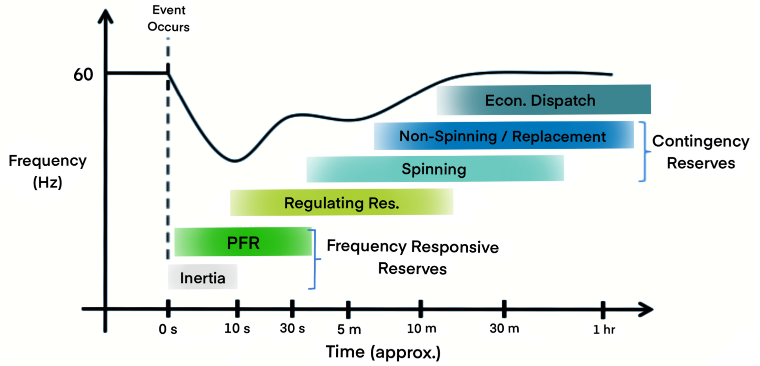


Figure 5. Frequency regulation response ladder
Source: Denholm, Paul "Greening the Grid" NREL, (2019) https://cleanenergysolutions.org/sites/default/files/documents/battery-storage-webinar-feb-27-final.pdf

Regulating reserve, also commonly referred to as frequency regulation, requires a response within five minutes and is currently the most profitable ancillary service market in the MISO region for energy storage on a per kW-Year basis (figure 6).[16] Batteries are well suited to capture this revenue stream due to their fast response times.[17] This has led to new storage deployments used for regulating reserves.[18] Spinning and non-spinning reserve services are the second highest revenue stream for MISO but are significantly lower than regulating reserves (figure 6). This occurs because it is easier for other assets to provide regulating services, given the longer required response time of approximately 10 minutes (figure 5).

---

[15] Erik Ela, Michael Milligan, and Brendan Kirby "Operating Reserves and Variable Generation" NREL (2019)
[16] Lazard's Levelized Cost of Storage Analysis - Version 4.0, November 2018 https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf
[17] Tyson, Madeline, Charlie Bloch. Breakthrough Batteries: Powering the Era of Clean Electrification. Rocky Mountain Institute, 2019. http://www.rmi.org/breakthrough-batteries
[18] Denholm, Paul, *NREL* "Greening the Grid". 2019 https://cleanenergysolutions.org/sites/default/files/documents/battery-storage-webinar-feb-27-final.pdf

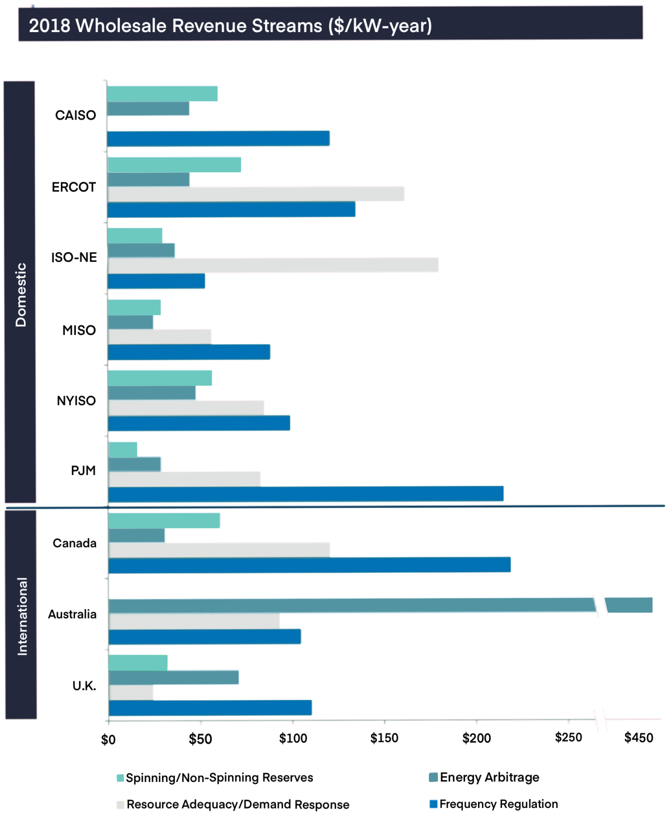


Figure 6. Wholesale revenue streams for market services in various RTOs
Source: Lazard's Levelized Cost of Storage Analysis - Version 5.0, November 2019, https://www.lazard.com/media/451087/lazards-levelized-cost-of-storage-version-50-vf.pdf

The market for operating reserve services is limited. This is because the services must follow NERC guidelines stating that there must be enough reserves to respond to the largest "event" in a grid system, which corresponds with the largest generation asset tripping offline.[19] This limits the operating reserve services market to a little more than 2 GWs.[20] With the advent of cheaper energy storage technologies, this market could quickly become saturated, which would drive down the revenue potential for providing these services.[21]

---

[19] NERC, "Standard BAL-002-0-Disturbance Control Performance," 2005.

[20] Denholm, Paul "Greening the Grid" NREL, (2019) https://cleanenergysolutions.org/sites/default/files/documents/battery-storage-webinar-feb-27-final.pdf

[21] Newell, Samuel, Ariel Kaluzhny, Kathleen Spees, Kevin Carden, Nick Wintermantel, Alex Krasny, and Rebecca Carroll "Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region" Brattle Group (2018) https://brattlefiles.blob.core.windows.net/files/15258_estimation_of_the_market_equilibrium_and_economically_optimal_reserve_margins_for_the_ercot_region.pdf

VOLTAGE SUPPORT

Electrical transmission and distribution lines need to maintain a certain amount of voltage to ensure that electricity flows efficiently through the lines. NERC coordinates with RTOs to set these standards. There are no formal market structures for voltage support and it is instead compensated on a FERC approved cost of service basis in MISO.[22] This service is traditionally provided by transformers and capacitors, though energy storage technologies can also provide voltage support. Hoosier Energy can consider the ability for battery storage to provide voltage support as a secondary, stacked service, but it is not a promising primary use case for energy storage.

BLACK START

Black start is the ability of a resource to provide the energy needed to restart the grid in the case of a blackout. Similar to voltage support, energy storage technologies can provide this service, but it is also compensated at FERC approved cost of service basis in MISO. As a result, black start is not a promising primary use case.[23]

UTILITY SERVICES

RESOURCE ADEQUACY

RTOs are tasked with ensuring that their grid system can support the peak demand of electricity over a given year. This often occurs during the summer months when air conditioning drives demand above normal levels. If this demand is not met, blackouts will occur, causing social and economic harm. Economic activity would be disrupted, amounting in cost in the millions of

---

[22] MISO. “FERC Electric Tariff Reactive Supply and Voltage Control From Generation or Other” (2018) https://cdn.misoenergy.org/Schedule%2002109650.pdf

[23] Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. The Economics of Battery Energy Storage:How multi-use, customer-sited batteries deliver the most services and value to customers and the grid.Rocky Mountain Institute, September 2015. http://www.rmi.org/electricity_battery_value

dollars. In addition, power outages could lead to deaths during dramatic weather events or the inability to power medical equipment.

To ensure that the system has enough resources to meet demand, RTOs set mandates or run capacity markets, to ensure an appropriate amount of capacity is available. Supply for capacity in the MISO region is currently very high, which corresponds to very low prices. The clearing price for capacity at the voluntary auction in 2019 for Zone 6, Indiana, was $2.99 per MW per day.[24] This is low in comparison to the Pennsylvania, Jersey, Maryland Power Pool (PJM) where the clearing price for capacity in some cases is over $200 per MW per day.[25]

These market conditions could change in the future. As renewable energy penetrations increase in the MISO region, market analysts predict that capacity market prices will increase.[26] Renewable energy assets are expected to displace fossil fuel assets that have traditionally provided this service. As fossil fuel generation assets retire, there will be a decreased supply of resource adequacy in the MISO region. Theoretically, generators could connect to PJM to take advantage of their higher prices, resulting in an equilibration of the two markets.[27]

Energy storage technologies can potentially provide this service by discharging energy during a peak demand event. However, this is limited by the asset's ability to continue to discharge energy over a period of time. RTOs have set rules for their resource adequacy markets requiring an asset to have the ability to provide 4 to 10 hours of electricity when called upon. FERC Order No. 841 will require that energy storage assets be partially compensated in these markets for the percentage

---

[24] MISO, 2019/2020 Planning Resource Auction (PRA) Results, (April 12, 2019) https://cdn.misoenergy.org/20190412_PRA_Results_Posting336165.pdf

[25] PJM, 2021/2022 RPM Base Residual Auction Results (2019) https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-base-residual-auction-report.ashx

[26] ICF International, MISO's Capacity Auction: Uncertainty Going Forward (2015) https://www.ourenergypolicy.org/wp-content/uploads/2015/05/MISO_Capacity_Auction.pdf

[27] ICF International, MISO's Capacity Auction: Uncertainty Going Forward (2015) https://www.ourenergypolicy.org/wp-content/uploads/2015/05/MISO_Capacity_Auction.pdf

of the required duration that they can provide energy. Energy storage assets that can discharge energy for longer periods of time are therefore better suited to provide this service.

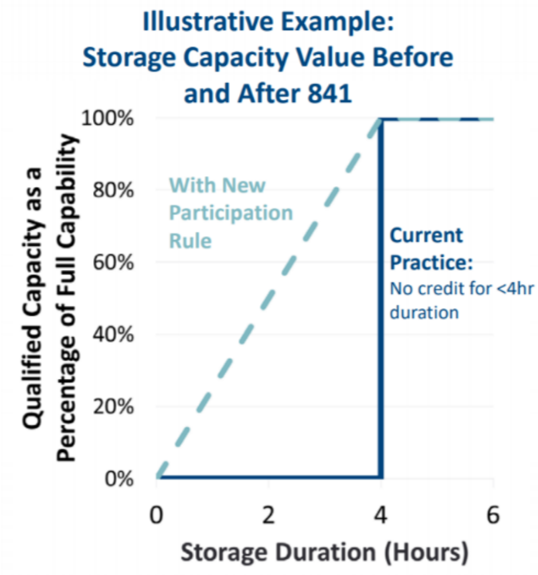


Figure 7. Storage capacity valuation as a percentage of full capacity requirement
Source: Judy Chang, Roger Lueken, Hannes Pfeifenberger, Pablo Ruiz, and Heidi Bishop, “Getting to 50 GW? The Role of FERC Order 841, RTOs, States, and Utilities in Unlocking Storage’s Potential”, *The Brattle Group*, (2018) https://www.brattle.com/news-and-knowledge/publications/getting-to-50-gw-the-role-of-ferc-order-841-rtos-states-and-utilities-in-unlocking-storages-potential

TRANSMISSION CONGESTION RELIEF

Energy storage technologies can relieve transmission congestion by storing energy downstream from congested transmission assets. This energy is then released during high congestion events to satisfy demand.

TRANSMISSION DEFERRAL AND DISTRIBUTION DEFERRAL

Energy storage provides many of the same services that traditional transmission and distribution assets provide with several distinct advantages. First, energy storage technologies are modular allowing for a closer following of the increase in demand for transmission and distribution assets. Second, energy storage technologies like batteries are more flexible in their deployment, which allows them to be physically moved to accommodate changes in demand for transmission and distribution services throughout the grid. This allows energy storage technologies to have a lower risk adjusted value as they are less likely to become a stranded asset. Energy storage applications also have several other advantages compared to traditional transmission and distribution assets including less impact on property, which decreases community opposition, and shorter permitting periods.[28] As particular value to Hoosier Energy, energy storage technologies may also avoid transmission charges from the use of other utilities' transmission assets.

MEMBER-CONSUMER SERVICES

TIME-OF-USE BILL MANAGEMENT

Energy storage technologies can allow member-consumers to shift their energy demand through time to take advantage of lower rates under a time-of-use rate scheme. Time-of-use billing has the advantage of more accurately reflecting the real cost of providing electricity at different times and incentivizes member-consumers to consume more energy during periods of low demand increasing overall efficiency.

DEMAND CHARGE REDUCTION

Large commercial and industrial member-consumers often pay demand charges that correspond to their peak energy demand alongside energy charges. These charges can be around 50 percent of their total electricity bill.[29] Energy storage technologies can shift these peaks and consequently decrease the charges. The highest potential for reducing demand charges are from member load profiles that have high narrow peaks which can be easily shifted. Higher demand charges correspond with greater incentives in an attempt to reduce them. A study of load profiles in Berkeley, California found that commercial operations with rooftop solar tended to have peak

---

[28] Eller, Alex. "Energy storage will disrupt transmission and distribution investments" *Utility Dive* October 17, 2017 https://www.utilitydive.com/news/energy-storage-will-disrupt-transmission-and-distribution-investments/506945/

[29] Naïm Darghouth, Galen Barbose, and Andrew Mills "Implications of Rate Design for the Customer Economics of Behind-the-Meter Storage" Lawrence Berkeley National Laboratory. (August 2019) http://eta-publications.lbl.gov/sites/default/files/darghouth_rate_design_storage_final.pdf

demands that are easily shifted with energy storage technologies. This analysis found that the reduction of demand charges was significantly more valuable to commercial customers than energy arbitrage.[30]

INCREASED PV SELF-CONSUMPTION

Under a net-billing arrangement, owners of DERs are compensated below the retail rate of electricity for any electricity sold back to the grid. Energy storage allows member-consumers to store electricity that is then used later instead of being sold back to the grid. The benefit of this process is the difference between the retail rate and the rate of compensation set by the net-billing arrangement, which may be as low as the wholesale rate of electricity.

BACKUP POWER

Many member-consumers value the ability to have some form of back-up power in the event of a power disruption. One survey found that 20 percent of households currently own some form of back-up power source and that 50 percent were interested in one.[31] Energy storage technologies can provide electricity in the case of these events, but for a limited period of time. Storage combined with distributed renewable energy technology and back-up generators can potentially provide power at a lower cost for longer periods of time than a back-up generator alone.

CONCLUSION

Overall, energy storage has the opportunity to provide a variety of services, and is unique in its ability to stack multiple services. However, storage does not fit into any of the traditional categories that utilities typically use, making full access to all these services difficult. Market rules in

---

[30] ibid.

[31] Stephen Lacey "Survey: Batteries Still Can't Give Consumers What They Expect for Backup Power" GreenTechMedia (September, 2016) https://www.greentechmedia.com/articles/read/batteries-still-cant-give-consumers-what-they-expect-for-backup-power

many regions do not allow projects to take full advantage of the benefits storage can provide. FERC is now addressing some of the barriers to energy storage participation with Order 841.

FERC'S ORDER NO. 841 AND MISO'S COMPLIANCE

Historically, many of the RTO/ISO services detailed above have not been open to storage participation due to RTO/ISO market barriers. These barriers stemmed from a lack of aggregation and market rules that have not accounted for the unique characteristics of energy storage technologies. To facilitate the participation of energy storage and to address these barriers, FERC issued Order No. 841 in March 2018. Order No. 841 mandated the six RTO/ISOs under FERC's jurisdiction to reform their energy markets to include energy storage assets. Order No. 841 requires RTO/ISOs to submit a compliance plan six months after the order came into effect on 4 June 2018.[32] MISO submitted its compliance plan within the six month window and has responded to information requests from FERC following their original submission. MISO is currently awaiting final approval of its compliance plan. Meanwhile, the compliance plans of Southwest Power Pool and PJM Interconnection were approved on 17 October 2019.

SUMMARY OF FERC ORDER NO. 841

The key provision of Order No. 841 is to direct RTO/ISOs to amend their tariffs by creating a participation model for energy storage technologies. The creation of a participation model establishes updated market rules for electric storage resources (ESRs) as a new class of energy resources.[33] The participation model for ESRs must address the following requirements issued in Order No. 841: eligibility of ESRs to participate in the RTO/ISO markets, ability of ESRs to participate

---

[32] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets: An Analysis of FERC Order No. 841" (Master of Science in Energy Systems Management, University of San Francisco, 2019).

[33] Federal Energy Regulatory Commission, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators Docket No. RM16-23-000.* 2018

in markets as supply and demand, account for ESRs' physical and operational characteristics through bidding parameters, management of ESRs' state of charge, establish a minimum size for ESRs, and ensure that ESRs will pay the locational marginal price (LMP) when withdrawing electricity. [34]

ELIGIBILITY OF ESRS TO PARTICIPATE IN THE RTO/MISO MARKETS

FERC defines an ESR as "a resource capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid."[35] This definition encompasses a wide range of technologies including flywheel, pumped hydroelectric energy storage (PHES), and batteries.[36] Furthermore, Order No. 841 does not specify the location of an ESR on the transmission grid, implying that ESRs at the transmission, distribution, and BTM levels are similarly eligible to participate in an RTO/ISOs wholesale markets.[37]

Under Order No. 841, FERC requires RTO/ISOs to ensure that all ESRs are eligible to provide all market services that ESRs are technically capable of providing, while receiving "just and reasonable" compensation for those services.[38] This includes services provided via competitive markets such as energy, capacity, and ancillary services, as well as services including black start and voltage support that are not procured through competitive markets.[39] In order to aid ESRs in meeting the technical requirements for providing capacity services, ESRs are permitted to de-rate their capacities by operating at a lower capacity in order to prolong its run-time to meet minimum run-time requirements in capacity markets.[40]

---

[34] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018

[35] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018: 38

[36] ibid.

[37] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets,"

[38] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018:

[39] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets,"

[40] ibid.

FERC PARTICIPATION IN THE RTO/ISO MARKETS AS SUPPLY AND DEMAND

In addition to defining ESRs and ensuring their eligibility to provide services within RTO/ISO markets, Order No. 841 requires participation models to allow ESRs to be dispatched as a "buyer" or a "seller" and set the market-clearing price in a wholesale energy markets.[41] This means that ESRs can participate in energy markets much like other energy resources by submitting wholesale bids to purchase or sell energy.[42]

Due to ESRs' unique ability to inject and withdraw electricity from the grid, RTO/ISOs are also required to demonstrate that ESRs do not receive conflicting dispatch instructions to withdraw and discharge electricity simultaneously during the same market intervals.[43] Conflicting dispatch instructions occur when an ESR submits an offer to sell energy that is lower than its bid to buy energy during the same market interval, resulting in an RTO/ISO dispatching the ESR to both charge and discharge energy simultaneously.[44] FERC has opted to allow RTO/ISOs to create their own mechanism to ensure conflicting dispatch is mitigated.

Finally, in the event of out-of-merit dispatch orders, RTO/ISOs are required to provide make-whole payments to ESRs. By doing so, ESRs avoid bearing financial losses when dispatched to supply electricity to the grid at a market price under its regular offer price or when dispatched to withdraw electricity from the grid at a market price above its regular bidding price.[45]

---

[41] ibid.

[42] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018: 86

[43] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets,"

[44] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018: 99

[45] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets,"

PHYSICAL AND OPERATIONAL CHARACTERISTICS OF ESRS

Bidding parameters describe the physical and operational characteristics of generation resources, informing RTO/ISOs of the optimal ways in which generating resources are dispatched.[46] Existing bidding parameters only describe the attributes of traditional generation resources and do not account for the unique features of ESRs, leaving ESRs at a competitive disadvantage in terms of dispatchability. Using solely the existing bidding parameters limits the services ESRs can provide in RTO/ISO markets despite their technical capability.

Order No. 841 remedies these conditions by requiring RTO/ISOs to include thirteen bidding parameters specific to ESRs within their participation model in order to account for the physical and operational characteristics of ESRs, as they submit bids to wholesale energy markets. Listed below are the bidding parameters that RTO/ISOs are required to consider along with their definitions.

---

[46] ibid.

Table 2. Bidding Parameters

Bidding Parameter	Definition
State of Charge	State of Charge represents the amount of energy stored in proportion to the limit on the amount of energy that can be stored, typically expressed as a percentage. It represents the forecasted starting State of Charge for the market interval being offered into.
Maximum State of Charge	Maximum State of Charge represents a State of Charge value that should not be exceeded (i.e., gone above) when a resource using the participation model for ESRs is receiving electric energy from the grid (e.g., 95% State of Charge).
Minimum State of Charge	Minimum State of Charge represents a State of Charge value that should not be exceeded (i.e., gone below) when a resource using the participation model for ESRs is injecting electric energy to the grid (e.g., 5% State of Charge).
Maximum Charge Limit	Maximum Charge Limit represents the maximum MW quantity of electric energy that a resource using the participation model for ESRs can receive from the grid.
Maximum Discharge Limit	Maximum Discharge Limit represents the maximum MW quantity that a resource using the participation model for ESRs can inject to the grid.
Minimum Charge Time	Minimum Charge Time represents the shortest duration that a resource using the participation model for ESRs is able to be dispatched by the RTO/ISO to receive electric energy from the grid (e.g., one hour).
Maximum Charge Time	Maximum Charge Time represents the maximum duration that a resource using the participation model for ESRs is able to be dispatched by the RTO/ISO to receive electric energy from the grid (e.g., four hours).
Minimum Run Time	Minimum Run Time represents the minimum amount of time that a resource using the participation model for ESRs is able to inject electric energy to the grid (e.g., one hour).
Maximum Run Time	Maximum Run Time represents the maximum amount of time that a resource using the participation model for ESRs is able to inject electric energy to the grid (e.g., four hours).
Minimum Discharge Limit	The minimum MW output level that a resource using the participation model for ESRs can inject onto the grid.
Minimum Charge Limit	The minimum MW level that a resource using the participation model for ESRs can receive from the grid.
Discharge Ramp Rate	The speed at which a resource using the participation model for ESRs can move from zero output to its Maximum Discharge Limit.
Charge Ramp Rate	The speed at which a resource using the participation model for ESRs can move from zero output to its Maximum Charge Limit.

Source: Data adapted from Federal Energy Regulatory Commission, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators Docket No. RM16-23-000.* 2018. 150-151

STATE OF CHARGE MANAGEMENT

State of charge management is an important consideration for owners of ESRs. Order No. 841 grants owners the right to self-manage ESRs. With self-management, ESR owners have discretion over the services it elects to provide and reap the highest amount of benefits. However, owners are responsible for meeting performance requirements and may face penalties for failures to do so.[47] RTO/ISO management of state of charge is the alternative to self-management. RTO/ISO management relieves owners of this responsibility and can optimize the value of ESRs through the services they provide.

MINIMUM RESOURCE SIZES

Under existing market rules, many energy storage projects may not qualify to enter RTO/ISO markets due to the size of its capacity. Order No. 841 requires RTO/ISOs to lower the minimum size requirement of ESRs to 100 kW or less, easing the entry of smaller-scale ESRs into RTO/ISO markets.[48]

ENERGY USED TO CHARGE ESRS

Under Order No. 841, ESRs will be treated no differently from other generation resources, and will pay a wholesale LMP at the nodal level when withdrawing electricity from the grid with the purpose of reselling energy at a later time. This includes reselling energy in wholesale energy markets as well as ancillary services markets. It is important to make the distinction between the withdrawal of electricity for wholesale purposes or retail purposes, since the wholesale LMP reflects the cost of energy, congestion, and transmission losses.[49] In addition, ESRs will pay transmission

---

[47] ibid.

[48] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018:

[49] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets,"

charges like other load serving entities when electricity is purchased for wholesale purposes.[50] On the other hand, if an ESR is dispatched to withdraw electricity to provide an ancillary service , then transmission charges are not applicable. To accurately assess these costs, RTO/ISOs are required to implement metering or other means of accounting in order to determine the final destination of the withdrawn electricity.

MISO'S COMPLIANCE PLAN

Currently, there are only limited ways in which energy storage technologies can participate in MISO's markets. Energy storage technologies are allowed to participate as stored energy resources (SER). SERs are eligible to provide ancillary services by participating in regulating reserve markets.[51] However, SERs are barred from participating in wholesale energy markets unless they are classified as demand response resources . [52] Furthermore, SERs are also prevented from participating in MISO's capacity markets since the SER participation model is designed to provide only short-term services.[53]

In compliance with Order No. 841, MISO submitted its plan to amend its Opening Access Transmission, Energy and Operating Reserve Markets Tariff (Tariff) on December 3, 2018.[54] In the compliance plan, MISO proposed the creation of a single participation model for ESRs that attempted to address all of the requirements laid out by Order No. 841. Functionally, MISO's creation of an ESR participation model replaces the SER participation model.[55] Finally, MISO

---

[50] ibid.

[51] Lindsey Forsberg,"Market Rules in Transition: Energy Storage Value and the U.S. Electric Grid." (Master of Science in Science, Technology, and Environmental Policy, University of Minnesota, 2019).

[52] ibid.

[53] ibid.

[54] Midcontinent Independent System Operator. *Midcontinent Interdependent System Operator, Inc.'s Filing to Revise Tariff as Necessary in Compliance with Order No.841 Docket No. ER19-465-000.* 2018:

[55] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets,"

requested an extension of its implementation date to March 1, 2020 while allowing ESR owners to begin registering for ESR status on December 3, 2019.[56]

MISO'S ESR PARTICIPATION MODEL

MISO's proposed participation model for ESRs adopted the requirements stated in FERC's Order No. 841 while tailoring the specific provisions to MISO's unique market structure.

ELIGIBILITY OF ESRS TO PARTICIPATE IN RTO/ISO MARKETS

In MISOs proposal to revise its tariff, MISO defined ESRs as a technologically neutral "resource, capable of receiving energy from the transmission system and storing energy for later injection of energy back to the transmission system."[57] This definition would allow technologies ranging from flywheel to compressed air, to qualify as ESRs as long as they are located within MISO's balancing authority, meeting the requirements stated in Order No. 841.

The compliance plan also affirms that ESRs will be able to participate in MISO's energy, capacity, and ancillary services markets as well as provide non-market services. These services include: day-ahead and real-time energy, capacity, day-ahead and real-time frequency regulation (up/down ramping), regulation reserves, spinning reserves, supplemental reserves, black start service, and reactive supply and voltage control.

By complying with Order No. 841, MISO will allow ESRs to de-rate their capacity in order to meet MISO's minimum run-time requirement of four hours, across a "coincident peak" to participate in MISO's capacity market.[58]

---

[56] Midcontinent Independent System Operator. *Filing to Revise Tariff.* 2018:

[57] ibid.

[58] Forsberg, "Market Rules,"

PARTICIPATION IN MISO MARKETS AS SUPPLY AND DEMAND

ESR owners will determine the unit commitment status of the ESR, which will inform how, and whether or not, the ESR is dispatched during a market interval.[59] MISO recognizes eight unit commitment statuses, which are: charge, discharge, continuous, available, not participating, emergency charge, emergency discharge, and outage. Of particular note, “continuous” means an ESR is able to transition from “charge” to “discharge” immediately.[60] “Not participating” also allows an ESR to participate solely in MISO’s ancillary services markets, and not the energy markets.[61] Conflicting dispatching instructions can be avoided by submitting a “continuous” bid curve, indicating that charging and discharging are both possible and determined by economic efficiency. Finally, in the event that MISO directs ESRs to comply with out-of-merit dispatch orders, make-whole payments will be provided to owners of ESRs to recoup financial losses.

PHYSICAL AND OPERATIONAL CHARACTERISTICS OF ESRS

To ensure that the physical and operational characteristics of ESRs are included in the ESR participation model, MISO will adopt all thirteen bidding parameters required by Order No. 841 as its minimum set of offer parameters. In addition to Order No. 841’s parameters, MISO has included additional parameters in their compliance proposal. These additional parameters include setting separate dispatch limits and energy storage levels for use during emergency system conditions.[62] These emergency charge and discharge limits, allow MISO to define their own maximum or minimum charge and discharge limits at which an ESR can operate during emergency system conditions.[63] An energy emergency is defined in the compliance plan as “a condition when a

---

[59] Midcontinent Independent System Operator. *Filing to Revise Tariff.* 2018:

[60] ibid.

[61] ibid.

[62] ibid.

[63] These additional MISO parameters are: Emergency Maximum Energy Storage Level, Emergency Minimum Energy Storage Level, Hourly Emergency Maximum Discharge Limit, Hourly Emergency Minimum Discharge Limit, Hourly Emergency Maximum Charge Limit, Hourly Emergency Minimum Charge Limit, Hourly Electric Storage Resource, and Efficiency Factor.

balancing authority can no longer meet the energy requirements of the firm end-use load within its balancing authority."

Additionally, MISO created a new parameter called the "Hourly Electric Storage Resource Efficiency Factor" that is defined as the increase in "Energy Storage Level" of an ESR for every 1 MWh of energy withdrawn from the transmission grid. This will require owners of ESRs to submit an "ESR Efficiency Factor" intended to reflect the real State of Charge of an ESR after accounting for efficiency losses.

STATE OF CHARGE MANAGEMENT

ESRs can participate in MISO's wholesale energy and ancillary services markets via self-management of an ESR's state of charge. The owners of ESRs, not MISO, will be responsible for managing the state of charge of the ESR. As a note, MISO has elected to use the term "Energy Storage Level" rather than *state of charge*. Owners of ESRs will primarily manage their own state of charge by communicating the ESR's commitment status and bid curves to MISO.

MINIMUM RESOURCE SIZES

Order No. 841 requires that an RTO/ISO's ESR participation model has a minimum capacity size requirement that is equal to or less than 100 kW. In its compliance plan, MISO has agreed to set 100 kW as its minimum capacity requirement.[64]

---

[64] Midcontinent Independent System Operator. *Filing to Revise Tariff.* 2018:

ENERGY USED TO CHARGE ESRS

As previously noted, ESRs will be required to pay the wholesale LMP for energy charged with the intent of reselling into the market. In compliance with Order No. 841's requirement that RTO/ISOs develop a robust metering or accounting system to ensure an accurate measurement of energy, MISO will measure all energy entering and exiting an ESR according to the current Tariff requirements.

MISO will require ESRs to meet the same metering requirements in its current Tariff. This includes provisions for direct metering. Owners of ESRs will measure energy charged with the intention of reselling to be metered separately from energy charged or discharged for wholesale or retail purposes.

ISSUES OUTSIDE THE SCOPE OF ORDER NO. 841

While FERC's Order No. 841 drastically altered the landscape governing the participation of energy storage technologies in RTO/ISO markets, several issues were considered notable, but were ultimately left out from the final rule. Three of these topics, however, are important to discuss when considering remaining existing barriers for ESR participation in the electric system. These include: the creation of a participation model for aggregated ESRs, the expansion of participation models to wholesale markets outside of RTO/ISO territory, and the incorporation of ESRs into RTO/ISO's transmission planning activities.

AGGREGATED RESOURCE PARTICIPATION

In the current market, "any storage resource rated at less than 100 kW would only be able to participate in wholesale electric markets through some form of aggregation mechanism allowing multiple storage resources to bid to inject or withdraw electric energy as part of wholesale transactions."[65]

There are no regulations mandating RTO/ISOs to allow aggregated ESRs of over 100 kW to participate in their markets. According to the U.S Energy Information Administration, only 0.4 percent of operational storage power projects in 2016 and 2017 had a capacity below 1 MW. 'Storage capacity of ESRs are a subset of all the wholesale electric markets and make up an even smaller percentage of this 0.4 percent.[66] However, as the costs and subsidies for storage technology change, so will the percent of ESRs and thus ESRs that do not meet the 100 kW maximum. Decentralization, explicitly, BTM aggregation, is listed as a core trend and strategy by MISO.[67] However, MISO has signaled in their compliance filing for FERC Order No. 841 that they are currently trying to limit the participation of "very small" (1 kW) storage assets from the grid. They have also made comments in meetings with FERC about their preference to retain control over the decision to allow the participation of aggregated DERs - rather than being forced to immediately allow for their participation.[68] In April of 2018, FERC began organized discussions about aggregated energy sources. In September, FERC sent RTO/ISOs data requests regarding the ability of their markets to provide transmission access to aggregated energy sources.[69] These data requests can help clarify RTOs/ISOs understanding of, and market ability for, aggregated DERs for further rulemaking considerations. In Hoosier Energy's service area, BTM storage can not provide utility services and RTO/ISO services due to lack of aggregation and inclusive market design. FERC has opened the Docket No. RM18-9-000

---

[65] Glenn Smith, "Enabling Electric Storage Participation in Wholesale Markets," 32 - 33

[66] ibid.

[67] "MISO Forward", MISO, 2019 https://cdn.misoenergy.org/MISO%20FORWARD324749.pdf

[68] Energy Storage Association Unveils Initial Assessment of Regional Grid Operator Compliance with Federal Energy Regulatory Commission Order 841, Energy Storage Association, (December 11, 2018) https://energystorage.org/energy-storage-association-unveils-initial-assessment-of-regional-grid-operator-compliance-with-federal-energy-regulatory-commission-order-841/

[69] Federal Energy Regulatory Commission, *Electric Storage Participation,* 2018.

which will ultimately result in an order that will rule on the aggregation of DERs including energy storage assets BTM.[70]

ESR PARTICIPATION IN MARKETS OUTSIDE OF FERC'S JURISDICTION

Order No. 841 does not address the ability of storage resources to participate in the markets outside of the RTO/ISOs under FERC's jurisdiction. It is within FERC's legislated authority to remove barriers for ESRs, including the barriers of outside market participation. As the use of ESRs increase, so will the need for FERC to intervene to "ensure storage resources can contribute to the achievement of increased competition and reasonable electricity rates."[71]

TRANSMISSION PLANNING WITH ESRS

FERC did not task RTO/ISOs with the mandatory inclusion of storage resources in their transmission planning processes. RTO/ISO's are responsible for maintaining short-term reliability, conducting long-term planning, and the expansion of the transmission system. With low amounts of storage resources in the current grid, the risk of disturbing this transmission market is low and therefore not a pressing concern of RTO/ISOs in the present. However, it is unclear whether or not the consideration of storage resources in transmission planning presents barriers to storage resource participation.[72] This too will change if incentives for ESRs shift and ESR market participation grows. This may ultimately require RTO/ISOs to consider the penetration of ESRs within the distribution or BTM level during transmission planning, especially if aggregation is recognized in future FERC rulings.

---

[70] "FERC Order 841." Federal Energy Regulatory Commission, n.d. https://www.ferc.gov/whats-new/comm-meet/2018/021518/E-1.pdf.
[71] ibid.
[72] "Smith, Glenn, "Enabling Electric Storage Participation in Wholesale Markets: An Analysis of FERC Order No. 841" (2019): 37 - 38

TECHNOLOGY

Each energy storage technology provides distinct services and participate in MISO's markets differently. These services can participate in front of the meter on the transmission and distribution side, or behind the meter as shown in figure 8.

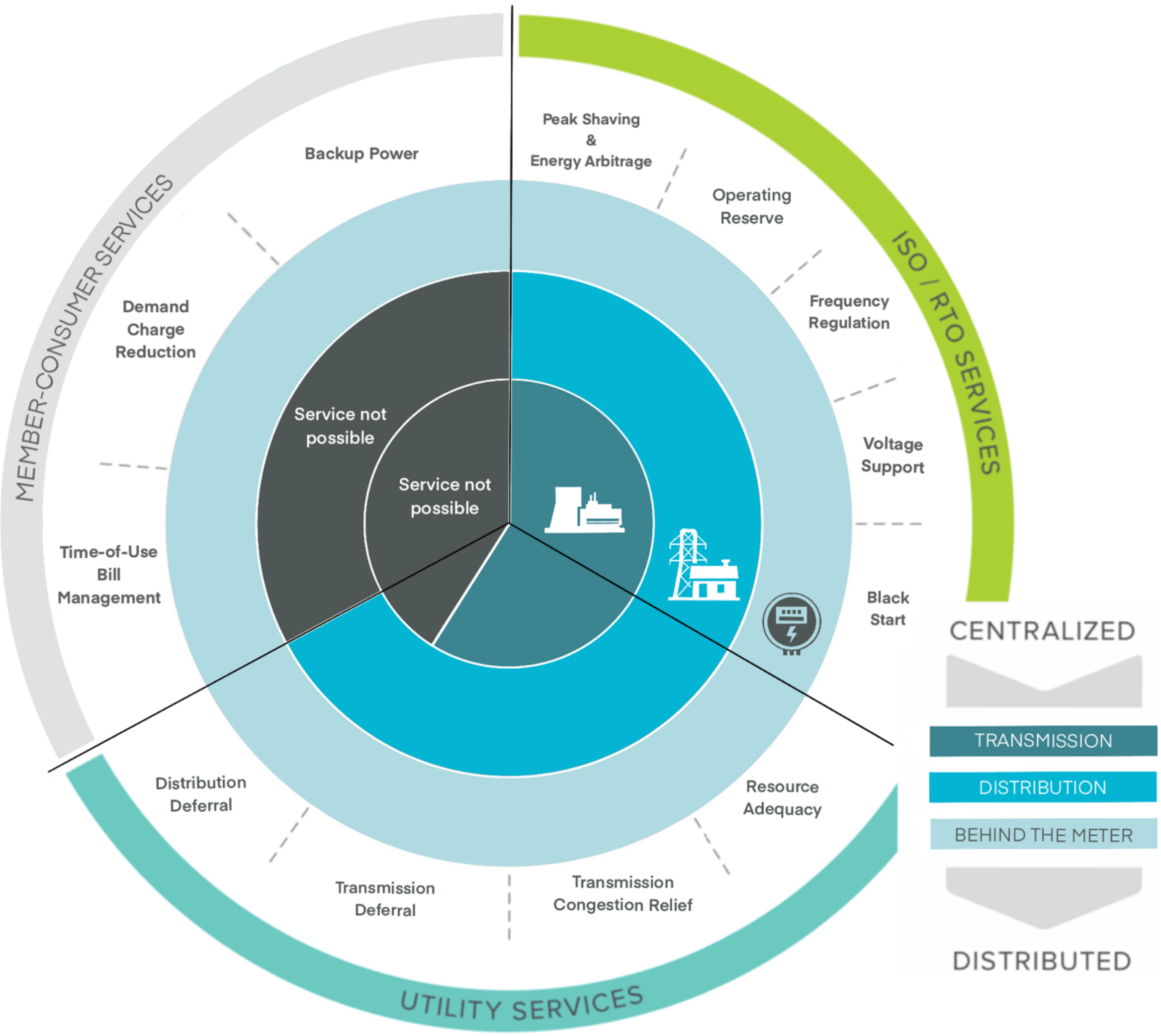


Figure 8. The location at which the services that energy storage can be provided.
Source: Adapted from Garret Fitzgerald, James Mandel, Jesse Morris, and Hervé Touati, "The Economics of Battery Energy Storage," *Rocky Mountain Institute* (2015) https://rmi.org/insight/economics-battery-energy-storage/

Storage technologies can either be placed FTM or BTM as depicted in figure 9. FTM corresponds to the placement of energy storage on the generation, transmission, or distribution parts of the grid while BTM corresponds to the placement of energy storage behind the meter of a member-consumer. The placement of storage on the grid defines what services the asset will be able to provide and which technology will be most cost effective. This section will present an overview of promising and emerging energy storage technologies that can be deployed in FTM and BTM.

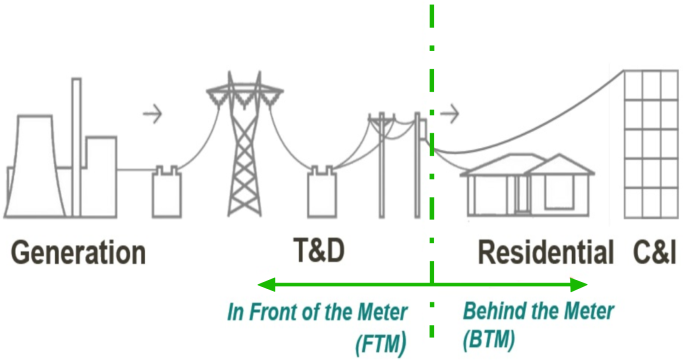


Figure 9. Division of FTM and BTM
Source: Robert Sarai, "2018 Energy Storage Market Trends," LA Solar Group

FRONT OF THE METER

AVAILABLE TECHNOLOGIES

Generally, energy storage technologies fall into five categories: chemical, mechanical, electromagnetic, electrochemical, and thermal (table 3). A number of these technologies are described in more detail in table 4.

Table 3. Storage technology classifications and examples

Storage Classification	Examples
Chemical	Hydrogen, biofuel, syngas
Mechanical	Flywheel, pumped hydroelectricity, compressed air
Electromagnetic	Supercapacitor, superconducting magnets
Electrochemical	Lithium-ion, lead-acid, flow batteries
Thermal	Molten salt, heat pump, ice, chilled and hot water

Source: Adapted from Sandia National Laboratories, "DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA", 2015.

Table 4. An overview of energy storage technologies.

		Description	Size (MW)	Life (Yrs)
Mechanical/Thermal	**Compressed Air**	Compressed Air Energy Storage ("CAES") uses electricity to compress air into confined spaces (e.g. underground mines, salt caverns, etc.) where the pressurized air is stored. When required, this pressurized air is released to drive the compressor of a natural gas turbine.	150 MW +	20
	Flywheel	Flywheels are mechanical devices that spin at high speeds, storing electricity as rotational energy, which is released by decelerating the flywheel's rotor, releasing quick bursts of energy (i.e., high power and short duration) or releasing energy slowly (i.e., low power and long duration).	30 kW – 1 MW	20+
	Pumped Hydro	Pumped hydro storage uses two vertically separated water resevoirs, using low cost electricity to pump water from the lower to the higher reservoir and running as a conventional hydro power plant during high electricity cost periods.	100 MW+	20+
	Thermal	Thermal energy storage uses conventional technology, compressing and storing air into a liquid form (charging) then releasing it at a later time (discharge). Best suited for large-scale applications; the technology is still emerging but has a number of units in early development and operation.	5 MW – 100 MW+	20+
Electrochemical	**Flow Battery**	Flow batteries store energy through chemically changing the electrolyte or plating zinc. Physically, systems typically contain two electrolyte solutions in two separate tanks, circulated through two independent loops, separated by a membrane. Emerging alternatives allow for simpler and less costly designs utilizing a single tank, single loop, and no membrane. The subcategories of flow batteries are defined by the chemical composition of the solution, most prevalently vanadium and zinc bromide. Other solutions include zinc chloride, ferrochrome and zinc chromate.	25 kW – 100 MW+	20
	Lead Acid	In the charged state, the chemical energy of lead-acid batteries is stored in the potential difference between the pure lead at the negative side and the PbO_2 on the positive side. The electrical energy produced can be attributed to the energy released when the strong chemical bonds of water molecules are formed from H^+ ions of the acid and O^{2-} ions of PbO_2.	5 kW – 100 MW+	5-10
	Lithium-Ion	Lithium-ion batteries move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. They use an intercalated lithium compound as the amterial at the positive electrode and typically graphite at the negative electrode.	5 kW – 100 MW+	10
	Sodium	"High temperature"/"liquid-electrolyte-flow" sodium batteries are analogous to the lithium-ion batteries but using sodium ions as the charge carriers.	1 MW – 100 MW+	10
	Zinc	In zinc batteries, zinc serves as the anode with a negative electrical polarity while an inert carbon rod is the positive electrical pole cathode.	5 kW – 100 MW+	10

Source: Adapted from Lazard, "Levelized Cost of Storage Analysis 4.0," 2018. https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

While pumped hydroelectricity, a form of mechanical storage, has historically dominated the energy storage market, recent technological advancements and cost declines in lithium-ion batteries, a type of electrochemical storage, have led to the majority of new energy storage projects being electrochemical storage, as shown in figure 10.[73]

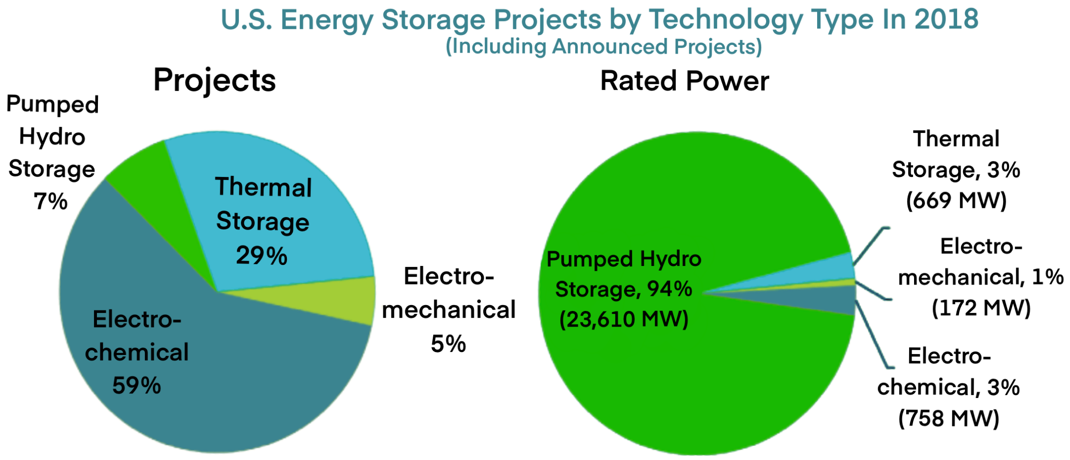


Figure 10. U.S. Energy Storage Projects by Technology Type in 2018
Source: Center for Sustainable Systems, University of Michigan, "U.S. Grid Energy Storage Factsheet." 2019.

COSTS/PRICING

From 2012 to 2017, costs of lithium-ion storage systems fell 72 percent to an average 587 dollars/kWh, with 20 percent of this decline coming from the decline in battery pack costs and 80 percent coming from decreases in balance of system (BOS) costs, engineering, procurement, construction costs, and other soft costs (figure 11).[74] More recent estimates put the installed cost of lithium-ion systems below 500 dollars/kWh in 2018.

---

[73] Center for Sustainable Systems, University of Michigan. 2019. "U.S. Energy Storage Factsheet." Pub. No. CSS15-17. http://css.umich.edu/sites/default/files/U.S._Grid_Energy_Storage_Factsheet_CSS15-17_e2018.pdf

[74] McKinsey & Company, "The new rules of competition in energy storage", June, 2018

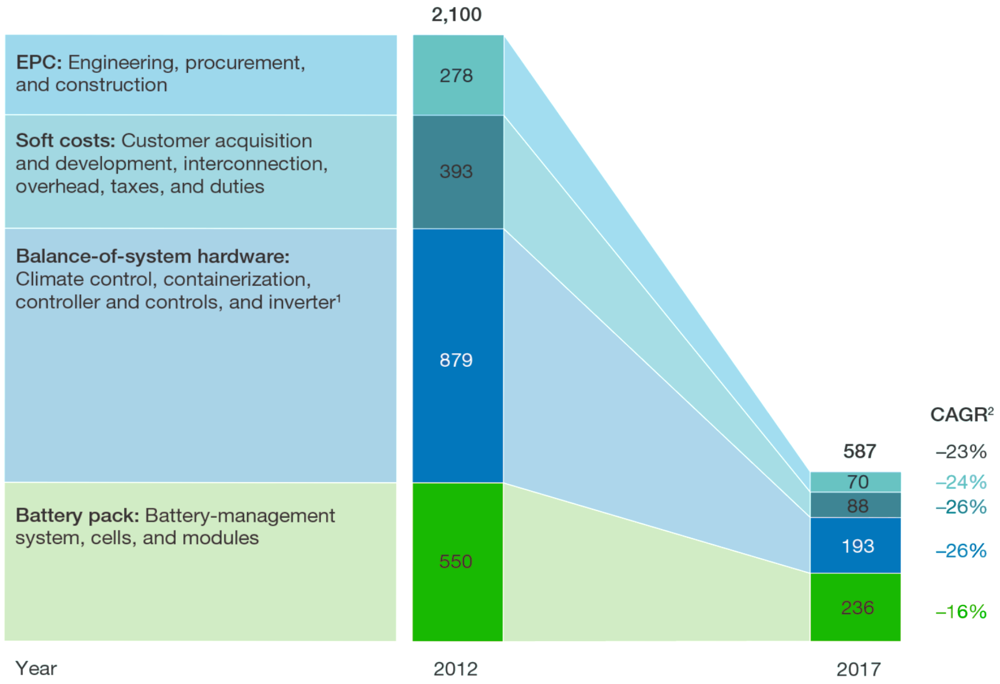


Figure 11. Cost of a 1-megawatt energy - storage system with a 1-hour duration by segment ($/kilowatt-hour/% change)
Source: David Frankel, Sean Kane, and Christer Tryggestad, "The new rules of competition in energy storage", McKinsey & Company. 2018.

The levelized cost of storage (LCOS) reflects the "all-in cost to design, construct, and utilize the battery energy storage system (BESS) over the course of its useful life."[75] LCOS is comparable to the levelized cost of electricity (LCOE) for electric generation resources such as coal, natural gas, or solar. Lazard estimated the LCOS of a standalone utility-scale 100 MW 4-hour duration lithium-ion systems to be between 204 dollars/MWh and 298 dollars/MWh in 2018 and estimated the LCOS of a solar plus storage system to be between 108 dollars/MWh and 140 dollars/MWh.[76] Bloomberg New Energy Finance estimated the LCOS of standalone storage fell 35 percent in 2018 alone to be 187 dollars/MWh in 2019. Although these estimates are currently much higher than the LCOEs of solar and conventional combined cycle plants (both 0.046 dollars/kWh), as storage costs fall the LCOE for solar plus storage will become competitive as a dispatchable type of energy.[77]

---

[75] National Rural Utilities Cooperative Finance Corporation, "Battery Energy Storage Overview", 2019

[76] Lazard, "Levelized Cost of Storage Analysis 4.0," 2018

[77] US Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019", 2019

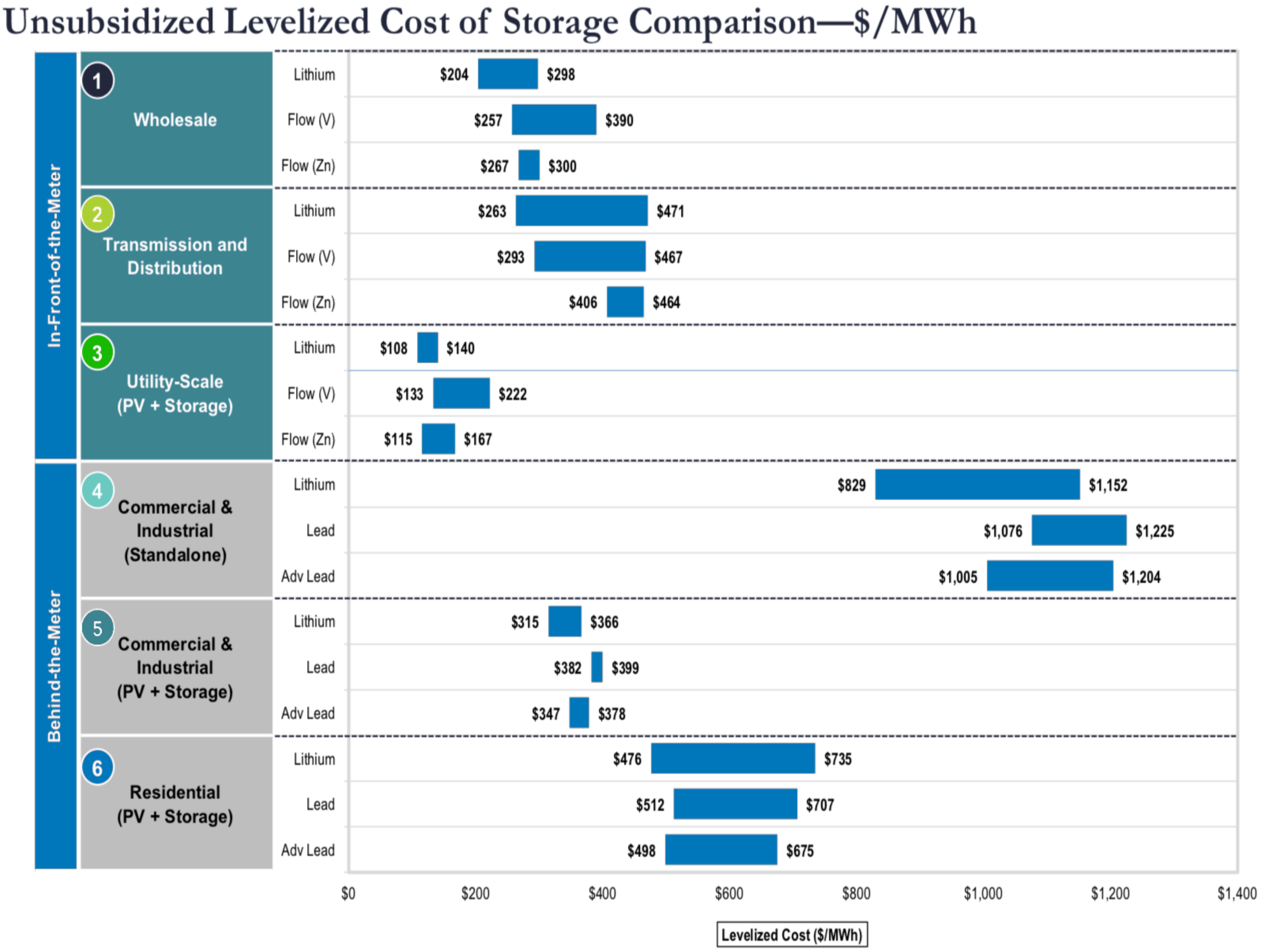


Figure 12. Unsubsidized LCOE comparison
Source: Lazard, “Levelized Cost of Storage Analysis 4.0,” 2018. https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

OPPORTUNITIES AND CHALLENGES

Each of these technologies has opportunities and challenges as outlined in table 5. Many of the mechanical and thermal technologies depend on specific geological features. Some technologies, like flow batteries, sodium, and zinc are notably safer than alternatives like thermal. Both batteries, compressed air, and thermal have flexible sizing. Multiple technologies are mature, and therefore commercially available like compressed air, pumped hydro, and lead acid. Others, like lithium-ion batteries, are rapidly expanding.

Table 5. Advantages and disadvantages of various technologies.

		ADVANTAGES	DISADVANTAGES
Mechanical/Thermal	Compressed Air	• Low cost, flexible sizing, relatively large scale • Mature tech • Safe	• Requires suitable geology • Difficult to modularize for smaller installations • Relies on natural gas
	Flywheel	• High power density and scalability for short-duration technology; low power, higher energy for long-duration technology • High depth of discharge capacity • Compact design with integrated AC motor	• Relatively low energy capacity • High heat generation • Sensitive to vibrations
	Pumped Hydro	• Mature tech • High-power capacity solution • Large scale, easily scalable in power rating	• Relatively low energy density • Limited available sites (i.e., water availability required) • Cycling generally limited to once per day
	Thermal	• Low cost, flexible sizing, relatively large scale • Power and energy ratings independently scalable • Mature industrial tech; can utilize waste industrial heat to improve efficiency	• Technology is pre-commercial • Difficult to modularize for smaller installations • On-site safety concerns from cryogenic storage
Electrochemical	Flow Battery	• Power and energy profiles independently scalable for vanadium system • Zinc bromide designed in fixed modular blocks for system design • No degradation in "energy storage capacity" • No potential for fire • High cycle/lifespan	• Power and energy rating scaled in a fixed manner for zinc bromide technology • Electrolyte based on acid • Relatively high balance of system costs • Reduced efficiency due to rapid charge/discharge
	Lead Acid	• Mature tech with established recycling infrastructure • Advanced lead-acid technologies leverage existing technologies • Low cost	• Poor ability to operate in a partially charged state • Relatively poor depth of discharge and short lifespan • Acid-based electrolyte
	Lithium-Ion	• Multiple chemistries available • Rapidly expanding manufacturing base leading to cost reductions • Efficient power and energy density • Cost reduction continues	• Cycle life limited, especially in harsh conditions • Safety issues from overheating • Requires advanced manufacturing capabilities to achieve high performance
	Sodium	• High temperature tech: Mature tech; high energy capacity and long duration • Low temperature tech: Smaller scale design; emerging tech and low-cost potential; safer	• Inherently higher costs • Potential flammability issues for high-temperature batteries • Poor cycling capability
	Zinc	• Deep discharge capability • Designed for long life • Designed for safe operation	• Currently unproven commercially • Lower efficiency • Poor cycling/rate of charge/discharge

Source: Adapted from Lazard, "Levelized Cost of Storage Analysis 4.0," 2018. https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

An additional benefit of FTM lithium-ion batteries is their ability to provide multiple services. Lithium-ion batteries can conduct energy arbitrage and are technically capable of providing frequency regulation, voltage support, black start, resource adequacy, transmission congestion relief, and transmission and distribution upgrade deferral. Technologies such as flywheel and supercapacitors can generally only provide frequency regulation and voltage support due to their low energy capacity and high discharge rates. Meanwhile, pumped hydroelectricity and compressed air can generally only provide energy arbitrage and resource adequacy due to their slower discharge rates (figure 13).[78] Although lithium-ion batteries have the technical capability to provide all services, battery configurations are generally optimized for a primary service. However, secondary services may be "stacked" on top of the primary service to maximize revenue. Thus, when an asset's primary service isn't needed a secondary service may be provided. The ability to stack many services is unique to electrochemical storage and can be used to generate maximum revenue.

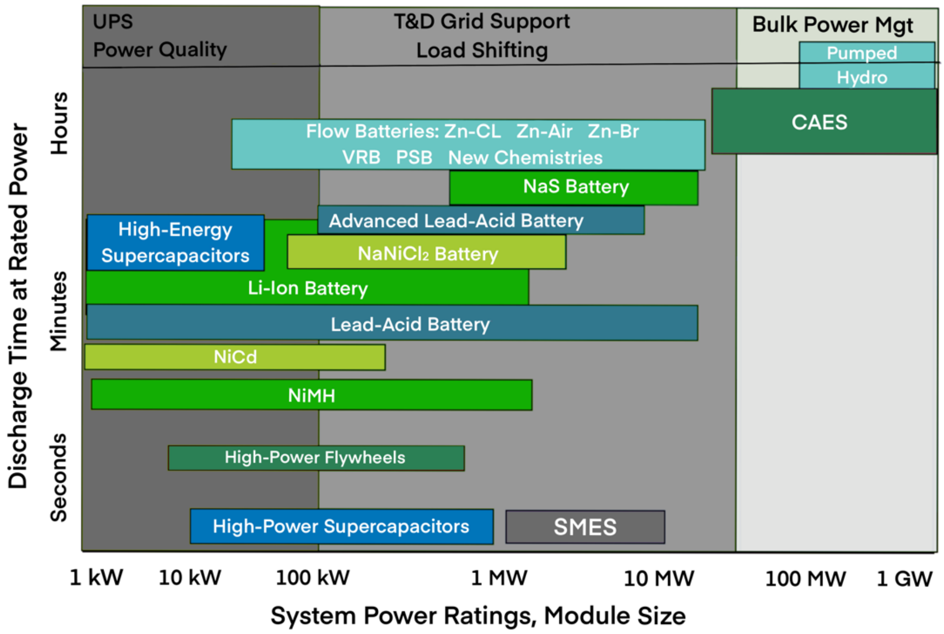


Figure 13. Positioning of Energy Storage Technologies
Source: Sandia National Laboratories, "DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA", 2015

While transmission and distribution investment deferral has been a source of value for electrochemical storage, it is an unneeded service for Hoosier Energy in the near future as indicated by their most recent Integrated Resource Planning (IRP).[79] Given that and the low cost of energy

---

[78] Sandia National Laboratories, "DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA", 201

[79] Hoosier Energy, 2017 Integrated Resource Plan, 2018

capacity in MISO, the greatest primary service of FTM storage may be frequency regulation in the short term, energy arbitrage, as well as reduced renewable curtailment in the long run. In addition, siting storage along with renewable energy resources can lead to a lower LCOE than stand-alone FTM lithium-ion storage.[80]

It should be noted that the battery industry faces several barriers to broader development. First, if a battery overheats it can catch fire, producing gases that can explode.[81] In April 2019, an explosion ripped through a grid in Arizona run by Arizona Public Service (APS). An investigation is still underway, and it is still unclear what caused the fire. In the meantime, several municipalities are beginning to address how batteries are stored. Several new laws include rules that require utilities to notify cities when building new infrastructure, receiving permits and inspections, and follow certain safety features.[82] Though laws like these are not currently wide-spread, as the industry matures, safety measures will likely become more rigorous.[83]

PROMISING TECHNOLOGY: SOLAR PLUS STORAGE

Declining costs of storage technologies and utility-scale solar have created interest in coupling solar and energy storage in order to provide dispatchable power. In addition to providing dispatchable power that can compete with natural gas peaking plants, the coupling of these technologies could provide future resource adequacy, transmission upgrade deferral and congestion relief, generate revenue through energy arbitrage, and provide backup power.[84] Additionally,

---

[80] Lazard, "Lazard's Levelized Cost of Storage Analysis - Version 4.0,", 2018

[81] "To have and to hold." (2019, Nov 30). *The Economist, 433*, 66-67. Retrieved from https://proxyiub.uits.iu.edu/login?qurl=https%3A%2F%2Fsearch.proquest.com%2Fdocview%2F2319662763%3Faccountid%3D11620

[82] Jen Fifield, "After APS explosion injures 4 firefighters, Arizona cities enact storage laws for utilities, homeowners," *AZ Central* (September 30, 2019) https://www.azcentral.com/story/news/local/surprise/2019/09/30/phoenix-peoria-and-surprise-enact-battery-storage-laws/2305933001/.

[83] To have and to hold. (2019, Nov 30). *The Economist, 433*, 66-67. Retrieved from https://proxyiub.uits.iu.edu/login?qurl=https%3A%2F%2Fsearch.proquest.com%2Fdocview%2F2319662763%3Faccountid%3D11620

[84] U.S. Department of Energy, "Considerations for Implementing PV plus Storage Systems," August 2018

storage plus solar has a lower LCOE because of shared infrastructure (e.g., inverters, interconnection), reduced curtailed production, and captured “clipped” solar production.[85]

The cost for PV plus storage systems depends on the configurations which include first, co-located PV plus storage system versus PV in one place and storage systems in a different location and second, direct current (DC) coupled versus alternating current (AC) coupled battery configurations for the co-located PV plus storage systems as illustrated in table 6.

Table 6. Cost difference between co-located PV plus storage system versus different locations

Model Component	**Co-located PV plus storage system**	**PV plus storage in different locations**
Site preparation	Once	Twice
Land acquisition cost	Lower	Higher
Hardware sharing between PV and energy storage	Yes	No
Installation labor cost	Lower	Higher
Engineering, procurement, and construction (EPC) costs / Developed overhead and profit	Lower	Higher
Interconnection and permitting	Once	Twice

Source: Data adapted from Fu, Ran, Timothy Remo, and Robert Margolis. U.S. Utility-Scale Photovoltaics- Plus-Energy Storage System Costs Benchmark. 2018.

Based on table 7, the cost model for co-located PV plus storage system will have lower costs than the PV plus storage in different locations. This will reduce costs because co-located will provide PV and storage systems to share similar hardware components than having to install at two different locations. Besides that, co-location enables the utility to reduce costs in terms of site preparation, land acquisition, labor, EPC, interconnection and permitting. Essentially, there are two configurations to integrate PV and storage in a single location; integrating using either DC-coupled or

---

[85] Lazard, “Lazard’s Levelized Cost of Storage Analysis - Version 4.0,”2018

AC-coupled with different costs when implementing as shown in Table 4. AC-coupled means the PV and storage systems are connected to separate inverter, while DC-coupled enables the PV and storage systems to share bi-directional inverter.

Table 7. Comparison of DC and AC Coupling for PV-Plus-Storage Systems

Model Component	DC-Coupled Configuration	AC-Coupled Configuration
Number of inverters	1 (bidirectional inverter for battery)	2 (bidirectional inverter for battery plus grid-tied inverter for PV)
Battery rack size	Smaller	Larger
Structural BOS	More (Because of smaller battery rack size)	Less
Electrical BOS	Less	More (Because of additional wiring for inverters)
Installation labor cost	More	Less
EPC overhead	More	Less
Sales tax	Less	More (Because higher total hardware costs)
EPC/developer profit	Less	More (Because higher total EPC and developer costs)

Source: Data adapted from Fu, Ran, Timothy Remo, and Robert Margolis. U.S. Utility-Scale Photovoltaics- Plus-Energy Storage System Costs Benchmark. 2018.

Furthermore, utilities often meet peak demand by building peaking plants that operate on natural gas, due to their ability to quickly ramp up or down to meet demand. However, peaking plants are a large investment and deemed to be inefficient since they may only operate for a few hours out of the year. With the dispatchability of solar plus storage, these projects have the potential to compete with peaking plants and provide secondary services when they are not needed during the limited peak demand hours. In addition, building new transmission infrastructure has been the default solution to issues facing the electric grid. These upgrades are required to address load growth, congestion network, and increase peak demand.

The integration of solar plus storage will be useful when offsetting the intermittency and of solar energy in order to provide more predictable power supply.[86] Battery storage systems are able to reduce renewable energy curtailment, with excess electricity can be stored and then used at peak demand when most needed. For instance, Florida Power & Light Company is piloting innovative DC-coupled battery system at its Citrus Solar Energy Center.[87] The battery system capture energy has the potential to capture millions of kilowatt-hours of surplus solar energy a year that usually will be at lost, this improving both quantity and predictability of the power plant's output.

Finally, solar plus storage can provide grid resiliency by having back-up power during grid outages. Grid operators are able to use the stored solar-generated energy to ensure grid stability and continuous electricity flow across the power grid. Utilities will benefit from these systems as stored energy will provide an alternative source of energy should grid disturbances occur. Solar plus storage systems are usually deployed for one of these benefits, however stacking the services to provide multiple, stacked services create additional value for stakeholders and are more economically viable for system-wide benefits.

EMERGING TECHNOLOGIES

Despite huge market opportunities of lithium-ion batteries, research suggests that costs and characteristics of lithium-ion batteries are less suitable for long duration services. [88] Lithium-ion batteries can be outcompeted by other emerging technologies based on performance improvements on safety, energy density, and long-life cycle. For safety, Lithium-ion batteries require costly thermal

---

[86] National Rural Utilities Cooperative Finance Corporation, “Battery Energy Storage Overview, April 2019

[87] Deloitte, “Supercharged: Challenges and opportunities in global battery storage markets,” 2018

[88] Rocky Mountain Institute, “Breakthrough Batteries: Powering the Era of Clean Electrification,” 2019

management to reduce lithium-ion fire-related hazards, while batteries with high-energy and high-power applications will improve energy density, and finally long-life cycles are crucial for grid applications. Lithium-ion batteries will need to achieve two times cycle life improvements at 100 percent depth of discharge in order to remain competitive for today's most basic grid applications on levelized cost basis, as shown in figure 14.[89]

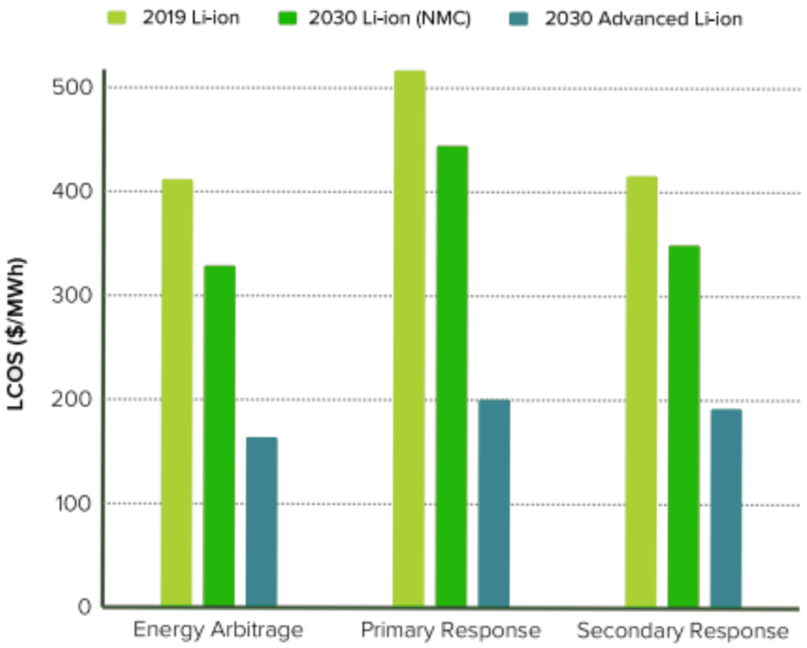


Figure 14. Modelized Levelized Cost of Storage for Battery Technologies for Various Grid Services *Source*: Rocky Mountain Institute, "Breakthrough Batteries: Powering the Era of Clean Electrification," 2019

There are six other categories of emerging battery technologies that may significantly achieve commercial production by 2025 for Hoosier Energy to watch out in future. They are lithium metal, lithium sulfur, zinc Batteries, flow batteries, high-temperature, and high-power batteries. Details are as follows:[90]

---

[89] ibid.

[90] ibid.

- Lithium Metal: Using improved electrolytes, including solid-state can have higher energy density. Lithium metal may reduce battery cell costs 3 times with high performance.
- Lithium Sulfur: Using solid-state and hybrid electrolytes have high energy density with low material costs.
- Zinc Batteries: Zinc-based anodes, with low-cost cathodes can be used to create inexpensive battery while improving cycle life. Cost for zinc batteries are cheaper than Lithium-ion and will continue to decrease in cost.
- Flow Batteries: Using externally stored fluids to generate energy and able to outcompete Lithium-ion batteries for long duration storage with durations greater than six hours.
- High-Temperature Batteries: Using liquid-metal batteries can provide low-cost, long-duration grid balancing, and longer cycle life; It can also provide energy shifting or peaking capacity.
- High-Power Batteries (Supercapacitors): Using graphene and sodium-ion batteries which are low-cost, and have high power density that can charge or discharge rapidly.

BEHIND THE METER

On the electricity market, multiple services can be fulfilled by BTM storage. At the moment, BTM storage mainly serves customer services like backup power, increasing PV self-consumption, or demand charge reduction. With the advance of technology and more DERs, aggregation is becoming more important. Aggregation is especially important for BTM technology, as multiple customers can manage storage portfolios collectively to provide energy, capacity, or ancillary services, which can enable BTM member-consumers to participate in the wholesale market.

EXISTING TECHNOLOGY

BTM storage technologies include: batteries (including batteries in EVs), industrial thermal energy storage, and office building heat and cooling regulations. Heat pumps can be combined with storage to maximize load shifting. The advantages and disadvantages of batteries are discussed extensively above. The following information is on technology that is specific to BTM.

ELECTRIC VEHICLES

The amount of capacity that will be available to the grid from an EV depends on whether the car has unidirectional charging or bidirectional charging/discharging. An aggregator can control a fleet of EVs and optimize the storage and capacity available to the grid. The aggregator can provide the available capacity to the grid at peak hours on the condition that the car is not used, and charge the car during the off-peak period when prices are low. EV aggregation could provide operating reserves since the energy capacity of EV batteries are relatively low but the response time can be very quick.[91]

HEAT PUMPS AND HVAC

Heat pumps are becoming more common for residential use allowing for greater opportunity to include them in aggregated portfolios. A project in Denmark called Control Your Heat Pump gathers data and incentivizes how heat pumps can be operated in electricity markets.[92] A set of houses using heat pumps can be controlled by the aggregator who decide what amount of heat can enter the building and through this control, provide services to the grid by adapting electricity usage.[93]

---

[91] Borne, O., et al. (2018). Barriers to entry in frequency-regulation service markets: Review of the status quo and options for improvements. *Renewable and Sustainable Energy Reviews, 81, 605-614.*

[92] Biegel, B., Andersen, P., Pedersen, T. S., Nielsen, K. M., Stoustrup, J., & Hansen, L. H. (2013). Electricity market optimization of heat pump portfolio. 2013 IEEE International Conference on Control Applications (CCA), pp. 294-301.

[93] Georges, E., Cornélusse, B., Ernst, D., Lemort, V., & Mathieu, S. (2017). Residential heat pump as flexible load for direct control service

THERMAL ENERGY STORAGE AND HVAC

An aggregator can control a combination of equipment, like heating, ventilation, and air conditioning (HVAC) within a building. An aggregator can optimize energy use within a building from which market services can be provided. For the client, the effects are barely noticeable as temperatures vary little. This service could provide 15 percent of extra reserve capacity in the operating reserve market.[94] Considering 36 percent of electricity consumption in the USA is used in commercial buildings, this BTM saving may have a considerable impact.[95]

A second control of cooling services can be through industrial or commercial thermal energy storage. For example, grocery stores can change their electricity demand through their cooling systems by adding pre-cooling in off peak times and reduce their demand at peak-hours. The hardware needed to implement this is similar to the equipment grocery stores already have. Research shows that an increase in energy demand of 13.5 percent during off-peak times could result in a 24.7 percent decrease in peak times.[96]

RESIDENTIAL BATTERIES

Small scale batteries can be used in homes to provide BTM storage. Residential batteries can be used for non-spinning reserve capacity where a battery may be owned by an individual household (Home Energy Systems (HES)) or by a community (Community Energy Storage (CES))[97].

---

with parametrized duration and rebound effect. Applied Energy, 187, 140-153.

[94] Vrettos, E., Oldewurtel, F., Zhu, F., & Andersson, G. (2014). Robust provision of frequency reserves by office building aggregations. IFAC Proceedings Volumes, 47(3), 12068-12073.

[95] Mai, W., & Chung, C. Y. (2014). Economic MPC of aggregating commercial buildings for providing flexible power reserve. IEEE Transactions on Power Systems, 30(5), 2685-2694.

[96] Pedersen, R., Schwensen, J., Biegel, B., Stoustrup, J., & Green, T. (2014). Aggregation and control of supermarket refrigeration systems in a smart grid. IFAC Proceedings Volumes, 47(3), 9942-9949.

[97] Terlouw, T., AlSkaif, T., Bauer, C., & van Sark, W. (2019). Multi-objective optimization of energy arbitrage in community energy storage systems using different battery technologies. Applied Energy, 239, 356-372.

COSTS/PRICING

Cost shift refers to a customer being compensated (usually by net metering) for their own distributed resources without paying for the grid services sufficiently, and shifting the fixed costs of the grid to other customers. This often leads to a debate surrounding net metering practices and how to value distributed resources “fairly”. For Hoosier Energy, this means that when a subset of member-consumers reduce their electricity consumption through distributed resources, other member-consumers will bear a higher price.

Another related concept is grid defection, where DERs become more affordable than retail electricity, incentivizing consumers to stop relying on the electricity supply from the grid. This can be treated as an extreme form of cost shift. Even without massive grid defection, simply having large scale grid-connected solar plus storage (so-called “load defection”) can greatly impact Hoosier Energy’s revenues.[98] Growing numbers of adopters can create a vicious cycle of decreasing sales, increasing electricity prices, and more people defecting. In the worst case scenario, Hoosier Energy will be forced to charge members prohibitively high prices, possess large amount of stranded assets, and lose market relevance. In this case, low-income households which can’t afford defection are harmed the most.

For Hoosier Energy, given its relatively low electricity price and more conservative energy policy from the State of Indiana, the possibility of grid defection is not a significant problem currently. However, there are a few factors that might accelerate this process, with load defection coming before true grid defection. These include technological innovation, subsidy schemes favoring energy storage and distributed generation, market designs allowing value stacking or aggregation of storage assets, and rate structures incentivizing self-generation and consumption, such as net billing.

---

[98] *The Economics of Load Defection*. Rocky Mountain Institute, 2015.

Notably, fixed charges do not eliminate the risk of grid defection, but simply delay it. By adding more fixed charges, utilities can reduce the energy charges by kWh and persuade consumers to stay on the grid and purchase its electricity. However, as long as the trend of increasing retail electricity prices and decreasing cost of adopting grid defection does not change, defection will eventually be more economic. At that critical point, consumers will defect without any intermediate steps like load defection.[99]

Nevertheless, this challenge can serve as an opportunity. Passively, it can be used to defer or even replace grid infrastructure investments. Additionally, DERs should be included in the IRP process, considering both purchasing energy storage and DERs owned by member-consumers. Proactively, Hoosier Energy can utilize innovative business models to share the value of DERs. These non-exclusive strategies may include: innovative rate structures, providing financing for DERs (possibly through the addition of a tariff on adopters' bills), aggregating DERs to participate in the wholesale market through a virtual power plant, developing and leasing DERs (not controlled by the utility), or owning customer-sited systems (controlled by the utility).

RATE STRUCTURES

Rate structures are not only a reflection of the cost of service, but also a potential approach to mitigate the issue of cost shifting. Thus, understanding where costs comes from and who bears the cost is important. For Hoosier Energy, cost mainly incurs with the generation/purchase of energy (variable costs) and the infrastructure to meet the electricity demand (fixed costs).

Variable cost is normally cheap, and has limited marginal effect on project development. Additionally, variable costs are proportionally borne by each user. On the other hand, fixed costs are evenly distributed to all users. That being said, customers pay a fixed amount of demand charge

---

[99] ibid.

regardless of how much electricity they use. However, one undesired consequence of this problem occurs when small-scale energy users inevitably subsidize large-scale users because some users contribute a greater amount to the peak demand of the grid.

BTM battery storage is an ideal approach to mitigate this problem by shifting the evenly distributed long-term fixed cost of operating and maintaining the grid to a relatively short-term fixed cost of installing a set of batteries. There are two advantages to this. First, the operation and maintenance cost in the long run is substantially lower than that of the grid beyond the installation cost. Second, as a BTM facility, each user bears the cost of installation, operation, and maintenance. The less electricity one consumes, the less one pays, instead subsidizing bigger users. Storage would decrease the demand charge burden on residential users in the long run, while easing the pressure on the grid, especially during peak loads.

As the energy supply shifts from the transmission grid to battery storage, rate structures will need to be redesigned. Multiple options for rate design and billing exist, each of which are associated with particular advantages and disadvantages.

ENERGY POLICY

Energy policy has existed in the United States since the early 1950s.[100] Since then, energy policy has transformed and evolved at both the state and federal level, aiming to reduce greenhouse gas emissions.

There are six basic types of energy policy that aim to reduce greenhouse gas emissions. These include: direct regulation, taxes, tradable permits, voluntary agreements, subsidies or other incentives, and information programs. Most well-developed policies are a mix of one or more of

---

[100] National Research Council, “Designing, Implementing, and Evaluating Climate Policies,” in *Advancing the Science of Climate Change* (Washington, DC: The National Academies Press, 2010), 401-420.

these types.[101] These six types of policy can be simplified into two basic categories: emissions reduction policies and incentivization policies. Emission reduction policies act to discourage emissions through regulation, taxes, and/or permits. Incentivization policies encourage sustainable development through tax credits, subsidies, and/or grants. Voluntary agreements can act as either emission reduction or incentivization policies.

Overall, both emission reduction policies and incentivization policies would act to move energy utilities into the future. Any energy policy would significantly affect the landscape for energy storage.

EMISSION REDUCTION POLICIES

Emission reduction policy could take many forms including direct regulation, carbon taxes, or a permit system. A direct regulation approach consist of direct command-and-control policies that set standards such as pollution output or technology requirements. These standards are usually paired with enforcement mechanisms to encourage compliance. In 2013, the Obama administration published a climate action plan that proposed direct regulation including rules to cut carbon pollution. This plan ordered the EPA to set limits on carbon emissions from new power plants. Additionally, under the climate action plan, the EPA proposed separate standards for coal and natural gas to limit emissions further.

Emission reduction policies can also come from the state level. Several states have mandated storage to help reduce emissions. In 2013, California was the first state to set an energy storage target of 1,325 MW by 2020, with another 500 MW added to the target since. Oregon followed in 2015 with a target of 5 MWh by 2020. Massachusetts passed an initiative in July 2018

---

[101] National Research Council, “Designing, Implementing, and Evaluating Climate Policies,” in *Advancing the Science of Climate Change* (Washington, DC: The National Academies Press, 2010), 401-420.

with a goal of 1,000 MWh of storage by 2025. In December of the same year, the New York Public Service Commission approved two initiatives aimed at reducing emissions including an ambitious energy storage target of 3,000 MW by 2030 with an interim goal of 1,500 by 2025.[102] In 2018, New Jersey became the fifth state with an energy storage target, with a law mandating New Jersey's Board of Public Utilities to begin work to establish 600 megawatts of energy storage by 2021 and 2,000 megawatts by 2030. Arizona's Corporation Commission has proposed a 3,000 MW by 2030 target that has yet to be approved.[103]

A carbon tax is a price imposed on all fossil fuels including coal, petroleum, and natural gas combustion. The price of the tax is based on the carbon content of the fuel. The price is applied at a rate of $X per ton of CO2 emitted through combustion, rising at Y percent above inflation. This kind of carbon tax could be implemented through legislation like the SWAP Act that was introduced in July 2019 and would impose a carbon tax by 2021.

Alternatively, similar legislation limits future emissions through a permitting system. For example, the Healthy Climate and Family Security Act was introduced in March 2019 and would create a carbon permitting system with the number of permits reduced each year (the permits for 2020 would be equal to 12.5 percent less than the metric tons of carbon dioxide emitted in the US in 2005, the permits for 2025 would be equal to 50 percent less, etc.).[104] Though there are a number of bills aiming to curb emissions, they have not yet passed the senate, and are unlikely to do so under the current administration. Though regulation like this is not probable in the next few years, it is likely that some greenhouse gas emission reduction legislation will be passed in the near future.

---

[102] Peter Maloney, "New York sets 3 GW storage target, doubles efficiency goals for utilities," *Utility Dive* (December 14, 2018) https://www.utilitydive.com/news/new-york-psc-sets-states-energy-storage-target-at-3-gw-by-2030/544371/

[103] To have and to hold. (2019, Nov 30). The Economist, 433, 66-67. Retrieved from https://proxyiub.uits.iu.edu/login?qurl=https%3A%2F%2Fsearch.proquest.com%2Fdocview%2F2319662763%3Faccountid%3D11620

[104] S.940 Healthy Climate and Family Security Act of 2019 (March 28, 2019) https://www.congress.gov/bill/116th-congress/senate-bill/940/text.

INCENTIVES

Incentive policy can be implemented at the federal or state level. At the federal level there are a number of grants and loan programs available for storage projects such as the Federal Investment Tax Credit (ITC) incentive program.

Incentive policies act to encourage sustainable practices such as renewable energy or storage. Battery storage implementation is a relatively new resource for energy providers, and as such, federal and state incentives regarding storage have lagged behind technological innovation. However, there is progress in many states indicating that lawmakers are interested in increasing storage assets. Seventeen states are currently incentivizing or considering policy related to battery storage. These policies fall within five main categories: state-funded battery storage research, storage procurement targets and Renewable Energy Portfolio Standards (RPS), regulatory adaptation, direct grant funding and rebates, and tax incentives for battery projects.

Adoption of state policies sends an encouraging message to the battery storage industry. Broadly, any state incentive to develop battery storage benefits utility providers by reducing costs, driving innovation, and spurring pilot battery storage projects. Positive progress in the industry should be seen as a positive for Hoosier, as they will help reduce technological hurdles for Hoosier if they decide to implement a storage project in the future. Five types of battery storage policies are described below:

State-funded research into battery storage has been implemented in several states. While the policies differ state to state, there are a number of policies that if implemented in Indiana, would be an effective means of reducing costs for storage implementation for Hoosier Energy. States such as Washington and Massachusetts have authorized direct rebates, not tax incentives, for battery storage pilot projects. If a similar program were implemented in Indiana, Hoosier would be able to take advantage of state funds to create pilot projects and reduce the cost of exploring integration of storage assets into the grid.

States with storage procurement targets largely identify them within their RPS. These storage goals are often non-binding, but their existence indicates that energy storage is a relevant issue to lawmakers within the state and signals the potential for future growth. Often states with procurement goals pass other policies that incentivize battery storage in FTM and BTM. Indiana currently has an RPS that provides incentives for implementing renewable energy and storage, however the program is voluntary and applies only to investor-owned utilities. An RPS's effectiveness is contingent on a multitude of policy design features and varies state to state. Regardless, the presence of an RPS indicates the state has taken steps towards clean energy development in the state, and indicates potential for future policy shifts and steps towards storage development.

Certain states have also taken to adapting regulations to better-fit battery storage needs and streamline approval processes for projects. California has passed an ordinance requiring local governments to digitize the permitting process in order to allow for greater accessibility and ease the application burden on utilities. Other states have mandated that utilities promote BTM storage applications, such as a recent ordinance by the Arizona State Legislature requiring utility companies to begin offering rebates for residential battery storage projects. While Indiana has not implemented many regulatory policies, it is important to maintain abreast of the current regulatory landscape across the country.

Many of the current policies at the federal and state level are tax-based incentives, and therefore even if implemented in Indiana, would not be available for Hoosier Energy to directly take advantage of. However, the benefits of a tax policy would have auxiliary benefits for Hoosier. If other providers in the state are incentivized to build storage projects, Hoosier could still benefit from the increased grid resiliency, and could still potential take direct advantage of storage assets through purchasing agreements. Furthermore, the presence of tax incentives for battery storage indicates that energy storage is a salient issue for relevant lawmakers. Having energy storage policy as an important policy point is its own asset, as it could increase the possibility of further positive policy implementation.

At the federal level, the ITC acts as the main incentive available for energy providers. There are also a number of other grant programs and loans specifically aimed at rural Utility Service providers that will be summarized below, along with the policies in each of the seventeen states. While it cannot be assumed that any of the individual state-level policies will be implemented in their entirety in Indiana even in the most ideal of circumstances, they can be used as a framework of analysis for the best possible future policy outcomes for Hoosier Energy. Brief summaries of these policies are listed below, providing an overview of the storage policy landscape.

FEDERAL LEVEL

FEDERAL INVESTMENT TAX CREDIT

For battery projects, federal incentives are tax based and tied to renewable energy. ITC is a standing federal incentive that allows for up to 30 percent of commercial and residential solar projects' start-up costs to be deducted from federal taxes.[105] While this deduction has largely been used for solar systems, it can be used to deduct the cost of battery storage as long as the asset is charged through renewable energy. The exact level of deduction is determined by the frequency at which the battery is charged by on-site renewable energy sources. To receive the full thirty-percent deduction, the battery must be charged one hundred percent by renewable energy.[106] Any percent amount the battery is charged by, sources other than on-site renewable energy is deducted from the

---

[105] Department of Energy Office of Energy Efficiency and Renewable Energy. *Residential and Commercial ITC Factsheets*, 2019,

[106] ibid.

credit; for example a battery charged eighty percent by on-site renewables would receive a twenty-four-percent tax deduction (eighty percent of thirty percent).[107] These incentives still apply to batteries installed to an existing solar grid, assuming the installer owns the panels charging the battery.

The ITC will begin to be phased out starting in 2020. Until the end of 2019 the tax credit will remain at the thirty percent level, however, beginning in 2020 this will drop to a maximum of twenty-six percent, falling further to twenty-two percent in 2021. From 2022 onwards, the maximum credit receivable will be ten percent.

FEDERAL GRANT AND LOAN PROGRAMS - RURAL UTILITY SERVICE (RUS)

At the federal level there are two loans programs that are geared towards rural cooperatives that could potentially help Hoosier Energy finance future pilot or full scale energy storage projects. In addition, the federal government offers a grant program for rural businesses or farms that may be beneficial to incentivizing BTM storage in Hoosier's network.

One grant available for Hoosier member-consumers would be the Renewable Energy Development Assistance Grant. This grant provides funding at 50 million dollars per year for rural businesses or farms to develop renewable energy projects. This program was reauthorized by the 2018 farm bill. Energy storage is eligible for funding if it is co-located with renewable energy generation. This could be used to incentivize behind the meter storage options within Hoosier's member cooperatives.

The Rural Energy Savings Program (RESP) is a program supported by the USDA originally authorized by the 2014 Farm Bill and reauthorized in 2018 to be extended to 2023.[108] RESP allocates

---

[107] ibid.

[108] Environmental and Energy Study Institute, "Rural Energy Savings Program," *Environmental and Energy Study Institute,* https://www.eesi.org/Rural-Energy-Savings-Program

approximately 100 million dollars a year. This program provides zero-interest loans to rural electric cooperatives to facilitate relending to member-consumers at interest rates of up to five percent. These loans have previously funded energy storage projects.[109]

Similar to RESP, the Energy Efficiency and Conservation Loan Program (EECLP) provides loans to rural electric cooperatives to relend to member-consumers for capital improvements. These improvements, however, are focused on the utilization of alternative energy or to improve the load profile. These loans are tied to the treasury interest rate (which is currently low and under two percent).[110] There is no specific mention of energy storage within these programs, but as energy storage can provide the services related to this program, funding could potentially be used for these technologies now or in the future.

PROPOSED FEDERAL BILLS RELATED TO STORAGE

Finally, there are several bills that have been proposed in Congress that could have future impacts on energy storage implementation in Indiana. Because these bills have not cleared either the House or Senate and are still in the proposal stage, they should be considered as 'on the horizon' and taken more as a litmus test for the state of energy consideration at the federal level and less as impending legislation. These bills should be monitored moving forward, and are identified in table 8.

---

[109] Jason Walsh and John-Michael Cross, "Rural Energy Savings Program," Environmental and Energy STudy Institute, https://www.eesi.org/files/RESP_Overview_June_2018.pdf

[110] Bob Coates, "Rural Energy," United States Department of Agriculture, http://energyoutlook.naseo.org/data/energymeetings/presentations/Coates--USDA.pdf

Table 8. Proposed federal bills related to storage

Bill	Description	Status
Expanding Access to Sustainable Energy Act of 2019 (S.1183)	Grant money for Rural Energy Membership Corporations for energy storage and microgrids	Introduced
Joint Long-Term Storage Act of 2019 (S.2048)	Requires the Advanced Research Projects Agency-Energy to create demonstration projects for long-range energy storage technologies	Introduced
Battery Storage Innovation Act (H.R.1742)	Expands DOE loan guarantee programs to include battery storage technologies	Introduced
Advancing Grid Storage Act of 2019 (H.R.1743)	Establishes a loan program for energy storage systems and financing for energy storage systems	Introduced
S.T.O.R.A.G.E Act (H.R.1744)	Requirement for state utility ratemaking authorities to require storage to be considered in IRP planning	Introduced (seems to conflict with federalism)
Energy Storage Tax Incentive and Deployment Act of 2019 (H.R.2096)	Extension of ITC to energy storage technologies	Introduced
Better Energy Storage Technology Act (H.R.2986, S.1602)	Funding for energy storage research, development, and demonstration - Requires FERC to develop a procedure for utilities to recover energy storage costs - Includes language from S.1183, S.1593, S. 1741, and S.2048	Introduced

STATE LEVEL

ARIZONA: POLICY MANDATES DRIVING PRIVATE REBATES FOR RESIDENTIAL SYSTEMS

Arizona has taken steps towards increasing energy storage assets in their state, primarily through BTM projects. The Arizona Corporation Commission has ordered two electric utilities to develop residential battery storage programs, as well as a demand displacement program to facilitate energy storage technologies to help customers lower their energy use during peak demand.[111] In response, Arizona's largest utility company, Salt River Project, created a residential

---

[111] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*, 2018

storage project for up to 4,500 homeowners, which provides a rebate up to $3,600 for residential battery systems contingent on their sharing of data as participation in the states battery storage research project.[112]

CALIFORNIA: DIRECT REBATE FUNDING WITH FAVORABLE LOCAL POLICY IMPLEMENTATION

California's incentives and policy structure, if implemented in Indiana, would be extremely beneficial for Hoosier Energy. California has implemented policy requiring local governments to make documents and forms for advanced storage permitting, public and accessible online beginning September of 2018.[113] Furthermore, the California Public Utility Commission has approved rules that increase the ways energy storage systems can obtain revenue: i.e. from frequency regulation, capacity or spinning reserve services.[114]

In addition, California has implemented an ambitious incentives program. The Self-Generation Incentive Program (SGIP), provides rebates for energy storage systems based on the asset's power capacity, energy storage capacity, and system duration.[115] This incentive is a straight rebate, with a 270 million dollar budget as of 2019.[116]

California and Indiana are substantively different states, however, the incentives structure outlined in the SGIP could be a beneficial framework for state lawmakers if they were to aim for an aggressive increase in statewide energy storage capabilities.

CONNECTICUT: PRELIMINARY POLICY STEPS TOWARDS ENERGY STORAGE TARGETS

Connecticut has taken some steps to address energy storage assets by promoting the development of micro-grids and energy storage technologies within the state's energy plan.[117]

---

[112] Salt River Project, *Reserve Your Battery Storage Incentive*, 2019

[113] Government Accountability Office, *Energy Storage Information*, 2018

[114] ibid.

[115] California Public Utilities Commission. *Self-Generation Incentive Program Handbook* 2019.

[116] ibid.

[117] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to*

While they have not taken tangible steps towards incentivizing storage, their energy plan indicates that lawmakers are considering the issue.

HAWAII: PRELIMINARY STEPS TAKEN TOWARDS TAX INCENTIVE POLICY

Hawaii has considered Senate Bill 665 within their state legislature, which would create a state tax credit for energy storage systems.[118] The issue is still under review, indicating that storage is being considered at the state level.

INDIANA: VOLUNTARY RENEWABLE PORTFOLIO STANDARDS WITH TAX INCENTIVES

In Indiana, the Voluntary Clean Energy Portfolio Standard Program provides incentives for utilities that generate a certain percentage of their total electricity from clean or renewable sources. These set standards would be seven percent of a company's total energy must be from clean sources by 2024, and ten percent by 2025.[119] In meeting the clean energy targets, participating utilities will be allowed to increase their rate of return by altering their rate design schemes. As the law currently stands, only investor-owned utilities are eligible to participate in the voluntary program. It is however beneficial to know the renewable targets set forth in the program, as they indicate the level at which state lawmakers would like to see renewable resources at in a company's portfolio. If there is a substantive change in state incentive structures in Indiana allowing Hoosier to participate, it is likely that the standards would be substantively similar to those in the Voluntary Clean Energy Portfolio Standard Program.

NEVADA: PRELIMINARY RESEARCH INTO SOLAR PLUS STORAGE TAX INCENTIVES

The Nevada Public Utility Commission has opened an investigatory docket to explore energy storage technologies and interconnection issues, and has been required by the state legislature to

---

Address Them. 2018.

[118] Hawaii State Legislature. *SB665 SD2 HD1:Relating to Renewable Energy.* 2018.

[119] Indiana General Assembly. *IC 8-1-37: Voluntary Clean Energy portfolio Standard Program.* 2019.

establish, as part of an existing solar incentive program, incentives for the installation of energy storage systems.[120] This would be a tax-based incentive structure.

MARYLAND: TAX CREDIT FOR STORAGE ASSETS

Maryland has established a state tax credit for thirty percent of startup-installed costs for commercial and residential energy storage systems.[121] The state budgeted 450,000 dollars for commercial systems, and 300,000 dollars for residential.[122] In addition, The Public Service Commission has initiated a grid modernization rulemaking strategy to defining residential energy storage, how it is classified in the rules, and criteria for evaluation of storage as a grid investment.[123]

MASSACHUSETTS: GRANT FUNDING AND TAX INCENTIVES FOR STORAGE ASSETS

The Massachusetts Department of Energy Resources created a 20 million dollar grant program to help fund a total of twenty-six energy storage projects with 32 MW of storage.[124] These projects were a mix of utility scale and BTM projects.[125] This is part of an ambitious overall target of 200 MW of storage for the state as a whole. Massachusetts is taking aggressive steps to become the national leader in energy storage.[126]

The Massachusetts State Legislature is also considering passage of House Bill 2600 would allow municipalities to exempt storage systems from property taxes, adopt a sales tax exemption for storage systems, and direct establishment of a rebate for Massachusetts commercial companies installing and manufacturing BTM storage systems.[127]

---

[120] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.
[121] Maryland Energy Administration. *Maryland Energy Storage Income Tax Credit- Tax Year 2019*. 2019.
[122] ibid.
[123] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.
[124] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.
[125] Commonwealth of Massachusetts. *ESI Demonstration Program Advancing Commonwealth Energy Storage (ESI ACES).* 2019
[126] Commonwealth of Massachusetts. *Energy Storage Initiative.* 2019
[127] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.

NEW JERSEY: BEHIND THE METER GRANT FUNDING FOR COMMERCIAL ENTITIES

New Jersey has implemented an incentives structure for BTM storage options for offsetting peak loads and for emergency backup services for non-residential commercial entities.[128] New Jersey's Renewable Electric Storage Program is a rebate incentives program that provides direct rebate for initial development costs. The project is still in its infancy, having funded one project for 300,000 dollars with another two projects approved and planned with an expected payout of 210,600 dollars.[129] If a similar project were to be implemented in Indiana, it could prove beneficial for Hoosier Energy. A similar project could incentivize large member commercial energy users within Hoosier to install on-site BTM projects, the data from which could be used to aid Hoosier in creating future assets. Furthermore, the grid stabilization and demand displacement could prove to be beneficial to the grid without requiring Hoosier to invest in its own storage assets.

NEW MEXICO: INTEGRATED RESOURCE PLAN CHANGES

New Mexico's Public Utility Commission amended their IRP rules to include energy storage as a resource for utility planning purposes.[130] This is a small step, but one that would increase awareness and potentially increase the likelihood of future energy storage asset development.

NEW YORK: PROPOSED TAX CREDITS FOR RESIDENTIAL SYSTEMS PLUS CURRENT GRANT FUNDING FOR UTILITY STORAGE ASSETS

The New York Public Service Commission approved a 10-year, 5.322 billion dollar Clean Energy Fund, including a portfolio focused on addressing barriers for energy storage.[131] New York State Energy Research and Development Authority made available 15.5 million dollar to support certain energy storage demonstration projects.[132]

---

[128] New Jersey Board of Public Utilities. *New Jersey's Clean Energy Program: Renewable Electric Storage.* 2019.

[129] ibid.

[130] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.

[131] ibid.

[132] ibid.

The New York State Senate is currently considering Assembly Bill 6235, which would create a state tax credit for residential energy storage systems equal to 25 percent of cost up to a total of 7,000 dollar.[133] This Bill is still in the preliminary stages being considered in Committee.[134]

NORTH CAROLINA: PRELIMINARY RESEARCH ON STORAGE INITIATED

A North Carolina state legislator initiated a study on energy storage to address how and if storage may benefit consumers, the feasibility of storage in the state and policy recommendations.[135] This effort is ongoing, and indicates that state lawmakers are considering the impact of storage assets, which may have future implications on whether the state will institute further action in incentivizing storage.

OREGON: INTEGRATED RESOURCE PLAN CHANGES

Oregon's Public Utility Commission directed Portland General Electric to address energy storage in future IRPs.[136] Furthermore, the Public Utility Commission has been directed by the state legislature to develop a framework for utilities to use in conducting storage evaluations. This indicates that while the state does not provide incentives, they are preparing for a future in which storage assets are implemented in their state.

PENNSYLVANIA: PRELIMINARY CALL FOR RESEARCH ON STORAGE PROJECTS

Pennsylvania's General Assembly considered House Bill 1412 authorizing all distribution companies to propose energy storage and microgrid pilot programs.[137] This was largely a voluntary

---

[133] ibid.

[134] The New York State Senate, *Assembly Bill A6235: Establishes a Tax Credit for the Purchase and Installation of New Residential Energy Storage Systems*. 2017-2018 Legislative Session.

[135] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.

[136] ibid.

[137] General Assembly of Pennsylvania. *House Bill No. 1412 Session 2017*. 2017.

measure to call for utilities to look into storage and microgrid options, and had no binding power or requirements on the utilities.

SOUTH CAROLINA: PRELIMINARY LEGISLATIVE CONSIDERING TAX INCENTIVES FOR STORAGE

The South Carolina Senate has been considering implementing energy storage incentives through Senate Bill 44, which would adopt an 80 percent tax exemption for DERs, including energy storage, as well as allow residential project costs to be exempted from property tax valuation.[138] As it stands, the bill has been shelved by the South Carolina House after passing the Senate, indicating that it is unlikely to pass in its current form.[139]

VIRGINIA: RPS STORAGE GOALS AND MANDATED PILOT PROJECTS

Virginia recently passed new regulations for utility energy providers with the goal of increasing storage and efficiency within the state. The Virginia Senate passed Senate Bill 966, which requires the two Investor-owned utilities to develop a pilot program to deploy battery storage.[140] The bill also allocated 100,000 dollar for the Solar Energy Development and Energy Storage Authority to research regulatory reforms and incentives that could encourage energy storage in the state.[141] In response Dominion Energy announced four utility-scale pilot projects with a combined capacity of 16 MW, to be completed by December 2020.[142] The Virginia legislature has authorized Dominion to create projects up to a 30 MW capacity.[143] It is unlikely that Indiana would pass similar legislation that would mandate Rural Energy Membership Corporations to take similar action, however it does show that some states are taking significant steps to implementing storage.

---

[138] South Carolina General Assembly 122nd Session. *S. 44: Property Tax Exemptions.* 2017-2018.

[139] ibid.

[140] Office of the Secretary of Commerce and Trade Department of Mines, Minerals and Energy. *The Common Wealth of Virginia's 2018 Energy Plan.* 2018.

[141] Office of the Secretary of Commerce and Trade Department of Mines, Minerals and Energy. *The Common Wealth of Virginia's 2018 Energy Plan.* 2018.

[142] Connor Ryan, *Dominion Energy Announces Energy Storage Pilot Projects in Virginia*. Energy Storage News.

[143] Connor Ryan, *Dominion Energy Announces Energy Storage Pilot Projects in Virginia*. Energy Storage News.

WASHINGTON: INCREASED POLICY OVERSIGHT AND GRANT FUNDING

The Washington Utilities and Transportation Commission's policy statement directs utilities to demonstrate when considering a new energy generation resource acquisition, that their analysis of options includes a storage alternative.[144] Furthermore, they established a Clean Energy Fund to expand clean energy projects and technologies, including energy storage setting aside $112 million dollars for clean energy projects from 2013 through 2019.[145]

CASE STUDIES

As the electricity grid evolves and transforms with the growth of renewable energy, energy storage will play an important role. Several utilities in the MISO region have already built energy storage projects or have projects planned to take advantage of the potential energy storage in serving a variety of roles. Some of these case studies are detailed below.

COMED

ComEd, the largest utility in Illinois, built the first of several solar plus storage projects in June of 2018. According to CEO Joe Dominguez, the evolution of energy storage will be slower in Illinois than some other states, but will be "absolutely a necessary component of the future."[146] The project aims to meet the peak electricity demand of 1060 residential, commercial, and small industrial customers. The system will also be used to maintain services when the microgrid is islanded. Additionally, ComEd seeks to demonstrate the value of storage to encourage state

---

[144] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.

[145] Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.

[146] David Thill, "In Illinois, storage is among the next hurdles for renewables expansion," *Renewable Energy World*, May 3, 2019,https://www.renewableenergyworld.com/2019/05/03/in-illinois-storage-is-among-the-next-hurdles-for-renewables-expansion/#gref

regulators to consider energy policy incentives and developers to make storage more affordable and efficient through technological innovation. Illinois, like Indiana, currently has a limited storage capacity at just 0.3 MWs deployed in 2017.[147] Other states like New York and California have initiated long-term deployment plans that aim to increase storage capacity. While most mid-western states have not pursued storage deployment this aggressively, Illinois' Future Energy Jobs Act focuses on building renewable generation through solar and wind. This Act aims to shift the state to 100% renewables by 2050. The expansion of renewables makes a conversation on energy storage inevitable, even in states that have not already made storage deployment a priority. In response to the intermittency of renewable resources, ComEd has five storage projects that are already operating or are being planned. These pilot projects range from a 25-kilowatt community energy storage system to a planned 2-megawatt battery system.[148] While these projects will ultimately meet peak demand and provide resiliency, ComEd primarily aims to prove to regulators that the technology is able to defer costly distribution system upgrades over time. According to the company, the 2-megawatt planned system will "defer expensive upgrades at a substation and feeder for about five years" or longer if distributed energy expands and slows load growth. Ultimately, the project is projected to cost less than half of what it would cost to upgrade the substation using traditional technologies. Projects like this are only feasible on a small scale for now.

The cost of producing electricity over the lifespan of ComEd's project is $187 per megawatt-hour for lithium-ion batteries. This is a steep drop from previous years, but still much higher than solar photovoltaic at $57 per megawatt-hour. While prices will continue to drop as technology evolves and alternative resources are found, policy can make storage possible sooner. Several states have incentive programs for storage, and some state commissions have issued guidance to utilities

---

[147] Thill, "In Illinois, storage is among next hurdles."
[148] ibid.

to include storage in the IRPs. Most midwestern states are not there yet, but projects like these can encourage decision-makers to be proactive and consider storage as a long-term solution.

CHERRYLAND ELECTRIC COOPERATIVE

The Michigan Municipal Electricity Association (MMEA) invested in a community solar program in 2013. Michigan is one of several states where legislation or policies have been adopted to enable or mandate community solar projects. Cherryland Electric Cooperative (Cherryland) and Traverse City Light and Power (TCL&P) have partnered to offer the Solar Up North (SUN) Alliance to their members. Cherryland is an electric cooperative with 33,000 members and TCL&P is a municipal utility with 12,000 members. As municipal and co-op electric companies, they are not restricted by the Michigan Public Service Commission regulations and can choose to offer a community solar program if they feel it is in the best interest of their members.[149]

As a cooperative, Cherryland is ineligible to qualify for federal tax incentives. Therefore, an agreement was negotiated with Spartan Renewable Energy (Spartan), a for-profit subsidiary of Wolverine Power Cooperative that supplies electricity to Cherryland. Under the agreement, Spartan, who can take advantage of the tax credits, owns the panels and leases the collectors back to the SUN project. After six years, SUN will purchase the collectors from Spartan.

As a community solar program, Cherryland's battery storage system covers a community as a group. The utility combined a time-of-use rate structure with an innovative "virtual net metering" billing system, which has since proven effective. Virtual net metering is a billing system that groups a number of households, or even commercial and industrial facilities (figure 15). It allows net metering credits generated by a single renewable system to offset the load at multiple retail electric accounts

---

[149] Dave Konkle, "Michigan's First Community Solar Program: Solar Up North (SUN)," in *A Guidebook for Community Solar Programs in Michigan Communities*, February 2014. https://www.michigan.gov/documents/mdcd/Michigan_Community_Solar_Guidebook_437888_7.pdf

within a utility's service territory. Group net metering can occur with different structures. Three common examples are: (1) virtual net metering where a solar array is owned by multiple unaffiliated customers; (2) multiple, affiliated customers owning and operating a single generator whose output is netted against multiple billing accounts; and (3) a single customer with a single generator with the output netted against multiple billing meters, all on the same or adjacent premises. Michigan was not the first state to employ this billing method. There are currently 16 states with some form of group net metering provisions including Colorado, Delaware, Massachusetts, California, and Minnesota.

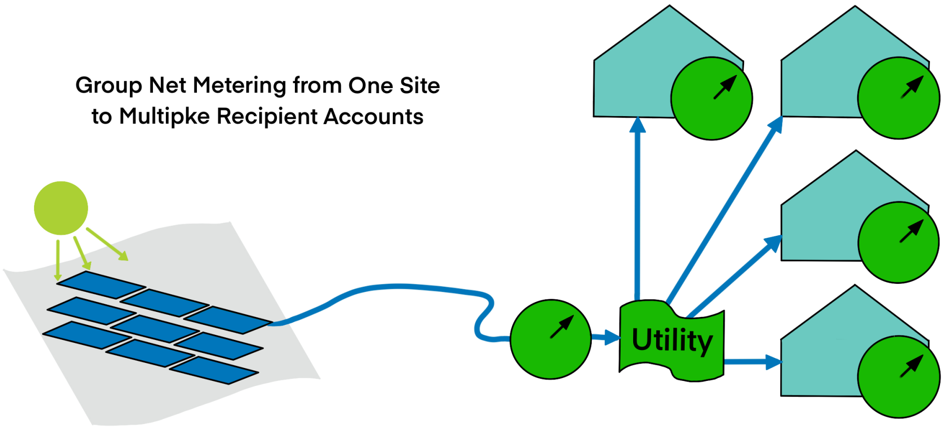


Figure 15. Virtual/Group Net-Metering
Source: Adapted from Michael, "Vermont Solar Savings Made Simple: Receive Net Metering Credits From A Group Net Metering Project," *Suntility Renewable Energy Services,* April 8, 2019. https://www.suntilityelectric.com/vermont-solar-savings-made-simple-receive-net-metering-credits-from-a-group-net-metering-project/

CONNEXUS

Connexus, an energy cooperative in Minnesota, put two solar plus storage projects into operation at the end of 2018. Connexus Energy is the largest member-owned utility in Minnesota, providing electricity to around 132,000 homes and businesses. The project came about as a result of increased member interest in expanding renewable energy while keeping electricity costs low. Ultimately, the project added ten megawatts of renewables to Connexus's energy portfolio along with a total of 15 megawatts of battery storage. The project is one of the first in the country to use batteries integrated with solar to meet peak demand. Both projects are 25 year power purchase agreements (PPAs) with ENGIE North America and NextEra Energy Resources. A subsidiary of NextEra Energy Resources will build, own, and operate the two battery energy storage facilities while ENGIE North America manages the solar equipment. The storage project will utilize advanced lithium-ion battery technology and will be fully integrated with the co-located solar facilities to provide solar energy time-shifting services. The National Renewables Cooperative Organization ran a Request for Proposals on behalf of Connexus and supported the development and structuring of the project. Connexus Energy consulted with a number of groups for advice and support including Fresh Energy and the University of Minnesota's Energy Transition Lab.[150] In addition to meeting peak demand, the project will also act as an example, similarly to ComEd's pilot projects in Illinois. According to Ellen Anderson, executive director of the University of Minnesota's Energy Transition Lab, the project "is going to be an extremely influential example" to show how "energy storage is an opportunity right now for utilities looking to combine customer benefits and cost savings and renewable energy goals" in Minnesota and the Midwest.[151]

Connexus, like Hoosier Energy, is a member owned cooperative. However, the setting for energy storage is much different in Minnesota than in Indiana. For example, Minnesota has state greenhouse gas reduction goals. Governor Pawlenty signed The Next Generation Energy Act in 2007 that requires the state to reduce greenhouse gas emissions by 80 percent by 2050. The Act also sets interim goals including a 15 percent reduction by 2015 and a 30 percent reduction by 2025.[152] As a result, in Minnesota, under an optimal set of future energy resource investments and operating

---

[150] Samantha Neral, "Connexus Energy's innovative solar-plus-storage project under construction," *Media Newsroom Connexus Energy,* August 7, 2018, https://www.connexusenergy.com/blog/2018/connexus-energys-innovative-solar-plus-storage-project-under-construction/

[151] Frank Jossi, "Minnesota co-op plans state's biggest energy storage project," *Energy News Network,* July 28, 2017, https://energynews.us/2017/07/28/midwest/minnesota-co-op-plans-states-biggest-energy-storage-project/

[152] Anne Claflin and Fawkes Steinwand, "Greenhouse gas emissions in Minnesota: 1990-2016," *Minnesota Pollution Control Agency,* ed. Ralph Pribble, January 2019, https://www.pca.state.mn.us/sites/default/files/lraq-2sy19.pdf

practices, the least-cost solutions included energy storage. Where these greenhouse gas reduction goals constrain emissions, fossil fuel resource additions were capped, and the ITC applied to storage projects, energy storage became a cost-effective resource in Minnesota by 2030. Even without the ITC, energy storage was still more cost-effective than other resource investments, though sometimes not until later. Regardless of the differences between Minnesota and Indiana, Connexus's project is relevant as one of the first cooperatives taking on solar plus storage. Connexus pushed the project after strategic planning highlighted a strong desire by coop members. They found that "members wanted [them] to do more renewables as long as it didn't adversely affect rates," leading the coop to look to add renewable energy without negative impacts.

INDIANAPOLIS POWER AND LIGHT COMPANY

The Indianapolis Power and Light Company (IPL) constructed a similarly sized lithium-ion battery array at their Harding Street Station to provide primary frequency response by instantaneously injecting and withdrawing energy. The storage project has a capacity of 29 megawatts and was completed in May of 2016. The project is the first storage system in the country to provide primary frequency response. By mitigating deviations from the nominal frequency for 60 Hertz, IPL prevents problems with process equipment, computers, lighting, and electric motors, and avoids potential brownouts or blackouts caused by power plant trip-offs.[153] This project illustrates a push in Indiana towards using storage as a solution.

---

[153] Claire Dalton, "IPL and AES leaders officially open first battery-based energy storage in MISO region," *Indianapolis Power and Light Company*, 2016, https://www.iplpower.com/About_IPL/Newsroom/News_archives/2016/IPL_and_AES_leaders_officially_open_first_battery-based_energy_storage_in_MISO_region/

NORTHERN INDIANA PUBLIC SERVICE COMPANY

The shift towards storage in Indiana is not isolated to IPL. In fact, Northern Indiana Public Service Company (NIPSCO), Indiana's largest natural gas distribution company and its second-largest power generator, made history in the state when it announced that it would retire its coal fleet to invest in renewables.[154] Currently, NIPSCO's portfolio is comprised primarily of coal, followed by natural gas-fired electric generation.[155] In response to an increasing demand for affordable, reliable, and sustainable energy, the company began a 'Your Energy, Your Future' initiative. As part of this initiative, NIPSCO aims to reduce emissions and focus on the long-term strength of the economy. In 2016, the company issued a request for proposals to move away from coal. NIPSCO found that the most cost-effective option was natural-gas generation. The company issued a similar request in 2018, and came to a markedly different conclusion.[156] Empowered by the low price of renewables, the company's latest IRP detailed an effort to generate 65% of power from renewables by 2028. To do this, NIPSCO plans to close all their coal facilities by 2028. Many of these coal facilities could have stayed open past 2035, but would have cost customers millions more than shifting to renewables according to the company. The youngest generating units at NIPSCO's 1900 megawatt Schahfer plant were built in the mid 1980s, and the utility's analysis found that keeping them on the system would cost more than replacing them with renewables.[157] They plan to replace these facilities with solar, solar plus storage, wind, demand side response, and purchases from the wholesale market. To prevent rising costs, NIPSCO modeled eight scenarios, ranging from a reduction to 65% coal by

---

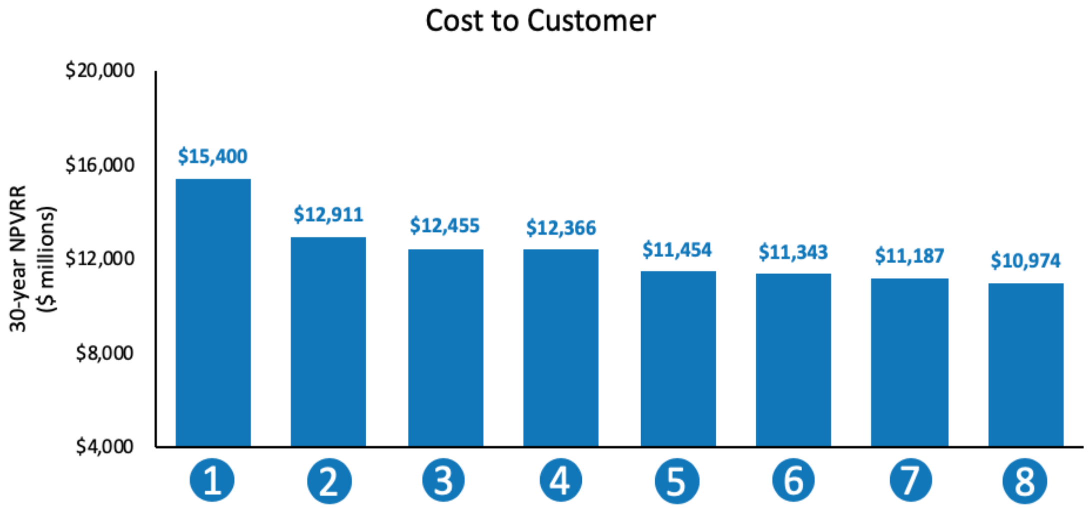
[154] Emily Hopkins and Sarah Bowman, "Indiana utilities are in midst of identity crisis as customers take power into own hands," *Indy Star*, May 20, 2019, https://www.indystar.com/story/news/environment/2019/05/20/how-indiana-utilities-no-longer-have-monopoly-energy-generation/3693882002/

[155] NIPSCO, "2018 Integrated Resource Plan Executive Summary," *Your Energy Your Future*, 2018, https://www.nipsco.com/docs/librariesprovider11/rates-and-tariffs/irp/irp-executive-summary.pdf

[156] Jeff McMahon, "In Conservative Indiana, Utility Chooses Renewables Over Gas as it Retires Coal Early," *Forbes,* July 2, 2019,https://www.forbes.com/sites/jeffmcmahon/2019/07/02/mike-pences-indiana-chooses-renewables-over-gas-as-it-retires-coal-early/#59fe9d1f43b4

[157] Gavin Bade, "Even in Indiana, New Renewables are cheaper than existing coal plants," *Utility Dive*, October 25, 2018, https://www.utilitydive.com/news/even-in-indiana-new-renewables-are-cheaper-than-existing-coal-plants/540242/

through 2035 to a complete elimination of coal by 2023 (figure 16). Of all the options, full elimination would actually be the cheapest option, but presented reliability risks to the utility. According to NIPSCO, keeping their Michigan City plant open will buttress the energy delivery system while the utility upgrades its grid and secures new wind and solar generation.[158] Therefore, NIPSCO chose a more moderate plan to reduce to 15 percent coal by 2023 as their preferred plan.



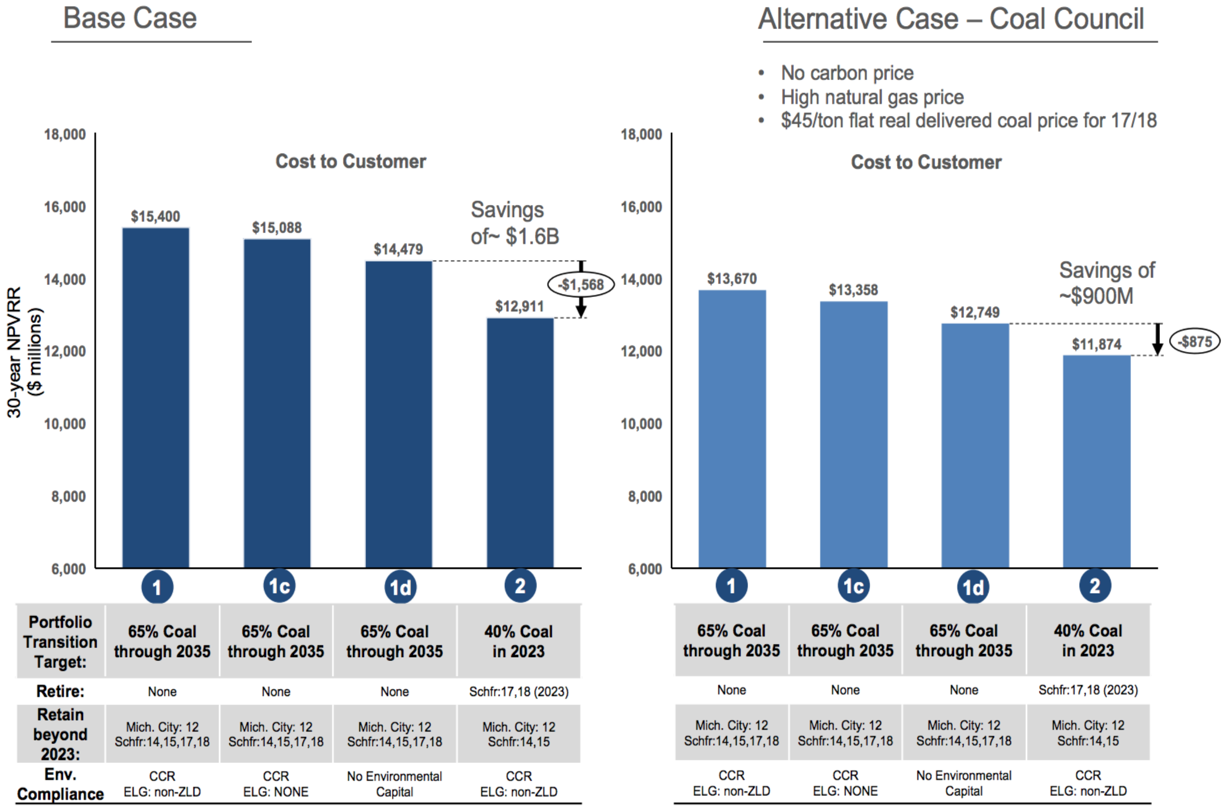
Portfolio Transition Target:	65% Coal through 2035	40% Coal in 2023	15% Coal in 2028 w/ ELG	15% Coal in 2028 w/o ELG	15% Coal in 2023 (MC 2035)	15% Coal in 2023 (MC 2028)	15% Coal in 2023 (17/18 2021)	0% in 2023
Retire:	None	Schfr: 17, 18 (2023)	Schfr: 17, 18 (2023) Schfr: 14, 15 (2028)	Schfr: 17, 18 (2023) Schfr: 14, 15 (2028)	Schfr: 17, 18 (2023) Schfr: 14, 15 (2023)	Mich. City: 12 (2028) Schfr: 17, 18 (2023) Schfr: 14, 15 (2023)	Mich. City: 12 (2028) Schfr: 17, 18 (2021) Schfr: 14, 15 (2023)	Mich. City: 12 (2023) Schfr: 17, 18 (2023) Schfr: 14, 15 (2023)
Retain beyond 2023:	Mich. City: 12 Schfr: 14, 15, 17, 18	Mich. City: 12 Schfr: 14, 15	Mich. City: 12 Schfr: 14, 15	Mich. City: 12 (2035) Schfr: 14, 15	Mich. City: 12 (2035)	Mich. City: 12 (2028)	Mich. City: 12 (2028)	None
Delta from Least Cost:	$4,426M 40%	$1,937M 18%	$1,481M 13%	$1,361M 12%	$479M 4%	$369M 3%	$213M 2%	$0M 0%

Figure 16. Graph adapted from a NIPSCO presentation representing the eight scenarios NIPSCO modeled ranging from 0% to 65% reliance on coal in the coming years with varying speeds of plant retirement.
Source: Gavin Bade, "Even in Indiana, New Renewables are cheaper than existing coal plants," *Utility Dive*, October 25, 2018, https://www.utilitydive.com/news/even-in-indiana-new-renewables-are-cheaper-than-existing-coal-plants/540242/

This plan would see the entire Schahfer plan retired in 2023, and the last of their coal units at its Michigan City plant shut down in 2028. Even when NIPSCO modeled scenarios friendly to coal, it was still unable to compete. The utility analyzed a scenario with high natural gas prices, no price on carbon, and a flat fee for delivered coal. In that scenario, retiring coal was still cheaper than maintaining the plants (figure 20).

---

[158] Jeff Brooks-Gillies, "Indiana NAACP leaders say coal plant timeline is unacceptable for residents," *Energy News Network*, February 7, 2019,https://energynews.us/2019/02/07/midwest/indiana-naacp-leaders-say-coal-plant-timeline-unacceptable-for-residents/



	1	1c	1d	2
Portfolio Transition Target:	65% Coal through 2035	65% Coal through 2035	65% Coal through 2035	40% Coal in 2023
Retire:	None	None	None	Schfr:17,18 (2023)
Retain beyond 2023:	Mich. City: 12 Schfr:14,15,17,18	Mich. City: 12 Schfr:14,15,17,18	Mich. City: 12 Schfr:14,15,17,18	Mich. City: 12 Schfr:14,15
Env. Compliance	CCR ELG: non-ZLD	CCR ELG: NONE	No Environmental Capital	CCR ELG: non-ZLD

1	1c	1d	2
65% Coal through 2035	65% Coal through 2035	65% Coal through 2035	40% Coal in 2023
None	None	None	Schfr:17,18 (2023)
Mich. City: 12 Schfr:14,15,17,18	Mich. City: 12 Schfr:14,15,17,18	Mich. City: 12 Schfr:14,15,17,18	Mich. City: 12 Schfr:14,15
CCR ELG: non-ZLD	CCR ELG: NONE	No Environmental Capital	CCR ELG: non-ZLD

Figure 17. Graph adapted from a NIPSCO presentation representing the eight scenarios NIPSCO modeled under two cases. These two cases represent the status quo and an alternative scenario with high natural gas pricing.
Source: Gavin Bade, "Even in Indiana, New Renewables are cheaper than existing coal plants," *Utility Dive*, October 25, 2018, https://www.utilitydive.com/news/even-in-indiana-new-renewables-are-cheaper-than-existing-coal-plants/540242/

In order to retire coal, NIPSCO plans to shift their capacity to 1500 megawatts of solar and storage, 150 megawatts of wind, 125 megawatts of efficiency and demand-side management, and 50 megawatts of market purchases by 2028 (figure 18).[159]

---

[159] Jeff Brooks-Gillies, "Indiana NAACP leaders say coal plant timeline is unacceptable for residents."

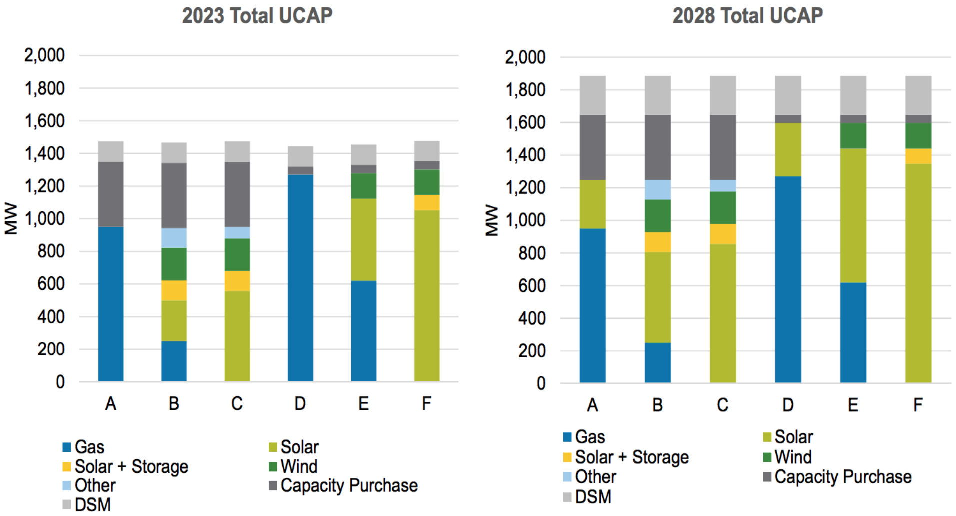


Figure 18. Graph adapted from a NIPSCO presentation representing NIPSCO's projected total unforced capacity in 2023 and 2028.

Source: Gavin Bade, "Even in Indiana, New Renewables are cheaper than existing coal plants," *Utility Dive*, October 25, 2018, https://www.utilitydive.com/news/even-in-indiana-new-renewables-are-cheaper-than-existing-coal-plants/540242/

On October 1, 2019, NIPSCO issued three Requests for Proposals; the first proposal seeks 2.3 GW of capacity from solar plus storage, the second pursues 300 megawatts of wind, and a third seeks other resources. NIPSCO will accept bids that are PPAs or asset purchase agreements.[160]

VECTREN

Another Indiana utility, Vectren, is currently working on a similar IRP, aiming to fulfill a projected capacity of 700 megawatts by the 2023/24 planning year. So far, 32 companies have submitted a note of intent, with the large majority proposing wind, solar, and storage projects (figure 19).[161]

---

[160] John Weaver, "Hoosiers shoot from deep for solar, storage and wind," *PV Magazine*, October 11, 2019, https://pv-magazine-usa.com/2019/10/11/hoosiers-shoot-from-deep-for-solar-storage-and-wind/

[161] John Weaver, "Indiana gas plant spurned – wind, solar and storage respond, "*PV Magazine,* August 29, 2019, https://pv-magazine-usa.com/2019/08/29/indiana-gas-plant-spurned-wind-solar-and-storage-respond/

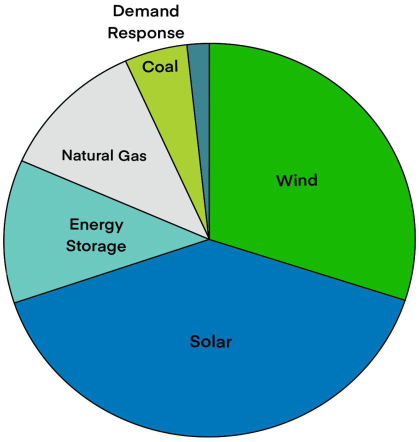


Figure 19. A breakdown of the Notices of Intent submitted to Vectren organized by energy type.
Source: Adapted from John Weaver, "Indiana gas plant spurned – wind, solar and storage respond," *PV Magazine,* August 29, 2019, https://pv-magazine-usa.com/2019/08/29/indiana-gas-plant-spurned-wind-solar-and-storage-respond/

ANALYSIS AND RESULTS

Considering the services storage can provide, developments from FERC, the technology landscape, relevant energy policy, and the case studies above, there are four main factors that will impact storage opportunities in the coming years. These factors are: technological innovation, renewable penetration, DER aggregation recognition, and energy policy. Two opposing scenarios are analyzed below for each factor.

FACTORS AND SCENARIOS

How these four main factors that will impact storage opportunities in the near term can be explored using a scenario approach. In this framing, the manner in which a factor unfolds or is implemented has a significant impact on the overall outcome. In each of the four factors found to be critical, how they evolved was conceptualized as one of two extremes. The scenarios are: 1) technological innovation can either be incremental or disruptive depending on price competitiveness of various technologies, 2) renewable energy penetration can be high or low, 3) DER aggregation can be recognized by MISO or not, and 4) energy policy can be stagnant or expanded. In reality, each of these factors influences, and is influenced by, the other three factors. Ultimately, the state of these four factors will determine the energy storage opportunities available to Hoosier Energy in the coming years. A summary of the four factors, their interactions, and their probability and importance follows.

TECHNOLOGICAL INNOVATION

INCREMENTAL TECHNOLOGICAL INNOVATION

In this scenario, progress on battery storage technologies progresses slowly and incrementally and does not reach commercial viability in the next ten years. Lithium-ion based batteries continue to see some price declines, but these are limited by the costs of rare earth metals that become increasingly scarce. Even in this case, lithium-ion batteries will still have a major impact on the electricity sector. The National Renewable Energy Laboratory projects that 4-hour lithium-ion systems will reduce by around 30% by 2050 even at their highest cost trajectory.[162]

DISRUPTIVE TECHNOLOGICAL INNOVATION

Emerging battery storage technologies and chemistries like lithium-metal, high temperature, and flow batteries achieve commercial viability around 2025. These technologies specialize in different applications, but in many cases are cheaper, more energy dense, can be charged quicker, and have more life cycles than lithium-ion technologies. These multiplying effects lead to a major expansion in the applications of battery technology including long-range EVs and grid connected energy storage. These economies of scale help drive down costs further.

---

[162] Wesley Cole & Will Frazier, “Cost Projections for Utility-Scale Battery Storage,” National Renewable Energy Laboratory.

RENEWABLE ENERGY PENETRATION

HIGH PENETRATION

Renewable energy penetration increases dramatically in the MISO region, primarily from new wind and solar installations. This is driven by a combination of technological development and declining prices for photovoltaic panels, which displaces fossil fuel generation. Ultimately, this propels renewable energy to the forefront of the energy transition. Studies suggest that penetrations of renewables of 40 percent and higher would necessitate more wide scale deployments of storage whereas lower penetrations could be accommodated by other, cheaper alternatives like energy efficiency (EE) or demand side management.[163] MISO's analysis suggests that the complexity of integrating renewable energy increases significantly between penetrations of 30 and 40 percent.[164]

Coupling storage with solar can lead to a lower LCOE than having a stand-alone battery storage project because of shared infrastructure such as inverters, site preparation, hardware sharing, and interconnections. Additionally, the cost of solar plus storage depends on the DC- or AC-coupled-configurations that will impact the cost of deployment.

LOW RENEWABLE PENETRATION

Renewable energy technology continues to improve, but only marginally. Relatively low natural gas prices and the absence of major climate action at the federal and state level results in the expansion of natural gas combined cycle and peaking plants that provide a growing amount of electricity generation in the United States.

---

[163] Martinot, Eric. "Grid Integration of Renewable Energy: Flexibility, Innovation, and Experience." *Annual Review of Environment and Resources* 41, no. 1 (2016): 223–51. https://doi.org/10.1146/annurev-environ-110615-085725.

[164] MISO "Renewable Integration Impact Assessment" (2018) https://cdn.misoenergy.org/20181128%20RIIA%20Workshop%20Presentation295441.pdf

DISTRIBUTED ENERGY RESOURCES AGGREGATION

DERs are smaller technologies generating or shifting power, often by a distributed customer rather than a centralized operator. Often these resources are BTM solar paired with storage. DERs have three main benefits: minimizing the effects of high renewable energy penetration, resiliency, and improved transmission and efficiency.[165]

In theory, if aggregation is recognized by MISO, then the grid can have a more efficient allocation of resources in the long run because more flexible options are available. In addition, with aggregation, Hoosier Energy can utilize innovative business models to share the benefit of DERs with its member-consumers, and mitigate the risks of grid defection. Without aggregation, Hoosier Energy can still develop energy storage at FTM level, but with higher risks of grid defection in the long run.

ENERGY POLICY

Energy policy could take the form of emission regulations such as direct regulation, carbon taxes, and/or permitting. Alternatively, energy policy could incentivize sustainable development through tax credits, subsidies, and/or grants. These mechanisms would ultimately encourage storage penetration and create new opportunities for utilities.

ENERGY POLICY EXPANSION

New energy policies are enacted to encourage renewable and storage penetration. New incentive policies are implemented to make projects more economically feasible and may even recognize storage specifically. Emission regulations at the federal or state level make natural gas and coal less competitive, ultimately making storage projects more economical.

---

[165] Krysti Shallenberger, "DER aggregation: Sector experts identify emerging trends in a nascent market," *Utility Drive,* July 24, 2017, https://www.utilitydive.com/news/der-aggregation-sector-experts-identify-emerging-trends-in-a-nascent-marke/447670/

ENERGY POLICY STAGNATION

Energy policies that currently exist remain in place, but do not expand significantly. No emissions regulations are put into place at the federal level or in Indiana. Current incentives such as the ITC stay in place, but no new incentive policies are put into place.

INTERACTIONS

The four factors considered in this assessment are highly dependent on one another (figure 20). Therefore, it is unlikely that any one factor will change independent of the other three. This section will explore the effects each factor will have on the others and the most important dependencies.

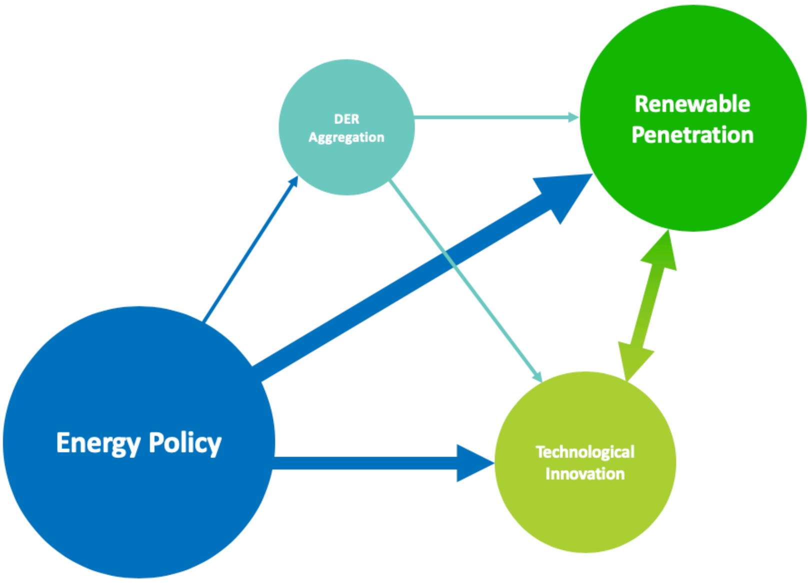


Figure 20. Interactions between the four factors are displayed with thicker arrows signifying a stronger potential impact. Larger circles display a larger overall potential to effect the other three factors. Note: a stronger potential impact does not necessarily imply a more likely impact. More information on the probability for each factor follows in the section *Probability* on page 90.

TECHNOLOGICAL INNOVATION

Technological innovation is most dependent on energy policy and renewable penetration, and somewhat dependent on DER aggregation. If renewable penetration increases, technological innovation would increase. As renewable energy becomes more popular, there will be a higher demand for energy storage, ultimately driving innovation. Therefore, renewable penetration will cause an increase in technological innovation. Energy policies would also encourage utilities and individual users to invest in renewables and storage, increasing demand and thereby innovation. Energy policies would first encourage renewable penetration, thereby encouraging technological innovation, making technological innovation most dependent on renewable penetration. Finally, DER aggregation recognition would increase the demand for energy storage, driving innovation. However, DER aggregation would cause the smallest immediate increase in demand, making technological innovation the least dependent on DER aggregation. Ultimately, any of these scenarios would lead to an increase in technological innovation.

RENEWABLE PENETRATION

Though the level of renewable penetration would respond to a change in the other factors, it will also likely increase independently. However, any large changes in the other factors would impact the level of renewable penetration. Energy policy would have the largest impact on renewable penetration, followed by technological innovation, and finally DER aggregation.

If energy policies are enacted, renewable penetration will increase dramatically. For example, a carbon tax or policy would encourage utilities to replace coal and natural gas with renewables. Similarly, incentives like tax credits and grants would increase penetration by making projects more economically feasible for utilities and users. If energy policies are not enacted, renewable penetration will still increase, just not as dramatically. The rate at which renewable penetration increases is dependent on the other three factors. Energy policies would have the most dramatic effect on renewable penetration, while technological innovation and DER aggregation recognition would increase renewable penetration less significantly.

If technology improves significantly to make storage more economically viable, renewable penetration will likely increase. If storage become more price competitive, many utilities would likely build renewable plus storage projects, increasing the penetration of renewable energy. On the other hand, if technology improves incrementally, renewable penetration will still likely increase, though at a slower rate. Though storage expands the opportunities for renewables, projects involving renewable energy are still extremely competitive on their own.

Finally, if DER aggregation is recognized, renewable penetration will increase. Small scale projects involving renewable energy plus storage would become more feasible for individual users and groups of users. If DER aggregation is not recognized, renewable penetration will likely still increase, though not as quickly.

DER AGGREGATION

DER aggregation is less dependent on the other factors. However, if renewable energy and DERs continue to grow, the probability for aggregation being recognized may increase slightly due to pressure from the industry and consumers who want to see their assets valued appropriately in the wholesale market. Whether or not DER aggregation is recognized will ultimately be determined by FERC and the RSO/ISOs.

ENERGY POLICY

Energy policies have the most potential to impact the other factors, but are unlikely to be significantly affected by the other factors. While renewable penetration and technological innovation would increase significantly in response to energy policies, it is unlikely that an increase in renewable penetration or technological innovation would lead to energy policies. Rather, it is more likely that low renewable penetration or technological innovation would lead policy makers to enact energy policies to counteract the negative consequences of high coal and natural gas use.

PROBABILITY

TECHNOLOGICAL INNOVATION

It is likely that technological innovation will slowly accelerate in the coming years. The National Renewable Energy Laboratory (NREL) estimated an average cost of $380/kWh (±$100/kWh) in 2018 for a 4-hour duration utility-scale lithium-ion battery system and estimated cost reductions of 10-52% by 2025, 21-67% by 2030, and 31-80% by 2050 (figure 21). These cost reductions would result in storage costs of between $124/kWh and $338/kWh in 2030 and between $76/kWh and $258/kWh in 2050.[166] Lazard estimated the installed cost of a solar plus storage project with 40 MW of solar and 20 MW of 4-hour lithium-ion battery storage to be between $390/kWh-$540/kWh. However, the rate of innovation is highly dependent on other factors, as discussed above.

---

[166] *National Renewable Energy Laboratory. Cost Projections for Utility-Scale Battery Storage. 2019.*

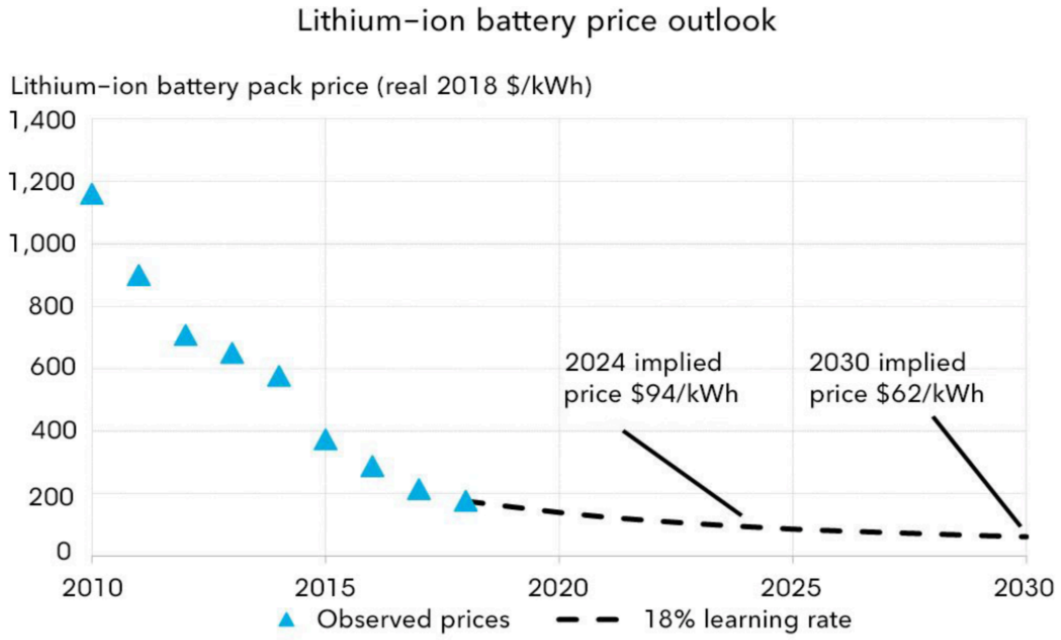


Figure 21. Lithium-ion battery pack price predictions through 2030.
Source: Logan Goldie-Scot, "A Behind the Scenes Take on Lithium-ion Battery Prices," *BloombergNEF* (March 5, 2019) https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

RENEWABLE PENETRATION

Renewable penetration will also likely increase in the coming years regardless of the other three factors. This increase will be driven by cost declines of renewable technology and decreasing coal competitiveness and power generation. The price of solar energy has dropped roughly 80 percent since 2009 according to the International Renewable Energy Agency (IRENA). They predict that prices will continue to drop, as much as 59% by 2025 due to different technology and market drivers.[167] In addition, U.S. Energy Information Administration (EIA) predicts U.S. coal production will decrease due to declining demand and related bankruptcies, ownership changes, and sudden mine closures. The EIA expect this production to decline further, by 11%, in 2020.[168] Due to these trends, the EIA predicts the renewable energy supply in the U.S., most notably wind and solar, will continue

---

[167] Ian Clover, "IRENA forecasts 59% solar PV price reduction by 2025," *PV Magazine*, June 15, 2016, https://www.pv-magazine.com/2016/06/15/irena-forecasts-59-solar-pv-price-reduction-by-2025_100024986/#ixzz4CJTSTOnm.

[168] U.S. Energy Information Administration, "Short-Term Energy Outlook," November 2019, https://www.eia.gov/outlooks/steo/pdf/steo_full.pdf

to grow in the coming years (figure 22). The EIA predicts prices of natural gas to increase in the future.

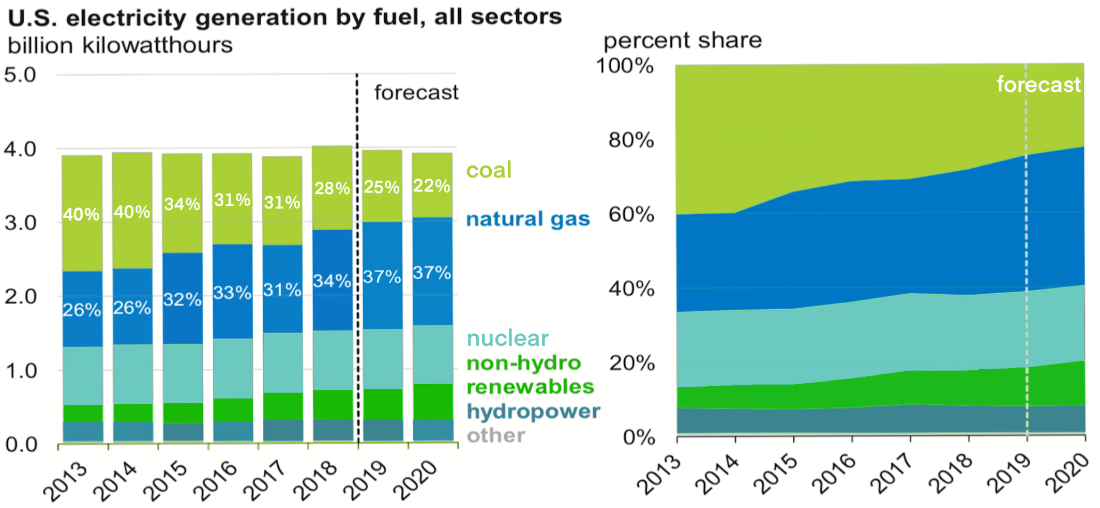


Figure 22. Labels show percentage share of total generation provided by coal and natural gas.
Source: Adapted from U.S. Energy Information Administration, "Short-Term Energy Outlook," October 2019, https://www.eia.gov/outlooks/steo/pdf/steo_full.pdf

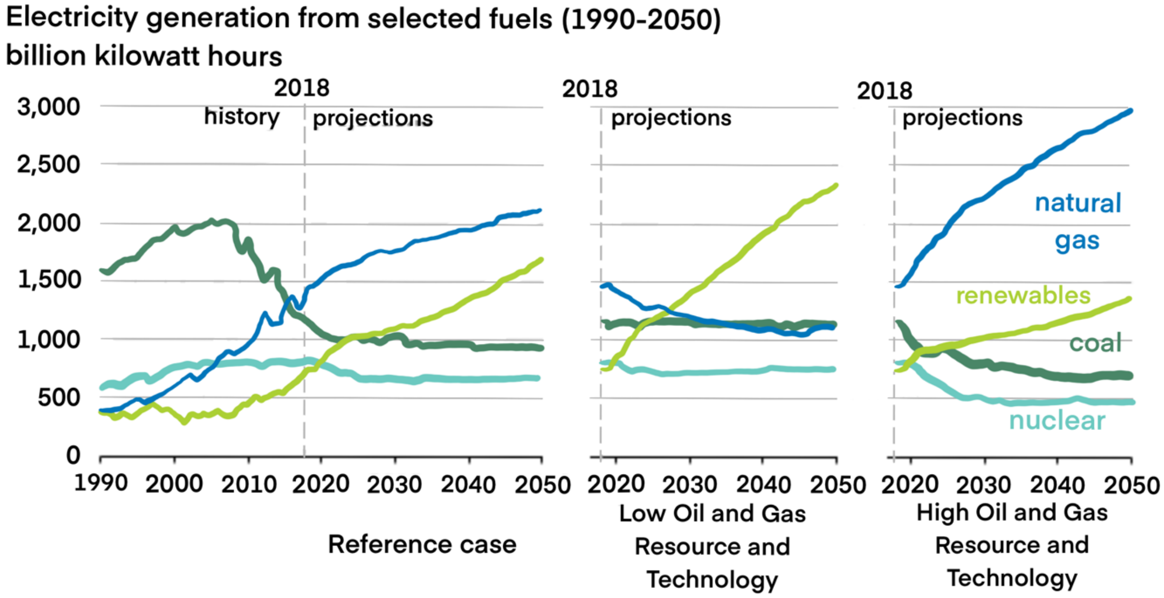


Figure 23. EIA renewable generation projections as a function of natural gas prices
Source: U.S. Energy Information Administration, "Annual Energy Outlook," January 2019, https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf

DER AGGREGATION

At this time, aggregation of energy storage resources is not recognized by MISO. Order No. 841 also does not address aggregation. Ultimately, a participation model will need to address how DERs can participate in wholesale power markets, with standard rules and protocols. At this point, there are a number of obstacles to aggregation. It is unlikely that aggregation will be recognized by MISO independently. However, FERC has voiced an intent to issue a future order relating to aggregation, and is closely monitoring CAISO's efforts to allow aggregated resources to participate in the market.

California is home to multiple aggregated DER projects. CAISO developed independent rules allowing aggregated resources to participate in the market. On June 2, FERC approved tariff revisions to allow aggregated DERs to participate in CAISO's energy and ancillary services markets. The tariff establishes a framework for the aggregation of DER's, allowing resources to meet the 0.5 MW requirement to participate in CAISO's wholesale markets. DER's are defined within the rule as "any resource connected to the distribution system, regardless of size or whether it is connected behind or in front of the end use customer meter."[169] FERC's approval is conditional on CAISO reporting their implementation efforts and conducting annual market performance reviews.

Up to this point, technology trends are moving faster than regulation surrounding DER aggregation, making utilities hesitant to invest in these resources. However, with CAISO pushing forward with aggregation, FERC has indicated an intent to put out another order specifically addressing regulation on aggregation. It is likely that aggregation will become a viable option within MISO in the coming years.

---

[169] Chris Vlahoplus and Paul Quinlan, "FERC Approves Aggregated DER in CAISO's Energy and Ancillary Markets," *Scott Madden*, August 2016, https://www.scottmadden.com/insight/ferc-approves-aggregated-der-caisos-energy-ancillary-markets/

ENERGY POLICY

A reformation to current federal energy policy has been recommended in both the United States House and Senate. The current ITC incentive is set to be phased out in the next three years, however, legislation has been introduced to extend the credit at current levels. This along with other legislation setting up further grants and loans programs, as well as the actions by state legislators across seventeen states, indicates that the issue is salient to lawmakers. The probability of major State legislative change incentivizing storage projects in Indiana beyond current programs in the short term, is low. However, the sheer volume of proposed legislation and programs at the federal level in recent years would indicate that attention is shifting towards this issue and that in the next thirty years we could see significant legislative action.

Table 9. An analysis of the four primary factors influencing the future of storage.

	Renewable Energy Penetration	**Technological Innovation**	**DER Aggregation**	**Energy Policies**
Promote Storage	🟩 High Penetration	🟦 Disruptive	🟦 Recognized*	⬜ Expansion
Inhibit Storage	⬜ Low Penetration	🟦 Incremental	🟦 Not Recognized	🟩 Stagnation

Key
🟩 Likely
🟦 Possible
⬜ Unlikely

* Probably in the long-term, but unlikely to have a significant impact in the next ten years.

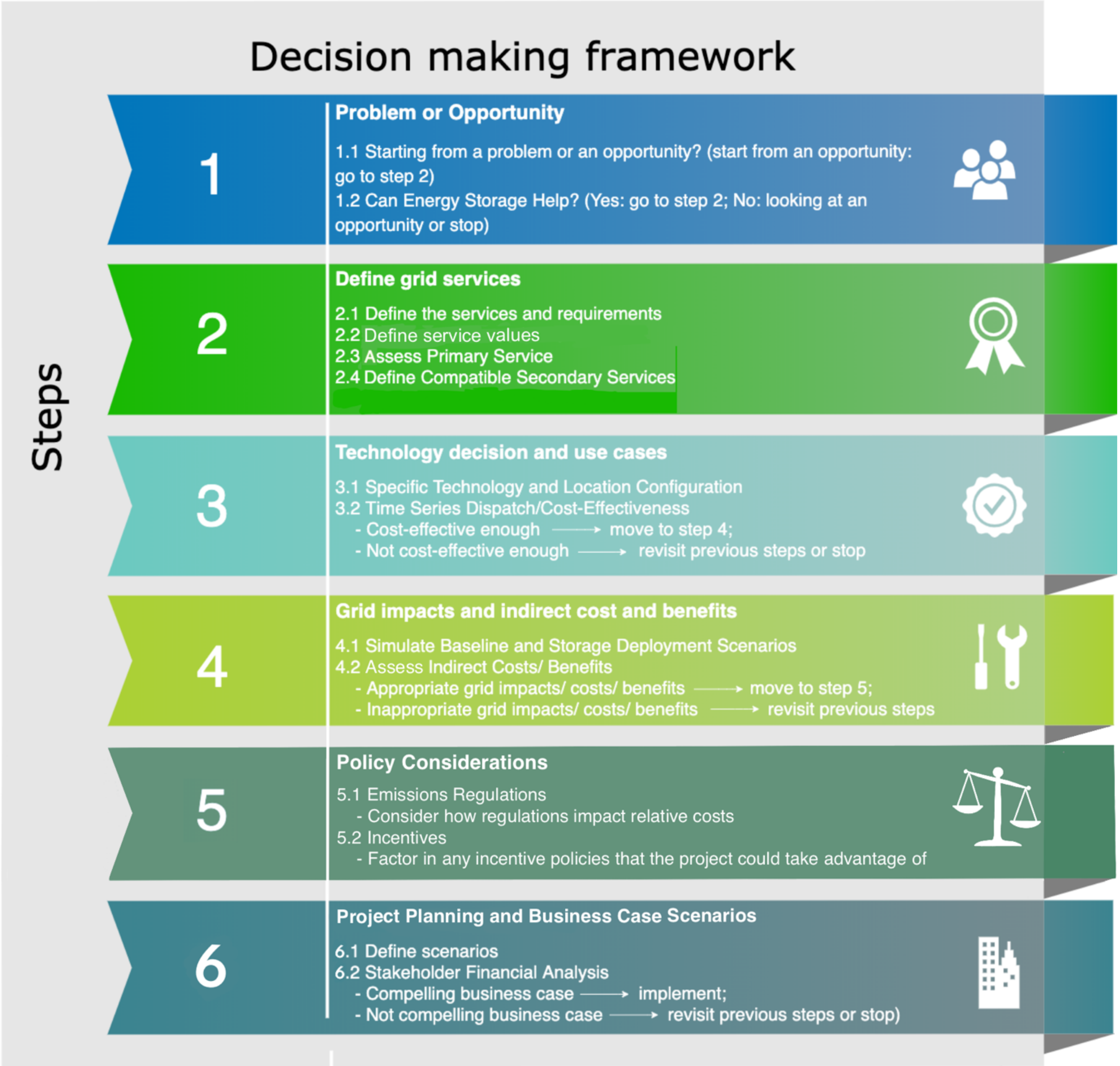
DECISION MAKING FRAMEWORK

Considering the probability of occurrence of the principal factors and as exemplified in the case studies, circumstances indicate that Hoosier Energy should begin considering the addition of energy storage assets to their portfolio. However, energy storage does not fit into the traditional framework of a generation asset. It can both give and take energy; it does not generate electricity itself, but can increase the capacity factor value of other generation assets; and can provide multiple grid services using the same facility. These dynamic characteristics make an energy storage project complicated, requiring a unique framework to appropriately propose a project and define its value.

In order to address this challenge, a decision making framework was conceptualized that aims to identify the most effective energy storage projects and uses a process that analyzes and narrows down the options available to consider in each step. The framework is shown in figure 24.[170] This framework follows a funnel structure, implementing more preliminary analyses at the beginning to filter out clearly infeasible projects, and executing the more resource-intensive analyses at the end to closely scrutinize feasible projects. In step one, energy storage is approached as either a solution to a problem, or an economic opportunity in and of itself. In step two, storage services are defined and prioritized. In step three, technologies are identified and compared. In step four, indirect costs and benefits are analyzed. In step five, relevant policies are incorporated. Finally, based on the results in step six, a detailed plan and associated business case is formulated.

---

[170] *Bulk Energy Storage Valuation and Impact Analysis: Proposed Methodology and Supporting Tools*. EPRI, Palo Alto, CA: 2012. 1024288; *DOE/EPRI Electricity Storage Handbook In Collaboration With NRECA*. 2016. Washington, D.C.: United States. Sandia National Laboratories.



Decision making framework

Steps

1

Problem or Opportunity

1.1 Starting from a problem or an opportunity? (start from an opportunity: go to step 2)
1.2 Can Energy Storage Help? (Yes: go to step 2; No: looking at an opportunity or stop)

2

Define grid services

2.1 Define the services and requirements
2.2 Define service values
2.3 Assess Primary Service
2.4 Define Compatible Secondary Services

3

Technology decision and use cases

3.1 Specific Technology and Location Configuration
3.2 Time Series Dispatch/Cost-Effectiveness
- Cost-effective enough → move to step 4;
- Not cost-effective enough → revisit previous steps or stop

4

Grid impacts and indirect cost and benefits

4.1 Simulate Baseline and Storage Deployment Scenarios
4.2 Assess Indirect Costs/ Benefits
- Appropriate grid impacts/ costs/ benefits → move to step 5;
- Inappropriate grid impacts/ costs/ benefits → revisit previous steps

5

Policy Considerations

5.1 Emissions Regulations
- Consider how regulations impact relative costs

5.2 Incentives
- Factor in any incentive policies that the project could take advantage of

6

Project Planning and Business Case Scenarios

6.1 Define scenarios
6.2 Stakeholder Financial Analysis
- Compelling business case → implement;
- Not compelling business case → revisit previous steps or stop)

Figure 24. Energy Storage Decision Making Framework
Source: Adapted from *DOE/EPRI Electricity Storage Handbook In Collaboration With NRECA*. (Washington, D.C: Sandia National Laboratories, 2016)

As this framework is utilized and refined, the process is expected to become more flexible and integrated with Hoosier Energy's dynamic needs. If Hoosier Energy decides to outsource energy storage development to external consultancies or developers, this framework can still be used to initially determine what factors or scenarios that Hoosier Energy wants to emphasize, and to more effectively evaluate those external entities' procedures, proposals, and plans.

This decision making framework incorporates the previously discussed four factors. Technological innovation and renewable penetration are incorporated into step three and four in determining which technologies are most viable and which alternatives are competitive. DER aggregation is incorporated into step three in determining use case configuration. The impacts of any enacted energy policy are considered in step five.

STEP 1: PROBLEM OR OPPORTUNITY

STARTING FROM A PROBLEM OR AN OPPORTUNITY?

An energy storage project can be approached as either a solution to a specific problem, or as an opportunity in and of itself. Using energy storage as a solution would address some existing or foreseeable grid operational or planning problem, which may stem from intermittent renewable generation, lack of generation capacity, the need to pursue more revenue, or transmission line congestion.

Pursuing an energy storage project as an opportunity aims to improve the grid as a whole without identifying a particular problem beforehand. This approach is desirable for Hoosier Energy since the cooperative currently lacks experience with energy storage. Exclusively waiting for a pressing problem might distract from valuable opportunities. Additionally, more risk is involved when using a storage project to solve a problem, since the project could fail. However, by gaining experience with a storage project before a problem arises, the utility has a better chance of creating a successful project to solve a problem later on. If pursuing an opportunity is chosen, see step 2 directly.

CAN ENERGY STORAGE HELP?

If a problem is identified and defined, the next question is if the problem can be technically solved by energy storage. The prohibitive factor could be economic or regulatory in nature, such as non-inclusive market design. Nevertheless, Hoosier Energy should rule out the possibility of energy storage at this step only when it is unquestionably unfeasible or inferior to an alternative. This prevents neglecting storage as an option prematurely.

STEP 2: DEFINE GRID SERVICES (WHAT MUST BE ACCOMPLISHED)

DEFINE THE SERVICES AND REQUIREMENTS

After conceptualizing a problem or opportunity, the next step is to define a list of potential services and their requirements (as outlined on page 15). The technical requirements should then be produced based on specific market rules. These may include requirements on capacity size or duration, referring to parameters mentioned in "MISO's ESR Participation Model" section at page 34. At this point, Hoosier Energy should communicate with their stakeholders to determine the appropriate metrics, the minimum operating requirements, and the best available alternate solution(s) to the problem.

DEFINE SERVICE VALUES

The value of an energy storage project can be calculated based on avoided cost (if it defers investment), or expected revenue, based on the services under investigation. An analysis of the value of the proposed project should be done with operationalized benefit descriptions rather than quantitative modelling results for each service. For example, if the interested service is transmission deferral, the value would be the avoided cost of a transmission line expressed in present value; if the service is energy arbitrage, then the value would be the price difference between charged and discharged electricity times kWh dispatched.

ASSESS PRIMARY SERVICE

An energy storage project can provide multiple services through value stacking. When stacking values, one service often is valued higher than the others. This higher valued service is then the primary service. The primary service usually provides 25-50 percent of value.[171]

Identifying the primary service is important due to the extra costs and operational constraints of adding secondary services. To provide more than one service, the storage system must satisfy multiple sets of minimum technical requirements, which adds increasing costs and gives decreasing marginal value with each additional service provided. For this, a developer should first pick a service from the ones defined in the previous steps that can deliver the most value as the primary service, and then consider adding more.

DEFINE COMPATIBLE SECONDARY SERVICES

After the primary service has been assessed, the next step is to define compatible secondary services by considering: joint satisfaction of minimum requirements, timing of service, and flexibility of additional services.

If an additional service can be added without significant incremental cost to satisfy additional technical requirements, there is joint satisfaction of minimum requirements. In terms of timing of service, different services' demand might have identical, overlapping, or non-overlapping timing, which creates different challenges for state of charge management depending on the services.

Due to frequency, duration, and term of commitment, some services are more flexible than others, making them more compatible secondary services. For example, if an energy storage facility is built to replace a distribution infrastructure upgrade, then it may be required to be frequently

---

[171] *Bulk Energy Storage Valuation and Impact Analysis: Proposed Methodology and Supporting Tools*. EPRI.

available. Comparatively, if the facility is built to provide capacity, it may be more flexible due to the availability of other resources that can provide capacity. Long term services, such as transmission and distribution deferral, or resource adequacy are less flexible compared to short term services, such as energy arbitrage and ancillary services.

Steps 1 and 2 allow the utility to draw a qualitative picture of one or more potential energy storage projects, and define the relevant sets of services, requirements, and benefits for each project. This lays the foundation for later more quantitative analyses.

STEP 3: TECHNOLOGY AND USE CASES (SERVICES, LOCATION, AND TECHNOLOGY)

After defining the services, values, and requirements of a potential project, step 3 moves to producing feasible use cases. A use case is a technically feasible combination of grid services at a particular location with particular technologies.

SPECIFIC TECHNOLOGY AND LOCATION CONFIGURATION

Formulating specific technology and location configurations is necessary to produce use cases for further analysis. Technology choices include lithium-ion battery, solar plus storage, EV, etc. (more on available technologies on page 42). Location choices involve not only geographical location, but also the distinction between FTM and BTM application. The latter one has much higher soft costs for permitting and interconnection, and requires market rules for aggregation of distributed resources for Hoosier Energy.

In addition, energy storage might not be the optimal option compared to alternatives, namely other energy demand management measures like EE or demand response. One of the main substitutes to storage technologies are EE projects. Many of the same benefits that storage can provide are also provided by EE. On the whole, EE solutions are hard to compare because the benefits and costs are site specific and have no uniform cost metrics (e.g. the cost of a single solar panel is considered a cost metric). Most projects must be solely considered with a project to project comparison. EE is often overlooked as a solution to optimizing energy resources, improving reliability, and producing a flexible grid.[172] EE projects are considered “low-hanging fruit” or the “first fuel” because they are generally cheaper than building more generation and may therefore be a more effective option than storage projects.[173] At this step, any storage project that would be clearly less effective and/or more expensive than alternatives should be eliminated.

TIME SERIES DISPATCH/COST-EFFECTIVENESS

After identifying the use cases (with different combinations of secondary services and technologies), the next step is to quantify the cost and benefit of each with time series modelling, using the service value description defined previously. For most cases, preliminary modelling should be sufficient to filter out clearly inferior or uneconomic use cases. However, certain use cases might need more sophisticated analysis, especially when the quantity of storage capacity is large compared to the overall demand for the service, causing the price to shift dynamically with the quantity of supply. If the use case is determined to be feasible, it should be analyzed further in step 4.

STEP 4: GRID IMPACTS AND INDIRECT COSTS AND BENEFITS (HOW STORAGE IMPACTS THE ENTIRE SYSTEM)

SIMULATE BASELINE AND STORAGE DEPLOYMENT SCENARIOS

After identifying possible use cases, step 4 involves more sophisticated modelling to determine system-wide cost, reliability, and external factors, including increased costs for member-

---

[172] "Solving Challenges In Energy Storage". 2019. Office of Technology Transition. https://www.energy.gov/sites/prod/files/2019/07/f64/2018-OTT-Energy-Storage-Spotlight.pdf.

[173] "Energy Efficient Prosperity: Low-Hanging Fruits". 2019. International Energy Agency. https://www.iea.org/newsroom/news/2016/october/energy-efficient-prosperity-low-hanging-fruits.html; "Capturing The Multiple Benefits Of Energy Efficiency". 2019. International Energy Agency. https://webstore.iea.org/capturing-the-multiple-benefits-of-energy-efficiency.

consumers, system flexibility, transmission asset utilization, generator operation and environmental impact. Through simulating scenarios with and without baseline storage deployments, this step creates a more holistic and accurate picture of use cases' impact on the grid and community.

ASSESS INDIRECT COSTS/BENEFITS

Indirect costs or benefits are those not directly from the operation of storage system, and should be considered separately. For example, for energy arbitrage, a storage system might store electricity generated by coal during off-peak times, decrease utilization of natural gas peaker plants, and increase carbon emissions, pollution, and other social costs. On the other hand, a storage project coupled with renewable energy could decrease carbon emissions, pollution, and other social costs. Environmental impact of this kind is distinct from pure financial costs and benefits.

Given that Hoosier Energy closely considers the perspectives of its member-consumers, non-financial, social considerations should be closely examined. Therefore, any analysis should include opinions from the member-consumers.

STEP 5: POLICY CONSIDERATIONS

At this step, policies that have the potential to impact the proposed project should be considered. These policies could be at the federal or state level. Energy policy could be in the form of incentives or emissions regulations. Emission regulations such as direct regulation, carbon taxes, and/or permitting would make alternative technologies like natural gas peaker plants less viable in comparison to energy storage. Alternatively, incentives like tax credits, subsidies, and/or grants could make an energy storage project more feasible.

EMISSION REGULATIONS

Any emission regulations could make an energy storage project more feasible in comparison to more traditional technologies. In the case of NIPSCO, the utility found that retiring coal plants became even more economical in scenarios where emissions regulations like carbon taxes were enacted. More information on emissions regulations is on page 59.

INCENTIVES

Incentive programs could make storage projects more economically feasible. Though Hoosier Energy may not be able to take advantage of these opportunities directly, a PPA with another utility would allow Hoosier Energy to indirectly take advantage of incentive policies. If incentive policies are implemented, Hoosier Energy should, at this point, consider partnering with another utility much like Connexus. More information on energy incentives can be found on page 61.

STEP 6: PROJECT PLANNING AND BUSINESS CASES SCENARIOS (HOW STORAGE CAN MONETIZE BENEFITS)

A business case is the refinement of a use case, which includes all relevant technological and policy consideration to create a specific financial analysis that can be implemented with a clear expectation of costs, risks, and rewards. In addition, it is important to distinguish “technical value” from “monetizable value,” so as to ensure financial return for different parties.

DEFINE SCENARIOS

To formulate business cases from use cases, scenarios should be defined to include all relevant factors and their interactions, including technological innovation, renewable energy penetration, DER aggregation recognition, and energy policy implementation. In addition, BTM projects will need more consideration on business model innovation, as mentioned in the cost shift and grid defection section on page 56. These scenarios will be used to present a more in-depth picture of the use cases, especially the most uncertain regulatory risks.

STAKEHOLDER FINANCIAL ANALYSIS

After defining the scenarios, a comprehensive stakeholder financial analysis should be used to review the use cases based on the scenarios. The analysis includes but is not limited to: dynamic regulations and subsidies, transaction costs, cost of capital, PPA opportunities, safety risks, acceptable level of risk, permitting, and insurance. Leaving these complex considerations to the final step avoids spending unnecessary time on a proposal that is not feasible. However, under certain circumstances, like if the grid impact is small, conducting step 3 and step 5 concurrently might be more practical and efficient. The final decision on whether to implement the project or not will be determined with this final business case including the detailed costs, risks, and rewards.

DISCUSSION

While the analysis in this report and the decision making framework touch on important factors relevant to energy storage, they have some limitations. One limitation is the lack of quantitative analysis. Without information on Hoosier Energy and its member customers’ load profiles, it is difficult to pinpoint where and when energy storage would have the most benefit. Without rigorous economic modeling, it is also not possible to quantitatively assess the impacts of technology cost declines and policy changes. Currently, the scenarios constructed in our analysis are anchored around four main factors: technological innovation, renewable energy penetration, DER aggregation, and energy policy. The scenarios within each factor are presented as a binary and do not fully take into account the complexities underlying them. Similarly, the likelihood of the scenarios was assessed based on current trends and have not been subjected to rigorous quantitative analysis. In addition, this analysis is not focused on the specific engineering specifications of relevant energy storage projects that may factor into a project's value.

The decision making framework provides a useful roadmap for planning and analysis, with a step by step process to evaluate a potential energy storage project. However, it does not include all useful considerations and analytical tools.

CONCLUSIONS

Based on the evaluation of background material, the identification of the four factors, and the assessed probability of occurrence and relative impact of each factor, the following conclusions were determined.

Technological innovation is projected to increase slightly, and even at the lowest levels, will have an impact on the market. Even if certain applications of energy storage are not found to be cost-effective immediately, there is significant value gained from direct experience with storage deployment and operation. This is especially important given that as solar and battery projects combined with demand control become more widely recognized, gas powered plants may become stranded assets.[174] By gaining an experience with smaller pilot projects, Hoosier Energy will be well placed to incorporate large-scale storage options in the future. Pilot projects should, therefore, be large enough to attract industry attention, contribute to price discovery, and provide meaningful operational experience.[175]

If the aggregation of DERs is allowed in the wholesale market, the following list shows the most promising technologies of BTM storage. For these technologies to be applied, Hoosier Energy

---

[174] "To have and to hold." (2019, Nov 30). *The Economist, 433*, 66-67. Retrieved from https://proxyiub.uits.iu.edu/login?qurl=https%3A%2F%2Fsearch.proquest.com%2Fdocview%2F2319662763%3Faccountid%3D11620

[175] Energy Transition Lab, *Modernizing Minnesota's Grid: An Economic analysis of Energy Storage Opportunities,* Energy Transition Lab. 45

would have to change their way of doing business by becoming an aggregator. The technologies are listed as follows, in order of importance:

1. Batteries: Highly modularized, can be installed relatively easily in most households or commercial buildings, with continuous cost reduction expected.
2. EVs: Difficult to manage as the demand of individual usage is often unpredictable. In addition, large fleets are needed to obtain capacity to participate in markets.

If the aggregation of DERs is recognized by the market rules, Hoosier Energy can utilize innovative business models to share the value of DERs. These non-exclusive strategies may include: innovative rate structuring, subsidizing DERs (possibly through the addition of a tariff on adopters' bills), aggregating DERs to participate in the wholesale market through a virtual power plant, developing and leasing DERs, or owning customer-sited systems (controlled by the utility).

As renewable penetration increases, projects pairing storage with solar will become more feasible. Pilot projects incorporating storage into current solar arrays could provide opportunities to educate members on the benefits of storage and display an interest in storage to state policy makers. This could, in turn increase support for storage across various stakeholders. Education programs should target commercial and industrial users to raise awareness of the long-term benefit of solar-battery projects.

Even though Indiana does not have enforced greenhouse gas reduction goals or energy storage mandates, there are renewable and storage investments in the state as demonstrated by IPL and NIPSCO initiatives. Hoosier Energy cannot take advantage of tax incentives, but it, like Connexus, can use PPAs where partner organizations are able to take advantage of these incentives and reduce the overall cost.

In addition, while considering energy storage, other demand-side management measures like energy efficiency and demand response should be considered together to optimize grid operation. Educational information on reducing demand charge should be provided to commercial and industrial users to encourage them to reduce peak load and release some burden on the grid.

In sum, when considering the four key factors, Hoosier Energy is well placed to begin considering energy storage projects. Technological innovation and renewable energy penetration is increasing, DER aggregation will likely be recognized in the coming years, and energy policy is becoming more popular. Even without DER aggregation currently recognized, there are some FTM opportunities that are currently cost effective, especially when taking advantage of PPA's that can benefit from tax credit programs.

RECOMMENDATIONS

Considering the changing state of affairs in the world of energy storage in general, along with the general conclusions that were based on this assessment, the following recommendations are offered to Hoosier Energy for their consideration that may benefit the company and their members:

1) As Hoosier Energy turns its attention to energy storage, the best attitude is to be open-minded, vigilant, and focus on value in the long term. Be open-minded to seize opportunities of innovative technical solutions and business models without locking-in suboptimal practices and assets. Be vigilant so that the uncertainties surrounding technology, markets, and regulation can be fully accounted for. Focus on the long term, because even though energy storage today may not be the most promising option, it has great potential to be unlocked by technology cost reduction and regulatory inclusion.

2) In planning for the future, Hoosier Energy should first consider the status of the four key factors (technological innovation, renewable energy penetration, DER aggregation, and energy policy). While prices are falling, they are not currently low enough to make energy storage the most cost-effective option in every circumstance. If prices continue to fall, it is likely that storage will become the most cost-effective option in the near future. Similarly, renewable energy penetration will likely continue to increase in the coming years, making projects coupling solar and storage more feasible. FERC will likely rule on DER aggregation in the coming years, forcing MISO to recognize aggregation. However, it is unclear when this will happen, and FERC will likely wait until the RTO/ISOs have fully complied with Order 841 before they issue another order regarding energy storage. The enactment of energy policy is similarly difficult to predict. Though incentive programs like tax credits will likely be extended, stronger energy policy like carbon taxes or regulation is unlikely in the short-term. However, the sheer number of bills regarding emissions reductions shows a clear interest in the subject. Therefore, it is likely that energy policy will become more relevant in the long-term.
3) After considering the status of the four factors, Hoosier Energy should then consider the case studies of energy storage projects outlined above along with other relevant storage projects that are either planned or in operation. These projects can offer important guidance for Hoosier Energy moving forward. For example, current incentive programs can make storage a more attractive option for private developers in the near term through tax credits, allowing Hoosier Energy to take advantage of storage assets through PPAs much like Connexus. Potential proposed grant and loan programs could make production of a pilot project feasible in the long term if coupled with falling costs of technology. Further, in all of the case studies above, storage was used to solve various

problems including increased capacity needs, resiliency issues, and peak demand. However, another major aim of these projects was to increase awareness of the benefits of energy storage and encourage decision-makers to be proactive when considering the future of energy.

4) Based on what can be observed in the various case studies, Hoosier Energy should consider developing a project through the decision making framework outlined above. Ultimately, Hoosier Energy should partner with a private company to build a solar plus storage pilot project that can be used to educate member customers on the benefits of storage and give the utility the experience necessary to consider storage on a larger scale in the future.

BIBLIOGRAPHY

Bade, Gavin. “Even in Indiana, New Renewables are cheaper than existing coal plants,” Utility Dive, October 25, 2018. https://www.utilitydive.com/news/even-in-indiana-new-renewables-are-cheaper-than-existing-coal-plants/540242/

Brooks-Gillies, Jeff. “Indiana NAACP leaders say coal plant timeline is unacceptable for residents,” Energy News Network, February 7, 2019. https://energynews.us/2019/02/07/midwest/indiana-naacp-leaders-say-coal-plant-timeline-unacceptable-for-residents/

Bulk Energy Storage Valuation and Impact Analysis: Proposed Methodology and Supporting Tools. EPRI, Palo Alto, CA: 2012. 1024288.

California Public Utilities Commission. *Self-Generation Incentive Program Handbook 2019*.

Center for Sustainable Systems, University of Michigan. 2019. "U.S. Energy Storage Factsheet." Pub. No. CSS15-17. http://css.umich.edu/sites/default/files/U.S._Grid_Energy_Storage_Factsheet_CSS15-17_e2018.pdf

Claflin, Anne and Steinwand, Fawkes. “Greenhouse gas emissions in Minnesota: 1990-2016,” Minnesota Pollution Control Agency, ed. Ralph Pribble, January 2019. https://www.pca.state.mn.us/sites/default/files/lraq-2sy19.pdf

Clifford Power, “Peak Shaving with Generators” *Case Studies*, May 24, 2018, http://www.cliffordpower.com/peak-shaving-with-generators-1

Clover, Ian. “IRENA forecasts 59% solar PV price reduction by 2025,” PV Magazine, June 15, 2016, https://www.pv-magazine.com/2016/06/15/irena-forecasts-59-solar-pv-price-reduction-by-2025_100024986/

Coates, Bob. “Rural Energy,” United States Department of Agriculture, http://energyoutlook.naseo.org/data/energymeetings/presentations/Coates--USDA.pdf

Cole, Wesley, and A. Will Frazier. 2019. Cost Projections for Utility-Scale Battery Storage. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-73222. https://www.nrel.gov/docs/fy19osti/73222.pdf.

Commonwealth of Massachusetts. *Energy Storage Initiative.* 2019.

Commonwealth of Massachusetts. *ESI Demonstration Program Advancing Commonwealth Energy Storage (ESI ACES).* 2019.

Connor Ryan, *Dominion Energy Announces Energy Storage Pilot Projects in Virginia*. Energy Storage News. August 9th 2019. https://www.energy-storage.news/news/dominion-energy-announces-energy-storage-pilot-projects-in-virginia

Dalton, Claire. “IPL and AES leaders officially open first battery-based energy storage in MISO region,” Indiana Power and Light Company, 2016. https://www.iplpower.com/About_IPL/Newsroom/News_archives/2016/IPL_and_AES_leaders_officially_open_first_battery-based_energy_storage_in_MISO_region/

David Frankel, Sean Kane, and Christer Tryggestad, “The new rules of competition in energy storage”, McKinsey & Company. 2018

Deloitte. 2018. “Supercharged: Challenges and Opportunities in Global Battery Storage Markets.”

Department of Energy Office of Energy Efficiency and Renewable Energy. *Residential and Commercial ITC Factsheets*. 2019.

DOE/EPRI Electricity Storage Handbook In Collaboration With NRECA. 2016. Washington, D.C.: United States. Sandia National Laboratories.

Environmental and Energy Study Institute, “Rural Energy Savings Program,” *Environmental and Energy Study Institute,* https://www.eesi.org/Rural-Energy-Savings-Program

Federal Energy Regulatory Commission. *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators Docket No. RM16-23-000.* 2018

Forsberg, Lindsey. “Market Rules in Transition: Energy Storage Value and the U.S. Electric Grid.” Master of Science in Science, Technology, and Environmental Policy, University of Minnesota, 2019.

Fitzgerald, Garret; Mandel, James; Morris, Jesse; and Touati, Hervé. “The Economics of Battery Energy Storage,” *Rocky Mountain Institute* (2015) https://rmi.org/insight/economics-battery-energy-storage/

Fu, Ran, Timothy Remo, and Robert Margolis. 2018. “U.S. Utility-Scale Photovoltaics- Plus-Energy Storage System Costs Benchmark.” *National Renewable Energy Laboratory*. https://www.nrel.gov/docs/fy19osti/71714.pdf.%0Ahttps://www.nrel.gov/docs/fy19osti/71714.pdf.

General Assembly of Pennsylvania. *House Bill No. 1412 Session 2017*.

Logan Goldie-Scot, “A Behind the Scenes Take on Lithium-ion Battery Prices,” *BloombergNEF* (March 5, 2019) https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

Government Accountability Office, *Energy Storage Information and Challenges to Deployment for Electric Grid Operations and Efforts to Address Them*. 2018.

Hawaii State Legislature. *SB665 SD2 HD1:Relating to Renewable Energy.* 2018.

Homer Energy, “Operating Reserve,” *Glossary of Terms*. (2018) https://www.homerenergy.com/products/pro/docs/latest/glossary.html

Hoosier Energy. "About". 2019. https://hoosierenergy.com/about/.

Hopkins, Emily and Bowman, Sarah. “Indiana utilities are in midst of identity crisis as customers take power into own hands,” Indy Star, May 20, 2019. https://www.indystar.com/story/news/environment/2019/05/20/how-indiana-utilities-no-longer-have-monopoly-energy-generation/3693882002/

Indiana General Assembly. *IC 8-1-37: Voluntary Clean Energy portfolio Standard Program.* 2019.

International Energy Agency. "Capturing The Multiple Benefits Of Energy Efficiency". 2019. https://webstore.iea.org/capturing-the-multiple-benefits-of-energy-efficiency.

International Energy Agency. "Energy Efficient Prosperity: Low-Hanging Fruits". 2019. https://www.iea.org/ newsroom/news/2016/october/energy-efficient-prosperity-low-hanging-fruits.html.

Jossi, Frank. "Minnesota co-op plans state's biggest energy storage project," Energy News Network, July 28, 2017. https://energynews.us/2017/07/28/midwest/minnesota-co-op-plans-states-biggest-energy-storage-project/

Konkle, Dave. "Michigan's First Community Solar Program: Solar Up North (SUN)," in *A Guidebook for Community Solar Programs in Michigan Communities*, February 2014. https://www.michigan.gov /documents/mdcd/Michigan_Community_Solar_Guidebook_437888_7.pdf

Lazard "Lazard's Levelized Cost of Storage Analysis - Version 4.0," 2018. https://static1.squarespace.com/ static/58648612e3df28f032aa8bdd/t/5be598dd8a922da66745f81/1541773535709/lazards-levelized-cost-of-storage-version-40-vfinal-enovation.pdf.

Lazard, "Levelized Cost of Storage Analysis 5.0," 2019. https://www.lazard.com/media/451087/lazards-levelized-cost-of-storage-version-50-vf.pdf

Maryland Energy Administration. *Maryland Energy Storage Income Tax Credit- Tax Year 2019*.

McMahon, Jeff. "In Conservative Indiana, Utility Chooses Renewables Over Gas as it Retires Coal Early," Forbes, July 2, 2019. https://www.forbes.com/sites/jeffmcmahon/2019/07/02/mike-pences-indiana -chooses-renewables-over-gas-as-it-retires-coal-early/#59fe9d1f43b4

Michael, "Vermont Solar Savings Made Simple: Receive Net Metering Credits From A Group Net Metering Project," *Suntility Renewable Energy Services,* April 8, 2019. https://www.suntilityelectric.com/ vermont-solar-savings-made-simple-receive-net-metering-credits-from-a-group-net-metering-project/

Midcontinent Independent System Operator. *Midcontinent Interdependent System Operator, Inc.'s Filing to Revise Tariff as Necessary in Compliance with Order No.841 Docket No. ER19-465-000.* 2018

National Research Council. "Designing, Implementing, and Evaluating Climate Policies." In *Advancing the Science of Climate Change*, 401-420.Washington, DC: The National Academies Press, 2010.

National Rural Utilities Cooperative Finance Corporation. 2019. "Business & Technology Report Battery Energy Storage Overview." https://www.cooperative.com/programs-services/bts/Documents/Reports/Battery-Energy-Storage-Overview-Report-Update-April-2019.pdf.

Neral, Samantha. "Connexus Energy's innovative solar-plus-storage project under construction," Media Newsroom Connexus Energy, August 7, 2018. https://www.connexusenergy.com/blog/2018/connexus-energys-innovative-solar-plus-storage-project-under-construction/

New Jersey Board of Public Utilities. *New Jersey's Clean Energy Program: Renewable Electric Storage 2019*.

New York State Senate, *Assembly Bill A6235: Establishes a Tax Credit for the Purchase and Installation of New Residential Energy Storage Systems*. 2017-2018 Legislative Session.

NIPSCO. “2018 Integrated Resource Plan Executive Summary,” Your Energy Your Future, 2018, https://www.nipsco.com/docs/librariesprovider11/rates-and-tariffs/irp/irp-executive-summary.pdf

Office of the Secretary of Commerce and Trade Department of Mines, Minerals and Energy. *The Common Wealth of Virginia’s 2018 Energy Plan.*

Office of Technology Transition. "Solving Challenges In Energy Storage". 2019. https://www.energy.gov/sites/prod/files/2019/07/f64/2018-OTT-Energy-Storage-Spotlight.pdf.

Rocky Mountain Institute. The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. 2015.

Rocky Mountain Institute. Breakthrough Batteries: Powering the Era of Clean Electrification. 2019.

Salt River Project. *Reserve Your Battery Storage Incentive*. 2019. https://www.srpnet.com/electric/home/batterystorage/default.aspx

Shallenberger, Krysti. “DER aggregation: Sector experts identify emerging trends in a nascent market,” Utility Drive, July 24, 2017. https://www.utilitydive.com/news/der-aggregation-sector-experts-identify-emerging-trends-in-a-nascent-marke/447670/

Smith, Glenn. “Enabling Electric Storage Participation in Wholesale Markets: An Analysis of FERC Order No. 841.” Master of Science in Energy Systems Management, University of San Francisco, 2019.

South Carolina General Assembly 122nd Session. *S. 44: Property Tax Exemptions.* 2017-2018.

Thill, David. “In Illinois, storage is among the next hurdles for renewables expansion,” Renewable Energy World, May 3, 2019. https://www.renewableenergyworld.com/2019/05/03/in-illinois-storage-is-among-the-next-hurdles-for-renewables-expansion/#gref

U.S. Department of Energy. 2018. “Considerations for Implementing PV plus Storage Systems at Federal Buildings and Campuses.” https://www.nrel.gov/docs/fy18osti/70679.pdf.

U.S. Energy Information Administration. “Short-Term Energy Outlook,” November 2019, https://www.eia.gov/outlooks/steo/pdf/steo_full.pdf

Vlahoplus, Chris and Quinlan, Paul. “FERC Approves Aggregated DER in CAISO’s Energy and Ancillary Markets,” Scott Madden, August 2016. https://www.scottmadden.com/insight/ferc-approves-aggregated-der-caisos-energy-ancillary-markets/

Walsh, Jason and Cross, John-Michael. “Rural Energy Savings Program,” Environmental and Energy Study Institute, https://www.eesi.org/files/RESP_Overview_June_2018.pdf.

Weaver, John. “Hoosiers shoot from deep for solar, storage and wind,” PV Magazine, October 11, 2019. https://pv-magazine-usa.com/2019/10/11/hoosiers-shoot-from-deep-for-solar-storage-and-wind/

Weaver, John. “Indiana gas plant spurned – wind, solar and storage respond,”PV Magazine, August 29, 2019. https://pv-magazine-usa.com/2019/08/29/indiana-gas-plant-spurned-wind-solar-and-storage-respond