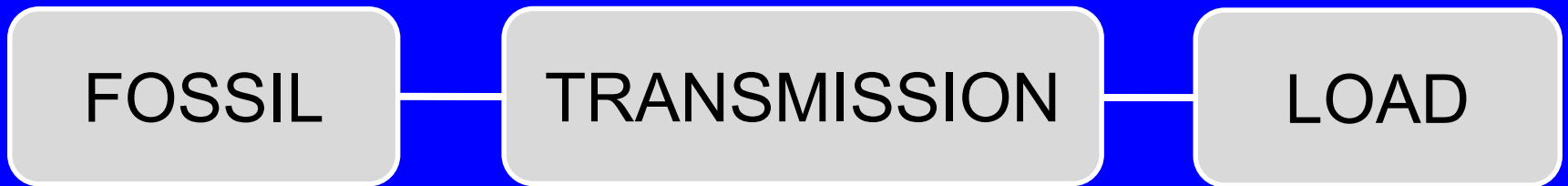


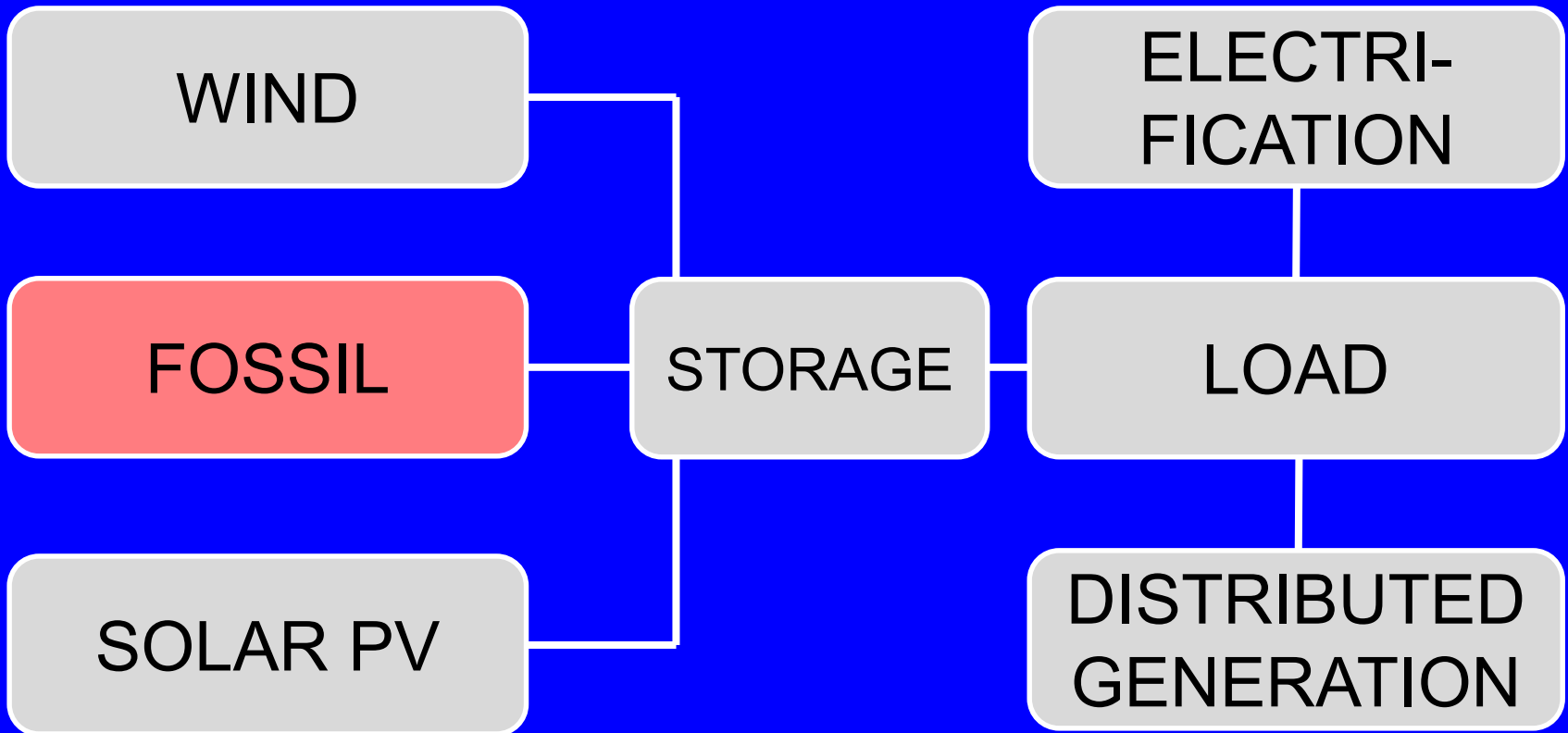
Energy Storage Transforming the Grid

IMRE GYUK, DIRECTOR,
ENERGY STORAGE RESEARCH, DOE-OE

The grid used to be Simple
and Deterministic!



Generation has become Variable - and so has the Load!



Storage is needed for reliable Resource Adequacy

Transmission provides Energy

where it is needed

But Energy Storage provides Energy

when it is needed

DOE - Office of Electricity Energy Storage Program:

Broad Range of R&D, Deployment, and Analysis Efforts
Materials – Devices – Systems – Analysis – Standards – Policy

Teaming with Sandia, PNNL, ORNL, Argonne
to work with Industry, States, and Utilities.

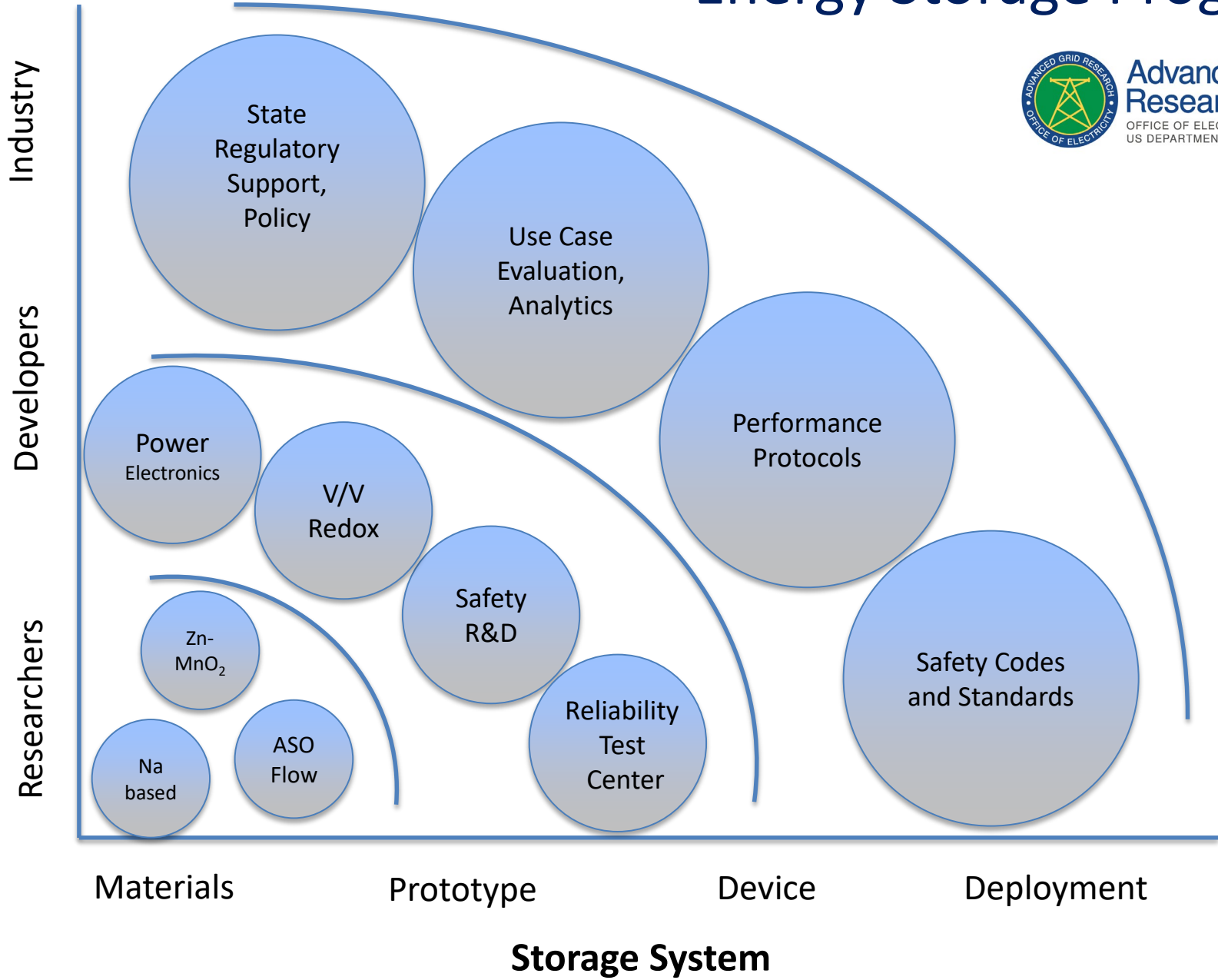
10 R&D 100 Awards, 2 EPA Green Chemistry Awards

Energy Storage Program



Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Stakeholder Engagement



Materials

Prototype

Device

Deployment

Storage System

- Build a Community
- Develop Technology
- Encourage Industry

Metlakatla, AK: Island System with Hydro

Hydro: 4.9 MW *Due to frequent brownouts:*
Load following Diesel: 3.3 MW

Increasing fuel costs (\$400K/yr) prompted GNB/GE/DOE-Sandia study

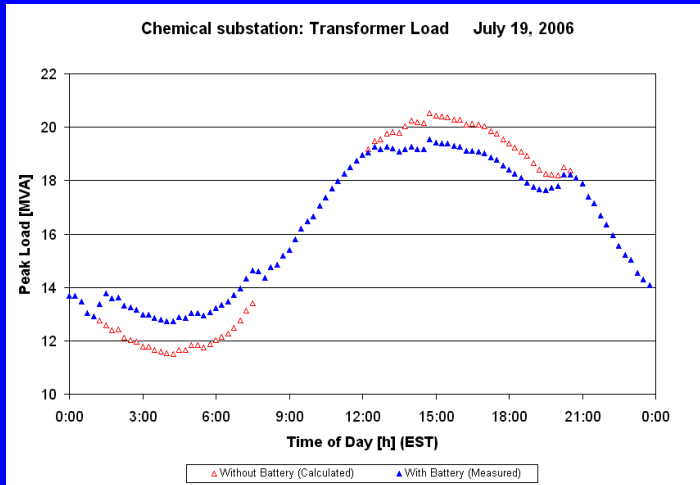
Retrofit L/A Storage: 1.0 MW (GNB, Exide)

Operating Costs \$K	w/o BESS	with BESS
Fuel Oil	4,864	184
Island Delivery	2,039	78
Diesel Maintenance	1,100	400
Replacement	N/A	682
Diesel Operation during Maintenance	N/A	21
Total 1997-2008	8,003	1,364



1MW / 1.4MWh Feb. 1997

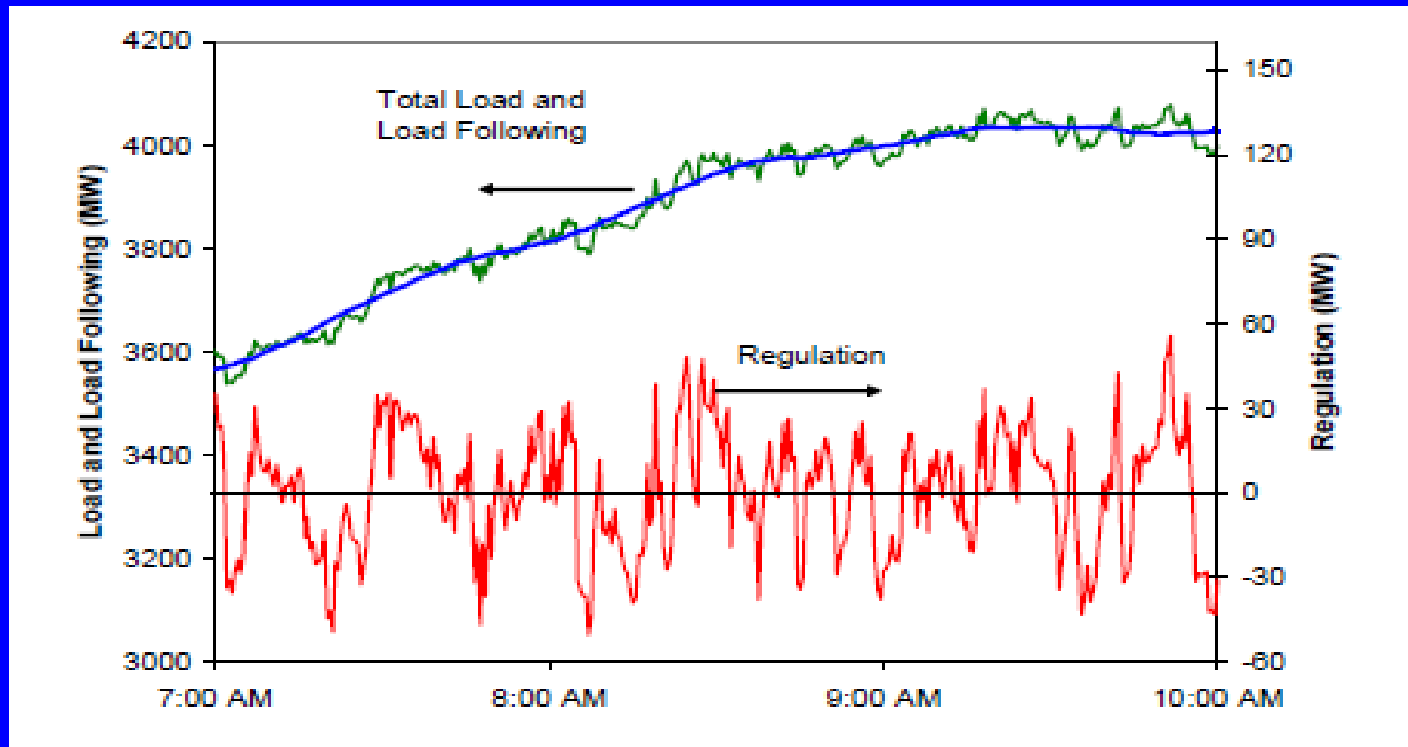
Storage for Substation Upgrade Deferral



AEP / DOE Project, Indiana
2MW, 14.4 MWh NaS

- Demand Charge Reduction
- Renewable Energy Management
- Aggregated Community Storage

Frequency Regulation



Old solution: Fossil fuel generator keeps 5-10% reserve – gets paid for capacity. Response time > duration of fluctuation.

Frequency Regulation



- **NYSERDA / DOE PROJECT:**
- **CEC / DOE PROJECT:**

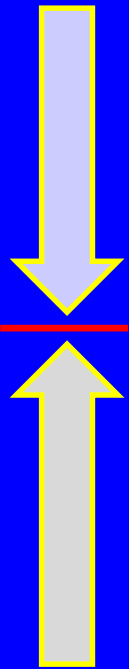
Beacon Power 100 kW Installation
2 Flywheel Systems in CA and NY

DOE Loan Guarantee
20MW Flywheel Storage for
Frequency Regulation in NY-ISO
Commissioned July 2011



► This project provided the basis for FERC
to establish “PAY FOR PERFORMANCE”!

Designing a Business Case:



The **Cost** of a Storage System depends on the Storage Device, the Power Electronics, and the Balance of Plant

The **Value** of a Storage System depends on Multiple Benefit Streams, both monetized and unmonetized

Metrics will depend on locality!

Power Electronics
20-25%

Energy Storage Device
25-50%

Facility 20-25%

Arbitrage

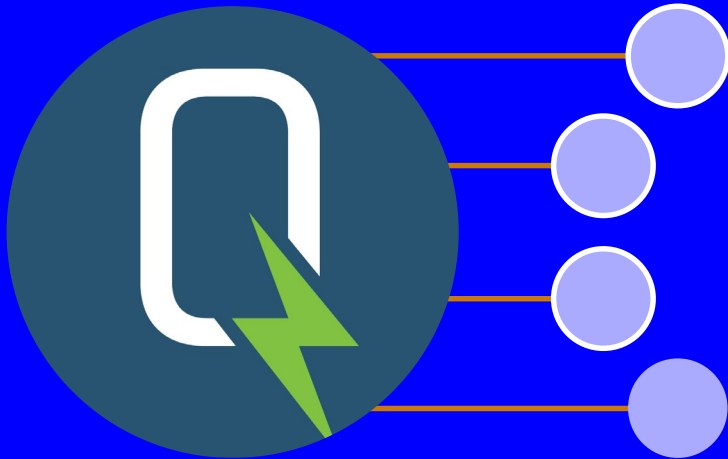
Frequ. Reg.

Dem. Charges
month, year

Resiliency

**Building and Validating
Business Cases:
Resilience, Sustainability,
Grid Stability**

QuEST a Tool for Valuation– Sandia/DOE (Deregulated Utilities)



- QuEST: An open source Python tool for Energy Storage evaluation
- QuEST Valuation: Stacking services in an electricity market
- QuEST BTM: Bill reduction for time-of-use/net metering customers
- QuEST: Data Manager: Data Acquisition

Sandia.gov/ess-ssl/tools/quest

[PNNL: availabletechnologies.pnnl.gov/technology.asp?id=413](http://PNNL:availabletechnologies.pnnl.gov/technology.asp?id=413)

Sterling, MA: Microgrid/Storage Project

Sterling Municipal Light Department.

\$1.5M Grant from MA Community Clean Energy Resiliency Initiative (Dept. of Energy Resources). Further Funding from DOE/Sandia.

2MW/2hr storage with existing 3.4 MW PV to provide **resiliency** for Police HQ and Dispatch Center. Li-ion batteries provided by NEC.



Sterling, MA, October 2016



Sterling, MA, December 2016

2016 Dec. till 2017 Nov.
Actual Savings:

- Arbitrage \$11,731
- Monthly Peaks \$143,447
- Annual Peak \$240,660
- Total \$395,839



Sean Hamilton

Chart: Carina Kaainoa

April 2019: 1 million Avoided Cost!

Visitors: Germany, Switzerland, Denmark, Sweden, England, Ireland, Australia, Japan, Malaysia, Taiwan, Brazil, Chile, Thailand

Cordova, Alaska, Municipal System



Cordova, Grid Isolated



6MW Run of River Hydro Power

Total Generating Capacity:

6MW + 1.25MW Hydro; 2x 1MW Diesel

0.5MW Deflected as Spinning Reserve

Hydro: \$0.06/kW; Diesel: \$0.60/kW



Ribbon Cutting with Sen. Murkowski



1 MW / 1 hr Li-ion Storage

Commissioned June 7, 2019

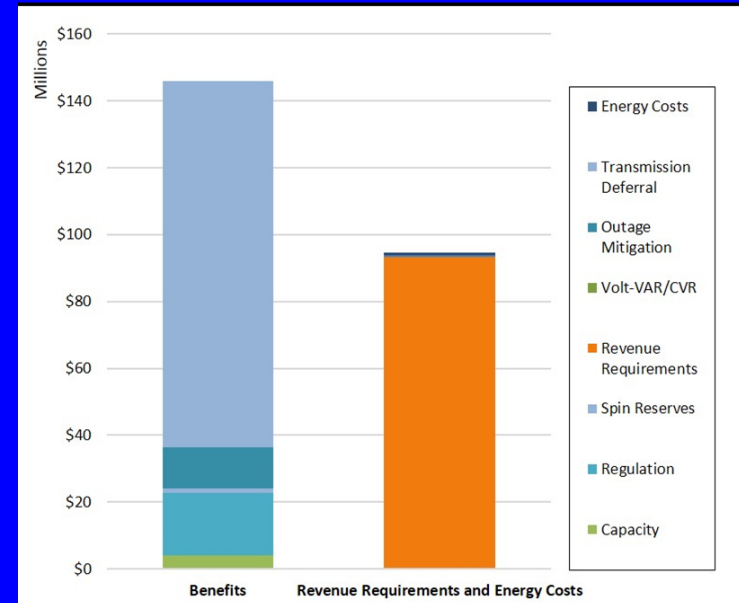
- Frequency Regulation
- Load following
- Emergency Supply

Thanksgiving, Nov. 2019
2 days: 4hrs diesel vs. 48 hrs
\$10,000 in savings

Nantucket – National Grid, Tesla, PNNL/DOE



71 MW Submarine Cables



Analytics: Balducci et al. PNNL

\$110 million Deferral Value + \$36 million Operational Benefits

Installation: 6MW/8hr Storage + 6-10 MW Generator to yield required 91MW Peaking Capacity



PNNL evaluated technical and financial benefits of energy storage:

- Financial benefits of ES
- Technical impact on distribution system
- Control strategies to maximize financial benefits while achieving resiliency goals.

Ribbon Cutting: Oct. 8, 2019. Return on Investment: 1.55

In addition to transmission deferral, other potential economic benefits could include:

- ISO-NE demand response program participation
- ISO-NE ancillary service markets
- ISO-NE forward capacity and reserve markets
- Energy arbitrage, Outage mitigation



Decorah, IA: Peak Shifting, Distribution Upgrade Deferral

Alliant Energy / DOE-OE, Sandia.

\$200K Grant from Iowa Economic Dev. Authority (IEDA),
and \$250K from DOE-OE, for a Total Cost of \$2,500k

3.3MW installed Renewables already on Circuit
2.5MW/2.9MWh storage will allow installation of 900kW new PV.



Li-ion batteries by ENEL-X

Atrisco Heritage Academy, Albuquerque, NM

Energy Storage for Social Equity

85% Hispanic,

Eliminate peak demand
during occupied hours

Battery: 721 kW/4hr = 2884 kWh
plus roof-mounted PV = 850 kW

Total cost with PV: **\$3.1 M**
DOE cost share: \$250,000

Contract awarded – May 2021
BESS ground work – 1/22 – 2/22
Commissioning – May 2022 ?

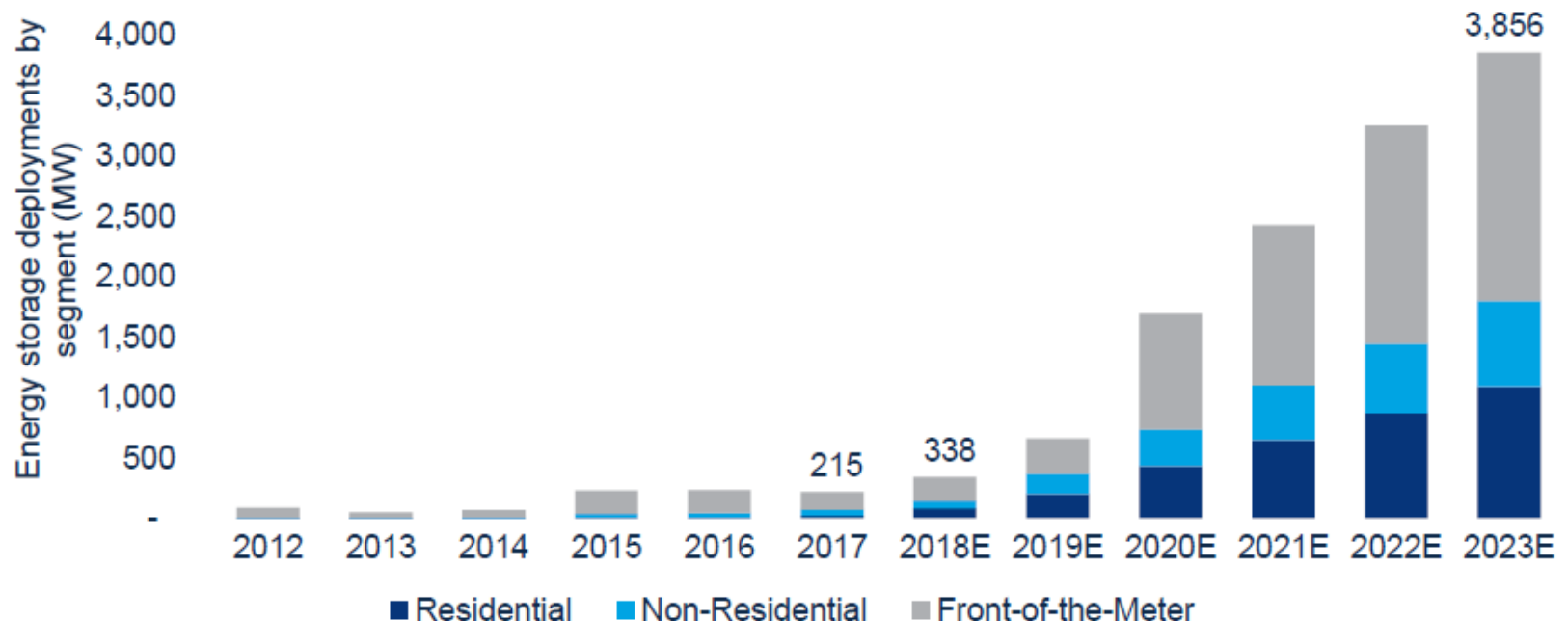


Energy Storage has become a Resounding Success!

U.S. energy storage annual deployments will reach 3.9 GW by 2023

Utility procurements, changing tariffs and grid service opportunities all drive the market forward

U.S. energy storage annual deployment forecast, 2012-2023E (MW)



Many Applications have been identified,
Valuation Models have been developed.
Business Cases with multiple
Benefit Streams have been established.

Global Energy Storage Data Base
at Sandia.gov/ess

Emergence of Storage Ecologies

California: Mandate, CEC, PUC, Utilities, LBL

New York: BEST, NYSERDA, CCNY

Northwest (WA, OR, AK): PNNL, WA Clean Energy, PUCs, Senate

Southwest (NM, AZ): Sandia, Congressional/State Support,

Northeast (MA, VT): DOER, National Grid, GMP, Universities

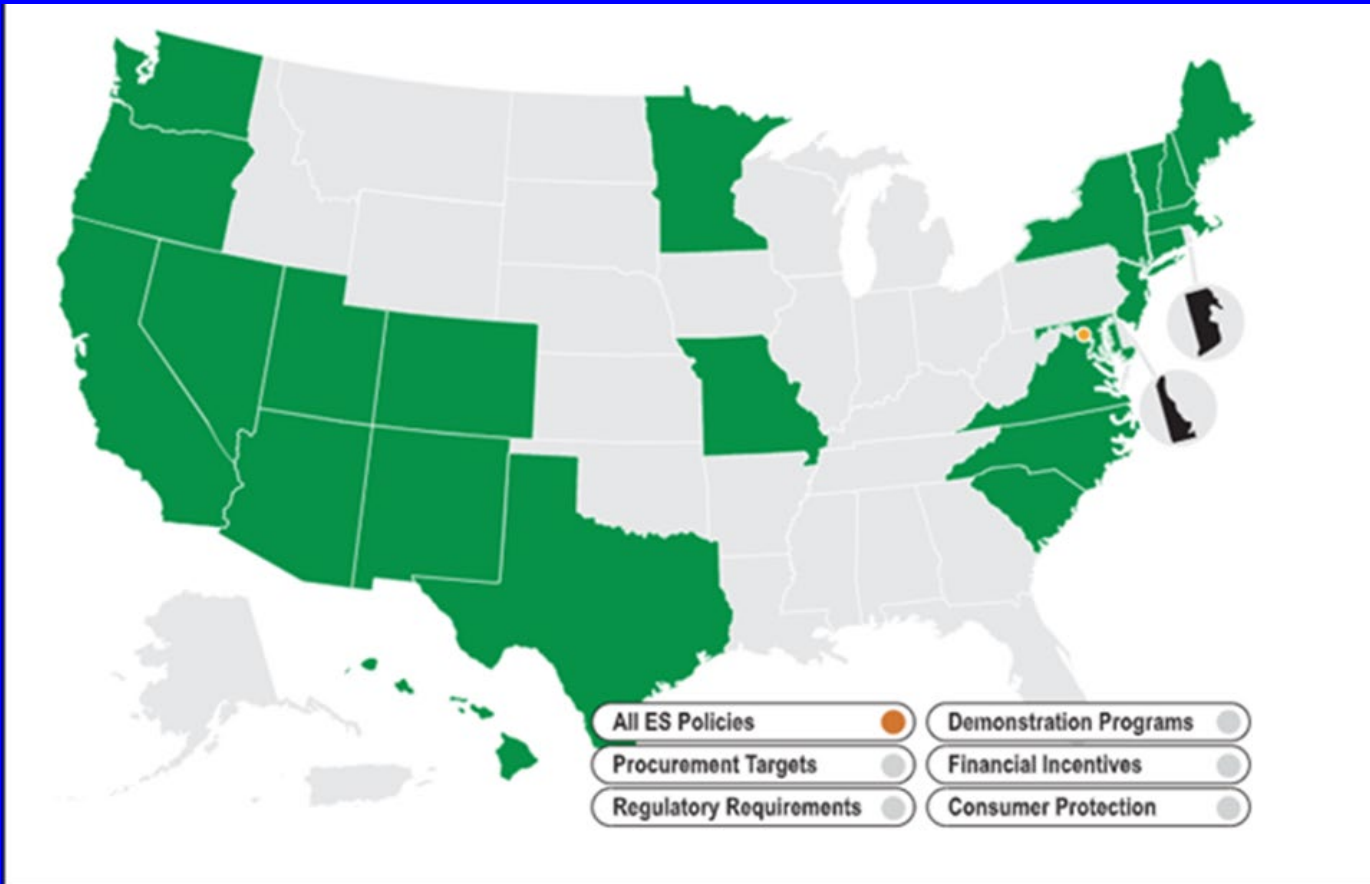


Congressional and State Support, Regulatory Structure,
National Laboratories, Universities, Utilities, Real Projects

Recent Workshops/Tutorials:

- Utah Governor's OED, (July – Aug.)
- Iowa State University /MISO, (July – Oct.)
- FERC, (Sept.)
- New Mexico PUC, (Nov. – Dec.)
- New Jersey BPU (Dec. – March)
- NECPUC (March – May)
- Wisconsin PSC (April)
- Microgrids FEMA (Sep.)
- Illinois Com. Commission (Nov)

From ES Policy Data Base



<https://energystorage.pnnl.gov/regulatoryactivities.asp>

But while the Transmission Grid
Spans the Continent
Storage only covers
rather Modest Durations

15 min -- 1hr – 4hrs

e.g. 2020 Q3: 476 MW / 764MWh
1 ½ hours!

As Penetration of Renewable Generation
Continues to increase,
Incremental Solutions
will no longer be sufficient

Longer Duration Storage
is urgently required!

8 Hours – 12 Hours – Days – Seasons

Storage of Various Durations will be Needed: Short, Medium, and Long

15 min – 4 hrs: smoothing renewables. Li-ion

4 – 12 hrs: day/night PV storage. Flow Batteries

12h – 3 days: bad weather backup. Thermal/Gravity

**We will need some 1200-2300 GWh
of Energy Storage!**

Storage started with Niche Applications,
has developed into a Utility Tool,
and will be a Vital Necessity in the Future!

Now and in Future
Energy Storage
Should be in the Toolbox
of every Utility