STATE OF RHODE ISLAND
OFFICE OF ENERGY RESOURCES

OER & Energy Storage

Docket 5000

1/26/23

OER Storage Work to Date

- Designed and Implemented an energy storage adder to the Renewable Energy Fund solar programs
- Updated the OER website with information about general energy storage information
  - http://www.energy.ri.gov/renewable-energy/energy-storage/
- Provided presentations about energy storage to:
  - EERMC – May 2019
  - DG Board – November 2020
  - Panel Presentation to the RI League of Cities and Towns on "Battery Energy Storage: Information for Planners and Decision Makers" – February 2020
- Worked with Pacific Northwest National Lab on battery energy storage safety resources
- In 2021, OER held a contest for developers to provide photos of energy storage projects for use in publications and marketing materials. Will do again in 2023.
- Provide updates to the industry during Solar Stakeholder meetings about the REF and Connected Solutions battery programs.
- Collect metrics and create reports on energy storage projects using RIE and REF program data
- Provide inspections for REG/REF PV+storage projects

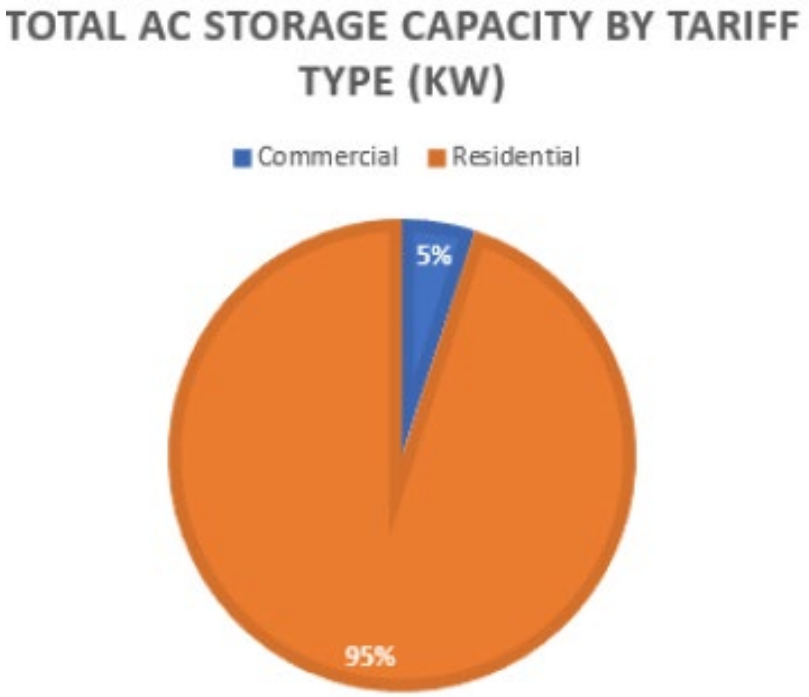
Interconnected Energy Storage Projects

RI Energy Q3 2022 Energy Storage Report (Through September 30, 2022)

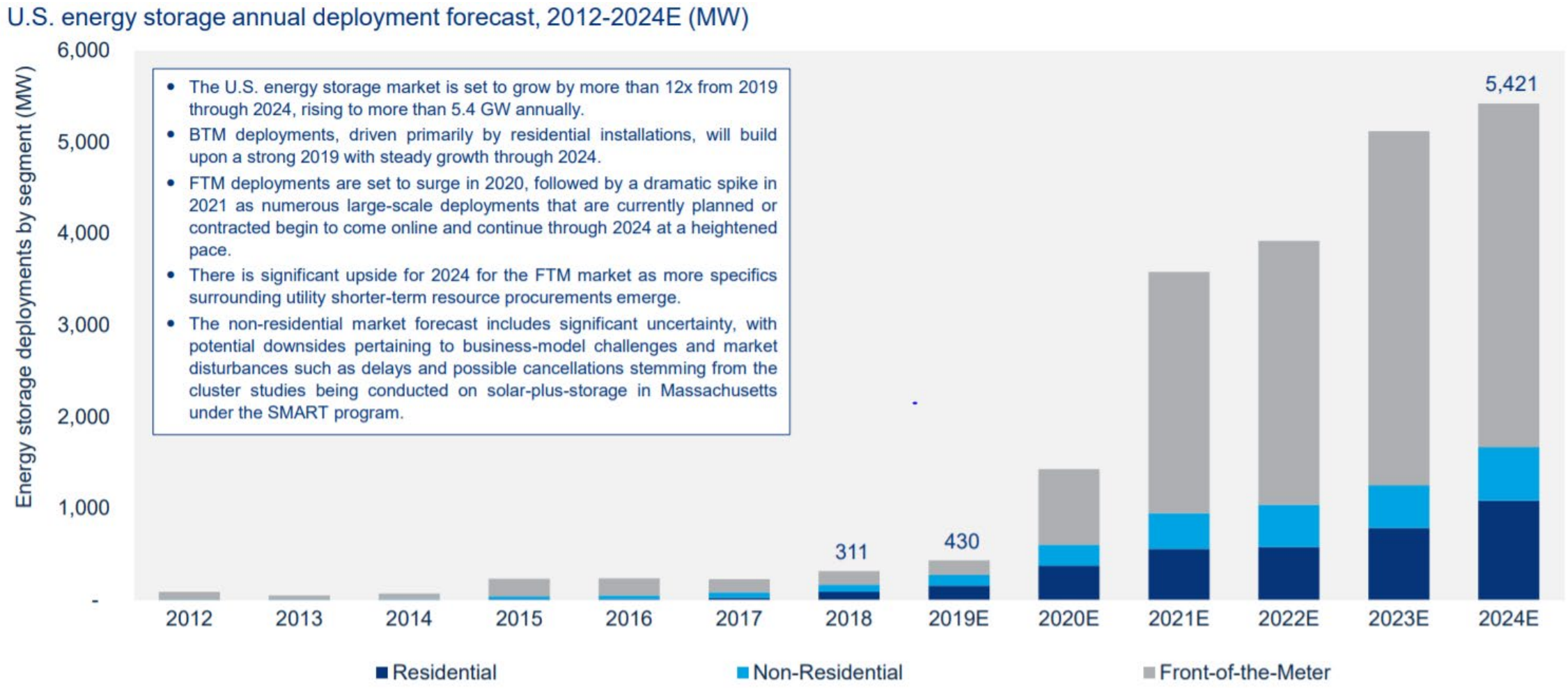
Table 1: Interconnected Storage Projects by Tariff Type

Tariff Type	Total Projects	Total AC Storage Capacity (kW)	Average AC Storage Capacity (kW)	Sum of Total AC Storage Capacity (kWh)	Average of Total AC Storage Capacity (kWh)
Commercial	3	224	74.67	1405.50	468.50
Residential	554	4223.86	7.62	7870.46	14.26
Grand Total	557	4447.86	7.99	9275.96	16.71

Note: This table includes the 557 energy storage projects that are interconnected, and does not include projects in the pipeline or interconnection queue. "Residential" tariff type includes both A-60 and A-16. Data from August 2013 Through September 2022. "Tariff Type" indicates how the property is zoned.



Installation Trends

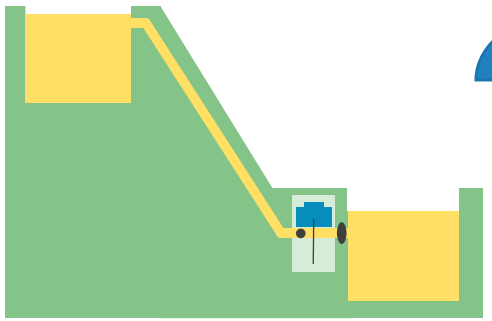


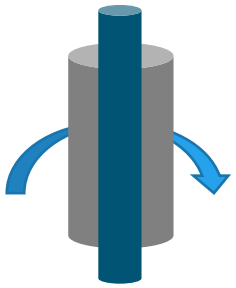
Source: Wood Mackenzie Power & Renewables, U.S. Energy Storage Monitor Q4 2019

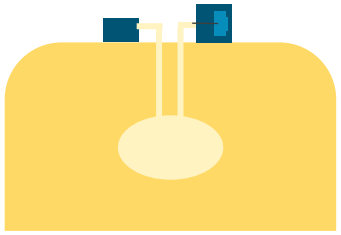
Types of Energy Storage Systems

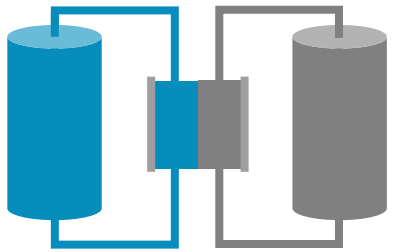
Energy Storage Systems

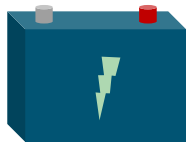
- Mechanical Energy Storage
  (something spins a generator)
  - Pumped Hydro
  - Flywheels
  - Compressed Air
- Thermal Energy Storage
  (store heat or ice)
- Electrochemical Energy Storage
  (chemical energy turns into electricity)
  - Batteries
    - Flow
    - Solid State



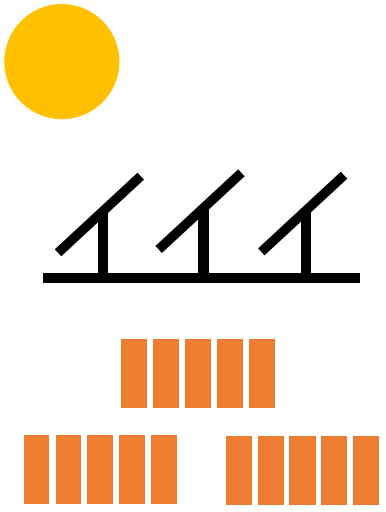




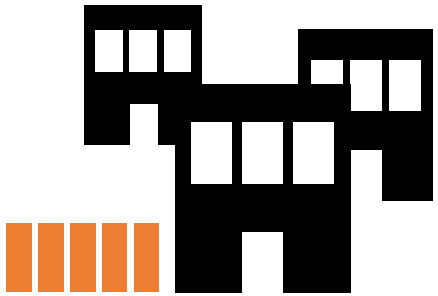




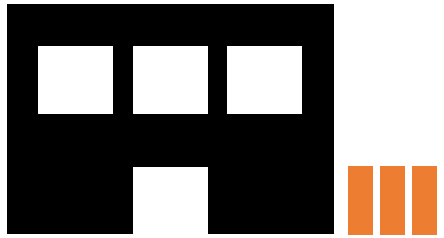
Scales of Energy Storage Systems



Utility Scale



Microgrid Campus



Commercial Scale

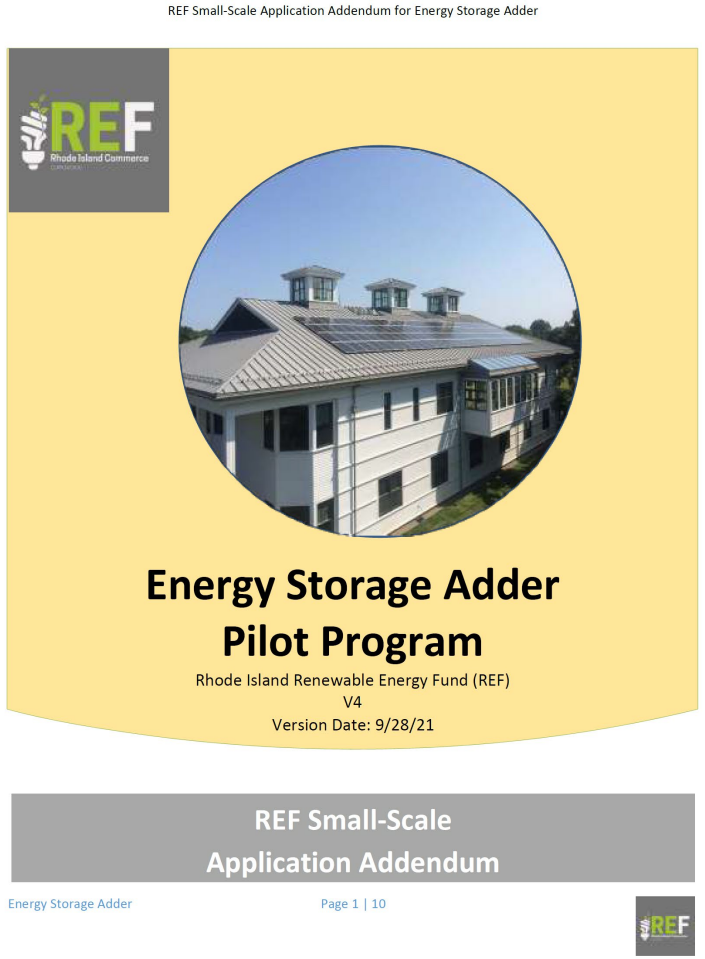
Residential Scale

REF Energy Storage Adder

- OER allocated $1.5 million of RGGI Funding to the REF
- Program was designed with two rounds of public comment
- All storage projects must be paired with a PV project at the time of application.
- All projects are required to be inspected

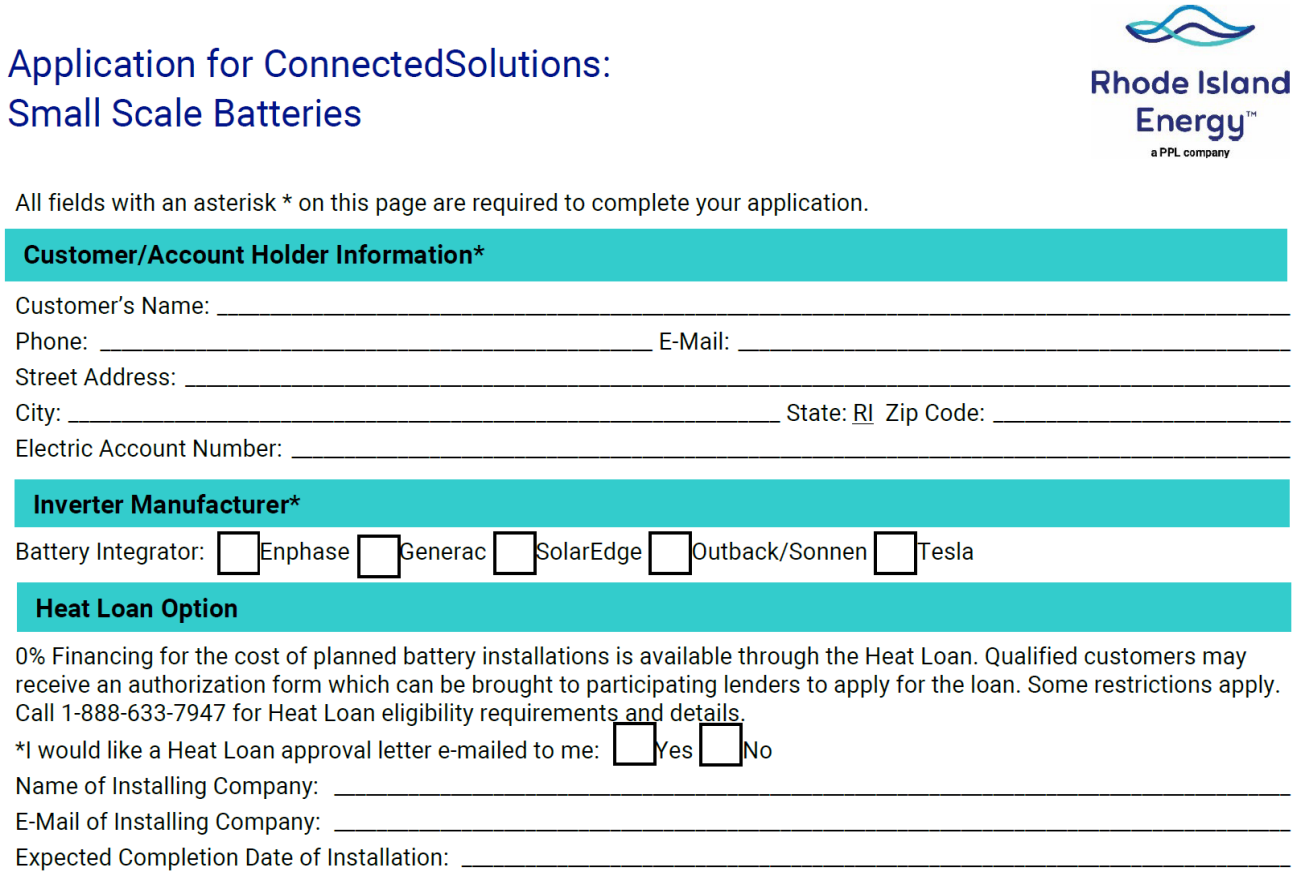
- Two adders available
  - Small Scale Adder - $2,000 per project
  - Commercial Scale Adder - $.50/Watt based on the maximum continuous power rating the battery project can deliver over three hours, cap of $40,000 per project

$$\text{Maximum Continuous Power Rating} = min\left(\frac{\text{total battery capacity in Wh}}{\text{3 hours}}, \text{maximum continuous power rating of inverter in W}\right)$$



REF Energy Storage Adder and Connected Solutions

- All REF PV+Storage applications must participate in Connected Solutions in order to leverage maximum savings to the customer
- More likely to be aware of RIE's Heat Loan because it is on the application →
- If customer chooses to opt out of Connected Solutions, they must sign a form indicating they understand.



Application for ConnectedSolutions:
Small Scale Batteries

Rhode Island Energy™
a PPL company

All fields with an asterisk * on this page are required to complete your application.

Customer/Account Holder Information*

Customer's Name: _____

Phone: _____ E-Mail: _____

Street Address: _____

City: _____ State: RI Zip Code: _____

Electric Account Number: _____

Inverter Manufacturer*

Battery Integrator: ☐ Enphase ☐ Generac ☐ SolarEdge ☐ Outback/Sonnen ☐ Tesla

Heat Loan Option

0% Financing for the cost of planned battery installations is available through the Heat Loan. Qualified customers may receive an authorization form which can be brought to participating lenders to apply for the loan. Some restrictions apply. Call 1-888-633-7947 for Heat Loan eligibility requirements and details.

*I would like a Heat Loan approval letter e-mailed to me: ☐ Yes ☐ No

Name of Installing Company: _____

E-Mail of Installing Company: _____

Expected Completion Date of Installation: _____

REF Data Collection

- Several data points are collected including
  - Inverter data
  - Battery type
  - Battery size
  - Rated battery output (kw)
  - Co-located PV system size
  - Connected Solutions Enrollment and assumed incentive
  - Total cost
  - Project location
  - Financing information

Round #	22-2
Applications Received	30
Residential Applications	30
Commercial Applications	0
Unique Installers	7
Unique Municipalities	19

	System Configuration
% DC-Coupled	33%
% AC-Coupled	63%
% Packaged	0%

Residential Average Cost Data	Number	Dollar Amount
Inverter	22	$2,636
Energy Storage Device	22	$15,461
Supplemental	22	$3,013
Labor	22	$4,706
Other	20	$588
Total	22	$24,251

Program Challenges and Barriers

- Program can only be paired with PV, stand alone projects are not eligible.
- The program cannot support battery projects for a customer who already has solar.
- REF rules require the PV system must be net metered.
- REF Small Scale projects are direct ownership only, no leases or PPAs*
- Relies on solar installers to educate customers about the adder
- Connected Solutions incentive is hard for customers to understand and incentive value difficult to predict
- Projects must comply with REF Rules and Regulations, including an 80% TSRF requirement

Some Real-Life Examples

Pika Energy: Panasonic Harbor Smart Battery

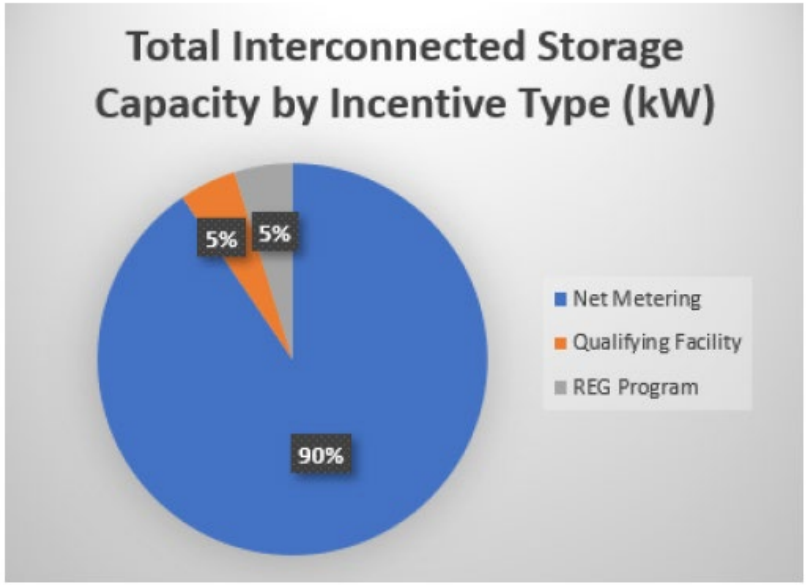
LG Chem

Tesla Powerwall

Residential Scale

Intersection with REG

- REG PV projects were allowed to pair with energy storage projects during the 2020 program year.
- Only small scale PV + Storage projects are currently allowed.
- Complex interconnection for both AC and DC Coupled systems
- Limited opportunities for inspections



Examples from Other States

States are designing programs and policies to value energy storage technologies

- Massachusetts
  - SMART program includes adder for paired systems
  - Clean Peak Standard implemented beginning 2020
- Connecticut
  - Residential battery program to alleviate localized load constraint and defer grid investment through Green Bank
- Vermont
  - Green Mountain Power residential battery lease program
- California
  - Self-Generation Incentive Program
- Hawaii
  - Solar compensation programs specific to paired systems and amount of and timing of export to the grid

Appendix

Residential & commercial batteries: Example products

Tesla Powerwall

Usable Capacity
13.5 kWh

Depth of Discharge
100%

Efficiency
90% round-trip

Power
7kW peak / 5kW continuous

Supported Applications
Solar self-consumption
Back-up power
Time-Based control
Off-grid capabilities (coming soon)

Warranty
10 years

Scalable
Up to 10 Powerwalls

Operating Temperature
-4°F to 122°F / -20°C to 50°C

Dimensions
L x W x D: 45.3" x 29.7" x 6.1"
(1150 mm x 755 mm x 155 mm)

Weight
276 lbs / 125 kg

Installation
Floor or wall mounted
Indoor or outdoor

Certification
North American and International Standards
Grid code compliant

Tesla

Sonnen Ecolinx

GENERAL

Usable capacity: 12 kWh - 20 kWh (in 2 kWh steps)
Dimensions (in) W/H/D: 26/84/19
Weight (approximate): 724 – 936 lbs
Grid integration: AC coupled
Ambient temperatures: 41 – 113 °F
Enclosure rating: NEMA 12

POWER UNIT

Continuous output: (AC) 8,000 W
AC specifications: 240 VAC / split phase / 60 Hz
Peak efficiency of inverter: 95%

Sonnen

UET ReFlex

SPECIFICATIONS	
Voltage	42-67V (48V nominal)
Current	360 A
Series Connection	Up to 22 modules (1500V)
Dimensions	0.9m W * 1.8m D * 2.1m H 36" W * 72" D * 83" H
Weight	3,000kg (6,600lbs)
Ambient Operating Temp	0℃ TO 45℃ (32°F to 113°F)
Storage Temp	-15℃ to 55℃ (SOC=50%)
Enclosure	IP 20 (NEMA 1)
Self Discharge Rate	OFF=0%, ON=0.1%/hour
Short Circuit Current	3kA Maximum
Communications	Modbus TCP
Auxiliary Supply Input	100-240 VAC 1ϕ,50/60Hz OFF=20W,Typical=300W, Max=500W

UET

- **Governing standards**
  - UL 1973: Cell level design and safety
  - UL 9540: System design and safety
  - UL 1741: Inverter performance & interconnection
  - NFPA 70 (National Electrical Code): appliance installation and inspection
  - NFPA 855: Storage-specific installation and inspection
- Professionally installed, standard-compliant devices will be safe for use in home, though garage is most likely site. No odors/sound under normal operations.

Commercial & utility-scale batteries: Example projects

Large

Greentech Media

Substation-sited

Snohomish Public Utility District (WA), *Wind Power Monthly*

Utility-Scale

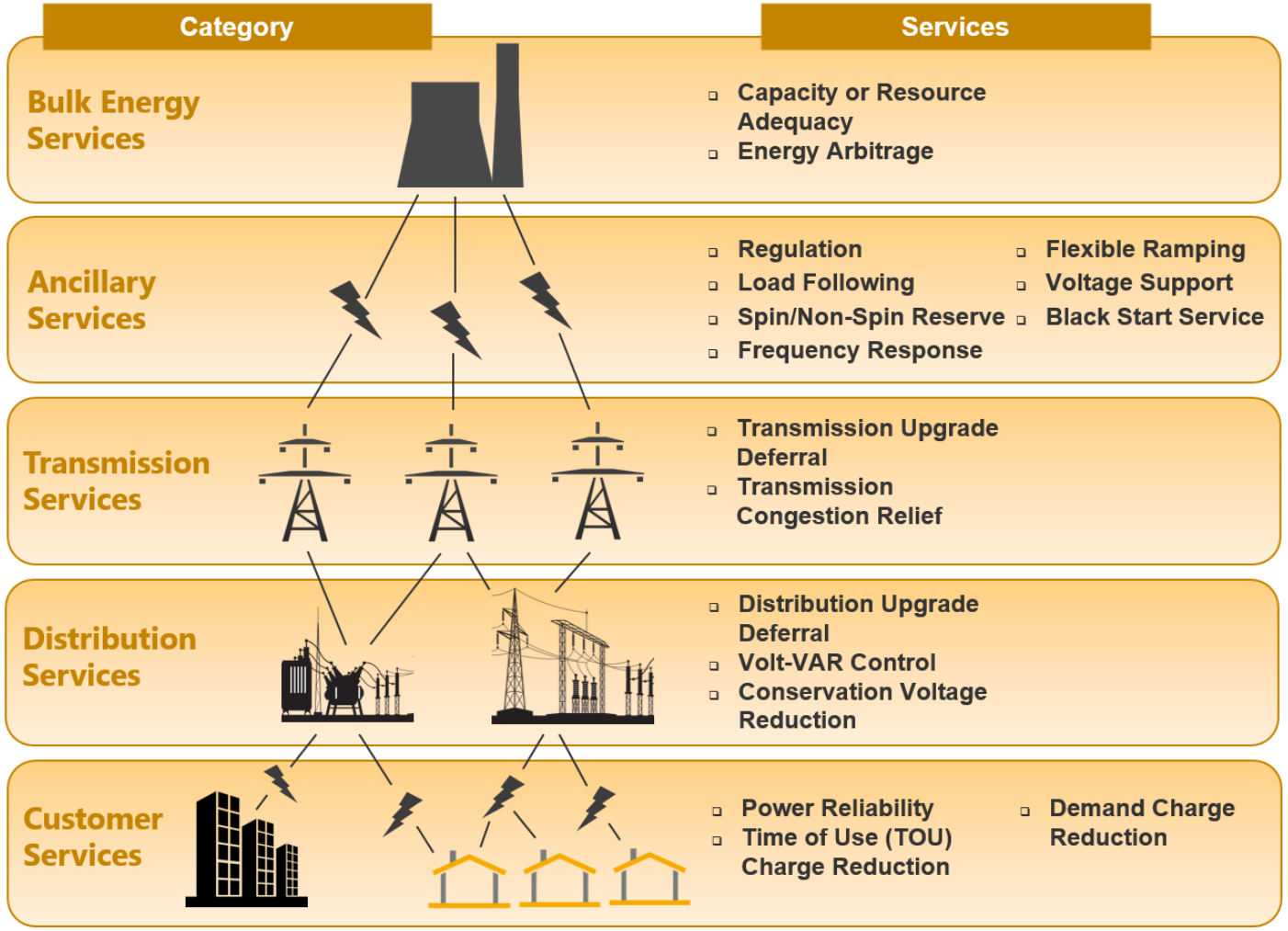
Hornsdale Power Reserve (AU), *Wind Power Monthly*

- **Governing standards**
  - UL 1973: Cell level design and safety
  - UL 9540: System design and safety
  - UL 1741: Inverter performance & interconnection
  - NFPA 70 (National Electrical Code): appliance installation and inspection
  - NFPA 855: Storage-specific installation and inspection
  - Grid interconnection requirements (FERC/PUC)
- Collectively, these standard require utility-scale (high-voltage) projects to be shielded from the public and ventilation/fire suppression

Salem Smart Power Center, *Greentech Media*

Pacific Northwest NATIONAL LABORATORY

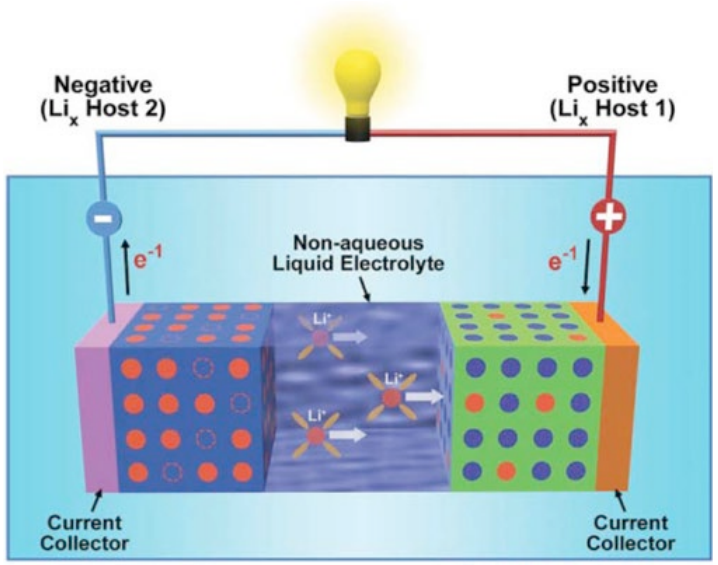
Taxonomy of Energy Storage Services



- Properly valuing energy storage is a complicated process of identifying and optimizing all value streams
- Storage can do a lot of things, but it can't do them all at once, and any time a service is selected, it comes with opportunity costs
- Granular models are needed to understand those tradeoffs and optimize value

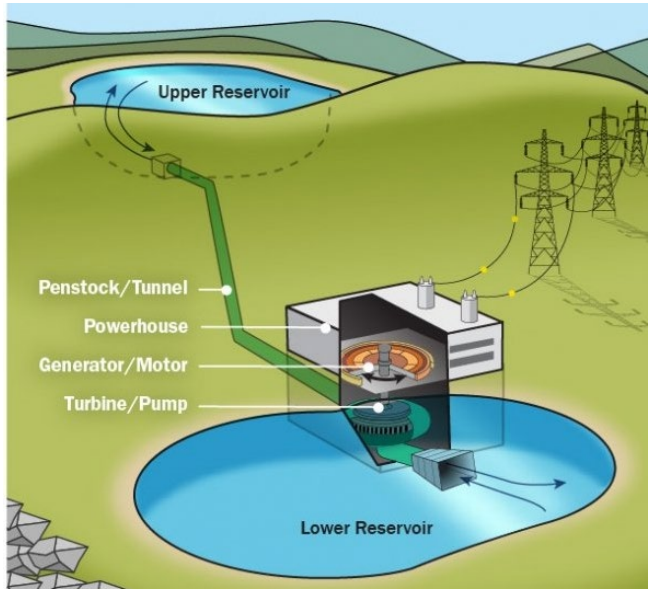
Energy Storage – Three basic types

Electrochemical



- **Energy stored via chemical reactions**
  - Electricity in, electricity out
- **Examples**
  - Lithium-ion
  - Flow batteries
  - Lead acid

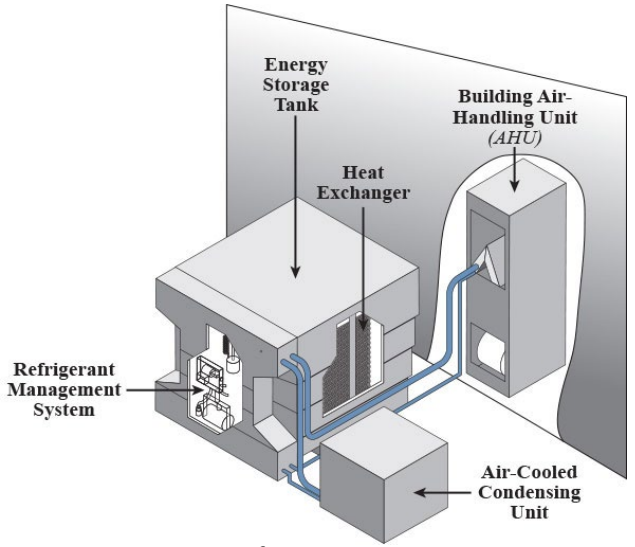
Mechanical



U.S. Department of Energy Water Power Technologies Office, https://www.energy.gov/eere/water/pumped-storage-hydropower.

- **Energy stored as potential energy**
  - Electricity in, electricity out
- **Examples**
  - Pumped storage hydro
  - Flywheels

Thermal

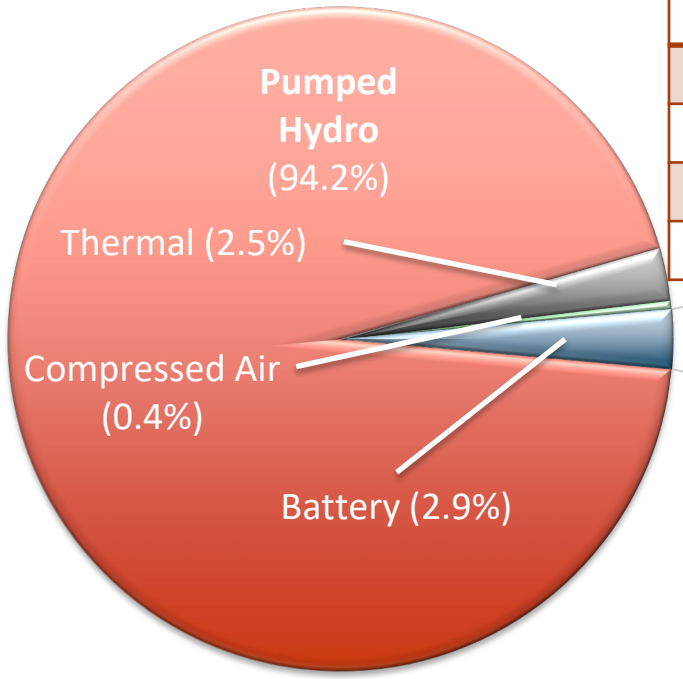


U.S. Department of Energy, https://www.energy.gov/eere/amo/ice-bear-storage-module

- **Various configurations**
  - Heat in, heat out
  - Heat in, electricity out
  - Electricity in, heat out
- **Examples**
  - Ice thermal storage
  - Concentrated solar power

Current Installed Capacity – U.S.

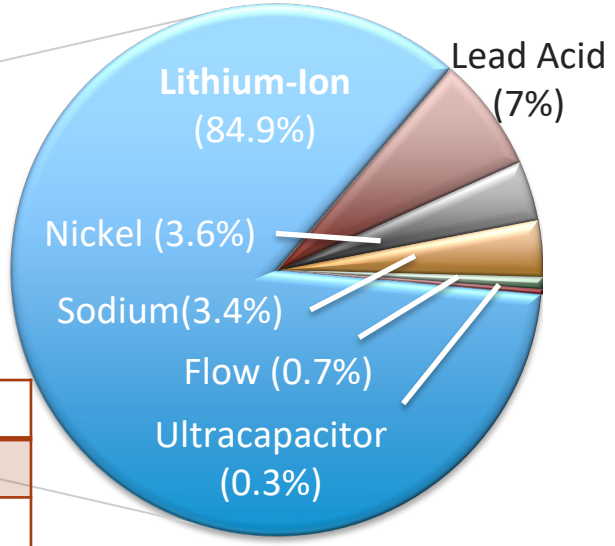
Total Energy Storage Capacity



Pumped Hydro	24.5 GW
Battery	0.7 GW
Thermal	0.7 GW
Compressed Air	0.1 GW
Total	**26 GW**

Source: DOE Global Energy Storage Database, https://energystorageexchange.org/.

Total Battery Capacity



Lithium-Ion	631 MW
Lead Acid	52 MW
Nickel	27 MW
Sodium	26 MW
Flow	5 MW
Ultracapacitor	2 MW

Under the hood: Lithium-ion

Cell → Pack → Rack → System

GE

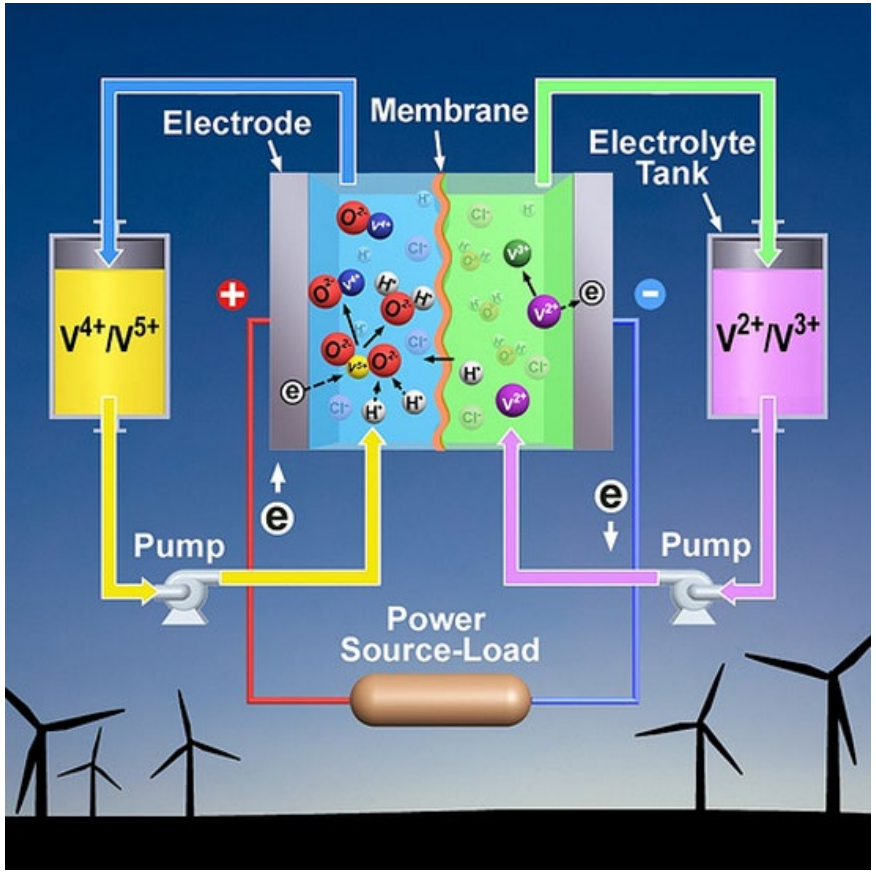
Salem Smart Power Center, *Greentech Media*

- **18650 Cell**
  - 18mm x 65.0 mm
  - Slightly thicker and longer than a AA battery

- **No noise**
- **No odors**
- **Low risk for fire, gas release (following codes and standards significantly reduces both the probability and impact of these events)**
  - NFPA 855 – ventilation, suppression requirements
  - 2018 IFC – Mitigation analysis, battery management systems
  - NEC Article 706 – behind-the-meter installations

Under the hood: Flow batteries

Internal Structure

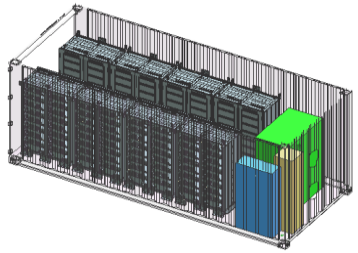


System

- **No noise**
- **No odors**
- **No fire risk**
- **Moderate risk of leaks (low-impact event)**
  - Generally, same codes apply (some variation in NEC)

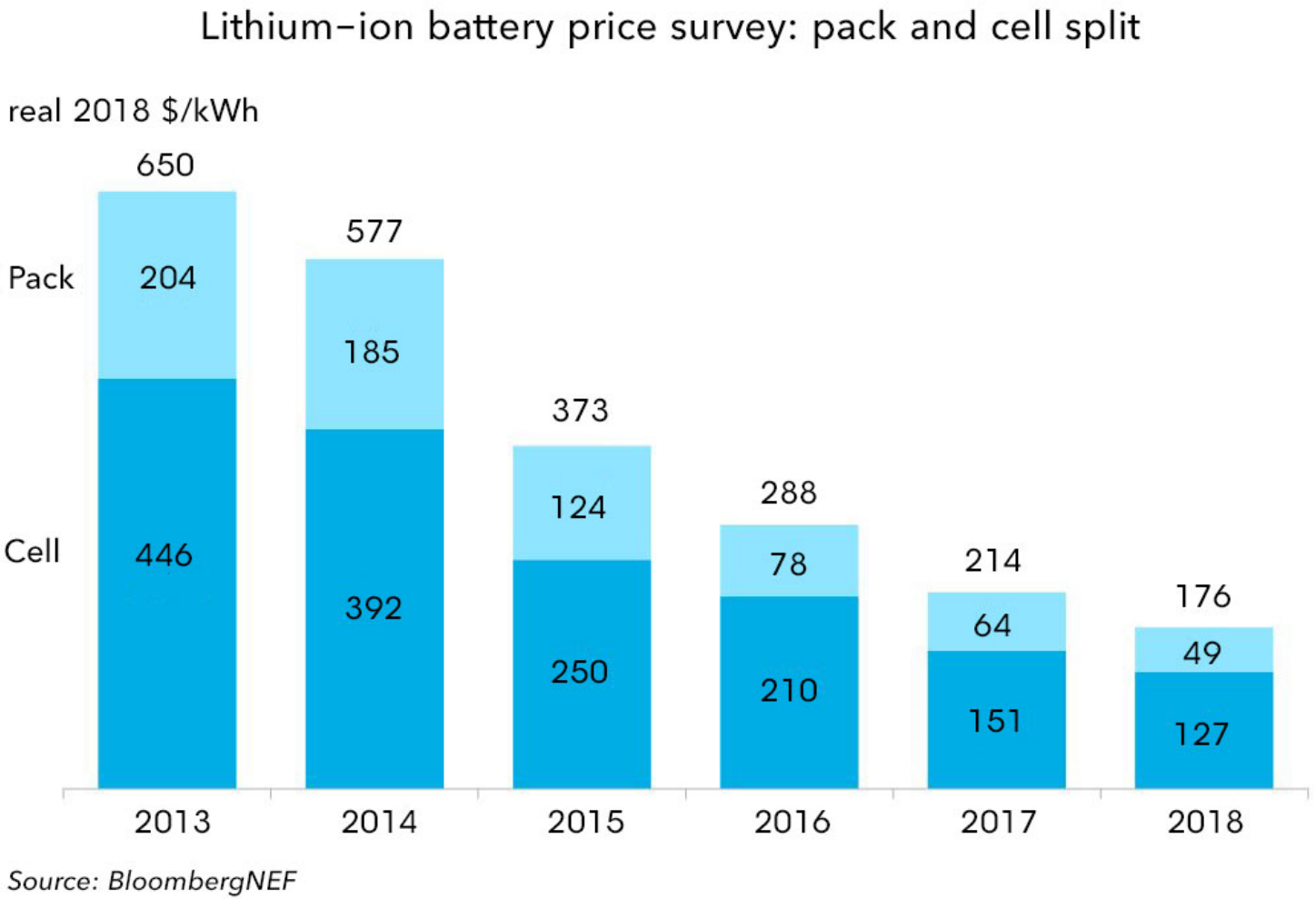
Elements of Battery Storage

Cell / Rack	Power Control System (PCS)	Energy management System (EMS)	Site Management System (SMS)	Balance of Plant
• Storage device • Battery Management & Protection (BMS) • Racking • $/KWh • Efficiency • Cycle life	• Bi-directional Inverter • Switchgear • Transformer • Interconnection • $/KW	• Charge / Discharge • Load Management • Ramp rate control • Grid Stability • Monitoring • $	• DER control • Synchronization • Islanding • Microgrid • $	• Housing • Wiring • Climate control • Fire protection • Permits • $



NOTE: All–in cost may be 4x higher than cell cost.

Lithium-ion Price Trends

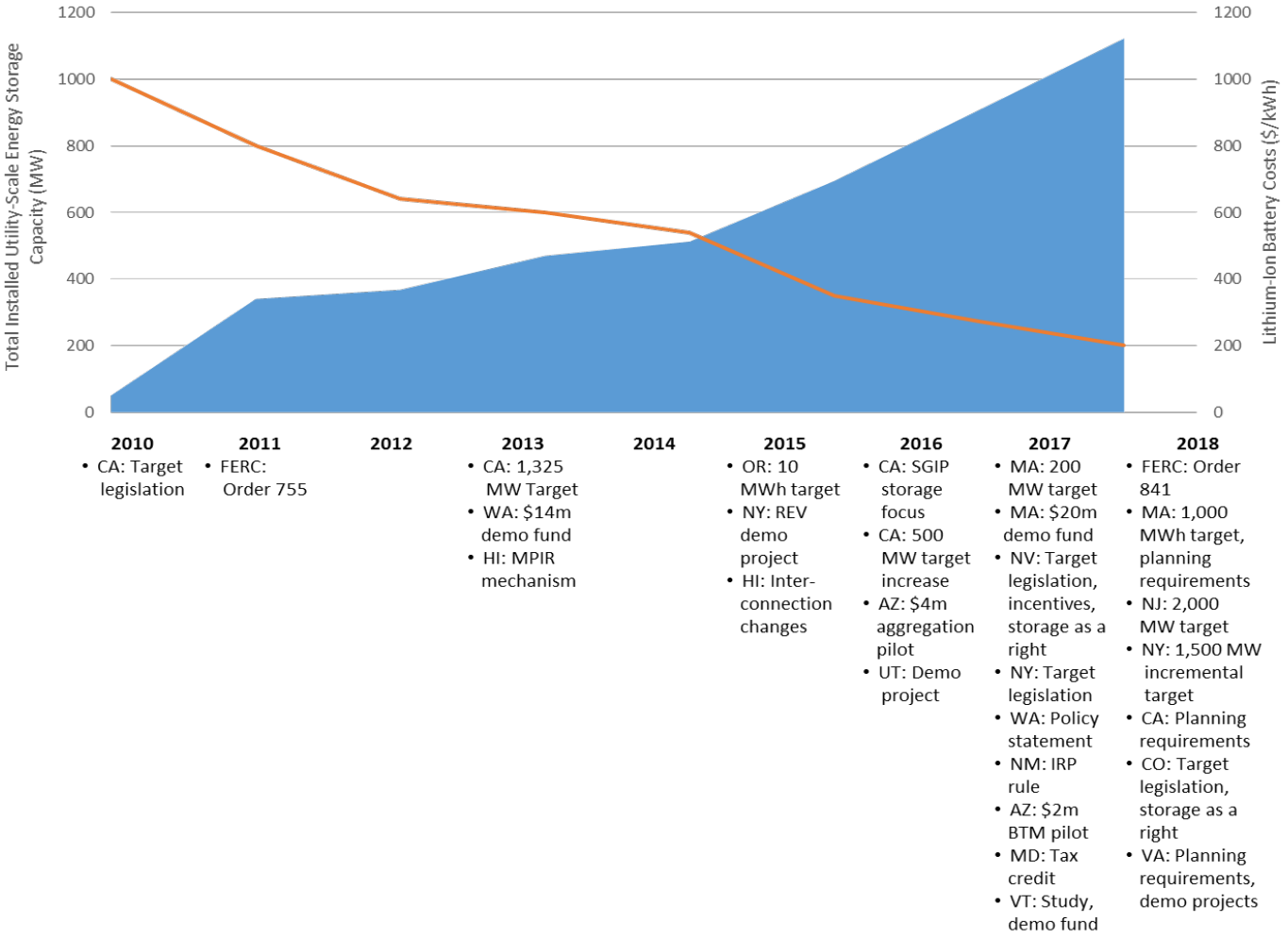


Source: BloombergNEF

- When comparing prices for different systems, ensure that it is done on equal terms (cell, pack, installed)
- As cell and pack prices fall, balance of plant constitutes an increasing share of total system costs
- Balance of plant costs vary significantly by site; installed cost may be 4x or more the cell + pack cost

Recent Energy Storage Policy Activity

Figure 2: Storage Policies, Installations, and Costs Since 2010



As energy storage costs (orange line) have fallen in recent years, the amount of new storage on the grid has rapidly increased (blue wedge), and state policy development has accelerated and differentiated.

The article explores the different types of polices that states are adopting, the drivers for different approaches, and early effects.

Report available at https://link.springer.com/article/10.1007/s40518-019-00128-1.

Additional Resources

- PNNL Energy Storage (energystorage.pnnl.gov)
- Sandia National Laboratories (www.sandia.gov/ess/)
- DOE Global Energy Storage Database (www.energystorageexchange.org)
- Energy Storage Association (www.energystorage.org)