Energy Storage for Critical Facilities

Massachusetts Clean Energy Conference:
Helping Communities with Renewables and Efficiency
Worcester, MA, September 22, 2016

Todd Olinsky-Paul
Project Director
Clean Energy States Alliance

Agenda for this presentation:

- Introduction to CESA and ESTAP
- Introduction to resilient power
- Economics of solar+storage
- Policy landscape

Energy Storage Technology Advancement Partnership (ESTAP)

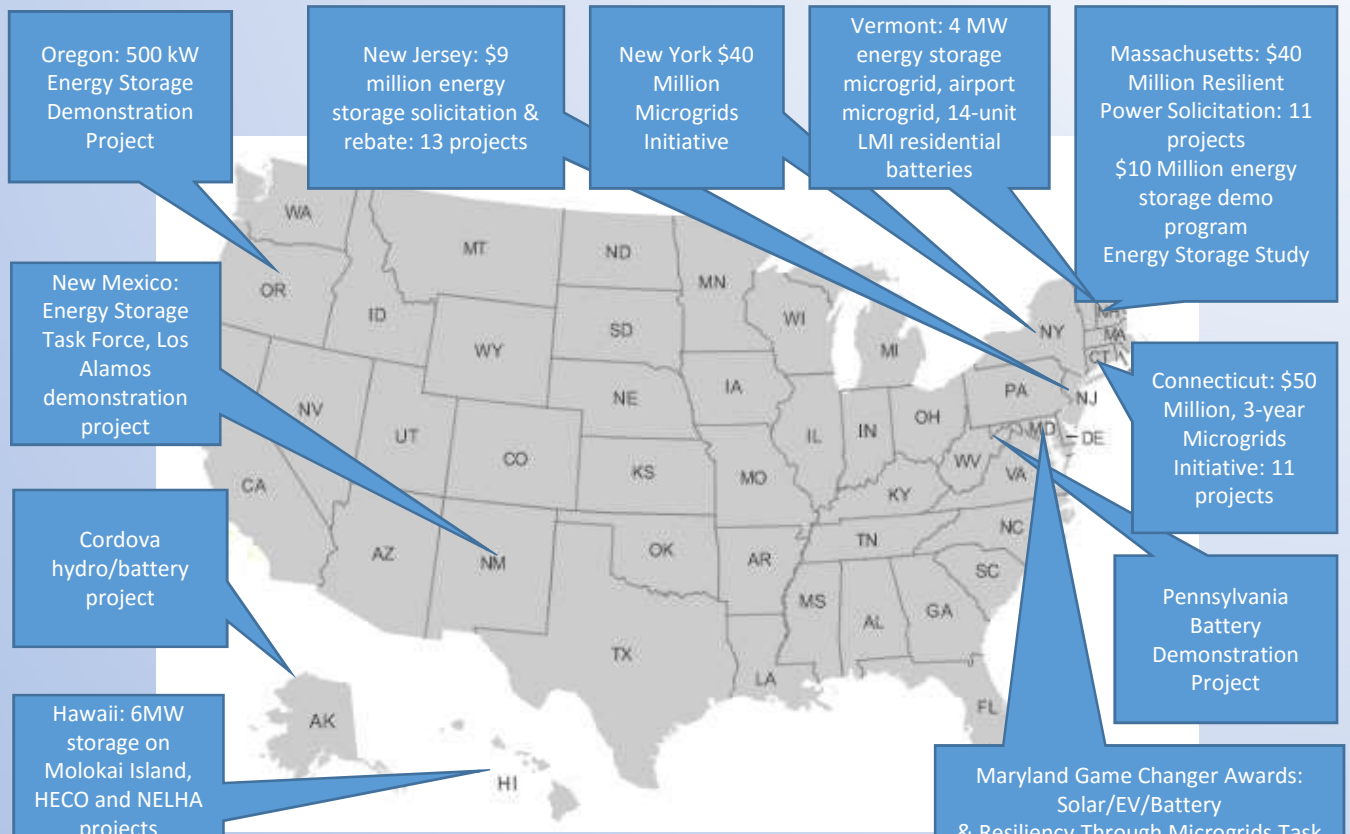
- A project of Clean Energy States Alliance (CESA)
- Conducted under contract with Sandia National Laboratories, with funding from US DOE-OE

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

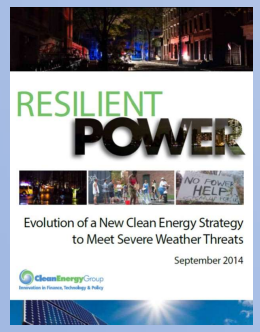
Clean Energy States Alliance

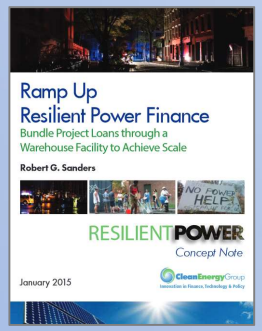
Sandia National Laboratories

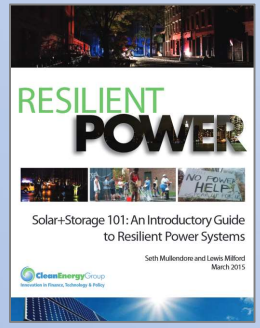
U.S. DEPARTMENT OF ENERGY

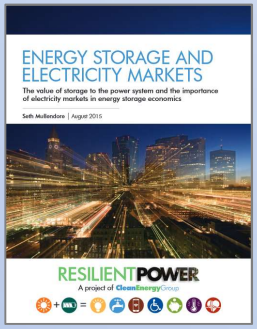
Resilient Power Project

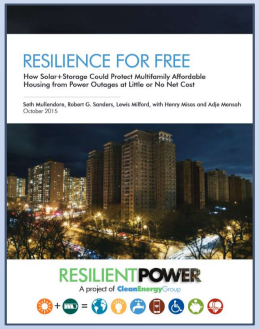
- Increase public/private investment in clean, resilient power systems
- Engage city officials to develop resilient power policies/programs
- Protect low-income and vulnerable communities
- Focus on affordable housing and critical public facilities
- Advocate for state and federal supportive policies and programs
- Technical assistance for pre-development costs to help agencies/project developers get deals done
- See www.resilient-power.org for reports, newsletters, webinar recordings







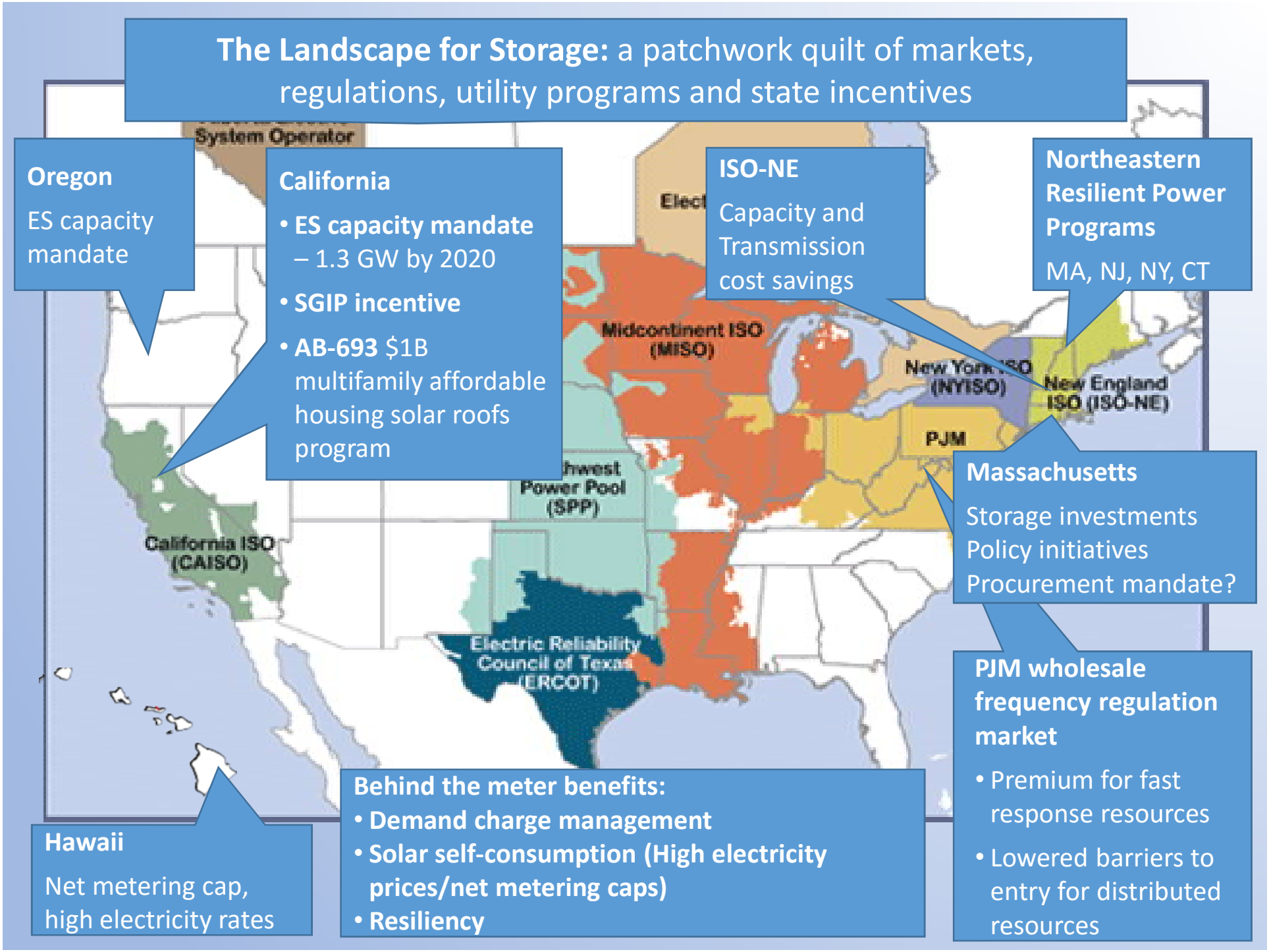




www.cleanegroup.org

www.resilient-power.org

The Landscape for Storage: a patchwork quilt of markets, regulations, utility programs and state incentives



Oregon

ES capacity mandate

California

- **ES capacity mandate** – 1.3 GW by 2020
- **SGIP incentive**
- **AB-693** $1B multifamily affordable housing solar roofs program

ISO-NE

Capacity and Transmission cost savings

Northeastern Resilient Power Programs

MA, NJ, NY, CT

Massachusetts

Storage investments
Policy initiatives
Procurement mandate?

PJM wholesale frequency regulation market

- Premium for fast response resources
- Lowered barriers to entry for distributed resources

Behind the meter benefits:

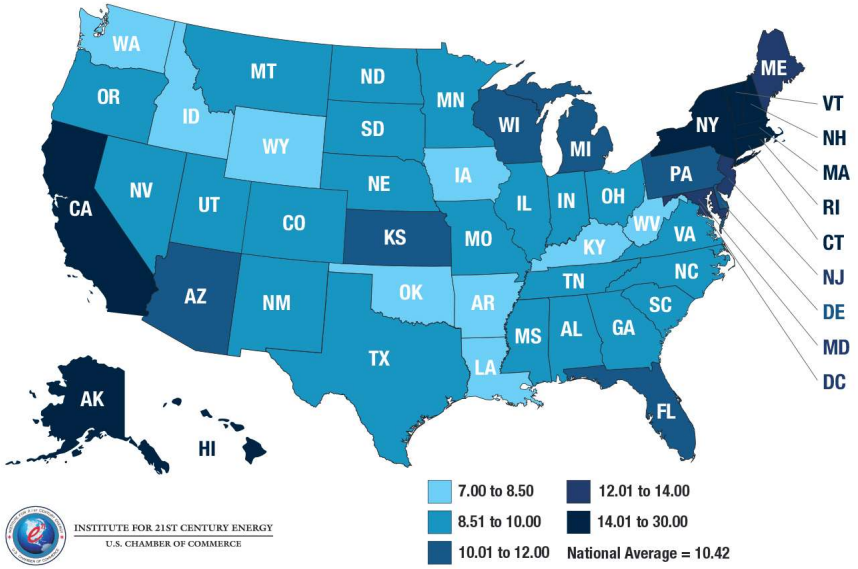
- **Demand charge management**
- **Solar self-consumption (High electricity prices/net metering caps)**
- **Resiliency**

Hawaii

Net metering cap, high electricity rates

2015 U.S. Average Electricity Retail Prices

(cents per kilowatt hour)



INSTITUTE FOR 21ST CENTURY ENERGY
U.S. CHAMBER OF COMMERCE

2015 U.S. Average Electricity Retail Prices

(cents per kilowatt hour)

Alabama	9.37	Kentucky	8.03	North Dakota	8.85
Alaska	17.94	Louisiana	7.64	Ohio	9.90
Arizona	10.40	Maine	12.97	Oklahoma	7.83
Arkansas	8.15	Maryland	12.14	Oregon	8.82
California	15.50	Massachusetts	16.86	Pennsylvania	10.41
Colorado	9.78	Michigan	10.84	Rhode Island	17.05
Connecticut	17.76	Minnesota	9.69	South Carolina	9.48
Delaware	11.21	Mississippi	9.55	South Dakota	9.31
Dist. of Columbia	12.08	Missouri	9.30	Tennessee	9.35
Florida	10.64	Montana	8.93	Texas	8.63
Georgia	9.52	Nebraska	9.04	Utah	8.61
Hawaii	26.17	Nevada	9.48	Vermont	14.36
Idaho	8.12	New Hampshire	16.03	Virginia	9.31
Illinois	9.28	New Jersey	13.93	Washington	7.41
Indiana	8.79	New Mexico	9.68	West Virginia	8.12
Iowa	8.47	New York	15.28	Wisconsin	10.93
Kansas	10.06	North Carolina	9.36	Wyoming	7.95

Source: U.S. Energy Information Administration; Electric Power Monthly: February 2016

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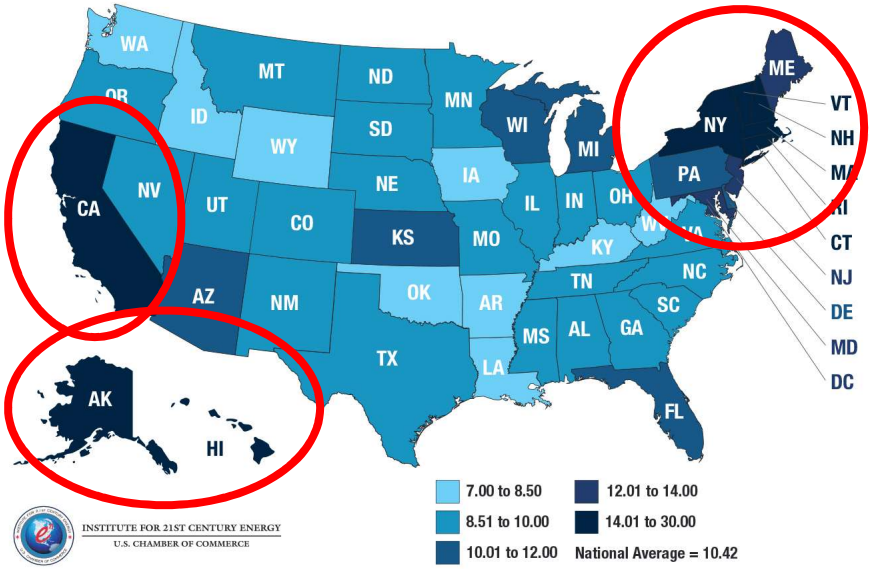

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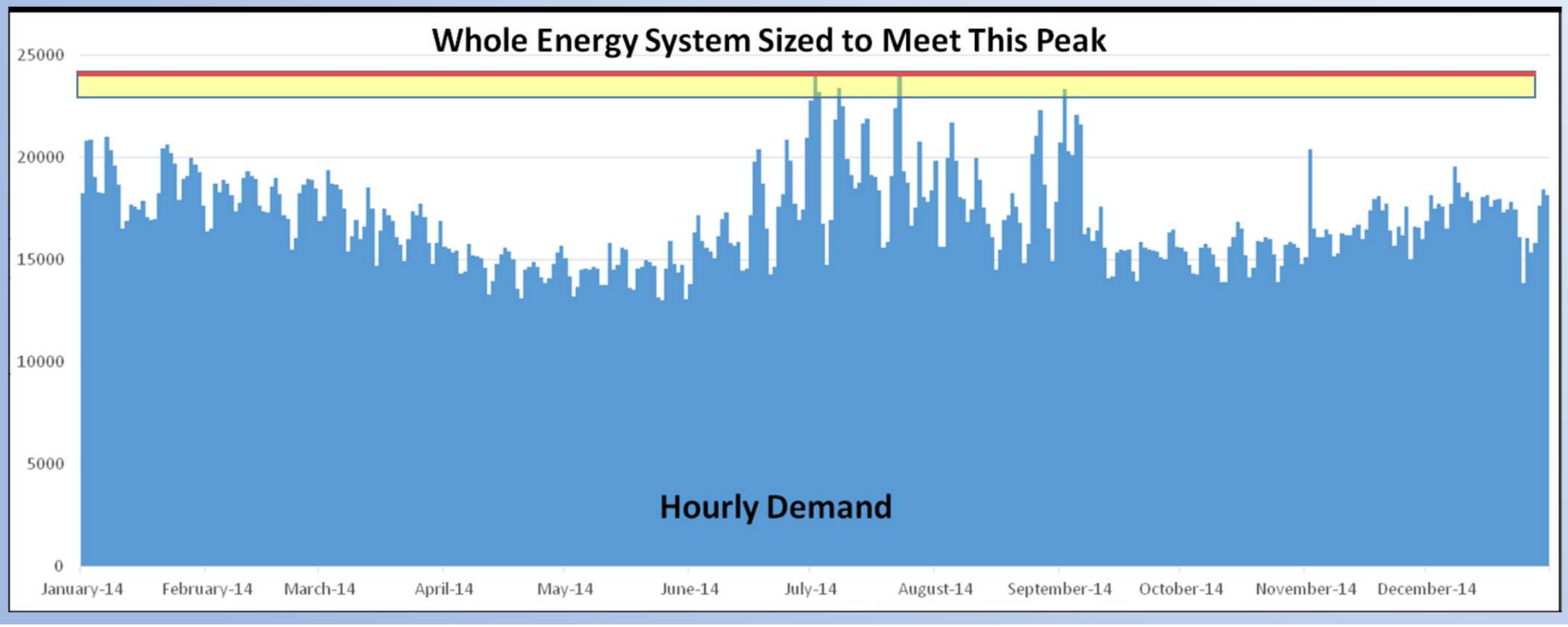
Modernizing the Grids

In addition to these resilient power initiatives, a few states have begun a process of revisioning the electric grid:

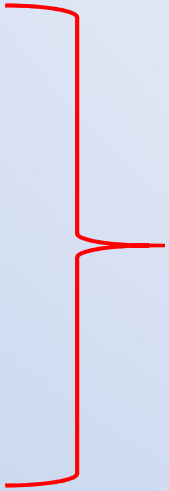
- New York REV
- Massachusetts grid modernization



Modernizing the Grids

Grid modernization initiatives are focusing on:

- More distributed clean generation
- Greater role for distribution utilities
- Smartgrid and microgrid development
- Peak shifting and reduction of grid overcapacity
- Reduced outages, greater resiliency
- Optimized demand
- Improved asset management

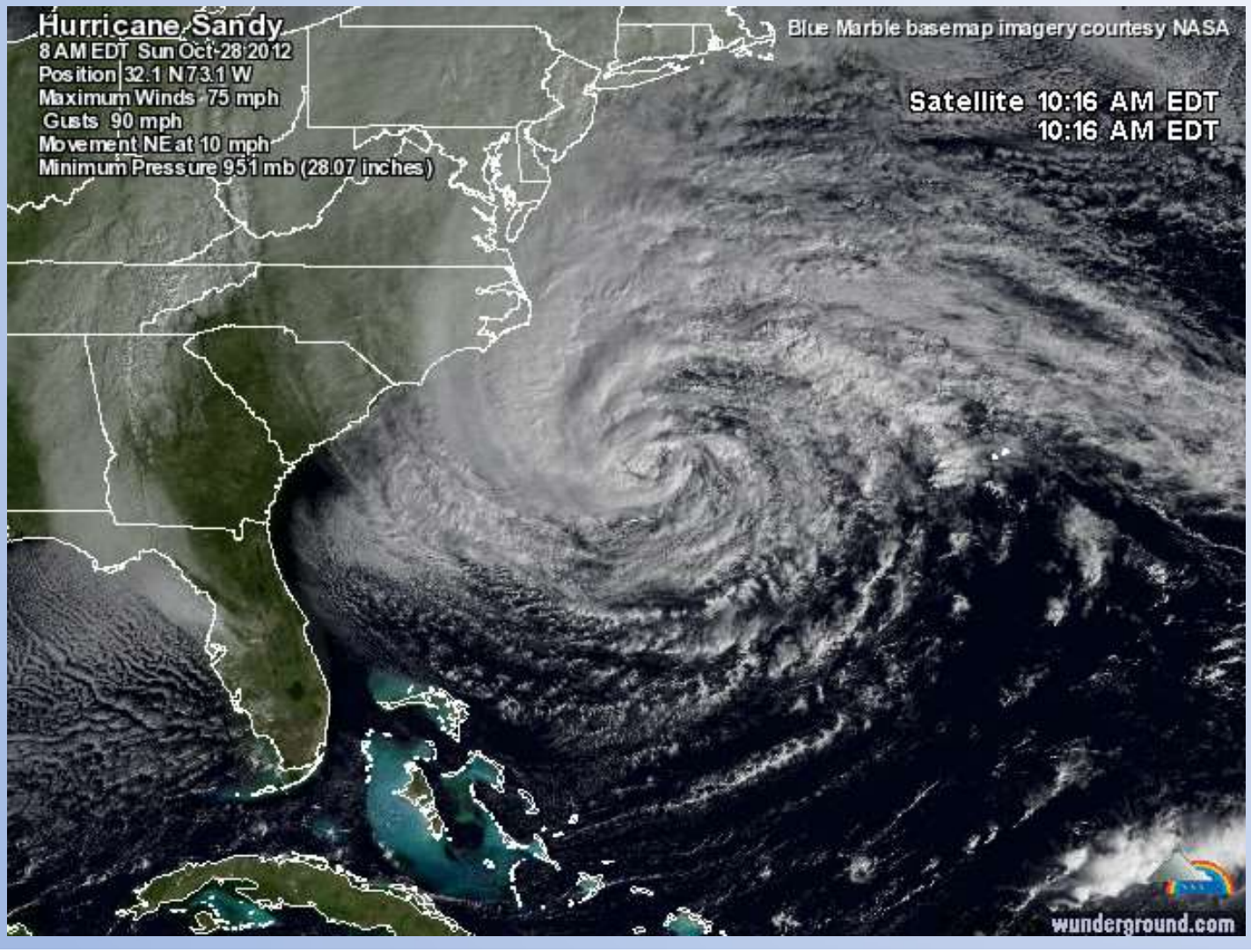


Opportunities for energy storage

Hurricane Sandy

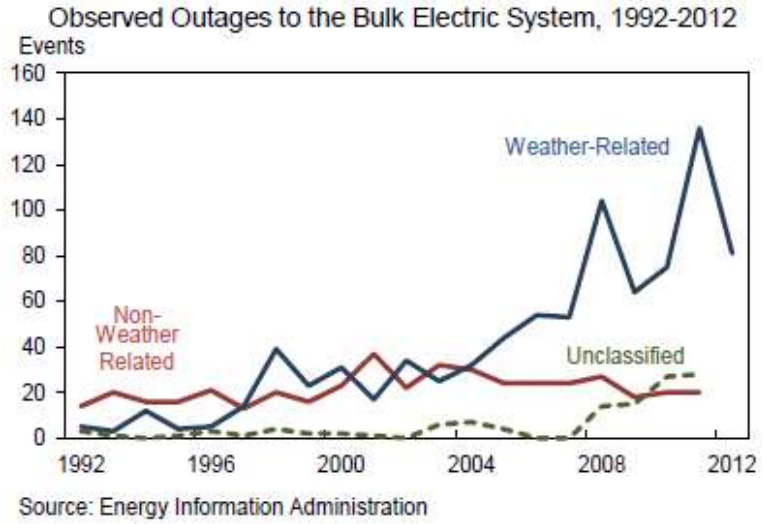
October 29, 2012

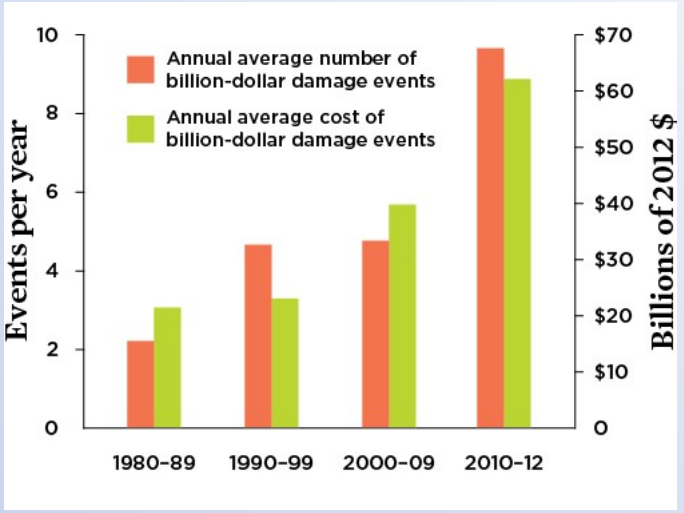
$37 Billion in damages




86
Street

Aging US Power Grid Blacks Out More Than Any Other Developed Nation





Source: Union of Concerned Scientists; Steve Clemmer, 2014

Year	Total number of outages	People affected
2008*	2,169	25.8 million
2009	2,840	13.5 million
2010	3,149	17.5 million
2011	3,071	41.8 million
2012	2,808	25.0 million
2013	3,236	14.0 million

**Partial-year data. Data collection began on February 16, 2008.*

Source: Blackout Tracker – 2013 US Report (Eaton)

Northeastern States
Resilient Power Initiatives

Following Superstorm Sandy, the Northeastern states came to CESA seeking help in developing resilient power solutions.

CEG/CESA role:

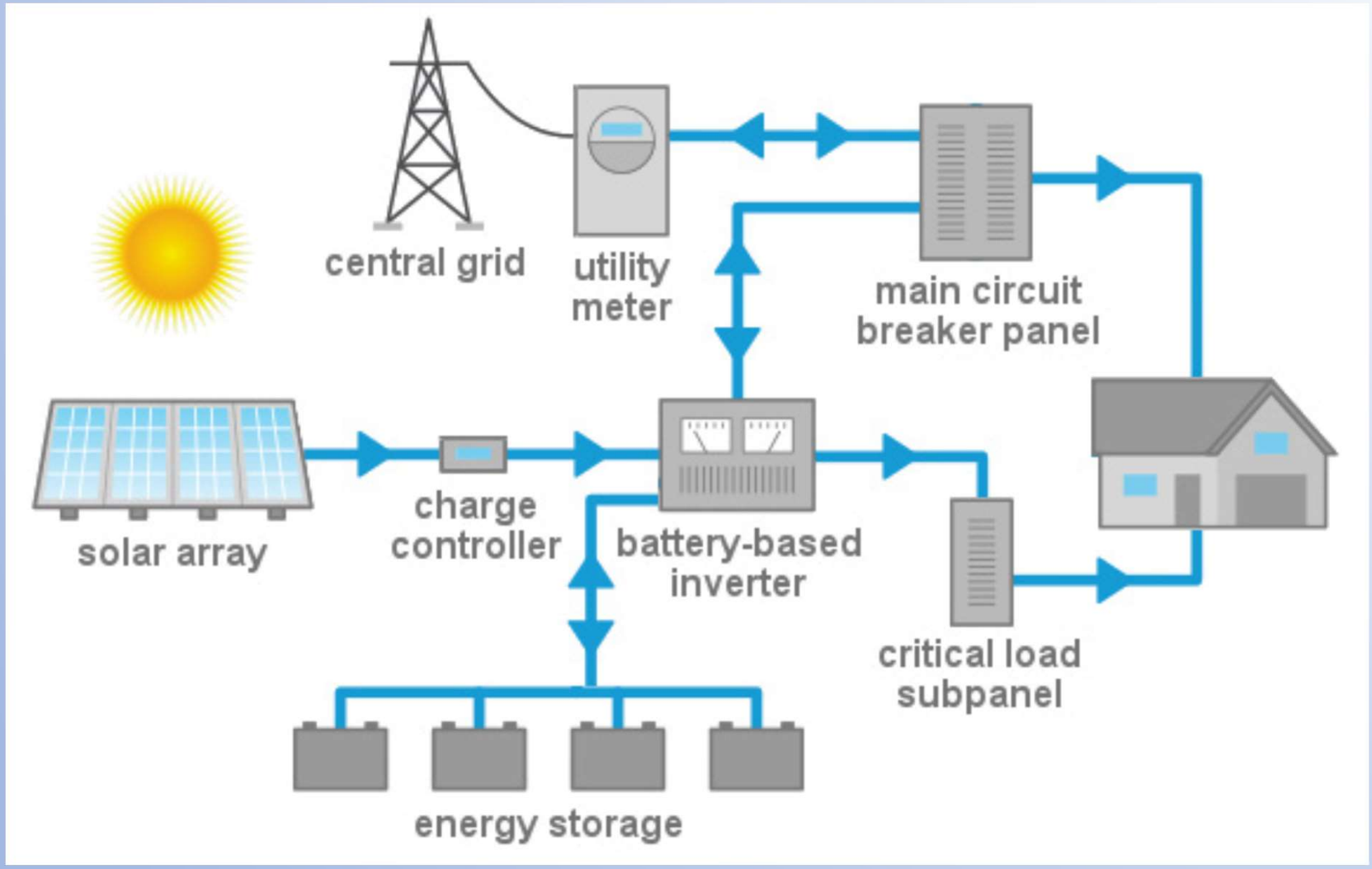
- Assist states in policy and RFP development
- Provide information to project developers
- Technical assistance to support qualifying projects
- Monitor and evaluate project performance
- Economic analysis
- Publications and webinars

Early results

- **Connecticut:** $50 Million Microgrid Grand and Loan Pilot Program
- **New Jersey:** $9 Million Energy Storage Program and $200 Million Energy Resilience Bank
- **Massachusetts:** $40 Million Community Clean Energy Resiliency Initiative, $10 Million Energy Storage Initiative, Energy Storage Study, Possible Procurement Mandate
- **New York:** $40 Million NY Prize microgrids competition
- **Maryland:** Microgrids study
- **Vermont:** Microgrid demonstration project

$350 Million in new state funds in the Northeast alone

Solar+Storage: The Resilient Power Solution



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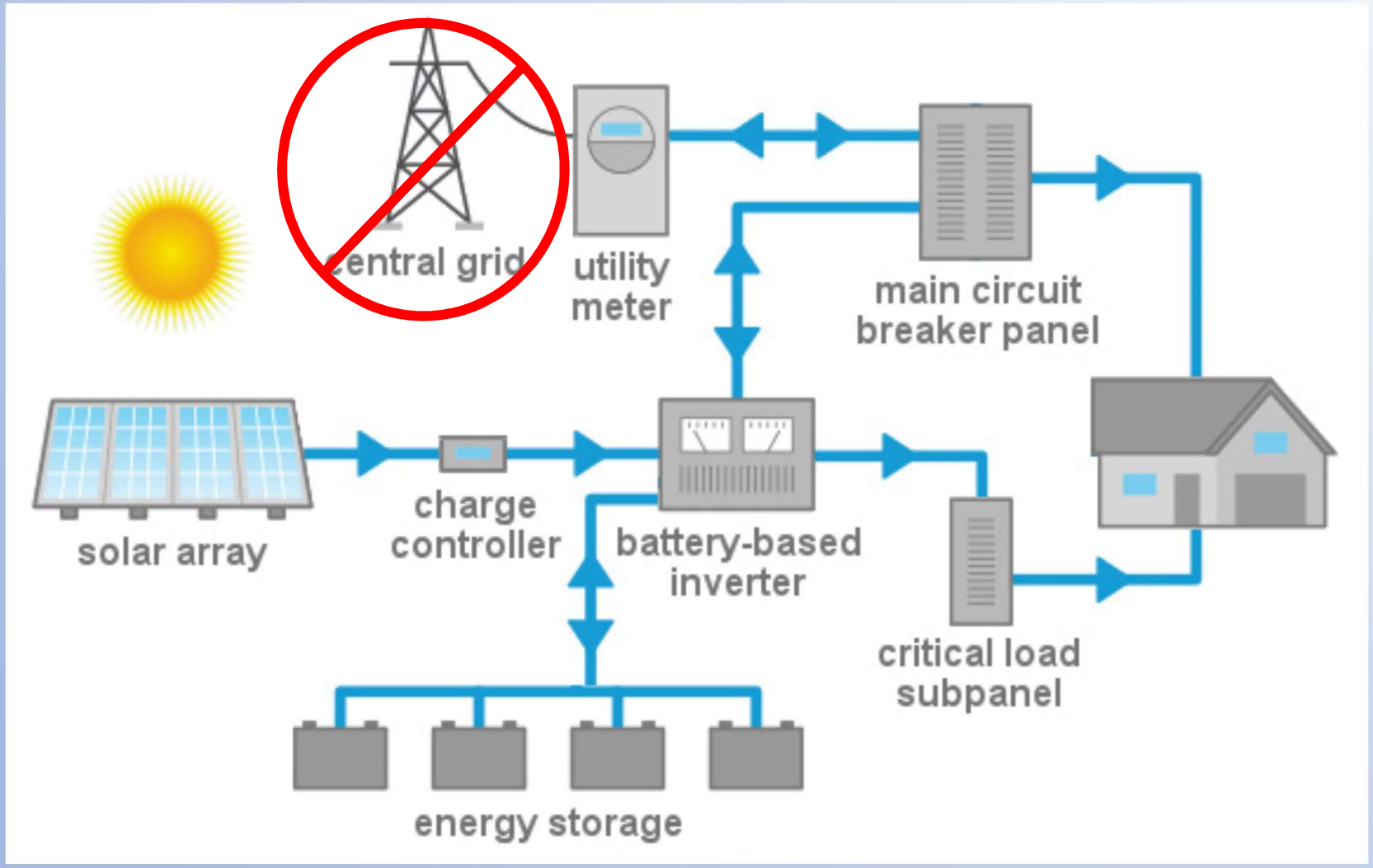

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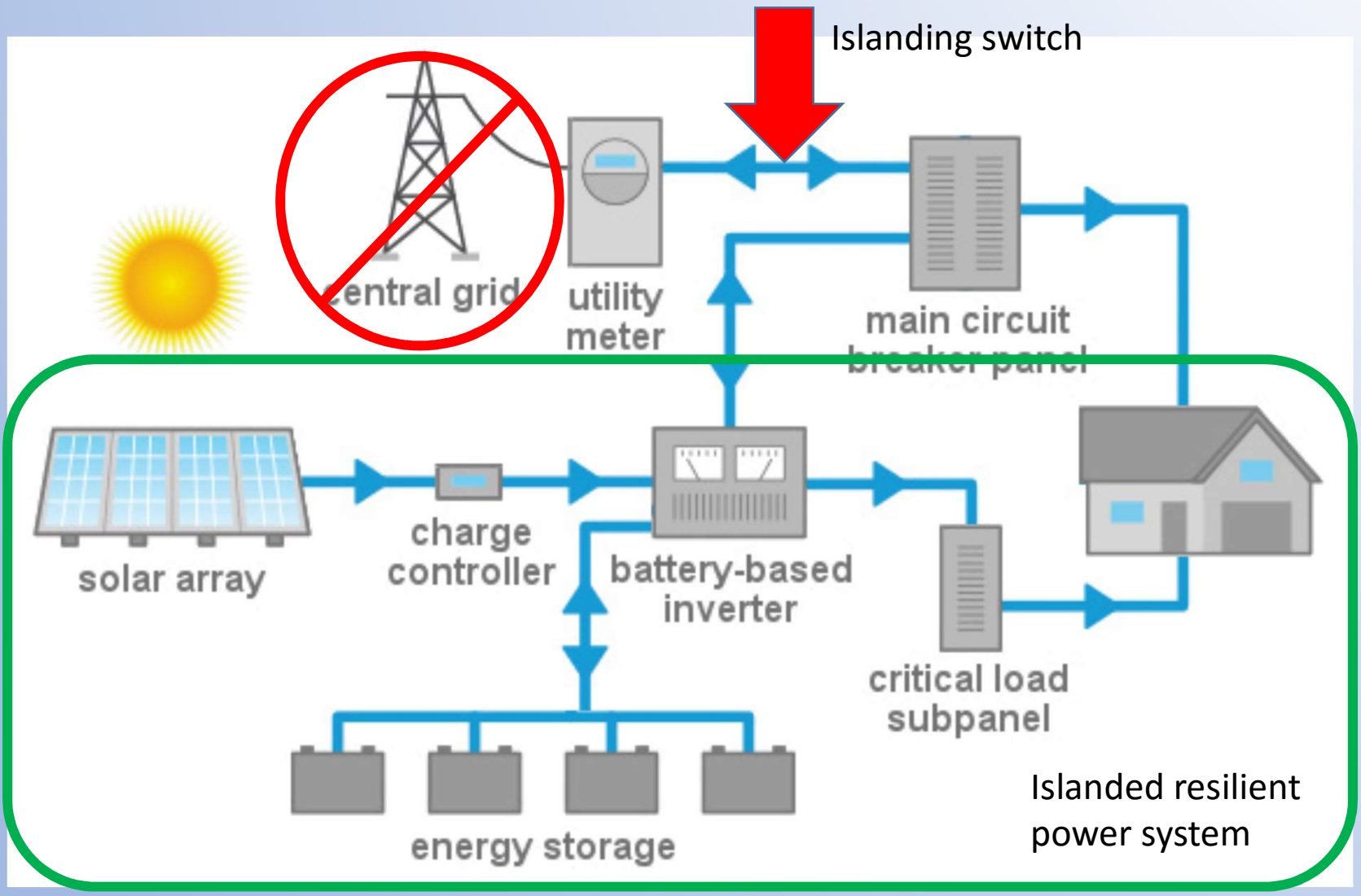
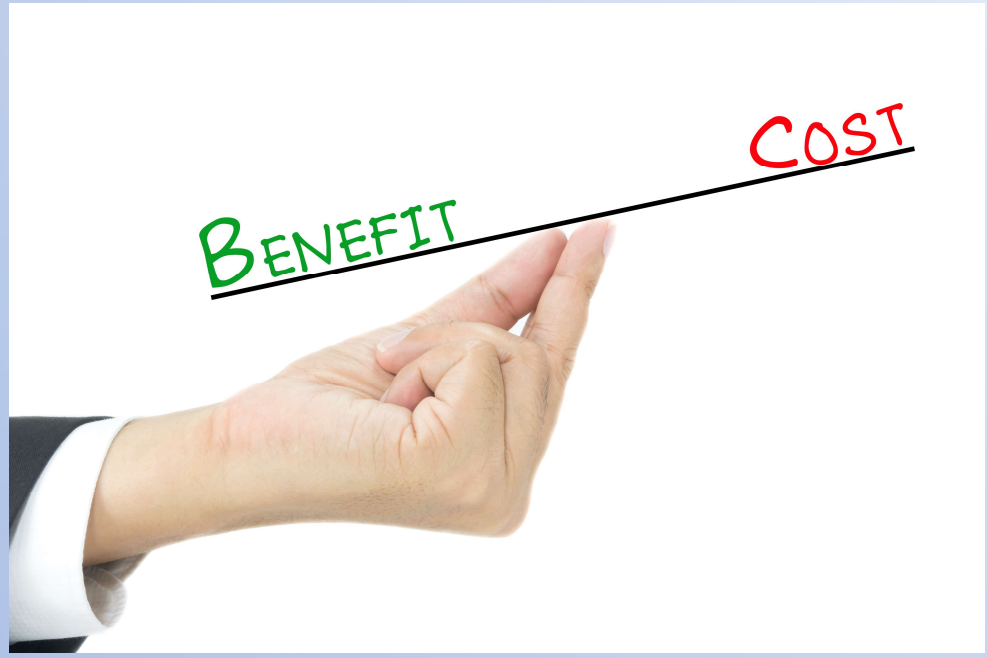


Energy Storage Business Cases



The business case for storage depends on multiple value streams that are locationally determined

"Locationally" means where on the map *and* where on the grid

Behind the meter

- **Demand charge management**
- Utility tariff switching
- Reduced energy purchases
- **Demand response**
- **Frequency regulation**
- TOU arbitrage

Transmission/Distribution

- **T&D investment deferral**
- Ancillary services provision
- **Utility capacity and transmission cost reductions**
- Renewables integration
- Ramping
- Arbitrage
- Frequency regulation

What's Missing???

Behind the Meter: Storage for resiliency and energy cost savings

- Energy savings
- Demand charge management
- Tariff switching

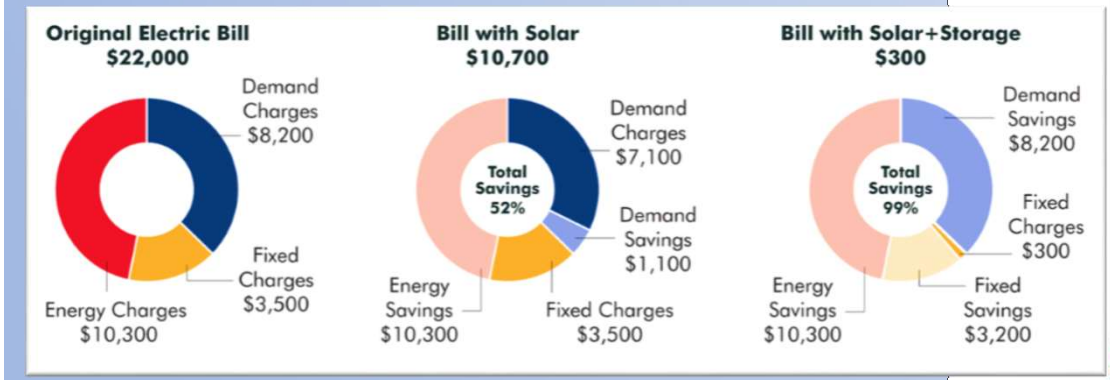


FIGURE 1
Explanation of Charges Commonly Found on an Electric Bill

Charges on an Electric Bill

Electric bills are primarily composed of three types of charges: energy charges, demand charges, and fixed charges.

Energy charges:
Energy charges (measured in kilowatt-hours) are based on the amount of electricity consumed from the grid over each billing cycle. Energy charges can vary depending on season and the time of day electricity is consumed (time-of-use rates) or the amount of electricity consumed (tiered rates).

SDG1 Annual Electric Bill

ENERGY

		Usage (kWh)	Cost ($/kWh)	Total cost ($)
Max	Summer	13,085	0.11447	1,497.82
	Winter	7,827	0.10565	826.97
Peak	Summer	15,259	0.10568	1,612.59
	Winter	35,189	0.09132	3,213.46
Part-Peak	Summer	26,959	0.07920	2,135.17
	Winter	46,612	0.07160	3,337.42
TOTAL		144,932		$12,623.43

49%

DEMAND

		Avg peak (kW)	Cost ($/kW)	Total cost ($)
Max	Summer	33	22.55	2,958.56
	Winter	30	22.55	5,195.52
Peak	Summer	33	19.19	2,517.73
	Winter	24	6.86	1,279.49
Part-Peak	Summer	30	0.00	0.00
	Winter	30	0.00	0.00
TOTAL				$11,951.30

46%

FIXED

	Total cost ($)
Meter charge	1,397.28
TOTAL	$1,397.28

5%

TOTAL ANNUAL BILL $25,972.01

Demand charges:
Demand charges (measured in kilowatts) are based on the highest rate of electricity consumption during a billing cycle, called peak demand. Utilities assess peak demand by measuring the highest average demand that occurs over any 15-minute period each billing cycle. Demand charges can vary depending on season and the time of day when peak demand occurs. Demand charges are typically found only on commercial or industrial customer accounts, where they often represent about half of the cost of an electric bill. Residential customers are usually not assessed these charges.

Fixed charges:
Fixed charges are usually static and do not vary from one billing cycle to the next. These charges typically cover the costs of metering, billing, and other customer-related operating expenses not accounted for in energy and demand charges. Fixed charges can also include additional fees to cover system benefit programs such as energy efficiency and renewable energy programs. For simplicity, only fixed charges related to billing and metering are considered in this analysis.

New England Utility Business Case: Sterling Municipal Light Department, Sterling, MA

The SMLD project, supported by DOER CCERI and DOE-OE grants, will provide resilient power to the town's police department and emergency dispatch system for 12 days using a 2 MW, 3 MWH system of lithium ion batteries paired with solar PV. In addition, the battery system should pay for itself through three primary value streams.

Sandia Analysis (preliminary results):

Total potential revenue analysis for 1MW, 1MWh system

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

Project is in development: groundbreaking October 12

*2017-2018 data. Rates will likely be higher in the future, resulting in additional savings.

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

Non-monetized value: 12 days of islanded backup power for police station / dispatch center

ESTAP Demonstration Projects

Demo purposes:

- Novel technologies
- Novel applications
- Novel economic cases

Three recent projects:

- VT: Rutland Microgrid
- OR: Eugene Microgrid
- MA: Sterling Microgrid

Vermont: GMP Stafford Hill Microgrid

- Joint federal/state, public/private demonstration
- 4 MW batteries (lithium ion and lead acid) + 2 MW PV microgrid
- Sited on closed landfill (brownfield redevelopment)
- Provides resilient power for school (public shelter)

- Funding: $40K VT DPS, $250K DOE-OE
- Total cost: $12 M
- Project partners: Green Mountain Power, Dynapower, VT DPS, DOE, Sandia, CESA
- Payback < 7 years via utility capacity and transmission cost reductions
- Follow-on projects:
  - 14 LMI high-efficiency modular homes equipped with resilient power solar+storage (rural mobile home replacement project)
  - Burlington Electric Department solar+storage microgrid at Burlington Airport

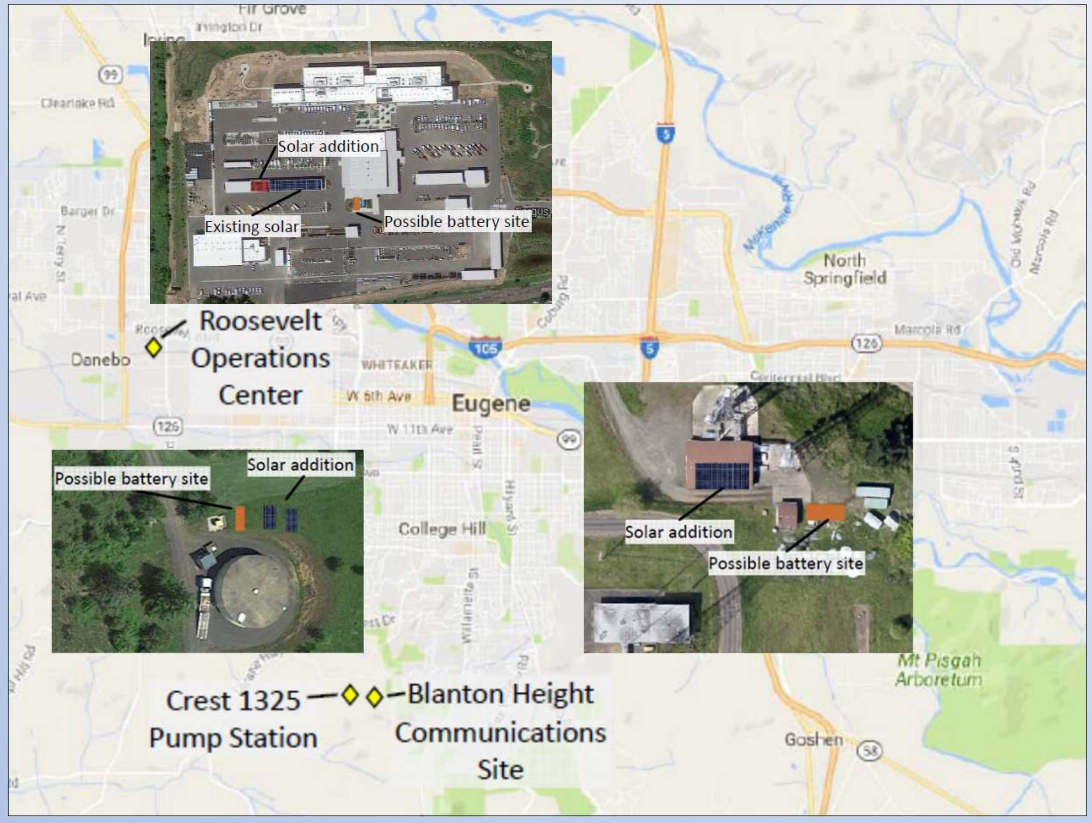
Oregon: EWEB Grid Edge Demonstration

- Joint federal/state, public/private demonstration project
- 500 kW / 900 kWh batteries (lithium ion) with 125 kW PV microgrid over three critical sites
- Partners: Eugene Water & Electric Board, ODOE, DOE, Sandia, CESA
- Funding: ODOE $45K, DOE-OE $250K
- Provides resilient power to utility operations center, communications facility and water pumping station

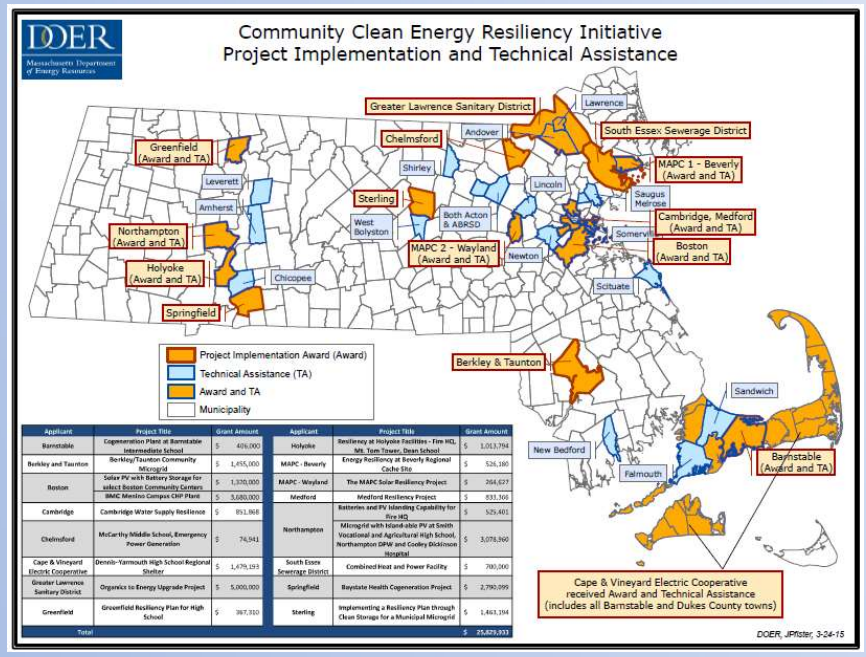
Demonstration goals:

- transmission and distribution upgrade deferral
- peak demand management
- service reliability/resiliency
- power quality
- voltage support
- grid regulation
- renewable energy firming
- ramp control
- energy shifting.

EWEB project has been awarded federal/state funding and is now contracting with vendors



Massachusetts CCERI projects

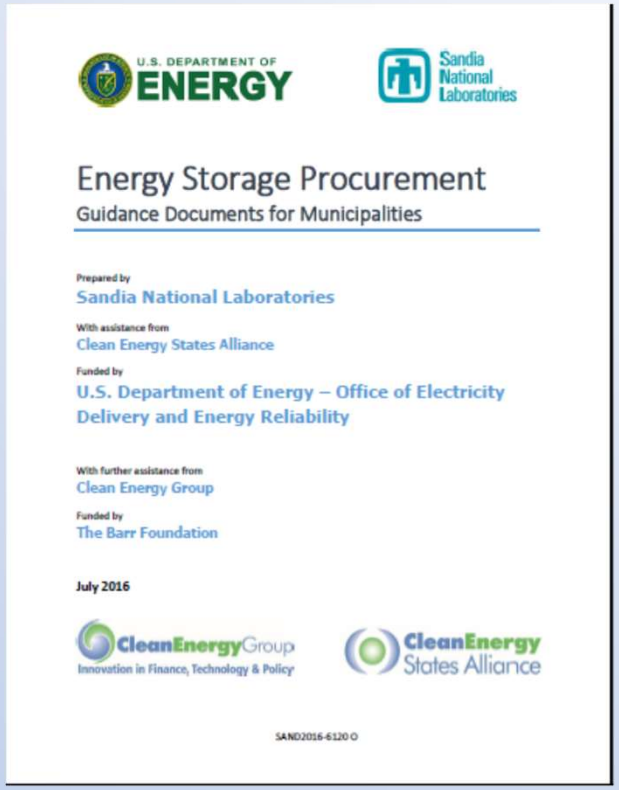


Applicant	Project Title	Grant Amount
Barnstable	Cogeneration Plant at Barnstable Intermediate School	$ 406,000
Berkley and Taunton	Berkley/Taunton Community Microgrid	$ 1,455,000
Boston	Solar PV with Battery Storage for select Boston Community Centers	$ 1,320,000
	BMC Menino Campus CHP Plant	$ 3,680,000
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	$ 3,078,360
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

With the national laboratories, CESA is providing technical assistance to 11 municipal CCERI awardees

- Sandia: Sterling, Holyoke, Cape & Vineyard
- PNNL: Northampton


U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

Energy Storage Procurement

Guidance Documents for Municipalities

Prepared by
Sandia National Laboratories

With assistance from
Clean Energy States Alliance

Funded by
U.S. Department of Energy – Office of Electricity Delivery and Energy Reliability

With further assistance from
Clean Energy Group

Funded by
The Barr Foundation

July 2016

CleanEnergyGroup
Innovation in Finance, Technology & Policy

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Take-Aways

- Energy storage is installed and operational in many states
  - Utility scale
  - Behind the meter
- Energy storage is providing many valuable services
  - Demand charge management
  - Demand response
  - Frequency regulation
  - Renewables integration
  - Resilience
  - T&D investment displacement/deferral
  - Arbitrage
  - Capacity and transmission cost savings
  - Ramping

Stacking benefits still needed in many cases to make storage economic, but can be challenging; May require regulatory reforms in some cases

- Some services provided by energy storage may not be properly valued; some cannot yet be monetized; Storage must be able to make money for providing services
- Energy storage can compete today in **open markets** under pay-for-performance conditions
- **It is possible to provide resilience to critical facilities AND generate revenues/cost savings, so that storage systems will pay for themselves**

Take-Aways (cont.)

- As prices continue to fall, energy storage will find new markets and applications
- State policymakers and regulators play a significant role in laying the groundwork for energy storage to compete
  - Demonstrations projects, incentives, mandates
  - Regulatory and policy changes that open markets
  - Pay for performance, valuation of services
- Demonstration projects are still important, not only for demonstrating new technologies and applications, but also business cases and economic performance of energy storage
- State incentive programs exist to stimulate market development, and should render themselves unnecessary over time

Thank You to:

Imre Gyuk, US DOE-OE

Dan Borneo, Sandia National Laboratories

Todd Olinsky-Paul

Project Director

CEG/CESA

Todd@cleanegroup.org

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

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

CleanEnergy States Alliance

Markets and Opportunities

How can states support energy storage?

States have a number of policy tools at their disposal to support energy storage deployment. These include:

- Competitive solicitations/RFPs
- Renewable Portfolio Standards and Stand-Alone Mandates
- Adders, multipliers and carve-outs
- Prescriptive rebates
- Integrating energy storage into longer-term state policy (energy reports, roadmaps, emergency planning)
- Green banks and energy resilience banks
- Tax credits/depreciation
- PACE loans
- Industry development (training/education, business incubators etc)

Note that these tools are available to various state agencies that often do not work together

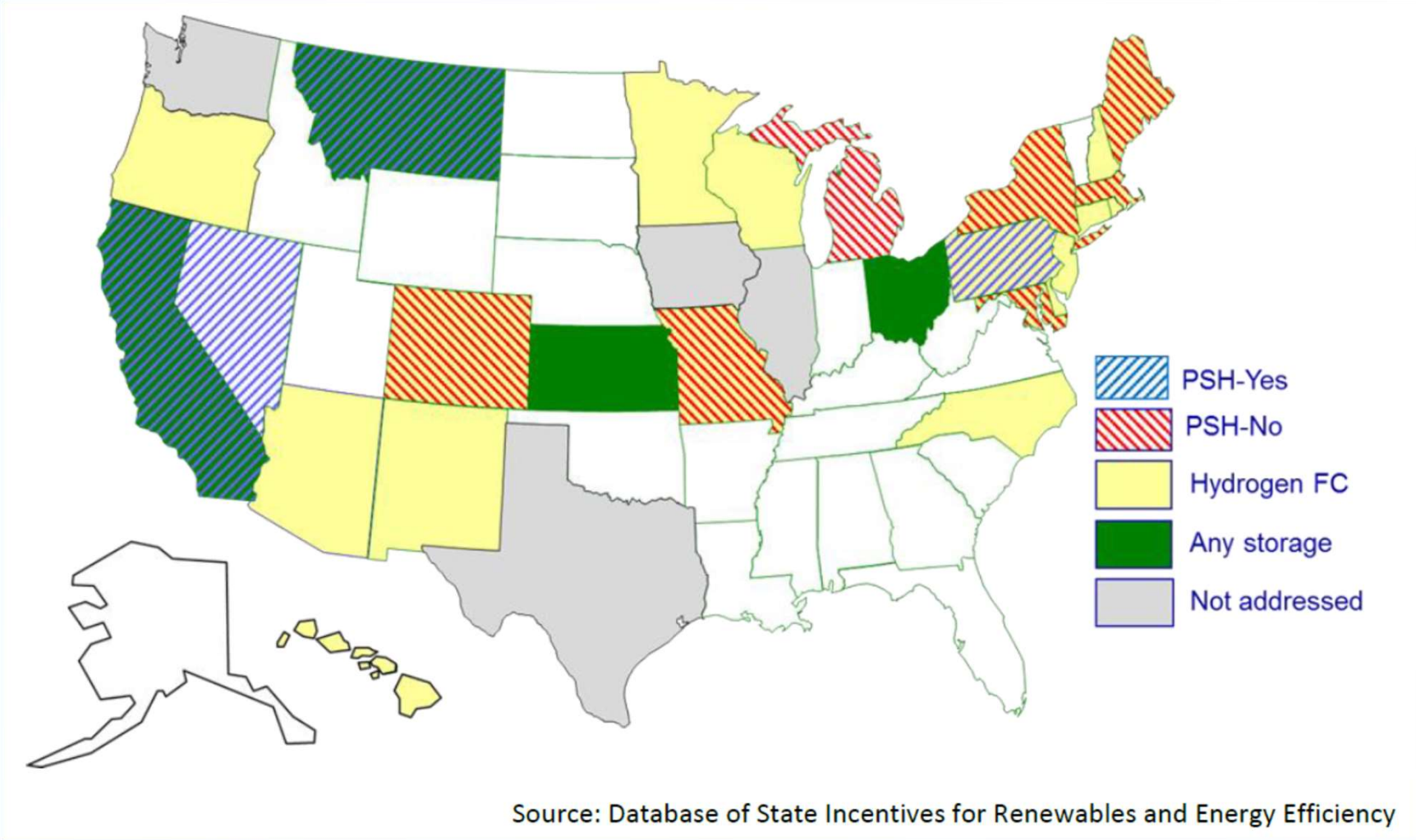
Existing state incentives, policies and programs

- California:
  - 1.3 GW energy storage utility mandate
  - SGIP incentive program includes energy storage
- Connecticut:
  - Microgrids grant and loan program
  - Clean Energy RFP (includes energy storage > 1MW anywhere in New England)
- Hawaii
  - HECO energy storage RFP
  - Proposed energy storage incentives
- Massachusetts:
  - Community Clean Energy Resilience Initiative – Ma DOER
  - Energy Storage Initiative (Energy storage study and demonstration projects) – MA DOER, MassCEC
  - Energy storage utility mandate (TBD) – MA DOER
  - Grid modernization initiative
  - Microgrids initiative - MassCEC

Existing state incentives, policies and programs

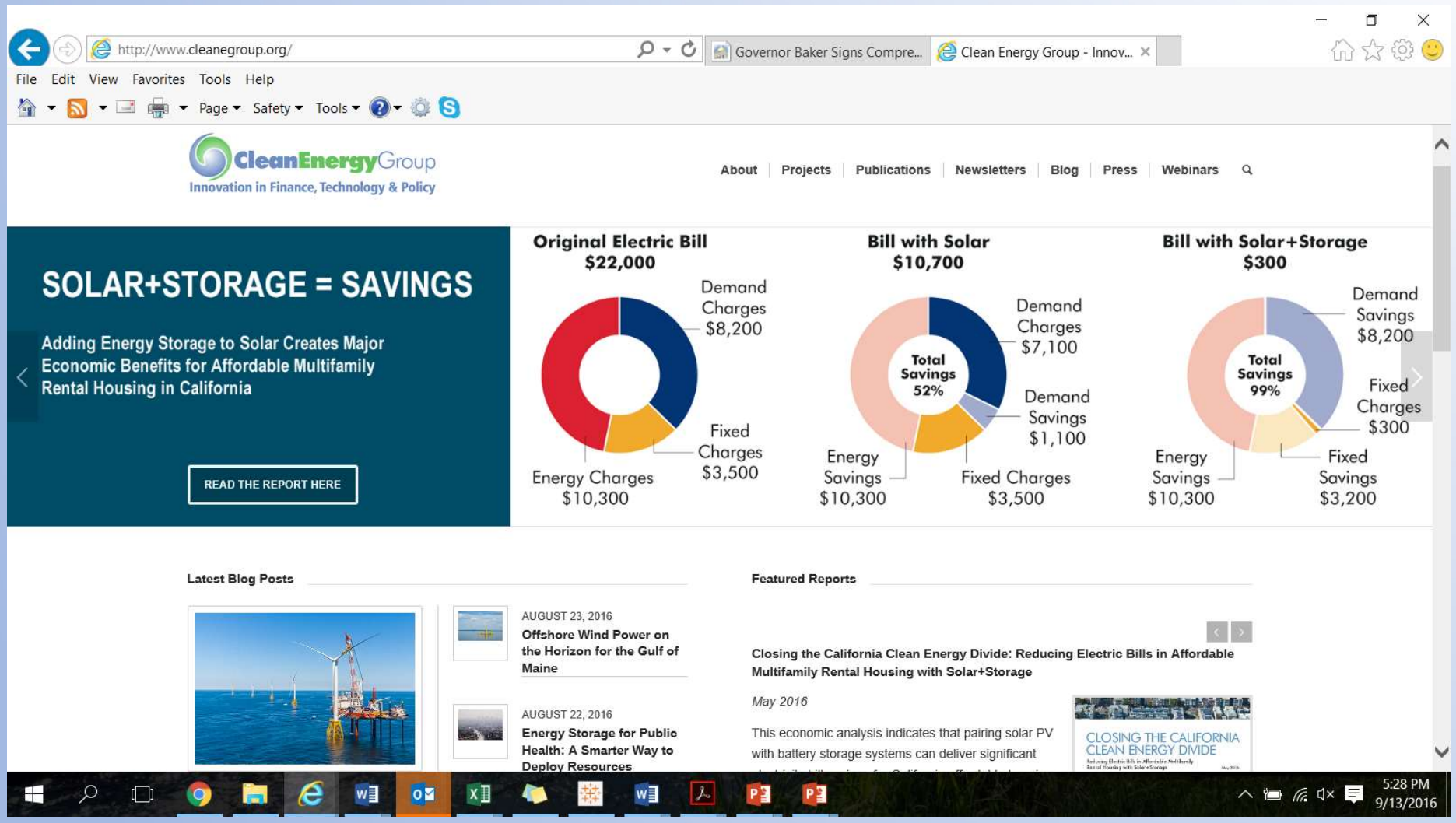
- New Jersey:
  - Distributed energy storage + renewables resiliency grants and rebates
  - Energy Resilience Bank
- New York:
  - NY Prize microgrids program (now in project design phase)
  - REV grid modernization (allows utilities to own storage in certain circumstances)
  - NYSERDA-ConEd load reduction program (nuclear retirement - includes storage incentives)
- Oregon:
  - 5 mWh energy storage utility mandate
- Puerto Rico
  - Energy storage mandate for renewable energy developers
- Washington:
  - Clean Energy Fund grid modernization grants

States that include energy storage in a mandatory RPS



NOTE: CA and OR have stand-alone storage utility mandates, and MA has adopted legislation allowing a stand-alone storage utility mandate to be created

http://www.cleanegroup.org/



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 Sterling Municipal Light Department, a municipal utility
- Potential value streams:
  1. **Energy arbitrage** revenues (buy low, sell high)
  2. **Reduction in transmission obligation** to ISO-NE (cost savings based on monthly peak hour)
  3. **Reduction in capacity obligation** to ISO-NE (cost savngs based on annual peak hour)
  4. **Resilient power provision** to critical emergency facilities (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	44.29	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	88.95	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

1. Energy Arbitrage

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

PRELIMINARY RESULTS

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

2. 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”

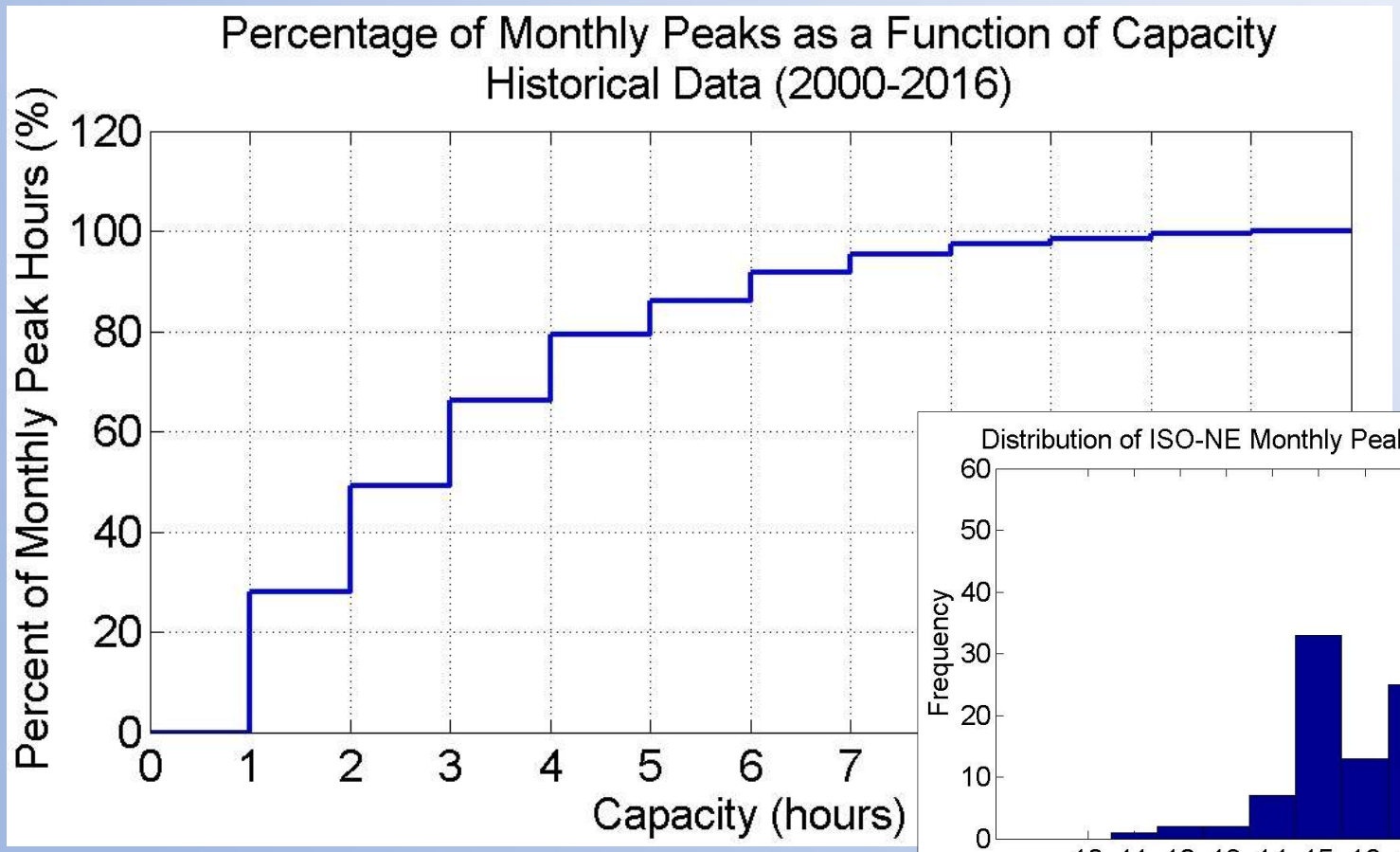
PRELIMINARY RESULTS

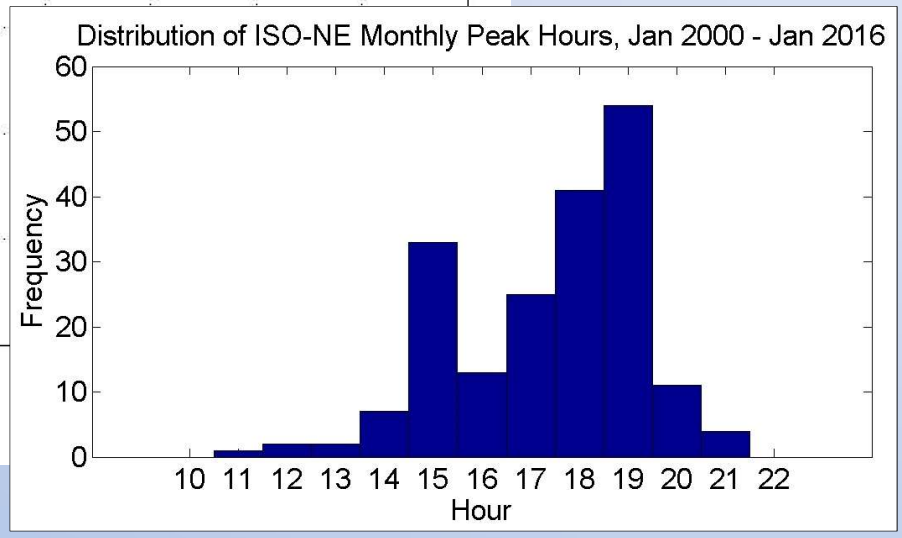
RNS Savings for 1 Hour Energy Storage System.

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





3. 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

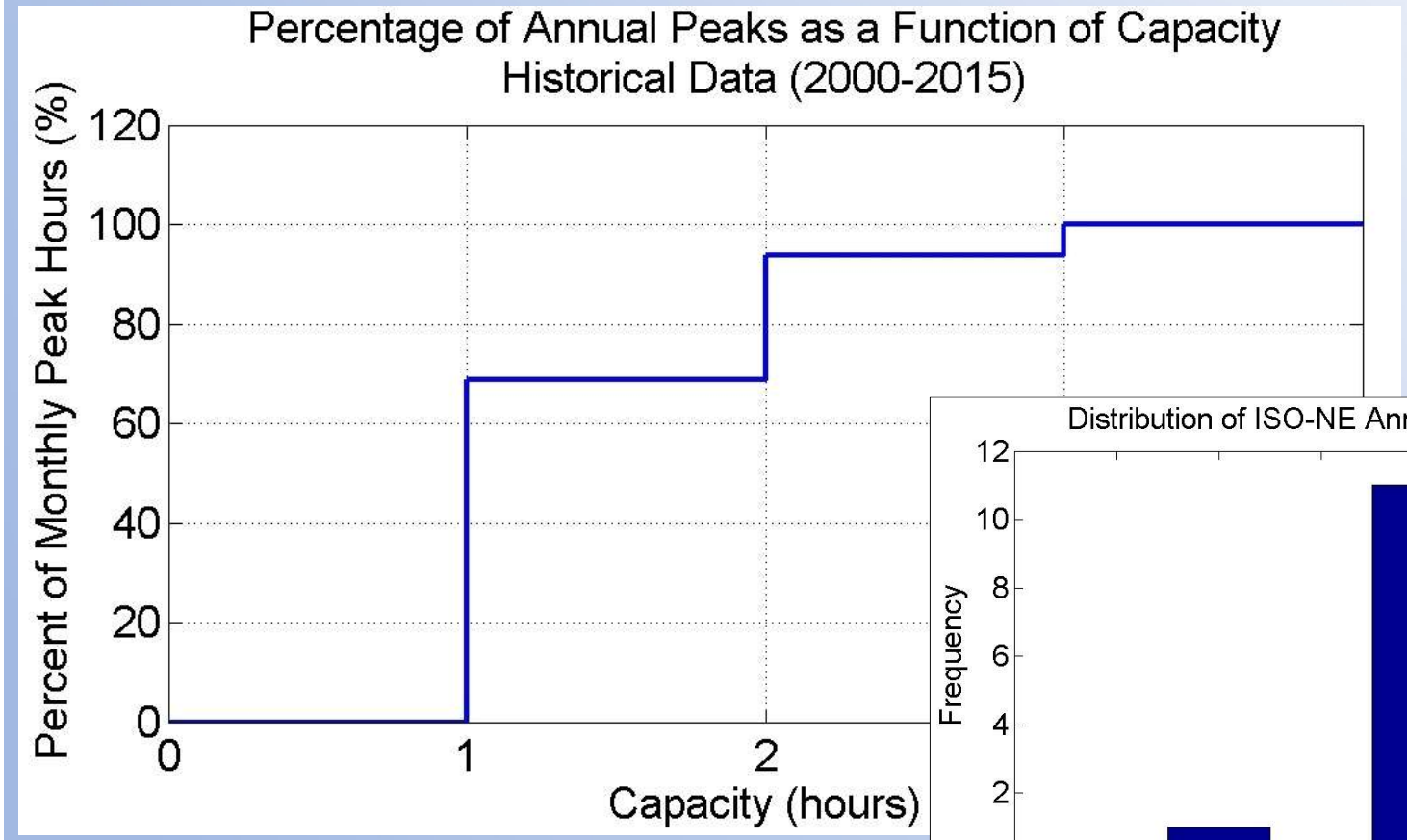
PRELIMINARY RESULTS

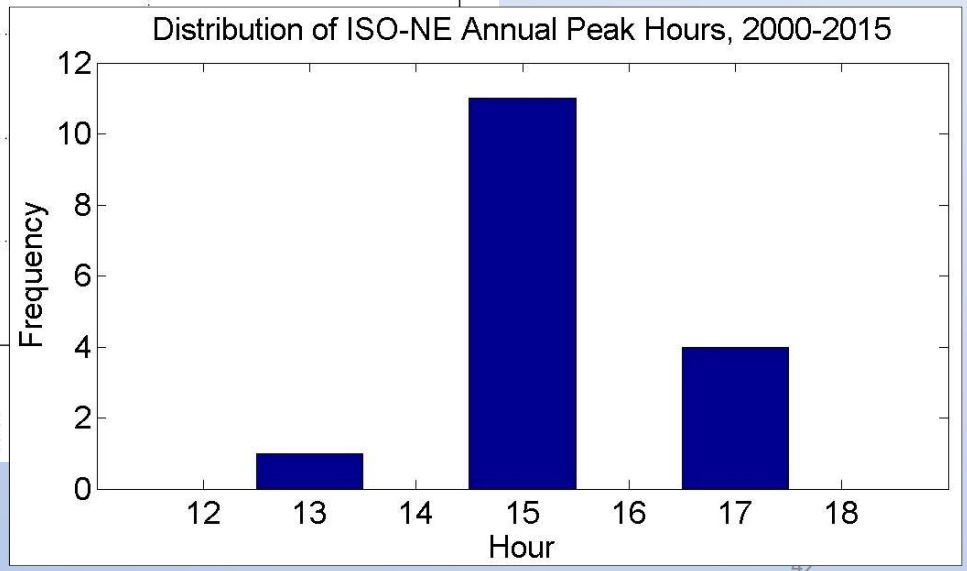
Capacity Clearing Price, ISO-NE.

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





4. Resilience (critical facility backup)

- Municipality has identified 10kW as the critical load at community critical emergency facilities
- Resilience is not monetizable through markets, but is valued highly by the community and the state (CCERI grants)

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

PRELIMINARY RESULTS

Total potential revenue, 1MW, 1MWh system:

Description	Total	Percent
Arbitrage (transmission)	$40,738	16.0%
RNS payment (capacity)	$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

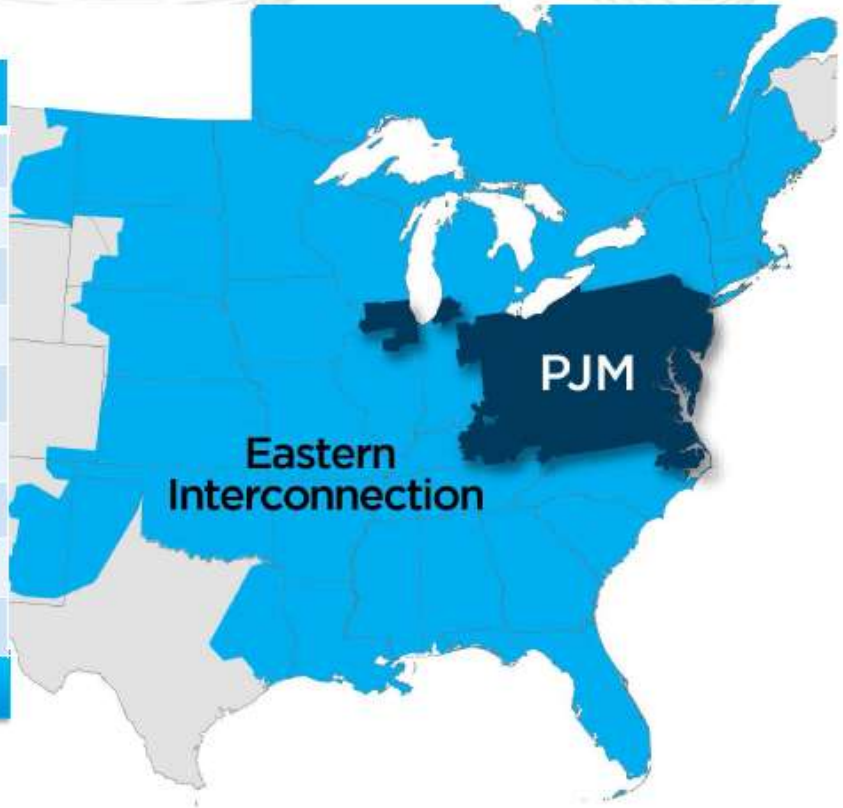
*2017-2018 data. Rates will be higher in 2018-2019, resulting in additional savings.

Frequency Regulation in PJM

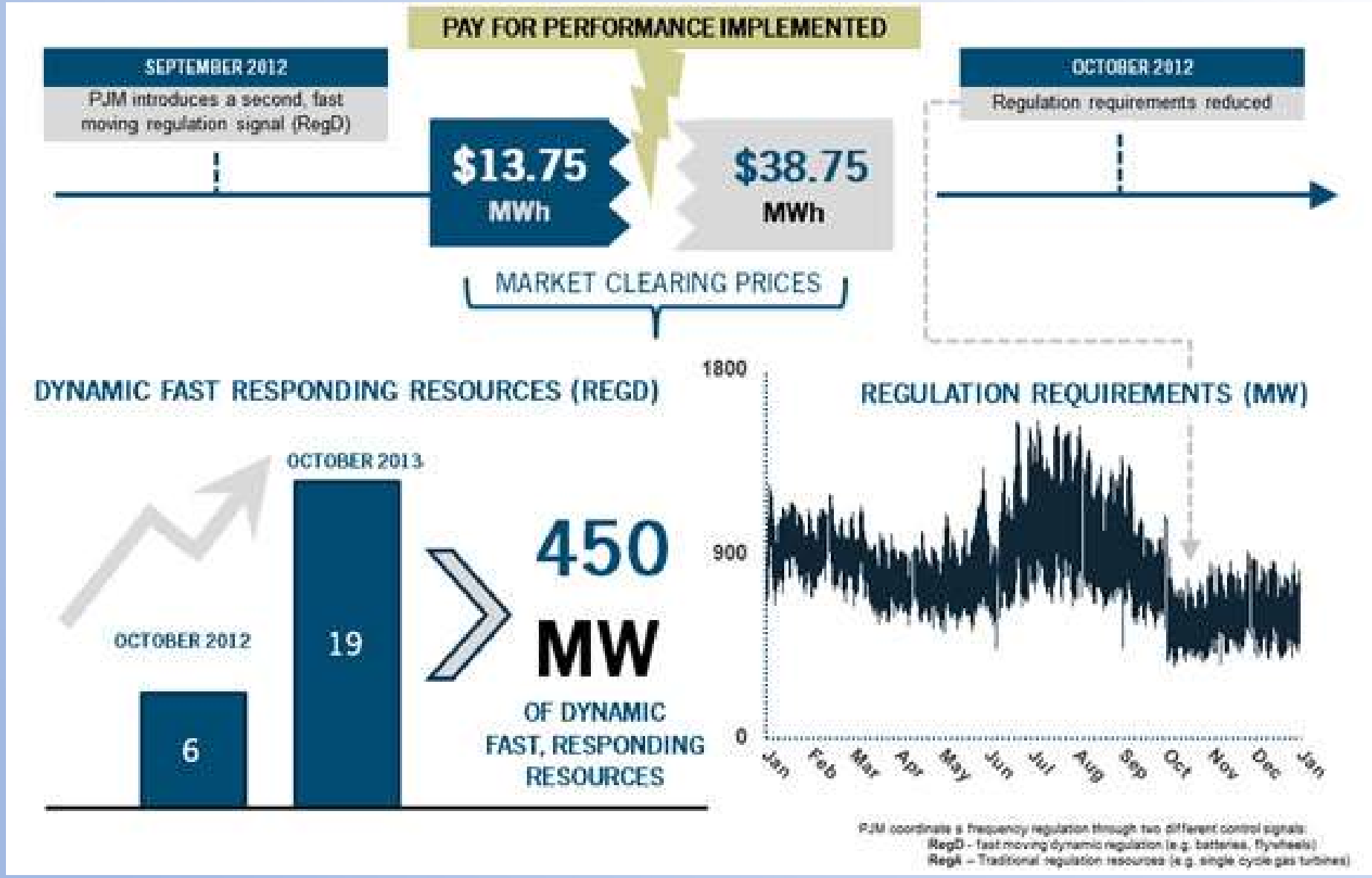
PJM as Part of the Eastern Interconnection

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

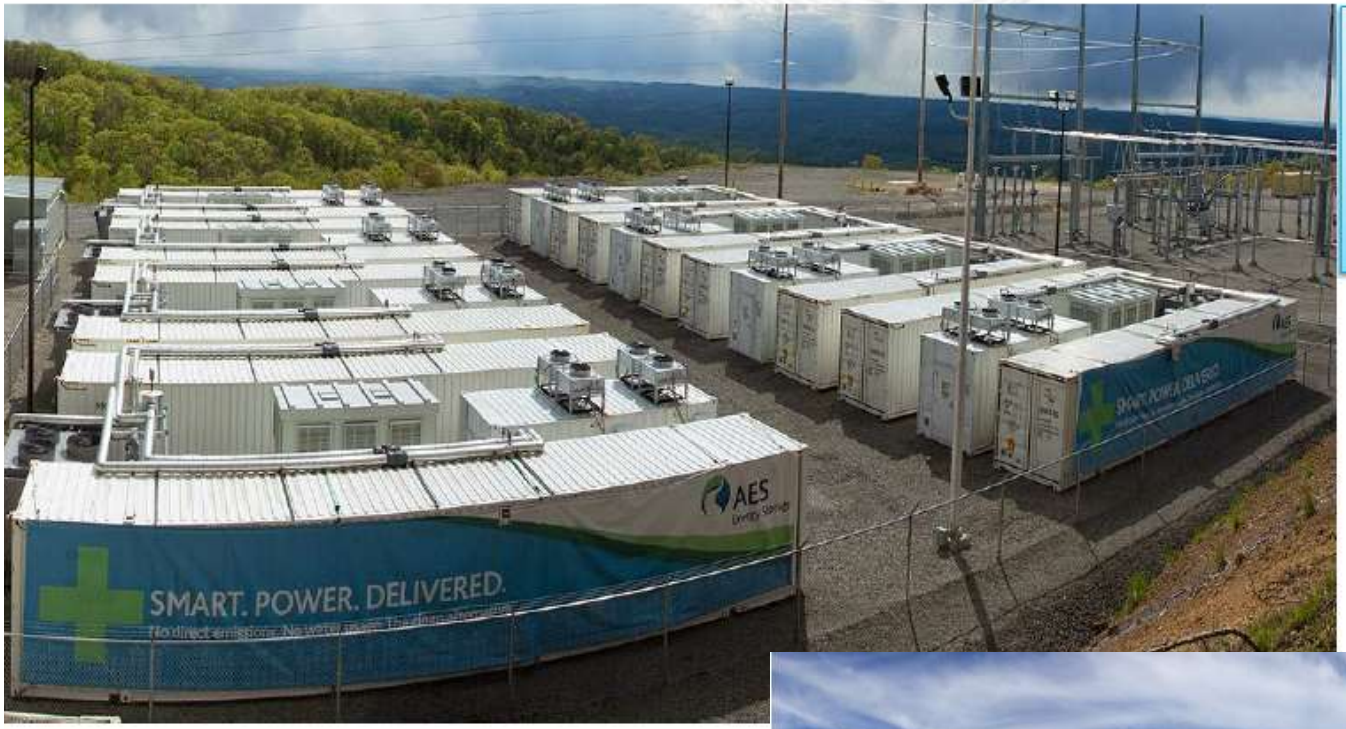
21% of U.S. GDP produced in PJM



1/2016


PAY FOR PERFORMANCE IMPLEMENTED
SEPTEMBER 2012
PJM introduces a second, fast moving regulation signal (RegD)
$13.75 MWh
$38.75 MWh
MARKET CLEARING PRICES
OCTOBER 2012
Regulation requirements reduced
DYNAMIC FAST RESPONDING RESOURCES (REGD)
OCTOBER 2013
OCTOBER 2012
6
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 a 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*

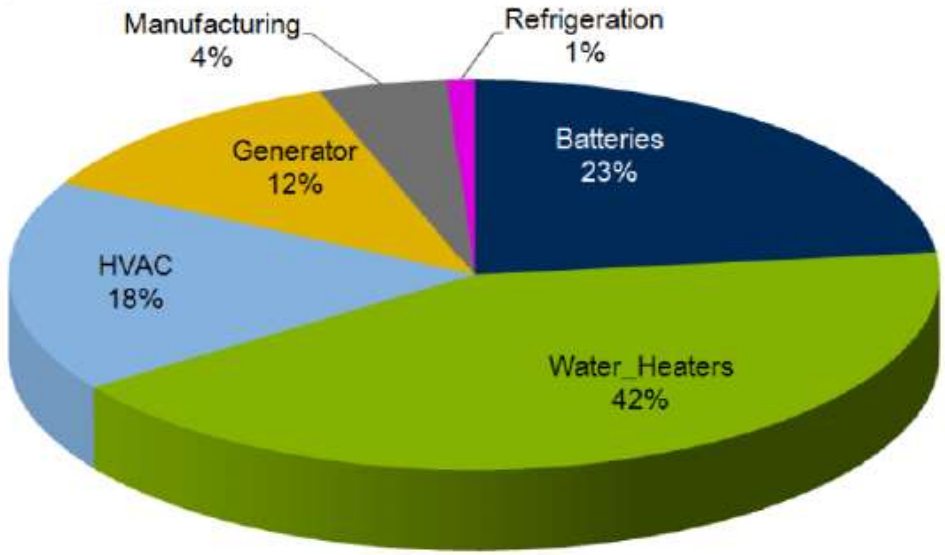
32 MW AES energy storage facility at 98 MW Laurel Mountain Wind Farm, West Virginia
-Source: PJM

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

Source: PJM

DR Market Participation: Regulation Market

Regulation	Zone	January 2016
Locations	RTO	293
MW	RTO	22



Note: Percent of CSP Reported Load Reduction MWs

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

- 22 Applications Received
- $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

- 13 Applications Approved
- $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

The business case for storage depends on multiple value streams that are locationally determined

"Locationally" means where on the map *and* where on the grid

Behind the meter

- Demand charge management
- Utility tariff switching
- Reduced energy purchases
- Demand response
- Frequency regulation
- TOU arbitrage

Transmission/Distribution

- T&D investment deferral
- Ancillary services provision
- Utility capacity and transmission cost reductions
- Renewables integration
- Ramping
- Arbitrage
- Frequency regulation