



Energy+Environmental Economics

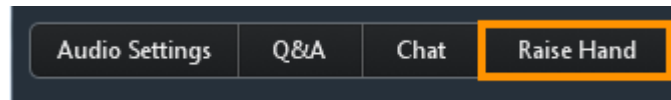
MN Storage Cost-Benefit Analysis

First stakeholder webinar

9/20/2019



- + Participants will be muted during the presentation. After each session, we will pause and answer a couple of questions. More questions will be discussed during the 30-min discussion period at the end of the webinar.
- + There are two ways to ask questions.
 - Send questions through the “**Chat**” function in the RingCentral. We will address them at the end of each session or during the 30-min discussion period at the end of the webinar
 - "Raise Hand" and we will open the mic for you to ask questions. To raise hand, on the top left of the Webinar Screen click the Raise Hand button.



- + The webinar will be recorded and uploaded at the following link:
 - <https://e3.sharefile.com/i/i72986cabde74d819>
- + Comments for the first webinar:
 - <https://forms.office.com/Pages/ResponsePage.aspx?id=h4PMTq6sZEUgQeMgVhRSYww6G-ilqMtJrpALeJkvN35URUJISTk0REI5R09UNTnZNkNEVUhaVkQ3Qy4u>



Agenda

- + (5 min) Introduction - Joe Sullivan (Department of Commerce)**
- + (15 mins) Project Overview - Arne Olson (E3)**
 - Project scope and timeline
 - Stakeholder engagement schedule and details
- + (20 mins) Energy Storage Background – Kush Patel (E3)**
- + (10 mins) Methodology Overview – Jasmine Ouyang (E3)**
- + (30 mins) Technologies & Use cases – Jasmine Ouyang (E3)**
- + (25 mins) Questions and Discussion**
- + (5 mins) Next Steps**



About E3

- Founded in 1989, E3 is an industry leading consultancy in North America
- E3 operates at the nexus of energy, environment, and economics
- Our team employs a unique combination of economic analysis, modeling acumen, and deep institutional insight to solve complex problems for a diverse client base



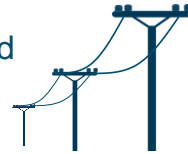


E3 Practice Areas

DERs & Rates

Analyzes distributed energy resources, emphasizing their costs and benefits now and in the future

Supports rate design and distribution system planning



E3 has five defined working groups that create continual innovation from cutting edge projects and constant cross-fertilization of best practices across the groups

Clean Energy

Provides market and policy analysis on clean energy technologies and climate change issues

Includes comprehensive and long-term GHG analysis



Asset Valuation

Determines asset values from multiple perspectives

Uses proprietary in-house models and in-depth knowledge of public policy, regulation and market institutions



Planning

Develops and deploys proprietary tools to aid resource planners

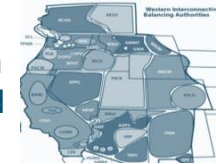
Informs longer-term system planning and forecasting



Market Analysis

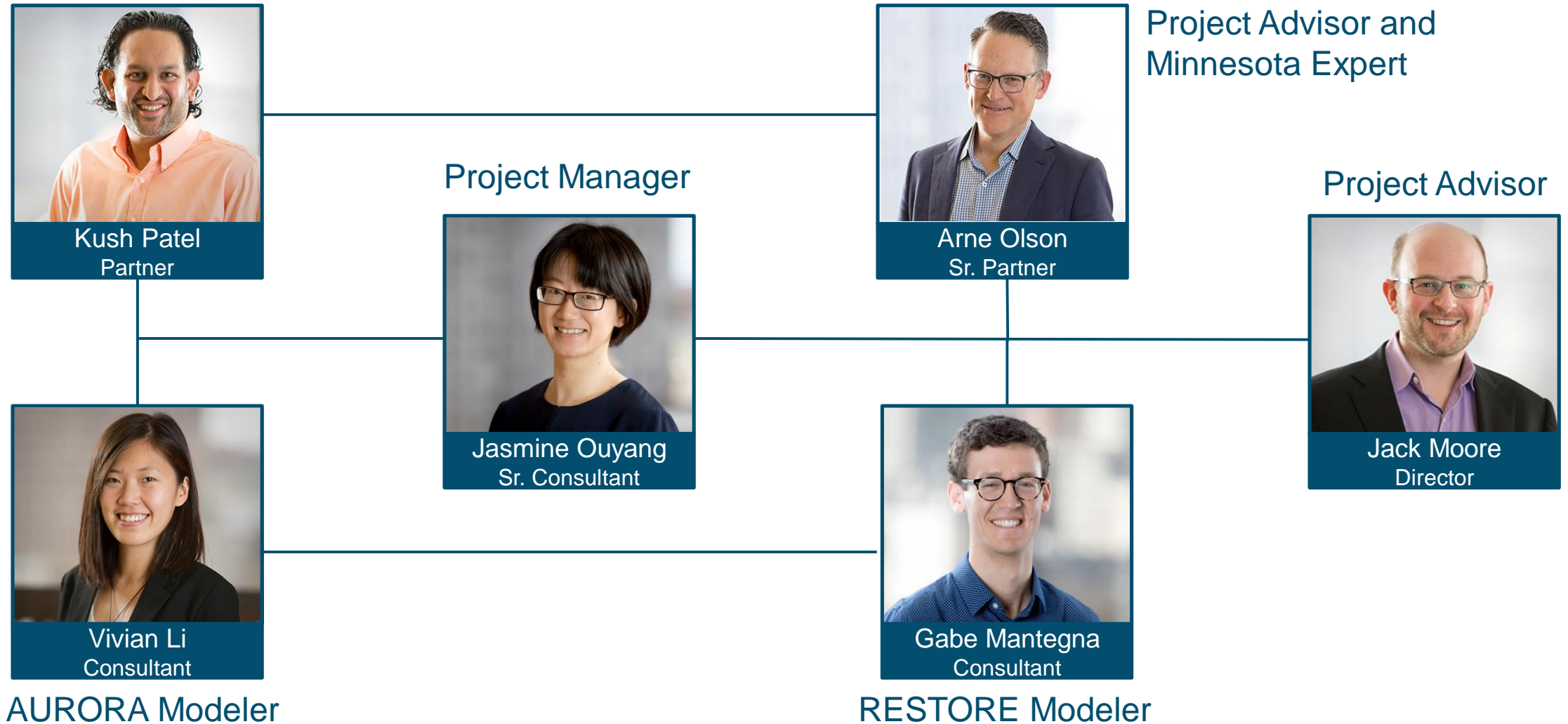
Models wholesale energy markets both in isolation and as part of broader, more regional markets

Key insights to inform system operators and market participants





Team





Project Overview

+ This study is made possible by legislation* passed in 2019. E3 is working with the Department of Commerce to conduct an independent analysis of the potential costs and benefits of energy storage systems in Minnesota. A public report will be produced to summarize the findings.

+ Tasks:

- **Cost-Benefit Analysis**
 - Identify use-cases for modeling
 - AURORA production simulation modeling
 - RESTORE Storage cost and benefit modeling
- **Stakeholder Engagement**
- **Final Report**
 - Case studies
 - Final report
- **Presentations to the Minnesota Legislature**



* [Minnesota Session Laws, 2019 Special Session 1, Chapter 7 \(HF2\), Article 11, Section 14](#)



Timeline

Workshops

Draft and Final Report

Deliverable

Task 1. Cost-Benefit Analysis

- 1.1 Identify use-cases for modeling
- 1.2 Identify and measure potential costs and benefits
 - 1.2.a Perform production cost simulation modeling in AURORA
 - 1.2.b Define inputs and assumptions for storage applications
 - 1.2.c Perform storage dispatch and cost and benefits modeling
- 1.3 Analyze and estimate the additional impact
- 1.4 Track the analysis conducted by MISO

Task 2. Stakeholder Engagement

- 2.1 Review use cases and methodology
- 2.2 Review initial results
- 2.3 Review final results

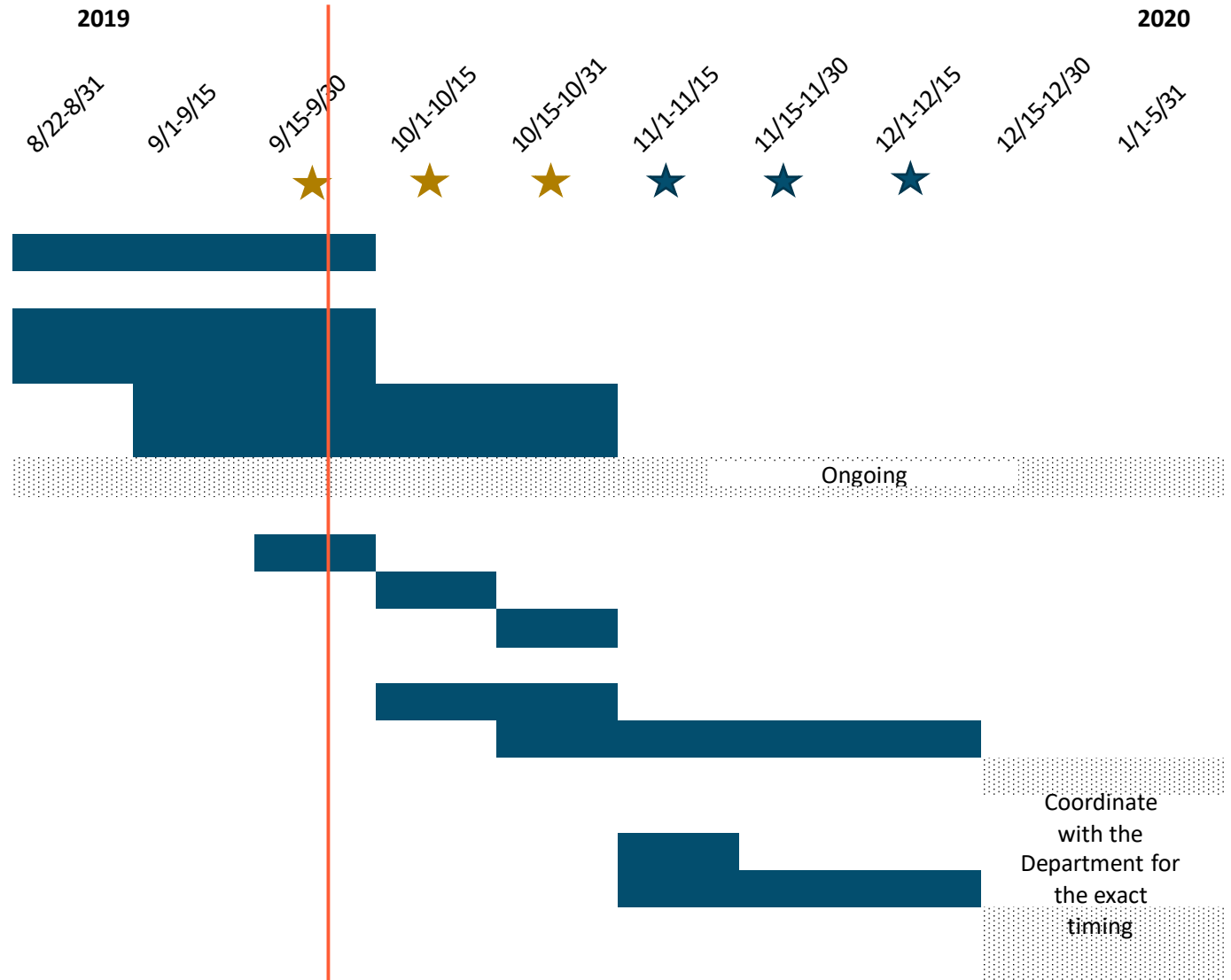
Task 3: Final Report & Executive Summary

- 3.1 Case studies of existing energy storage applications
- 3.2 Final report development

Task 4: Presentations to the Minnesota Legislature

Deliverables:

- Model result and description of cost-benefit analysis outcomes
- Draft and Final Report
- Slides for presentation to the Minnesota Legislature
- In-person presentation to the Minnesota Legislature





Stakeholder Engagement

+ We have three workshops for stakeholders to participate:

- **Storage Technology and Use Cases Overview (Today)**

- Time: 12:30 pm to 2:30 pm (CT) September 20th, 2019
- Comments due: September 27th, 2019

- **Draft Results Review (In-person Workshop)**

- Time: 9 am to 12 pm (CT) October 11th, 2019
- Location: Saint Paint, MN (exact location to follow)
- Comments due: October 18th, 2019

- **Final Results Review**

- Time: 12:30 pm to 2:30 pm (CT) October 25th, 2019
- Comments due: November 1st, 2019

+ We are excited to see you throughout the process





Questions for Stakeholders for Today's Discussion

+ Use cases

- Have we captured the important use cases? Any additional use cases we should consider?

+ Storage technologies

- Do we have a representative list of energy storage technologies to model? Any other storage technologies we should include or exclude in the study?

+ Input assumptions. Any suggestions for:

- example congested nodes to consider for congestion relief
- example distribution upgrades for deferral
- example utility rates to consider in the study, or
- other suggestions on input sources

+ We appreciate your feedback. Please submit your comments here:

- <https://forms.office.com/Pages/ResponsePage.aspx?id=h4PMTq6sZEUgQeMgVhRSYww6G-ilqMtJrpALeJkvN35URUJISTk0REI5R09UNTNZNkNEVUhaVkQ3Qy4u>

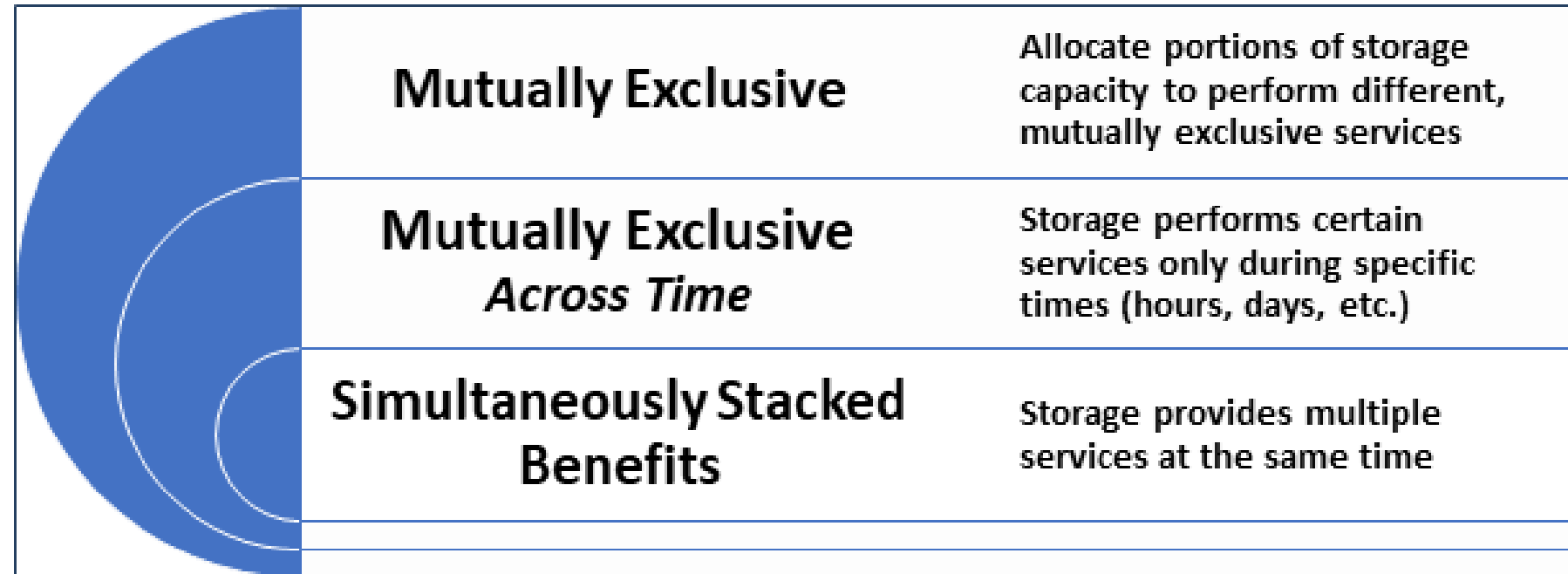


Energy Storage Background



Storage: The Multi-tool

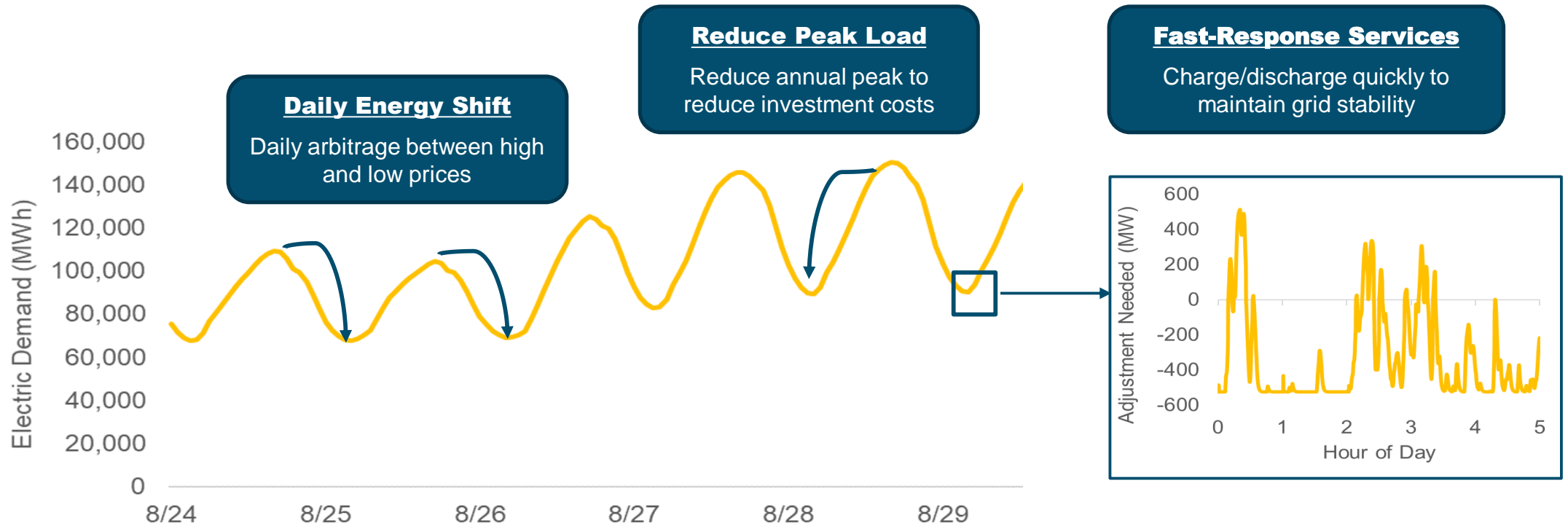
- + Storage is the most flexible energy resource currently available
- + It can offer a very broad set of grid and customer services but not all at the same time





Energy storage can provide several services to the grid today

- + The electricity grid is complicated – it must balance generation from hundreds of power plants and electricity usage from millions of people every second on the electric grid network
- + Storage can provide several services to the grid today

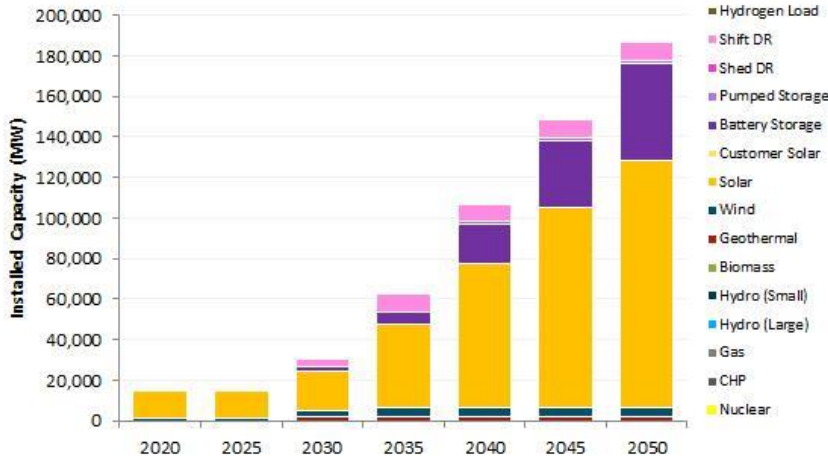


Example hourly load in the PJM market (Mid-Atlantic, OH, and parts of KY, IN, MI, and IL) in 2018 during a time period that covers the annual peak load

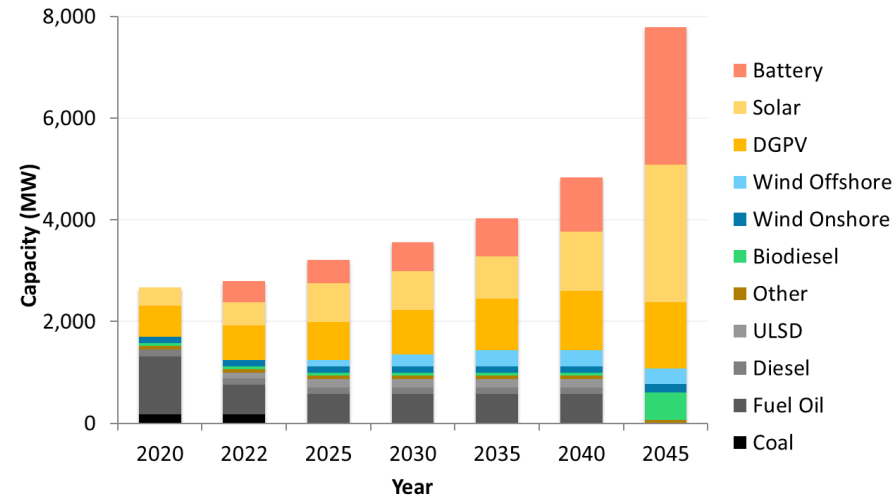


In the future storage could be a big part of a decarbonized grid

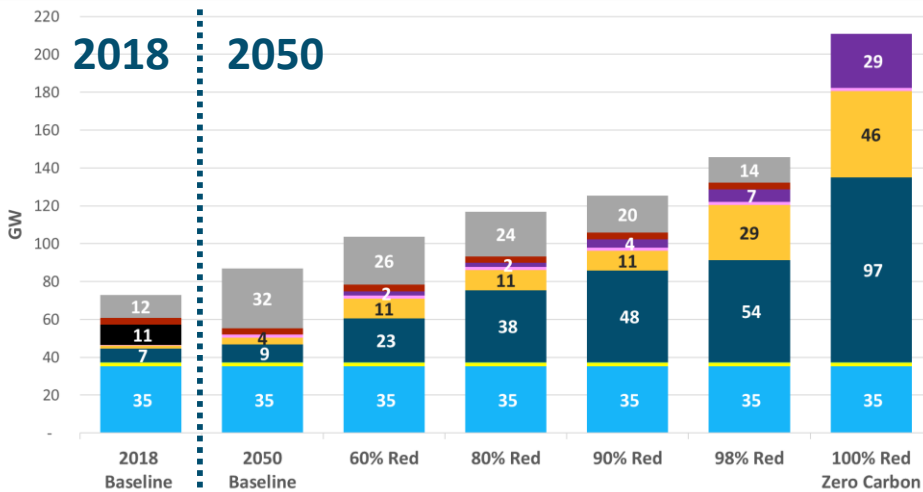
California



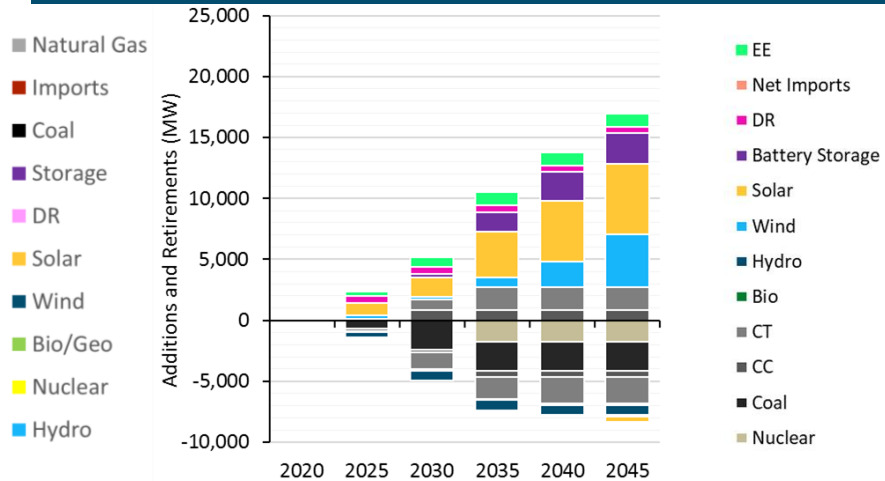
Oahu



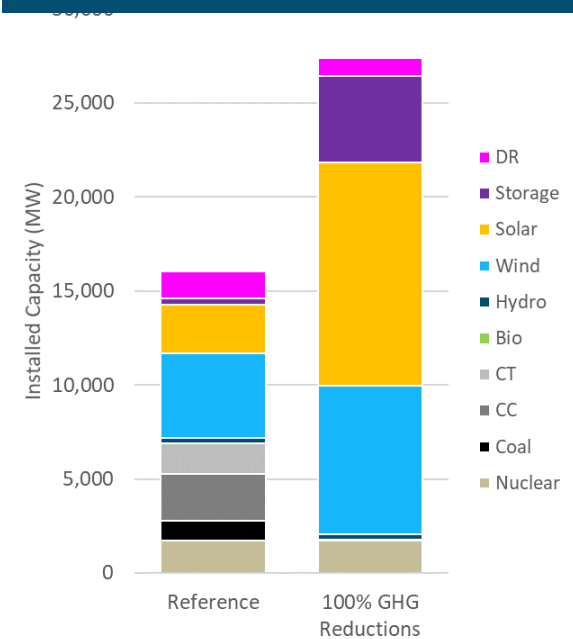
Pacific Northwest



Xcel Minnesota



Xcel Minnesota – Accelerated Decarbonization



Data Sources:

Xcel Minnesota: Upper Midwest 2019 IRP Support: the 80X30 100X50 scenario shown here assumes Sherco & King coal plants early retirement and no nuclear relicensing

Pacific Northwest: Resource Adequacy in the Pacific Northwest

California: Land Conservation and Clean Energy Pathways for California Report

Oahu: Hawaiian Electric Companies' PSIP Update Report



Energy Storage – Cost Declines and Other Factors Have Led to Rapid Growth

Drivers of energy storage – now and potentially in the future

Cost declines	Technology Improvement	Flexibility Need	Policy mandates	Regulatory changes	Market evolution
Li-ion battery costs	New storage technologies	Variable renewables	CA: 2 GW by 2025	FERC Order 841	Energy-limited products
Financing ecosystem		Evening ramp as sun sets	NY: 1.5 GW by 2025	Federal tax credit?	Small storage participation
Solar+storage gets tax credit		Localized system needs	NJ: 2 GW by 2030		
			MA: 1 GWh by 2025		
			Clean peak standards?		

Energy storage is expected to be more valuable on grids that are targeting high penetration levels for variable renewable energy resources especially solar

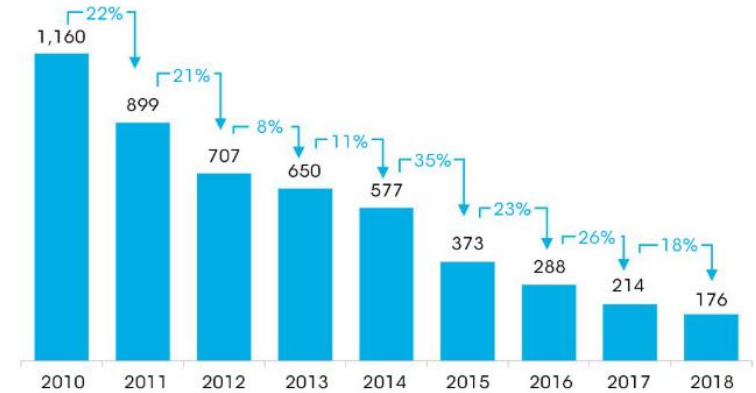
There are currently several barriers for energy storage (especially when located on a customer's premises) to participate in markets and monetize services provided to utilities

Significant policy mandates over the next 10 years

Lithium-ion battery price trend

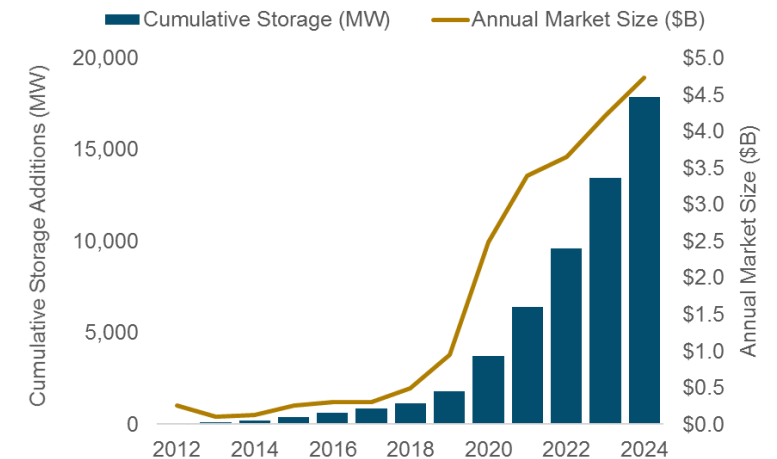
Lithium-ion battery price survey results: volume-weighted average

Battery pack price (real 2018 \$/kWh)



Source: BloombergNEF

US cumulative energy storage forecast



Source: Wood Mackenzie Power & Renewables



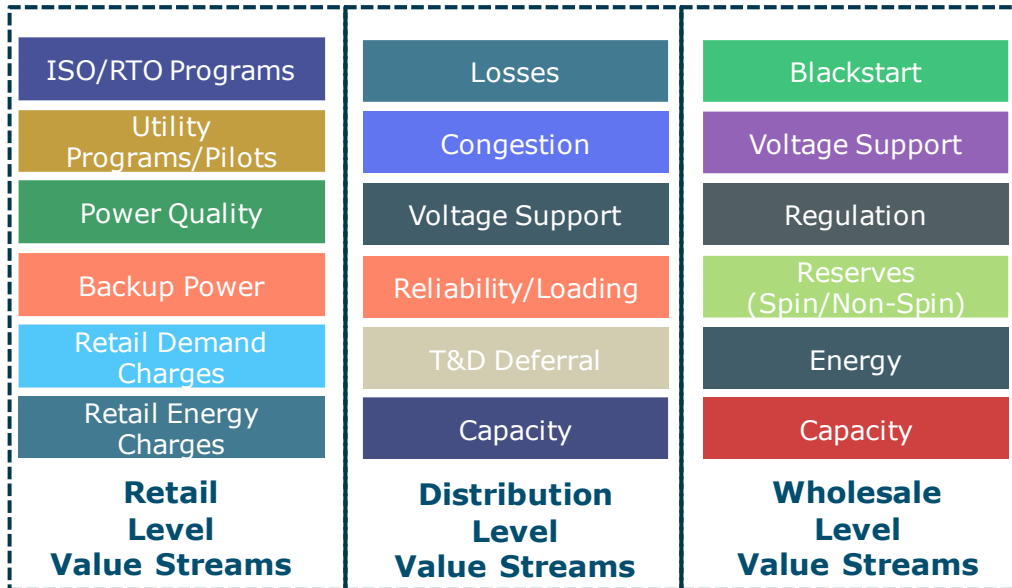
Storage can stack multiple fundamental value streams

+ Storage offers many stackable value streams depending upon siting, market products and prices, and co-location with solar, wind, or other generation

Fundamental Storage Values

Challenge #1:
Monetizing these Value Streams

Challenge #2:
Forecasting these Value Streams



Value Stream Drivers

Customer Market

- Retail electricity prices
- Retail demand charges
- Utility programs/pilots
- ISO/RTO programs

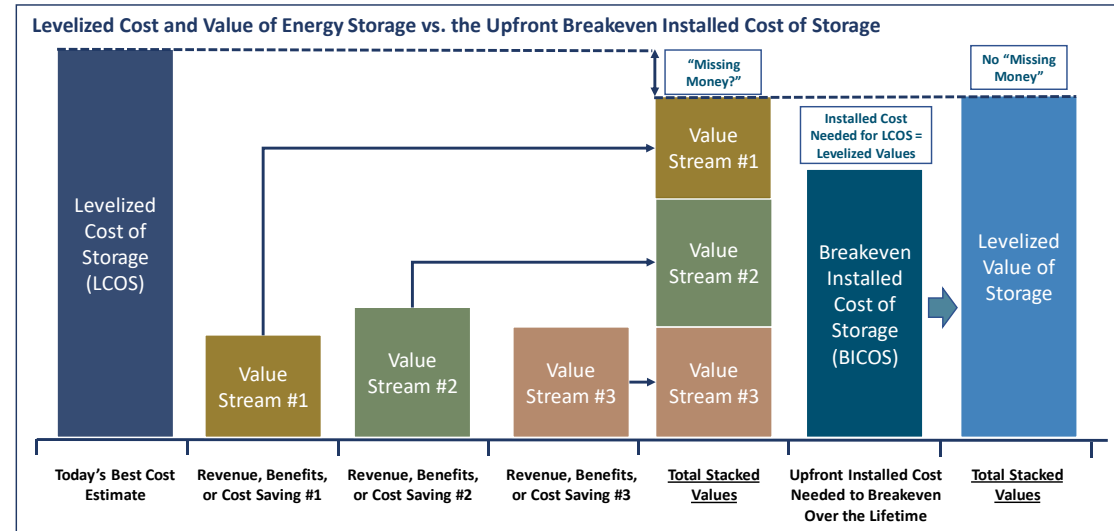
Distribution Market

- Emerging markets for distribution-level value streams like T&D deferral

Wholesale Market

- Wholesale capacity prices
- Wholesale energy prices
- Wholesale ancillary services prices

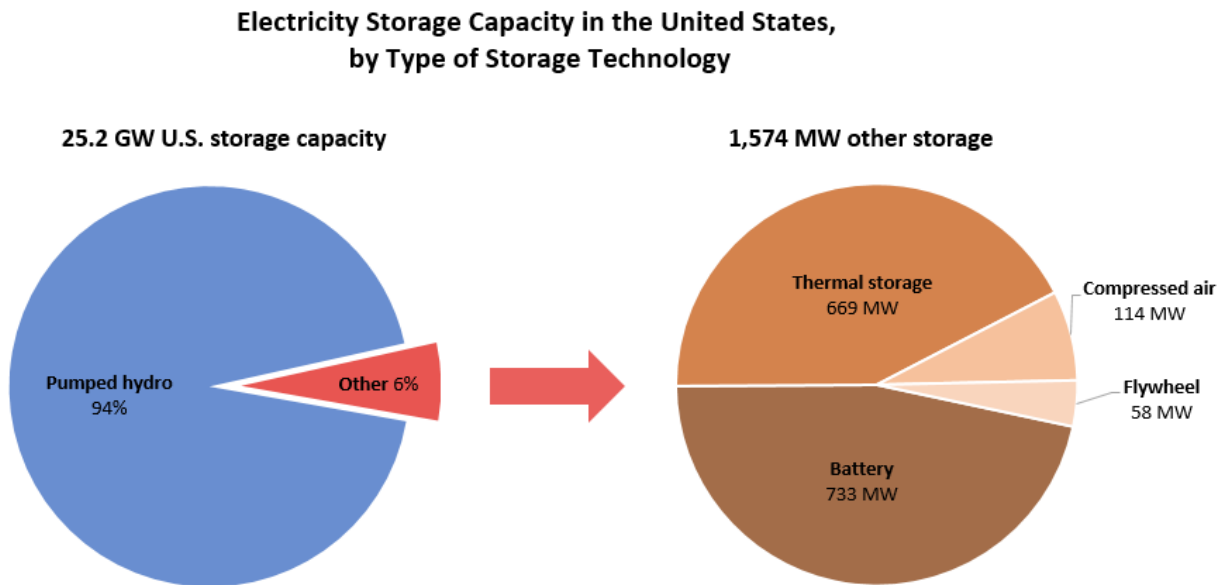
Fundamental Values can be Stacked



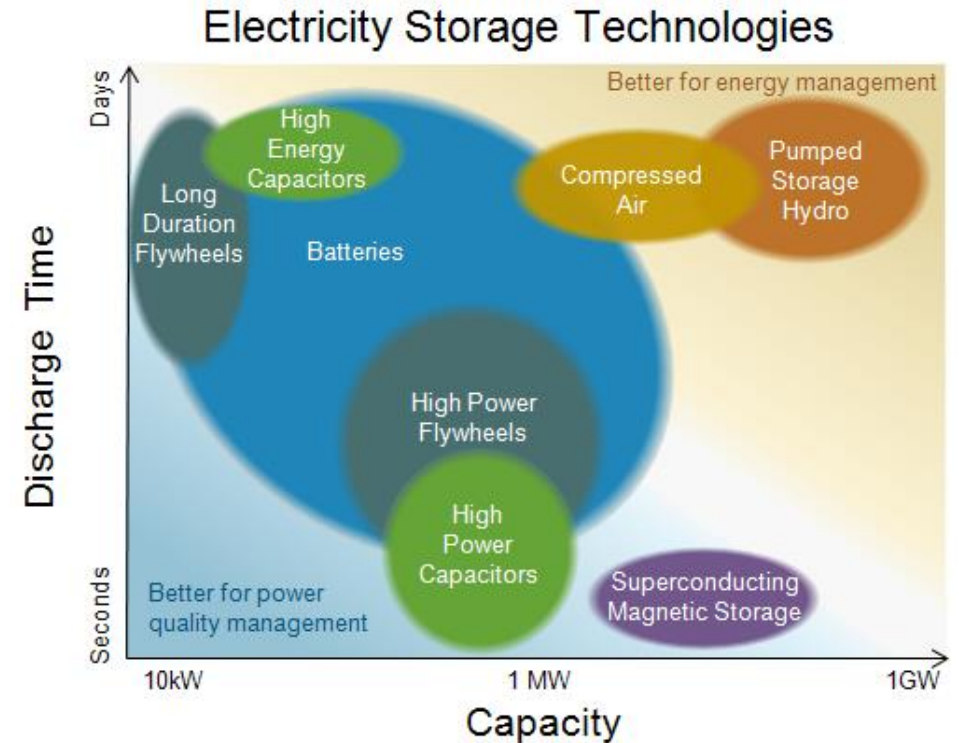


Energy Storage Types

- + Most of the existing energy storage in the US is pumped hydro, but there are limited development opportunities for pumped hydro; battery and thermal storage are the second and the third largest by installation capacity
- + Various types of storage technologies are designed to respond to changes on varying timescales and thus are suitable for different uses



Source: U.S. Department of Energy Global Energy Storage Database





Energy Storage in the US and in Minnesota

+ California, New York, Illinois, and Hawaii are leading storage deployment, but Minnesota is catching up

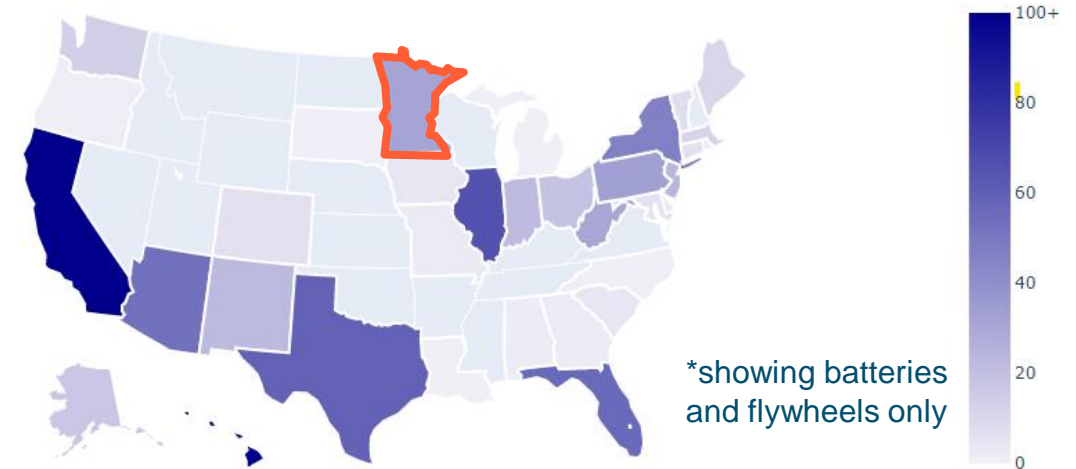
- As of 2018, **Minnesota** has 16.2 MW / 37.6 MWh of energy storage- mostly Lithium-ion
- Connexus energy added 15 MW / 20 MWh in Ramsey and Athens Township at the end of 2018

+ Applications Observations:

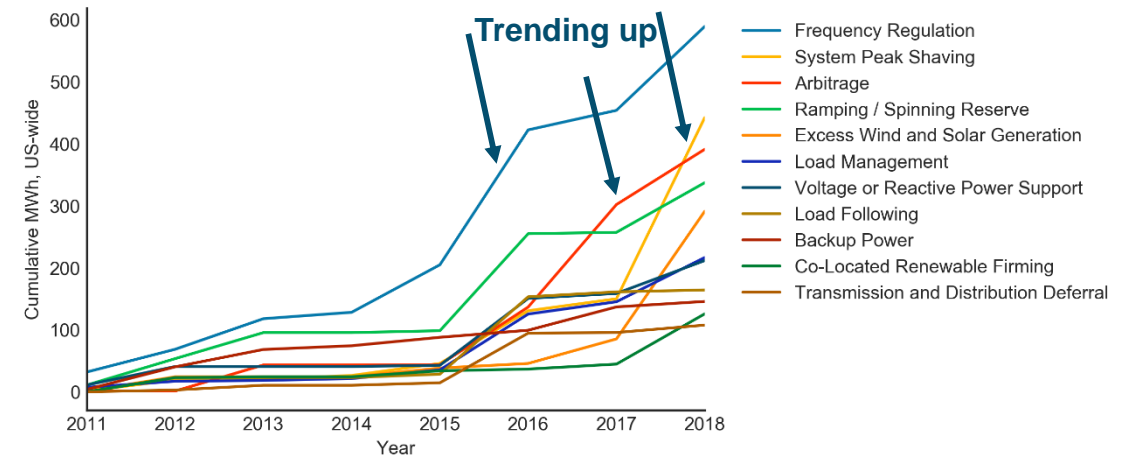
- 88% of large-scale battery storage provides frequency regulation and most of the energy storage (56%) provides more than one service
 - The three existing batteries in MN are used for system peak shaving, demand charge management, T&D deferral, and renewables firming
- In recent years, frequency regulation, system peak shaving, and arbitrage have emerged as the most common use cases (on an energy basis)

+ 90% of the current battery storage installations are Li-ion battery, followed by sodium-based batteries at 6% and flow batteries at 1%

Cumulative Energy Storage Deployment through 2018* (MWh)



Applications Served by U.S. Large-Scale Battery Storage over time



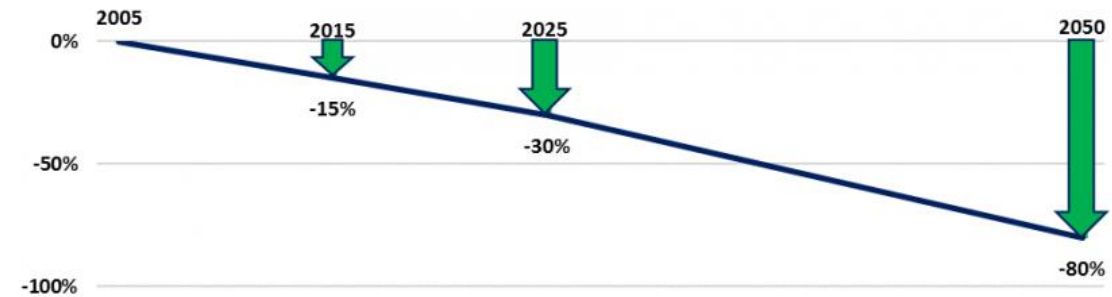
Source: EIA; excluding solar thermal with energy storage and natural gas with CAES



Minnesota State Policy and MISO Regulation

- + **Statewide goal of 80% GHG reductions by 2050 will require a significantly higher penetration of renewable energy, creating a significant market potential for energy storage**
 - Xcel Minnesota has set GHG reduction targets of 80% by 2030, and 100% by 2050, but has not announced storage assets in its 2019 IRP
- + **Current storage participation in MISO**
 - The first Li-ion battery was connected in 2016, providing frequency response¹
 - MISO's frequency regulation market is small. The total need is about 71 MW and regulation prices are between \$1/MWh and \$10/MWh²
- + **In December 2018, MISO filed its compliance plan for FERC Order 841, which will be implemented December 2019**
 - Storage will be able to participate in capacity, energy, and ancillary services markets – and bid in as either supply or demand
- + **Electric Storage as a Transmission-Only Asset (SATOA) is also under discussion**

MN Next Generation Energy Act:
GHG reduction goals



FERC



Federal Energy Regulatory Commission



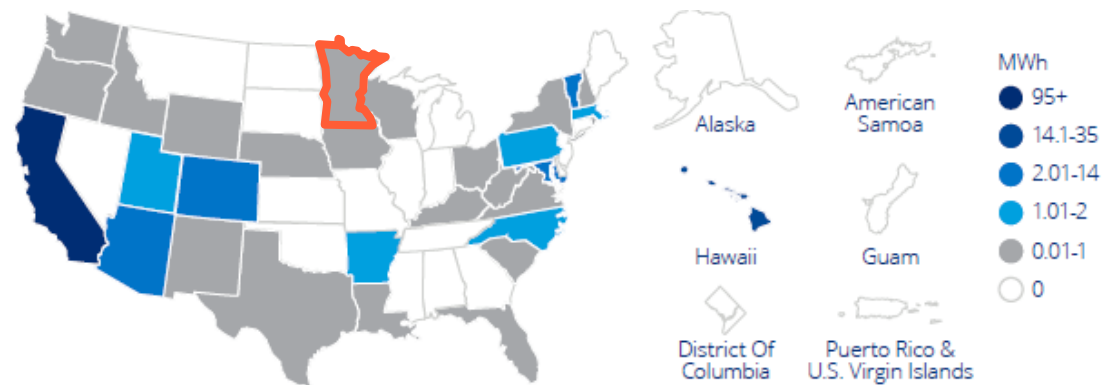
1. <https://www.utilitydive.com/news/first-battery-storage-project-begins-operating-in-miso/422505/>
2. <https://www.utilitydive.com/news/how-miso-is-reforming-market-rules-to-spur-storage-deployment/412590/>



Behind-the-Meter (BTM) Energy Storage

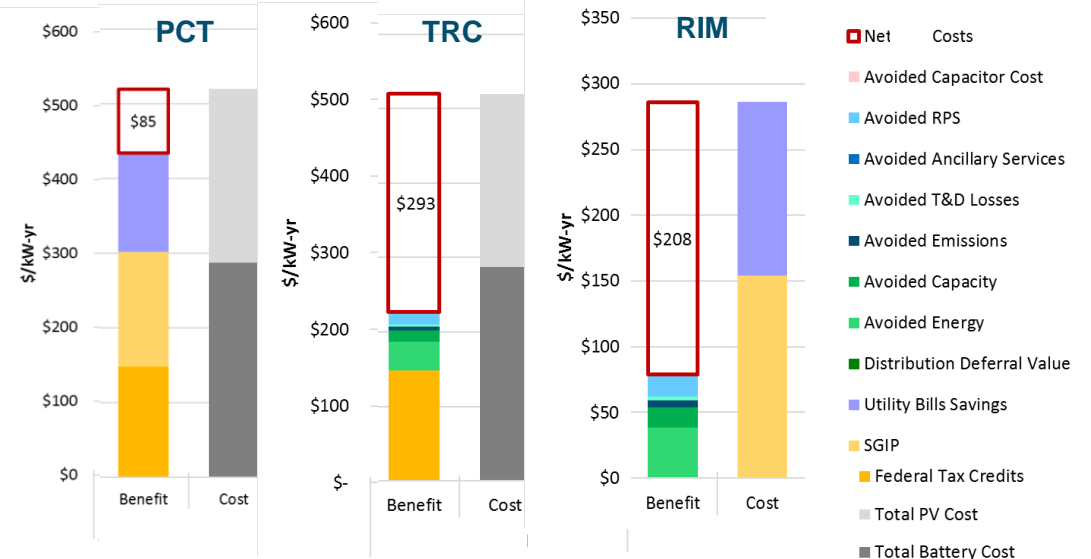
- + Residential storage deployments grew 500% in 2018 driven by favorable policies in CA, HI, VT and other states; non-residential storage displayed strong growth of 34.9%
 - Minnesota has less than 1 MWh of residential energy storage
- + Benefit-Cost Analysis for customer-adopted storage can be viewed from different perspectives
 - Total Resource Cost Test: the state's view
 - Participant Cost Test: participants' view
 - Ratepayer Impact Measure: non-participants' view

2018 Annual Residential Deployment (MWh)



Source: Smart Electric Power Alliance, 2019

Example Cost Test Results

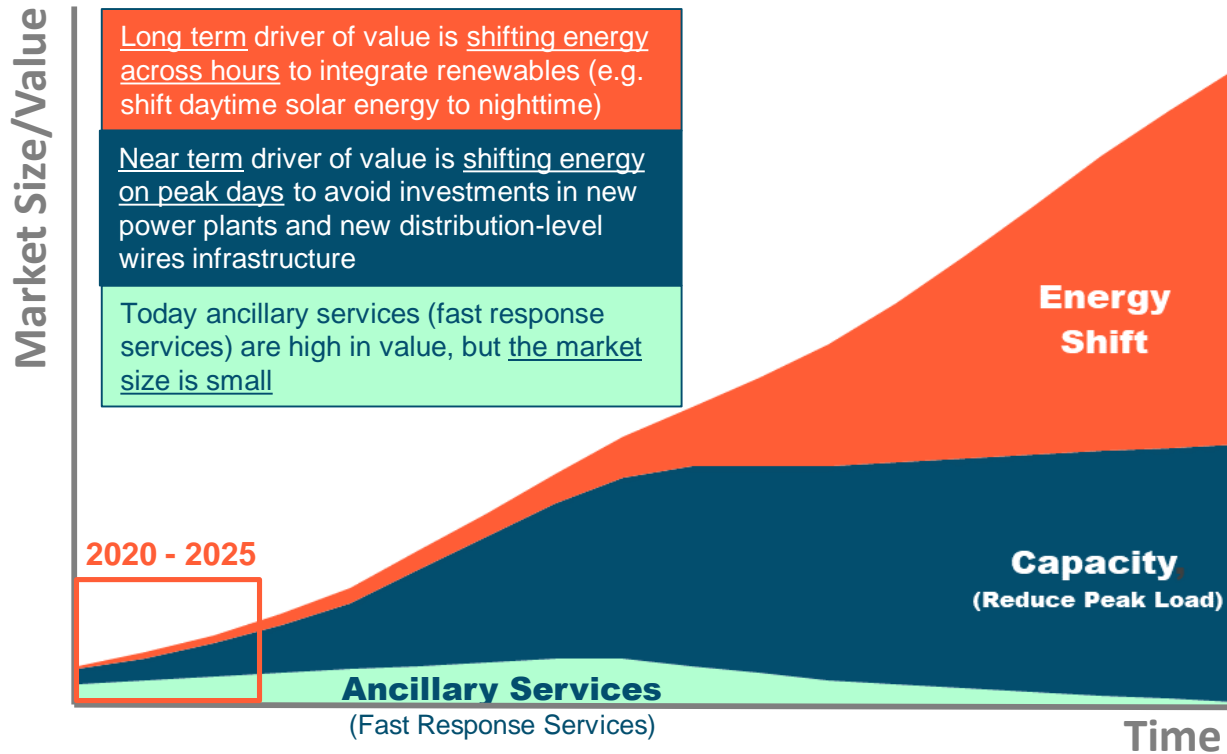




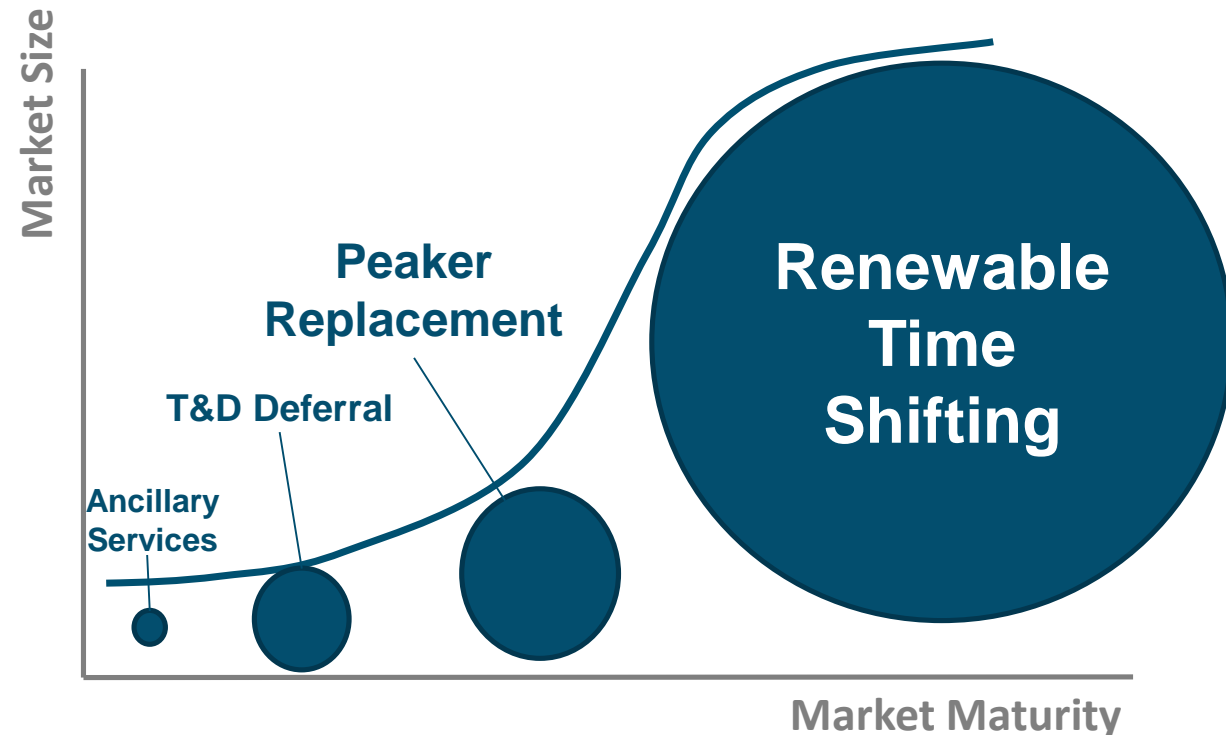
Evolution of value from energy storage

- + The value opportunity for energy storage is expected to shift over time
- + Some benefit streams are expected to shrink over the long-term from market saturation (e.g. ancillary services), while others are expected to increase dramatically over time with the proliferation of renewables (e.g. energy shift)

Illustrative Value Evolution



Illustrative Use Cases Evolution

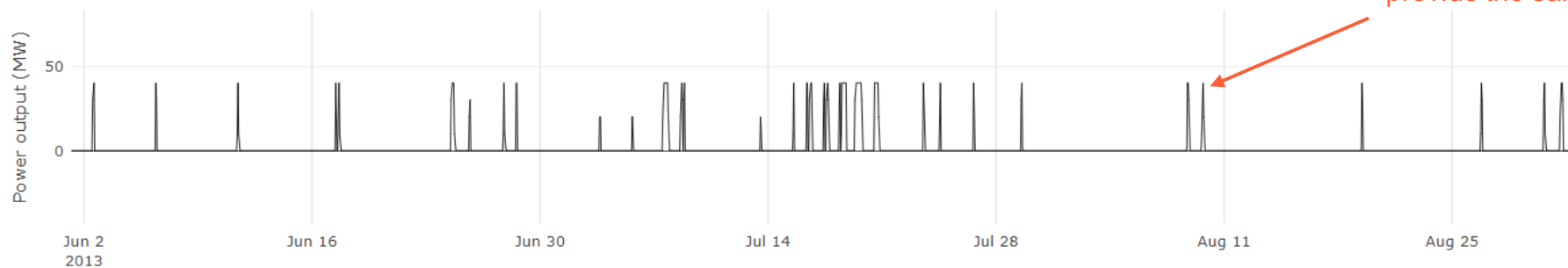




Storage can serve as an alternative to peakers

- + **Standalone storage and storage paired with solar are alternative solutions to gas peaker plants for capacity additions in the future**
 - In many cases, storage could perform the same service as existing peakers including energy, capacity, and ancillary services by charging off-peak and discharging on-peak
- + **E3 examined energy storage's ability to provide the same services as the existing peaker fleet in MN by replicating the historical operations of the peaker fleet using energy storage**
 - Preliminary analysis indicates that about **50%** of MN's peaking capacity (1.4 GW) could be served by 6-hour storage, or equivalently, 2.1 GW of 4-hour storage
 - The screening exercise demonstrates stand-alone energy storage's ability to serve a portion of incremental demand in the future
 - Storage paired with PV is able to provide the same services with less storage capacity

Typical peaker power plant operational profile

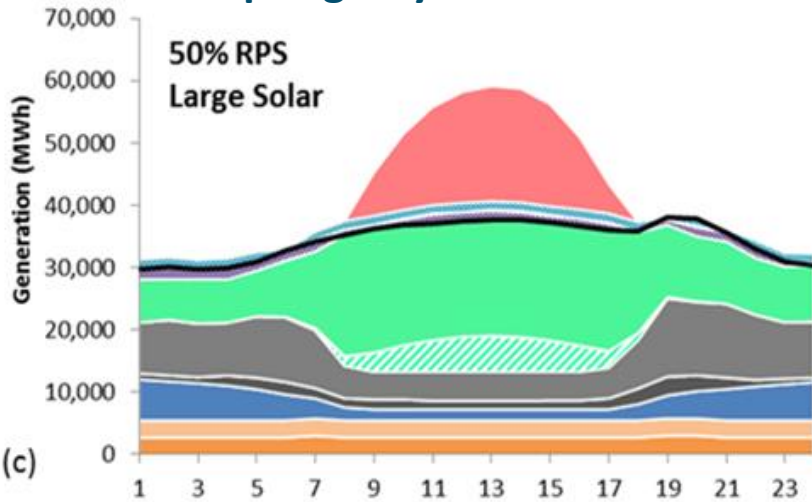




The value of energy storage depends on the physical characteristics of the power system

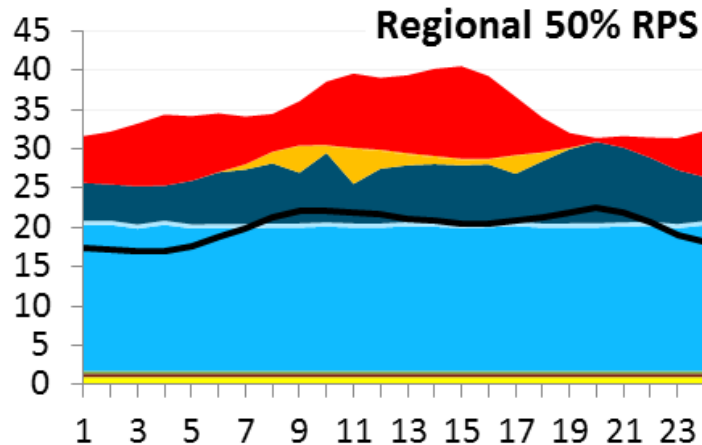
California can store surplus solar power with 4-6 hour grid batteries

Spring Day In California



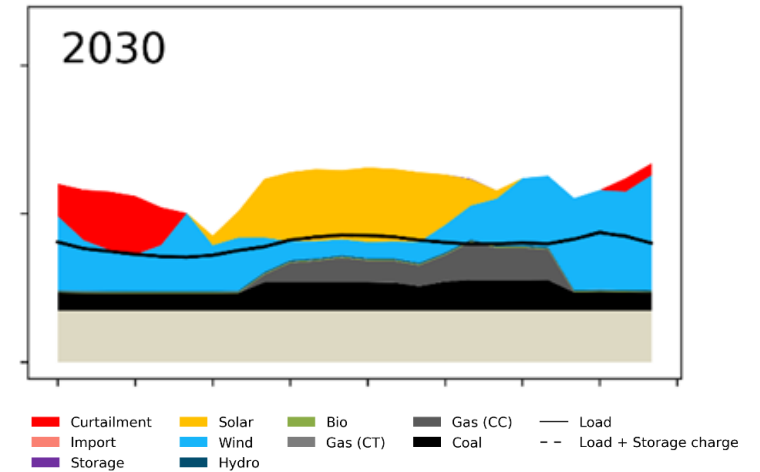
Northwest has surplus of wind and hydro generation that occurs day after day during high hydro years

Spring Day in the Northwest



MN is expected to have a balanced portfolio of wind and solar; storage can shift solar power to peak hours in most days

Spring Day in Xcel MN





How will capacity crediting for energy storage change in the future?

- + Decline is driven by limited discharge duration as “net peak” flattens with increasing penetration levels
- + Value is a function of loads and resources that are unique to each system
 - 0-15% of Peak Load: High value (80-100% ELCC)
 - 15-30% of Peak Load: Value declines quickly
 - >30% of Peak Load: Diurnal storage (4-12 hours) has limited additional value; loss-of-load probability driven by multi-day high load/low renewable production events

Data Sources:

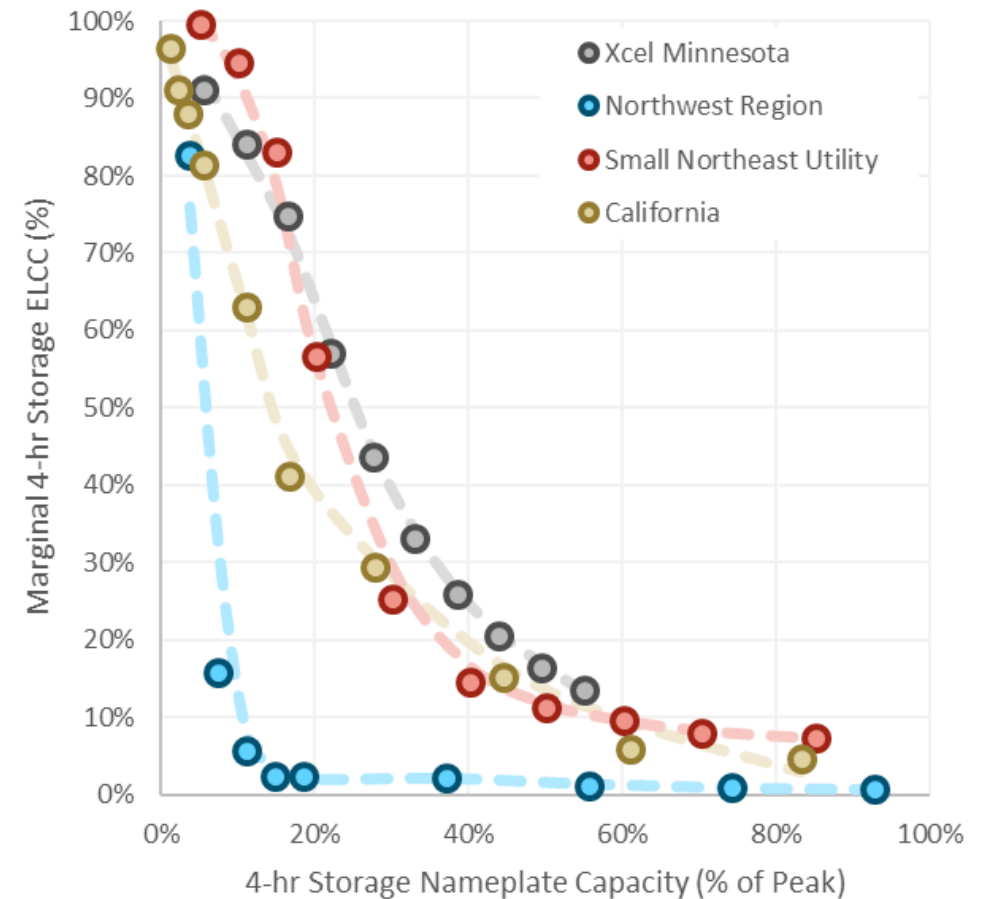
Xcel Minnesota: [Upper Midwest 2019 IRP Support](#)

Northwest Region: [Resource Adequacy in the Pacific Northwest](#)

Small Northeast Utility: confidential internal analysis

California: internal E3 analysis

4-hour Storage Marginal ELCC Curves



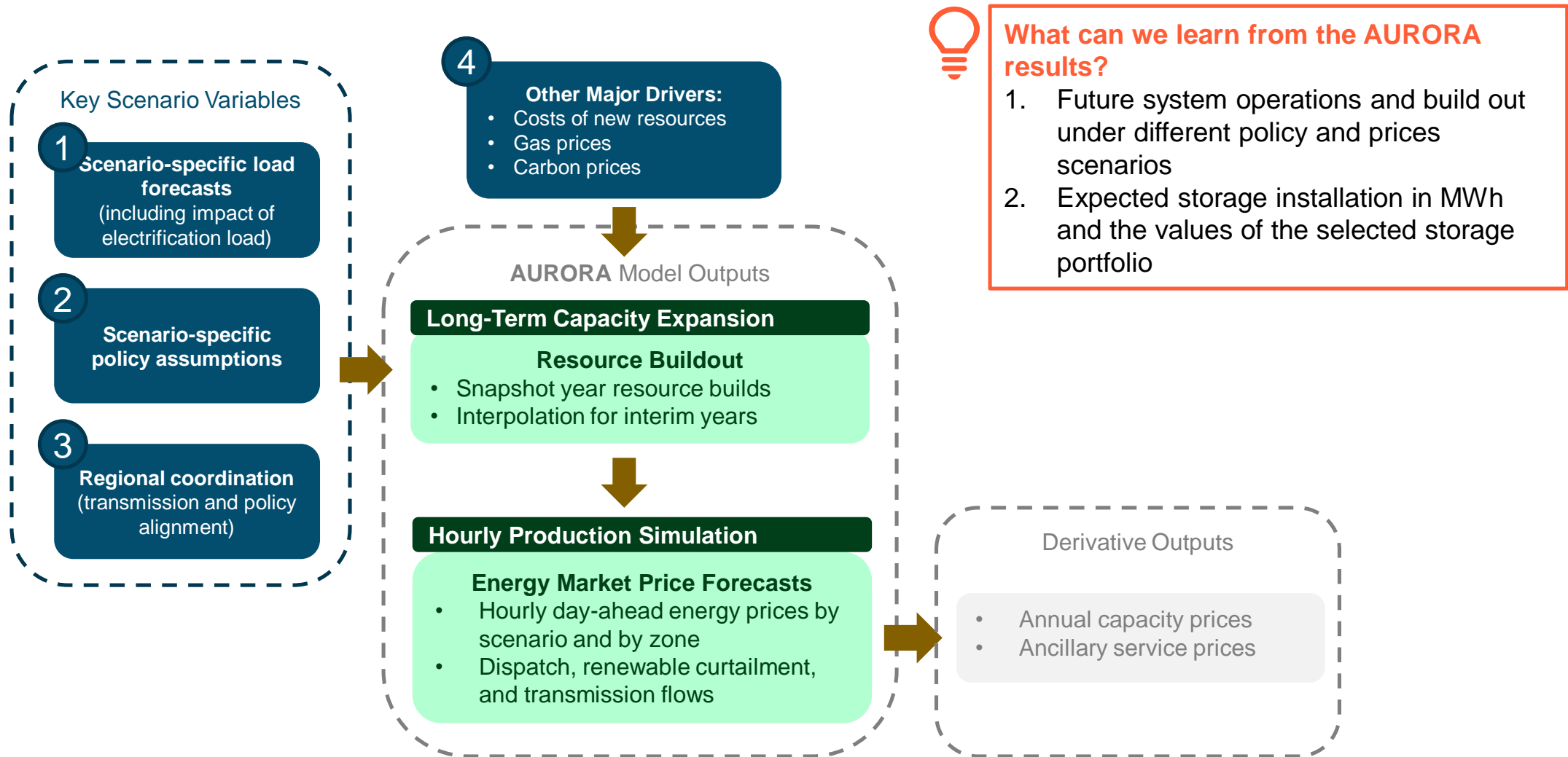


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Methodology Overview

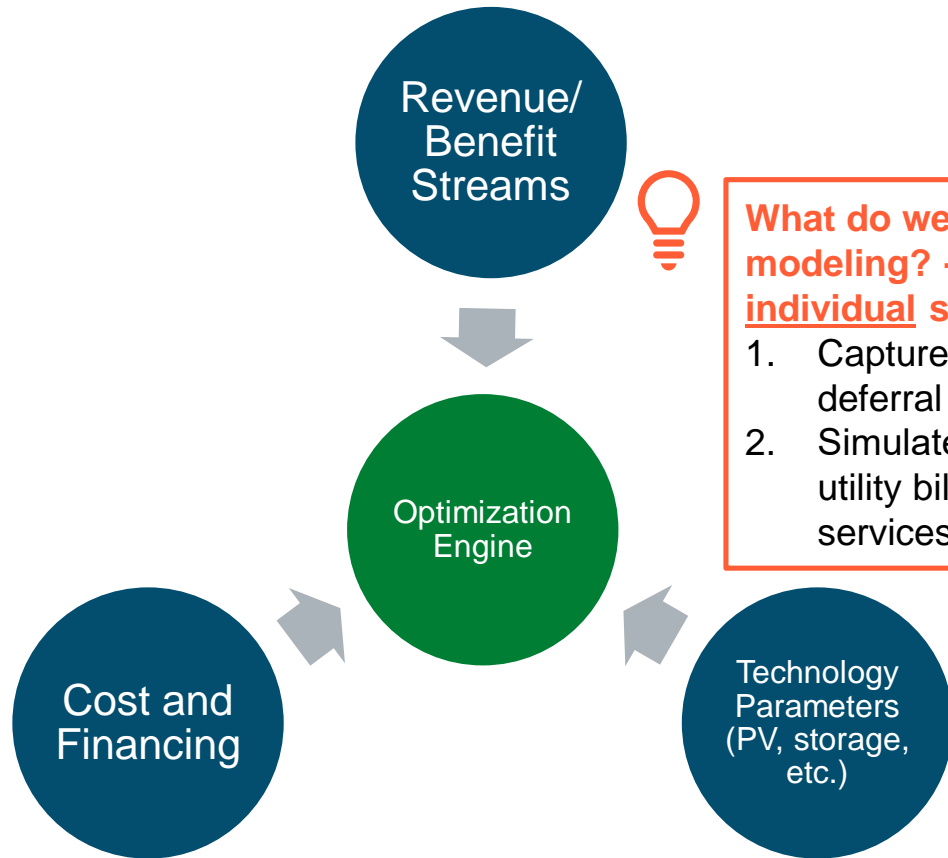


High-level visualization of E3's market price forecast modeling approach





+ A storage valuation tool with an optimization engine for dispatch

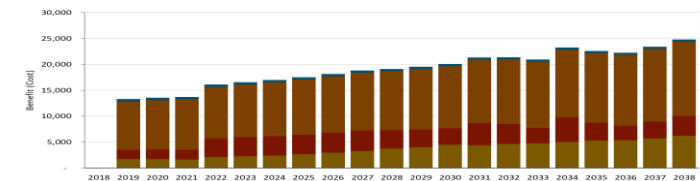
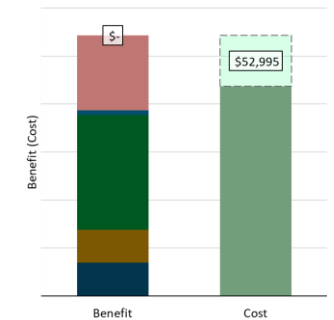
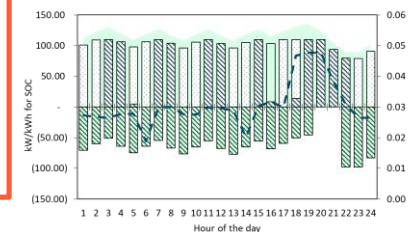


What do we learn from RESTORE modeling? - The cost-effectiveness of individual storage projects:

1. Capture the locational values: T&D deferral and congestion relief
2. Simulate owners' specific use cases: utility bill management, emergency services, and power quality

Results

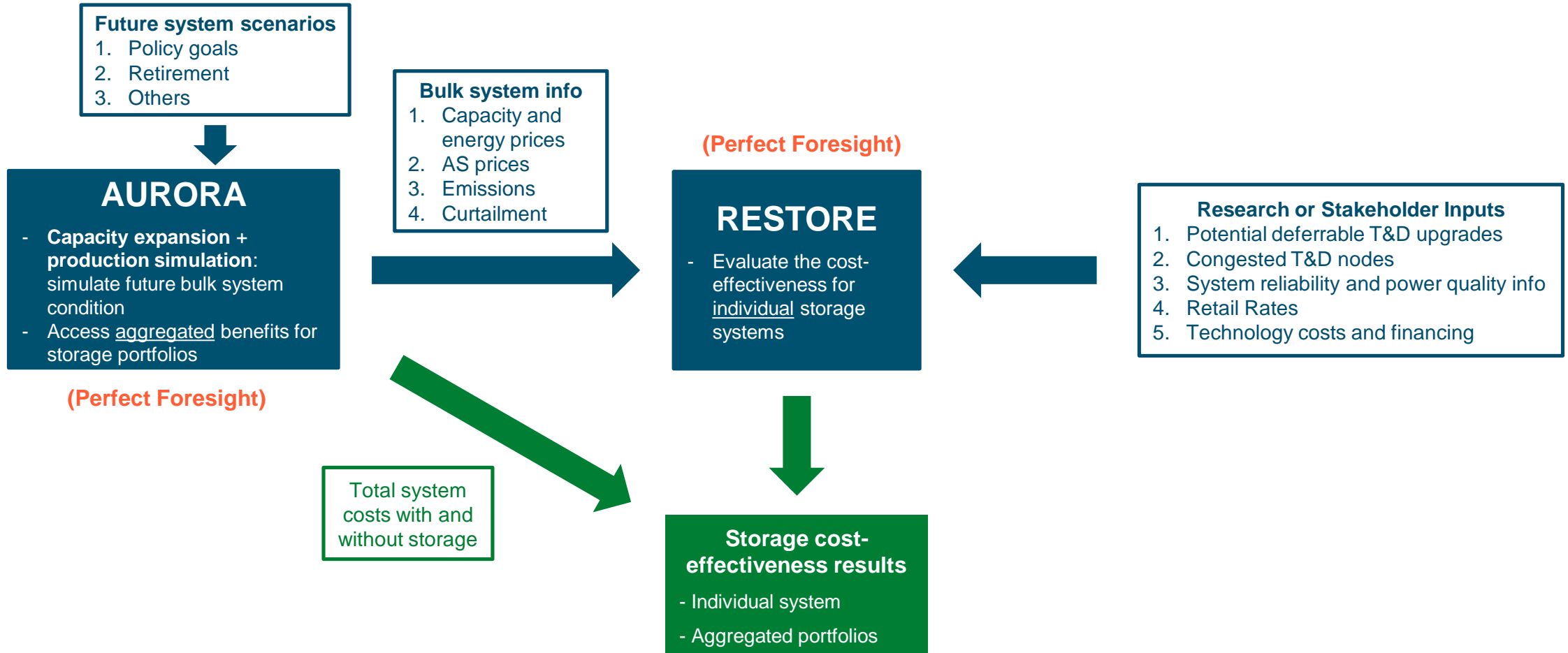
- NPV and annual benefits and costs
- Cost tests
- DER optimal dispatch
- ...





Cost-Benefit Analysis Framework

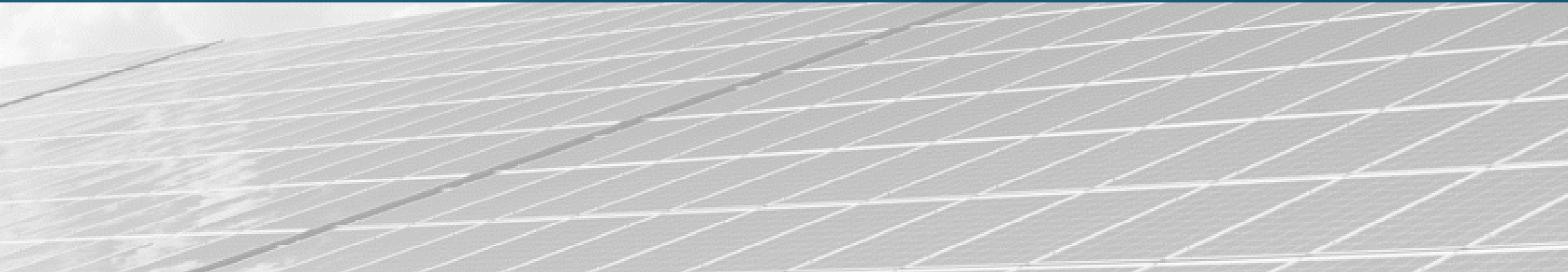
+ A production simulation model, AURORA, and an E3 in-house storage dispatch and cost-benefit analysis tool, RESTORE, will be used in the project





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Proposed Technologies for Modeling





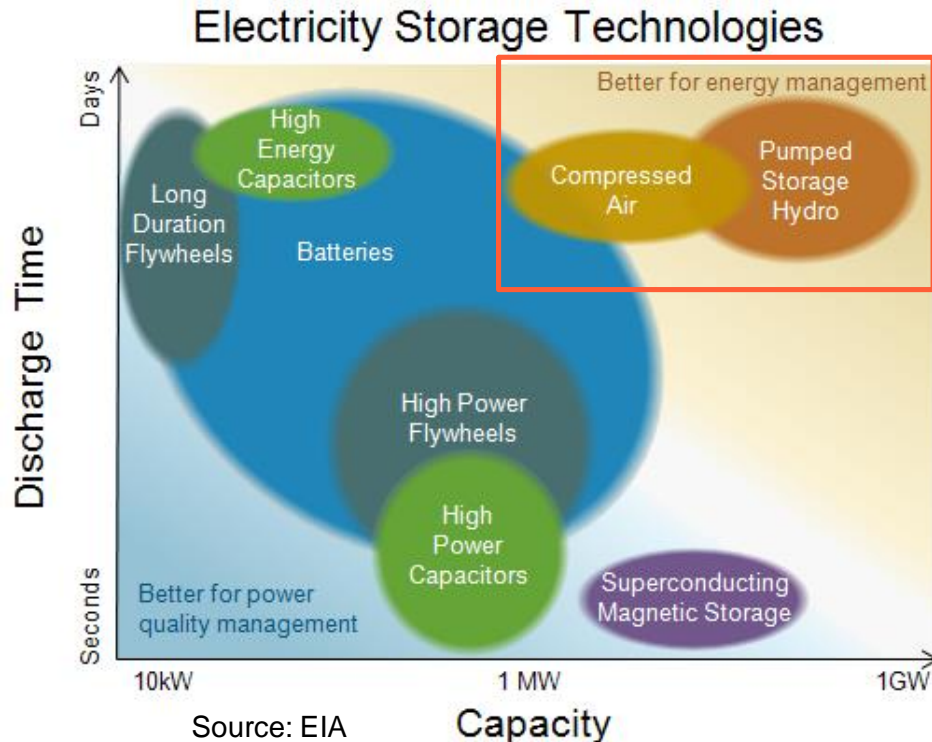
Storage Technology Selection Criteria

+ The candidate technology selection process includes the following key considerations:

1. Being able to provide high value services in the short term and in the long term
 - ✓ Long duration energy storage will be needed in the future for providing capacity during cold winter days without wind and solar
2. Low capital cost or has cost reduction potential
3. Can be deployed in Minnesota

Criteria 1: high value services in the short term and in the long term

- Frequency regulation
- System capacity (peaker replacement)
- T&D deferral
- Renewable integration



Future renewable integration needs energy storage with long duration and large capacity



Energy Storage Technology Types and the Services they can Perform

+ Can perform service

± May perform service under certain circumstances

- Cannot perform service

Types	Examples
Electro-chemical	Battery, flow batteries
Electrical	Capacitor, super capacitor
Thermal	Hot water storage, solar thermal
Mechanical	Pumped storage, compressed air, flywheel energy storage

Market Segment	Service (Value / Benefit)	Timescale	Chemical 😊	Electrical	Thermal	Mechanical 😊
Wholesale	Frequency Regulation	Seconds, minutes	+	+	-	+
	Load Following/Ramping	Seconds, minutes, hours	+	+	-	+
	Renewable Integration	Seconds, minutes, hours, days, seasons	+	+	-	+
	Spinning Reserves	Minutes, hours	+	+	-	+
	Non-Spinning Reserves	Minutes, hours	+	+	-	+
	Voltage Support	Minutes, hours	+	+	-	+
	Black Start	Minutes, hours	+	+	-	+
	Energy (arbitrage, peak shaving, shifting)	Minutes, hours, days	+	+	-	+
	Emission Reductions	Minutes, hours, days, months, seasons, years	±	±	±	±
	System Capacity or Resource Adequacy	Months, years	+	-	-	+
Transmission Deferral/Avoidance	Months, years	+	-	-	+	
Distribution	Volt/VaR Control	Seconds, minutes	+	-	-	-
	Outage Mitigation	Minutes, hours, days	+	-	-	-
	Distributed Generation integration	Minutes, hours, days	+	-	-	-
	Distribution Deferral/Avoidance	Months, years	+	-	-	-
	Distribution Congestion Relief	Months, years	+	-	-	-
Retail (Customer or Ratepayer)	Power Reliability	Seconds, minutes, hours	+	-	-	-
	Backup Power	Minutes, hours	+	-	-	-
	Utility Delivery Charge Savings	Minutes, days, months	+	-	±	-
	Retail Commodity Charge Savings	Hours, days, months	+	-	±	-

High Value Services →

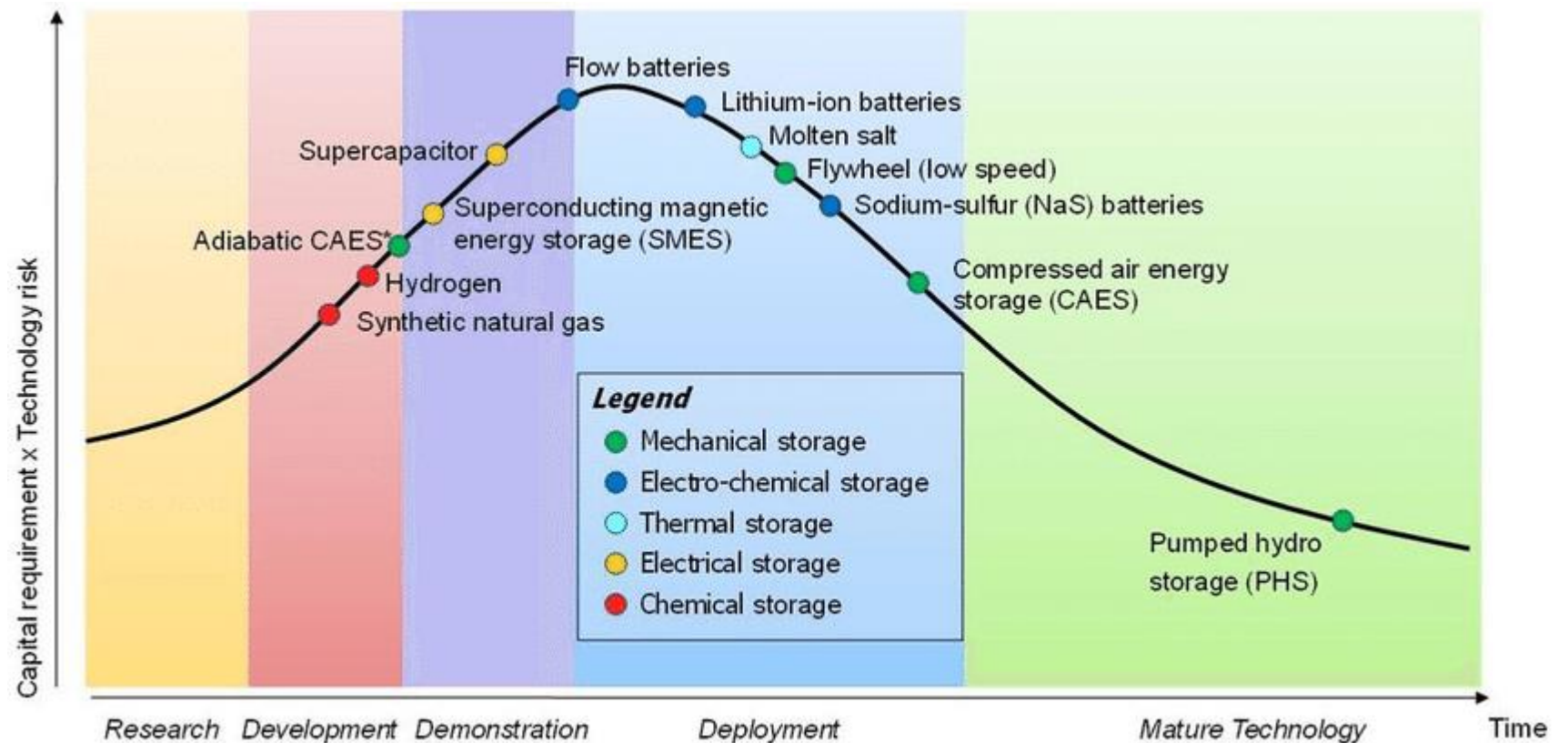


Technology Maturity

- + E3 proposes to focus on the chemical and mechanical energy storage technologies that are in the deployment or mature stages.
 - We expect to see more aggressive price reductions for technologies that are in the deployment stage

Criteria 2: low capital cost or cost reduction potential

- Technologies that are in the deployment or mature stages



Source: [The Benefits of Pumped Storage Hydro to the UK](#) (2016)



Technologies to Model

- + **The candidate technology selection process includes the following key considerations:**
 - System need in the near term and long term → chemical and mechanical energy storage
 - Cost-effective or the potential to be cost-effective in the future → technologies in the deployment and mature stages
 - Able to be deployed in Minnesota
- + **Among the remaining candidates, we selected the following three technologies to model as they represent three storage durations: short (2-4 hours), longer (6-8 hours), and very long (48 hours)**

Storage Technologies	Highlights
Lithium Ion Battery	Cost-effective, large market share
Flow Battery	No degradation; can be cheaper than Li-ion in longer durations (6 – 8 hours); cost decline potential
Compressed Air	Good for long duration (48 hours); cost decline potential, Candidate sites: Iron Ranges in Northern Minnesota



Other popular forms of energy storage

- + There are many other forms of energy storage in the market that can provide value to the system. But due to the time and budget constraints, we will not be able to include them in the study:
 - **Pumped Hydro**: there are limited opportunities and available sites for pumped hydro. The costs and operating requirements are also very specific to each site. As a result, the benefit-cost analysis result won't be representative if we analyze an example pumped hydro facility.
 - **Flywheel**: significant near-term performance or cost improvements are not expected
 - Other **load shifting** technologies, e.g. grid-connected water heater, EV managed charging, V2G, etc.



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Proposed Use Cases



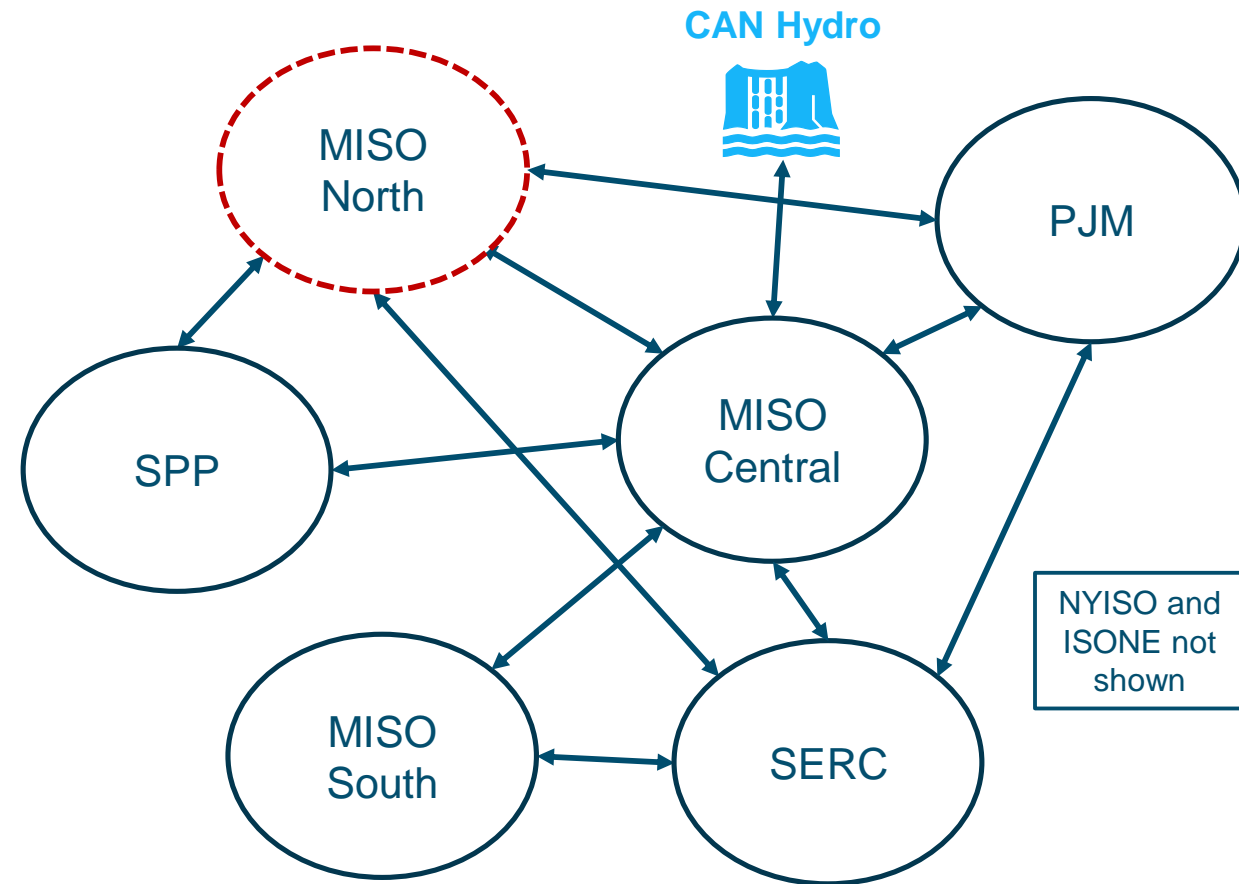
AURORA Topology and Scenarios

+ Three scenarios suggested by the Department will be investigated:

- **BAU:** Existing legislation, planned coal retirements, current-trend gas prices
- **High Gas:** 25% increase in Henry Hub prices across entire forecast
- **High MN Policy:** MN adopts Xcel's 80% by 2030, 100% by 2050 GHG reduction target

+ Assume all other states outside of MN will proceed with existing policy into the future

	Scenario	MISO North	Other	CES Targets
2030	BAU	Existing	Existing	
	High Gas	Existing	Existing	
	High MN Policy	42%	Existing	
2040	BAU	Existing	Existing	
	High Gas	Existing	Existing	
	High MN Policy	47%	Existing	





Use Cases

+ Proposed core use cases:

- Being able to access additional benefits reduces the opportunity to obtain the original benefits

Not a societal benefit

Benefit Streams →

Use Cases	Wholesale			Transmission and Distribution				BTM
	Energy arbitrage	Avoided generation capacity	Ancillary services ³	Transmission congestion relief	Transmission & Distribution deferral	Emergency services	Power quality improvement	Bill savings
Wholesale standard ¹²	✓	✓	✓					
Wholesale congestion relief	✓	✓	✓	✓				
Distribution deferral	✓	✓	✓		✓			
Emergency services	✓	✓	✓			✓		
Power quality	✓	✓	✓				✓	
BTM / Co-op bill savings	?	?						✓
PV paired with storage	✓	✓	✓					

1, Price signal for reducing GHG emission and curtailment is imbedded in the forecasted energy prices, thus there is no separate use cases for GHG emission and curtailment reduction. GHG emission and curtailment reduction will be quantified for each use case

2, Wholesale operation is assumed to use the new “continuous operation” mode proposed by MISO

3, Including ramp up/down, spin, and non-spin;



Model Runs Summary

+ Core runs for the AURORA + RESTORE process (Installation year: 2020)

- The marginal prices produced by AURORA have an hourly resolution, can be viewed as the DA prices

Sensitivities

Use Cases / Storage Technology	Li-ion	Flow Battery	CAES
Wholesale standard	✓	✓	✓
Wholesale congestion relief	✓		
Transmission and Distribution deferral	✓		
Emergency services	✓		
Power quality	✓		
BTM bill savings	✓		
PV paired with storage	✓		

Wholesale Standard	Li-ion	Flow Battery	CAES
High Natural Gas Scenario	✓	✓	✓
MN Clean Energy Scenario	✓	✓	✓
Real-time Market	✓		
2025 installation	✓		

+ Additional analysis

- Peaker replacement ability screening:** examine energy storage’s ability to provide the same services as the existing peaker fleet in MN by replicating the historical operations of the peaker fleet using energy storage



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Questions and Discussion



Questions for Stakeholders for Today's Discussion

+ Use cases

- Have we captured the important use cases? Any additional use cases we should consider?

+ Storage technologies

- Do we have a representative list of energy storage technologies to model? Any other storage technologies we should include or exclude in the study?

+ Input assumptions. Any suggestions for:

- example congested nodes to consider for congestion relief
- example distribution upgrades for deferral
- example utility rates to consider in the study, or
- other suggestions on input sources

+ We appreciate your feedback. Please submit your comments here:

- <https://forms.office.com/Pages/ResponsePage.aspx?id=h4PMTq6sZEUgQeMgVhRSYww6G-ilqMtJrpALeJkvN35URUJISTk0REI5R09UNTNZNkNEVUhaVkQ3Qy4u>



Next Steps

+ Submit your comments by 9/27 through the following link

- <https://forms.office.com/Pages/ResponsePage.aspx?id=h4PMTq6sZEUgQeMgVhRSYww6G-ilqMtJrpALeJkvN35URUJISTk0REI5R09UNTnZnkNEVUhaVkQ3Qy4u>
- We would love to hear your insights about the use cases, storage technologies, and input assumptions

+ Save the date for the next in-person workshop: 9 am to 12 pm (CT), October 11th, 2019

- Exact location to be announced
- We will be sharing the initial results with the group



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Thank You

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Appendix



AURORA Topology

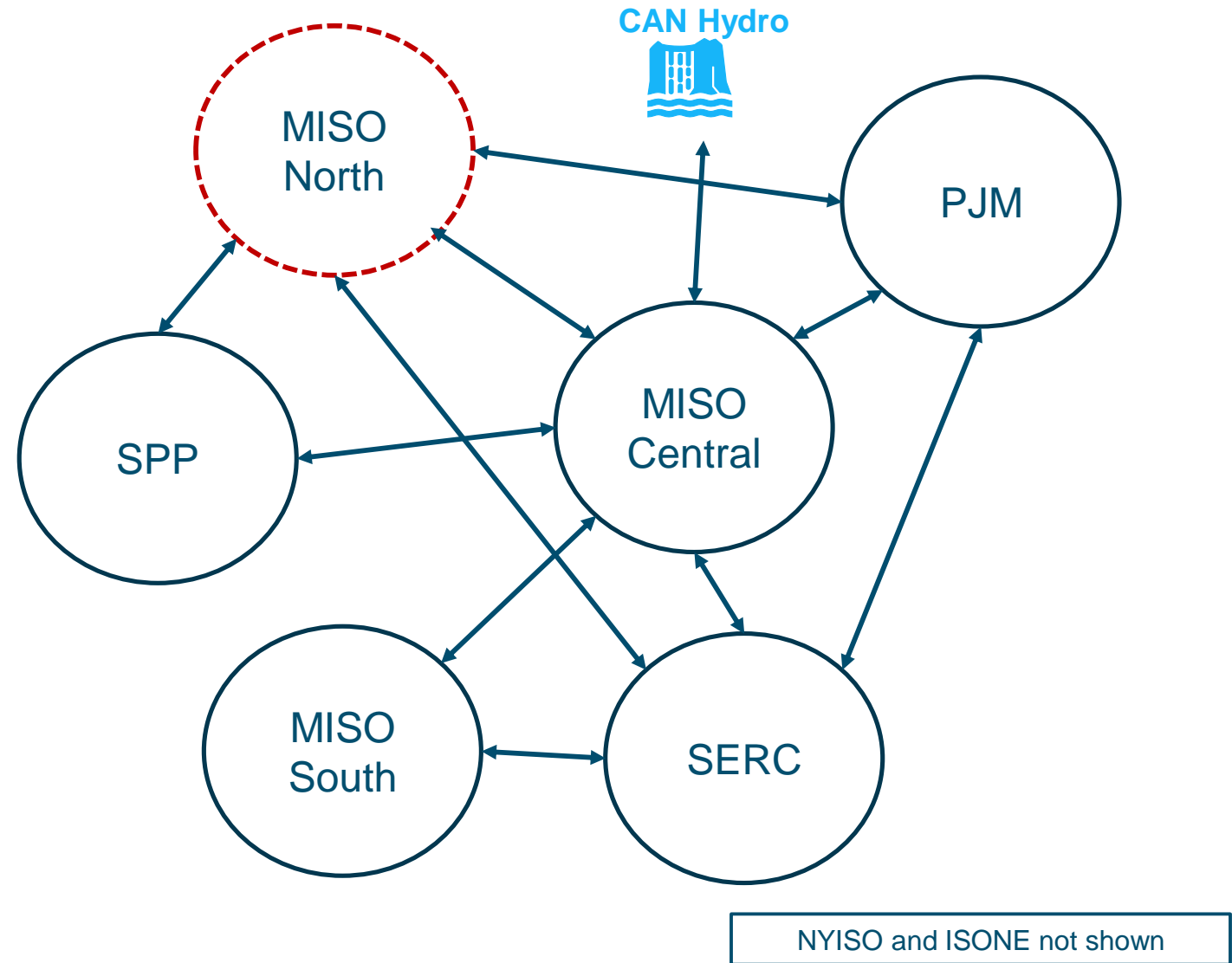
+ Eastern Interconnection is represented as aggregated zones

- MISO is split into 3 zones:
 - North (Minnesota, North Dakota, Iowa), Central, South
- Representation of the transmission network is dependent on the topology

+ MN prices will be proxied by zonal results

- Where MN policy is > neighboring states, RE build would be concentrated within state boundaries in reality

+ Full system representation captures the impacts of neighboring zones on prices





Benefits to Quantify

Benefits quantified in RESTORE	Value Streams / Inputs
Avoided generation	AURORA
Avoided generation capacity	AURORA + capacity price calculation
Impacts on ancillary services costs	AURORA + AS price forecast
Transmission and distribution facilities asset deferral or substitution	Stakeholder Inputs/Research
Impacts on transmission and distribution congestion	Stakeholder Inputs/Research
Impacts on peak power costs	AURORA
Impacts of emergency power supplies during outage	Stakeholder Inputs/Research
Impacts of curtailment of renewable energy generators	AURORA
Reduced greenhouse gas emissions	AURORA
Costs and savings to customers that deploy energy storage system	Rates with Stakeholder suggestions
Impact on the utility's ability to integrate renewable resources	AURORA
Impact on grid reliability and power quality	Stakeholder Inputs/Research
Effect on retail electric rates over the useful life of a given energy storage system compared to providing the same services using other facilities or resources	AURORA



Other benefit stream input assumptions

- + Example T&D upgrade for deferral**
 - TBD
- + Example congested node for congestion relief**
 - MISO
- + Emergency power supplies due to outage**
 - Value of Loss Load (VoLL) from NREL and outage frequency (SAIDI and SAIFI) from utilities
- + Example BTM customer retail rates for analysis**
 - e.g. large commercial customer rates with high demand charges
- + Impact on power quality**
 - TBD



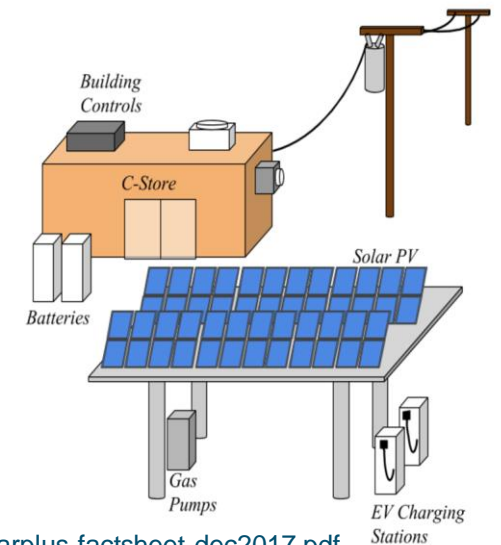
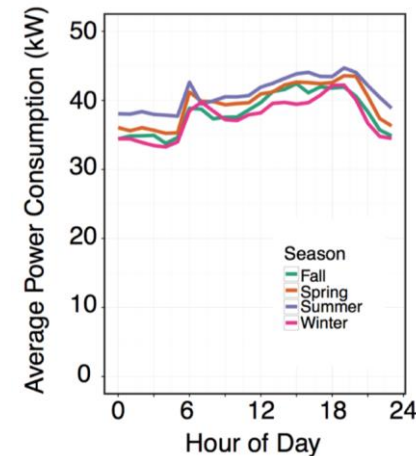
Qualitative Case Study Sites

+ A wholesale storage system for renewable integration and curtailment reduction

- Kaua'i island utility cooperative (KIUC) is committed to generating 70% of Kauai's power using renewables by 2030. Two utility-scale batteries are installed for peak capacity and renewable integration
 - In March 2017, a 52 MWh Tesla battery storage system paired with 13 MW solar was installed
 - In early 2019, KIUC and partner AES Distributed Energy opened the island's second solar plus battery storage facility in Lawai: 100 MWh battery coupled with 20 MW PV can move solar energy to the evening peak.
- As for today, 40% of Kauai's evening peak load can now be met with dispatchable solar.

+ A solar + storage system that is designed to provide emergency services during storms and wildfires and provide bill savings during normal operation

- 60 kW PV and 109 kW / 174 kWh Li-ion battery installed at a gas station in the Blue Lake Rancheria in Northern California
- The site host is on a large commercial rate with high demand charges (PG&E E19)



Source: <http://website.kiuc.coop/renewables>

More info: <https://schatzcenter.org/docs/solarplus-factsheet-dec2017.pdf>