Energy Storage: The Game-Changer

National Conference of State Legislatures
Capital Forum
Washington, DC
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Agenda for this presentation:

- Introduction to Clean Energy States Alliance (CESA) and the Energy Storage Technology Advancement Partnership (ESTAP)
- Why energy storage?
- Project examples
- Economic landscape for storage
- State policy landscape for storage
- What's next?

Clean Energy States Alliance (CESA)
www.cesa.org

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Energy Trust of Oregon

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DOER Massachusetts Department of Energy Resources

State of Rhode Island Office of Energy Resources

MassDEP

ALASKA ENERGY AUTHORITY

IPA ILLINOIS POWER AGENCY

Connecticut Energy Environment

Minnesota Department of Commerce

Oregon Department of Energy

State of Washington Department of Commerce
Innovation is in our nature.

New Hampshire Department of Environmental Services

ACEP Alaska Center for Energy and Power

Department of Energy & Environment

Prairie Island Indian Community

New Hampshire OEP Office of Energy and Planning

Energy Storage Technology Advancement Partnership (ESTAP) (bit.ly/ESTAP)

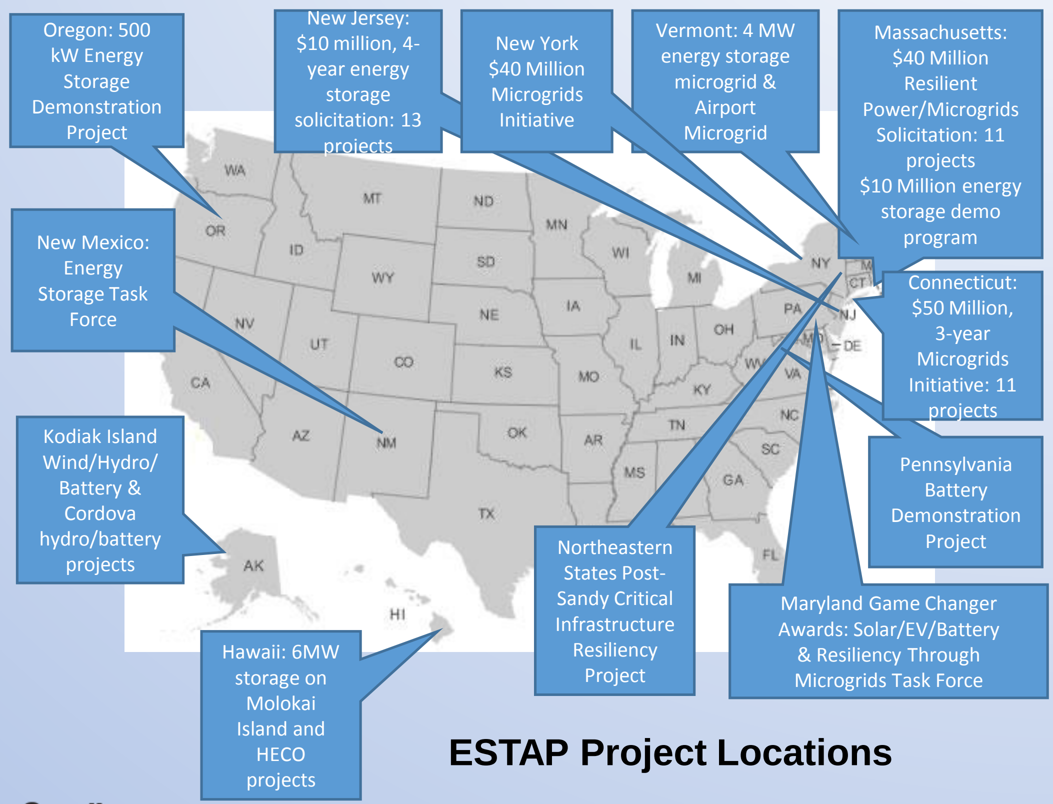
- Conducted by CESA
- Under contract with Sandia National Laboratories, with funding from US DOE-OE

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

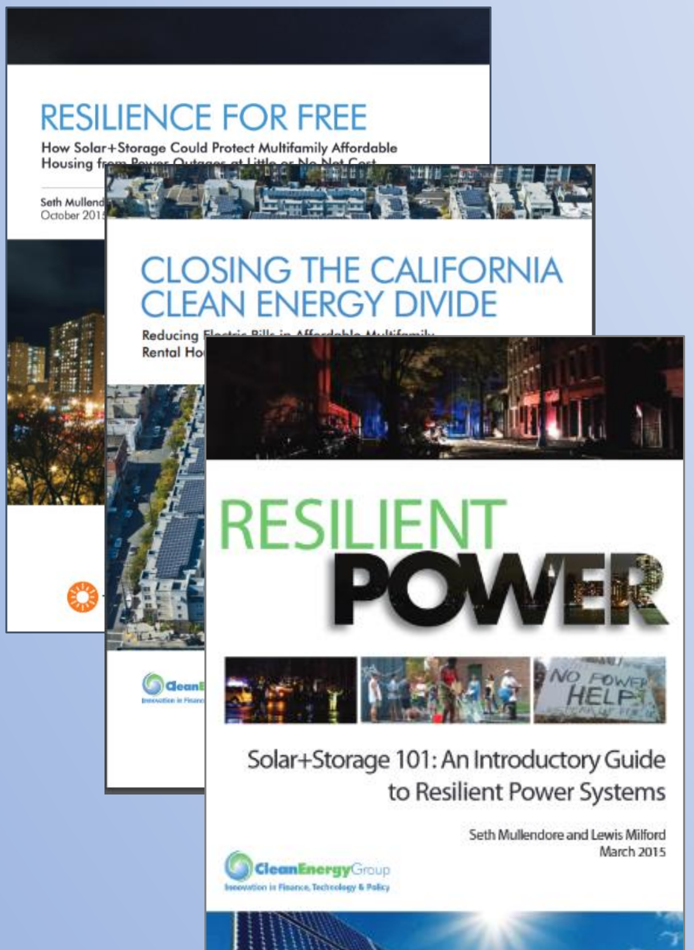
Clean Energy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Clean Energy Group
Resilient Power Project

CleanEnergyGroup
Innovation in Finance, Technology & Policy



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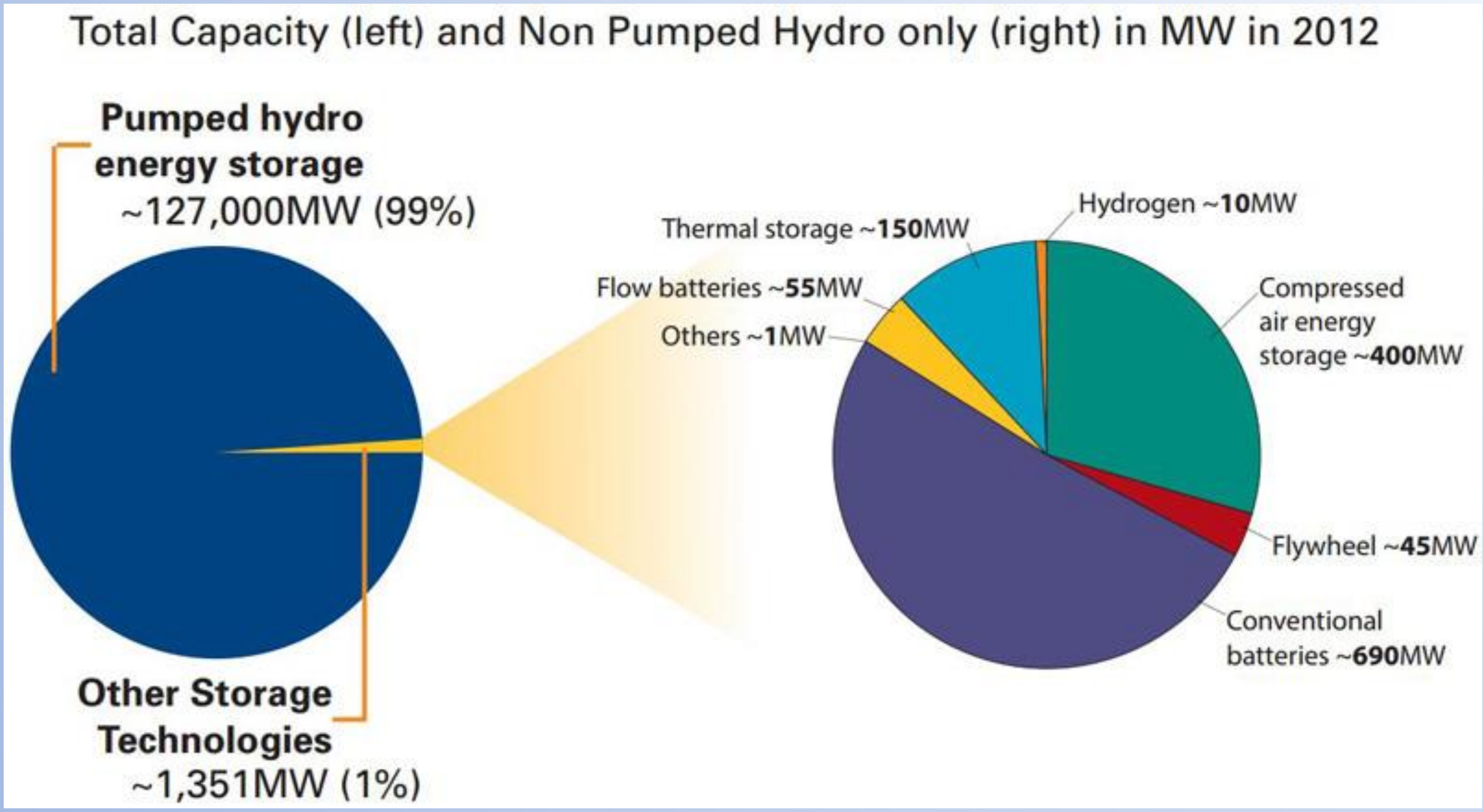
Why Energy Storage?

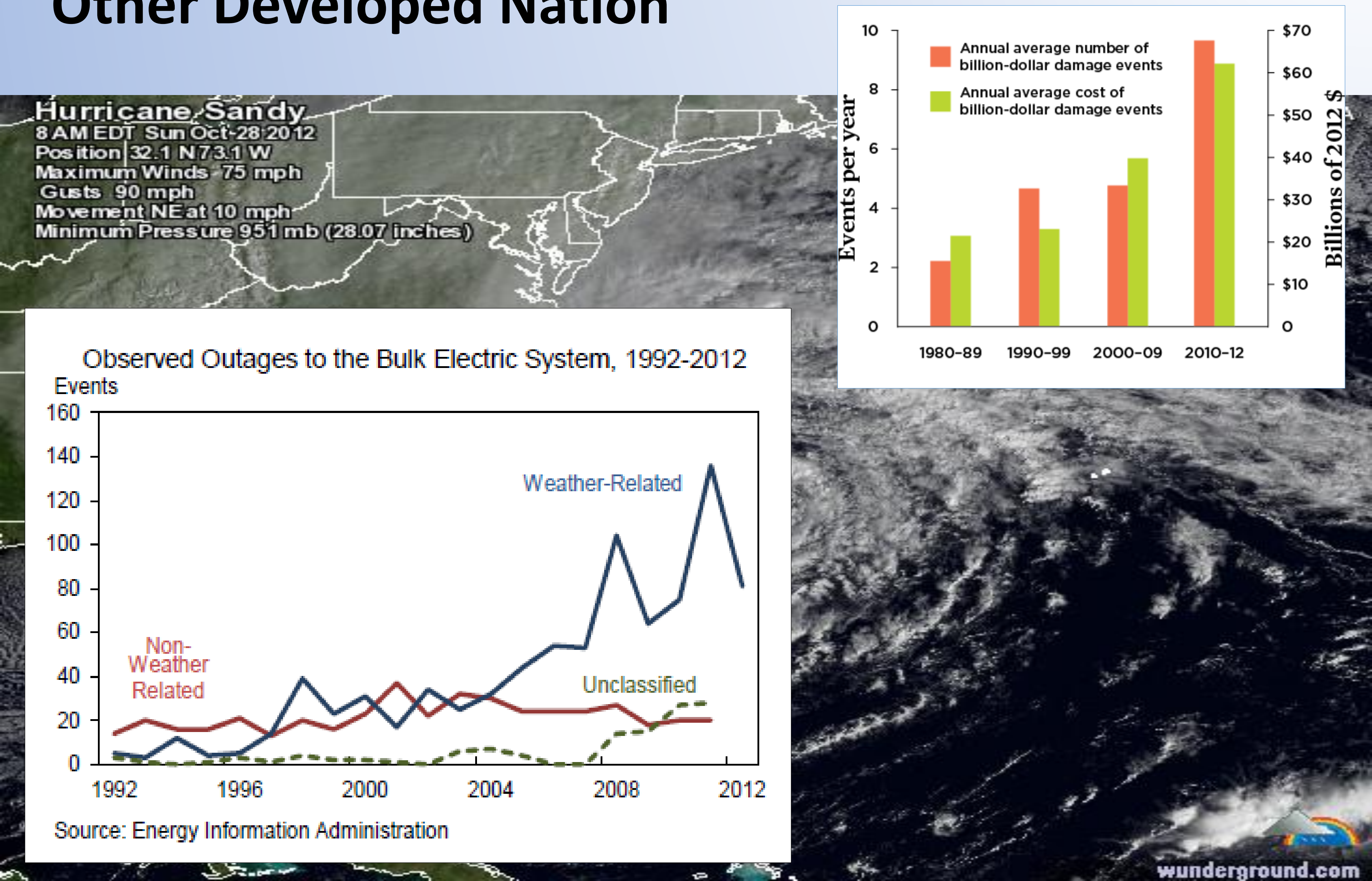
Total electricity storage capacity is less than 1%

Global Electricity Storage Capacity

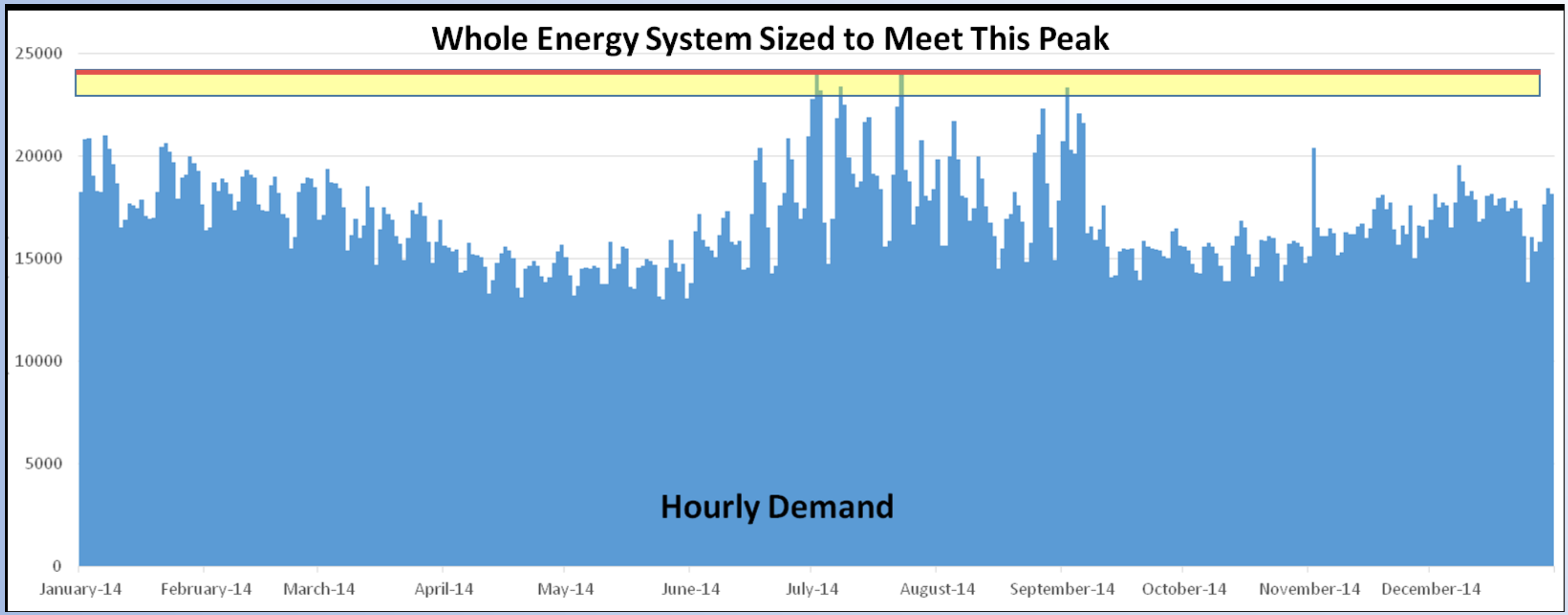


Current electricity storage: 99% pumped hydro

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



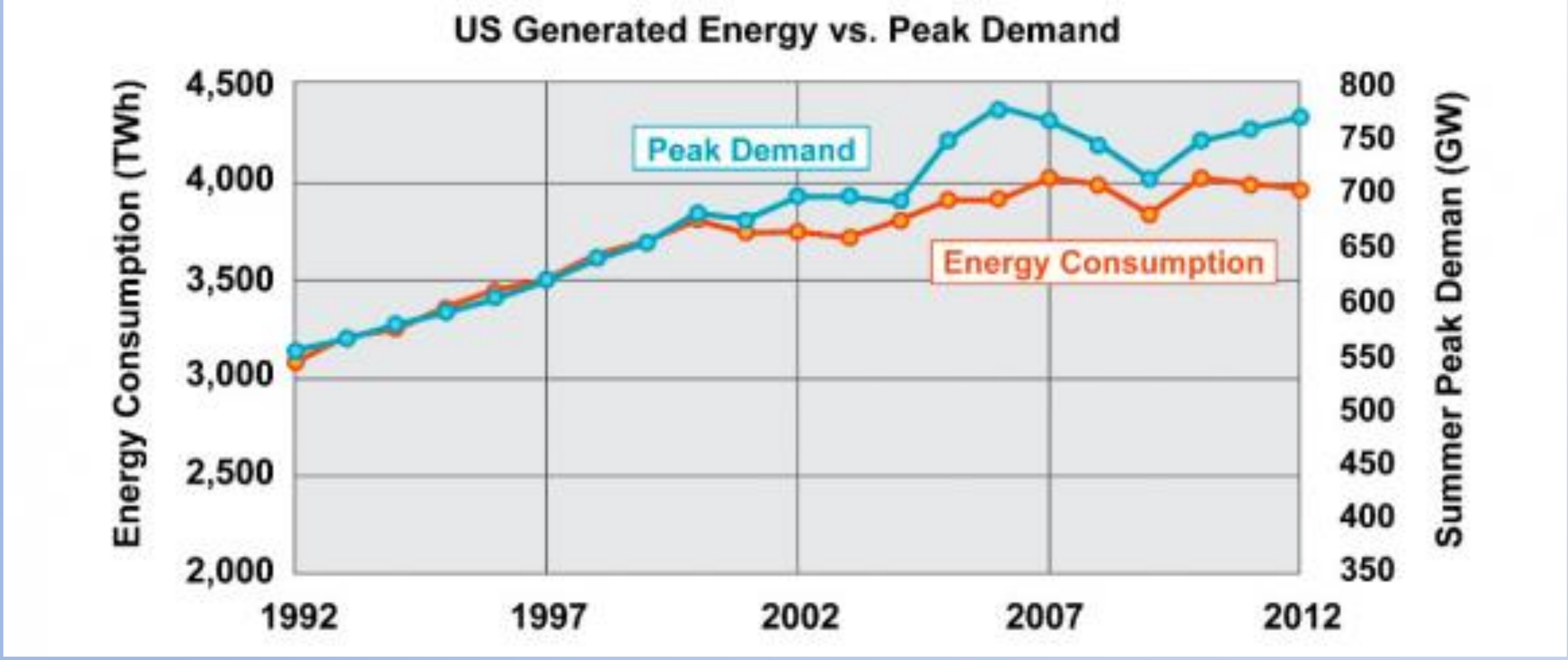
Generation and Grids are Overbuilt



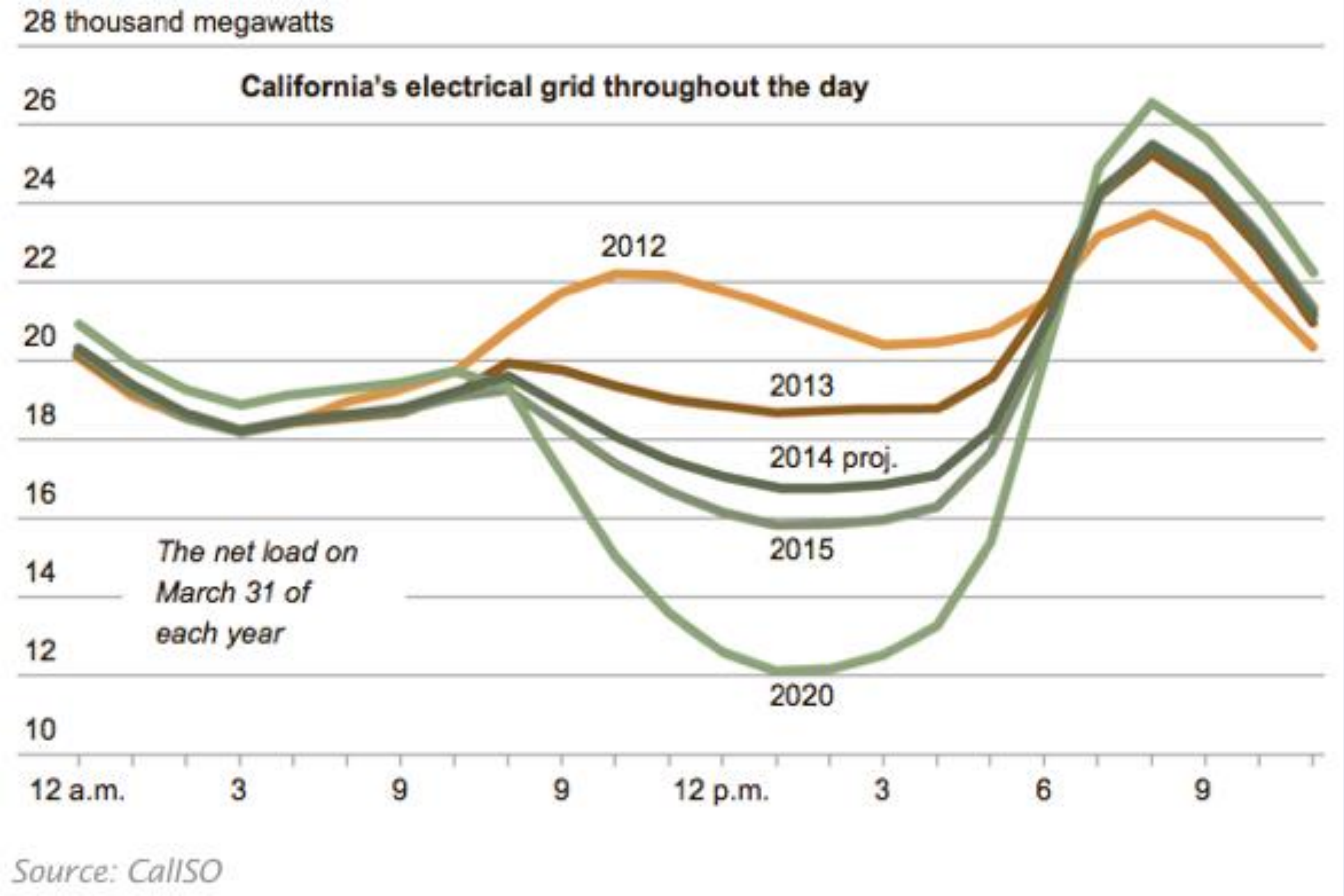
Some states have begun a process of revisioning the electric grid:

- New York REV
- Massachusetts grid modernization

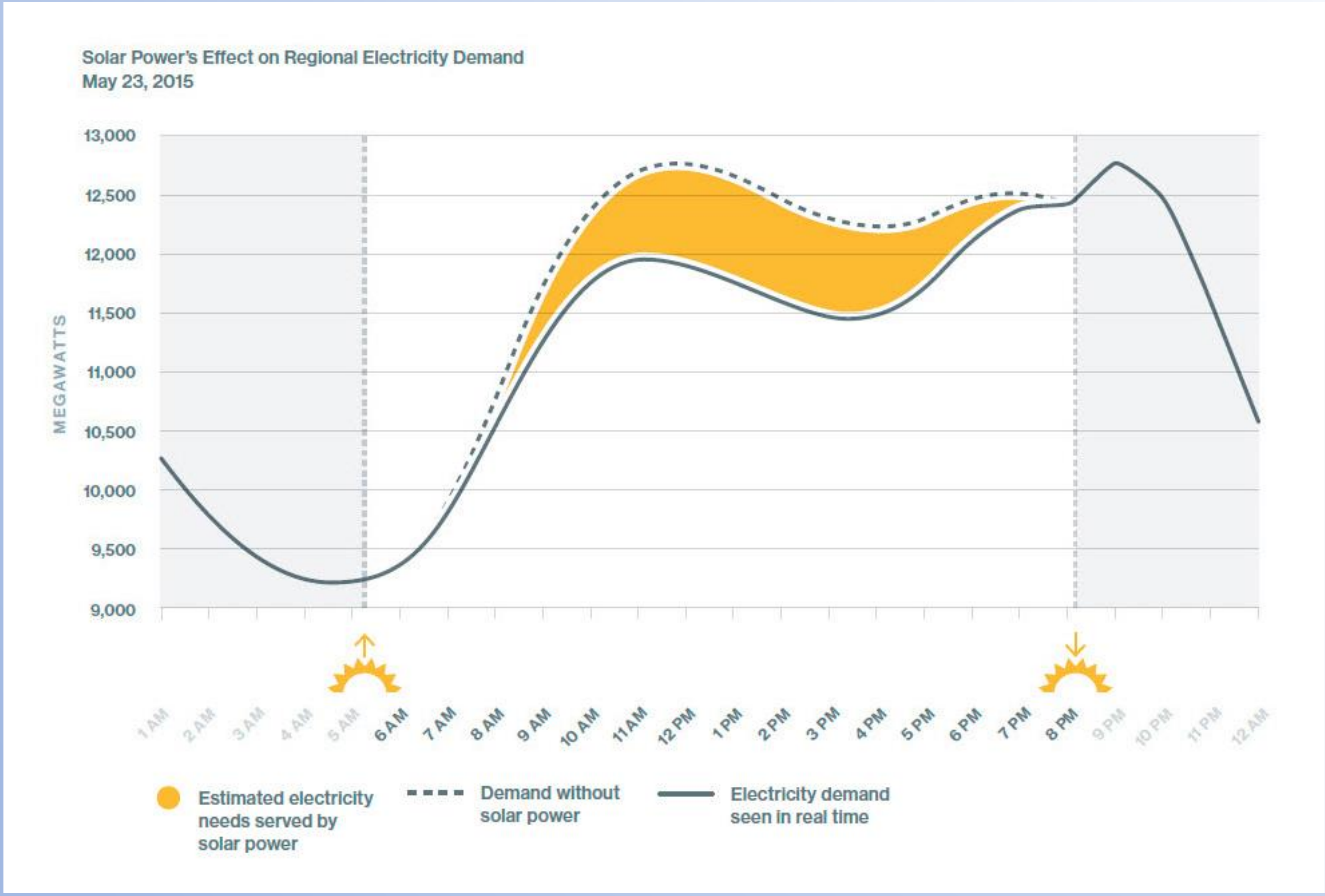
Electricity consumption is **flat**
While peak demand is **rising**



California "Duck" Curve



ISO-New England: Does this curve look familiar?



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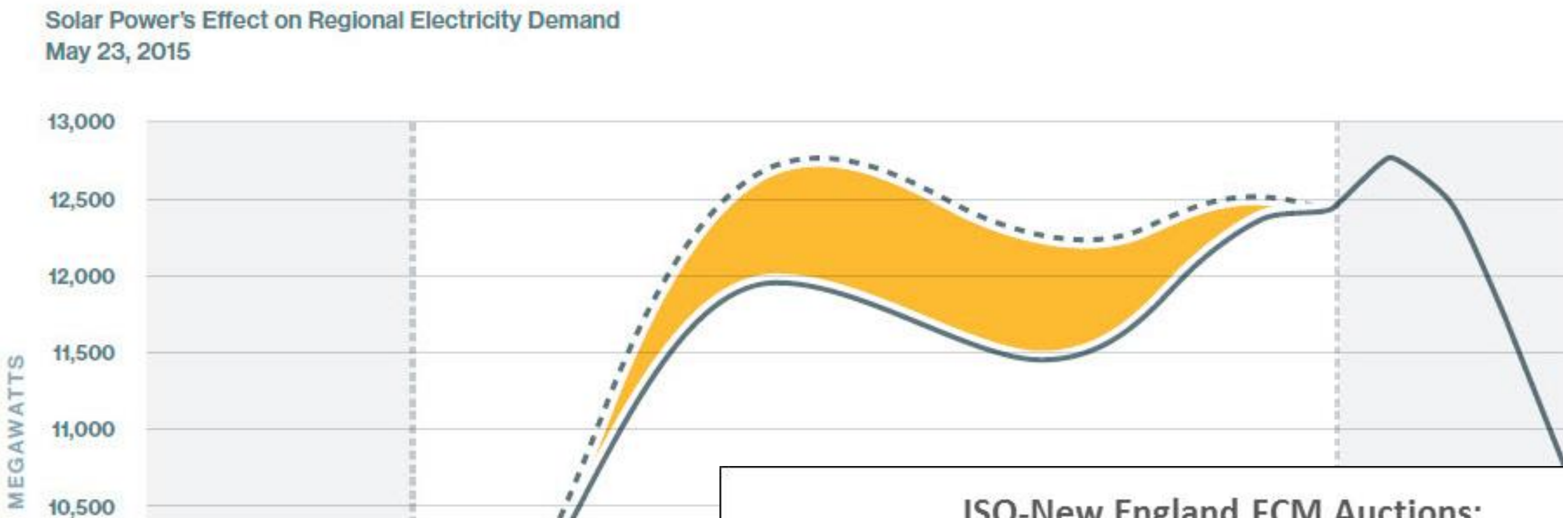
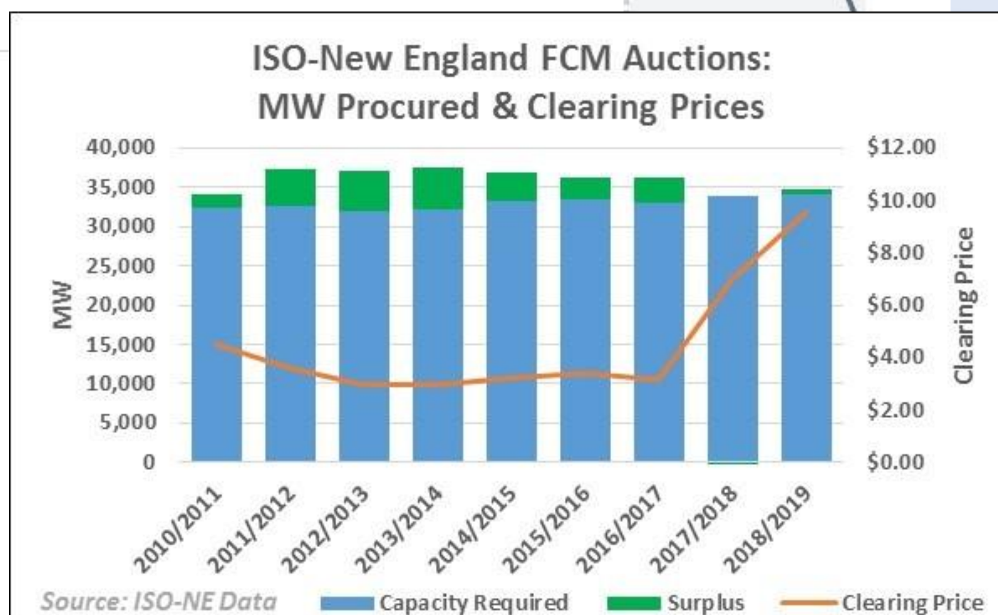
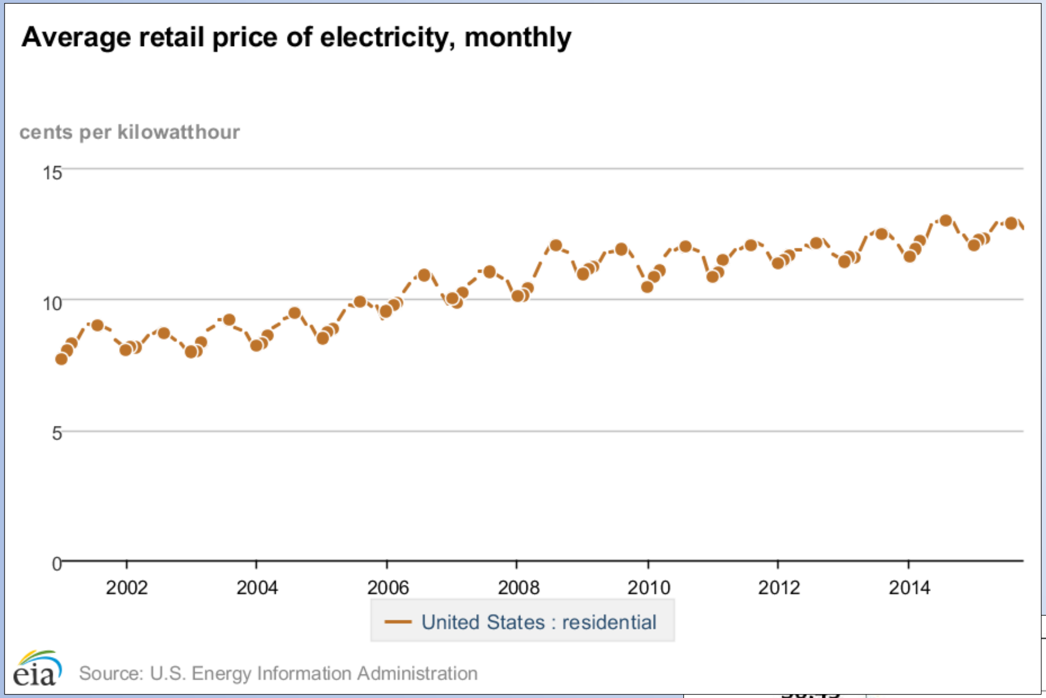


SMLD Capacity Clearing Price, ISO-NE.

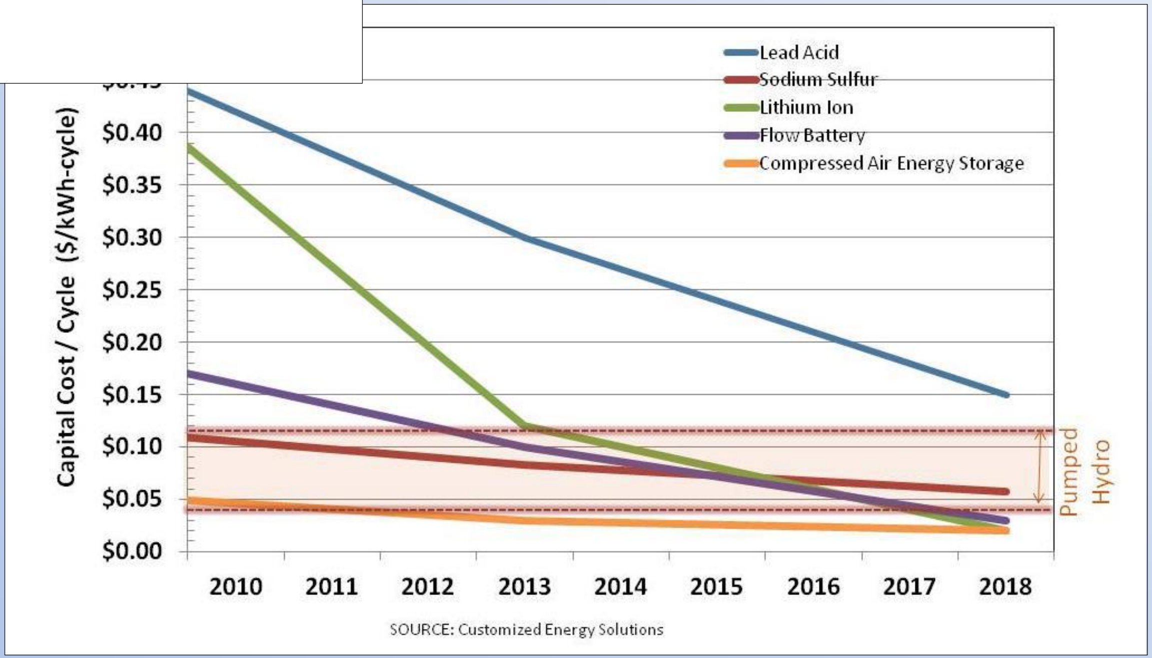
Year	Price ($/kW-Month)
2010-2011	$4.254
2011-2012	$3.119
2012-2013	$2.535
2013-2014	$2.516
2014-2015	$2.855
2015-2016	$3.129
2016-2017	$3.150
2017-2018	$7.025
2018-2019	$9.551



Price of electricity **increases**, while cost of battery storage **decreases**



Cost of battery storage (by technology)



Some recent solar+storage demonstration projects

- Vermont
  - Rutland Microgrid
  - McKnight Lane LMI housing project
- Massachusetts
  - CCERI projects
  - Sterling Microgrid
- Oregon
  - Eugene Microgrid

Vermont: GMP Microgrid, Rutland (Stafford Hill)

- 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)
- Project partners: Green Mountain Power, Dynapower, VT DPS, DOE, Sandia, CESA

- Funding: $40K VT DPS, $250K DOE-OE
- Total cost: $12 M
- 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 Dept solar+storage microgrid at Burlington Airport

Sterling, MA 2MW/3MWh Solar+Storage Microgrid

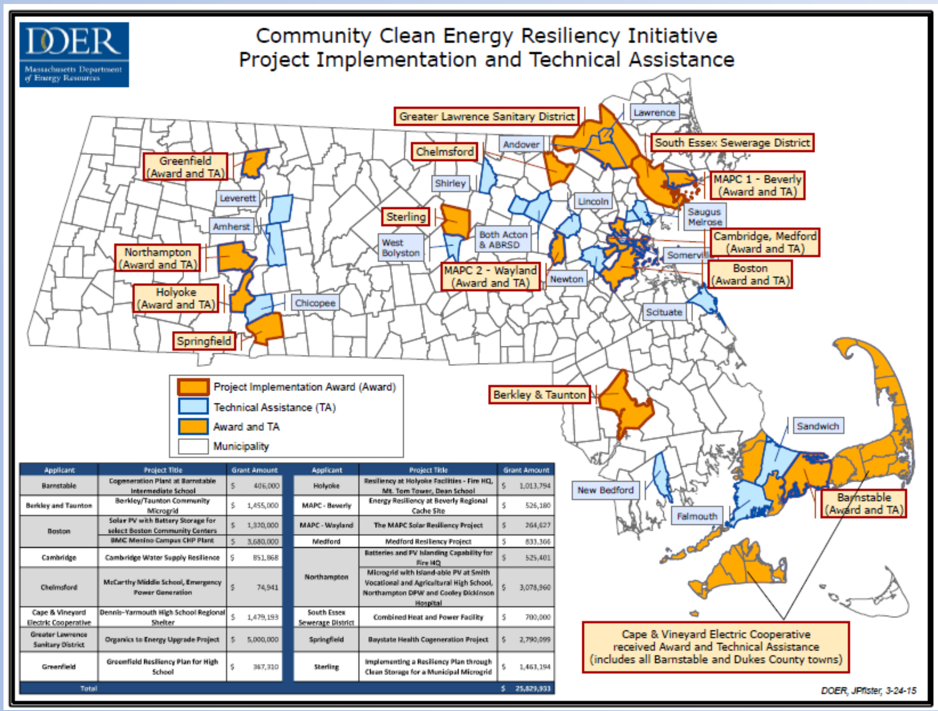
Project partners: SMLD, DOER, DOE-OE, SNL, CESA
Project funding: State CCERI grant, US DOE grant
Project timeline: Groundbreaking in October 2016, commissioning by end of year

Project Summary: 2 MW / 3 mWh lithium ion battery project, connected with 3.4 MW solar PV at utility substation; islanding capability to support municipal emergency facility.

Project Benefits and Revenue Streams:

- Backup power to support town police station / dispatch center during grid outages;
- Cost savings through reduction of SMLD's capacity and transmission obligations to ISO-NE;
- Revenues from electricity arbitrage
- Integration of intermittent solar PV

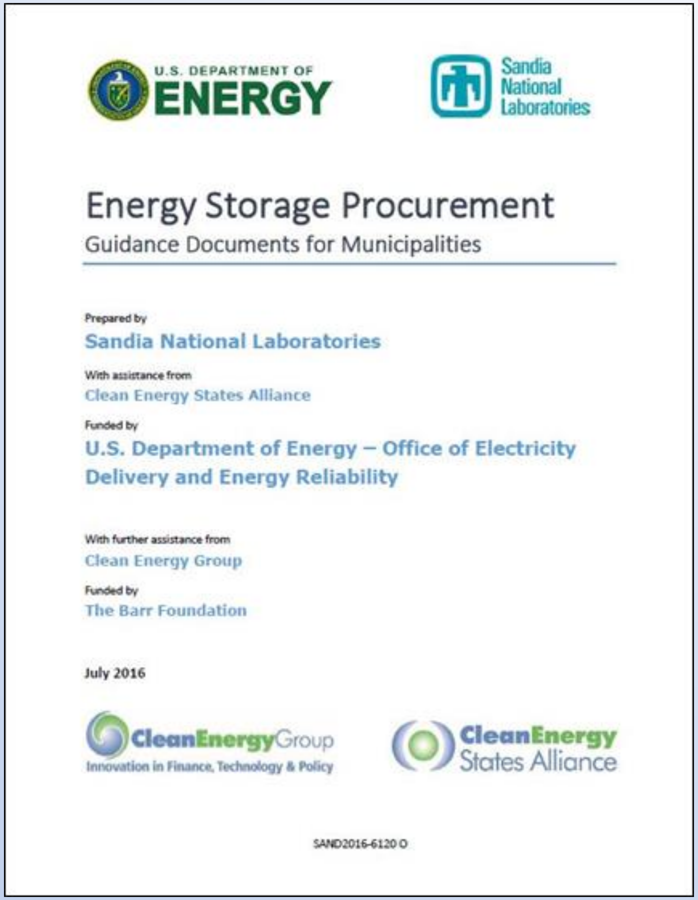
Massachusetts resiliency projects



Applicant	Project Title	Grant Amount	Applicant	Project Title	Grant Amount
Barnstable	Cogeneration Plant at Barnstable Intermediate School	$ 406,000	Holyoke	Resiliency at Holyoke Facilities - Fire HQ, Mt. Tom Tower, Dean School	$ 1,013,794
Berkley and Taunton	Berkley/Taunton Community Microgrid	$ 1,455,000	MAPC - Beverly	Energy Resiliency at Beverly Regional Cache Site	$ 526,180
Boston	Solar PV with Battery Storage for select Boston Community Centers	$ 1,320,000	MAPC - Wayland	The MAPC Solar Resiliency Project	$ 264,627
	BMC Menino Campus CHP Plant	$ 3,680,000	Medford	Medford Resiliency Project	$ 833,366
Cambridge	Cambridge Water Supply Resilience	$ 851,868	Northampton	Batteries and PV Islanding Capability for Fire HQ	$ 525,401
Chelmsford	McCarthy Middle School, Emergency Power Generation	$ 74,941		Microgrid with Island-able PV at Smith Vocational and Agricultural High School, Northampton DPW and Cooley Dickinson Hospital	$ 3,078,960
Cape & Vineyard Electric Cooperative	Dennis-Yarmouth High School Regional Shelter	$ 1,479,193	South Essex Sewerage District	Combined Heat and Power Facility	$ 700,000
Greater Lawrence Sanitary District	Organics to Energy Upgrade Project	$ 5,000,000	Springfield	Baystate Health Cogeneration Project	$ 2,790,099
Greenfield	Greenfield Resiliency Plan for High School	$ 367,310	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

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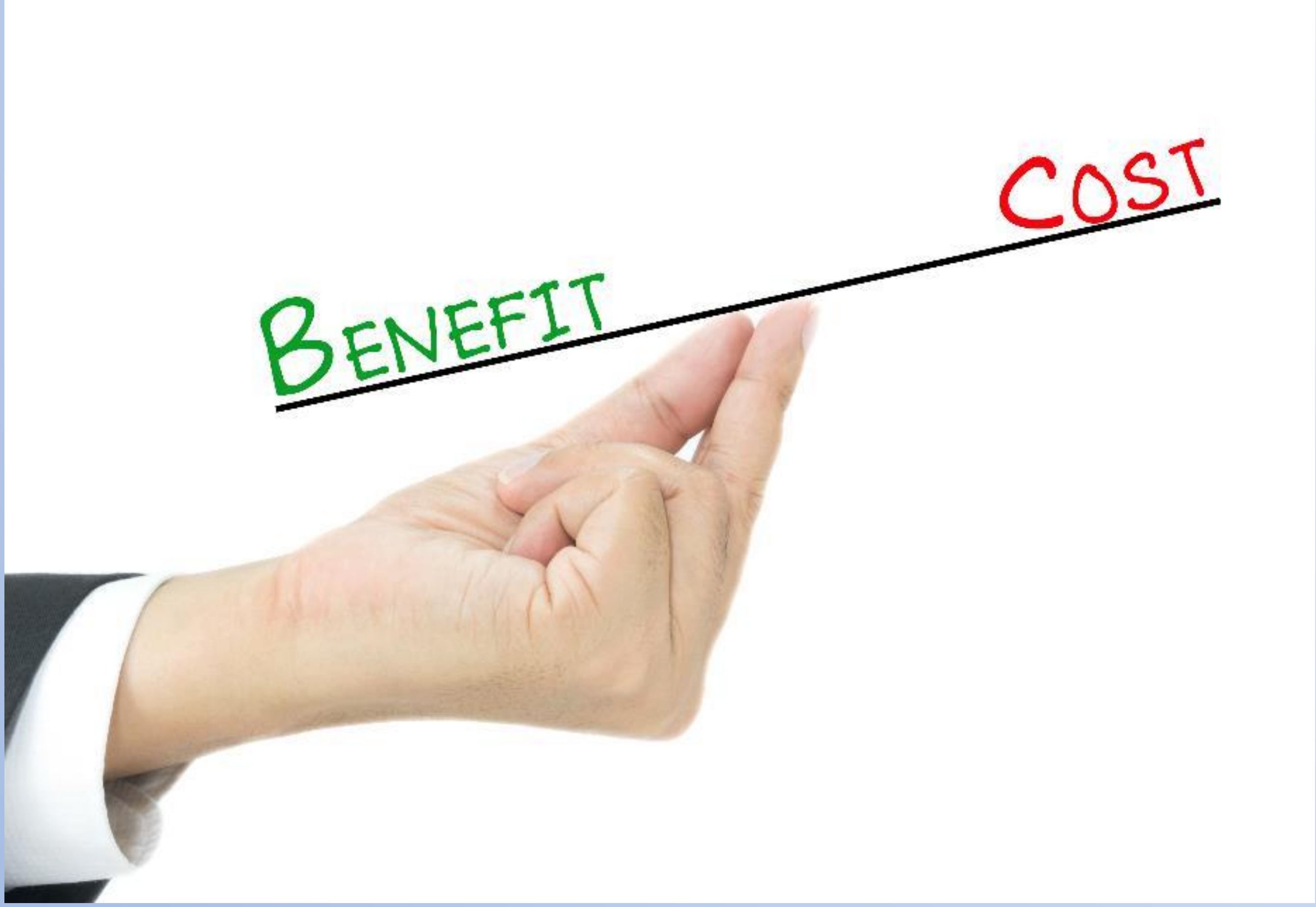
Oregon: EWEB Grid Edge Demo (Eugene)

- 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

Demonstration goals:

- transmission and distribution upgrade deferral
- peak demand management
- power quality
- voltage support
- grid regulation
- renewable energy firming
- ramp control
- energy shifting
- Provides resilient power to utility operations center, communications facility and water pumping station

Energy Storage Business Cases



The business case for storage depends on WHERE the batteries are located:

Front of the meter
(**utilities** can do this)

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

Behind the meter
(**Commercial customers** can do this)

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

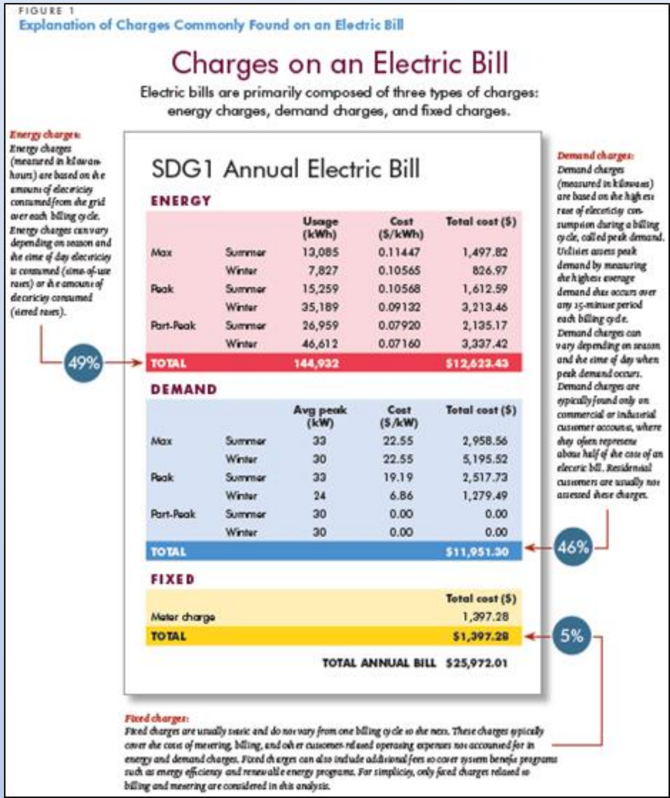


FIGURE 1
Explanation of Charges Commonly Found on an Electric Bill

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		$12,622.43

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 cost 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.

Utility case: 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	44.23	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

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

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

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:

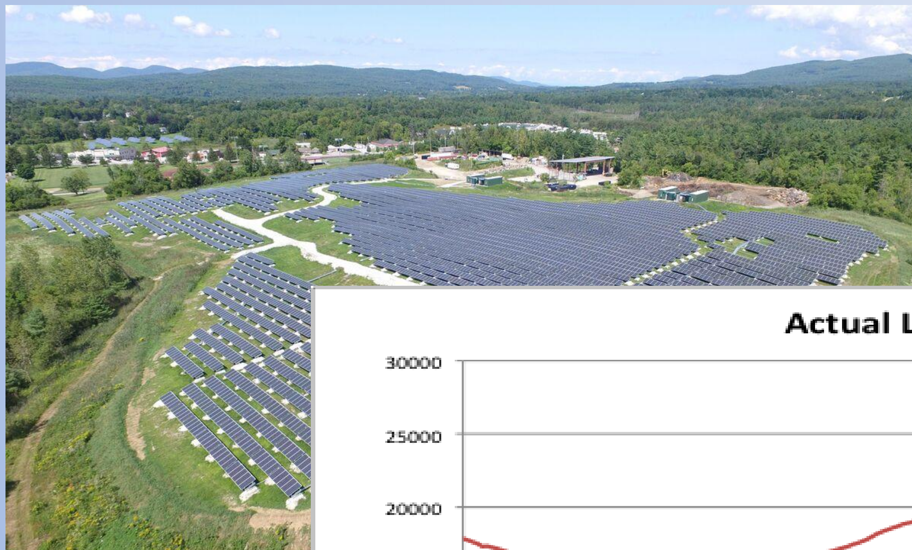
Description	Total	Percent
Arbitrage (transmission)	$40,738	16.0%
RNS payment (capacity)	$98,707	38.7%
FCM obligation*	$115,572	45.3%
Total	$255,017	100%

For a capital cost of ~1.7M, the simple payback is 6.67 years *without subsidies*

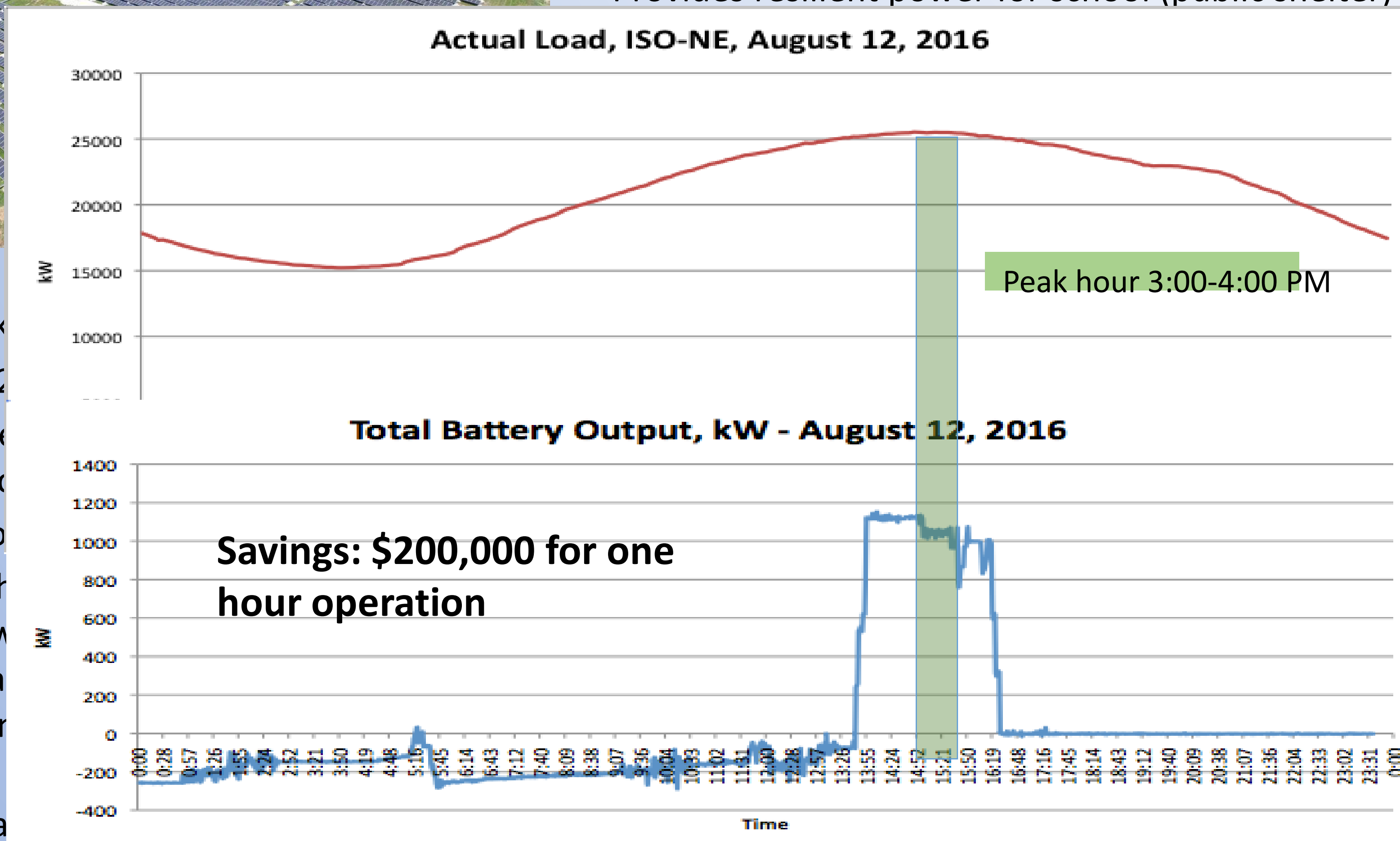
Resilience is *free*

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

Vermont: GMP Microgrid, Rutland (Stafford Hill)



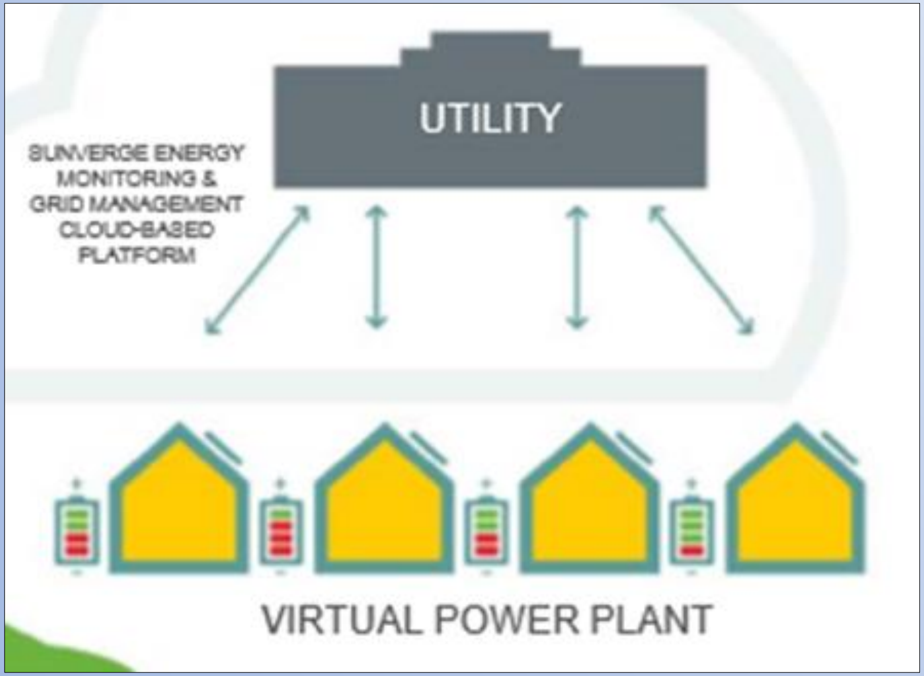
- 4 MW batteries (lithium ion and lead acid) + 2 MW PV microgrid
- Sited on closed landfill (brownfield redevelopment)
- Provides resilient power for school (public shelter)



- Funding: $40k
- Total cost: $12
- Payback < 7 ye transmission c
- Follow-on pro
  - 14 LMI high equipped w solar+stora replacemen
  - Burlington microgrid a

How can residential customers participate?
Solution: the Virtual Power Plant
Example: McKnight Lane project, Waltham, VT

The utility draws on batteries in McKnight Lane homes once or twice monthly to reduce peak demand; these savings reduce costs for ratepayers and help pay for the batteries



Utility gets cost savings

Tenants get clean backup power for free

McKnight Lane Redevelopment: A LMI Residential Solar + Storage Project in Rural Waltham, Vermont

- Redeveloped defunct trailer park
- 14 affordable rental units
- High efficiency, net-zero modular homes

- Each equipped with solar PV and a battery
- Can island 6+ hours in case of grid outage
- Lowers costs for utility ratepayers

Residential batteries are like any other home appliance

- Self-contained
- No tenant maintenance
- No emissions
- Works with solar to provide clean backup power during grid outages
- Provides energy savings year-round

Tenants get benefits at no added cost

Cost basis for adding energy storage to modular home

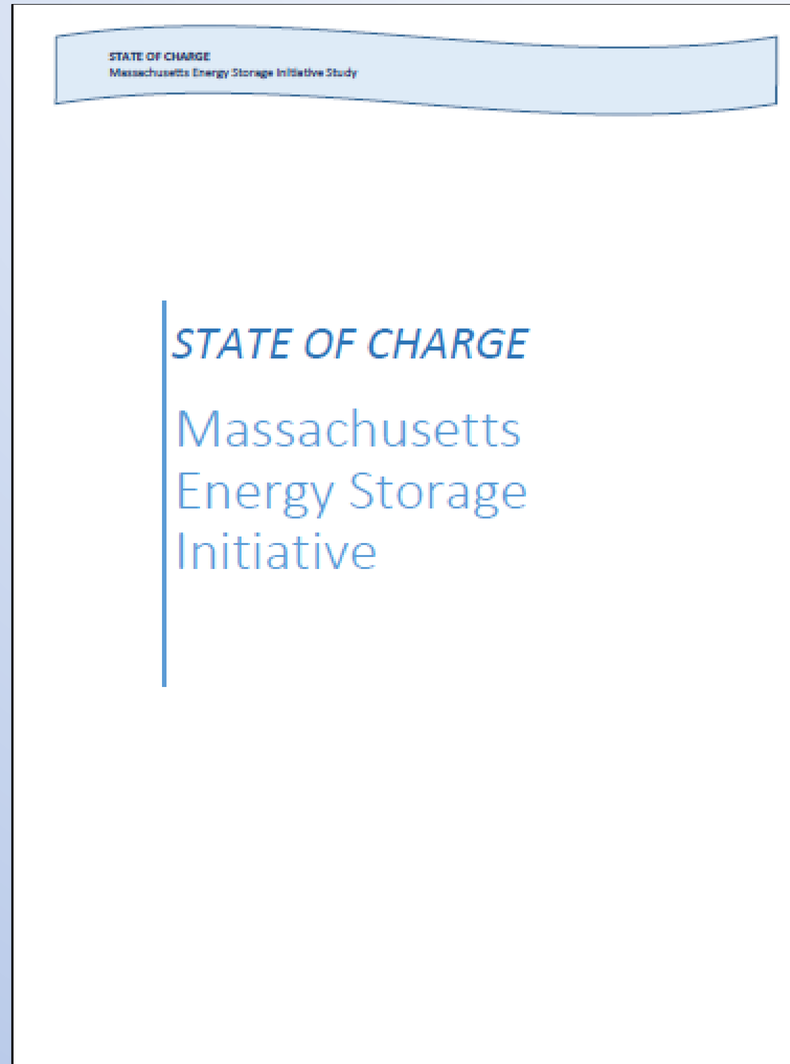
Product	List Price	Quantity	Total Price
Sonnen ECO 6	$ 11,950.00	11	$131,450.00
Installation	$ 1,600.00	11	$ 17,600.00
	Sonnen Discount	20%	$ (26,290.00)
	Solar Investment Tax Credit (ITC)	30%	$ (52,602.00)
	Accelerated Depreciation over 5yrs	25%	$ (39,435.00)
	Peak Savings over 10yrs		$35,354
	Total Cost Over 10yrs		$ (4,631.00)

Outlook for energy storage

- High and rising capacity and transmission costs
- Rising electricity prices, declining storage prices
- Rising fees, declining NEM rates for behind-the-meter solar PV
- Need for grid modernization
- Opportunities for cost savings:
  - Arbitrage
  - Frequency regulation and other ancillary services
  - Capacity and transmission savings
  - T&D savings

Massachusetts Energy Storage Report: State of Charge

- Optimization modeling results: 1,766 GW energy storage in MA by 2020
- Policy recommendations: 600 MW energy storage in MA by 2025



Massachusetts energy diversity legislation

- DOER directed to assess whether a utility storage mandate is appropriate, by December 2016; utilities would have to meet targets by 2020
- Distribution utilities may now own storage in MA

Policy Recommendations from MA State of Charge Report

1. $10 M ESI demonstration project grant funding (recommend increase to $20M)
2. $20 M rebate program for BTM C&I projects
3. $150 K grants for solar+storage site assessments at C&I (manufacturing) facilities
4. $14.2 M remaining CCERI grant funding (round 3) to focus on hospitals
5. $10 M/year Green Communities Competitive Grant Program (recommendation is to add storage as an eligible technology to this existing program. Cap is $10 M / year total expenditure)
6. $4.5 M demonstration project grants (over three years) for utility and market actors to test and demonstrate peak demand management.
7. Add storage to Alternative Portfolio Standard (currently only flywheels are eligible)
8. Include storage in new Next Gen Solar Incentive Program (replaces SREC II)
9. Clarify regulatory treatment of utility storage (IOUs revise grid mod plans)

Policy Recommendations from MA State of Charge Report

10. Support demand reduction demonstration programs using energy storage in the 2016-2018 Three-Year Energy Efficiency Investment Plan
11. Allow storage to be part of all future long-term energy procurements (requires statutory change)
12. Adopt safety and performance codes & standards for storage (probably with support from DOE and national labs)
13. Clarify and streamline interconnection requirements for storage
14. Education, sharing of use cases (with DOE/national lab support)
15. Facilitate sharing of utility customer load data and other info (such as transformer loading at substations) to allow storage developers to offer tailored products for specific customer classes (possibly in collaboration with a university or national lab that could serve as the data repository)

CEG proposal for Northeastern States Collaborative on Energy Storage Policy

- Northeastern states share similar markets (within ISO-NE)
- States can learn from the experience, lessons and analysis of Massachusetts
- States can share knowledge gained through their own experience
- States can collectively apply for DOE and foundation funding to support energy storage policy development
- States can collaborate on policies of regional importance
  - ISO regulatory reforms
  - Market development
  - Industry development
  - Utility interconnection issues

Thank You

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

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

Clean Energy States Alliance