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STRATEGIES FOR CLEAN ENERGY

White Paper Analysis of Utility-Managed, On-Site Energy Storage in Minnesota

Presentation Prepared for the Minnesota Department of Commerce, Division of Energy Resources

Presented By:
Giovanni Damato, Strategen Consulting

Analysis Support Presented By:
Ben Kaun, EPRI

Solar Powering Minnesota at the University of St. Thomas
March 7, 2014

Strategen Consulting Overview

We combine strategic thinking with deep industry expertise to create profitable businesses

Strategen Core Team

Partners

- Technology Specialists
- Structured Finance
- Controls & Smart Grid
- Project Developers
- Tariff & Rate Specialists

Clients:

- Corporations / Campuses Exploring Clean Energy Opportunities
- Clean Tech Manufacturers / Service Providers
- Private Equity / VC Firms Investing in Clean Tech

A sampling of our clients:

CESA California Energy Storage Alliance · Chevron Energy Solutions · DMB A Passion for Great Places · FMC · Hudson Clean Energy · U.S. Department of Energy

FluidicEnergy · GAF · Bosch Invented for life · Recurrent Energy · echo · Redwood City Saltworks

SunPower · Rockport Capital · 3M · Walmart · Sharp solar electricity

The Electric Power Research Institute (EPRI)

- Independent, non-profit, collaborative research institute, with full spectrum industry coverage
  - *Nuclear*
  - *Generation*
  - *Power Delivery & Utilization*
  - *Environment & Renewables*
- Major offices in Palo Alto, CA; Charlotte, NC; and Knoxville, TN

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

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Agenda

1. Executive Summary
2. Scope of Analysis
3. Results
4. Key Barriers
5. Conclustions & Recommendations
6. Q&A

Executive Summary

Context: Minnesota

» Climate change has spurred increased societal and political interest to investigate energy efficiency and renewables in Minnesota

» Distributed PV generation is one of the potential renewable options for further investigation

» Storage co-located with PV on the distribution system may have the potential to optimize economic, societal, and environmental impacts to achieve future Minnesota energy goals

» Minnesota currently has several distributed energy storage pilot projects, with many already eligible for the Conservation Improvement Program (CIP)

Context: Key Potential Benefits of Distributed Storage

» **Grid-Level Benefits**

- **Improved Economics:** avoided generation and T&D buildout
- **Increased Reliability:** improved flexibility and resiliency by providing fast, distributed reserves
- **Improved Environmental Performance:** reliably integrate higher penetration levels of solar and wind

» **Customer-Level Benefits**

- **Bill Savings:** demand charge reduction (commercial) or time-of-use energy saving
- **Backup Power:** outage mitigation, standalone or combined with PV

Executive Summary: Key Conclusions

» Utility controlled, customer sited storage in Minnesota has the potential to provide benefits to the grid greater than the storage system's costs

» Utility controlled, customer sited storage systems may need to capture **THREE** of the **FOUR** following key benefits to be economic:

a. Distribution upgrade deferral

b. Frequency regulation

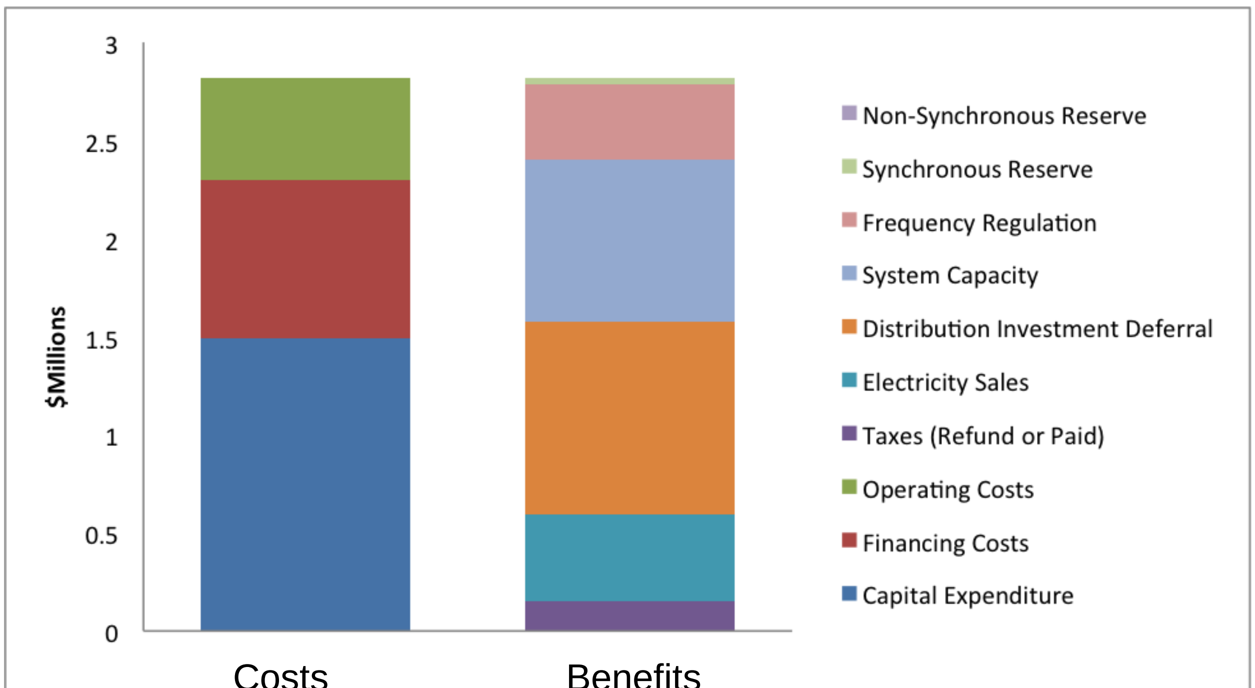
c. System capacity

d. Co-located and configured with PV to capture the Federal Investment Tax Credit (FITC)

» Customer controlled, customer sited storage that relies upon customer tariffs alone did not result in economic value without incentives

Executive Summary: Business Models

- Given that certain utility controlled, customer sited storage cases have potential positive economic returns, how might the business model work?
- One economic scenario modeled in this analysis is the example of capturing distribution upgrade deferral, MISO market participation, and system capacity:



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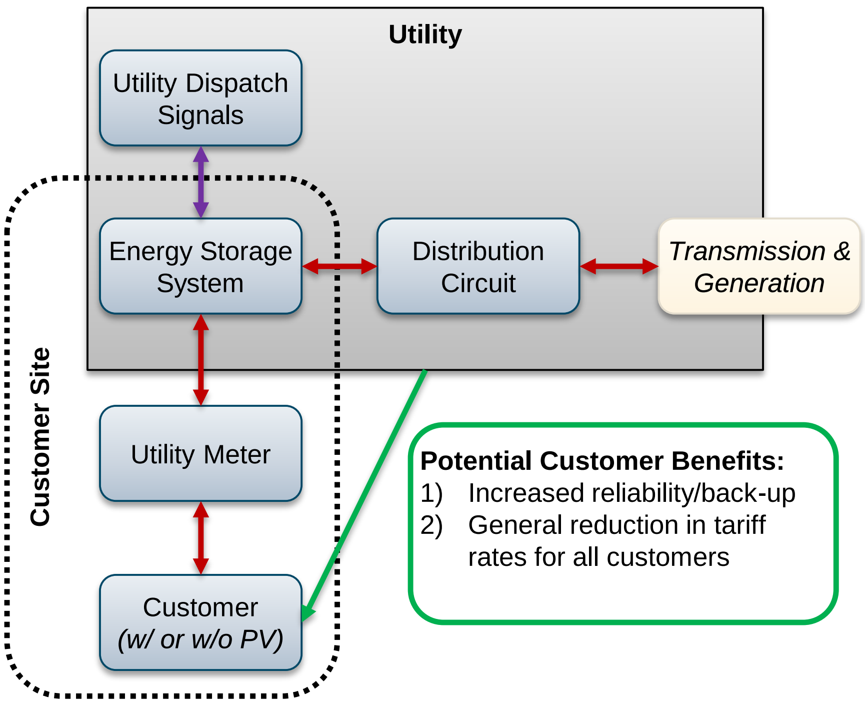
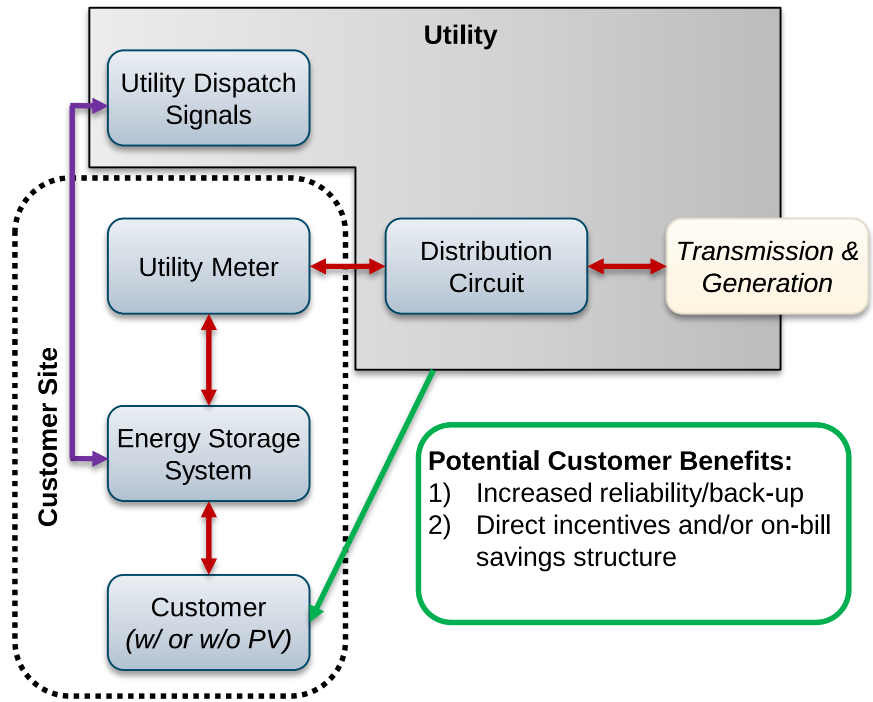
Executive Summary: Business Models (Cont.)

Using the example scenario of capturing distribution upgrade deferral, MISO market participation, and system capacity, two potential business models may work in this way:

Utility Owns & Operates Storage System



Customer Owns, Utility Operates, & Utility Provides Incentives



Electricity Flow — Communications — Benefits Transfer

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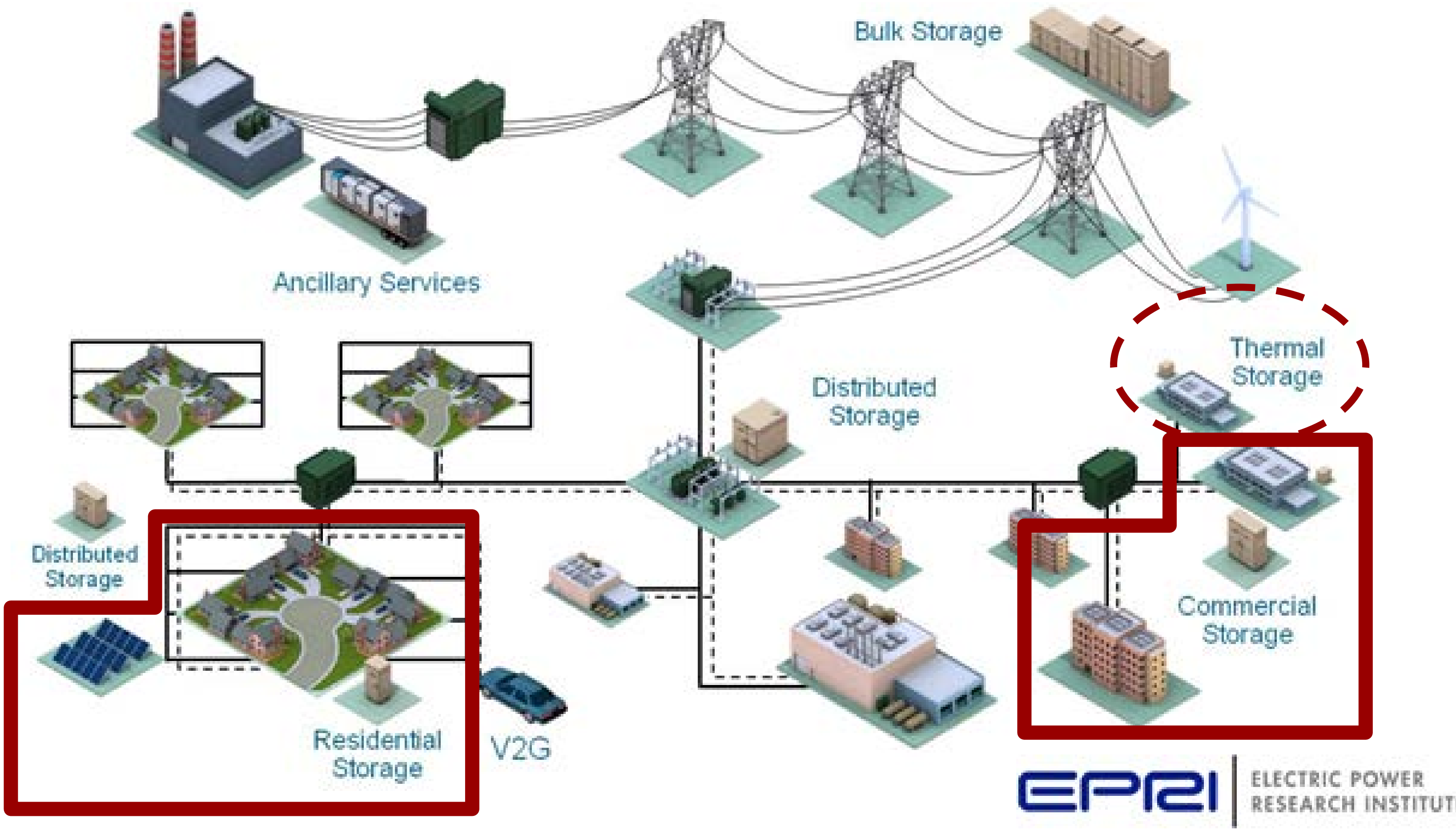
Additional Potential Benefits Outside Study Scope

- System-wide operational improvements
- Future grid services such as ramping and flexible capacity
- Improving utility reliability metrics (SAIDI/SAIFI, etc)
- Reducing GHGs
- Job creation

Scope of Analysis

Energy Storage Roles on the Grid: Study Scope

Energy storage is broad category including diverse technologies and benefits to the electric grid.



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Key Analytical Research Questions

- Does a customer sited energy storage scenario exist that is economical or nearly economical over the project lifetime from the customer or utility perspective, in the 1-3 year time frame?

- If the answer is 'yes', what are some of the key factors that affect the cost-effectiveness in those cases?

Pursuant to legislation passed in 2013 (Value of On-Site Energy Storage: MN Laws 2013, Chapter 85 HF 729, Article 12, Section 5),[1] the Minnesota Department of Commerce is required to contract with a qualified contractor to produce a white paper analysis of the potential costs and benefits of installing utility-managed, grid-connected energy storage devices in residential and commercial buildings in Minnesota.

[1] https://www.revisor.leg.state.mn.us/laws/?id=85&doctype=Chapter&year=2013&type=0

Scope

- **Project Lifetime Costs and Benefits (NPV)**

  Estimate the potential value (including project costs and benefits) of on-site energy storage devices as a load-management tool to reduce costs for individual customers and for the utility, including but not limited to reductions in energy, particularly peaking, costs, and capacity costs

- **Integration with Solar PV**

  Examine the interaction of energy storage devices with on-site solar photovoltaic devices

- **Barriers**

  Analyze existing barriers to the installation of on-site energy storage devices by utilities, and examine strategies and identify potential economic incentives to overcome those barriers

Use Cases

Four General Use Cases

1. Customer Controlled for Bill Savings
2. Utility Controlled for Distribution System Benefits
3. Utility Controlled for Distribution and Market Benefits
4. Shared Customer and Utility Controlled for Bill Savings and Market Revenue

Storage Siting Options for Each Use Case

» Standalone Storage
» Storage Integrated with Solar PV
» Residential Customer Sites
» Commercial Customer Sites

Across the four use cases, approximately fifty (50) different energy storage cases were modeled and simulated using the EPRI Energy Storage Valuation Tool (ESVT), spanning a range of input assumptions and benefit stream combinations

General Approach

Inputs

- » Utility Value - Public data, inputs from MN utilities
- » Energy Storage Technology - Public data from California PUC storage proceeding

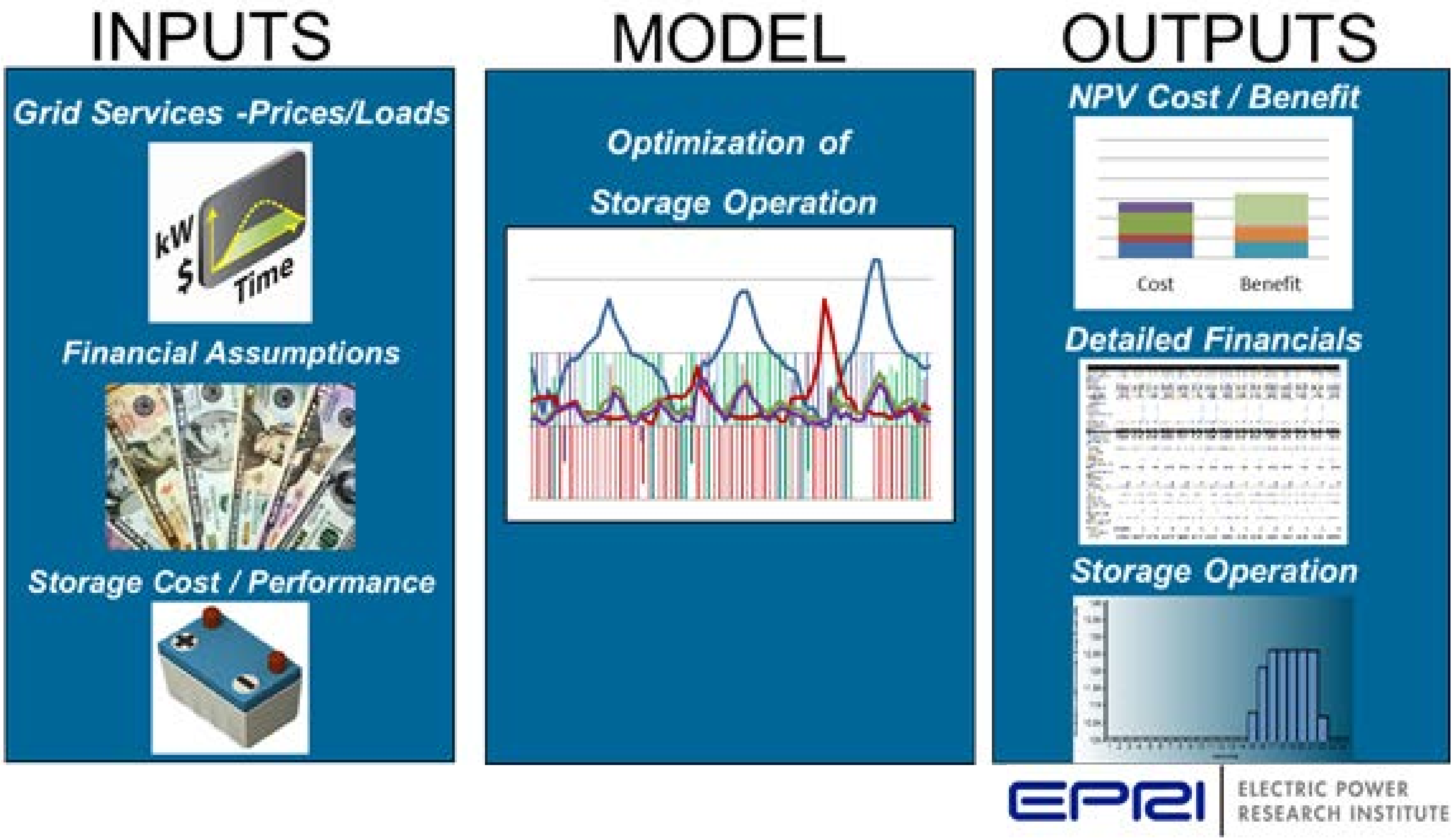
Model

- » EPRI Energy Storage Valuation Tool - Utilized previously with California PUC

Outputs

- » Project lifetime Benefit-to-Cost (B/C) ratio and Net Present Value (NPV)

Energy Storage Valuation Tool (ESVT)



1984 Cell Phone Thought Experiment

- Your employer would like you to perform an economic evaluation of new technology
- How would you determine the cost-effectiveness of new cell phone technology?

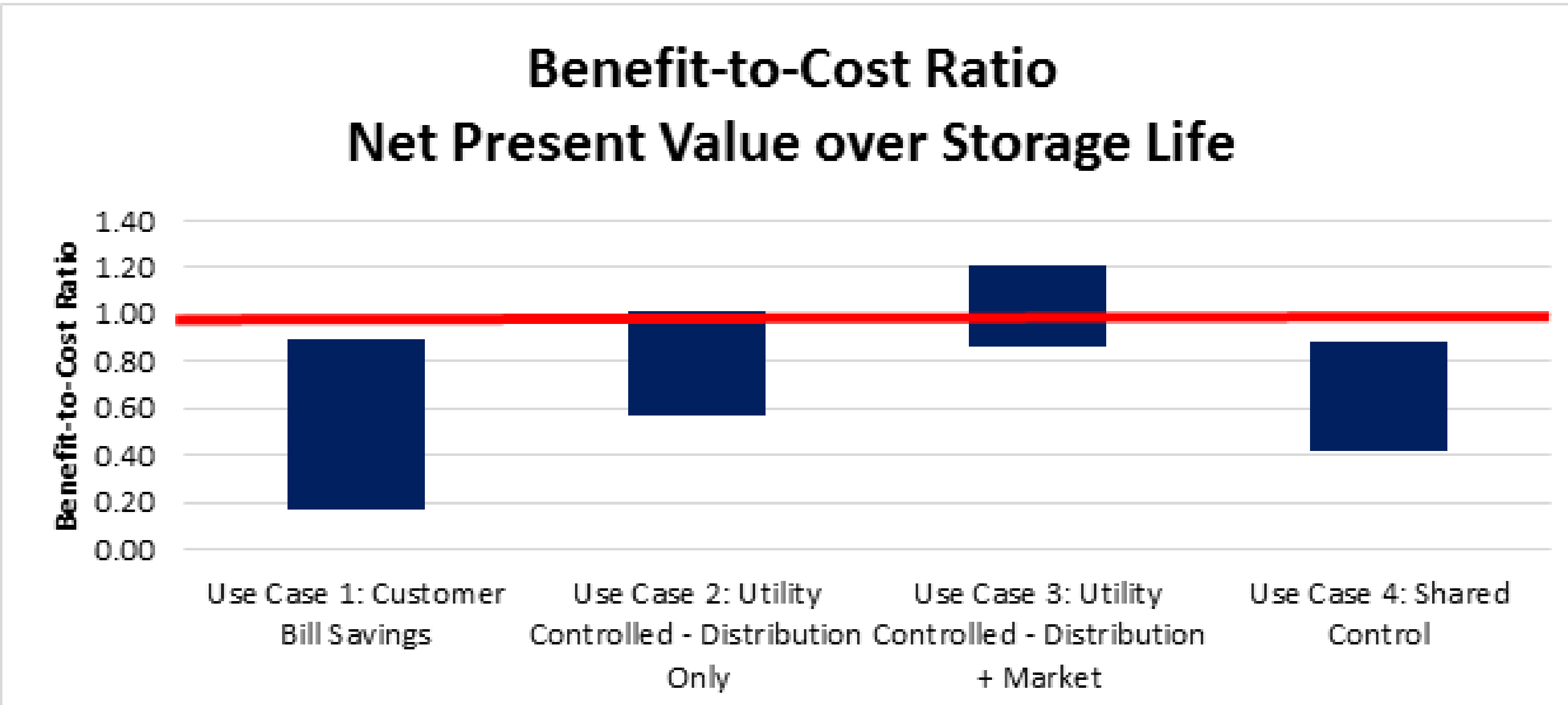
Answer: Avoided cost and incremental profit

(We know now that there is much more…)

Results

Benefit-to-Cost Ratio Ranges by Modeled Use Case

For each case, a benefit-to-cost (B/C) ratio was generated to show the direct, quantifiable fixed and variable costs and benefits, incorporating the time value of money, for the modeled project over its lifetime.



A benefit to cost ratio greater than one means that the _modeled_ benefits exceed the project costs; in other words, the net present value (NPV) was greater than zero, and for this study had an return (IRR) greater than the 11.5% discount rate

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Use Case 1 - Customer-Controlled Storage for Bill Savings

» **Storage can shift usage (from utility's perspective) from on-peak (day) to off-peak night**
  - Some customers pay varying electric rates by time-of-day

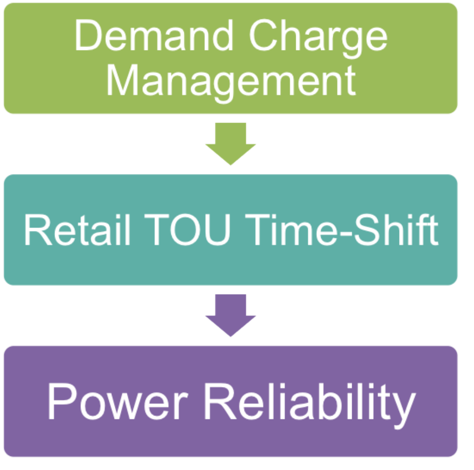
» **Storage can "shave peaks" of usage to reduce demand charges**
  - Many commercial customers pay a demand charge levied proportional to peak instantaneous monthly power draw (kW)

» **Storage may be available to provide back-up power if configured as a uninterruptible power supply (UPS)**

Use Case 1 - Modeling Approach

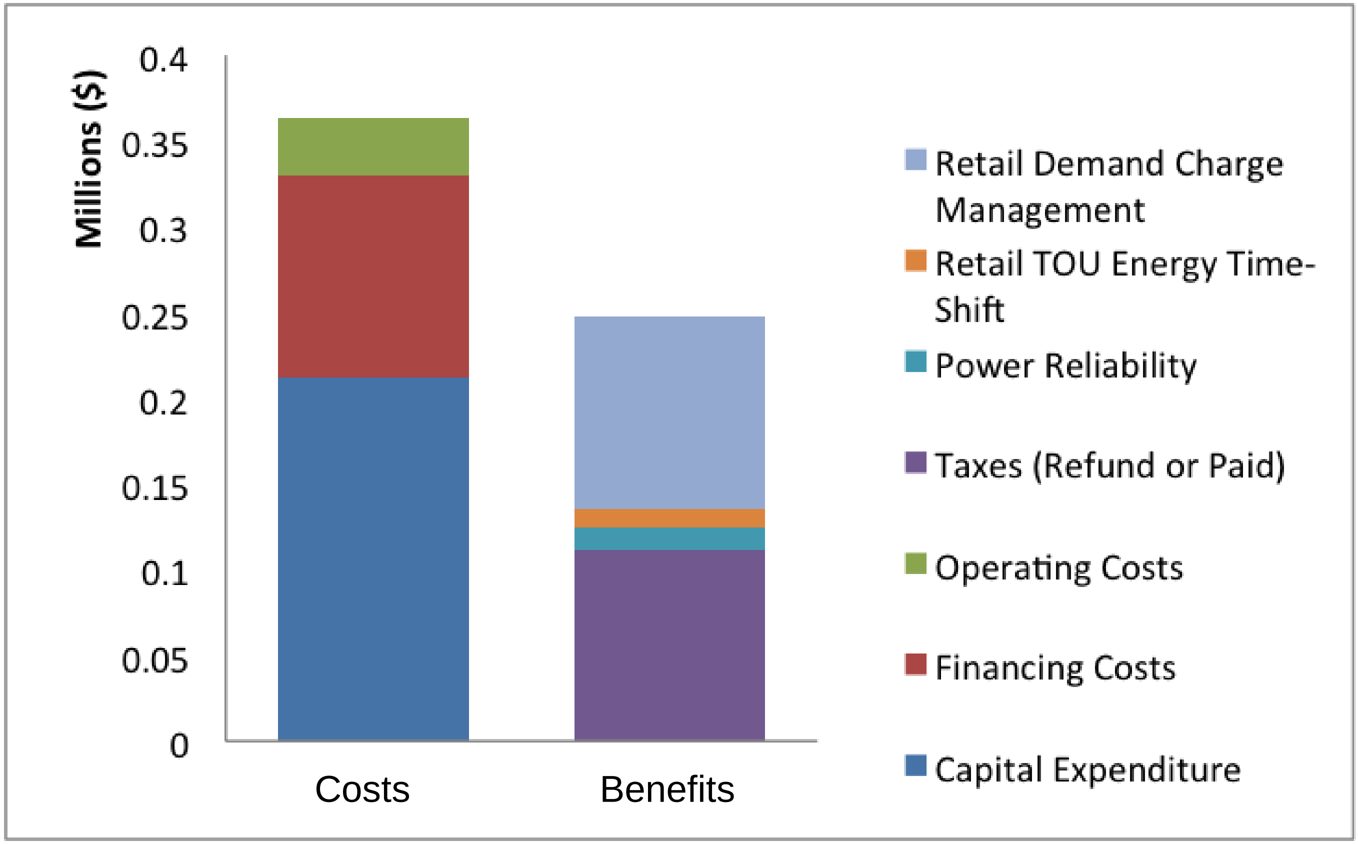
- **Screen utility tariffs for possible storage value**
  - Find high demand charges and large time-of-use (TOU) spreads
- **Collect (anonymous) customer load data in Minnesota**
  - Loads with more on-peak consumption and “peaky” peak usage
- **Model cases with highest potential for a value proposition**
  - Focus on demand charge savings, then find incremental opportunity for time-of-use shifting

ESVT Model Prioritization



Use Case 1 Results - Customer Controlled Storage

Best Case Result - University Load on Xcel GS-TOU (S) Tariff



Consistent with prior analyses showing challenging economics for customer controlled storage without additional incentives

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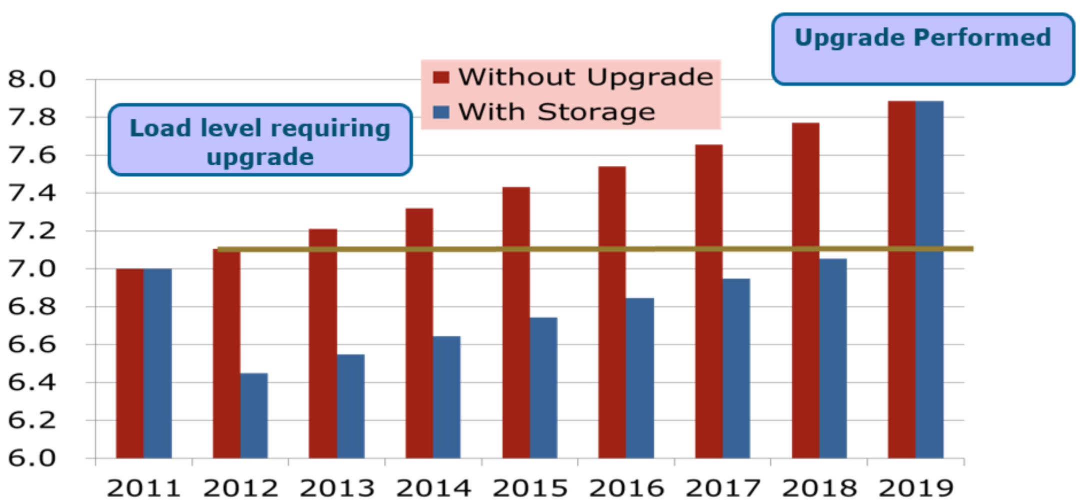
Use Case 2 - Utility Controlled for Distribution Benefits

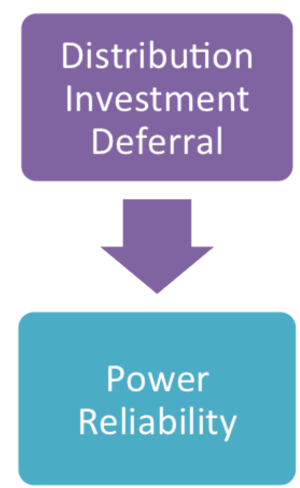
- **Storage can "shave peaks" from circuit loads to defer or avoid new capital expenditure**
  - Substation transformer upgrades can be expensive
- **Storage may also provide both real power and reactive power (VARs) to manage high penetration solar**
  - Quantification of this benefit not included -- subject of significant research
- **Storage may be available to provide utility supplied back-up power if configured as a uninterruptible power supply (UPS)**

Use Case 2 - Modeling Approach

- **Collect publicly available and utility-provided substation load and upgrade cost data**
  - Find high demand charges and large time-of-use (TOU) spreads
- **Model storage capability and value to defer upgrades driven by load growth for a few years**

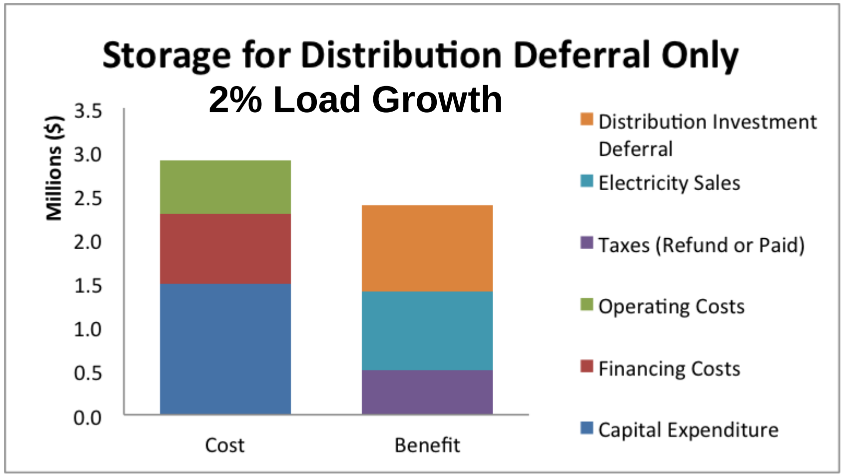


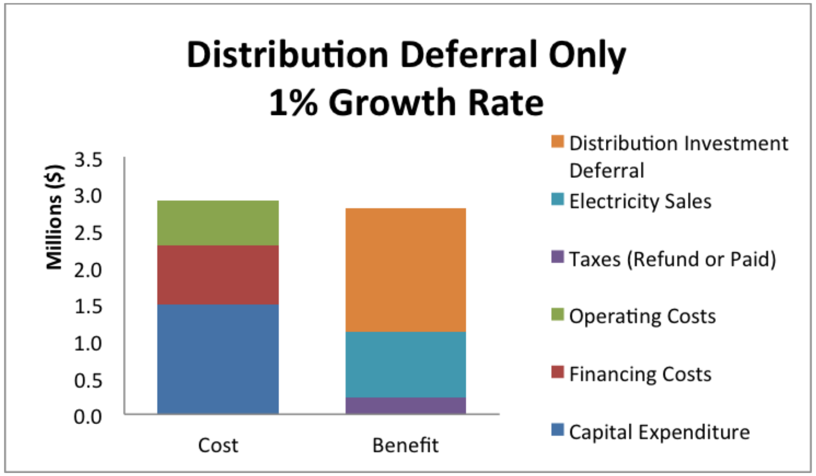
ESVT Model Prioritization



Use Case 2 Results - Storage for Distribution Benefits

Substantial value from upgrade deferral possible -- if available -- but typically insufficient as a single benefit stream to justify the costs of an energy storage system





Lower Growth Rate = Longer Deferral = More Value

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Use Case 3 - Storage for Distribution + Market Benefits

» **Builds on prior case with distribution upgrade deferral**

» **Similar "peak shaving" operation of storage may also offset the buildout of new generation**

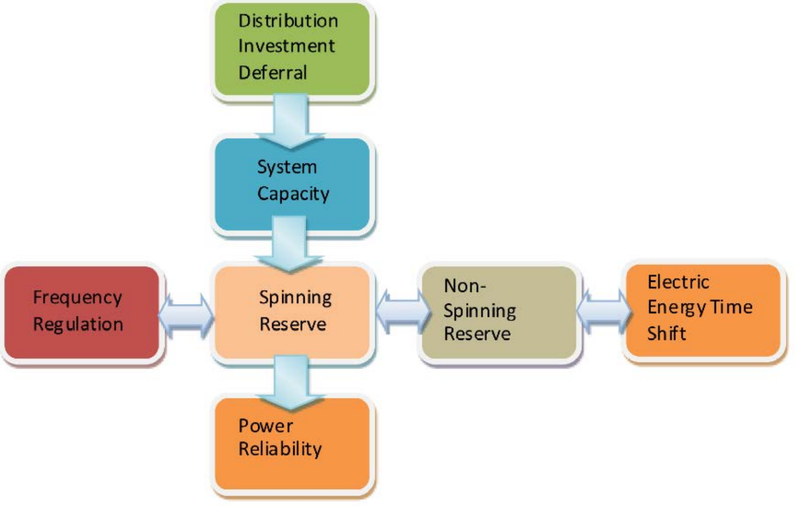
» **Wholesale energy and ancillary services markets provide additional revenue**

- day-ahead energy market
- frequency regulation
- spinning & non-spinning reserve

Use Case 3 - Modeling Approach

- » Utilize Distribution approach from Use Case 2
- » Collect historical market energy and ancillary service market data from MISO
- » Prioritize storage operation for local and long-term planning needs first, system and operational scheduling opportunities later
- » Co-optimize for market service profitability

ESVT Model Prioritization



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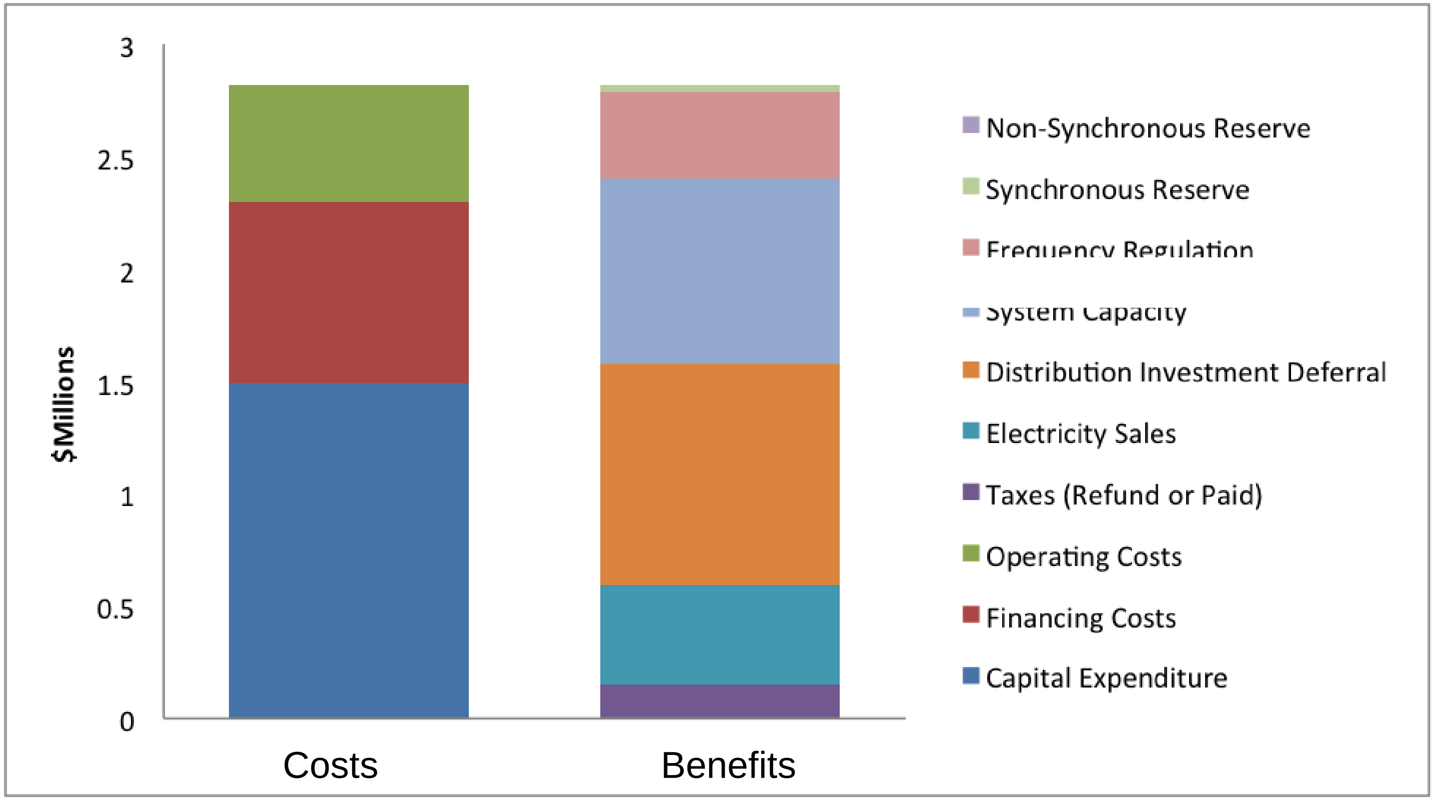
Use Case 3 - Results



- **Benefit stacking can provide a cost-effective outcome with simultaneous need for generation & distribution upgrades, and access to operational market benefits**
- **Technical and regulatory challenges possible**

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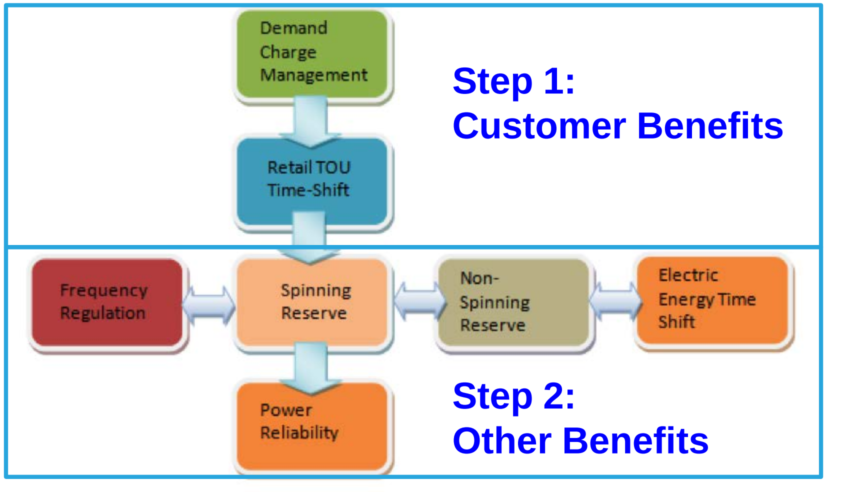
Use Case 4 - Customer + Utility Shared Control

- Customer demand bill savings top priority
- Potential to capture FITC when properly co-located and configured with a PV system
- Market ancillary service value off-peak when customer isn't using it

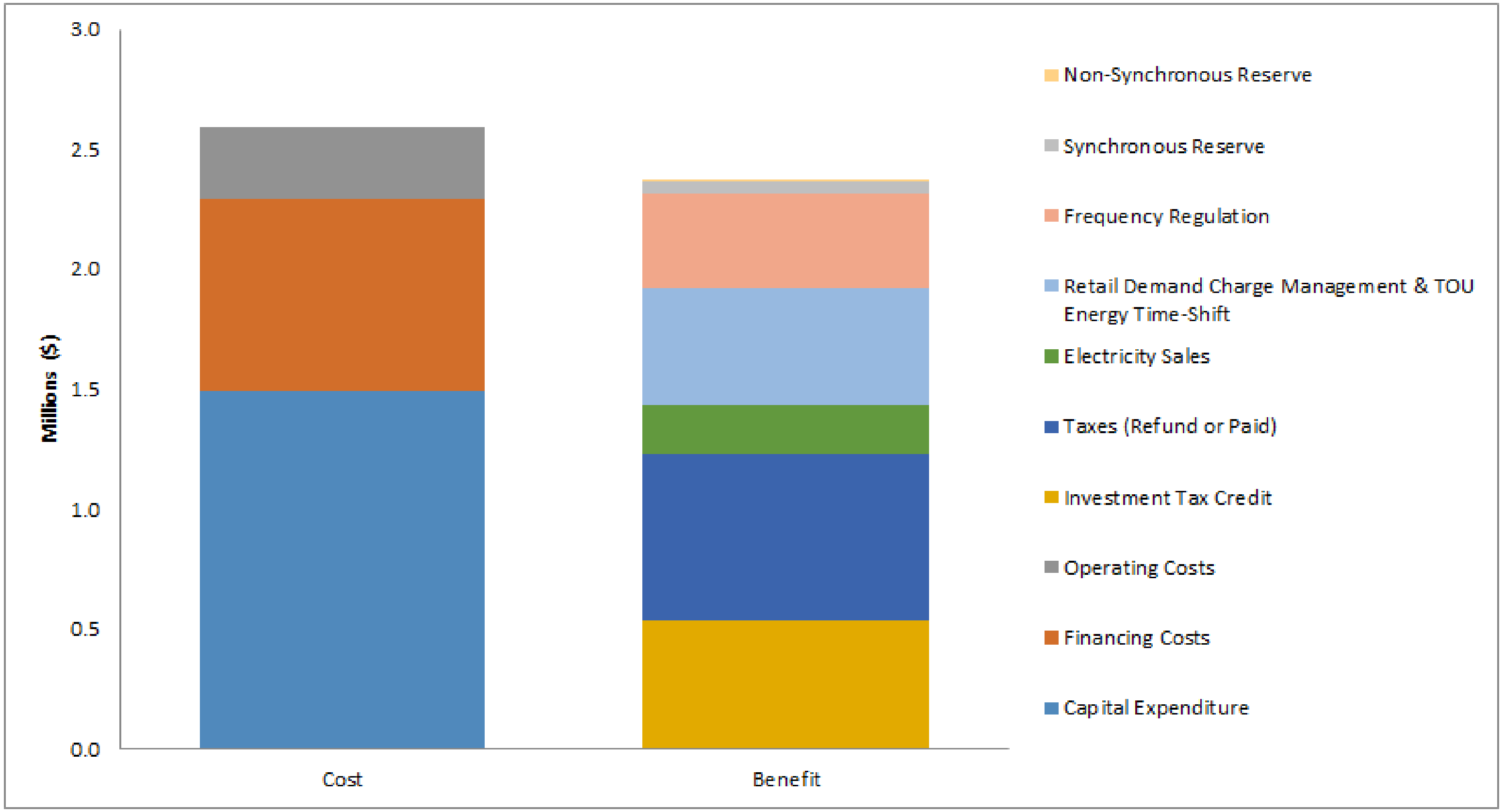
Use Case 4 - Modeling Approach

- **Use foundational data sources from Use Case 1 & 3**
- **Model customer bill savings-only operation**
  - Don’t allow utility or 3rd party control at those times
- **Simulate the residual value of additional market revenue when storage is idle**
  - Took conservative approach with “shoulder hours” to ensure storage is available to recharge for customer need

ESVT Model Prioritization



Use Case 4 - Results



- **Market participation benefit stacking in conjunction with PV (and access to the FITC) significantly improves the economics as compared to the Customer Only Control case (Use Case #1)**
- **Technical and regulatory challenges possible**

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Overall Modeling Conclusions

- **Current tariffs in Minnesota do not show clear customer ownership benefit**
- **Cost-effective cases stacked multiple major benefits, including distribution deferral, system capacity, frequency regulation, and solar investment tax credit**
  - Benefit stacking may have near-term technical and regulatory challenges
- **Existence of distribution deferral and system capacity is limited by "need", defined in utility IRP and distribution planning processes**
  - Typically requires load growth
- **New storage "need" may emerge when new flexibility constraints arise from large penetrations of wind & solar**
  - California is working to develop new tools and methods to plan for flexibility need and assess resources

Scope Limitations

1. Investigated a subset of possible battery storage technology configurations. Did NOT include:
   - Flow batteries
   - Flywheels
   - Traditional lead acid batteries
   - Modular compressed air energy storage (CAES)
2. Modeling was not exhaustive of all potential uses or scenarios
3. Excluded modeling of thermal energy storage (e.g. electric water heaters)
4. Excluded indirect or societal benefits (e.g. GHG reductions, job creation, improved grid operations, etc.)
5. Excluded conventional Uninterruptible Power Supply (UPS) case
6. Excluded secondary impacts of energy storage deployments to market prices (e.g. price suppression from competition)

Full Results in Minnesota Dept of Commerce Report

- Over 50 cases investigated across the 4 use cases
- Links to White Paper & Appendices:
  - http://mn.gov/commerce/energy/images/MNStorageStudy-2014-01-03-final.pdf
  - http://mn.gov/commerce/energy/images/MNStorage-Study-Model-Inputs-2013-12-27.xls
  - http://mn.gov/commerce/energy/images/MNStorage-Study-Model-Outputs-2013-12-27.xls

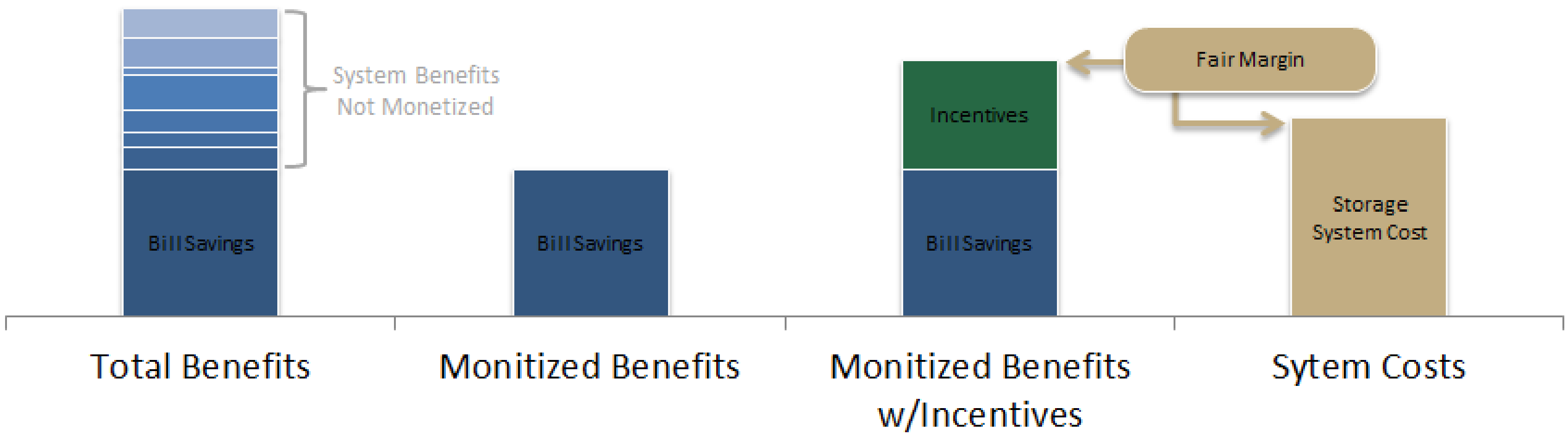
Key Barriers

Key Energy Storage Barriers

1. **Grid Planning**
   - Utilities need a way to start looking for opportunities for energy storage integration
   - Tools and methods need to be developed to enable utilities to do so
2. **Deployment & Interconnection**
   - System operators should expand and clarify eligibility for retail interconnection with local distribution utilities
   - Clarify MISO wholesale market interconnection procedures
   - Utility liability management associated with utility-owned storage systems sited on customer premises
3. **Monetization**
   - Through interconnection and market participation, storage system owners and operators may not be able to monetize all of the benefit streams that their storage systems provide
   - This can include greater system benefits (i.e. distribution upgrade deferral) as well as market services

Incentives—Example of Monetization of Benefits

Distributed storage has value streams that cannot be directly monetized by the end user. Incentives help align current costs & benefits.



Incentive Program Design

- » Performance Based Incentives ($/kWh)
- » Capacity Based Incentives ($/kW)

Example: Self-Generation Incentive Program (SGIP) by the California Public Utility Commission (hybrid $/kW and $/kWh structure)

Conclusions & Recommendations

Key Conclusions

1. Energy storage has the potential to provide multiple sources of value for customers and utilities.
2. Utility controlled, customer sited storage in Minnesota has the potential to provide benefits to the grid greater than the system's cost.
3. Customer sited commercial and residential storage that relies upon customer tariffs were not able to achieve a benefit to cost greater than one.
4. Reliability (backup power) and voltage support service benefits of energy storage, while conceptually attractive, have not been found to be materially sufficient to significant impact the cost-effectiveness of energy storage.
5. Certain storage benefits can vary by utility type. Energy storage should be modeled according to the benefits within a specific utility and to best suit each utility's characteristics.

Recommendations

1. Conduct Further Studies
2. Establish Utility Planning Procedures
3. Establish Pilot Projects
4. Perform Financial Due Diligence
5. Establish Clear MISO Processes
6. Consider Alternative Rate Structures
7. Define System Ownership/Control
8. Further Evaluate Standalone Energy Storage Located at Distribution Substations

Questions?

Links to White Paper & Appendices:

- http://mn.gov/commerce/energy/images/MNStorageStudy-2014-01-03-final.pdf
- http://mn.gov/commerce/energy/images/MNStorage-Study-Model-Inputs-2013-12-27.xls
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2150 Allston Way, Suite 210
Berkeley, CA 94704
(510) 665-7811
www.strategen.com

Appendix

Appendix I:
About Strategen & EPRI

Strategen Consulting Overview

We combine strategic thinking with deep industry expertise to create profitable businesses

Strategen Core Team

Partners

- Technology Specialists
- Structured Finance
- Controls & Smart Grid
- Project Developers
- Tariff & Rate Specialists

Corporations / Campuses Exploring Clean Energy Opportunities

Clean Tech Manufacturers / Service Providers

Private Equity / VC Firms Investing in Clean Tech

A sampling of our clients:

CESA California Energy Storage Alliance · Chevron Energy Solutions · DMB A Passion for Great Places · FMC · Hudson Clean Energy · U.S. Department of Energy

Fluidic Energy · GAF · Bosch Invented for life · Recurrent Energy · echo · Redwood City Saltworks

SunPower · Rockport Capital · 3M · Walmart · Sharp solar electricity

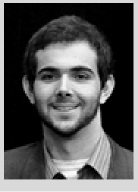
Strategen Team

Chris Edgette, Senior Director
- Extensive product development, engineering and field installation experience
- Founded and managed the Commercial Projects Division for SolarCity. Previously served as SolarCity's Director of Field Engineering
- Led Construction Management for PowerLight, directed worldwide installations and brought to market a successful rooftop solar system

Giovanni Damato, Senior Manager
- Focused on developing the value proposition and strategic implications of Solar PV, Solar Thermal, and Advanced Energy Storage for a wide range of key stakeholders
- Prior to Strategen, was Field Engineer for Granite Construction on Las Vegas Monorail project. Also founded home construction business and certified CA Class B General Contractor
- MBA from Stanford GSB, BS in Civil Engineering from Cal Poly, San Luis Obispo

Amanda Coggins, Associate
- Experienced in renewable energy technologies and policies, environmental sustainability, and energy efficiency
- Prior to Strategen worked for a variety of engineering companies in Washington, D.C. supporting private sector and federal government clients, including the DOE and DOD
- B.S. in Mechanical Engineering from Virginia Tech; M.S. in Environmental Systems - Energy, Technology, and Policy from Humboldt State University; Certified LEED® Accredited Professional

Janice Lin, Founder and Managing Partner
- Founded Strategen in 2005. Also co-founded the California Energy Storage Alliance in 2009
- More than a decade of clean energy strategy and market development experience
- Prior to Strategen, VP of Product Strategy and VP of Business Development at PowerLight. Former strategy consultant with Booz Allen and Hamilton
- MBA from Stanford GSB, BS from Wharton at the University of Pennsylvania



Alex Ghenis, Senior Analyst
- Focused on policy development for energy storage grid applications, public education through assorted media, and business positioning strategies
- Prior to Strategen, worked on internal sustainability strategies for US EPA Region 9. Also has extensive disability rights and media experience, and is a regular contributor to *Life in Action* magazine.
- MPP from the Goldman School of Public Policy at UC Berkeley, BA in Geography from UC Berkeley

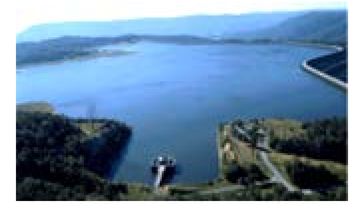
The Electric Power Research Institute (EPRI)

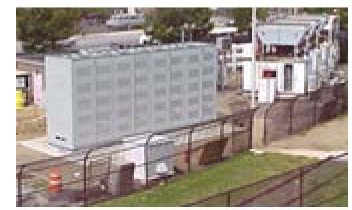
- Independent, non-profit, collaborative research institute, with full spectrum industry coverage
  - *Nuclear*
  - *Generation*
  - *Power Delivery & Utilization*
  - *Environment & Renewables*

- Major offices in Palo Alto, CA; Charlotte, NC; and Knoxville, TN

EPRI Energy Storage Program Mission

- Facilitate the development and implementation of storage options for the grid.
- Understanding storage technologies
- Identifying and calculating the impacts and value of storage
- Specification and testing of storage products
- Implementation and deployment of storage systems





EPRI Team

Ben Kaun, EPRI Project Lead

Sr. Project Engineer, Energy Storage

- Energy Storage Program Analysis Lead
- 7 years energy storage experience; R&D, testing, and analysis
- M.S. Stanford in Management Science & Engineering
- B.S. Univ of Illinois in Systems Engineering

Stella Chen

Project Engineer, Energy Storage

- 2 years grid energy storage experience with EPRI
- EPRI Energy Storage Valuation Tool modeling expert
- B.S. Pomona College in Economics and Mathematics

Ram Narayanamurthy

Sr. Project Manager, Energy Efficiency

- Over 10 years efficiency experience, building modeling, thermal storage
- Developed Ice Energy Ice Bear thermal energy storage product
- M.S. Penn State MechE, B.S. Indian Institute of Technology MechE

Appendix II:
Energy Storage Background

Energy Storage Technologies

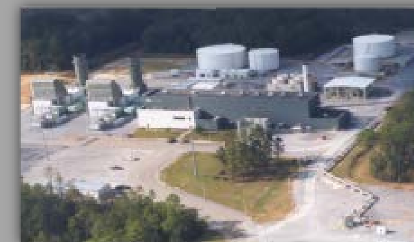
Electrochemical Storage

(Batteries)

Mechanical Storage

(Flywheel)

Bulk Mechanical Storage



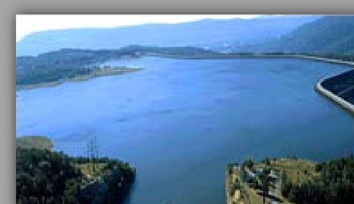
(Compressed Air)

Thermal Storage

(Ice)

(Molten Salt)

Bulk Gravitational Storage



(Pumped Hydro)

(Gravel)

Technologies Modeled in This Analysis

Technologies Modeled

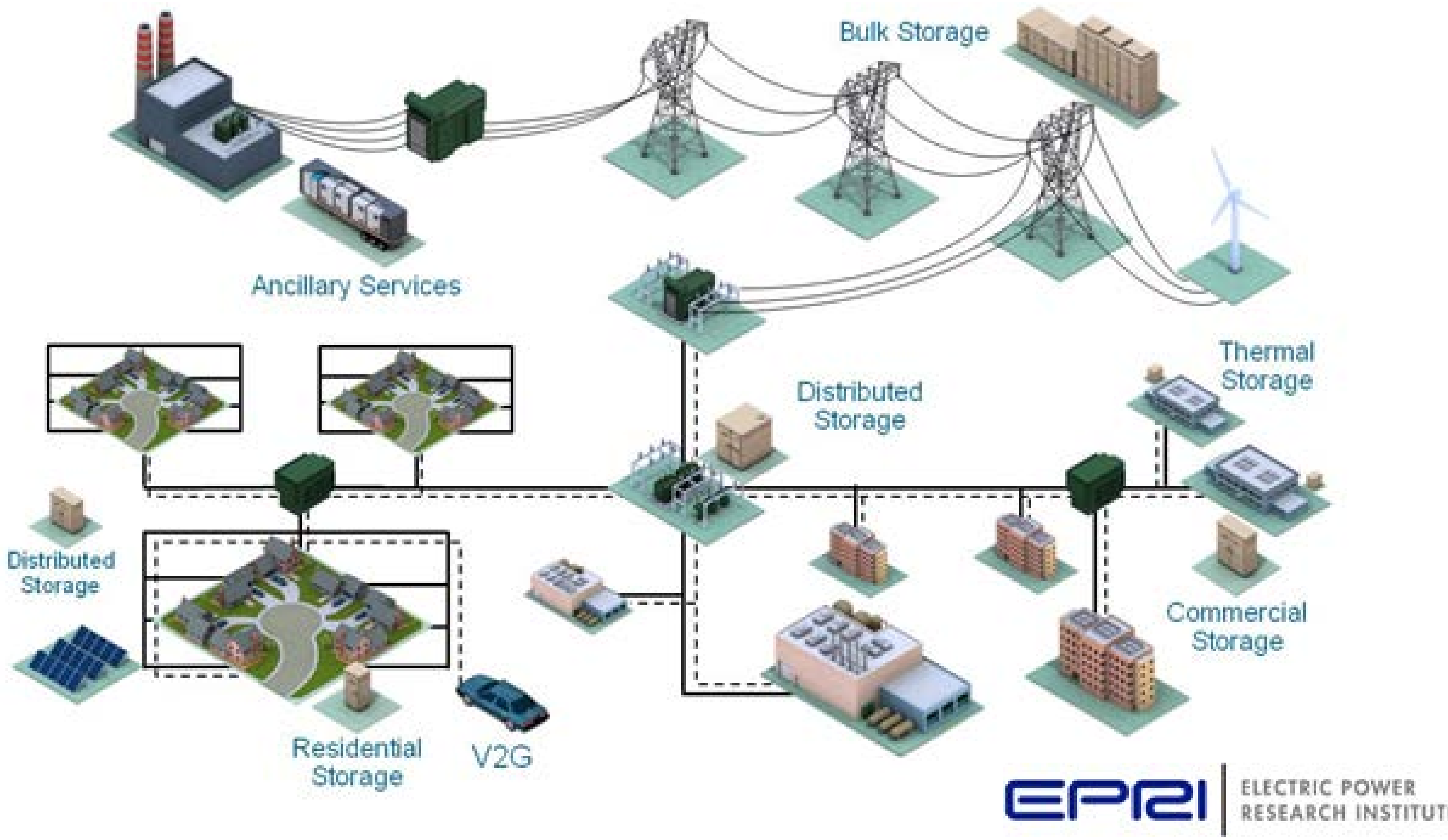
- Lithium ion batteries
- Advanced lead acid batteries
- Sodium nickel chloride batteries

Potential Customer Sited Technologies Not Modeled

- Flow batteries
- Flywheels
- Traditional lead acid batteries
- Modular compressed air energy storage (CAES)

Energy Storage Roles on the Grid

Energy storage is broad category including diverse technologies and benefits to the electric grid.



Identified Energy Storage Grid Services

Bulk Energy Services		Transmission Infrastructure Services
Electric Energy Time-Shift (Arbitrage)		Transmission Upgrade Deferral
Electric Supply Capacity		Transmission Congestion Relief
Ancillary Services		**Distribution Infrastructure Services**
Regulation		**Distribution Upgrade Deferral**
Spinning, Non-Spinning and Supplemental Reserves		*Voltage Support*
Voltage Support		**Customer Energy Management Services**
Black Start		Power Quality
Other Related Uses		**Power Reliability**
		Retail Electric Energy Time-Shift
		Demand Charge Management

Source:DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA. 2013.

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Appendix III: Results Details

Use Case 1 - Model Inputs

Use Case #1: Customer Controlled Energy Storage for Bill Savings

Category	Assumption	Value
Financial Inputs	Financial Model	Discounted Project Cash Flows
	Discount Rate	11.47%
	Inflation Rate	2%
	Fed Taxes	35%
	State Taxes	9.80%
Customer Site Data	Customer Type	Commercial (university)
	Tariff	Xcel GS-TOU (S)
	Tariff Escalation Rate	4%
	Peak Load (kW)	3012.18
	Average Load (kW)	1365.47
	Load Factor	45%

		Battery
Technology Cost / Performance	Nameplate Capacity (MW)	0.5
	Nameplate Duration (hr)	4
	Capital Cost ($/kWh) -Start Yr Nominal	500
	Capital Cost ($/kW) - Start Yr Nominal	2000
	Project Life (yr)	20
	Roundtrip Efficiency	83%
	Variable O&M ($/kWh)	0.25
	Fixed O&M ($/kW-yr)	15
	Replacement Cost ($/kWh)	250

Use Case 1 - Benefit to Cost Ratio

Use Case #1: Customer Controlled Energy Storage for Bill Savings

Customer Class	Customer Load	Tariff	Additional Sensitivity Considerations	Benefit-to-Cost Ratio
Commercial	Big Box Retail	Xcel GS (S)		0.54
	Big Box Retail	Xcel GS-TOU (S)		0.49
	School	Xcel GS (S)		0.56
	School*	Xcel GS (S)	Tax Benefits Excluded	0.17
	School	Xcel GS-TOU (S)		0.54
	University	Xcel GS-TOU (S)		0.66
	University	Xcel GS-TOU (S)	Reliability Benefit Included	0.68
	Hospital	Xcel GS-TOU (S)		0.58
	University	Connexus General Commercial		0.63
Residential	No Electric Space Heating	Xcel Residential – TOU		0.31
	Electric Space Heating	Xcel Residential – TOU		0.30

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Case 1 - Benefit to Cost Ratio (cont.)

Use Case #1: Customer Controlled Energy Storage for Bill Savings

Base Load & Tariff Combination	PV System Assumptions	FITC & Tax Considerations	Benefit-to-Cost Ratio
University Load Xcel GS-TOU (S)	800 kWp 20deg fixed tilt 180deg azimuth	FITC: N/A Depreciation: 7yr MACRS Other Tax Benefits: Included	0.66
		FITC: 30% Depreciation: 5yr MACRS Other Tax Benefits: Included	0.88
		FITC: 30% Depreciation: 5yr MACRS Other Tax Benefits: Excluded	0.55

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Case 1 - Net Present Value

Use Case #1: Customer Controlled Energy Storage for Bill Savings

Net Present Value Over Project Life		
	Cost	**Benefit**
Capital Expenditure (Equity)	212,534	0
Financing Costs (Debt)	117,508	0
Operating Costs	33,140	0
Taxes (Refund or Paid)	0	111,525
Power Reliability	0	13,454
Retail TOU Energy Time-Shift	0	10,281
Retail Demand Charge Management	0	112,358
Total	363,182	247,618
B/C ratio		**0.68**

Use Case 2 - Model Inputs

Use Case #2: Utility-Controlled for Distribution System Benefits

Category	Assumption	Value
Financial Inputs	Financial Model	Discounted Project Cash Flows
	Discount Rate	11.47%
	Inflation Rate	2%
	Fed Taxes	35%
	State Taxes	9.80%
Distribution	Base Year Reference	2012
	Distribution Load Peak (MW)	13.8
	Distribution Load Growth Rate	2%

		Battery (Utility Sited)
Technology Cost / Performance	Nameplate Capacity (MW)	1
	Nameplate Duration (hr)	4
	Capital Cost ($/kWh) -Start Yr Nominal	500
	Capital Cost ($/kW) - Start Yr Nominal	2000
	Project Life (yr)	20
	Roundtrip Efficiency	83%
	Variable O&M ($/kWh)	0.25
	Fixed O&M ($/kW-yr)	15
	Replacement Cost ($/kWh)	250

Use Case 2 - Benefit to Cost Ratio

Use Case #2: Utility-Controlled for Distribution System Benefits

Scenario	Load Growth	Upgrade Cost	Benefit-to-Cost Ratio
Commercial - 13.8kV	1%	$176-384/kW (Xcel Provided)	1.01
Commercial - 13.8kV	2%	$269/kW (90th percentile)	0.83
Commercial - 13.8kV	1%	$269/kWh (90th percentile)	0.97

Base Load & Tariff Combination	PV System Assumptions	FITC & Tax Considerations	Benefit-to-Cost Ratio
Commercial - 13.8kV with Reliability Benefits	800 kWp DC 10-30deg fixed tilt 150-210deg azimuth	FITC: N/A Depreciation: 7yr MACRS Other Tax Benefits: Included	0.824
		FITC: 30% Depreciation: 5yr MACRS Other Tax Benefits: Included	0.977

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Case 2 - Net Present Value

Use Case #2: Utility-Controlled for Distribution System Benefits

Net Present Value Over Project Life		
	Cost ($)	**Benefit ($)**
Capital Expenditure	1,491,428	0
Financing Costs	803,588	0
Operating Costs	605,845	0
Taxes (Refund or Paid)	0	513,526
Electricity Sales	0	896,060
Distribution Investment Deferral	0	979,608
Totals	2,900,860	2,389,193
Benefit to Cost Ratio		**0.82**

Use Case 3 - Model Inputs

Use Case #3: Utility-Controlled (Distribution + Market)

Category	Assumption	Value
Financial Inputs	Financial Model	Discounted Project Cash Flows
	Discount Rate	11.47%
	Inflation Rate	2%
	Fed Taxes	35%
	State Taxes	9.80%
Distribution	Distribution Load Peak (MW)	13.8
	Distribution Load Growth Rate	2%

Use Case 3 - Model Inputs (cont.)

Use Case #3: Utility-Controlled (Distribution + Market)

Category	Assumption	Value
System / Market	Base Year Reference	2012
	Real Fuel Escalation Rate	2%
	Energy & A/S Escalation Rate	3%
	Yr 1 capacity value ($/kW-yr)	$40
	Net CONE value ($/kW-yr)	$141
	Resource Balance Year	2018
	Mean RT Energy Price ($/MWh)	31.03
	Mean DA Energy Price ($/MWh)	32.01
	Mean Reg Price ($/MW-hr)	9.81
	Mean Spin price ($/MW-hr)	3.38
	Mean Non-Spin price ($/MW-hr)	1.45

Use Case 3 - Model Inputs (cont.)

Use Case #3: Utility-Controlled (Distribution + Market)

		Battery (Utility Sited)
Technology Cost / Performance	Nameplate Capacity (MW)	1
	Nameplate Duration (hr)	4
	Capital Cost ($/kWh) -Start Yr Nominal	500
	Capital Cost ($/kW) - Start Yr Nominal	2000
	Project Life (yr)	20
	Roundtrip Efficiency	83%
	Variable O&M ($/kWh)	0.25
	Fixed O&M ($/kW-yr)	15
	Replacement Cost ($/kWh)	250

Use Case 3 - Benefit to Cost Ratio

Use Case #3: Utility-Controlled (Distribution + Market)

Distribution Circuit Load Type	Additional Sensitivity Considerations	Benefit-to-Cost Ratio
Commercial - 13.8kV		0.9991
Commercial - 13.8kV	Reliability Benefit Included	1.0025
Residential - 13.8kV		0.95
Commercial and Residential - 13.8kV		0.92

Base Load & Tariff Combination	PV System Assumptions	FITC & Tax Considerations	Benefit-to-Cost Ratio
Commercial - 13.8kV with Reliability Benefits	800 kWp 10-30deg fixed tilt 150-210deg azimuth	FITC: N/A Depreciation: 7yr MACRS Other Tax Benefits: Included	0.96
		FITC: 30% Depreciation: 5yr MACRS Other Tax Benefits: Included	1.15

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Case 3 - Net Present Value

Use Case #3: Utility-Controlled (Distribution + Market)

Net Present Value Over Project Life		
	Cost	**Benefit**
Capital Expenditure (Equity)	1,491,428	0
Financing Costs (Debt)	803,588	0
Operating Costs	526,226	0
Taxes (Refund or Paid)	0	147,596
Electricity Sales	0	441,520
Distribution Investment Deferral	0	979,608
System Capacity	0	825,712
Frequency Regulation	0	382,780
Synchronous Reserve	0	34,773
Non-Synchronous Reserve	0	0
Power Reliability	0	16,184
Total	2,821,241	2,828,173
Benefit to Cost Ratio		**1.00**

Use Case 4 – Model Inputs

Use Case #4: Shared Control (Customer Bill Savings + Aggregated Market Services)

Category	Assumption	Value
Financial Inputs	Financial Model	Discounted Project Cash Flows
	Discount Rate	11.47%
	Inflation Rate	2%
	Fed Taxes	35%
	State Taxes	9.80%
System / Market	Base Year Reference	2012
	Real Fuel Escalation Rate	2%
	Energy & A/S Escalation Rate	3%
	Mean RT Energy Price ($/MWh)	31.03
	Mean DA Energy Price ($/MWh)	32.01
	Mean Reg Price ($/MW-hr)	9.81
	Mean Spin price ($/MW-hr)	3.38
	Mean Non-Spin price ($/MW-hr)	1.45

Category	Assumption	Value
Customer Site Data	Customer Type	Commercial (university)
	Tariff	Xcel GS-TOU (S)
	Tariff Escalation Rate	4%
	Peak Load (kW)	3012.18
	Average Load (kW)	1365.47
	Load Factor	45%

Use Case 4 – Model Inputs (cont.)

Use Case #4: Shared Control (Customer Bill Savings + Aggregated Market Services)

		Battery (Utility Sited)
Technology Cost / Performance	Nameplate Capacity (MW)	1
	Nameplate Duration (hr)	4
	Capital Cost ($/kWh) -Start Yr Nominal	500
	Capital Cost ($/kW) - Start Yr Nominal	2000
	Project Life (yr)	20
	Roundtrip Efficiency	83%
	Variable O&M ($/kWh)	0.25
	Fixed O&M ($/kW-yr)	15
	Replacement Cost ($/kWh)	250

Use Case 4 - Benefit to Cost Ratio

Use Case #4: Shared Control (Customer Bill Savings + Aggregated Market Services)

Distribution Circuit Load Type	Additional Sensitivity Considerations	Benefit-to-Cost Ratio*
Run 12.X	done w/ capacity value	0.88
Run 12.X (No Capacity)	done w/o capacity value	0.43
Run 12.X (No Capacity) (2x P4P)	done w/ capacity value	0.65
Run 12.X (No Capacity) (2)	done w/o capacity value and 7yr + 14yr replacement schedule	0.42

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Case 4 - Benefit to Cost Ratio (cont.)

Use Case #4: Shared Control (Customer Bill Savings + Aggregated Market Services)

Base Load & Tariff Combination	PV System Assumptions	FITC & Tax Considerations	Benefit-to-Cost Ratio
University Load Xcel GS-TOU (S)	800 kWp 20deg fixed tilt 180deg azimuth	FITC: 30% Depreciation: 5yr MACRS Other Tax Benefits: Included	0.91

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Case 4 – Net Present Value

Use Case #4: Shared Control (Customer Bill Savings + Aggregated Market Services)

Net Present Value Over Project Life		
	Cost	**Benefit**
Capital Expenditure	1,491,428	0
Financing Costs	803,588	0
Operating Costs	299,273	0
Investment Tax Credit	0	538,261
Taxes (Refund or Paid)	0	693,007
Electricity Sales	0	202,294
Retail Demand Charge Management & TOU Energy Time-Shift	0	490,557
Frequency Regulation	0	391,037
Synchronous Reserve	0	50,448
Non-Synchronous Reserve	0	914
Total	2,594,288	2,366,519
Benefit to Cost Ratio		**0.91**

A benefit to cost ratio exceeding 1.0 indicates that the modeled benefits of energy storage exceed its costs over the lifetime of the installation, considering the time value of money and associated discounting of future year costs and benefits.

Use Cases (cont.)

Summary of CPUC-Defined Use Cases for Energy Storage

Transmission Connected	Bulk Peaker
	Ancillary Services Only
	On-Site Traditional Generation
	On-site VER
Distribution Connected	Distributed Peaker
	Distributed - Substation Level
	Distribution Upgrade Deferral
	Community Energy Storage
Customer Sited Distributed	Demand Side Permanent Load Shifting
	EV Charging
	Customer Bill Management
	Customer Bill Management + Ancillary Service Market Participation
	Emergency Backup Only
	Customer Sited Utility Controlled

Benefit Streams

Use Case	1		2		3		4	
Ownership	Customer		Utility		Utility		Customer	
Control	Customer		Utility		Utility		Customer + Utility	
Technology Combination	Storage Only	Storage + PV	Storage Only	Storage + PV	Storage Only	Storage + PV	Storage Only	Storage + PV
Customer Energy	Modeling	Modeling					Modeling	Modeling
Customer Demand	Modeling	Modeling					Modeling	Modeling
Customer Reliability	Proof of Concept	Proof of Concept	Proof of Concept	Proof of Concept	Proof of Concept	Proof of Concept	Proof of Concept	Proof of Concept
Regulation					Modeling	Modeling	Proof of Concept	Proof of Concept
Spinning Reserve					Modeling	Modeling	Proof of Concept	Proof of Concept
Wholesale Energy			Modeling	Modeling	Modeling	Modeling	Proof of Concept	Proof of Concept
Capacity					Modeling	Modeling	Discussion Only	Discussion Only
Distribution Upgrade Deferral Due To Load Growth			Modeling	Modeling	Modeling	Modeling	Discussion Only	Discussion Only
Distribution Upgrade Deferral/Voltage Due to PV		Discussion Only		Discussion Only		Discussion Only		Discussion Only

Color Key: Modeling: [solid black] Proof of Concept: [dense dotted pattern] Discussion Only: [crosshatch pattern]

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Appendix IV: Barriers & Recommendations Details

Barriers Analysis

Use Case	Use Case #1: Customer-sited, customer controlled energy storage	Use Case #2: Utility-controlled, distribution-only use case	Use Case #3: Utility-controlled (Distribution + Market)	Use Case #4: Shared control (Customer bill savings + aggregated market services)
System need	Low	Medium	High	Medium
Cohesive regulatory framework	Low	Medium	High	High
Evolving markets	Medium	Medium	High	High
RA value			High	High
Cost-effectiveness analysis		High	High	Medium
Cost recovery policies		Medium	Medium	Low
Cost transparency & price signals	Low	Low	Medium	Medium
Commercial operating experience	Low	Medium	High	High
Interconnection processes	Medium		High	High
Tax Benefit for PV-connected systems		High	High	High
MISO Participation			High	High

Barrier Intensity: Low: Medium: High:

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Key Conclusions Details

Accessing the key benefits with a single storage resource requires a certain energy storage dispatch (i.e. charging and discharging) behavior and project structuring, as outlined below:

1. Distribution upgrade deferral benefits are dependent upon the need for an upgrade of a local distribution asset such as a substation or transformer and ability to defer it with storage, and thus are highly site and time-specific. The highest deferral values are associated with low load growth rates of (~1%/yr), which is consistent with the Minnesota average load growth rate.

2. Participation in frequency regulation requires bidding into the Midcontinent Independent System Operator (MISO) frequency regulation market. Capturing this benefit would require additional creation of MISO rules for customer-sited storage system market participation.

3. The system capacity benefit is based around supporting a utility's long-term Resource Adequacy requirements. Availability of this benefit is based on regional need at specific times. Additional tools and methods may be required to incorporate energy storage into the integrated resource planning (IRP) process that defines the need and potential solutions.

4. To capture the Federal Investment Tax Credit (FITC) and accelerated MACRS depreciation, the storage system must be linked to a solar PV system and receive 75% or more of its charging energy from solar. The utility must also be able to monetize the Investment Tax Credit and accelerated MACRS depreciation value, either directly or through a third party ownership structure.

Conclusion Details—Multiple Sources of Value

Energy storage has the potential to provide multiple sources of value for customers and utilities

a. **Demand Charges** – The majority of energy storage benefit for customers is derived from overall reduction in a customer's demand. Demand charges of $15 - $20/kW per month are generally needed to provide sufficient value to the customer to compensate for the cost of the energy storage system.

b. **Time of Use (TOU) Energy Charges** – This benefit accrues from buying energy at a low price and selling at a higher price. Modeling showed that this benefit was not significant. In many residential tariffs, there is not TOU energy charge on the bill, so this benefit cannot be realized.

c. **Federal Investment Tax Credit** – This tax credit can be applied to an energy storage system that obtains 75% or more of its charging energy from an integrated photovoltaic solar system. It requires that the system be co-located with on-site solar. Commercial end customers may be better positioned to take advantage this benefit than utilities.

d. **Accelerated MACRS depreciation** - Like the FITC, this benefit only applies to storage systems co-located with solar PV. Such systems can be depreciated over 5 years instead of 7, resulting in tax avoidance and time value of money benefits to the storage owner.

e. It is worth noting that demand response activities could provide additional value to customer operated systems, where load is reduced in response to a utility need for system capacity. This value was not quantified in the model.

f. Additionally, the value of customer backup power (enhanced reliability) could be obtained if energy storage has the capability to operate as an uninterruptible power supply. While the value of this service generally appears to be low, there are certain instances and customers where this value could be significantly higher, particularly with critical loads, such as hospitals and data centers. Appropriate configuration for the energy storage and the load are required to provide this functionality.

Conclusions Details—Achieving "Three of Four" Benefits

Utility controlled, customer sited storage in Minnesota has the potential to provide benefits to the grid greater than the system's cost if three of the four benefits are achieved

Opportunities for Energy Storage Projects in Minnesota

In general, customer controlled storage has the greatest value for customers on utility tariffs with high demand charges and access to market benefits like frequency regulation. Customer-sited, utility controlled storage systems provide the greatest benefits for utilities that are able to monetize the following key benefits identified in the modeled cases:

» Distribution upgrade deferral: utilities that need to procure high cost distribution upgrades, particularly substation transformers, on feeders with low load growth will gain the greatest value from this storage capability.

» Regulation value: utilities must be capable of capturing the value of regulation capabilities provided by energy storage. The value and effect of market participation with storage will heavily depend upon the individual utility's overall MISO participation strategy.

» Capacity value: the value of capacity to a utility depends upon its need to procure local and/or system generation capacity at that time in its integrated resource planning (IRP) process.

» Tax Benefits including federal investment tax (FITC) credit and accelerated depreciation (MACRS): different utilities will have varying degrees to which they can capture the tax benefits identified in the study. For utilities that cannot capture the tax benefits directly, project structures incorporating a third party may allow those utilities to capture a significant portion of the benefits

Recommendations Details

1. Based upon the results, we recommend that utility controlled customer sited storage and distribution upgrade deferral be included in Minnesota's Renewable Energy Integration and Transmission Study (Docket No. E-999/CI-13-486).

2. We recommend establishing planning procedures to support utilities in finding opportunities to install energy storage together with solar PV to defer high cost distribution upgrades. These procedures should allow utility controlled energy storage projects to be accepted and rate based if the cost-effectiveness exceeds that of the traditional infrastructure, and could be considered as part of CIP resource procurement.

3. We recommend establishing energy storage pilot projects based around the key benefits identified in the study. Pilot projects will provide demonstrations of the value proposition of energy storage with valuable lessons learned and operational track record for future commercial consideration of energy storage as applied in the modeling.

4. We recommend that utilities conduct financial due diligence to verify that they would be able to capture the Federal Investment Tax Credit for combined energy storage and solar PV projects. Likewise, it is important to validate that customer sited utility controlled systems would be able to provide frequency regulation to MISO.

5. We would encourage MISO to establish clear processes for load and customer side and utility owned resources to participate in MISO markets.

6. Utilities might consider rate structures and/or demand response programs that take in account the system value that might be provided by customer sited energy storage. If those rate structures were to change, customers might consider dual use for their UPS.

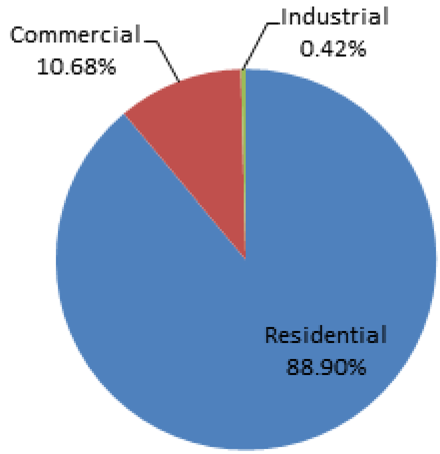
7. In order to provide the greatest benefit from customer-sited energy storage, utilities should define the control of these systems. Multiple options are possible for procurement, including rate based recovery or third party ownership. Incentives for energy storage could apply if the key benefits cannot be directly monetized, or if additional societal and/or system benefits could be shown to apply to energy storage assets.

8. The study results indicate a potentially positive business case for standalone energy storage located at distribution substations in order to provide upgrade deferral and regulation value. We recommend additional due diligence for this case.

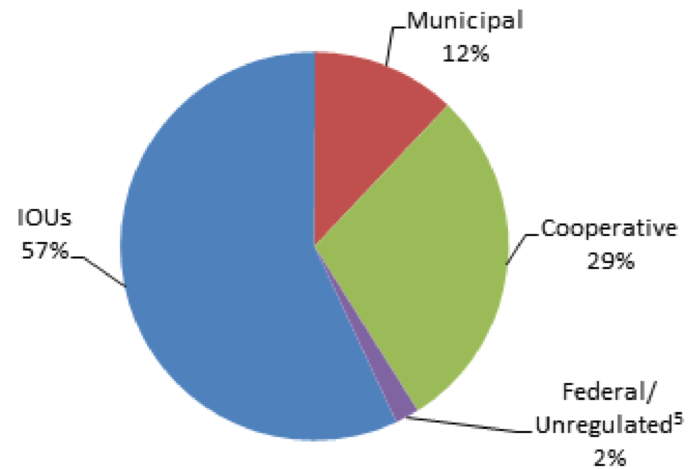
Appendix V:
Minnesota Electric Grid Background Data

Minnesota Electric Grid Background Information

The Minnesota electric grid is operated by the Midcontinent Independent System Operator (MISO), one of nine ISO/RTOs operating in the United States.

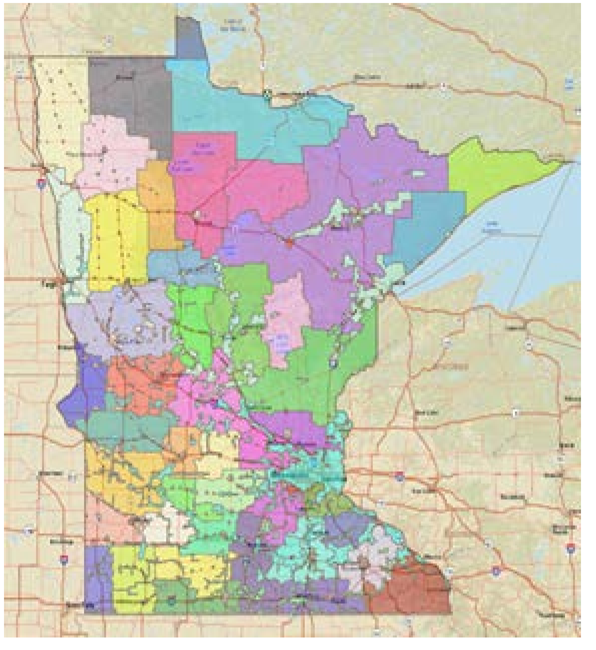


Proportion of Residential, Commercial, and Industrial Utility Customers



Proportion of IOUs, Municipal Utilities, and Cooperatives

Minnesota Electric Grid Background Information (cont.)



Minnesota Electric Utility Service Areas

Minnesota Electric Grid Background Information (cont.)

Investor Owned Utilities (IOUs)

- Xcel Energy – Northern States Power Company
- Allete – Minnesota Power
- Alliant Energy – Interstate power
- Northwestern Wisconsin Electric
- Otter Tail Power Company

Cooperative Utilities (Co-op)

- 45 distribution
- 6 generation and transmission

125 Municipal Utilities (Munis)