

**APPENDIX F7 – MINNESOTA ENERGY STORAGE SYSTEMS
ASSESSMENT****I. INTRODUCTION**

In the 2019 legislative session in Minnesota, there was legislation passed as a part of the jobs, economic development, energy, and commerce omnibus bill amending Minnesota Statutes 2018, section 216B.2422 to require utilities to include an assessment of energy storage systems in their resource plan filing. The full text of the legislation is included below:

Subd. 7. **Energy storage systems assessment.**(a) Each public utility required to file a resource plan under subdivision 2 must include in the filing an assessment of energy storage systems that analyzes how the deployment of energy storage systems contributes to:

- (1) meeting identified generation and capacity needs; and
- (2) evaluating ancillary services.

(b) The assessment must employ appropriate modeling methods to enable the analysis required in paragraph (a).

EFFECTIVE DATE. This section is effective the day following final enactment.

In this Appendix, we include background on Xcel Energy's growing experience with energy storage technologies, a narrative on the values that storage can provide to the system, some of the shortcomings of current storage technologies, and how we analyzed energy storage as a part of this Resource Plan.

Xcel Energy's long-term carbon strategy depends on the deployment of advanced clean technologies. We expect grid-scale energy storage to play an important role in our long-term plans. While we do not anticipate significant reliance on battery storage resources in this plan for the Upper Midwest in the near term, we are piloting storage technology across our system to test the capabilities, and will look for opportunities for more aggressive deployment of these resources in the future as we have generation capacity needs.

As discussed in more detail below, grid-scale storage can help integrate increasing levels of renewable resources. Storage can also provide other system benefits, including more reliable grid operations, voltage support, and frequency control. Utilities are already taking advantage of many different values of grid-scale storage. In fact, utilities are the leading developers of storage technology in the nation. As grid owners and operators, utilities are uniquely situated to maximize the potential benefits of storage. As detailed further in this Appendix, Xcel Energy has a number of advanced storage projects already deployed on our system and a growing interest in using storage in the future.

At the same time, we recognize that storage today has limitations. We discuss here three significant challenges for storage: First, storage cannot today solve the problem of the wide seasonal variation in renewable energy generation, which is the chief factor preventing the creation of fully renewable electricity system. Second, while storage can initially help integrate renewables by moving energy from the time it is produced to when it is needed, the value of each additional increment of storage capacity declines as more is added to the system. Finally, although storage can provide multiple services to the grid – power quality and grid support, for example – the value of all of these services are not all additive (or “stackable”). As a general rule, these services are not all available at the same time. Despite these limitations, we are bullish on the potential of storage as a part of our electricity system.

II. XCEL ENERGY’S ENERGY STORAGE EXPERIENCE

Electricity storage devices include a variety of technologies that store electrical energy directly (e.g. capacitors) or, more typically, after converting to some other form of potential or kinetic energy. For example, pumped hydro storage facilities use electrical energy to pump water to a higher elevation and store that water as gravitational potential energy; flywheels use electrical energy to rotate a mass to high velocities and thus store energy as kinetic energy; compressed air projects store energy in a geologic formation as pressurized potential energy; and batteries use electrical energy to drive chemical reactions and then store that energy as chemical potential energy. As no energy conversion process occurs without inefficiencies or losses, any energy storage system will discharge a lesser amount of energy than used to charge the device. If deployed properly, energy storage can help enable a smarter, stronger, cleaner and more reliable grid.

Xcel Energy has long been a leader in deploying energy storage. We have operated pumped hydro energy storage on our system for decades and have adapted its operation to meet our evolving system. Today, we are implementing pilots and other programs exploring new storage technologies that will play a role in our energy future.

A. Cabin Creek Pumped Storage

Historically, pumped storage hydro has been the dominant source of energy storage – even today, nearly 92 percent of operational storage in the US is pumped storage. Our largest energy storage asset is the 324 MW Cabin Creek pumped hydroelectric storage facility in Colorado. The Cabin Creek facility was built in 1967. Like all pumped storage facilities, it has an upper and a lower reservoir. When economic, we pump water from the lower to the upper reservoir. When the system has additional

energy needs, we allow the water to “spill” out of the upper reservoir to the lower through a hydro turbine to generate electricity. Originally, the facility was used to transfer excess energy from off-peak hours to on-peak hours, but today it is also used for renewable energy integration. We spill water to meet customer demand when the wind stops blowing and pump water to the upper reservoir during times when the wind energy generated on our system exceeds customer demands.

B. Luverne MinnWind Storage Project

The Luverne wind-to-battery project in Minnesota was one of the first battery storage pilot projects the Company pursued and the first U.S.-based pairing of wind energy and a storage battery. The pilot was intended to test the various ways batteries could be used to provide wind integration and regulation services supporting the energy grid. The 1 MW, 7 MWh sodium sulfur battery paired with an 11 MW wind project has been in-service since 2009, and was recently updated by the manufacturer with new grounding technology and cells, extending the life of the battery and allowing us to test new battery applications. It was funded in part by a \$1 million grant from Minnesota’s Renewable Development Fund.¹

C. SolarTAC

We are the original founding member, host utility and a development partner at the Solar Technology Acceleration Center (SolarTAC), an outdoor solar testing facility located in Aurora, Colorado.² Together, the solar industry and utilities work at SolarTAC to test, validate and demonstrate advanced solar technologies under actual field conditions. We worked with our SolarTAC partners to test two different battery storage projects.

- A community energy storage project at SolarTAC is testing a more cost-effective way to improve the integration of solar power in areas with high solar production. Working with the Electric Power Research Institute (EPRI), we are testing a 25-kilowatt battery integrated with four small photovoltaic installations that simulate a neighborhood with multiple rooftop solar power systems.
- Through our Solar2Battery project, we installed a 1.5 MW battery to evaluate how energy storage can help in operating the electricity grid with energy from large-scale solar facilities.

¹ Xcel Energy Wind-to-Battery Project:

<https://www.xcelenergy.com/staticfiles/xcel/Corporate/Environment/wind-to-battery%20fact%20sheet.pdf>

² Solar Technology Acceleration Center: <http://www.solartac.org/>

These projects have increased our knowledge of how batteries respond to intermittent solar generation, how battery chemistries perform over time, and how energy storage systems can create value for our system.

D. Innovative Clean Technologies Program

The Colorado Public Utilities Commission has approved an Innovative Clean Technologies (ICT) program to test emerging technologies that are designed to lower carbon emissions associated with electricity service. We currently have two battery storage demonstration projects operating under the ICT program:

- **Stapleton Community Energy Storage Project:** As demand for solar energy at our customers' homes and businesses increases, we are examining how battery storage can help integrate higher concentrations of customer solar energy on our system. Through a project in Denver's Stapleton neighborhood, Xcel Energy installed six customer batteries and six larger grid batteries to test rooftop solar integration and grid support capabilities.³
- **Panasonic Battery Demonstration Project:** Through a public-private partnership, Xcel Energy, Panasonic and Denver International Airport are collaborating to test a battery storage system that can both serve as a microgrid to provide backup power to Panasonic's Denver headquarters and support Xcel Energy's grid at other times. As part of the project, Xcel Energy owns a 1.3 MW solar carport installation and a 1 MW/2MWh lithium ion battery. Panasonic also owns a 0.20 MW solar array located atop its building, which is also tied into the system.⁴

E. Fort McCoy Solar plus Battery Microgrid Partnership Project

We are partnering with Fort McCoy, a U.S. Army installation in Wisconsin, to develop a solar-plus-storage microgrid demonstration project to provide a secure source of power to certain critical facilities on the Army Base. The project will combine onsite solar photovoltaic generation with energy storage to provide additional resilience to support identified facilities through a microgrid in an extended outage, likely in combination with existing backup generation.

³ Community Storage Project in Stapleton Neighborhood:
https://www.xcelenergy.com/energy_portfolio/innovation/stapleton

⁴ Panasonic Battery Demonstration Project: <https://www.xcelenergy.com/staticfiles/xeresponsive/Energy%20Portfolio/CO-Panasonic-Fact-Sheet.pdf>

Through this project, the Company will gain a solar resource to supply energy to its customers, as well as experience with operating and maintaining a solar-plus-battery microgrid and optimizing the use of these resources. We will also gain experience valuable to understanding the performance of these systems, applicability and implementation of new MISO rules for battery storage participating in MISO markets, as well as knowledge and insight that will enhance our ability to understand, plan for and accommodate future battery storage applications. We anticipate this project will be operational in 2021.

These pilot projects have provided operational experience for future, widespread deployment of batteries on our system. From these projects, we have gained detailed information on the value, costs and benefits of battery installations. The projects demonstrate the need for better interoperability between the devices and systems. They will inform future system architecture, including cybersecurity and interconnection issues associated with battery operation. In addition, we currently have nearly 300 residential batteries installed across our states and are working with customers and the storage industry to provide battery interconnection guidelines and support. The legislation passed in Minnesota in 2019 also allows for cost recovery of energy storage system pilot projects.

F. Colorado Energy Plan

The Colorado Energy Plan (CEP) is the next step in our efforts to transform our energy system for our Colorado affiliate. It includes the retirement of two existing coal units and the construction of 1,100 MWs of new wind and 700 MWs of new solar. As part of the all-source bids associated with the CEP, we received 133 total energy storage bids from 97 separate projects. Taking advantage of the tax credit incentives, several of the project developers were able to present us with competitive pricing for batteries paired with solar. From these bids, we selected two separate battery-plus-solar projects totaling over 600 MWs of universal scale solar paired with 275 MWs of battery storage, which was then the largest utility-proposed acquisitions of battery storage in the U.S. The Colorado Public Utilities Commission approved CEP in August 2018, and with this approval we are moving forward to implementation.

III. ENERGY STORAGE VALUES

Energy storage can be deployed in all parts of the energy grid, and can help to enable a smarter, stronger, cleaner, and more reliable energy grid for our customers. There are multiple opportunities for energy storage to add value to our system. We focus

here on four key areas: renewable integration, grid support, deferred investment, and power quality.

A. Renewable Energy Integration

As Xcel Energy continues to add significant amounts of renewable energy generation to our system, energy storage can support integrating those renewables into the energy grid. Renewable energy is available when the wind blows or the sun shines, and customer energy demand is often not synchronized with its availability. Storage can help shift renewable energy to time periods when it is needed, reducing the need for investment in peaking plants and support facilities. This is especially true for short-term deviations – a few minutes to a few hours – between customer demand and renewable generation.

B. Grid Support

As the owners and operators of the grid, utilities are first and foremost responsible for the safety, reliability, and optimal operation of our system for our customers. A reliable electric system requires attention to the physics of electricity transmission and distribution. It is not enough to match generation and power supply; we also must make sure that the power can be delivered to customers. Energy storage can help with grid reliability and resilience by providing:

- voltage support at critical places on the electric system where low voltage prevents the transmission of power;
- ancillary services such as:
 - frequency regulation – ensuring that the appropriate frequency of the alternating current on the system is maintained
 - spinning reserves – available resources to increase power output to meet fast changes in demand
 - operating reserves – resources to make up the difference between production and demand when production is low
- energy arbitrage, purchasing and storing electricity during off-peak times, and then utilizing that stored power during periods when electricity prices are the highest;
- readily available reserves, reducing the need for additional investments in “quick start” generation and transmission assets that maintain the system in the event of a disruption; and

- Black start capability, or the ability to restart the entire electric system in the event the whole system goes down.

Utilities are well-positioned to maximize the value of these storage capabilities to ensure system planning and visibility with the primary objective of enhancing reliability and optimizing performance in a cost-effective manner. We can facilitate the deployment of energy storage on our system when and where it is most needed.

C. Deferred Investment

Storage has the potential to take the place of traditional grid investments across our system, including investments in peaking generation, transmission and distribution upgrades, and reliability investments to maintain grid support. Its ability to do so depends on whether the proposed storage resource is (1) capable of providing the same benefits as the asset it replaces; (2) cheaper than the more traditional alternative; and (3) has some level of visibility and control by the grid operator. As storage technologies continue to improve and prices come down, there are greater opportunities for storage to take the place of existing technologies, especially in areas where the unique circumstances of the system make traditional technologies more expensive.

We are actively exploring additional deferral opportunities for our system where storage may provide a solution. This requires new tools and processes to analyze the appropriate location and size of the potential storage solution, as well as a cost-benefit analysis of those solutions as compared to traditional grid investments. Properly positioned storage can defer or reduce the need for incremental transmission and distribution investments, while poorly-sited storage may require additional investments in new capacity or distribution upgrades.

D. Power quality

Some of our customers seek power quality above and beyond what is provided by our standard electric service. Batteries can improve power quality by helping avoid the momentary outages that interfere with the operation of sensitive electronic equipment. Projects like our Panasonic pilot have demonstrated the value of customer-utility partnerships in addressing these issues by placing a utility-owned battery close to, or at, a customer site to provide premium power quality service, while also allowing the utility to leverage the battery for grid services.

We are optimistic about these and other benefits of grid-scale storage. Key to capturing the full spectrum of these benefits is the recognition that storage is first and

foremost a grid asset. As more and more energy storage is deployed on our system and across the country, it is important that the rules governing ownership and operation of energy storage assets are clear and aimed at maximizing the grid benefits of storage while encouraging its affordable, reliable and safe deployment. Utilities are uniquely situated to understand the grid and its needs and should play an important role both in owning and operating grid-scale storage.

IV. CHALLENGES OF CURRENT ENERGY STORAGE TECHNOLOGY

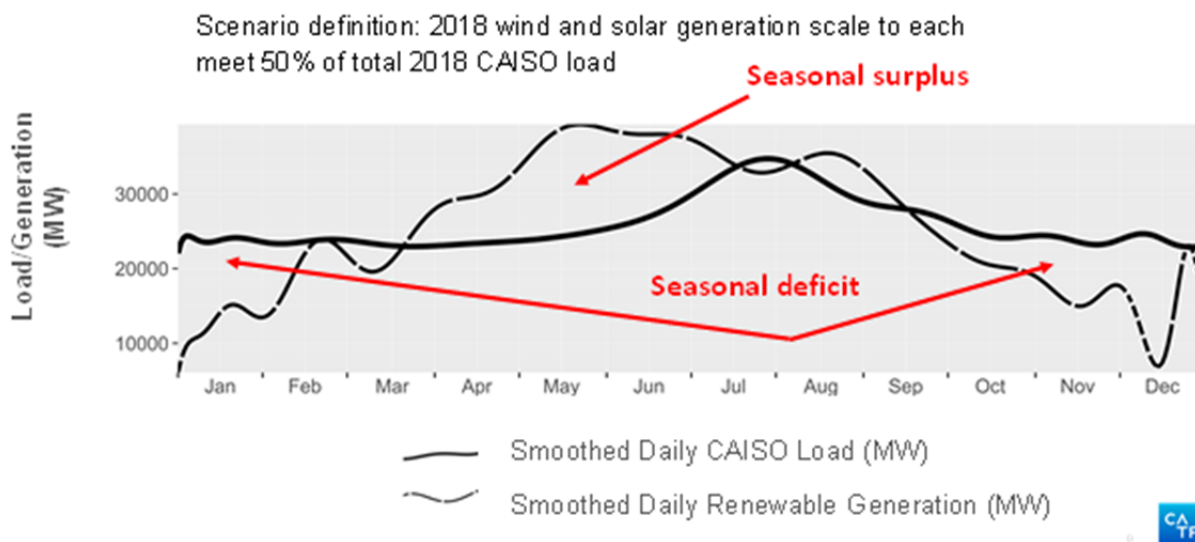
Energy storage offers opportunities to enhance our operations, help us integrate renewable energy, and play an important role in achieving our clean energy vision. At the same time, storage is not a silver bullet that would solve all electricity system challenges. While we see storage as a growing part of our energy system, it must be part of a diverse clean energy portfolio. Storage has inherent limitations that policy makers and utilities must keep in mind as we invest in the energy system of the future.

A. Seasonal Renewable Variation

Xcel Energy has been a long-time leader in renewable energy, and has done nation-leading work to integrate growing levels of renewables across our system. Wind and solar have been a key part of our strategy for more than a decade, and we plan to continue to add renewable energy as long as we can do so cost effectively and reliably.

As discussed above, storage has growing value to help integrate renewable energy on the electric system. Seasonal variation in renewable generation is the primary reason that the cost of renewable energy grows so substantially as renewable penetration increases. The Clean Air Task Force (CATF) chart below shows that, during the periods when renewable output is very high, the California energy system would generate substantial additional renewable energy. This additional renewable energy would have to charge a massive amount of storage capacity to ensure that load is served when renewable output is relatively low.

**Figure 1: Clean Air Task Force –
Smoothed Daily Load and Renewable Energy Generation, Mixed Renewable
Scenario**



In fact, CATF estimates that 9.6 million MW-hours of energy storage would be required to achieve 80 percent renewables in California—compared to the roughly 150,000 MW-hours of storage in California now. To reach 100 percent renewables, CATF has concluded that California would need 36 million MW-hours of storage. The cost of storage to achieve 100 percent renewable electricity in California would be astronomical – an estimated \$3.6 trillion in capital costs to store all the surplus renewable generation, even assuming a 60 percent drop from today’s storage costs.

We believe similar challenges would exist on our system. Based on E3’s analysis of our carbon reduction scenarios for our Upper Midwest System, excluding new gas resources more than doubles the costs of reducing CO₂ emissions 85% by 2030 and 95% by 2045 compared to reaching the same goal with only renewable energy and storage additions.⁵

We remain committed to providing our customers with a carbon-free electric system, and we will add renewable energy to that system as long as it makes sense. We expect that storage will play an important role in a future clean energy system. However, given the huge challenge of seasonal variation in renewable generation, it is not realistic to expect that storage will make a 100 percent renewable energy system possible. Storage alone cannot provide our customers with the reliable and affordable

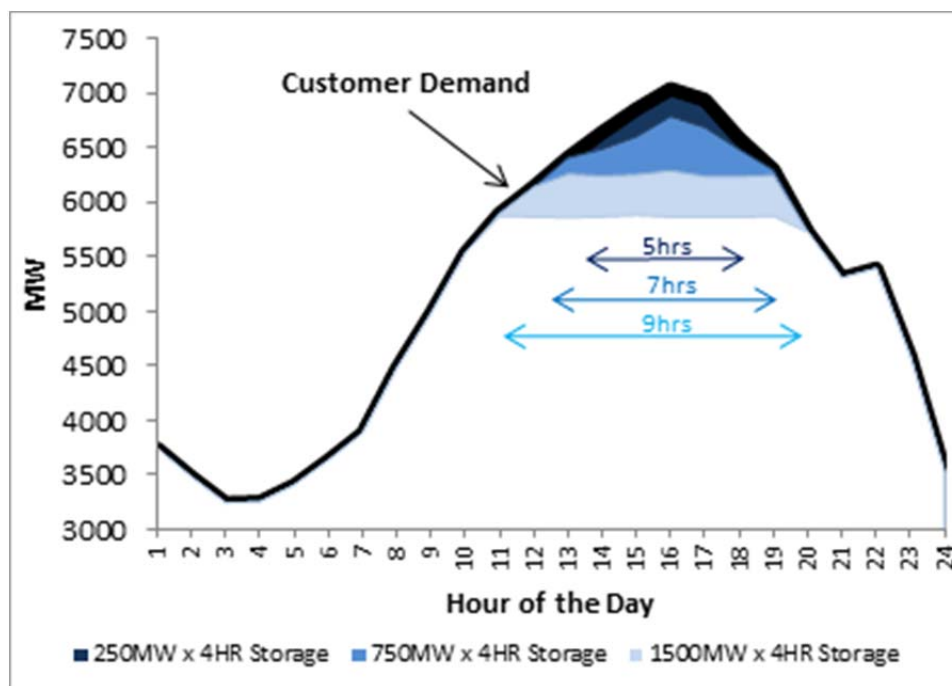
⁵ Energy and Environmental Economics analysis of Low Carbon Scenarios on Xcel Energy’s Upper Midwest System (E3 System Study), Appendix P2.

energy that they need. A broader suite of new dispatchable zero carbon technologies will be key to achieving our long-term carbon goals.

B. Declining Marginal Capacity Value

Storage can help meet peak energy demand by shifting some excess renewable energy to periods when it is needed, but this value declines dramatically as more storage is added to the system. As its name implies, a system peak is like the top of a mountain or a pyramid. It represents a short period of time during each day when energy usage is at its highest. Energy storage can shave off and lower the top of the peak, but it also widens it. As a result, larger, more expensive storage systems are required to further reduce the system energy needs.

The following chart illustrates this problem. The black line represents a single illustrative day of energy demand for one of our operating companies. Suppose that a 250 MW battery with four hours of storage capability is added to the system. It will shave off the top of the peak for a five hour period and shift the curve so that it takes advantage of parts of the day where excess renewables may be generated. The result is a lower, wider peak – more like a plateau. The next tranche of peak reductions requires substantially more storage to achieve the same effect – in this example, 750 MW of four hour batteries that are able to discharge over an approximately 7-hour period. The next tranche of demand reduction will require an even more substantial investment in storage i.e. a 1500 MW battery operating for almost 9 hours.

Figure 2: Battery Storage for Peak Demand Reduction

This chart illustrates that more batteries with longer duration are required at each step to reduce the peak. This problem is further compounded during periods of low renewable production, when excess generation may not be available to re-charge batteries to be available for the next peak.⁶ At some point, it is not technically or economically feasible to continue to use storage to shift energy from off-peak to on-peak periods.

C. Stacking Storage Values

As referenced above, storage provides multiple values, each of which can enhance the operation and efficiency of the grid. Adding multiple values together – “stacking” – can make the storage resource more valuable as a whole. For example, a storage resource that provides voltage support and renewable integration will be more valuable than a storage resource that provides only one of these benefits. As the cost of storage continues to decline, stacking these benefits together increases the probability that a utility would choose to add a battery or other storage resource to its system.

⁶ See E3 System Study, Figure 4-4, Appendix P2.

At the same time, in determining the value of a storage resource, its multiple potential benefits should not be added if one value precludes another. A battery may simultaneously provide voltage support and frequency regulation, but it cannot, for example, simultaneously integrate renewables and provide black start capability. In the latter case, the battery must be available to restart the system, and it may not be available to do so if it has been discharged to integrate renewables. Thus, the value of storage must be determined based on a utilities need for the potential value streams storage provides, and the ability and efficiency of storage to meet those needs.

V. ENERGY STORAGE ANALYSIS IN THE RESOURCE PLAN

We are considering storage opportunities in our resource planning processes in a number of our states. As mentioned above, our Colorado system already has 324 MW of pumped storage and we will be adding another 275 MW of storage embedded in solar by 2022. In this Resource Plan analysis we included a four hour generic battery storage resource in the modeling as an option to meet energy and capacity needs. The characteristics and cost assumptions for the storage resource can be found in the Strategist Assumptions in Appendix F2. In our modeling, the generic storage was allowed to compete with other resources to meet energy and capacity needs per the statutory requirement. If we have future needs, our model will select storage when it is a cost-effective resource. We continue to consider new tools and processes to analyze the appropriate location and size of storage solutions including the evaluation of potential values storage assets might provide to the system.

The Strategist model includes a spinning reserve requirement of 137 MW based on a 12 month rolling average of spinning reserves carried by the NSP System within MISO. Strategist does not account for other ancillary services and the associated value storage or any other resource may provide. Costs related to integrating renewables are included in Strategist by adding an integration cost to wind and solar.

Included as Appendix P2 is E3's Low Carbon Scenario analysis which used E3's RESOLVE model to evaluate deep decarbonization scenarios on our Upper Midwest System. The RESOLVE model utilizes a chronological hourly dispatch in contrast to the load duration curve methodology utilized by Strategist. In addition, RESOLVE includes the following operating reserve requirements which must be met by each resource portfolio:

1. Load following reserves requirements are set at 3% of load;
2. Frequency regulation reserve requirements are 27 MW; and
3. Spin reserve requirements are set at 1% of load.

The conclusions of E3's Low Carbon Scenario analysis generally support our preferred plan as a least cost way to achieve deep reductions in CO₂ emissions. Regarding storage, E3's analysis found the storage additions were not cost-effective on our system in the near-term, but were selected later in the planning period.

We will continue to evaluate storage in future resource plans, and will acquire new modeling tools that are better able to analyze high renewable scenarios. We expect storage to be part of our resource portfolio as costs continue to decline and we add more renewables to our system. Like other resources, much of the value of storage is in its ability to provide capacity and energy (arbitrage) and therefore it is primarily those needs will help drive storage additions in the future. Given our excess capacity position thru the mid-2020s, storage is unlikely to be cost-effective in the near term. However, the Company will continue to explore near term storage opportunities that could provide value to our system. In addition, storage resource will be considered to help meet firm, dispatchable capacity needs that have been identified in our Preferred Plan in the 2030s.