Towards the Future: Energy Storage for Deep Decarbonization

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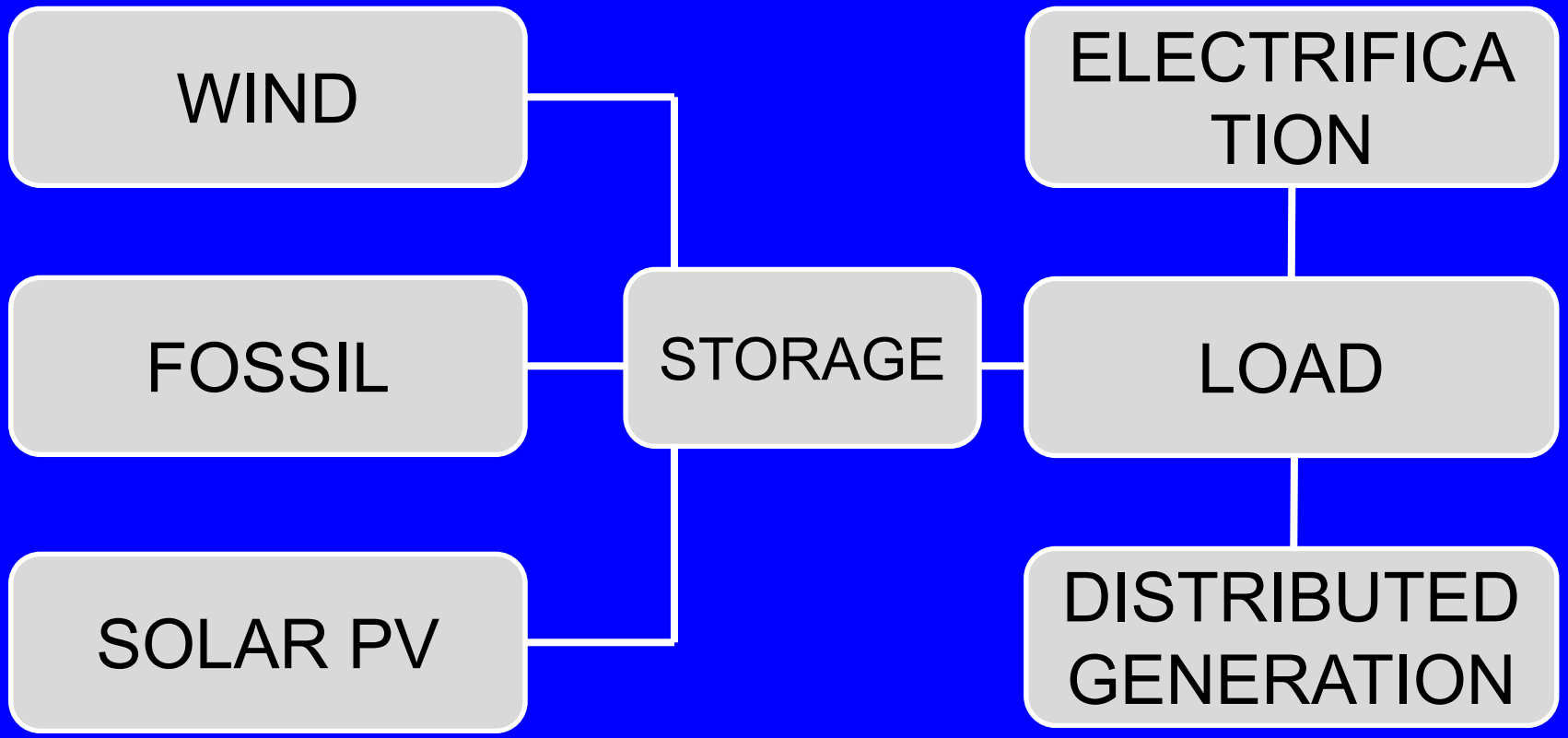
The World at Night
Light – Electricity - Commerce

One Billion People lack Access!

The grid used to be Simple and Deterministic!

The grid has become stochastic!



Energy Storage provides Energy

when it is needed

just as Transmission provides Energy

where it is needed

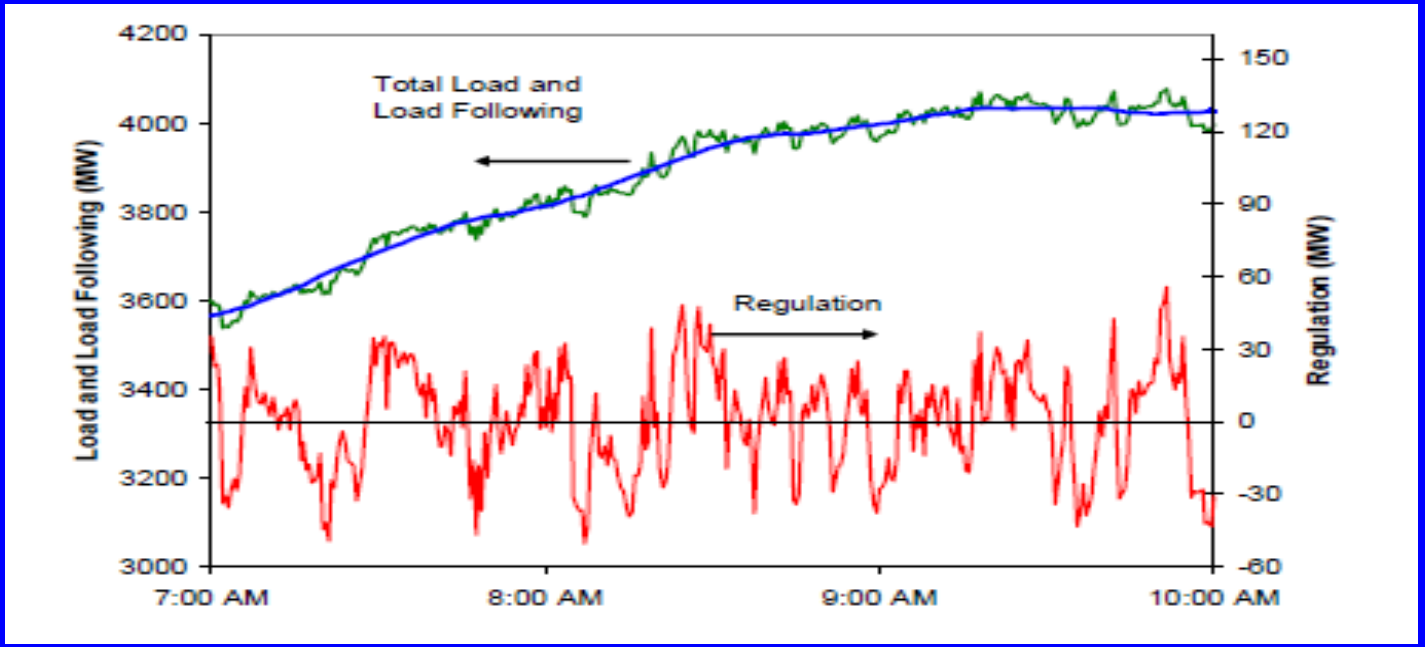
Two Decades
DOE - Office of Electricity
Energy Storage Program

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

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

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

Frequency Regulation



Old solution: Fossil fuel generator keeps 5-10% reserve – gets paid for capacity. Response time > duration of fluctuation.
New solution: Storage responds instantaneously
Gets paid for actual performance

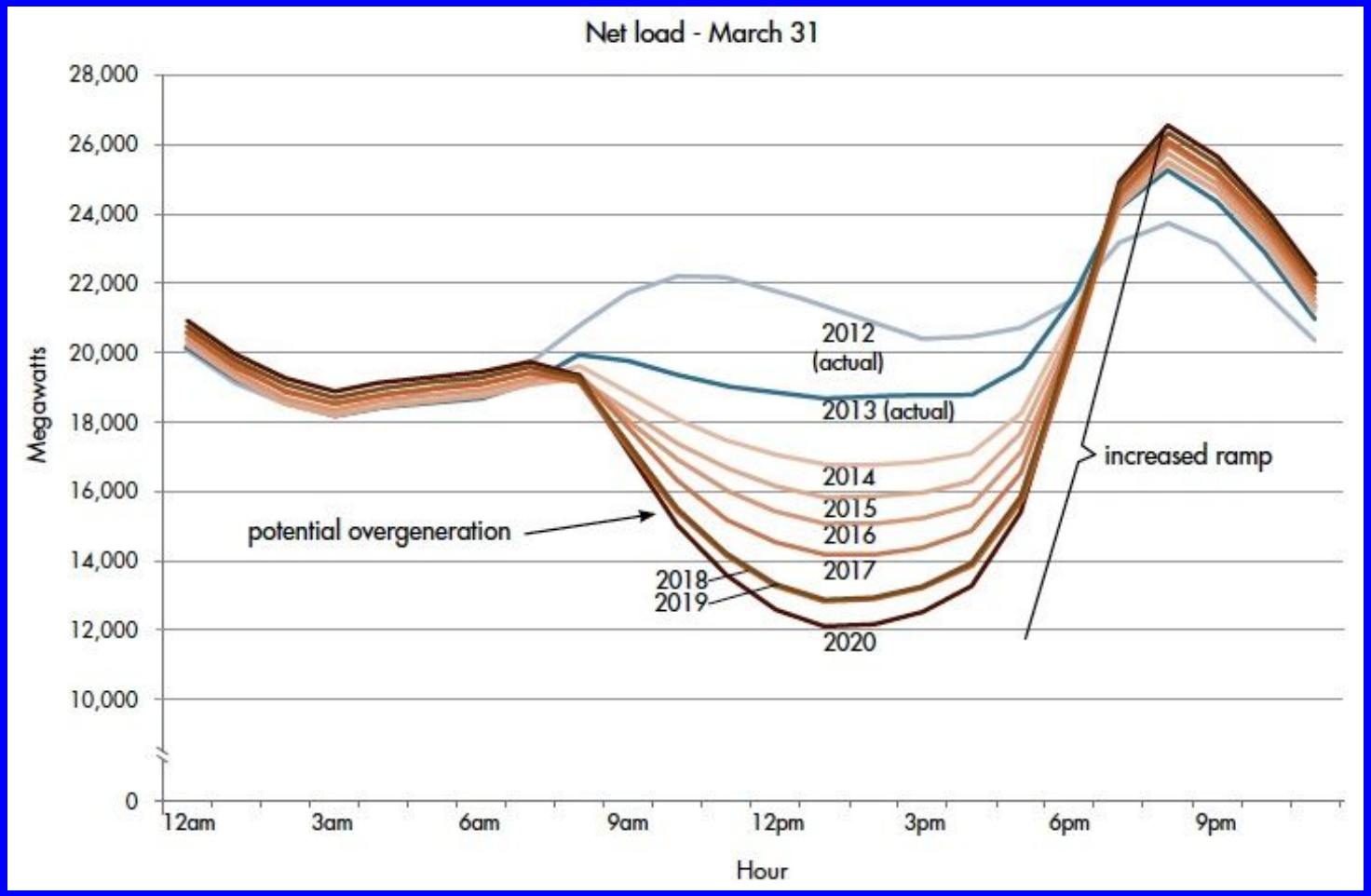
Frequency Regulation

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

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

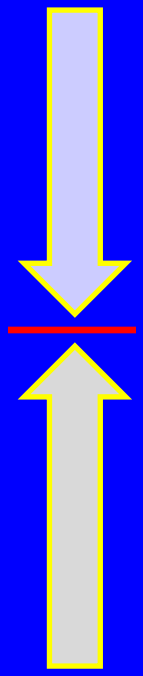
20MW Flywheel Storage for
Frequency Regulation in NY-ISO
Commissioned July 2011

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



As PV increases Net Load decreases and Ramps get steeper:
Storage is required - about 2 hours → CA Mandate, 1.325GW

Designing a Business Case:



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

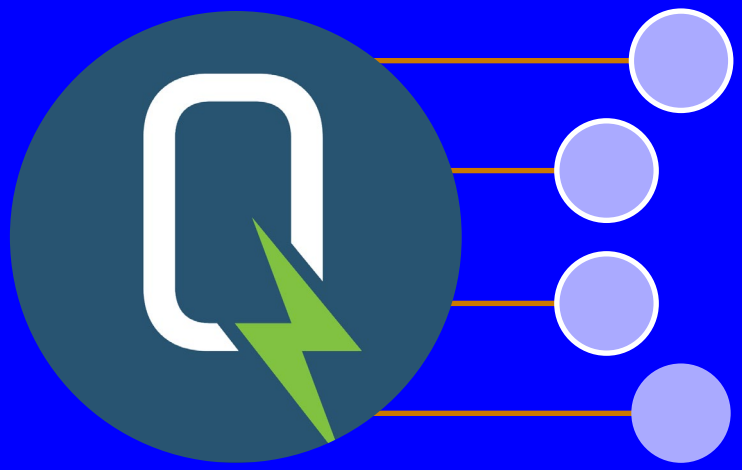
The **Value** of a Storage System depends on Multiple Benefit Streams, both monetized and unmonetized

Metrics will depend crucially on Regulatory Structure and Locality!

- Power Electronics 20-25%
- Energy Storage Device 25-50%
- Facility 20-25%

- Arbitrage
- Frequ. Reg.
- Dem. Charges month, year
- Resiliency

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

Sterling, MA: Microgrid/Storage

$1.5M Grant from MA. Additional DOE Funding, Sandia Analytics

Sterling, MA, Oct. 2016, NEC, Li-Ion

Dec. 2016, 2MW/2hr Storage, 3MW PV

2016 Dec. till **2017** Nov.
Actual Savings:

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

Sean Hamilton

Carina Kaainoa

Capital Cost: $2.7M

April 2019: 1 million $ Avoided Cost!

Cordova, Alaska, Municipal System

Cordoba, Grid Isolated

6MW Run of RiverHydro Power

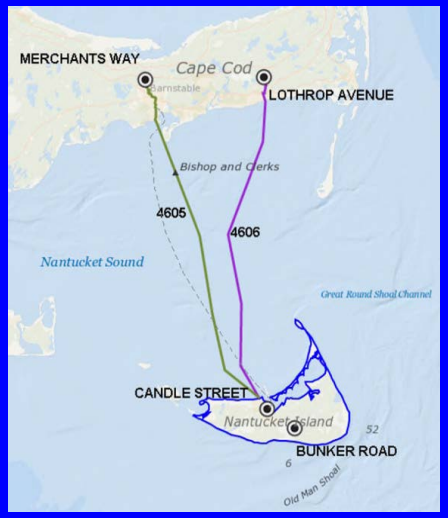
Total Capacity: 7.25MW Hydro; 2x 1MW Diesel

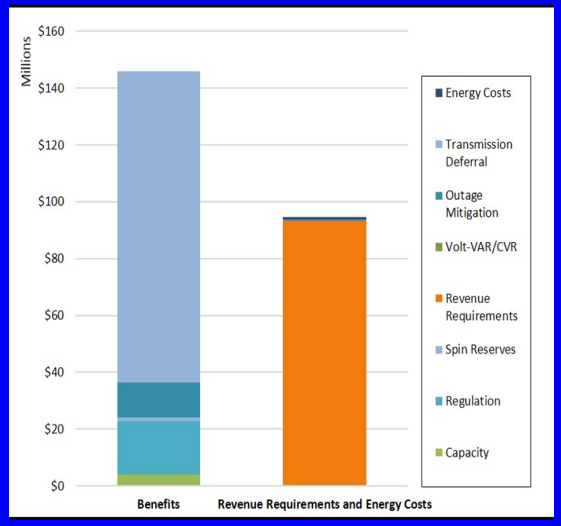
0.5MW Deflected as Spinning Reserve

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

1MW/1hour Battery, Commissioned June 7, 2019

Nantucket Island, MA
National Grid, PNNL/DOE, Tesla





71 MW Submarine Cables Analytics: Balducci et al. PNNL Storage: Tesla

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

Ribbon Cutting: Oct. 8, 2019. Return on Investment: 1.55
$110 million Deferral Value + $36 million Operational Benefits

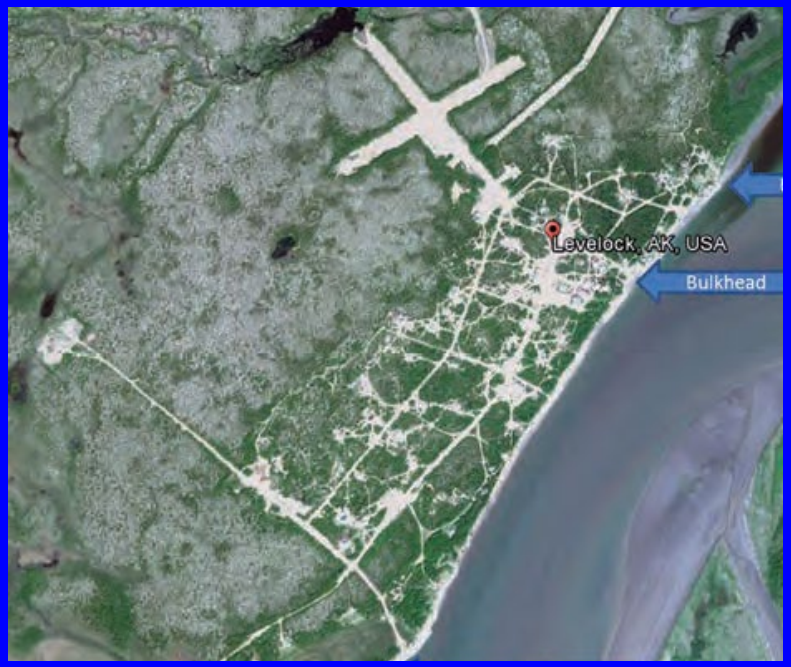
Levelock, AK

Pop. 69

On the Kvichak River

Proposed microgrid,

British American Energy

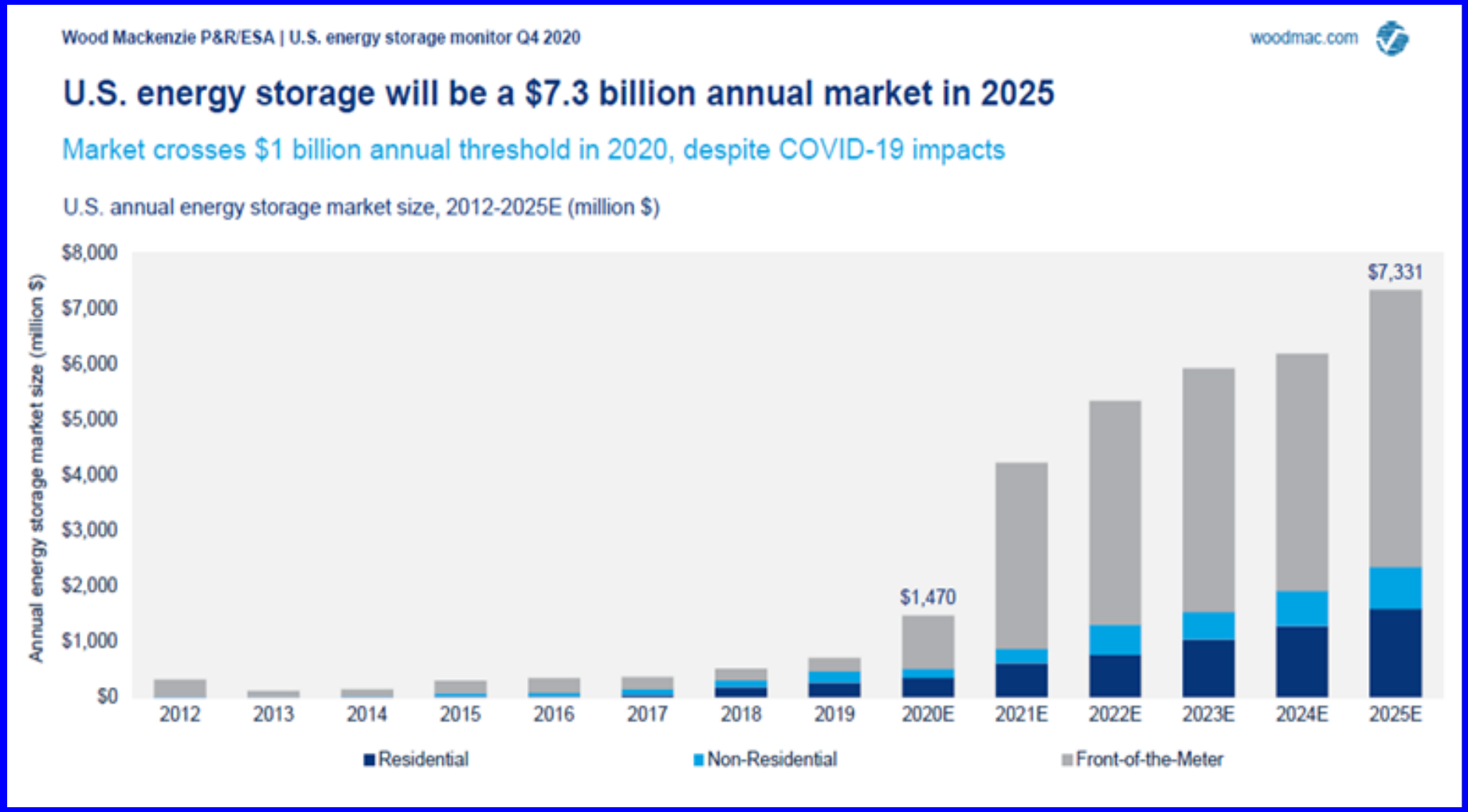


- **Pre-microgrid baseline analysis – install meters on 3 diesels and analyze load profile, fuel usage, resiliency**
- **Post-installation – Analyze battery performance, fuel usage, load profile, heat output, cost of operation and resiliency over the course of a year**

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

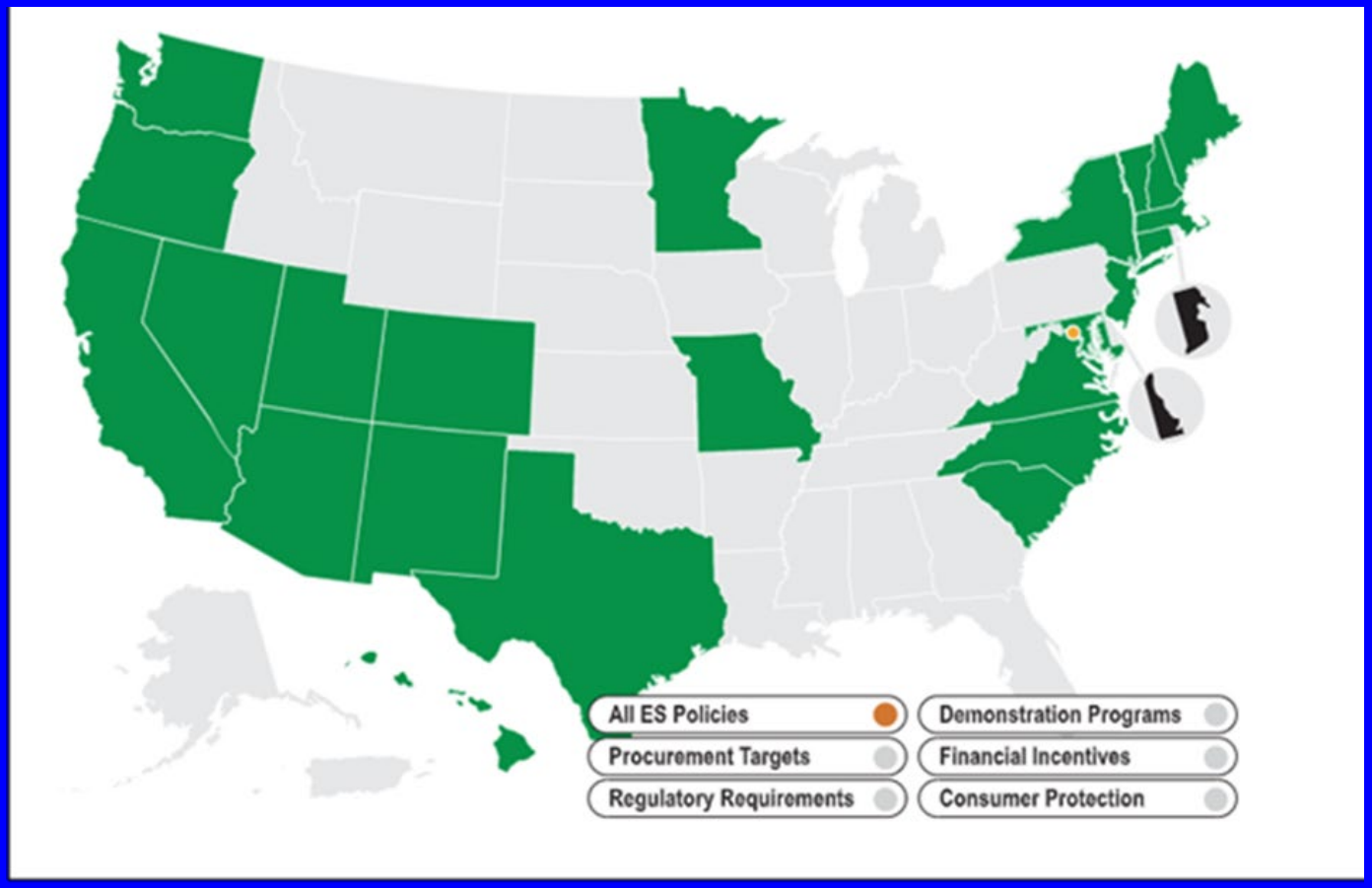
Global Energy Storage Data Base
at Sandia.gov/ess

Energy Storage has become a Resounding Success!



Despite Covid, 2020 has seen extraordinary growth of ES

From ES Policy Data Base



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

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

Incumbent Lithium Ion Technology:

Sourcing, Ecological, and Sociological Issues

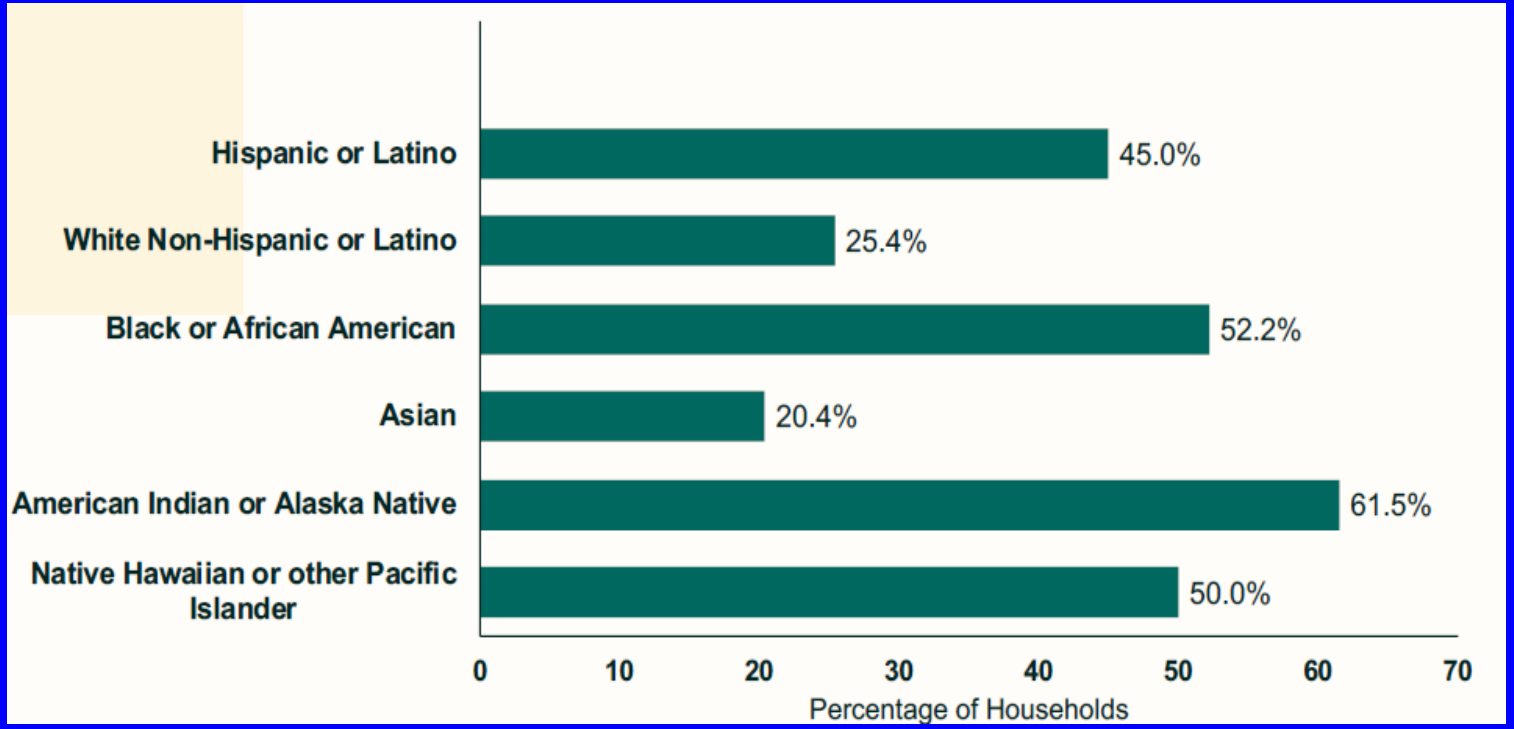
Safety, Reliability,

Re-Use, Recycling, Disposal

To achieve real Sustainability
we would Ultimately like
to have a Circular Technology
Based on
Earth Abundant and Inexpensive
Materials!

Supply Chain and Waste Stream
Must be part of the design!

Households Experiencing Energy Insecurity (2015)



S. Baker/Yale

Lower income households are disproportionally non-white
Storage can help with Social Equity!
DOE has Initiative to develop Metrics and Projects

Towards Long Duration:

For many States in the U.S. 2050 has become common as a Planning Horizon for 100% Renewables and Deep Decarbonization

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

Cost Goals for Focus Technologies

Manufactured at scale

Li-ion Batteries (cells)	$100/kWh
V/V Flow Batteries (stack+PE)	$300/kWh
Zinc Manganese Oxide (Zn-MnO_2) 2 Electron System	$ 50/kWh
Low Temperature Na / Na-ion based Batteries	$ 60/kWh
Aqueous Soluble Organic (ASO) Redox Flow Batteries (stack+PE)	$125/kWh
Advanced Lead Acid	$ 35/kWh

On the Horizon:

"Better" Lithium, Solid State / Non-Lithium Technologies:
Vanadium Redox, Zinc-Bromine, Zinc-Manganese,
Iron-Chlorine (ESS), Ambri, Sodium (NGK), Lead

Vehicle to Grid – Fleets: School bus. Postal, Military

Thermal Storage in Buidings. Demand Management

Non-Battery Technologies:
Cement Blocks, Rail Systems, CAES, Pumped Hydro
Thermal Systems (Ice, PCMs, Aesthus, Malta, Liquid Air)

Chemical Systems: Hydrogen, Ammonia, etc.

But what
is the Business Case??

We need to develop new metrics
and new models that allow inclusion
of Social Equity and Environmental Values
in the operation of Utilities and in
Statewide Integrated Resource Planning

We need to use Systems Dynamics,
Showing how Factors Interact
and Evolve through time.

How do we get from Here to There??

- It will take everything we've got!

We need to take care
of the Environment
but we must also
take care of each other!

But the goal is clear:

100% Decarbonization
by 2050

Around the Entire World!