UM 1751 WORKSHOP 2

Implementation of HB 2193

Energy Storage Guidelines

February 29, 2016

***Reminder* – Please add your name to the sign in sheet.**

Welcome & Introductions

- Welcome and thank you for your participation.
- Reminders:
  - Sign In: Please add your name & contact information to the sign-in sheet.
  - Phone Participants Sign in – please email your name and contact information to elaine.prause@state.or.us to “sign-in” electronically.
  - Microphone Use – please speak into the microphone (5 inches away) for the benefit of phone participants.
  - Notice List – Sign up for the UM 1751 notice list by emailing a request to puc.hearings@state.or.us (include UM 1751 in subject line).

Agenda

- Welcome and introductions
  - Quick review of UM 1751
  - Questions for today
- Presentations
  - ODOE and Clean Energy Group
  - PNNL
  - PGE and Strategen
  - PacifiCorp
  - Solar City
  - AES
- BREAK
- Next steps (11:40-12)

Recap of HB 2193, UM 1751

Phase 1	Phase 2	Phase 3
PUC adopts guidelines by 1/1/17 for proposals submitted in Phase 2	Utilities submit one or more ES project proposals to the commission by 1/1/18	Commission may authorize projects
• Rule or Order, PUC staff prefer Order • Docket UM 1751 • Workshops started January 2016	• Data to identify potential system locations • Complements other planning efforts • Project details and cost-effectiveness evaluation • Treatment of confidential information	• Capacity up to 1% peak 2014 load • Consistency with guidelines • Reasonable and in the public interest • May have above market cost
2016	2017	By 2020

Goals for Phase 1

1. Adopt guidelines by order by 1/1/17
2. Guidelines provide direction to utilities regarding what needs to be included in their proposals
   - Consider values listed in statute plus “other”
   - Consider encouraging different types

Goals for Workshop #2

1. Continue exploratory phase
   - What services can energy storage provide?
   - How to assess the value of services from energy storage?
   - What tools are available to help with the analysis?
   - Lessons learned in service valuation?

2. Better understanding for how to address valuation of energy storage in guidelines

Presentations

1. ODOE and Clean Energy Group – Diane Broad and Todd Olinsky-Paul
2. PNNL – Patrick Balducci
3. PGE and Strategen – Joe Ross and Mark Higgins
4. PacifiCorp – Hui Shu and Ian Andrews
5. Solar City – Brian Warshay
6. AES- Kiran Kumaraswamy

Energy Storage Technology Advancement Partnership (ESTAP)

Energy Storage Update

Oregon PUC
February 29, 2016

Todd Olinsky-Paul
ESTAP Project Director
Clean Energy States Alliance

Clean Energy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Thank You:

Dr. Imre Gyuk
U.S. Department of Energy,
Office of Electricity Delivery and
Energy Reliability

Dan Borneo
Sandia National Laboratories

ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

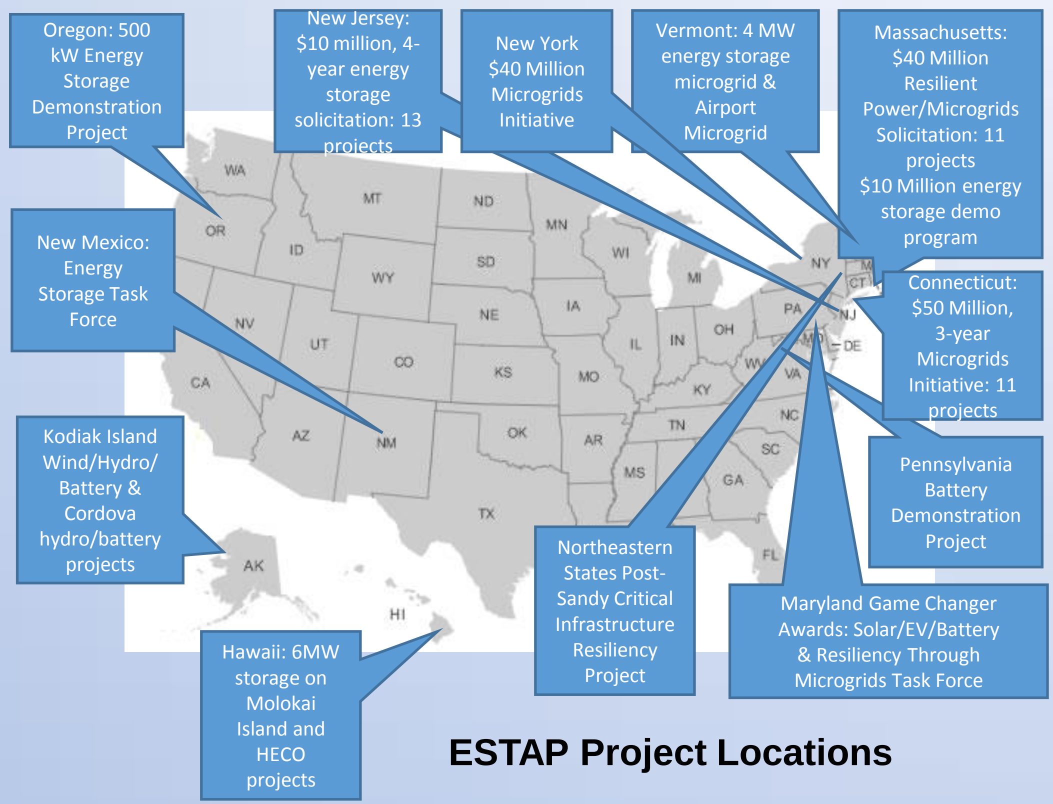
State & Federal Energy Storage Technology Advancement Partnership (ESTAP) is conducted under contract with Sandia National Laboratories, with funding from US DOE.

ESTAP Key Activities:

1. Disseminate information to stakeholders
   - ESTAP listserv >3,000 members
   - Webinars, conferences, information updates, surveys.

2. Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment

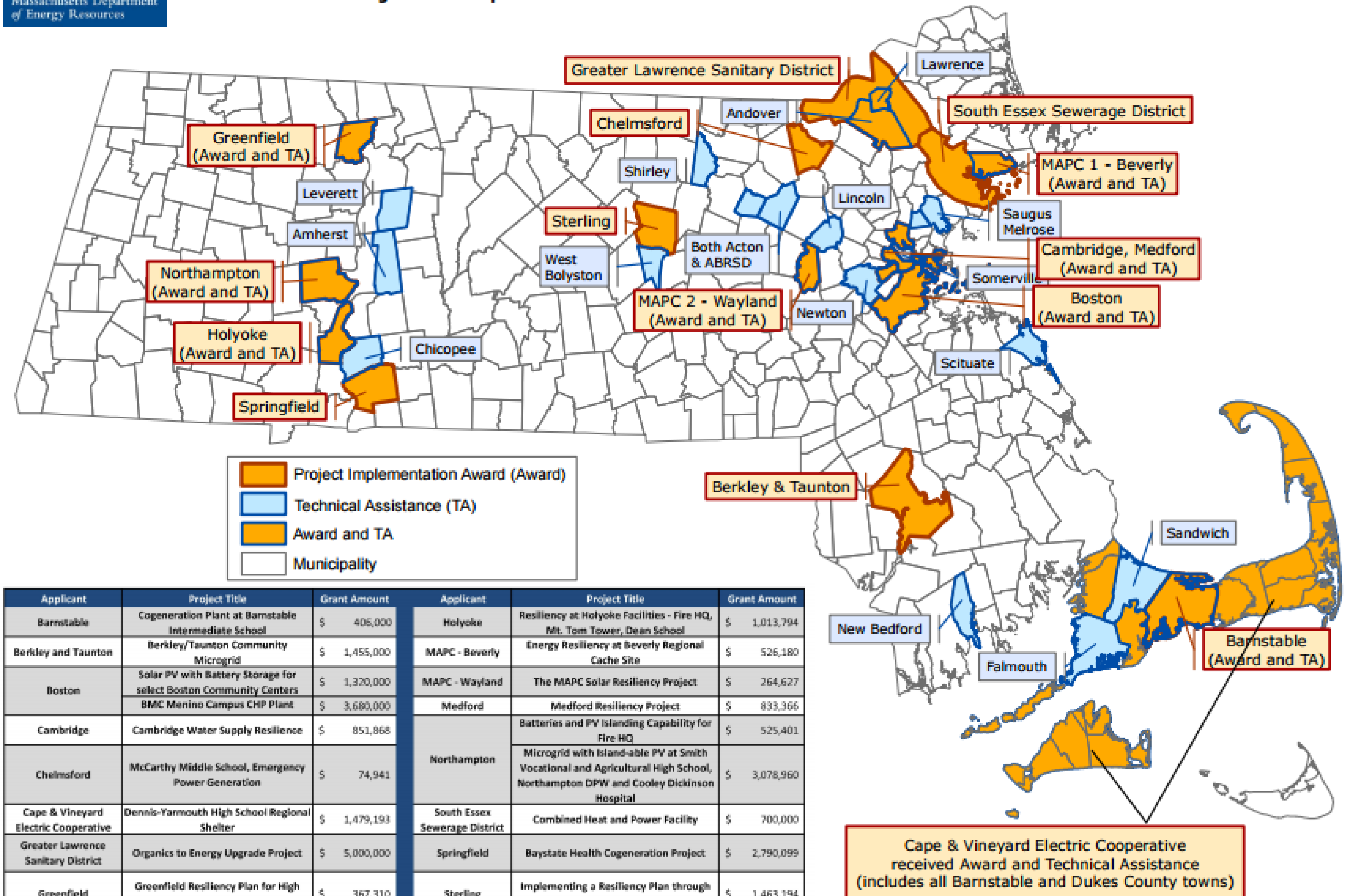
3. Support state energy storage efforts with technical, policy and program assistance



ESTAP Project Locations

Community Clean Energy Resiliency Initiative
Project Implementation and Technical Assistance

DOER Massachusetts Department of Energy Resources



Applicant	Project Title	Grant Amount
Barnstable	Cogeneration Plant at Barnstable Intermediate School	$ 406,000
Berkley and Taunton	Berkley/Taunton Community Microgrid	$ 1,455,000
Boston	Solar PV with Battery Storage for select Boston Community Centers	$ 1,320,000
	BMC Menino Campus CHP Plant	$ 3,680,000
Cambridge	Cambridge Water Supply Resilience	$ 851,868
Chelmsford	McCarthy Middle School, Emergency Power Generation	$ 74,941
Cape & Vineyard Electric Cooperative	Dennis-Yarmouth High School Regional Shelter	$ 1,479,193
Greater Lawrence Sanitary District	Organics to Energy Upgrade Project	$ 5,000,000
Greenfield	Greenfield Resiliency Plan for High School	$ 367,310

Applicant	Project Title	Grant Amount
Holyoke	Resiliency at Holyoke Facilities - Fire HQ, Mt. Tom Tower, Dean School	$ 1,013,794
MAPC - Beverly	Energy Resiliency at Beverly Regional Cache Site	$ 526,180
MAPC - Wayland	The MAPC Solar Resiliency Project	$ 264,627
Medford	Medford Resiliency Project	$ 833,366
Northampton	Batteries and PV Islanding Capability for Fire HQ	$ 525,401
	Microgrid with Island-able PV at Smith Vocational and Agricultural High School, Northampton DPW and Cooley Dickinson Hospital	$ 3,078,960
South Essex Sewerage District	Combined Heat and Power Facility	$ 700,000
Springfield	Baystate Health Cogeneration Project	$ 2,790,099
Sterling	Implementing a Resiliency Plan through Clean Storage for a Municipal Microgrid	$ 1,463,194
Total		**$ 25,829,933**

DOER, JPfister, 3-24-15

Municipal Utility Analysis - Massachusetts

- Analysis conducted by Sandia National Laboratories
- Based on 1 MW/1MWh lithium ion battery installed on distribution grid, with 3 MW solar PV
- System to be owned and operated by a western MA municipal utility
- Potential value streams:
  - Energy arbitrage revenues (buy low, sell high)
  - Reduction in transmission obligation to ISO-NE (cost savings based on monthly peak hour)
  - Reduction in capacity obligation to ISO-NE (cost savngs based on annual peak hour)
  - Resilient power provision to municipal police station and emergency dispatch center (non-monetizable benefit)

Arbitrage basis

Final Real-Time Locational Marginal Prices ($/MWh)

9/2/2014

Hour	HUB	WCMA	NEMA	SEMA	CT	RI	NH	VT	ME
1	44.23	44.35	44.48	44.03	44.40	44.39	43.85	43.75	41.88
2	38.15	38.31	38.22	37.84	38.36	38.17	37.74	37.75	36.11
3	32.98	33.11	33.01	32.68	33.09	32.96	32.67	32.54	31.54
4	28.23	28.34	28.26	28.01	28.26	28.19	28.02	27.90	27.13
5	28.06	28.19	28.07	27.83	28.17	27.97	27.89	27.81	26.98
6	32.97	33.10	32.98	32.67	33.11	33.09	32.86	32.82	31.77
7	37.33	37.46	37.49	37.03	37.51	37.24	37.44	37.29	36.38
8	40.87	40.99	41.07	40.62	41.05	40.90	41.01	40.86	39.96
9	35.01	35.09	35.25	36.10	35.06	41.63	35.25	34.96	34.33
10	45.85	45.99	46.13	46.51	46.09	50.20	46.07	45.92	44.34
11	73.81	74.12	74.15	73.39	74.69	73.55	74.11	74.15	71.31
12	89.80	90.11	90.35	89.45	93.48	89.51	90.14	89.86	86.67
13	185.70	186.25	187.11	185.44	190.47	185.53	186.15	184.95	178.01
14	554.71	555.62	560.77	555.12	558.00	555.55	555.69	551.95	530.00
15	206.54	206.72	209.37	207.47	308.93	207.60	206.72	205.66	196.51
16	70.45	70.57	71.51	70.86	158.68	70.91	70.15	70.67	65.38
17	86.23	86.34	87.48	86.72	168.94	86.71	85.96	86.14	80.60
18	133.90	134.22	135.05	134.18	174.45	134.14	133.38	133.73	126.21
19	72.92	73.14	73.35	72.90	107.74	72.81	72.65	73.38	68.10
20	75.16	75.35	75.60	75.14	82.61	75.08	75.14	75.41	71.28
21	74.36	74.62	74.61	74.20	75.75	73.96	74.14	74.76	70.18
22	55.07	55.27	55.32	54.86	55.76	54.56	54.81	54.91	52.16
23	38.60	38.75	38.82	38.36	39.02	38.21	38.48	38.42	36.99
24	54.55	54.76	54.98	54.15	55.00	54.01	54.41	54.12	52.48
AVG	88.98	89.20	89.73	88.98	104.53	89.45	88.95	88.74	84.85
On Peak AVG	114.94	115.20	116.00	115.08	138.17	115.68	114.99	114.73	109.50
Off Peak AVG	37.06	37.20	37.19	36.78	37.24	37.00	36.86	36.75	35.53

Energy Arbitrage

- Analyzed 33 months of data (January 2013-September 2015)
- Optimization using perfect foresight
- Cycling limitations were not included

Maximum Potential Arbitrage Revenue, Average Monthly Arbitrage Opportunity for a 1 MW Plant.

	1 MWh	2 MWh	3 MWh	4 MWh
Monthly Average	$3,395	$5,117	$6,227	$6,949
Annual Savings	$40,738	$61,407	$74,722	$83,383

Reduction in Transmission Obligation (Regional Network Service (RNS) payments) to ISO-NE

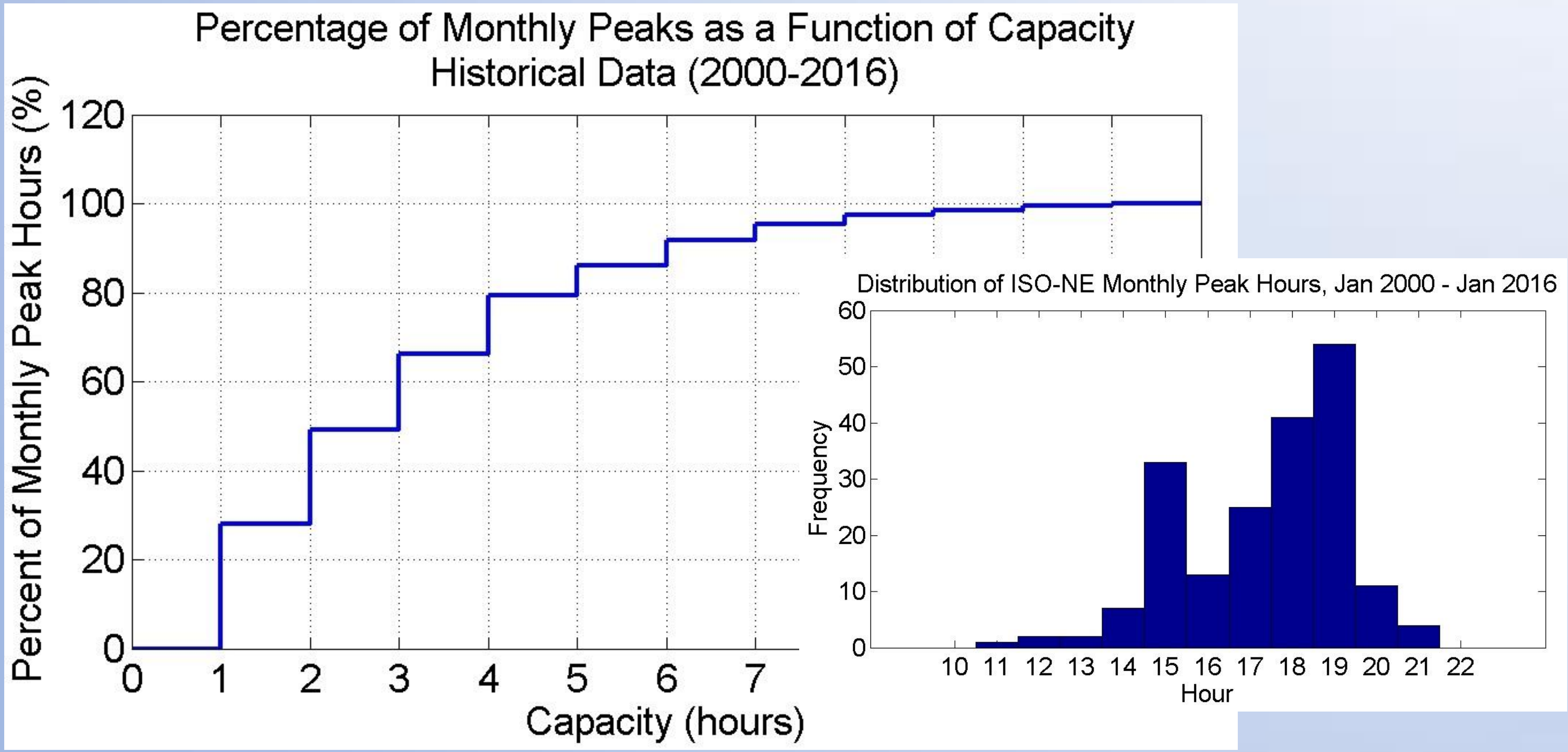
- Monthly payment based on maximum load
- Payment for using transmission facilities to move electricity into or within New England
- Current pool rate, effective June 1, 2015: $98.70147/kW-yr
- Need to "hit the hour" to reduce load, or else no benefit
- Having a multi-hour battery (more capacity) provides no increase in benefit, but increases the odds of "hitting the hour"

RNS Savings for 1 Hour Energy Storage System.

Power (MW)	Annual Savings ($)
1	$98,707
2	$197,403
3	$296,104
4	$394,806

Impact of Energy Storage Capacity on Transmission Savings

Increased energy storage capacity increases the likelihood of hitting monthly peaks



Reduction in Capacity Obligation to ISO-NE

- Each load serving entity is responsible for a fraction of the Forward Capacity Market obligations
- Based on one annual peak hour
- Rates due to triple in three years
- Increasing capacity does not increase revenue, just increases the odds of "hitting the hour"

Capacity Clearing Price, ISO-NE.

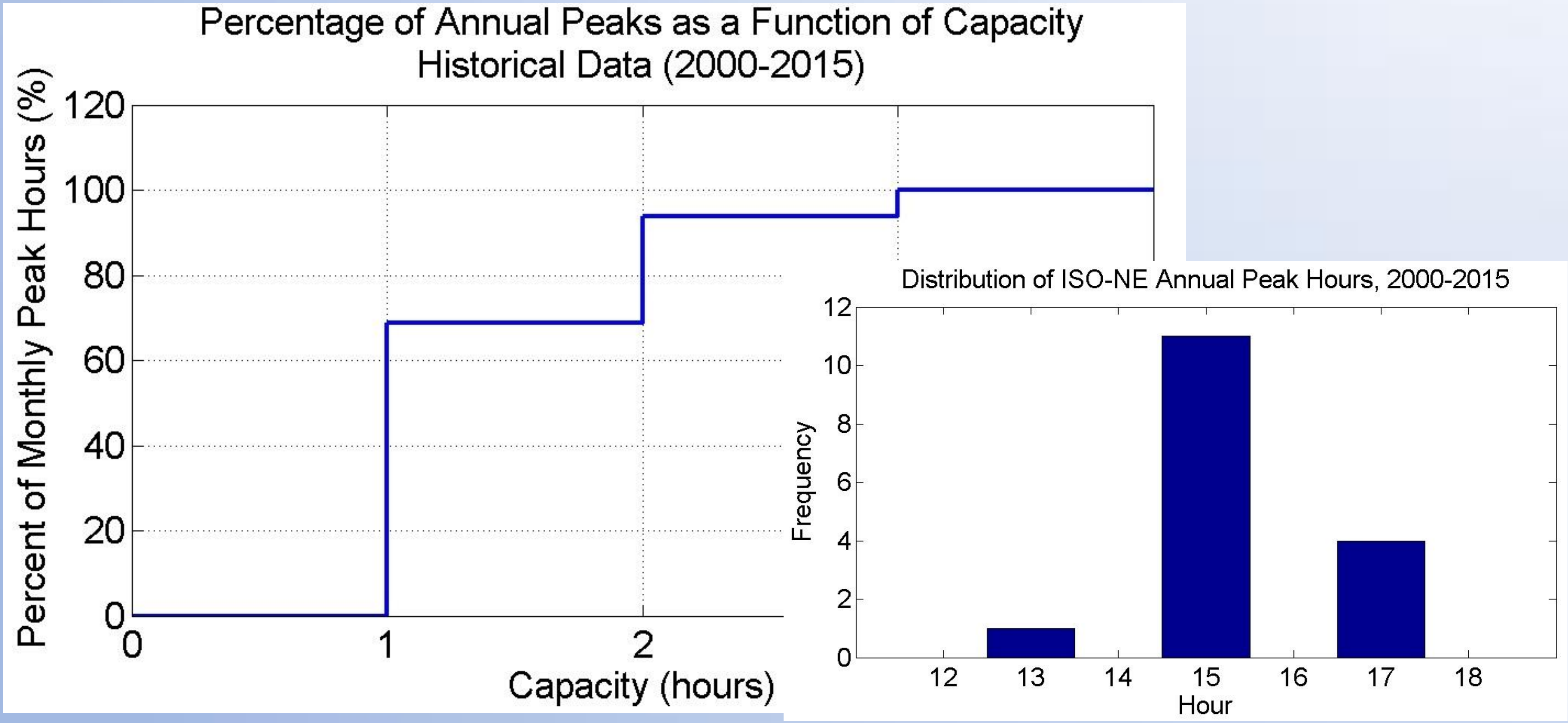
Year	Price ($/kW-Month)
2010-2011	$4.254
2011-2012	$3.119
2012-2013	$2.535
2013-2014	$2.516
2014-2015	$2.855
2015-2016	$3.129
2016-2017	$3.150
2017-2018	$7.025
2018-2019	$9.551

Capacity Clearing Price, ISO-NE.

Year	Price ($/kW-Month)	1 MW	2 MW	3 MW	4 MW
2015-16	$3.129	$51,477	$102,958	$154,443	$205,932
2016-17	$3.150	$51,822	$103,649	$155,479	$207,315
2017-18	$7.025	$115,572	$213,153	$346,744	$462,344
2018-19	$9.551	$157,128	$314,269	$471,424	$628,591

Impact of Storage Capacity on Capacity Savings

Increased energy storage capacity of limited benefit, due to distribution of annual peaks



Grid Resilience

- Municipality has identified 10kW as the critical load at community police and dispatch station
- Resilience is not monetizable but is valued highly by the community and the state

Days of Back-up Power for Critical Loads

	1 MWh	2 MWh	3 MWh	4 MWh
Days	4.167	8.333	12.5	16.667

Summary of Monetizable Benefits

- Total potential revenue, 1MW, 1MWh system

Description	Total	Percent
Arbitrage	$40,738	16.0%
RNS payment	$98,707	38.7%
FCM obligation*	$115,572	45.3%
Total	$255,017	100%

- For a capital cost of ~1.7M, the simple payback is 6.67 years

*2017-2018 data. Rates will be higher in 2018-2019, resulting in additional savings.

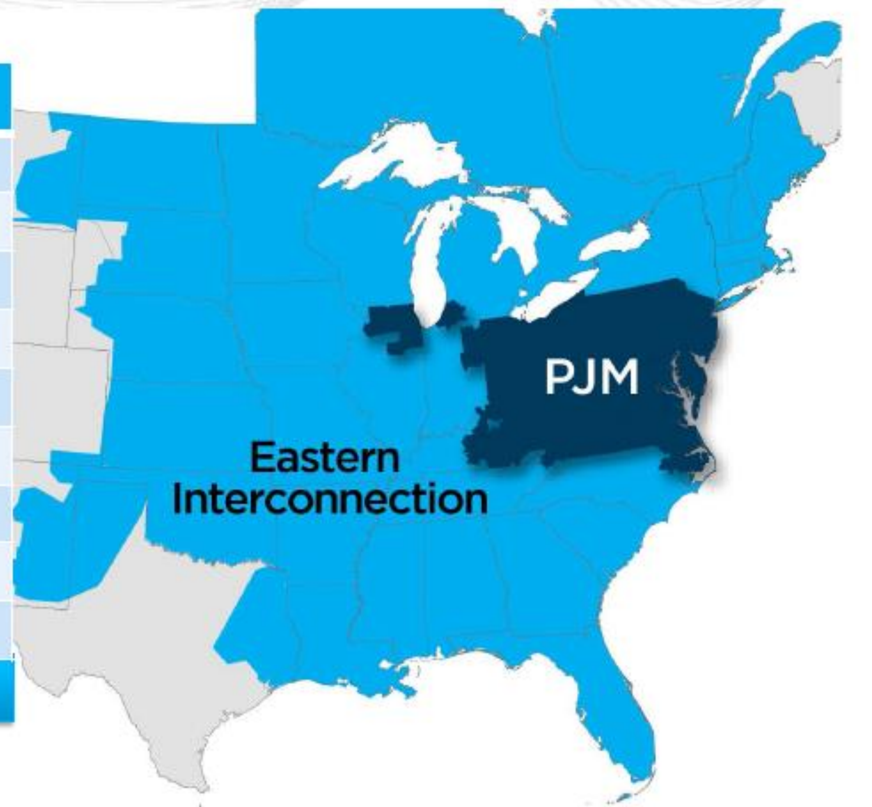
Frequency Regulation in PJM

pjm

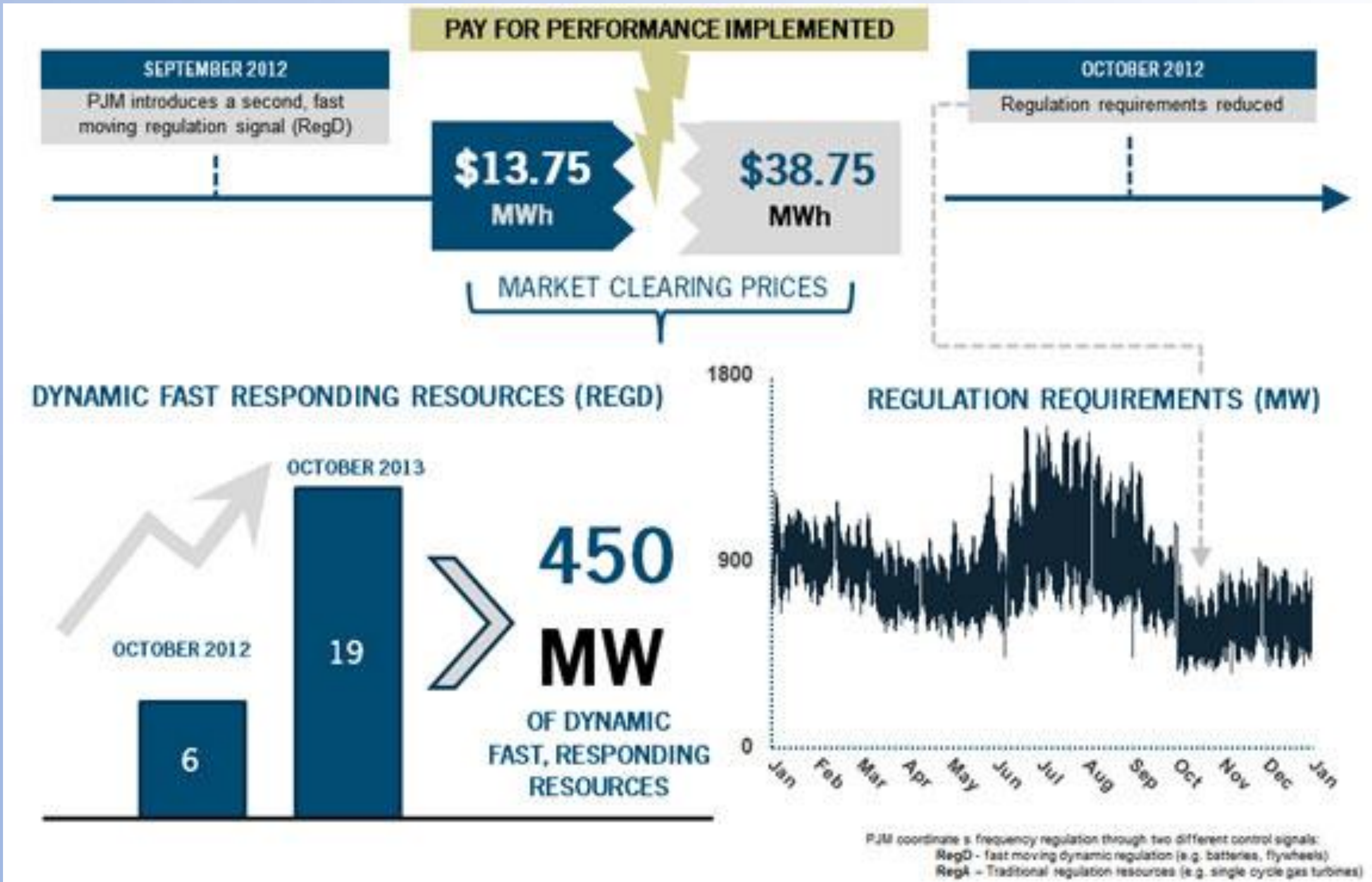
PJM as Part of the Eastern Interconnection

Key Statistics	
Member companies	960+
Millions of people served	61
Peak load in megawatts	165,492
MW of generating capacity	171,648
Miles of transmission lines	72,075
2014 GWh of annual energy	792,580
Generation sources	1,304
Square miles of territory	243,417
States served	13 + DC

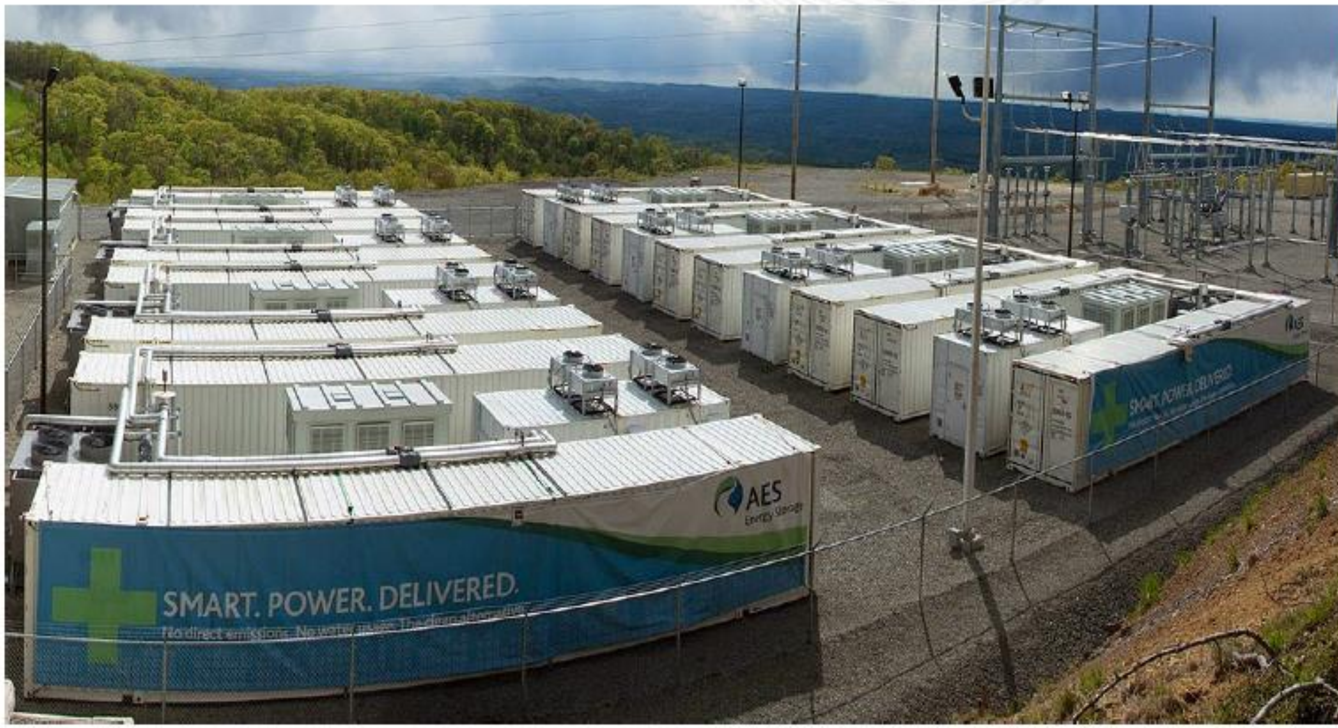
21% of U.S. GDP produced in PJM



1/2016


PAY FOR PERFORMANCE IMPLEMENTED
SEPTEMBER 2012
PJM introduces a second, fast moving regulation signal (RegD)
OCTOBER 2012
Regulation requirements reduced
$13.75
MWh
$38.75
MWh
MARKET CLEARING PRICES
DYNAMIC FAST RESPONDING RESOURCES (REGD)
OCTOBER 2012
6
OCTOBER 2013
19
450
MW
OF DYNAMIC FAST, RESPONDING RESOURCES
REGULATION REQUIREMENTS (MW)
1800
900
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
PJM coordinates frequency regulation through two different control signals:
RegD - fast moving dynamic regulation (e.g. batteries, flywheels)
RegA – Traditional regulation resources (e.g. single cycle gas turbines)

Grid-Scale Energy Storage – 250+ MW in Operation



Total Advanced Storage

Grid Connected – 263 MW
Under Construction – 53 MW
Under Study – 674 MW*

32 MW AES energy storage facility at 98 MW Laurel Mountain Wind Farm, WV

*historically, only a small percentage are actually delivered in-service

Source: PJM

Grid-Scale Energy Storage – 250+ MW in Operation

Total Advanced Storage

Grid Connected – 263 MW
Under Construction – 53 MW
Under Study – 674 MW*

Invenergy's Beech Ridge 32 MW energy storage project in West Virginia (paired with 100 MW wind energy)

*historically, only a small percentage are actually delivered in-service

Source: PJM

FY2015 Renewable Electric Storage Incentive Solicitation Results

October 22, 2014 - Board Approved Solicitation & Evaluation Process

December 08, 2014 - Applications Due; 22 Received => Evaluated

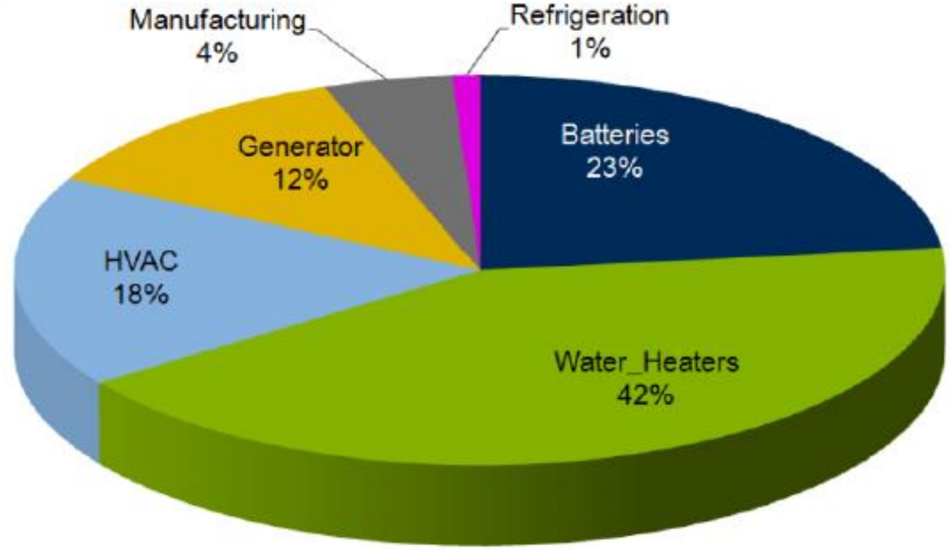
March 18, 2015 – Board Approved 13 Applications for Incentive Award

- <u>22 Applications Received</u>
- $4,694,642 Requested
- $70,000 to $468,708 per
- $323,585 to $1.86 million
- 13,430 kW total capacity
- 250 kW to 1,500 kW
- 19 Li-ion & 3 Lead Carbon
- 18 public & critical, 4 not

- <u>13 Applications Approved</u>
- $2,908,804 Awarded
- $70,000 to $468,708 per
- $330,766 to $1.855 million
- 8,750 kW total capacity
- 250 kW to 1,500 kW
- 13 Li-ion projects
- 13 public and critical

DR Market Participation: Regulation Market

Regulation	Zone	January 2016
Locations	RTO	293
MW	RTO	22



Note: Percent of CSP Reported Load Reduction MWs

Take-Aways

- Energy storage is installed and operational in many states
  - Utility scale
  - Behind the meter
- Energy storage can provide many valuable benefits
  - Demand charge management
  - Demand response
  - Frequency regulation
  - Renewables integration
  - Resilience
  - T&D investment displacement/deferral
- It is possible to provide resilience to critical facilities AND generate revenues/cost savings, so that storage systems will pay for themselves
- Energy storage can compete today in open markets under pay-for-performance conditions
- As prices continue to fall, energy storage will find new markets and applications

Energy Storage Technology Advancement Partnership

ESTAP

Project Director: Todd Olinsky-Paul

Contact: Todd Olinsky-Paul, Todd@cleanegroup.org

SIGN UP FOR THIS e-MAILING LIST

The Energy Storage Technology Advancement Partnership (ESTAP) is a federal-state funding and information sharing project, managed by CESA, that aims to accelerate the deployment of electrical energy storage technologies in the U.S.

The project's objective is to accelerate the pace of deployment of energy storage technologies in the United States through the creation of technical assistance and co-funding partnerships between states and the U.S. Department of Energy.

ESTAP conducts two key activities:

1) Disseminate information to stakeholders through:

- The ESTAP listserv (>2,000 members)
- Webinars, conferences, information updates

NEW RESOURCES

October 14, 2015
Resilience for Free: How Solar+Storage Could Protect Multifamily Affordable Housing from Power Outages at Little or No Net Cost
By Clean Energy Group

September 30, 2015
Webinar Slides: Energy Storage Market Updates, 9.30.15

UPCOMING EVENTS

December 16, 2015
ESTAP Webinar: State of the U.S. Energy Storage Industry,

More Events

LATEST NEWS

November 30, 2015
Massachusetts Takes the Lead on Resilient

Thank You

Todd Olinsky-Paul

Project Director

Todd@cleanegroup.org

ESTAP Website: http://bit.ly/CESA-ESTAP

ESTAP Listserv: http://bit.ly/EnergyStorageList

"Grid Edge Demonstration" ESS at EWEB

- EWEB will install a total of 500 kW / 903 kWh
  - Utility Operations Center
  - Water Pumping Station
  - Communications Facility

  Each of the three sites have diesel gen. back-up and will have 25-75 kW PV
- Energy storage demonstration will validate these value streams
  - Grid ancillary services – voltage support, regulation services, peak/shift capacity, demand response
  - Storing solar energy from an existing PV system
  - Resiliency

    >> Black start capability (Self Excitement), disaster Preparedness

    >> able to sustain basic level of self-supplied energy indefinitely
  - Reduced emissions (EV charging primarily from PV system)
- Microgrid Controller/Interoperability platform supporting interface with Distributed Energy Resources, Energy Storage System, advanced power/energy management applications, and utility SCADA system → "'active management"

Please contact ODOE for more information

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503-378-4035

ODOE Website

http://www.oregon.gov/energy/Pages/energy-storage.aspx

OREGON DEPARTMENT OF ENERGY

EWEB

OREGON BEST™

CleanEnergy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

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Evaluating the Cost Effectiveness of Energy Storage Projects

Patrick J. Balducci
Pacific NW National Laboratory

UM 1751 Energy Storage Workshop #2
February 29, 2016
Salem, OR.

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Key Questions Discussed in This Session

- What grid services can energy storage systems (ESSs) provide, and what is the significance of “stacking benefits”?
- Are the values associated with grid services provided by ESS consistent between, or specific to, individual utilities? If specific, why do they differ and what is the nature of these differences? How can they be measured?
- How can utilities effectively site, size and control energy storage in order to maximize benefits, and how important is this process?
- What are the primary challenges and barriers to expanded energy storage adoption?

Key Concepts

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- ESSs provide services or functions or values; a use case is a service that is specific to an installation
- Energy storage comes in many forms:
  - Battery energy storage (li-ion, flow batteries, na-s)
  - Compressed air energy storage
  - Pump storage hydro
  - Flywheels
- Categories of services:
  - Bulk energy – arbitrage and capacity
  - Ancillary services – regulation, spin and non-spin reserve, load following
  - Transmission congestion relief and asset deferral
  - Distribution deferral and voltage support
  - Customer benefits – bill reduction, outage mitigation, power quality
- Services/functions/values have to be stacked properly to avoid double counting, and a simulation/co-optimization process is required
- ESSs have both power and energy capacities and optimal sizing is important.

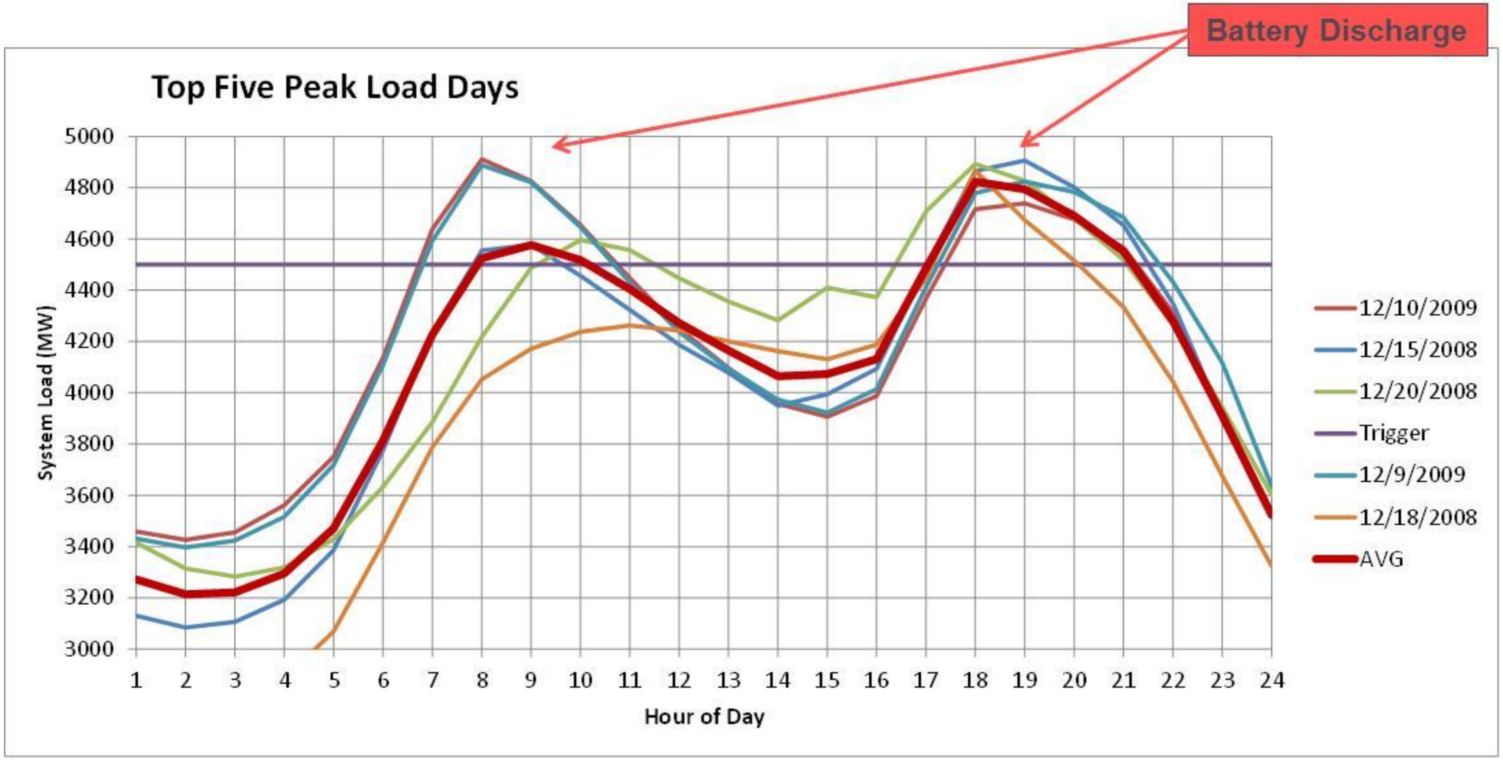
Grid Functions and Tools to Estimate Values

	Location/Service	Analysis Tools
	Transmission System	
1	Arbitrage	Production cost modeling
2	Balancing Regulation	Stochastic model w. & w/o valuation, KERMIT
3	Capacity	Financial models
	Distribution System	
4	Transformer Deferral and Volt/VAR Control	GridLab-D, OpenDSS
5	Upgrade Deferral	Financial Models
6	PV Integration	Gridlab-D, OpenDSS
7	Outage Mitigation	
	Customer Side	
	Industry, School, Multifamily	Optimization tools
	Bundled Services	Energy Storage Evaluation Tool (E3/EPRI), Battery Storage Evaluation Tool (PNNL), ESWare™ (24M), ES-Select™ (DNV-KEMA)

Benefit 1 – Peak Shaving

- Capacity value based on the incremental cost of next best alternative investment (peaking combustion turbine) with adjustments for the incremental capacity equivalent of energy storage and line losses
- Distribution upgrade deferral based on present value benefits of deferring investment in distribution system upgrades

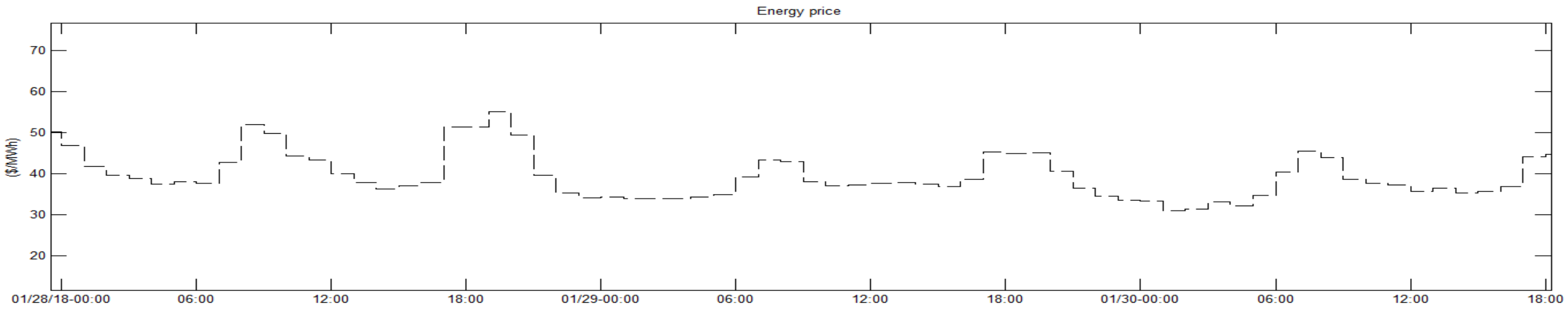
Key Lesson: Values will differ based on presence of markets, local distribution system conditions, and valuation policies.

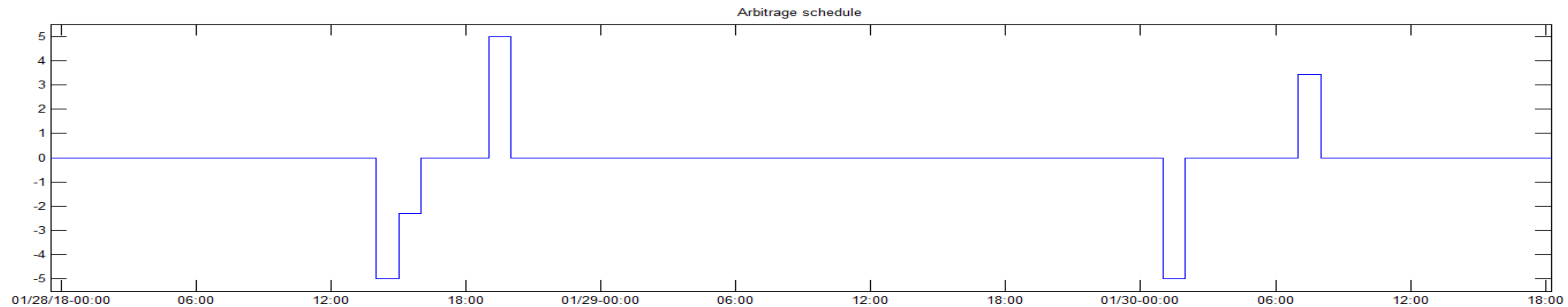


Benefit Example 2 – Energy Arbitrage

- Hourly indexed day-ahead energy market for mid-Columbia used to determine peak / off-peak price differentials
- Value obtained by purchasing energy during low price hours and selling energy at high energy price hours – efficiency losses considered

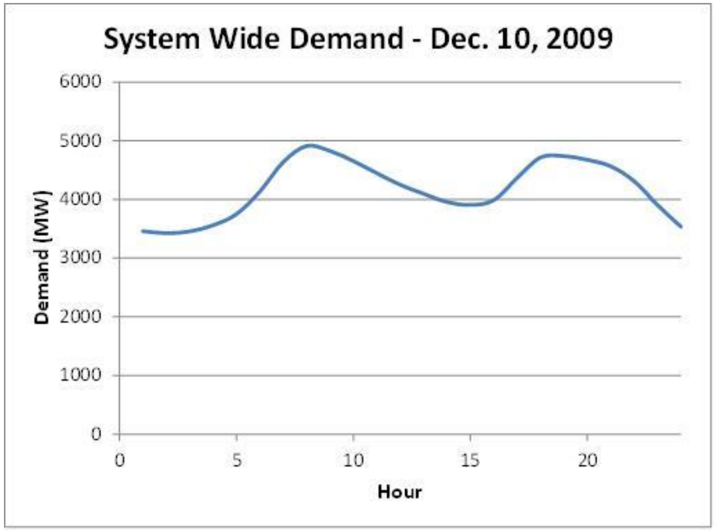
Key Lesson: Profitability differs significantly by region; profit also affected by round trip efficiency of the ESS.

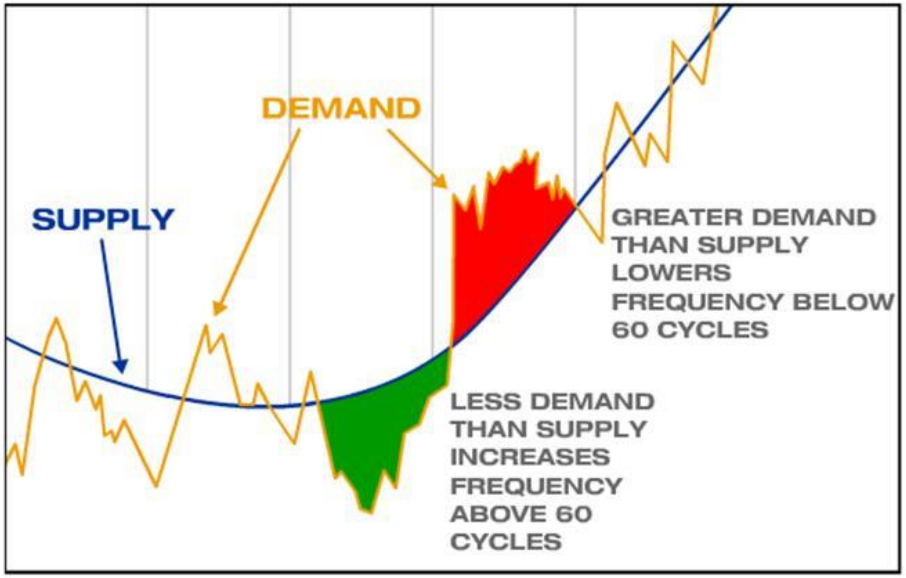




Benefit Example 3 – System Flexibility

- Battery fills the short-term gaps between supply and demand
- Reduces cost and emissions associated with idling fossil-fuel burning plants





Benefit Example 4 – Outage Mitigation

- Outage data
  - Outage data obtained from utility for multiple years
  - Average annual number of outages determined and outages randomly selected and scaled to approximate average year
  - Outage start time and duration
- Customer and load information
  - Number of customers affected each outage obtained from utility
  - Customer outages sorted into customer classes using utility data and assigned values
  - Load determined using 15-minute SCADA information
- Alternative scenarios
  - Perfect foreknowledge – energy storage charges up in advance of inclement weather
  - No foreknowledge – energy on-hand when outage occurs is used to reduce outage impact

	Cost per Outage ($2008)*		
Duration	Residential	Small C + I	Large C + I
Momentary	$2	$210	$7,331
Less than 1 hr	$4	$738	$16,347
2-4 hours	$7	$3,236	$40,297
8-12 hours	$12	$3,996	$46,227

Source: Sullivan, M., Mercurio, M., and J. Schellenberg. 2009. "Estimated Value of Service Reliability for Electric Utility Customers in the United States." Prepared for U.S. Department of Energy by Lawrence Berkeley National Laboratory. Berkeley, CA.

Key Lesson: Benefits, which can be very large, accrue primarily to the customer and are largely dependent on the effective placement of the ESS. If focused on utility benefits, we would focus on violation costs or lost energy sales.

Energy Storage for the Puget Sound Energy (PSE) Region*

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Project objective: Analyze and demonstrate the benefits of electrical energy storage on the distribution grid

Situation

- 25MVa transformers at radial substations at Murden Cove and Winslow operate at or above target load

Requirements

- ❑ Multiple hours of capacity required
- ❑ Small footprint to fit within a substation
- ❑ Year-round operation capabilities
- ❑ Flexibility to perform multiple applications (e.g., balancing svcs., islanding)

Novel technical solution

- Containerized, electrochemical energy storage with a 2nd generation flow battery technology

*Research Funded by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, Energy Storage Program and the Bonneville Power Administration.

Battery Storage Evaluation Tool (BSET) User Interface

Pacific Northwest
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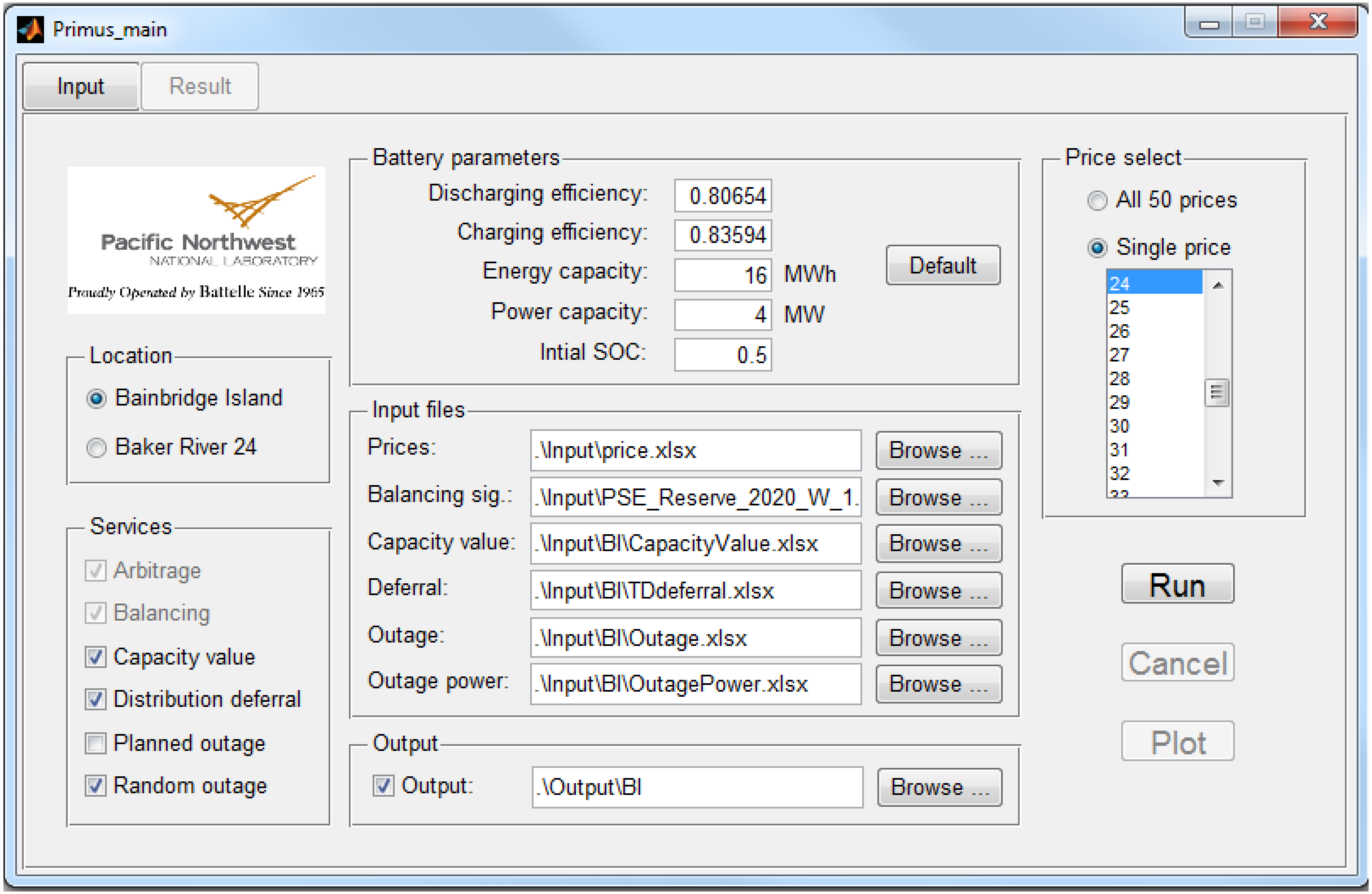
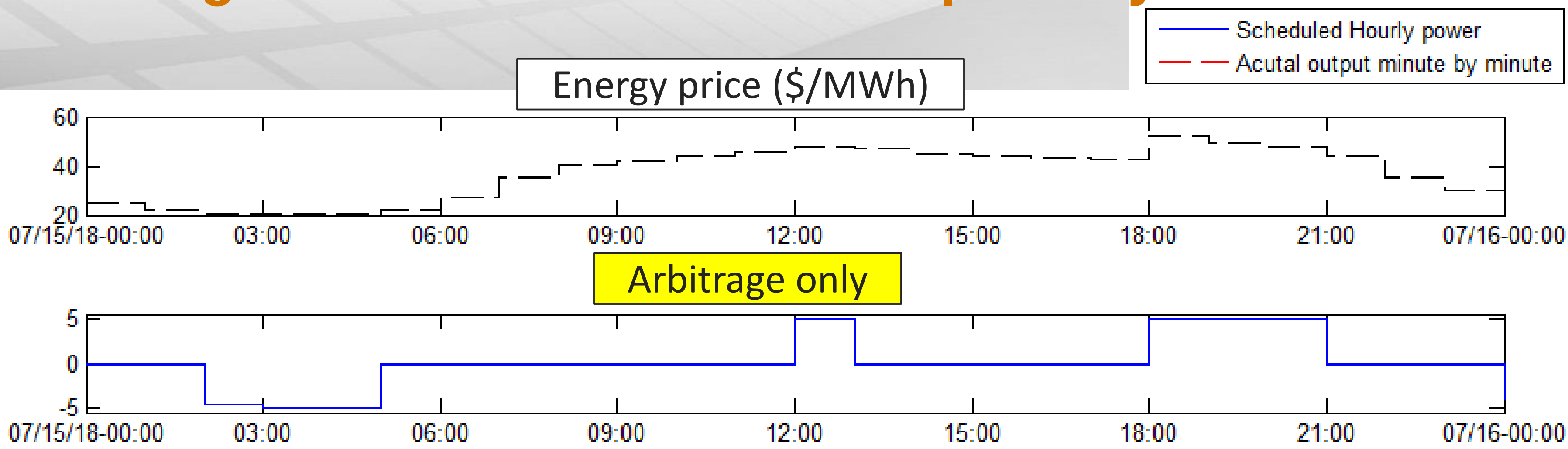
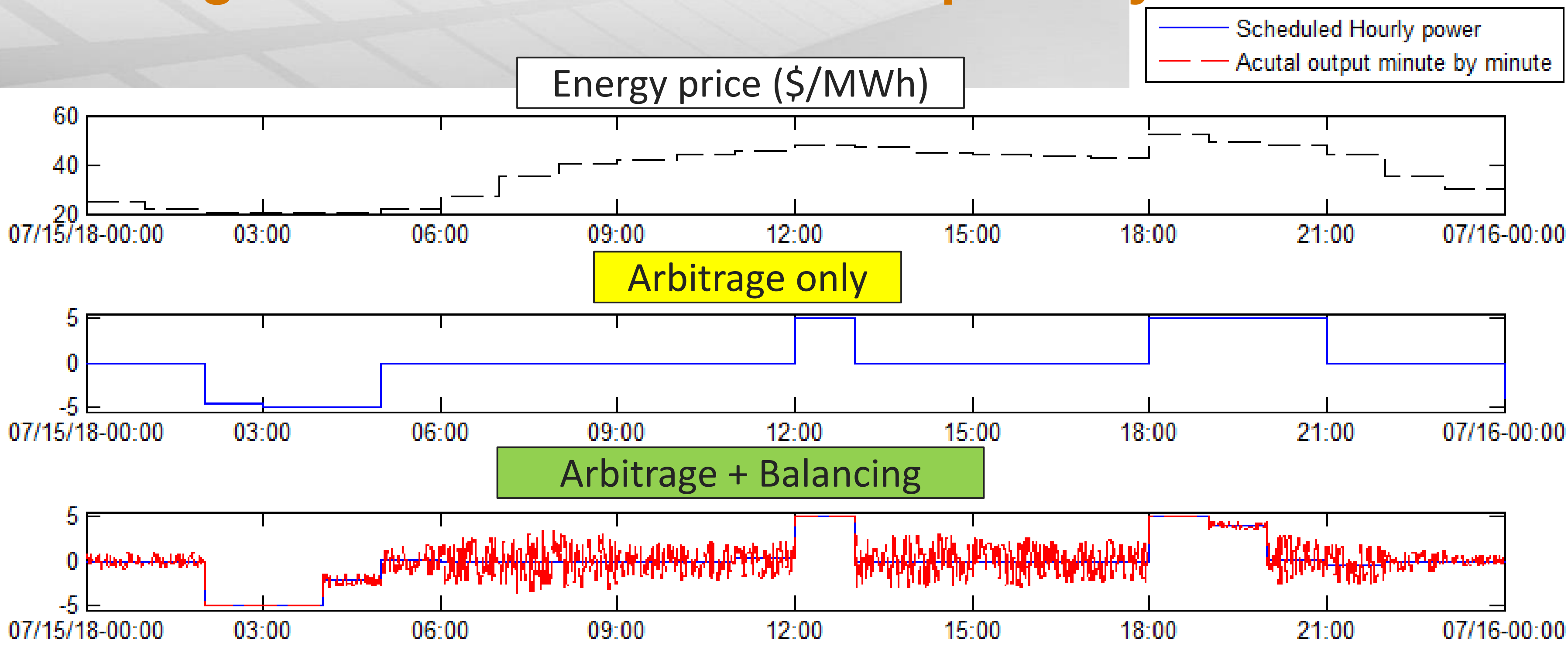


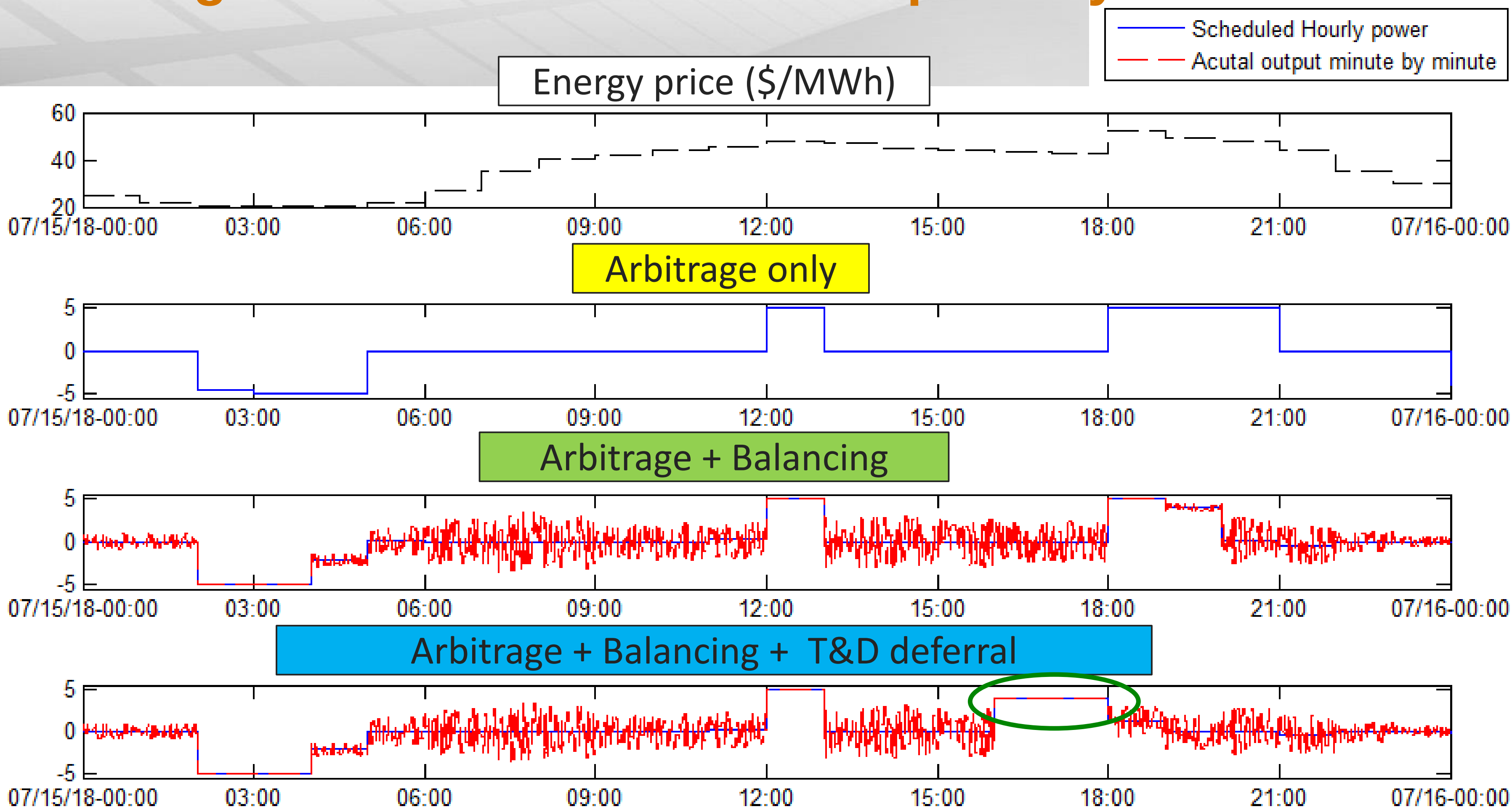
Bundling Services: How To Do It Optimally?



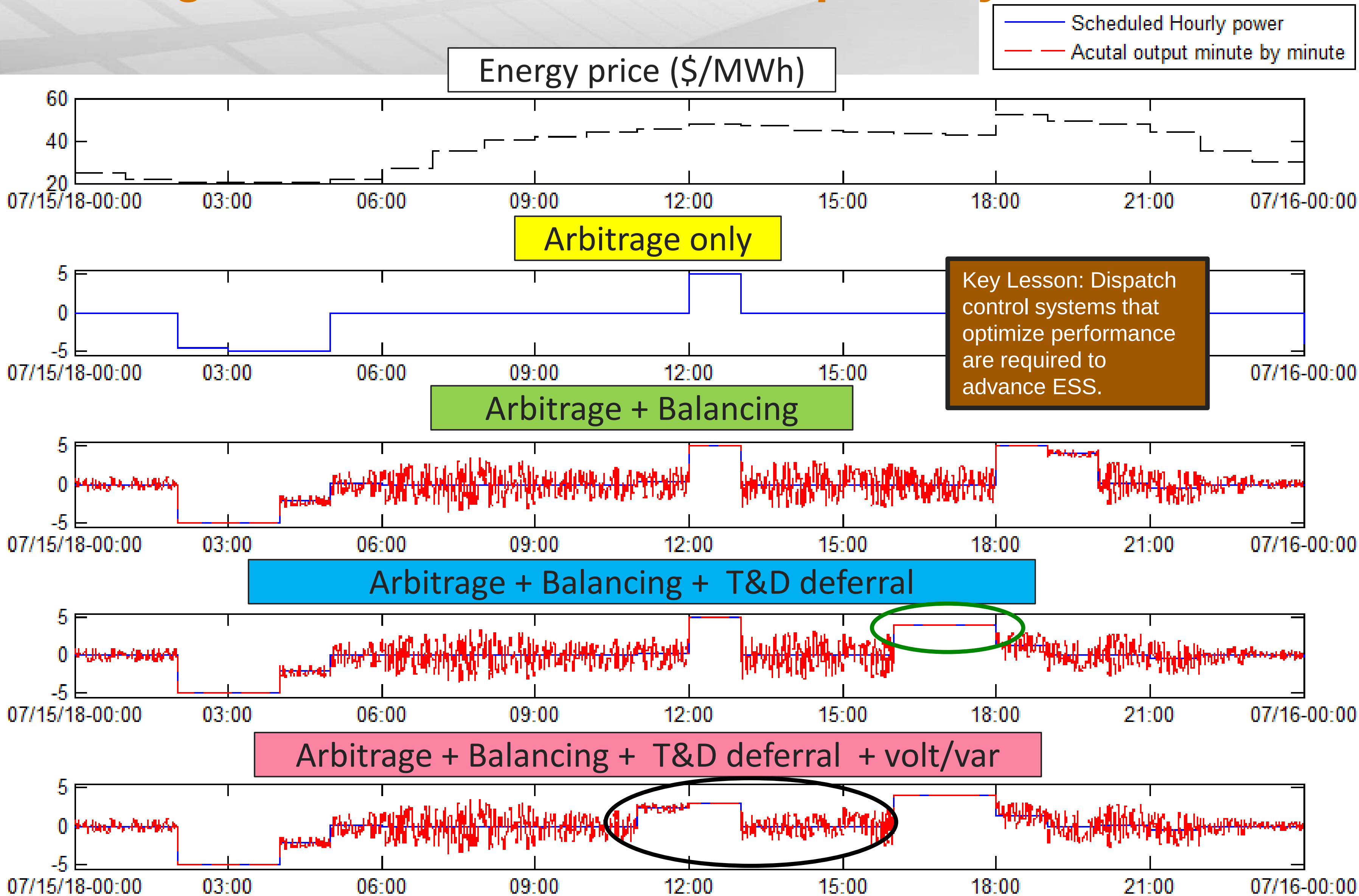
Bundling Services: How To Do It Optimally?



Bundling Services: How To Do It Optimally?

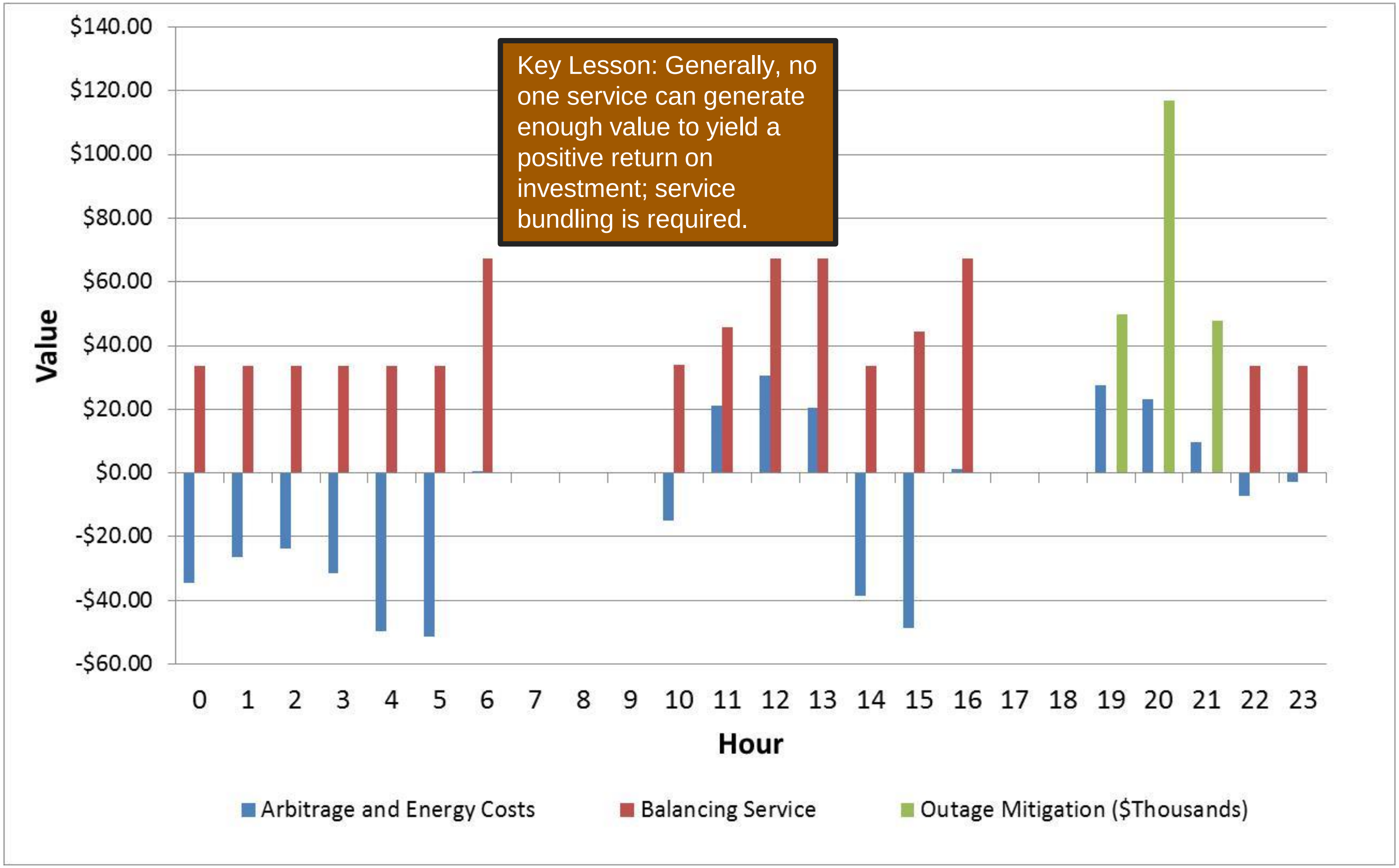


Bundling Services: How To Do It Optimally?



Key Lesson: Dispatch control systems that optimize performance are required to advance ESS.

Hourly Value at Bainbridge Island for 24-Hour Period



BSET Output

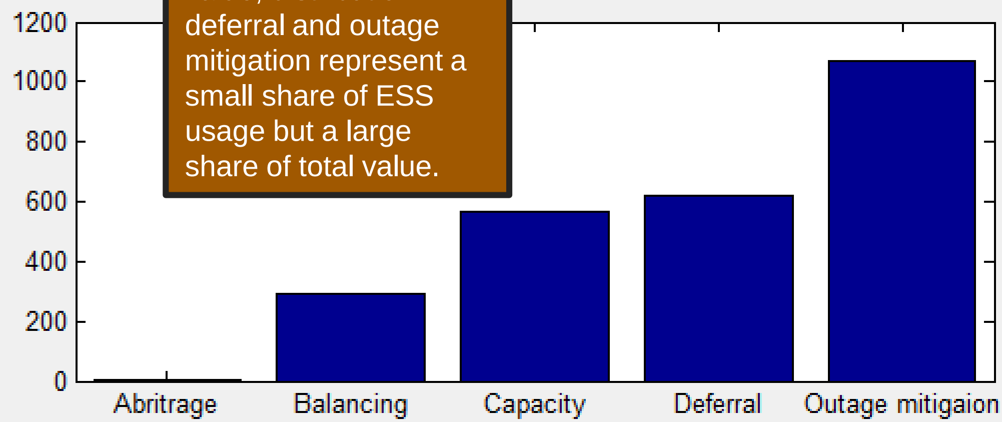
Primus_main

Input | Result

Key Lesson: Capacity value, distribution deferral and outage mitigation represent a small share of ESS usage but a large share of total value.

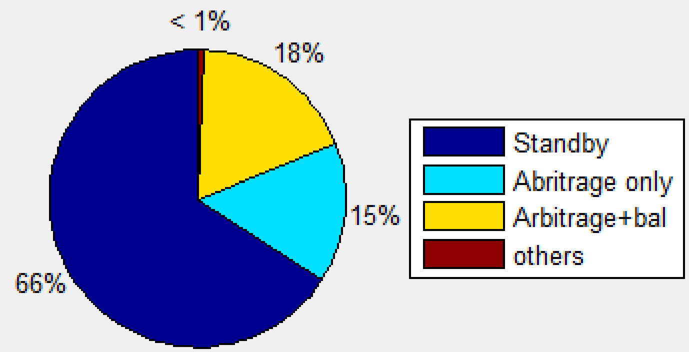
Value stream ($000)

Arbitrage:	5.336
Balancing:	290.251
Capacity value:	568.843
Deferral:	622.631
Outage mitigation:	1066.852
Total:	2553.914



Hour distribution (hours)

Standby:	5763
Abitrage:	1341
Arbitrage + bal.:	1593
Capacity value:	1
Deferral:	2
Outage mitigation:	60



Bainbridge System Cost Estimate

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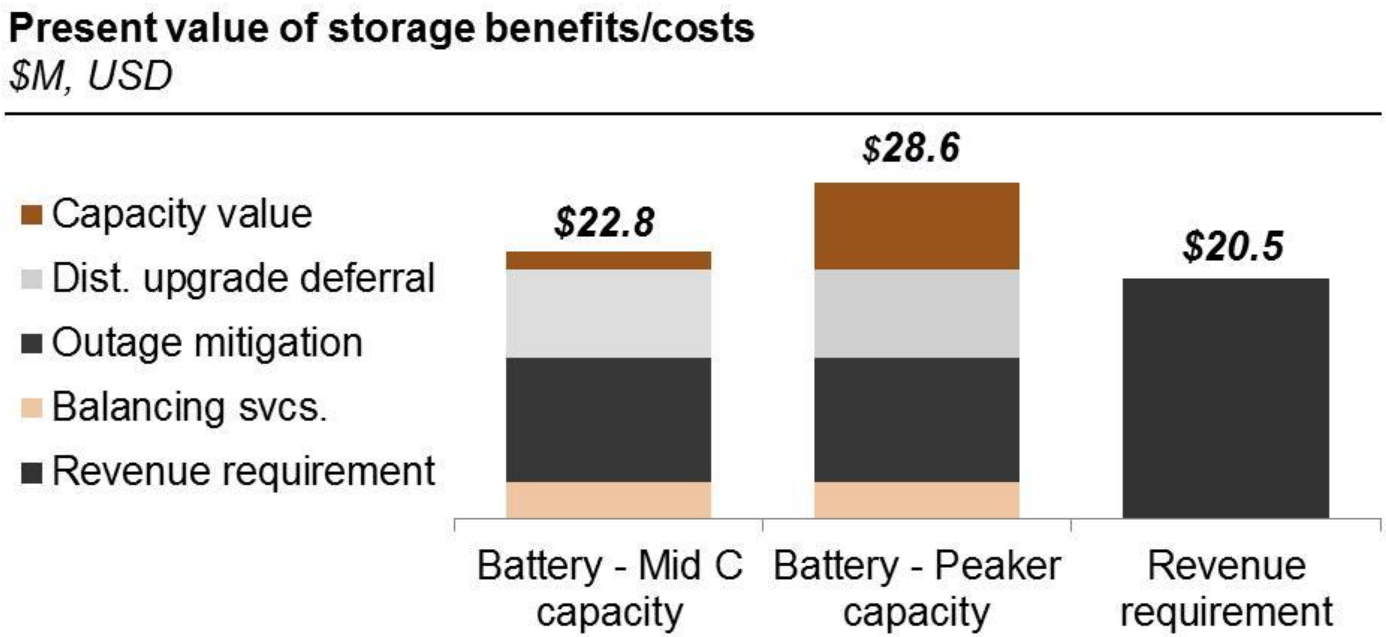
Budget Summary	Total Cost ($)	$/kW
Energy Farm Price	9,200,000	2,300
Siting	25,000	6
Electrical	564,000	141
Thermal Mgt	283,000	71
Site/Civil	318,000	80
Installation	247,000	62
Communications	185,000	46
IT	110,000	28
Overheads	2,266,000	567
WA Sales Tax	1,057,000	264
Contingency	505,000	126
TOTAL	**14,760,000**	**3,690**

- Greenfield build
- Some costs shared with future substation; subtracted from future sub costs
- Balance of plant (BOP) cost is ~20% of total cost
- Learning may reduce future costs
- Overhead costs may decline
- $20.5 million in revenue requirements.

Key Lesson: Site-specific non-battery costs can be significant ($750-$1,500 per kW).

Economics and Additional Benefits Bainbridge Island, WA



Key Lesson: When effectively sited and operated, energy storage can yield positive returns to investors.

- Regardless of capacity assumption economics "pencil out"
- Additional "difficult to quantify" value in
  - Knowledge transfer
  - Institutional know-how
  - Public awareness

Washington Clean Energy Fund Use Case Matrix

Use Case and application as described in PNNL Catalog	Avista	PSE	Sno – MESA1	Sno – MESA2	Sno - Controls Integration
UC1: Energy Shifting					
Energy shifting from peak to off-peak on a daily basis	Y	Y	Y	Y	
System capacity to meet adequacy requirements	Y	Y	Y	Y	
UC2: Provide Grid Flexibility					
Regulation services	Y	Y		Y*	
Load following services	Y	Y		Y*	
Real-world flexibility operation	Y	Y		Y*	
UC3: Improving Distribution Systems Efficiency					
Volt/Var control with local and/or remote information	Y		Y	Y	
Load-shaping service	Y	Y	Y	Y	
Deferment of distribution system upgrade	Y	Y			
UC4: Outage Management of Critical Loads		Y			
UC5: Enhanced Voltage Control					
Volt/Var control with local and/or remote information and during enhanced CVR events	Y				
UC6: Grid-connected and islanded micro-grid operations					
Black Start operation	Y				
Micro-grid operation while grid-connected	Y				
Micro-grid operation in islanded mode	Y				
UC7: Optimal Utilization of Energy Storage	Y	Y			Y

* A simulated set of signals will be provided by PNNL to test these use cases.

BSET – Behind-Meter User Interface

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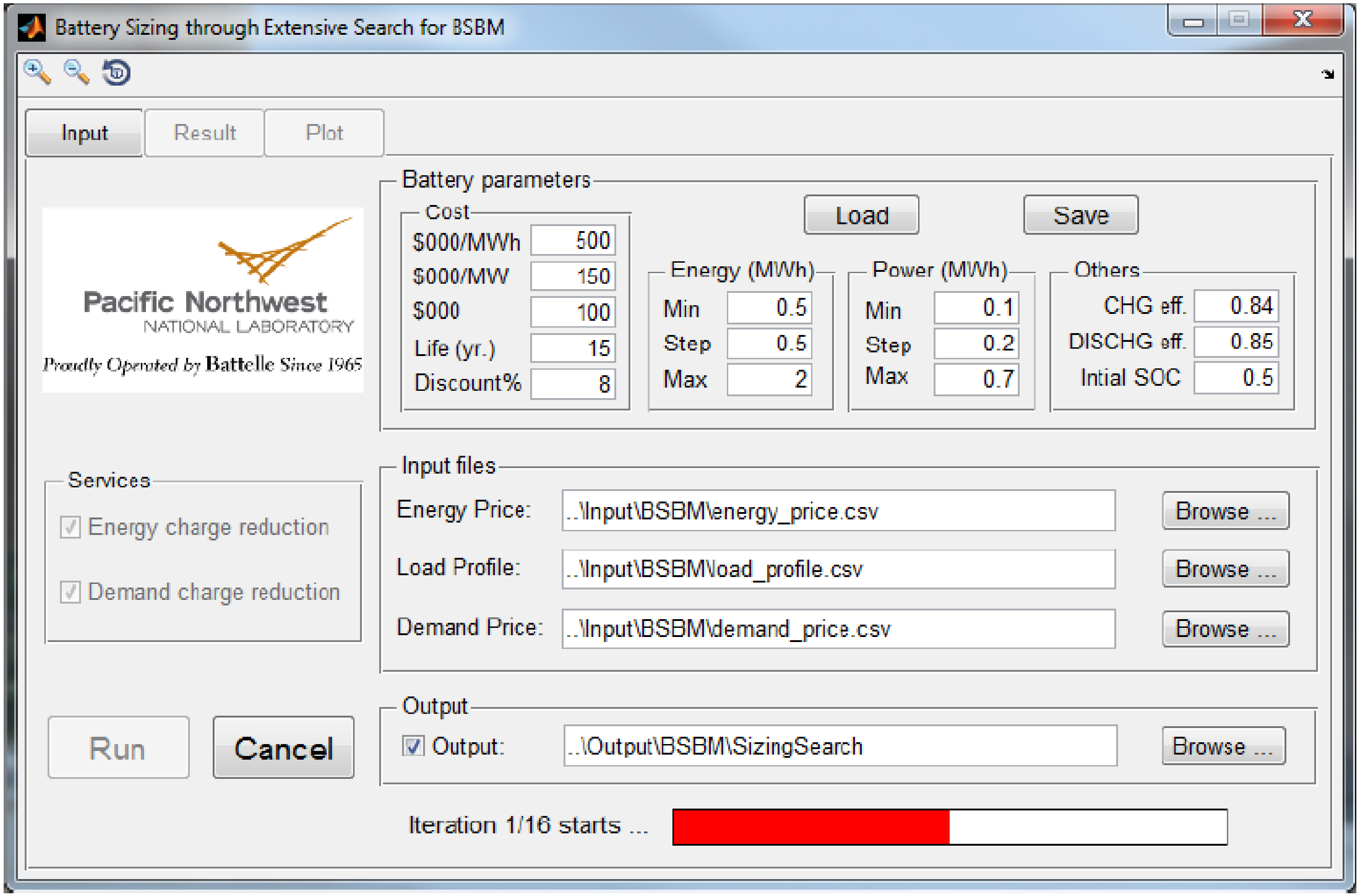
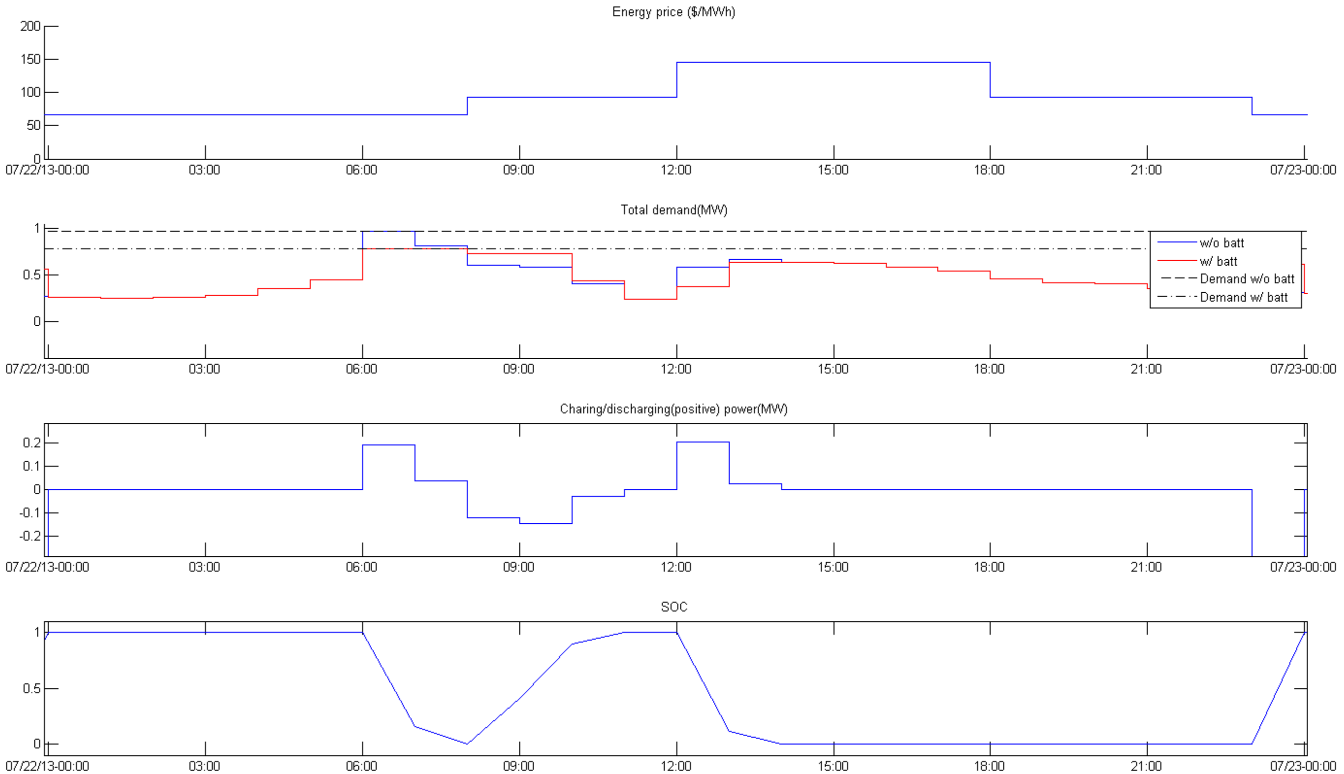


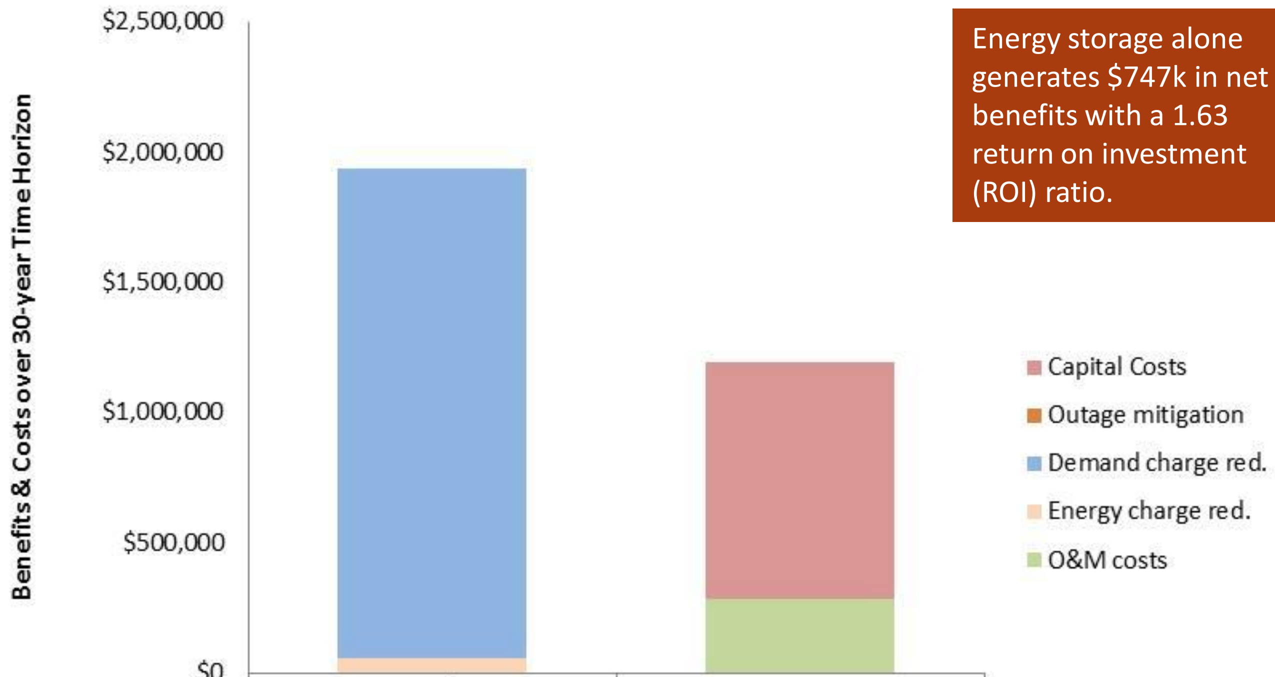
Battery Operation for An Illustrative Day



Key Lesson: The vast majority of energy storage benefits in behind-the-meter placements are tied to reductions in demand charges due to energy shifting.

Financial Results

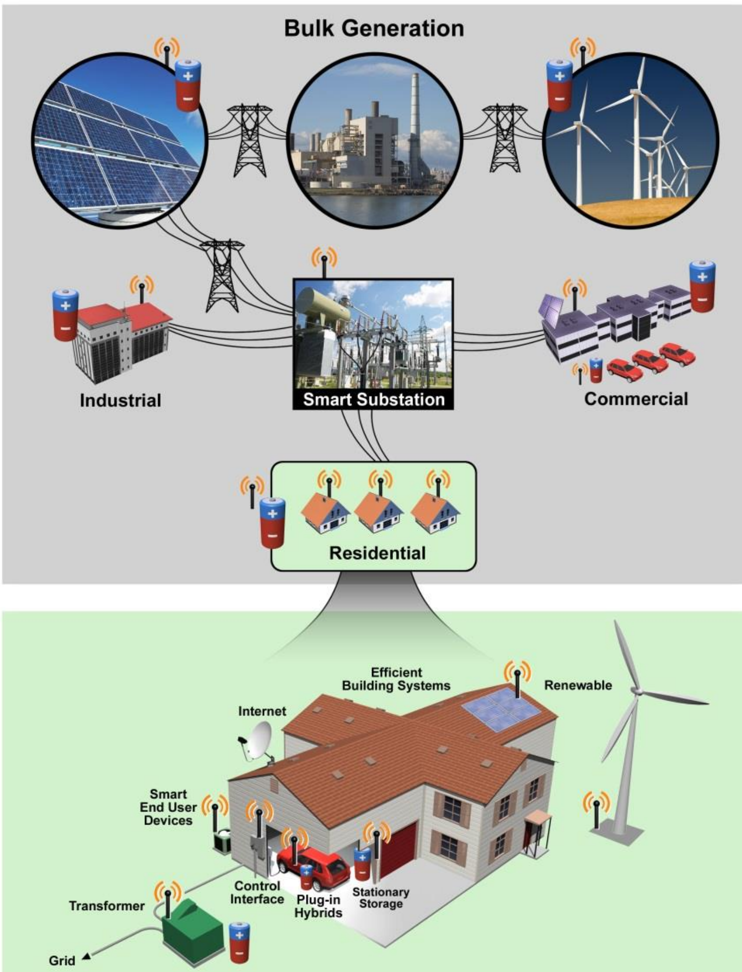
Scenario 1. 500 kW / 500 kWh energy storage



	Benefits	Costs
Capital Costs		$908,341
Outage mitigation	$-	
Demand charge red.	$1,883,644	
Energy charge red.	$56,162	
O&M costs		$284,443

Energy storage alone generates $747k in net benefits with a 1.63 return on investment (ROI) ratio.

Siting, Sizing, and Controlling Energy Storage to Maximize Benefits



Maximizing the Value of Storage Means:

- *Optimal location*
- *Optimal size*
- *Optimal control*
- *Optimal battery system design*

		Location		
		Transmission	Distribution	Customer-side
Control	Transmission	x	x	x
	Distribution		x	x
	Customer-side			x

Potential Projects for Evaluation in PSE Region

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- <u>Bainbridge Island</u>

  Two substations serving two-thirds of Bainbridge Island – Murden Cove built in 1980 and Winslow built in 1966 – are approaching their maximum capacity
- <u>Crystal Mountain</u>

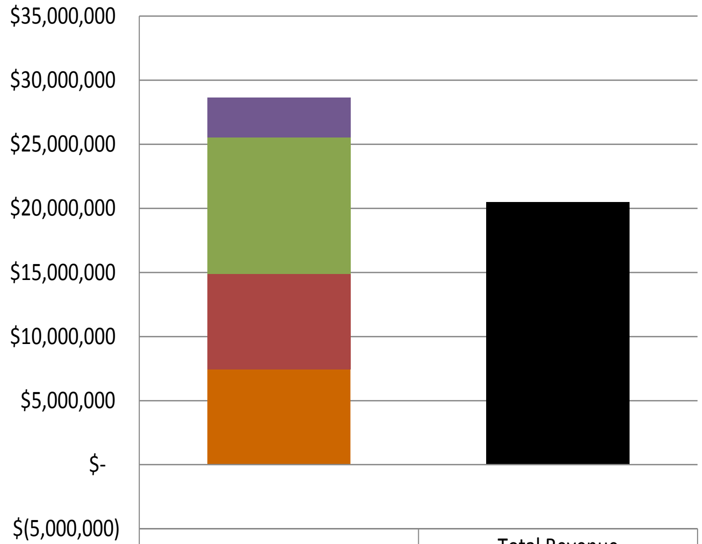
  Reliability problems associated with long, isolated feeder in mountainous region
- <u>Baker River 24</u>

  Long low-performing radial line where energy storage could be employed to isolate outages
- <u>Chico 12</u>

  Worst performing circuit where a new $10-$15 million substation is being considered to address reliability and capacity issues

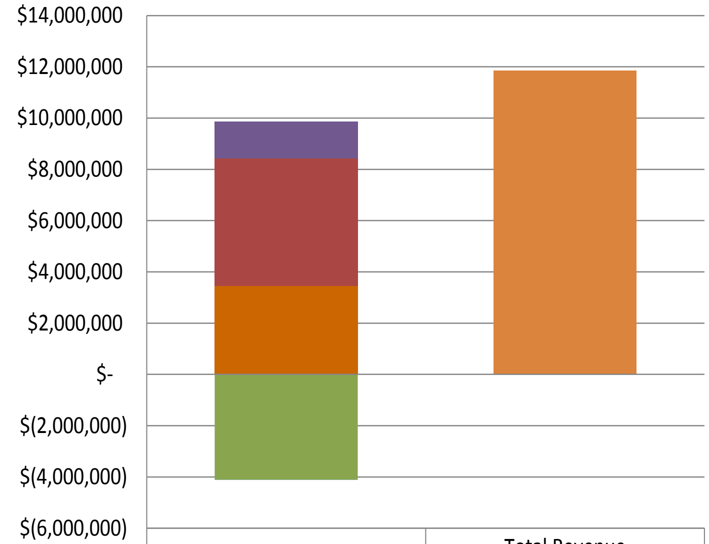
Summary of Results (PV Benefits and Revenue Requirements Over 20-year Time Horizon)

Bainbridge Island



	Scenario 3	Total Revenue Requirements
Revenue Requirements		$20,493,000
Arbitrage and Energy Costs	$(13,384)	
Balancing Services	$3,104,871	
Outage Mitigation	$10,632,260	
Distribution Upgrade Deferral	$7,454,000	
Capacity Value	$7,443,000	

Baker River

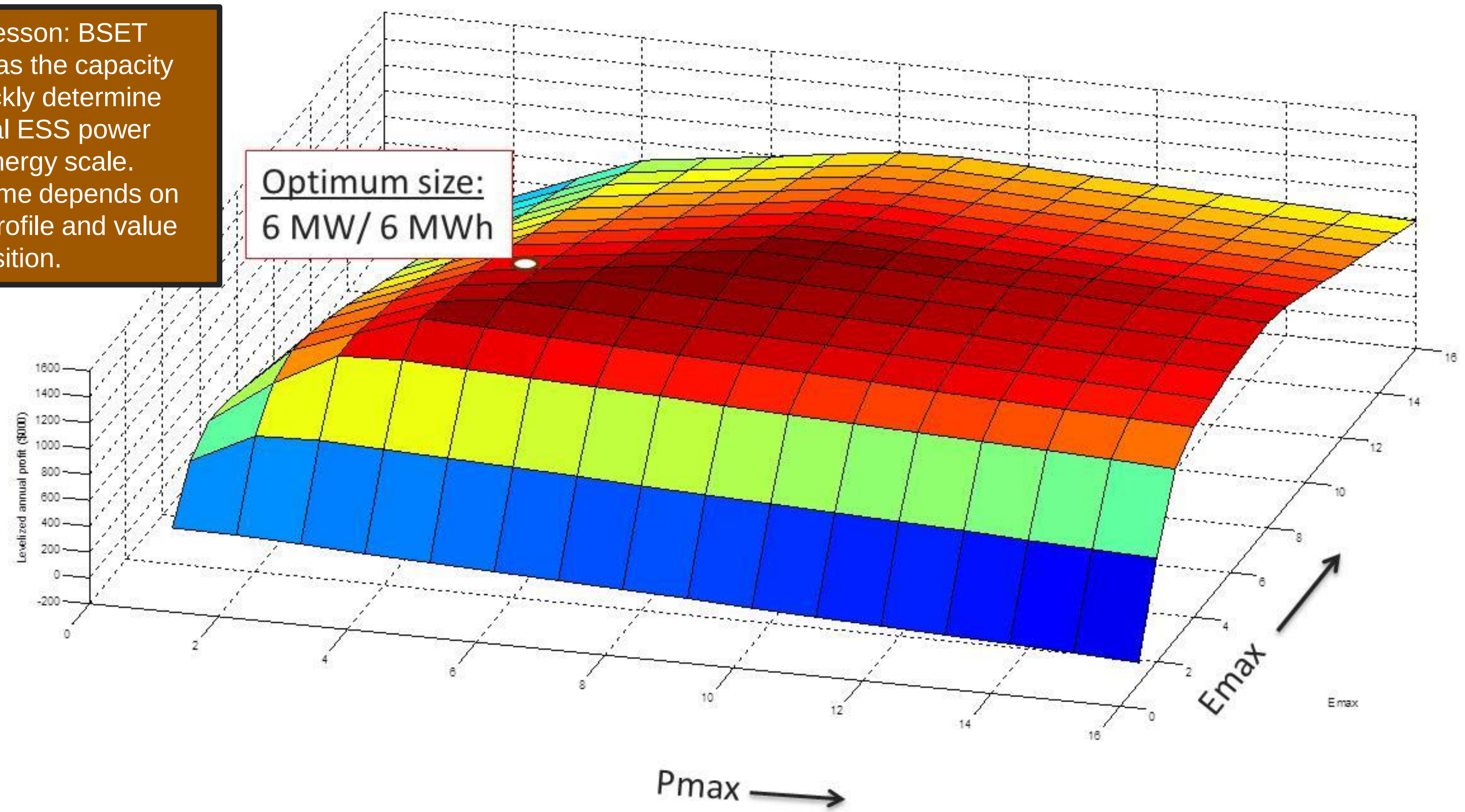


	Scenario 3	Total Revenue Requirements
Revenue Requirements		$11,862,000
Arbitrage and Energy Costs	$(5,930)	
Balancing Services	$1,437,248	
Outage Mitigation	$(4,111,598)	
Distribution Upgrade Deferral	$4,991,785	
Capacity Value	$3,442,000	

Key Lesson: Proper siting is extremely important. Baker River failed because the alternative distribution investment (placing lines underground) was more effective at improving reliability.

Sizing Energy Storage Optimally to Maximize Net Benefits

Key Lesson: BSET now has the capacity to quickly determine optimal ESS power and energy scale. Outcome depends on load profile and value proposition.



Conclusions

- Resource adequacy requirements and penetration of renewable, intermittent power are driving the need for investment in ESSs
- We have developed procedures to site and size ESSs and have made our tool (BSET) available for use; DOE has demonstrated a willingness to provide analytical support for proposed and existing ESS projects
- PNNL is currently supporting Portland General Electric's analysis of its Salem Smart Power Center; PNNL has provided BSET to PacifiCorp and partnered on a proposal to the Washington CEF
- Any single use would rarely yield positive returns on investment; services usually must be bundled and co-optimized
- We are evaluating a broader set of use cases through our Washington CEF engagement; use case values differ significantly by utility
- Maximizing the value of energy storage requires optimal siting, sizing, control and design of the ESS
- Dispatch control systems that optimize performance are required to advance energy storage.

Energy Storage Guideline Development

UM 1751

PGE Update

Monday, February 29, 2016

Portland General Electric

Agenda

- PGE vision and principles
- Energy storage definition
- Use cases
- Use case definitions
- Valuation methodology overview

Energy Storage

Vision

Provide a diversified energy storage portfolio while integrating all resources through PGE system operations

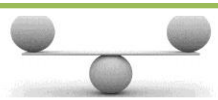
Principles. Energy storage…

is an integration resource serving as load or generation as required

provides a system benefit for all customers

integrates transmission and distribution with power operations

enables resource diversification and grid decarbonization efforts

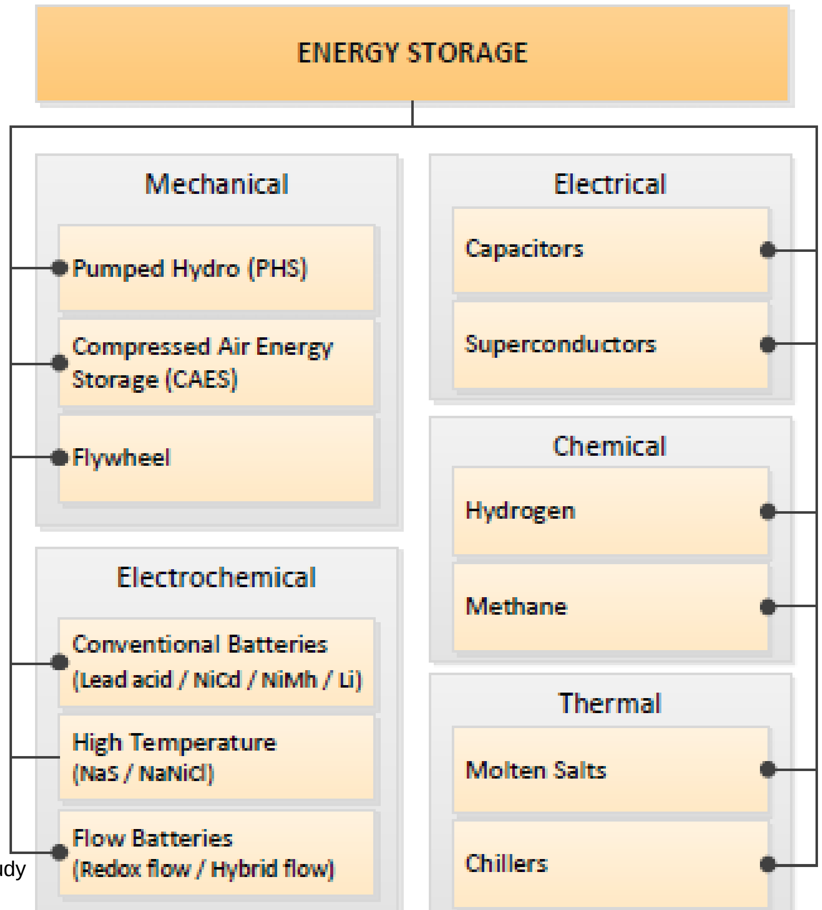


helps balance cost and risk while maximizing reliability

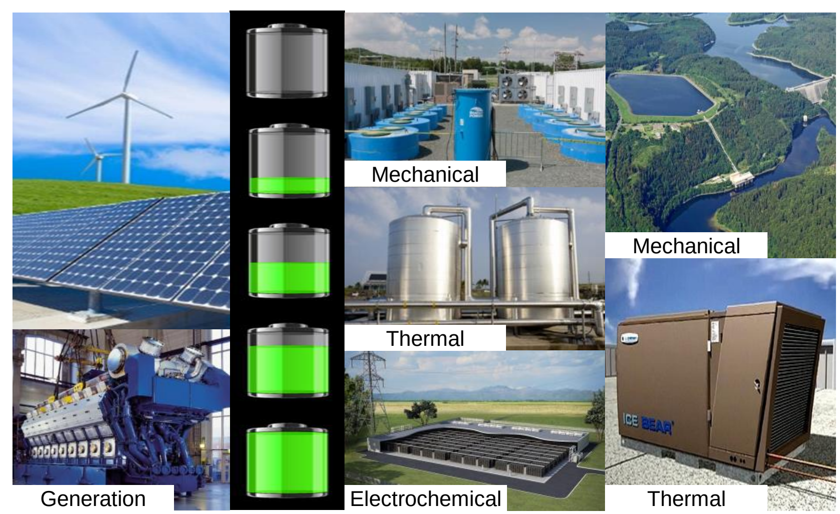
Energy Storage

Slide 4

Broadly, the definition of energy storage includes any system for absorbing energy at one time and releasing energy at a later time.



Storage technologies can be grouped by the similarities of the storage medium.



Source:
AECOM Australia,
Energy Storage Study
July 2015

Portland General Electric

Use Cases

Use Categories	Duration Of Output Energy (Continuous)		
	Short (< 2 min)	Medium (2min – 1 hr)	Long (1 hr +)
Economic Dispatch			Energy Shifting System Peak Capacity
Ancillary Services	Frequency Response Regulation	Contingency Reserves Regulation	Black Start
Integration		Ramping Following Forecast Error	Avoid Curtailment / Min Load Forecast Error
Asset Optimization	System Inertia / Power Quality System Reliability	System Reliability	Infrastructure Deferral System Reliability Transmission Congestion Relief Micro-grid

Dynamic Response ⟷ Sustained Response

Use Case Definitions

Slide 6

Economic Dispatch

- **System Peak Capacity:**
  - Instances of high system demand (load in excess of dispatched resources and purchases) where PGE has to dispatch additional peaking resources, call on peaking contracts, or procure capacity.

- **Energy Shifting:**
  - Provide load in off-peak or over-generation hours (charging) and energy in peak hours (discharging).

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Use Case Definitions

Slide 7

Ancillary Services

- **Frequency Response:**
  - Online and available capacity capable of responding to frequency events. Expressed in megawatts per 0.1 Hertz. Events are typically evaluated on a 20-52 second window. Required by NERC BAL–003–1 standard.
- **Contingency Reserves:**
  - Capacity available to respond to disturbance events (e.g. generator loss) or to mitigate operating emergencies. Requirement is 3% of load and 3% of generation, at least half spinning (online, 10 minute response, delivered for one hour) and the remaining non-spinning (offline, 10 minute response, delivered for one hour).Required by NERC BAL–002 standards.
- **Regulation:**
  - Upward and downward generator capacity capable of responding to automatic generation control used to balance second-to-second changes. Required by NERC BAL–001–1 standard.

Use Case Definitions

Slide 8

Integration

- **Forecast Error:**
  - Upward and downward generator capacity held to respond to errors in the day-ahead and hour-ahead forecasts.
- **Following:**
  - Capacity used to offset Variable Energy Resource (VER) generation and load fluctuations within the interval.
- **Ramping:**
  - Capacity to respond to sudden large output changes occurring in shorter durations (e.g. cloud cover of solar array) that require response from other generation assets.

Asset Optimization

- **Infrastructure Deferral:**
  - The use of energy storage device to avoid or defer upgrades on PGE's Transmission and Distribution systems.

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Valuation Methodologies

Slide 9

Data Sources	Applicable Use Cases	Opportunities	Challenges
Organized Markets	• System peaks • Shifting demand • Frequency response • Contingency reserve • Following and ramping	• CAISO indicators, future EIM participation • Transparent • Easily available data • Multiple Products	• None in Pacific NW • Price volatility • Different interpretation of product definitions
Tariff (Costs and Prices)	• Frequency response • Contingency reserve • Forecast error • Following and ramping	• Public • Definitions aligned with NERC/FERC	• Static values • Can be stale
Engineering Studies (Avoided Operation Costs)	• Forecast error • Following and ramping	• Detailed information	• PGE specific • Periodic update
Capital Cost/Revenue Requirement Models (Deferrals)	• Infrastructure deferral	• Standard costs • Transparent methodology • Industry norm model	• Identify all components that can be deferred • Need location

Valuation Methodologies

Slide 10

Data Sources	Applicable Use Cases	Opportunities	Challenges
Existing Bilateral Agreements	• All uses cases	• Indicative • OPUC reviewed	• Confidential • Can be stale • Illiquid market
Violation Penalties	• Frequency response • Contingency reserve	• FERC/NERC standards • Align with product definition • Some are WECC specific	• Unclear costs and penalties • Lack of costs and penalties data • Step-wise
Production Cost / Simulation Models	• System peak • Shifting demand • Contingency reserve • Forecast error • Following and ramping • Infrastructure deferral	• Industry norm • OPUC and Technical Review Committee accepted • Customizable • GHG reduction • Reduced stops/starts	• Model limitations • Scaling issues and unrealistic results • Only as good as inputs

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Portland General Electric

Storage Valuation Methodologies

Observations & Best Practices

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STRATEGIES FOR CLEAN ENERGY

Mark Higgins

Prepared for Oregon Public Utilities Commission, UM 1751
February 29, 2016

www.strategen.com

About Strategen Consulting

Our Core Strengths

- Unique focus in strategic advisory work in the clean energy industry
- Unparalleled Experience in New Grid Technologies
- Over 10 years consulting in PV and energy storage space

Certified WBENC Women's Business Enterprise
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Consulting Lines of Business

- **Utilities:** Focus on new grid technology implementation and strategy
- **Public Sector (Governments and Nonprofits):** Consultant on dozens of regulatory proceedings in numerous states
- **Corporate:** Strategy support for technology providers and project developers throughout the power sector ecosystem

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Storage Benefits Cut Across Multiple Silos

T&D Planning
- Transmission Asset Deferral
- Distribution Asset Deferral

Resource Planning
- System Capacity
- Flexibility / Ancillary Services
- Regulatory Compliance
- Fleet Optimization

Customer Programs
- Customer Bill Management
- Demand Response Participation
- Customer Programs
- DER/EV interconnection cost management

» Storage cost effectiveness is limited when based on a single benefit stream

» When system needs are prioritized and benefits are stacked, storage has potential to lower ratepayer costs and to increase reliability and efficiency of the grid

Approach to Evaluating Storage Opportunities

1. Identify primary need

2. Explore combinations of stackable benefits; discard incompatible value streams

3. Optimize value streams and understand tradeoffs

Valuation Methodology: California

» Each utility has least cost – best fit methodology based on unique needs:
- Utility-specific criteria
- Custom evaluation tools
- Proprietary, confidential evaluation criteria

» California Public Utilities Commission has Common Evaluation Protocol
- Provides transparency so stakeholders have common frame of reference
- Net Market Value = Benefits minus Costs

Market Benefits	Market Costs
• Capacity/Resource Adequacy Value • Energy Value	• Fixed Capacity Payments and Fixed O&M Cost* • Charging Costs and Variable O&M Cost
• Ancillary Services Value • Distribution Investment Deferral Value	• Network Upgrade Cost • GHG Compliance Cost (if applicable to project)
	• Debt Equivalency Cost • Market Participation Cost

*Includes developers' costs such as permitting, construction, decommissioning, etc.

Source: CPUC Energy Storage Workshop, July 28, 2015

California public assumptions will be updated in Fall 2016. Most recent avoided cost assumptions can be found here: http://www.ethree.com/public_projects/cpuc5.php

Valuation Methodology: Pacific Gas & Electric

Co-optimize Energy, A/S, Variable Cost => Charging/Discharging

+ Net Energy Value
- Value of discharging – cost of charging using projected LMP

+ Ancillary Services Value
- Regulation up/down/REM, Spin in a limited market

+ Capacity Value
- Generic Resource Adequacy using Net Qualifying Capacity
- Flexible RA using Effective Flexible Capacity

- Variable Cost
- Variable O&M price applied over *discharge* schedule
- includes fuel and start-up costs plus GMC, but not charging cost

- Fixed Cost
- Sum of capacity payment price times monthly contract capacity
- Fixed overhead (administrative costs plus cost of CAISO scheduling)

Adjustments for Localized Benefits and Portfolio Effects

+/- Location
- Preference for NP15 projects
- Local Capacity Requirements may warrant premium

- Transmission Network Upgrade Cost
- This is past first point of interconnection; cost to interconnect in bid

+ Transmission/Distribution Investment Deferral Value
- NPV of least expensive non-storage alternative
- If dual-use, meet reliability need first, remaining hours play in market

+ Increased Efficiency for Fossil Generation
- Value to smoothing out net load => fewer starts, better efficiency
- Portfolio-wide benefit, will probably depend on generic characteristics

+ Renewable Generation Curtailment Support
- Also, portfolio-wide: benefit of reduced curtailment, increased RPS

Source: PG&E Evaluation of Storage Offers Presentation, March 14, 2014

Case Study: Puget Sound Energy

- Puget Sound Energy evaluated storage as part of non-wires alternatives assessment for Energize Eastside project (www.energizeeastside.com)

Step 1: Identify primary system need

PSE: New transmission investment needed to address reliability needs due to load growth.

Step 2: Evaluate storage as a solution

PSE: Technical study assessed feasibility of storage as a transmission deferral option.*

Step 3: Identify secondary use cases with highest value

PSE: High value use cases included system peak capacity, flexibility, and reduced curtailment.

Step 4: "De-rate" secondary use cases based on compatibility with primary use case

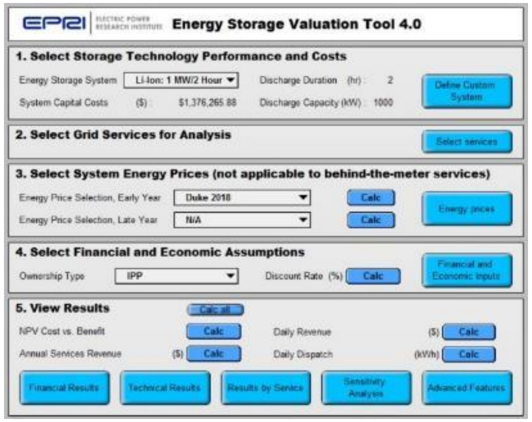
PSE: Capacity benefit was reduced to the extent it was not correlated with local (Eastside) peak.

Step 5: Evaluate cost-effectiveness of primary and secondary use cases

PSE: NPV of costs and benefits estimated.

**Note: The preferred storage configuration was found to be technically infeasible, however, one of the alternate configurations was still evaluated for cost-effectiveness.*

Cost-Benefit Analysis Tools

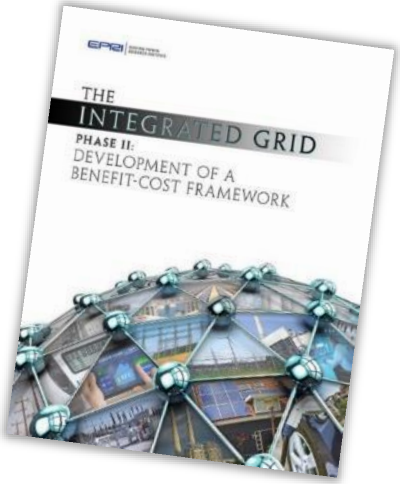


- »***Energy Storage Valuation Tool (ESVT) V4.0***
  - Developed by EPRI
  - Free to members, available for purchase to non-members
- »***Energy Storage Computational Tool (ESCT) V1.2***
  - Developed by Navigant for DOE
  - Public license:

    https://www.smartgrid.gov/recovery_act/analytical_approach/energy_storage_computational_tool.html
- »***ES-Select***
  - Developed by Sandia and KEMA (now DNV GL)
  - Public license:

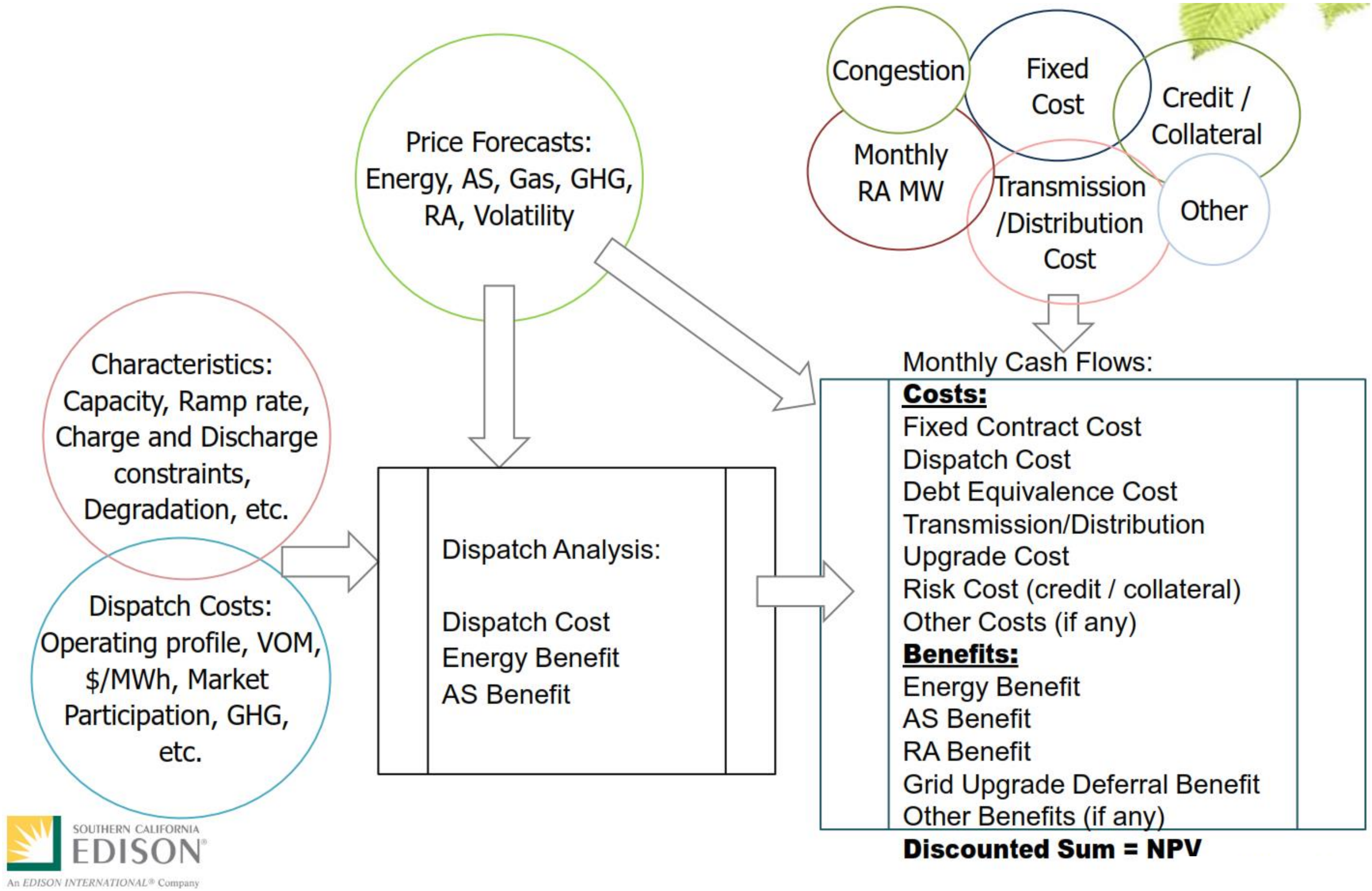
    http://www.sandia.gov/ess/tools/es-select-tool/
- »***Battery Storage Evaluation Tool (BSET)***
  - Developed by PNNL
  - PNNL is developing a PGE-specific BSET tool with DOE grant funding
  - Public license:

    http://www.sandia.gov/ess/docs/pr_conferences/2015/EESAT%202%20Wednesday/Balducci.pdf
- »***StorageVET-California*** (Coming late 2016 for public delivery)
  - Advances prior work on ESVT with a public, web-hosted model
  - Supports regulatory, planning, investment, and operations usage
  - Use case development and review occurring through ESIC Analysis Working Group



Appendix

SCE Methodology



Source: SCE Procurement Plan Workshop Presentation, March 14, 2014

California IOU 2014 Storage RFOs Compared

- » California IOUs launched RFOs on or before Dec 1, 2014.
- » Applications due by Dec 1, 2015

Detail	SCE	SDG&E	PG&E
# of MWs Solicited	At least 16.3 MW	25 – 300 MW	74 MW
Size	1 MW min	500 kW min	10 MW min for transmission-connected, 1 MW min for distribution-connected
Functions Solicited	Resource adequacy (required) and energy shifting, ancillary (optional)	Local resource adequacy. Participation in CAISO energy market, A/S markets.	Distribution system investment deferral. Participation in CAISO energy market, A/S markets.
Points of Interconnection	Transmission or distribution	Transmission, distribution, and customer	Transmission, distribution, and customer
Contract Terms	Preference of 10 year max	No minimum or maximum duration	Preference of 10 year max

Source: CPUC Storage OIR Workshop presentation July 28 2105

Other Solicitations Compared

Detail	HECO Energy Storage System RFP	Ontario Power Authority RFP	Kauai Island Utility Cooperative	Imperial Irrigation District RFQ	Austin Energy RFI
# of MWs Solicited	60 – 200 MW	0.5 – 2 (up to 5 MW for pumped hydro)	Open; 5 – 10 MW example	20 – 40 MW	10 – 170 MW
Size (MWh)	30 – 100 MWh	Not specified	Open; 20 – 40 MWh example	Not specified	Not specified
Functions Solicited	Renewable generation variability, voltage and frequency regulation	Energy time shifting	Over generation curtailment, renewable generation variability	Provide reserves, ramping and frequency regulation	General energy storage
Contract Terms	Not specified	Ten years	Preference for performance contracts	Not specified	Not specified

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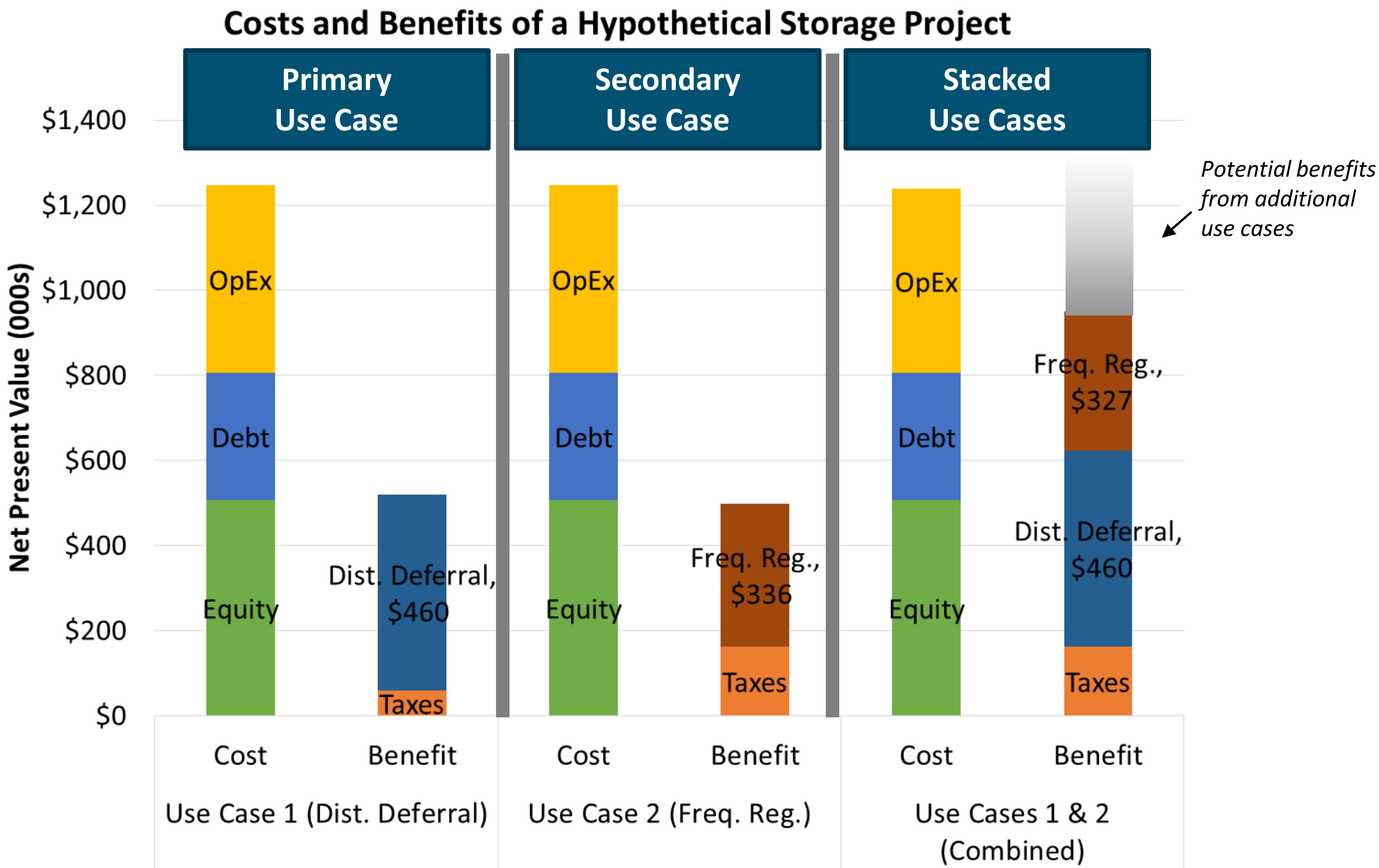
Benefit Stacking: Dist. Deferral + Frequency Regulation



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UM 1751 Energy Storage Workshop #2

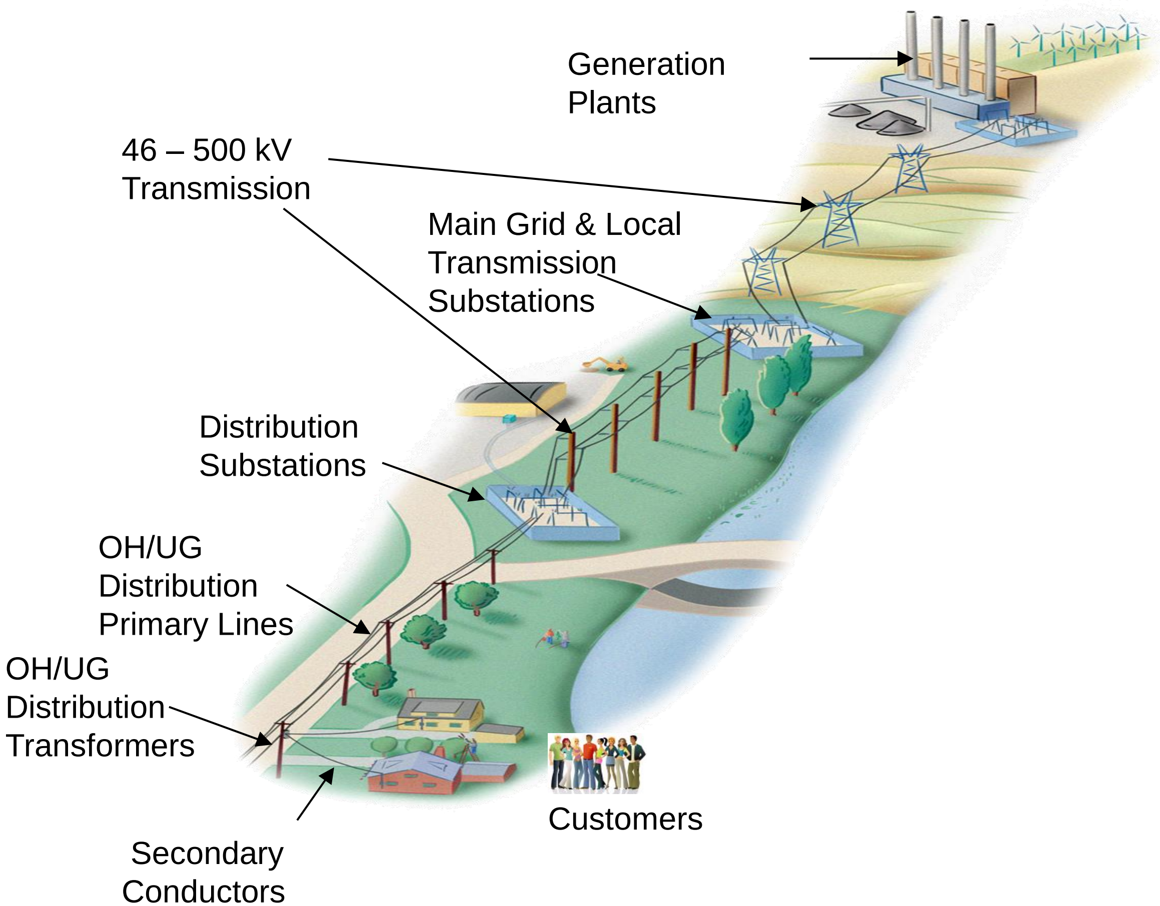
February 29, 2016



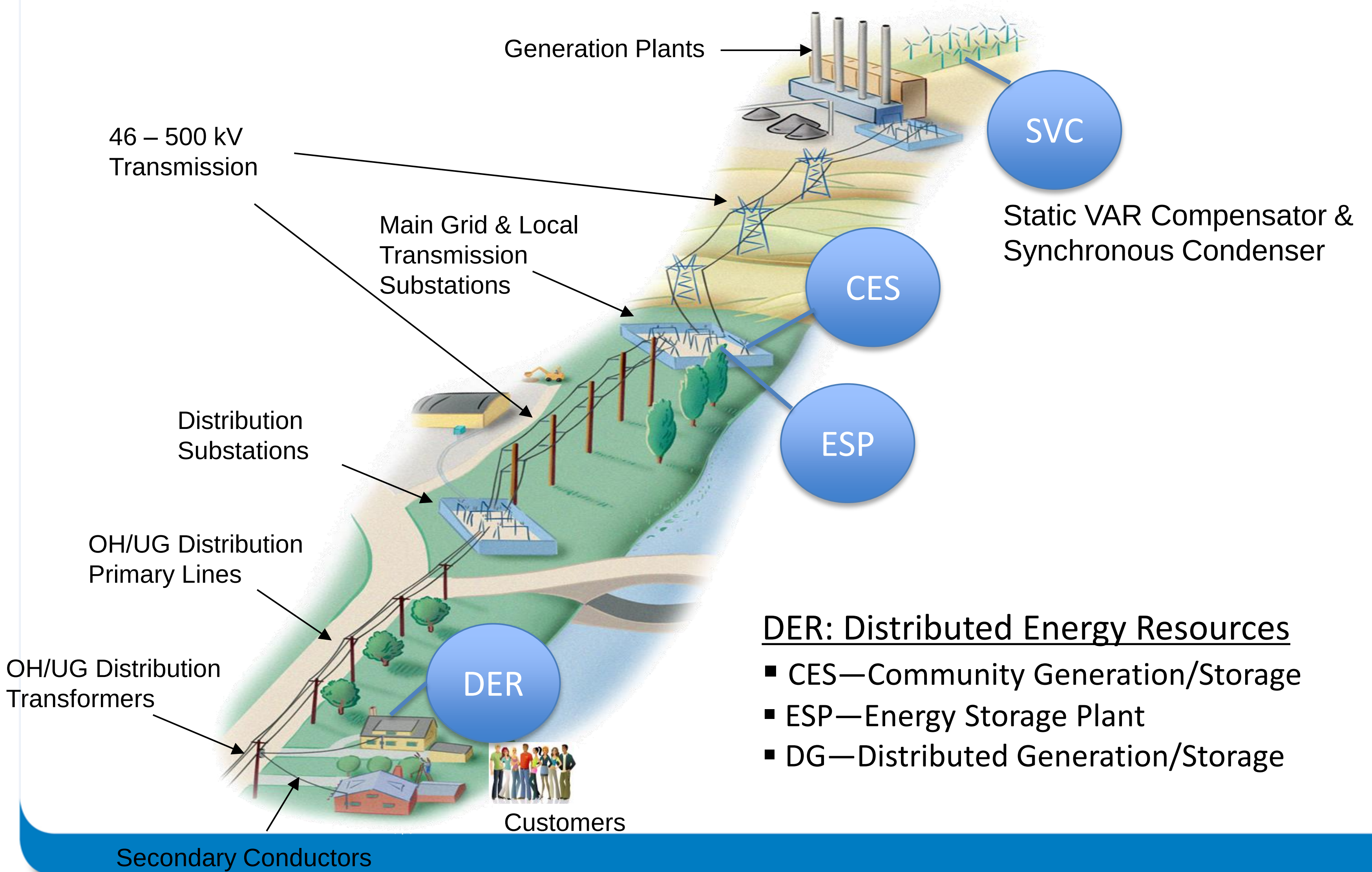


PACIFICORP

The Power System of Today



The Power System of the Future



DER: Distributed Energy Resources

- CES—Community Generation/Storage
- ESP—Energy Storage Plant
- DG—Distributed Generation/Storage

PacifiCorp's First Experience with Battery Storage

Castle Valley Vanadium Redox Battery Storage (VRB)

- 250 kW/8 hour; energy time shift
- End of very long 25 kV distribution feeder
- Load was growing; could not build new assets
- Near Moab, Utah – near Arches NP
- "Early adopter" issues
- Installed in 2002
- In-service in 2004
- De-commissioned in 2008

UM 1751 Preliminary Objectives

Examine the potential value of applying energy storage system technology :

- *Deferred generation and T&D*
- *Reduced need for generation during peak demand*
- *Improved renewable resource integration*
- *Reduced greenhouse gas emissions*
- *Improved reliability of T&D systems*
- *Reduced portfolio variable power costs*
- *Any other value reasonably related to application of energy storage*

Context of this Discussion

- Focus on electric energy Battery Storage.
- Large utility scale Pumped Storage or Compressed Air Energy Storage are important storage options. Understanding the granularity and flexibility of Battery Storage systems will help in valuing other large utility storage technologies.
- Focus on utility-owned storage, not customer-owned storage (peak demand shaving or reliability objectives).
- Key objectives are to identify optimized use cases, which may include simultaneous stacking (“benefit stacking”).
- Applying our interpretations of “value use” cases to fit in the UM 1751 categories.
- Need to adopt common language for use cases and which buckets to put them in.

What quantifiable values can be measured and recognized that provide net benefits to customers?

Deferred Generation and T&D

- **Deferred Generation** – deferred generation capacity benefit will depend on the following factors:
  - Timing, type and cost assumptions of deferred resource.
  - Performance characteristics of deferred resource and storage resource. Need to factor in differences in ancillary services performance of the peaking resource to the performance of the storage resource (i.e. ramp rate and energy).
- **Deferred Transmission & Distribution** – a time value of money analysis. Ten year deferral has a value of approximately $644,000 / $1 million in deferred expenditures (excluding energy recharge costs). Site specific analysis is needed.
- Potential for reduced transmission wheeling charges.
- Other use case applications when not in peak shaving mode.

Reduced Need for Generation During Peak Demand

- **Arbitrage** or **Electric Energy Time Shift**
- Deterministic values prepared under perfect knowledge
- Critical factors that influence arbitrage benefits:
  - Energy storage duration
  - Cycle efficiency
  - Seasonal loads and resource balances
  - Cost of peaking fuel and peaking resource type
  - O&M cost of “storage” (cycle cost, depth of discharge cost)
- 1 MW/4 MWhr battery value over 20 years = $400k+
- **Prediction: Traditional peak periods and values will change**

Improved Renewable Resource Integration

- Avoided balancing charges - reducing forecast error (especially for utility wind)
- Benefit in the form of capacity firming
  - Intermittency from shading or wind
- Time shifting (especially for solar PV) for peak management

Reduced Greenhouse Gas Emissions

- Storage is a generator, but fundamentally it is a net consumer of energy
- Storage may be an approach to reduce/eliminate the need for curtailment from intermittent renewable sources to assist in achieving RPS targets.
- Sources of reduced GHG emissions include reducing the operation of fossil-based integration resources for intermittent resources (i.e. gas-based generation)
- Storage may increase GHG emissions depending on sources of recharge energy, cycle efficiencies and displaced resources
- Market values for GHG emissions will need to be developed

Improved Reliability of T&D Systems

- Frequency regulation (primary use case for storage in RTOs with established markets for primary ancillary services) - needed to balance short term imbalances via AGC to maintain frequency within a balancing authority. **RTO-based pricing for these services would provide clearest indication of value.**
- Outage mitigation
- Backup Power (compare to cost traditional sources - reciprocating engines)
- Black Start (compare to cost of traditional solutions – reciprocating engines, combustion turbines and hydro)
- Power quality - volt/var control (compare to traditional solutions – capacitor banks, other inverter-based sources)
- Note: Analysis that includes a benefit for deferred generation capacity should recognize the differences attributable to the battery storage resource and the generation resource

Reduced Portfolio Variable Power Costs

- Transfer spinning reserve (10 minute) requirements from traditional "spinning" sources to storage resources. Benefits:
  - Increased power sales from traditional reserve-carrying units (value from incremental margin from sales)
  - Improved heat rate benefits from the fossil reserve carrying units operating at a higher efficiency (value based on reduction in fuel costs per new MWh generated)
- Non-spinning reserves
  - Benefit associated with reduced need for Demand Response resources (curtailable loads). Contract costs & energy sales
- **Reserves - RTO pricing would provide clearest indication of value**
- Recharge mode - value based on heat rate benefits of operating the recharge energy source at higher loads (and efficiency)

Challenges

- Critical analysis is needed to avoid double counting benefits
- Hypothetical values do not equate to need (and therefore benefit, to customers)
- Need to identify use cases that can be pancaked
- Value scenarios change with application, underlying generation resources, storage technology, location and timing
- Value will change based on time of year and then-current loads and resources
- Value analysis needs to include O&M costs of storage
- Recognize value differences between perfect knowledge and actual events
- Translate aggregated value use cases to a “real world” control system

Valuing Storage in IRP Modelling

- PacifiCorp's Integrated Resource Plan (IRP) planning process selects resources to meet forecasted load and firm obligations with a planning reserve margin (13% in the 2015 IRP).
- Resources are selected based on minimizing the cost of meeting capacity (at the time of system peak) and energy needs.
- IRP modeling tools are used to compare the relative cost and risk of different resource portfolios, which includes peak capacity benefits, energy benefits and operating reserve benefits of one resource portfolio relative to some alternative.
- IRP models are not inherently designed to capture value streams such as T&D deferrals, improved reliability of T&D systems and avoided balancing charges.

Valuing Storage in IRP Modelling

- Modeling tools that capture other value streams are needed to evaluate potential incremental benefits (beyond what the traditional IRP models are capable of simulating).
- PacifiCorp is looking at available modeling tools and methods for incorporating site specific project opportunities within the IRP resource modeling framework.

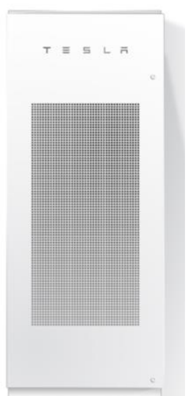
Energy Storage and Distributed Energy Solutions

Our Vision

To create the most compelling energy company of the 21st century by delivering cleaner, cheaper power through distributed generation.

Leader in storage technology

- Developed suite of battery products + internal software
- Fully integrated grid scale and distributed storage
- Over 340 batteries deployed by SolarCity with significant increased deployment
- SolarCity is currently using Tesla's energy storage systems, but continually monitors the market for best in class options



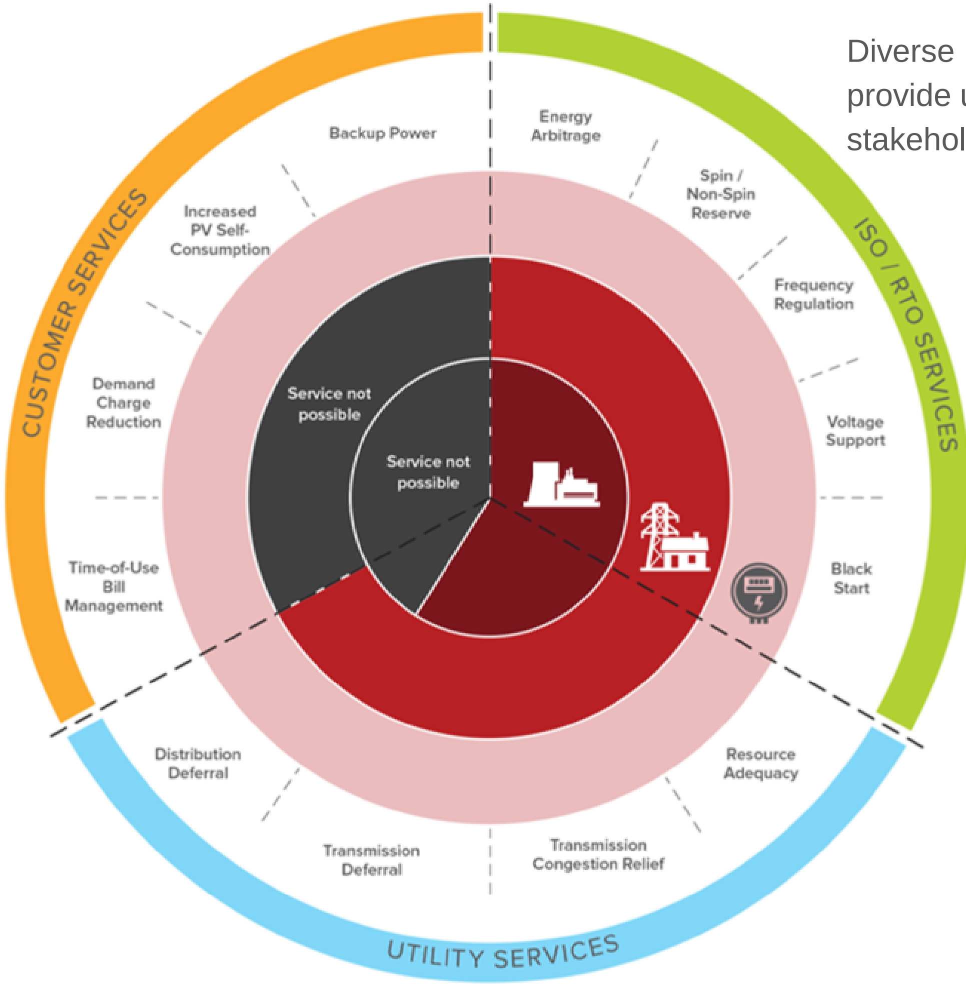
Powerpack

250kW /500 kWh blocks
Fully scalable

SolarCity Uses Li-ion Storage Technology

- Highly versatile – Lithium-Ion batteries can address both short and medium duration use cases
- Proven technology – Lithium-Ion batteries have been proven to be a highly reliable and safe power supply through a broad range of applications (consumer electronics, automotive, electric utility, etc.)
- Cost Advantage – As Lithium-Ion manufacturing scales notably due to electric vehicle deployment, Li-Ion battery pricing is positioned to benefit.

Stacked benefits of energy storage: Multiple benefits across all grid sectors



Diverse DER portfolios can provide up to 13 services to 3 stakeholder groups

Reprinted with permission from Rocky Mountain Institute

SolarCity

Distributed storage currently focuses on a few customer-facing applications, but has the capability of providing a broad range of services

Energy/Load Shifting	Transmission	Congestion reduction / Investment deferral
	Distribution	Congestion reduction / Investment deferral
	LSE/Utility	Minimize costs from load reduction (DR)
	Customer	Reduce energy bills (demand charges and TOU)
Back-up Power and Resiliency	Distribution	Microgrids
	Distribution/Transmission	Support Renewable Integration/Firm Power
	Customer	Back-up power
Ancillary Services	LSE/Utility	Frequency Regulation
	LSE/Utility	Spinning Reserves
	LSE/Utility	Voltage Control
	Customer	Potential to provide suite of grid services

SolarCity Launches Smart Energy Home in Hawaii

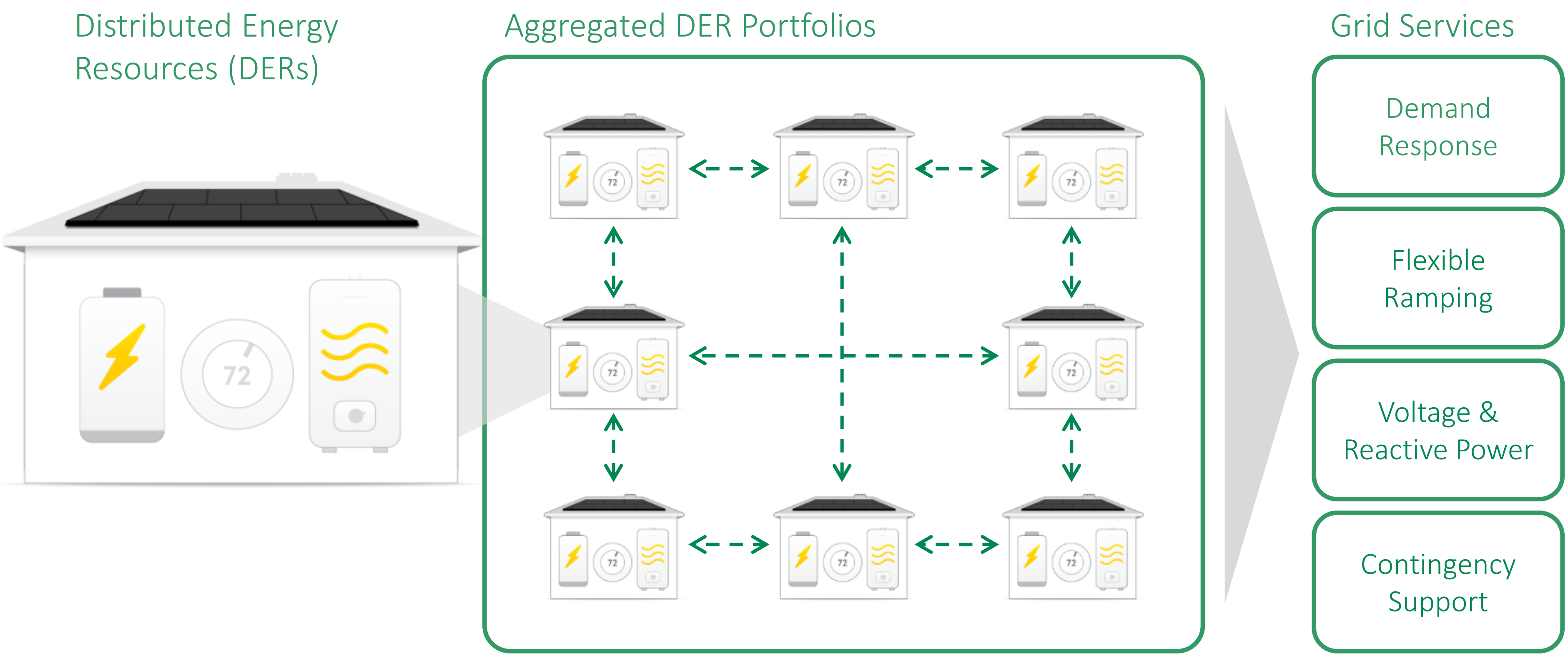
Customer Self Supply program offers a customized combination of solar, battery storage, smart electric water heater and Nest Learning Thermostat™

Feb 24, 2016

HONOLULU, Hawaii, Feb. 24, 2016 – SolarCity (NASDAQ: SCTY) is introducing a Smart Energy Home offering to new residential customers in Hawaii. It includes advanced technology: solar PV, battery storage, smart electric water heaters and the Nest Learning Thermostat™—all coordinated by a home gateway that controls the battery, water heater, thermostat and inverter to maximize solar PV generation and self-consumption.

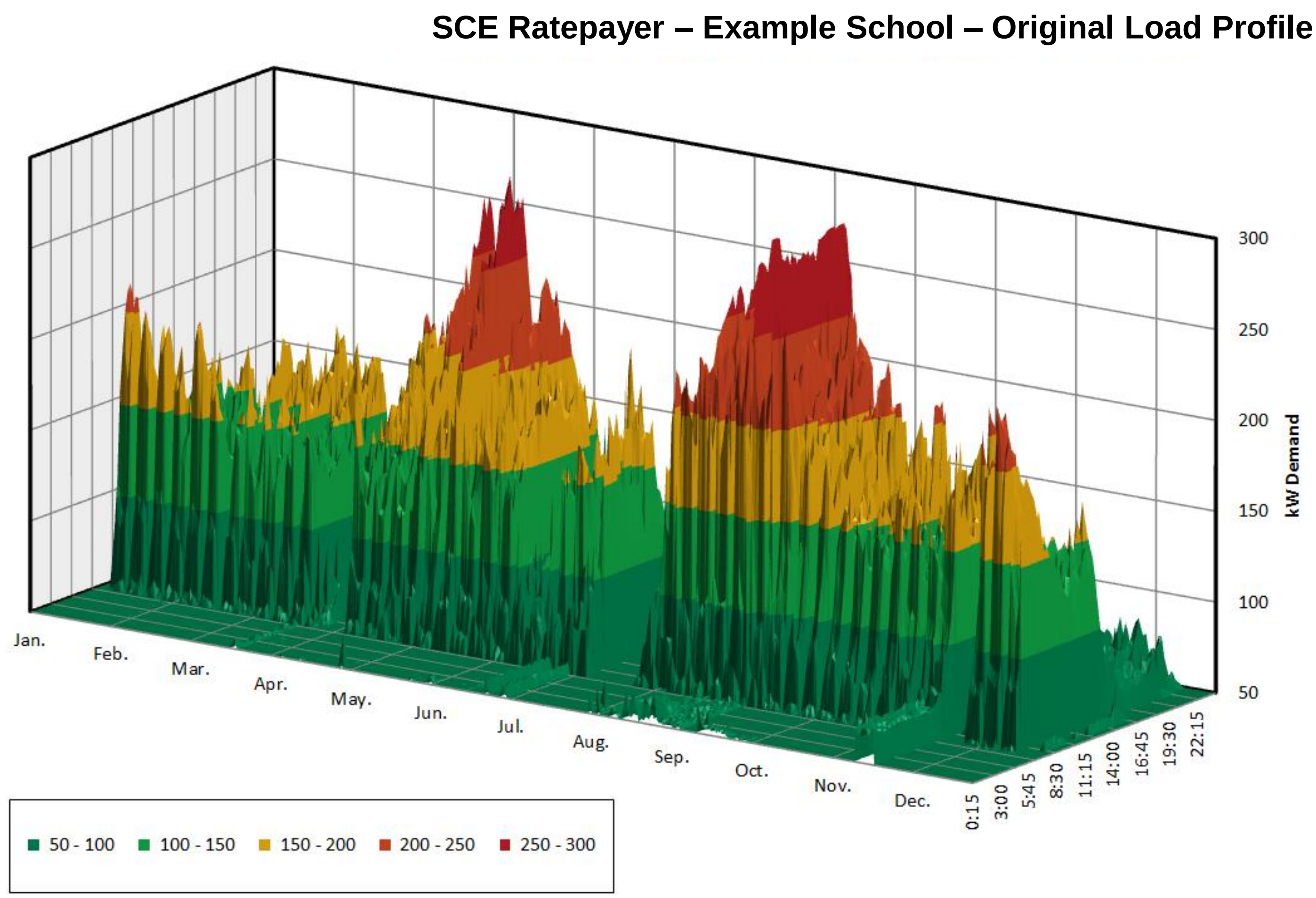
Distributed Energy Resource Aggregation

Utilize portfolios of distributed energy resources to provide grid services

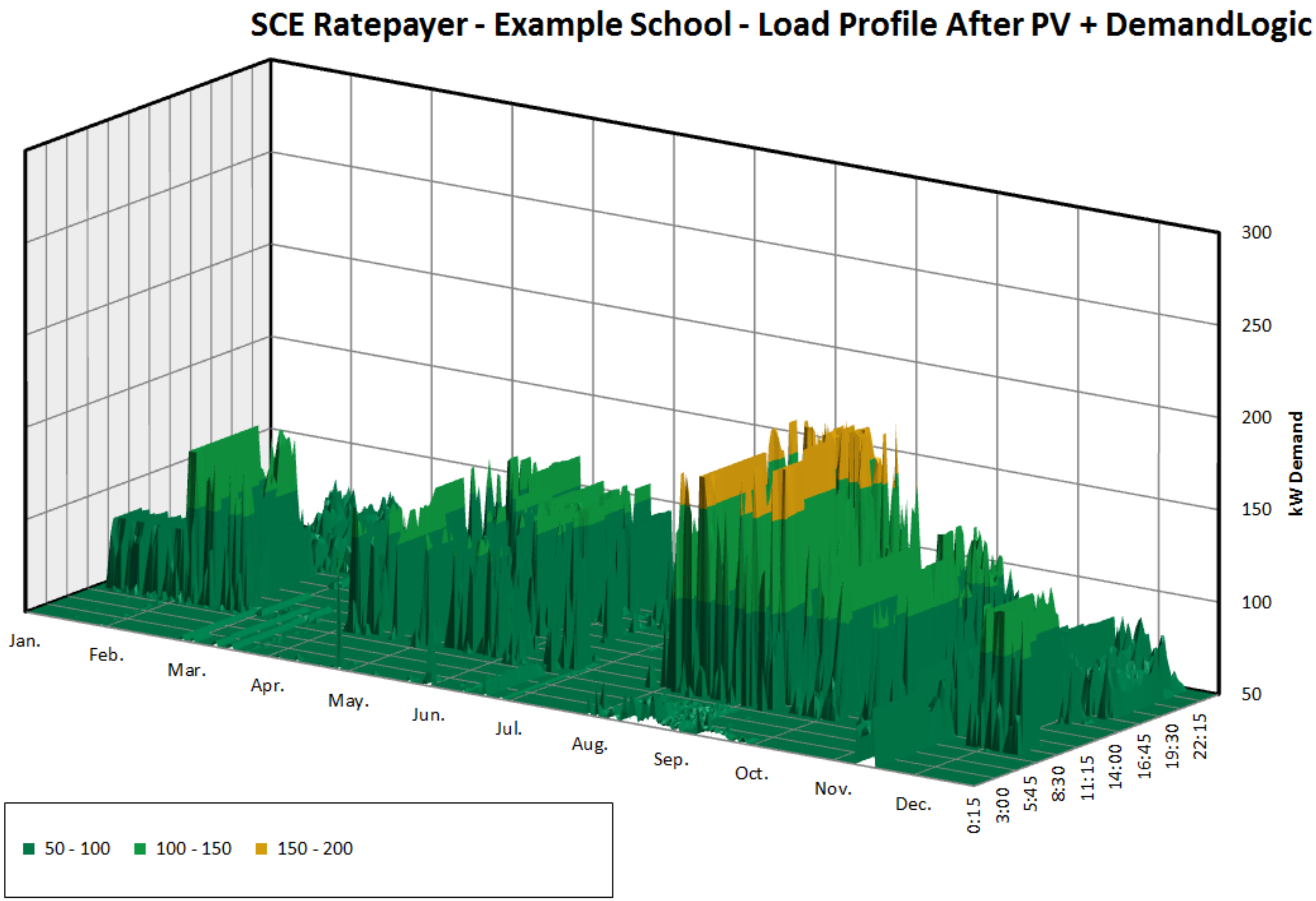


SolarCity

K-12 – Original Load Profile



K-12 – Load Profile after DemandLogic as seen by the Utility



K-12 Economic Overview

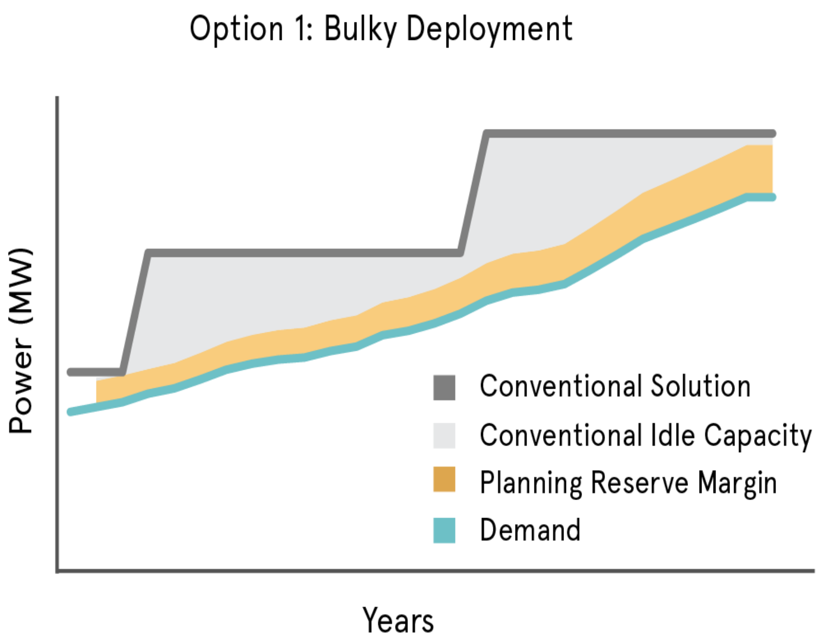
Avoided Energy Cost ($/kWh)	$0.145
Solar PPA Rate ($/kWH)	$0.125
Avoided Demand Cost ($/kWh)	$10.25
SolarCity Demand Rate ($/kWh)	$8.00

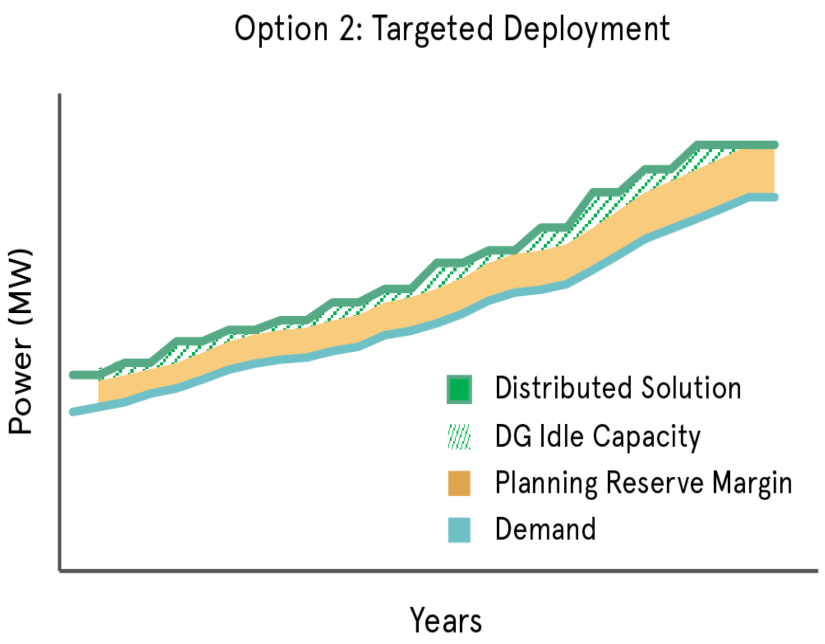
PV System Size (kW)	315
Storage System Size (kW)	100
Storage System Size (kWh)	200

Month	Demand			Energy			
	MAX Demand Reduction (kW)	Demand Payments to SolarCity	Utililty Demand Cost Reduction	Solar Production (kWh)	Energy Payments to SolarCity	Utility Energy Cost Reduction	Total Project Savings
January	98	$784	$1,005	26,238	$3,280	$3,805	$745
February	98	$784	$1,005	30,583	$3,823	$4,435	$832
March	98	$784	$1,005	41,152	$5,144	$5,967	$1,044
April	98	$784	$1,005	29,347	$3,668	$4,255	$807
May	98	$784	$1,005	55,983	$6,998	$8,117	$1,304
June	98	$784	$1,005	55,847	$6,981	$8,098	$1,337
July	98	$784	$1,005	54,156	$6,770	$7,853	$1,304
August	98	$784	$1,005	52,782	$6,598	$7,653	$1,276
September	98	$784	$1,005	47,863	$5,983	$6,940	$1,178
October	98	$784	$1,005	34,307	$4,288	$4,974	$907
November	98	$784	$1,005	26,057	$3,257	$3,778	$742
December	98	$784	$1,005	18,593	$2,324	$2,696	$592
Annual Totals	1,176	$9,408	$12, 054	472,908	$59,114	$68,572	$12,104
	Savings from DemandLogic: $2,646			Savings from Solar: $9,458			

Benefits of Integrated Distribution Planning: Value of small & targeted solutions

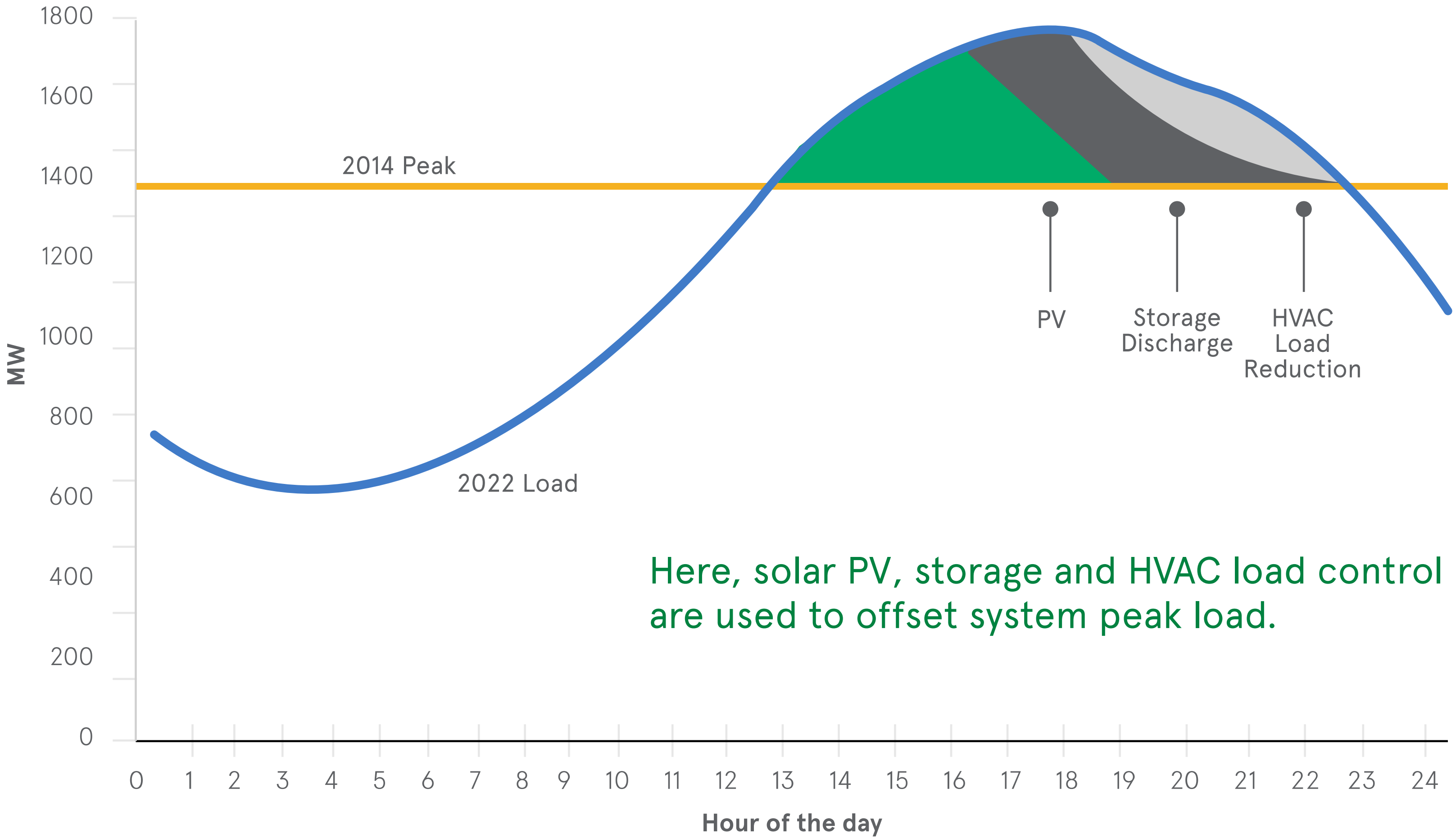
- Large utility capacity projects are designed based on long-term dynamic forecasts and result in significant idle capacity
- Smaller, targeted DER solutions can offset some utility capacity projects and provide the utility more flexibility to meet dynamic load





Distributed energy resources (DERs) can offset system peak load.

Johanna and Santiago Load, CA 2022



Here, solar PV, storage and HVAC load control are used to offset system peak load.

SolarCity

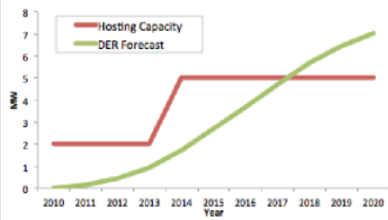
Changing the utility incentive mechanism to include Distributed Energy Resources (DERs)

1. Forecast Growth & Maintenance

Forecast load and DER growth and required equipment maintenance

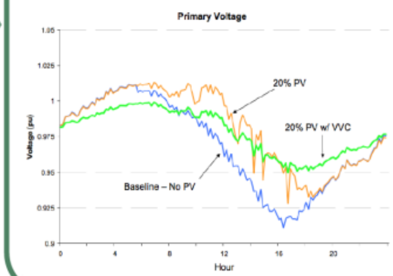
2. Identify Grid Needs

Compare growth to available hosting and circuit capacities



3. Evaluate Solutions

Propose solutions to meet identified needs, including the use of DER portfolios



Traditional Self-Supply

4. Select & Deploy Equipment

(e.g. transformer, capacitor bank)

5. Operate & Collect

Investment Income

Meet Grid Need

Infrastructure-as-a-Service

4. Select & Deploy Equipment

(e.g. circuit capacity, reactive power)

5. Operate & Collect

Service Income

Thank You

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Advancion Energy Storage

AES we are the energy

Utility-Scale Energy Storage: Proven and Cost-Effective for Meeting Capacity Needs

Kiran Kumaraswamy
Market Development Director
AES Energy Storage

February 29th, 2016

AES operates 116MW of advanced battery-based energy storage, the largest grid-connected fleet.

Los Andes
Atacama, Chile
2009

Laurel Mountain
West Virginia, USA
2011

Angamos
Mejillones, Chile
2012

Tait
Ohio, USA
Sep 2013

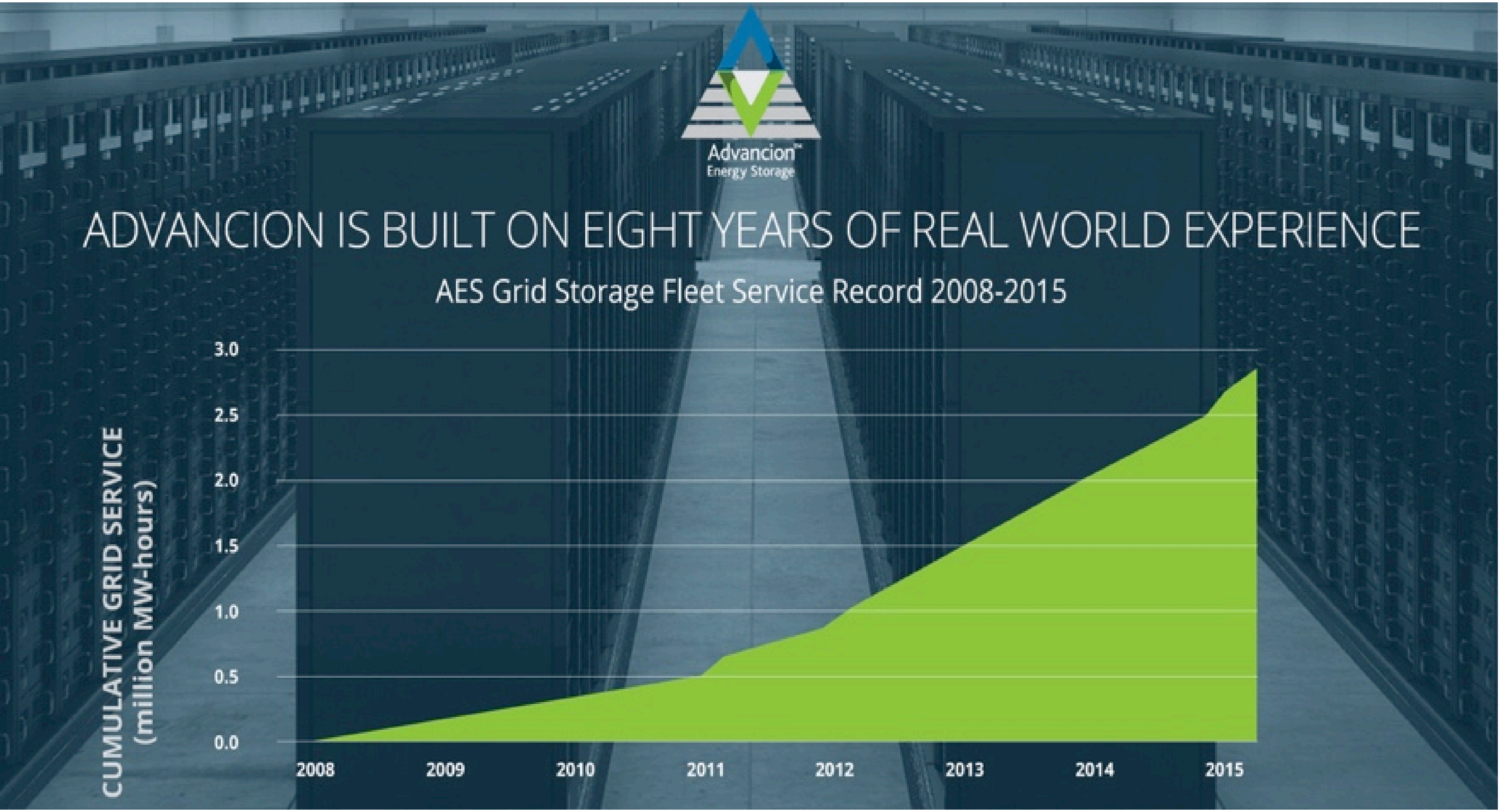
2015 Additions

10MW
Warrior Run
Cumberland, Maryland

10MW
Zeeland
Vlissingen, Netherlands

10MW
Kilroot
Belfast, N. Ireland

AES energy storage fleet has more than 3 million megawatt-hours of delivered service.



Flexible Peak Capacity: SCE selects 100MW

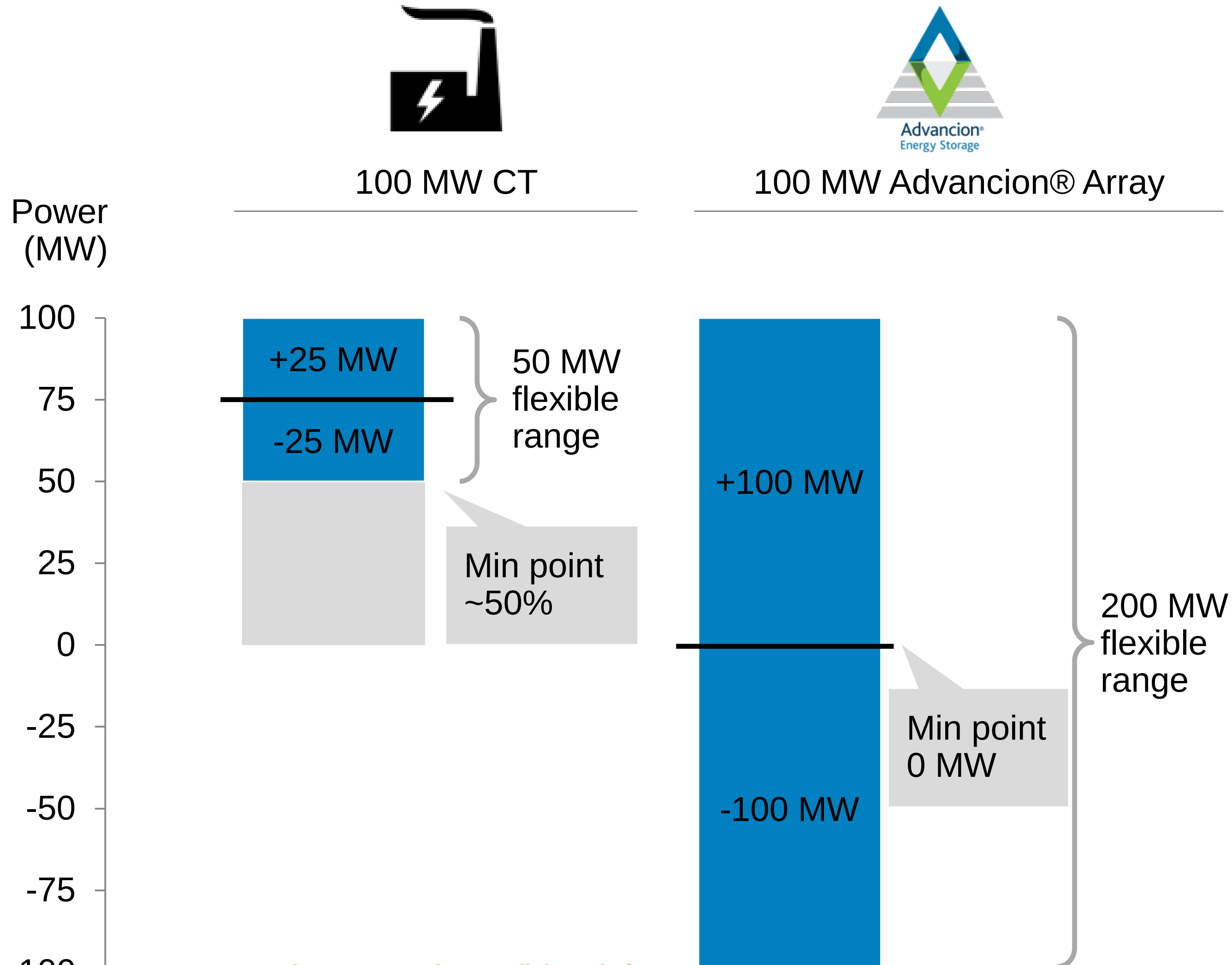
Competitive solicitation to meet peak capacity needs and provide flexibility

***100 MW Interconnection** (rendered)*
200 MW of flexibility (discharge + charge)

Project Description:

- 2x50 MW advanced battery array
- Provides local capacity reliability
- 4 hour duration
- 24x7 power resource
- No emission or water
- 20-Year Tolling PPA

Storage provides up to 4 x the effective resources and unique flexibility compared to traditional peakers



Unique capabilities of battery storage

- Fast ramp (<250 msec)
- Always synchronized
- Unlimited starts / stops (no cost)
- Broader operating range

Benefit Categories

1. Operational flexibility
2. Capacity value
3. Reduction in out of merit generation costs & transmission losses
4. Avoided generation unit start-up costs
5. Improvement in generation unit part-load efficiency
6. Environmental benefits (emission savings and reduction in renewable curtailment)

Capacity Release: Improving System Reliability in Chile

Initial project leading to over 50 MW of energy storage in Chile.

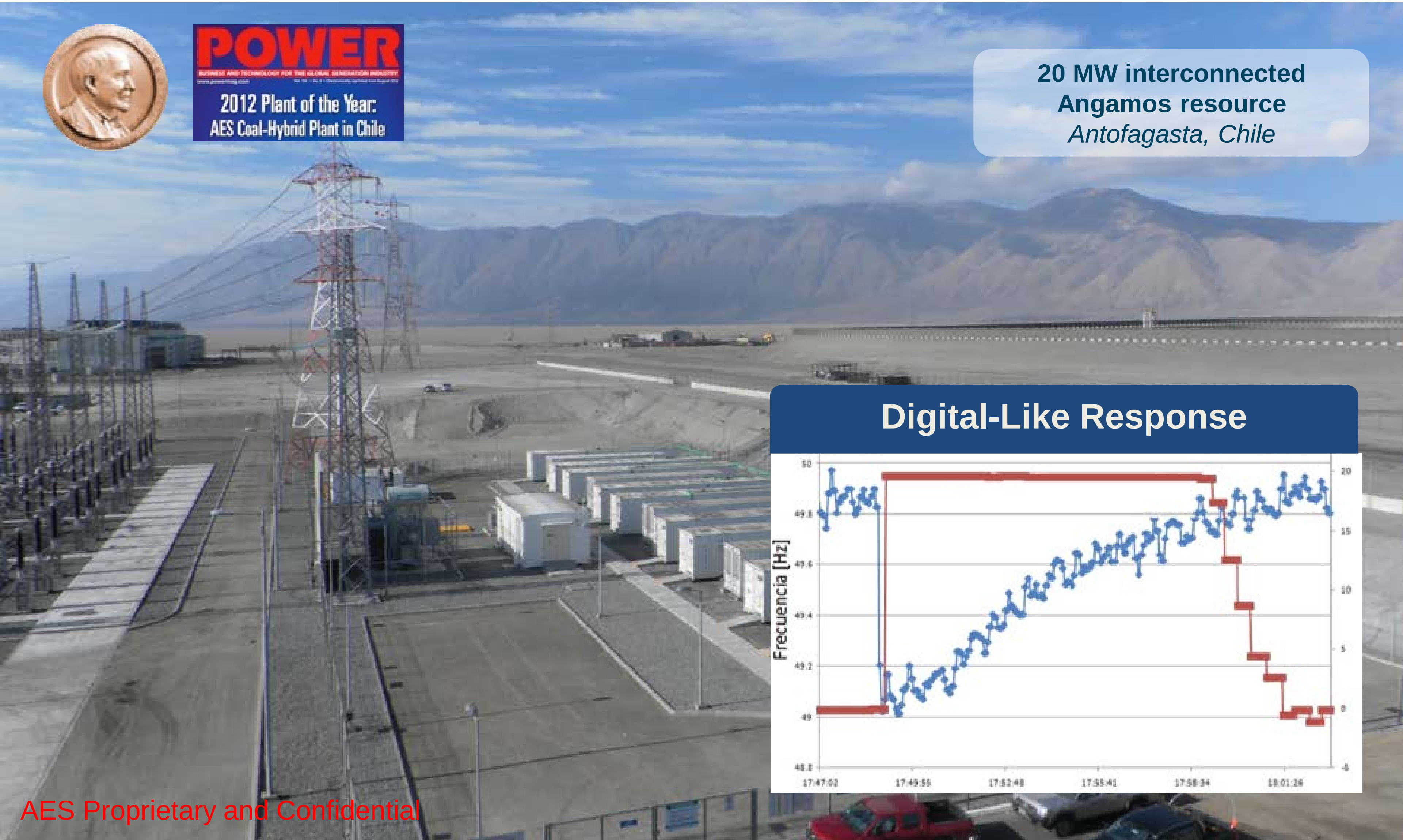
Benefits

- Avoided load shedding and emergency curtailment
- Increased energy production and reduced cost
- Increased system security
- Inertia-like performance

AES Proprietary and Confidential

Estimated to Save Customers $37 Million Annually

Energy storage unlocked low-cost generation in the CDEC-SING



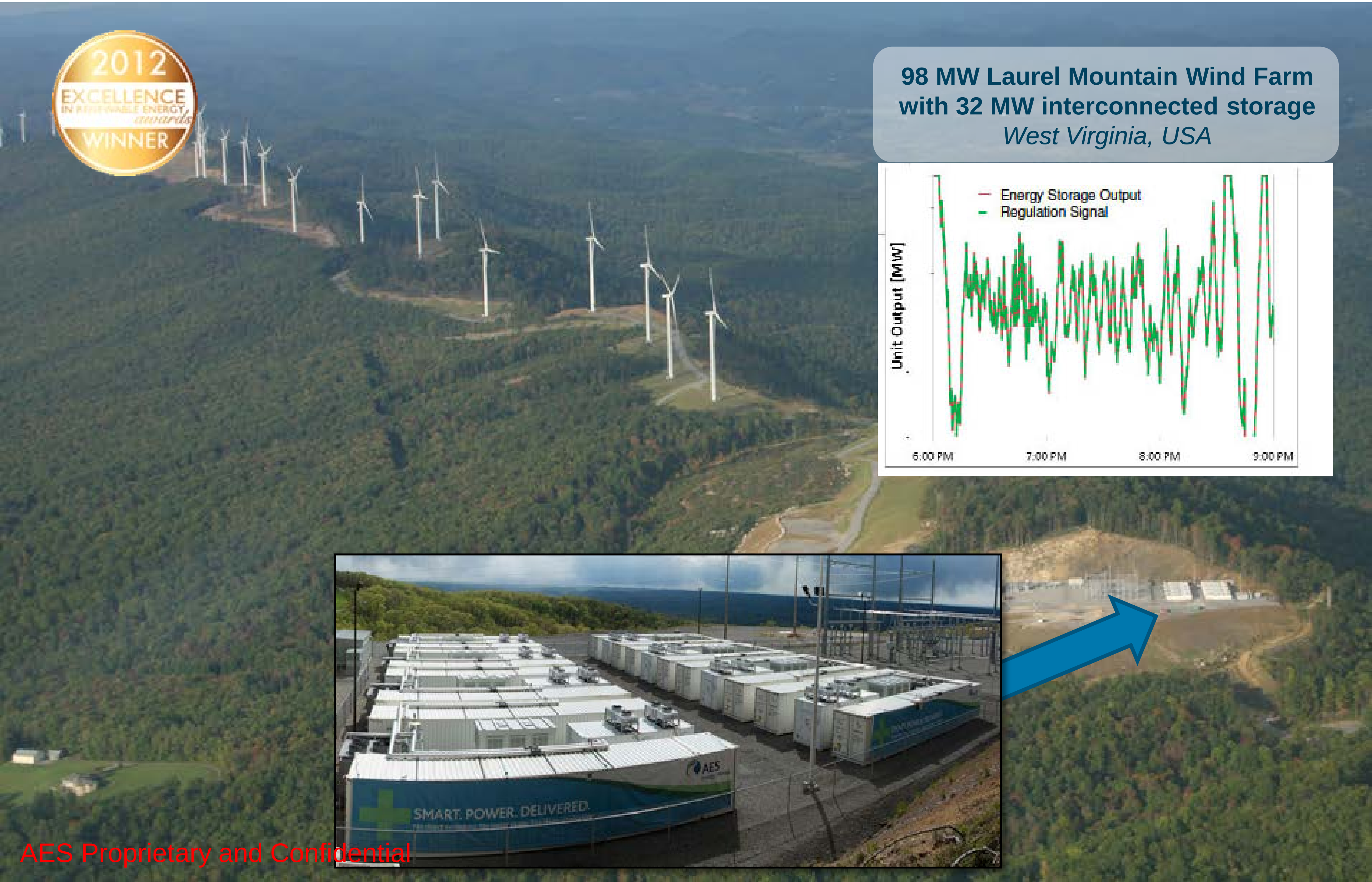
20 MW interconnected
Angamos resource
Antofagasta, Chile

Digital-Like Response

Frequency Regulation: Integrating Renewables in PJM

AES storage resources save PJM customers $20 million per year

98 MW Laurel Mountain Wind Farm with 32 MW interconnected storage
West Virginia, USA



Frequency regulation: Storage to serve TenneT

Initial 10MW storage online at end of 2015, providing 20MW of flexibility

- Primary Control Reserve (frequency regulation) for integrated market (DE, NL, CH, AU)

Impact:

✓ Reduce total reserve cost
✓ Fast, accurate reserves
✓ Increased system flexibility
✓ Opportunity to explore fast resource benefits

20 MW Zeeland Resource
Vlissingen, Netherlands

Thank you.

Kiran Kumaraswamy
Market Development Director, AES Energy Storage

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