Energy Storage Technology Advancement Partnership (ESTAP) Webinar

State of the U.S. Energy Storage Industry: 2018 Year in Review

Hosted by
Todd Olinsky-Paul, Project Director, CESA

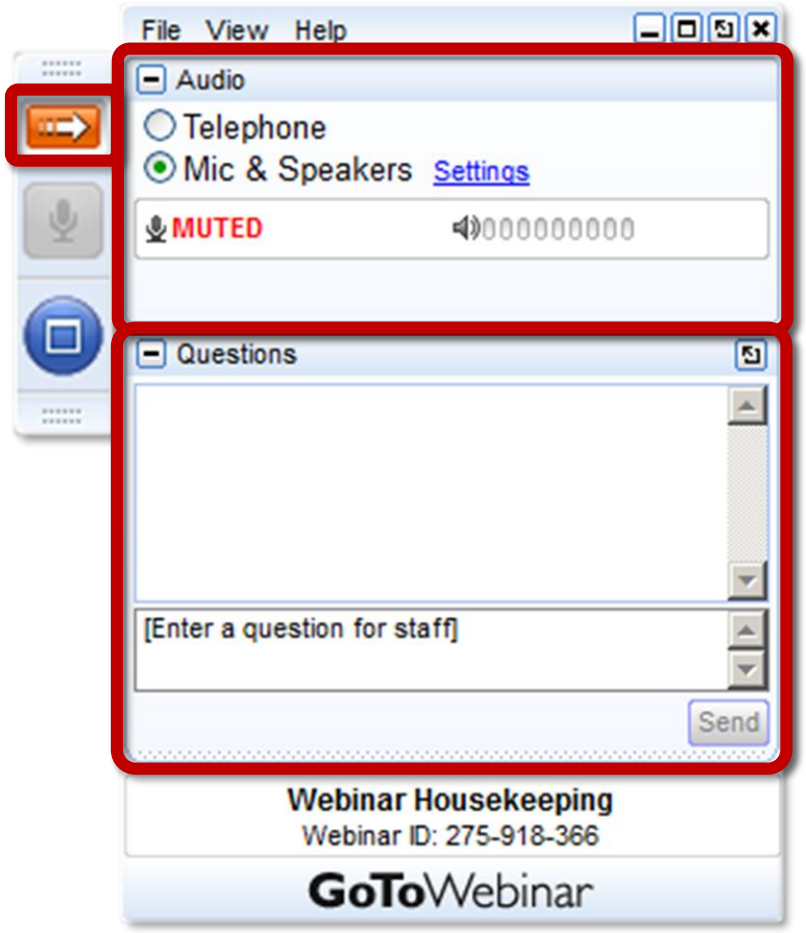
February 28, 2019

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

CleanEnergy States Alliance

Housekeeping



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Clean Energy States Alliance

ALASKA ENERGY AUTHORITY

STATE OF CALIFORNIA ENERGY COMMISSION

DEPARTMENT OF ENERGY & ENVIRONMENT

EnergyTrust of Oregon

IOWA economic development

MASSACHUSETTS CLEAN ENERGY CENTER

IPA ILLINOIS POWER AGENCY

NEW MEXICO emnrd Energy, Minerals and Natural Resources Department

OEI Wisconsin Office of Energy Innovation

NEW YORK STATE OF OPPORTUNITY. NYSERDA

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

ESTAP is supported by the U.S. Department of Energy Office of Electricity and Sandia National Laboratories, and is managed by CESA.

ESTAP Key Activities:

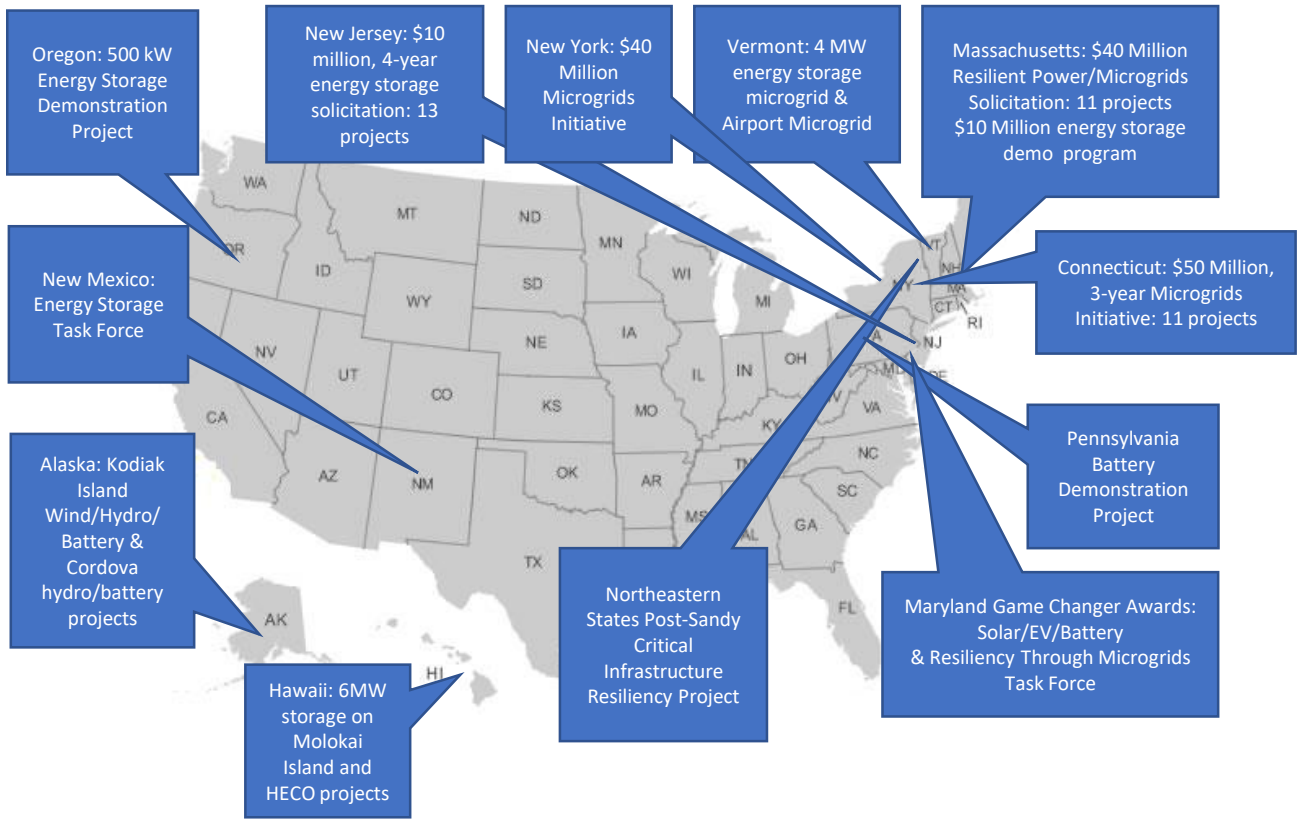
1. Disseminate information to stakeholders

   - ESTAP listserv >5,000 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:



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Webinar Speakers

Dr. Imre Gyuk
Director, Energy Storage Research, U.S. Department of Energy

Dan Borneo
Engineering Project Manager, Sandia National Laboratory

Dan Finn-Foley
Senior Analyst - Energy Storage, Wood Mackenzie Power & Renewables

Todd Olinsky-Paul
Project Director, Clean Energy States Alliance

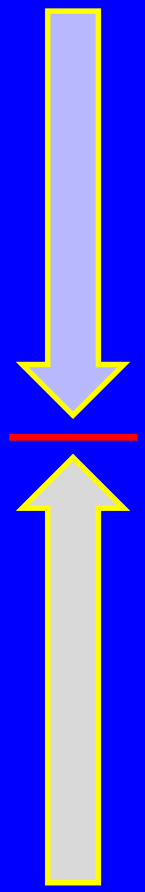
Gridscale Energy Storage, Goals and Directions

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

DOE Office of Electricity, Priorities:

- Puerto Rico and U.S. Virgin Islands
  Restoration and Resiliency Efforts
- North American Energy Systems Resiliency Model
- Mega-Watt Scale Grid Storage
- Revolutionize Sensing Technology Utilization
- Operational Strategy for Cyber and Physical Threats

Designing a Business Case:



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

► Research on Materials, Devices, and Systems

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

► Deployment, Benefit Valuation, Policy, Finance

Effective Business Cases:

Frequency Regulation,
Substation Upgrade Deferral,
Demand Charge Reduction.

Resiliency, Military Energy Assurance,
Emergency Preparedness.

Peakers, Transmission Congestion

Current OE Activities:

Supporting 20 Deployment Projects
+ Valuation
Regional PUC Workshops
ESTAP Webinars
Codes and Standards
The Global ES Data Base
Valuation Tool - QUEST
Policy Data Base
Financial Summits

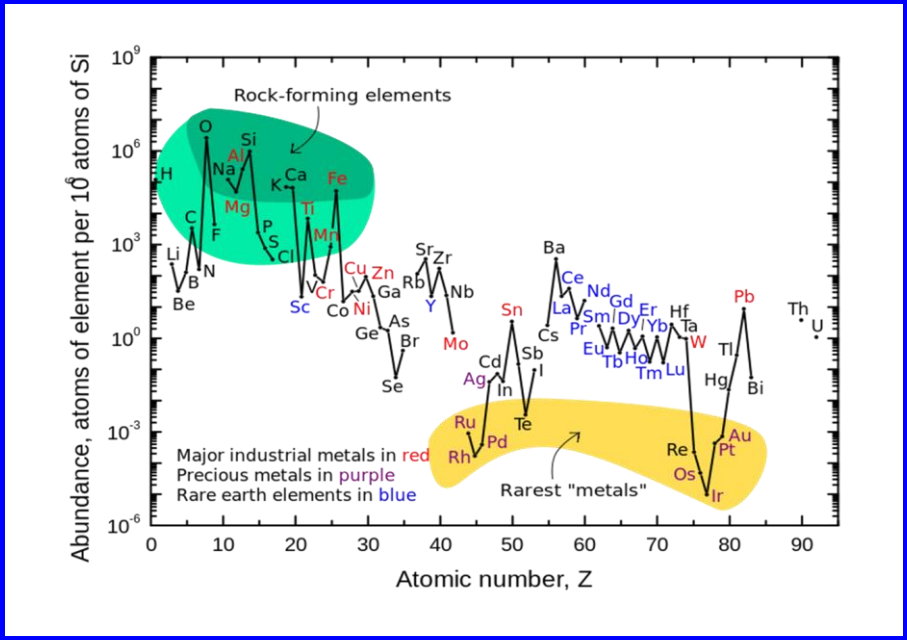
Obstacles and Impediments to Commercialization:

Safety, Reliability,

Ecological and Sociological Issues,

Re-Use, Recycling, Disposal

To develop Safe, Inexpensive,
and Environmentaly Benign Batteries
We must look towards Earth-Abundant Materials



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-NaI based Batteries	$ 60/kWh
Aqueous Soluble Organic (ASO) Redox Flow Batteries (stack+PE)	$125/kWh
Advanced Lead Acid	$ 35/kWh

With new Technology Solutions Cost will go down, Safety and Reliability will increase

With every successful Project the Value Propositions will continue to increase!

More jobs will be created!!

State of the U.S. energy storage industry

2018 year in review and trends to watch

Wood Mackenzie Power & Renewables | February 2019

Wood Mackenzie
POWER & RENEWABLES

About Wood Mackenzie

We provide commercial insight and access to our experts leveraging our integrated proprietary metals, energy and renewables research platform

Wood Mackenzie is ideally positioned to support consumers, producers and financers of the new energy economy.

- Acquisition of MAKE and Greentech Media (GTM)
- Leaders in renewables, EV demand and grid-connected storage
- Over 500 sector-dedicated analysts and consultants globally, including 75 specifically to power and renewables
- Located close to clients and industry contacts

About the Analyst

Dan Finn-Foley
Senior Analyst,
Energy Storage

» Dan is a Senior Analyst with the Energy Storage team at Wood Mackenzie Power and Renewables, where he focuses on front-of-the-meter energy storage market trends and applications. He previously worked as a Senior Consultant with DNV GL where he focused on competitive energy markets and the intersection of emerging energy business strategies within the broader evolving technological and regulatory environment. Prior to DNV GL Dan worked with Navigant Consulting and the Department of Energy.

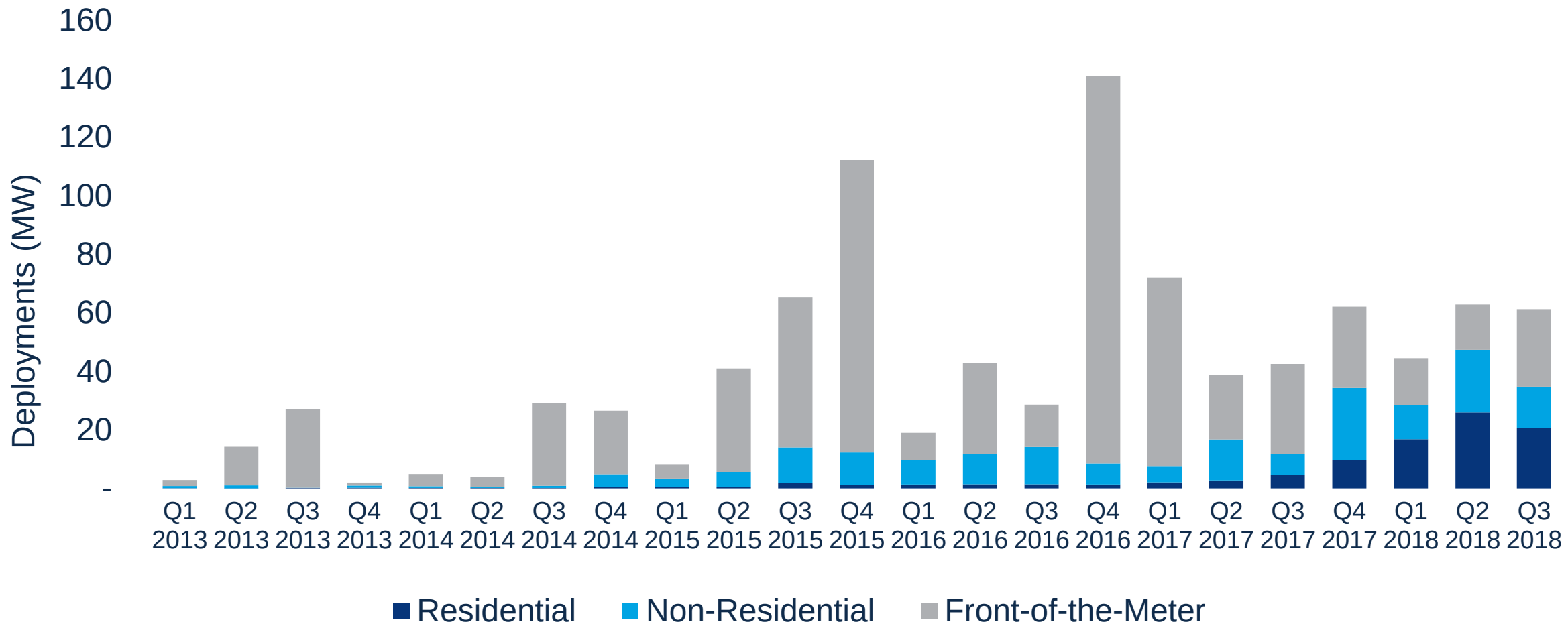
» Dan has over 9 years of experience in the energy space as a researcher, consultant, and analyst. Dan holds a Master's of Mechanical and Industrial Engineering degree from the University of Massachusetts Amherst Wind Energy Center and a Bachelor of Science in Mathematics-Physics from Brown University.

Contents

1. Deployment trends

U.S. Q3 2018 deployments in megawatts rose 44% YOY

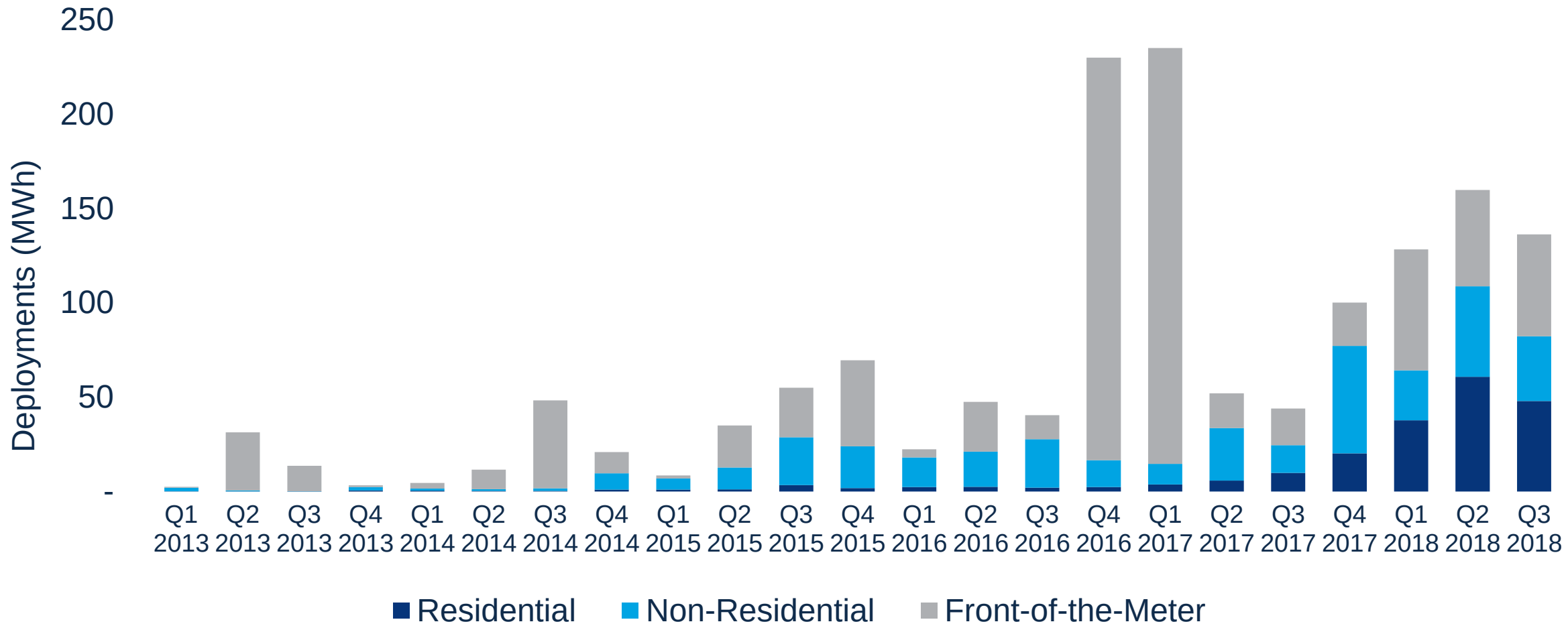
However, the market fell 3% QOQ



Source: Wood Mackenzie Power & Renewables

U.S. Q3 2018 deployments in megawatt-hours rose 3x YOY

For the second quarter in a row, YOY megawatt-hour growth tripled as average discharge duration increases



Source: Wood Mackenzie Power & Renewables

Top energy storage markets, Q3 2018

California leads across all segments

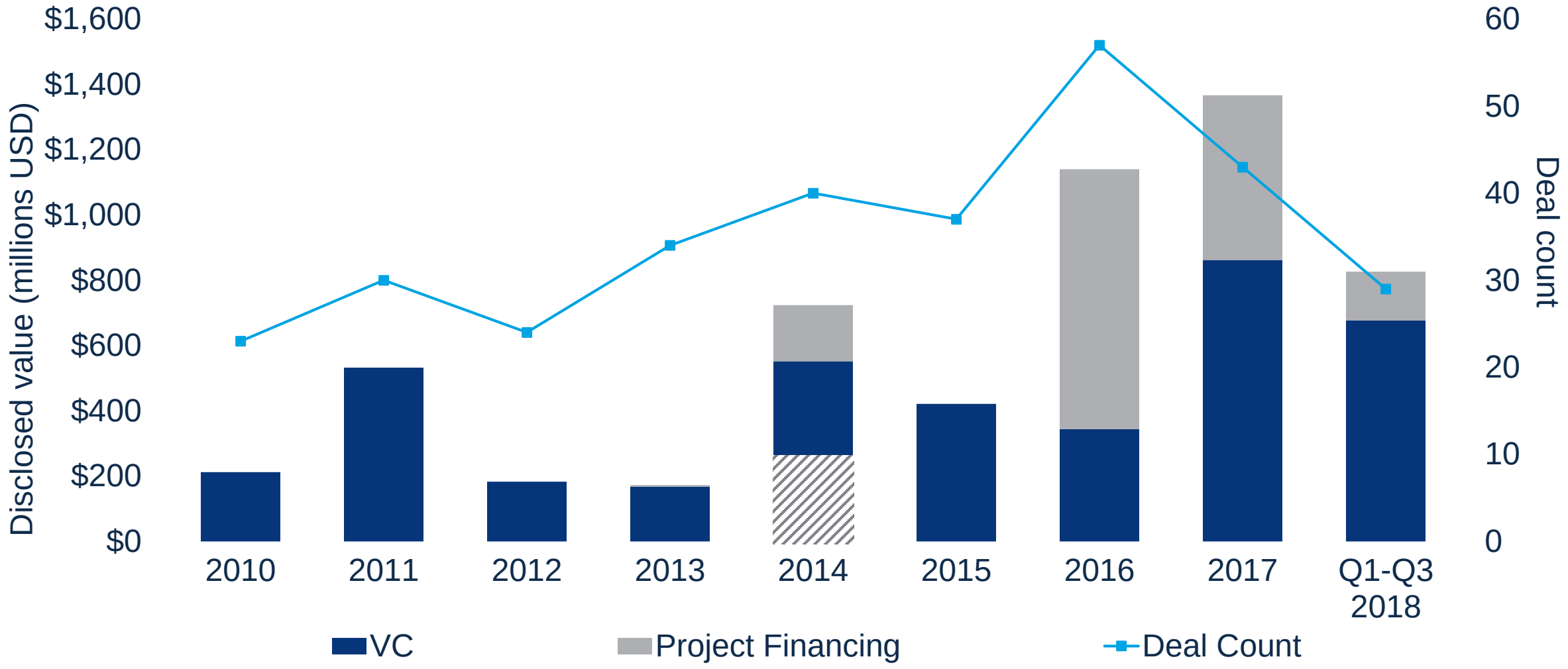
Top 3 markets by segment in Q3 2018 (power capacity)

Rank	Residential	Non-residential	Front-of-the-meter
1	California	California	California
2	All Others	Hawaii	New York
3	Hawaii	New York	All Others

Source: Wood Mackenzie Power & Renewables

Note: Wood Mackenzie Power & Renewables is currently monitoring 10 individual markets: Arizona, California, Colorado, Hawaii, Massachusetts, Nevada, New Jersey, New York, PJM and Texas

Corporate investments in energy storage reached $246M in Q3 2018



Source: Wood Mackenzie Power & Renewables

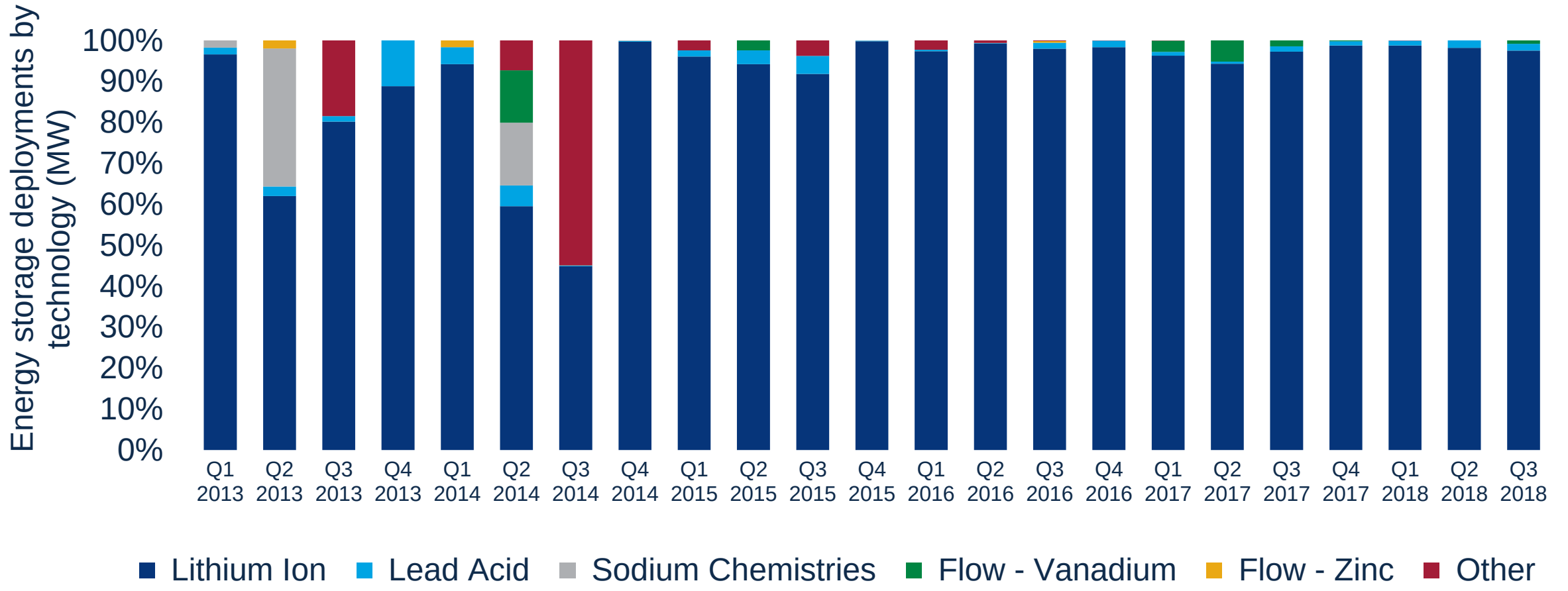
Note: The total disclosed investment in 2014 was boosted by a rumored $250 million investment in Boston-Power (shaded in the figure above); data excludes battery materials and upstream companies. 2014 data differs from *U.S. energy storage monitor 2014 year in review* due to exclusion of EV startup Atieva and inclusion of stealth startup Fluidic Energy.

2. Technology and system price trends

Lithium-ion still dominates the market with 97.5% share of MW in Q3 2018

Lead-acid held 1.7%, while a single vanadium-redox flow battery project took the remaining 0.8%

Quarterly energy storage deployment share by technology (MW %)

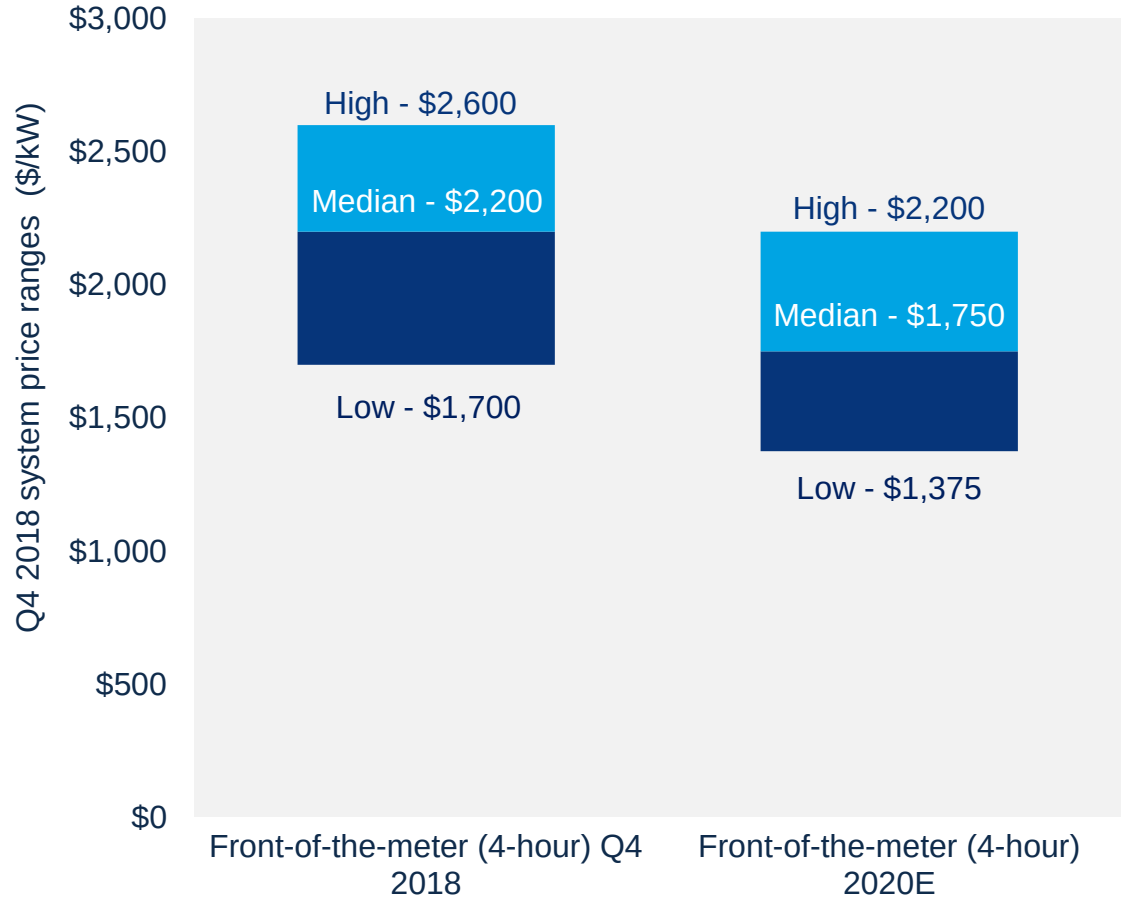


* “Other” includes flywheel and unidentified energy storage technologies.

Source: Wood Mackenzie Power & Renewables

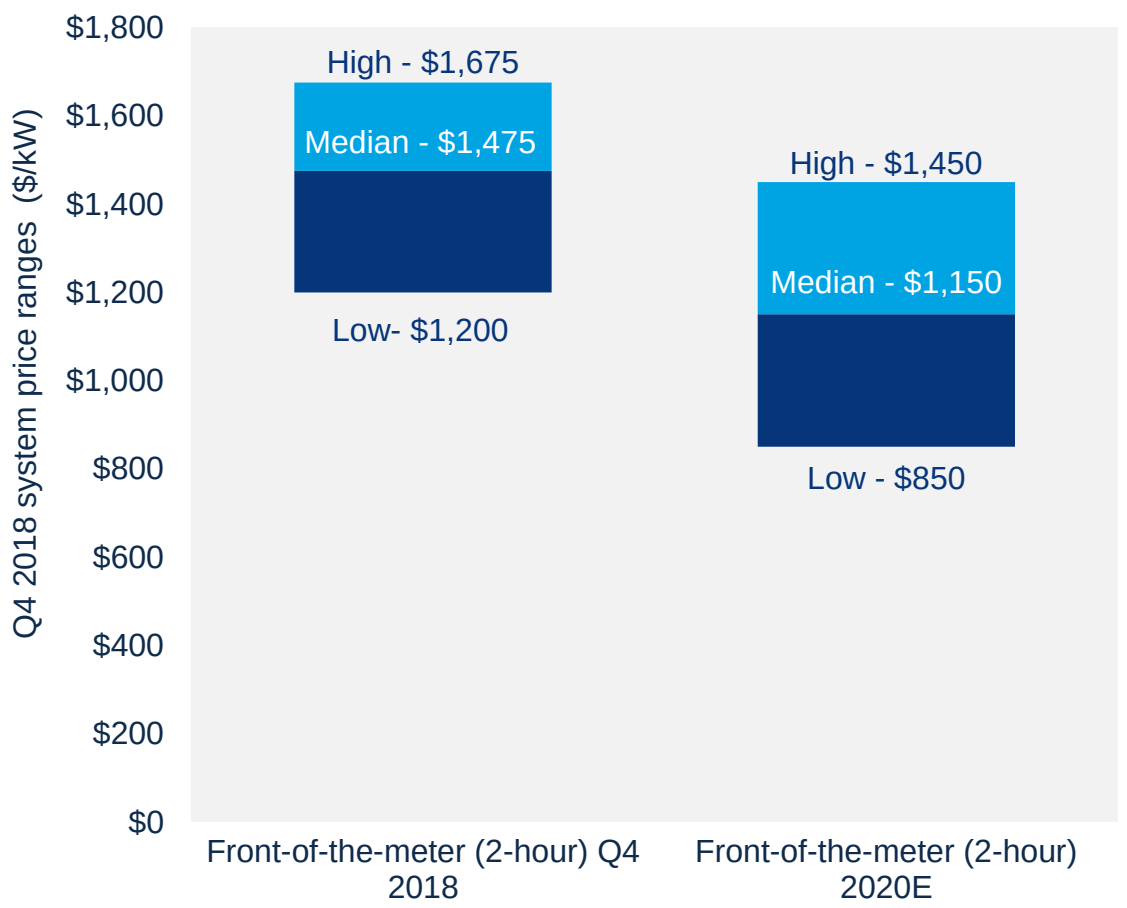
Front-of-the-meter system prices set to decline by more than 15% over the next two years

Front-of-the-meter fully installed system price trends, Q4 2018 and 2020E, 4-hour ($/kW)



Source: Wood Mackenzie Power & Renewables

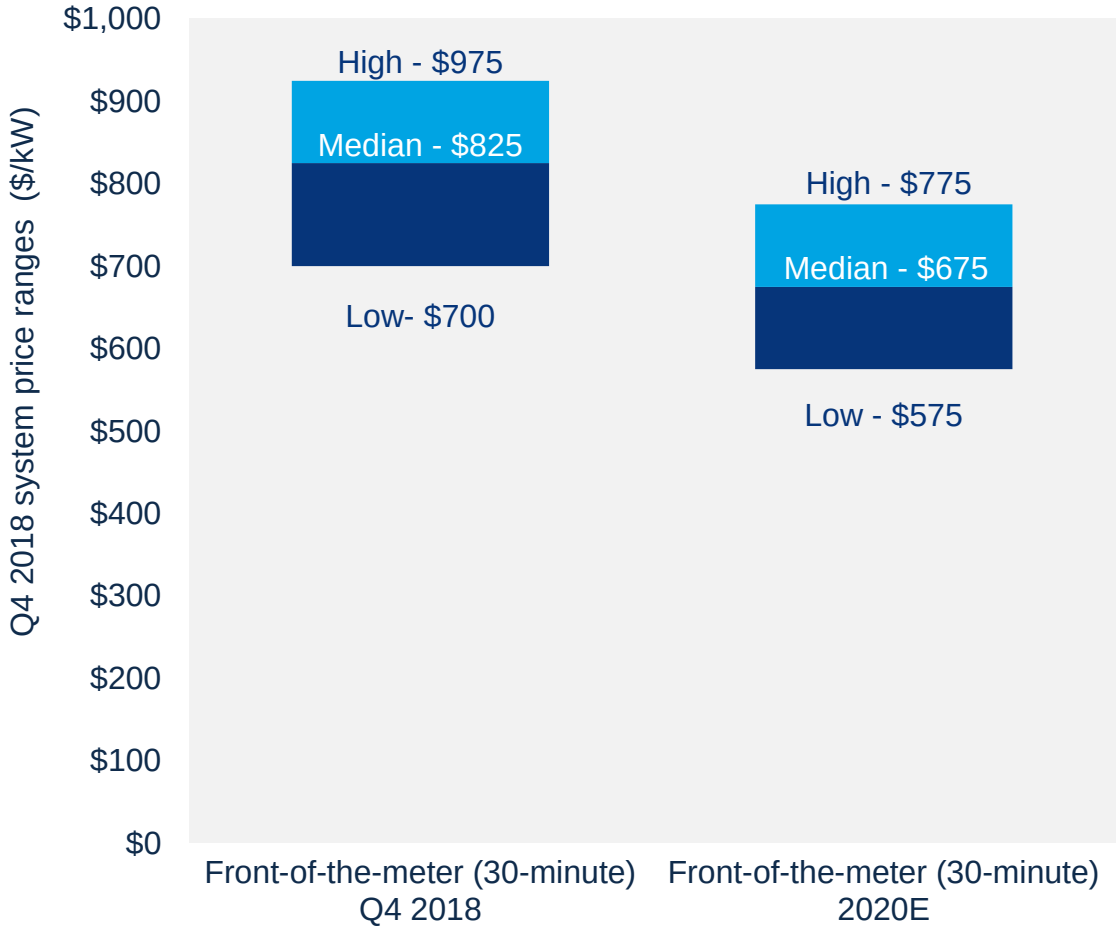
Front-of-the-meter fully installed system price trends, Q4 2018 and 2020E, 2-hour ($/kW)



Source: Wood Mackenzie Power & Renewables

Front-of-the-meter system prices set to decline by more than 15% over the next two years (cont.)

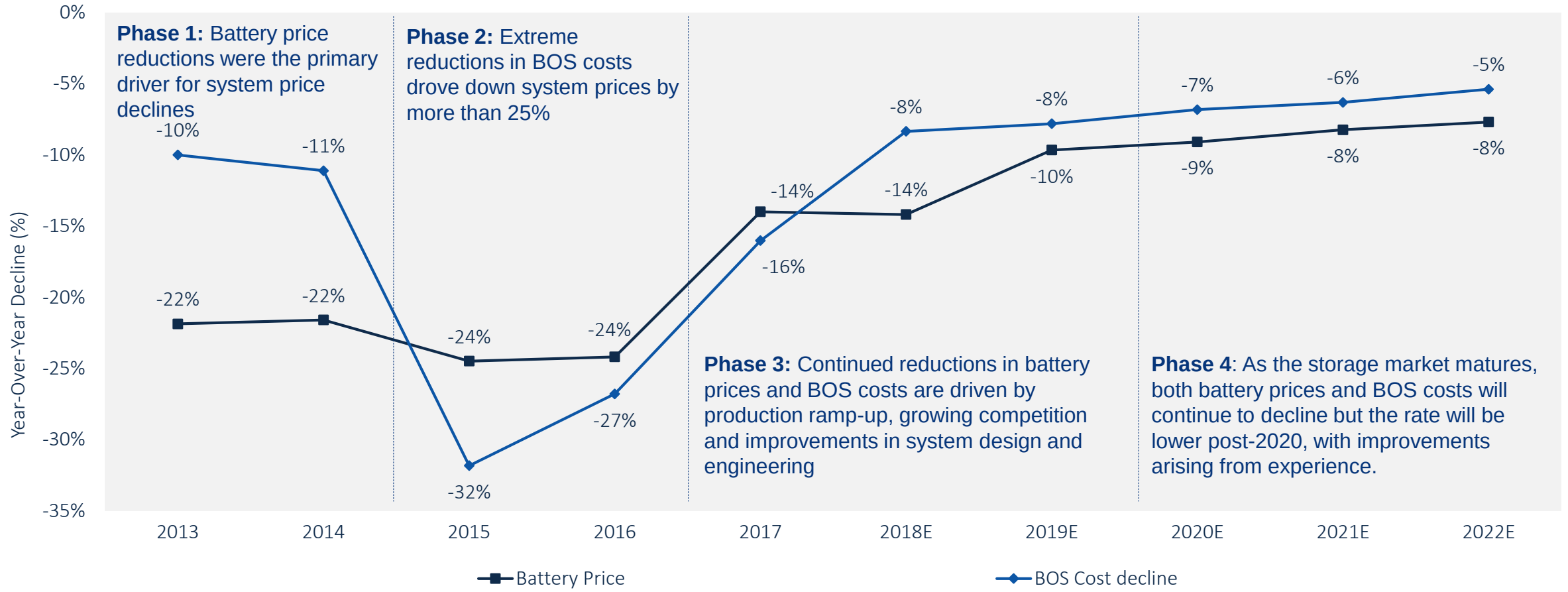
Front-of-the-meter fully installed system price trends Q4 2018 and 2020E, 30-min ($/kW)



Source: Wood Mackenzie Power & Renewables

Cost declines leveling off from steep drops but will persist

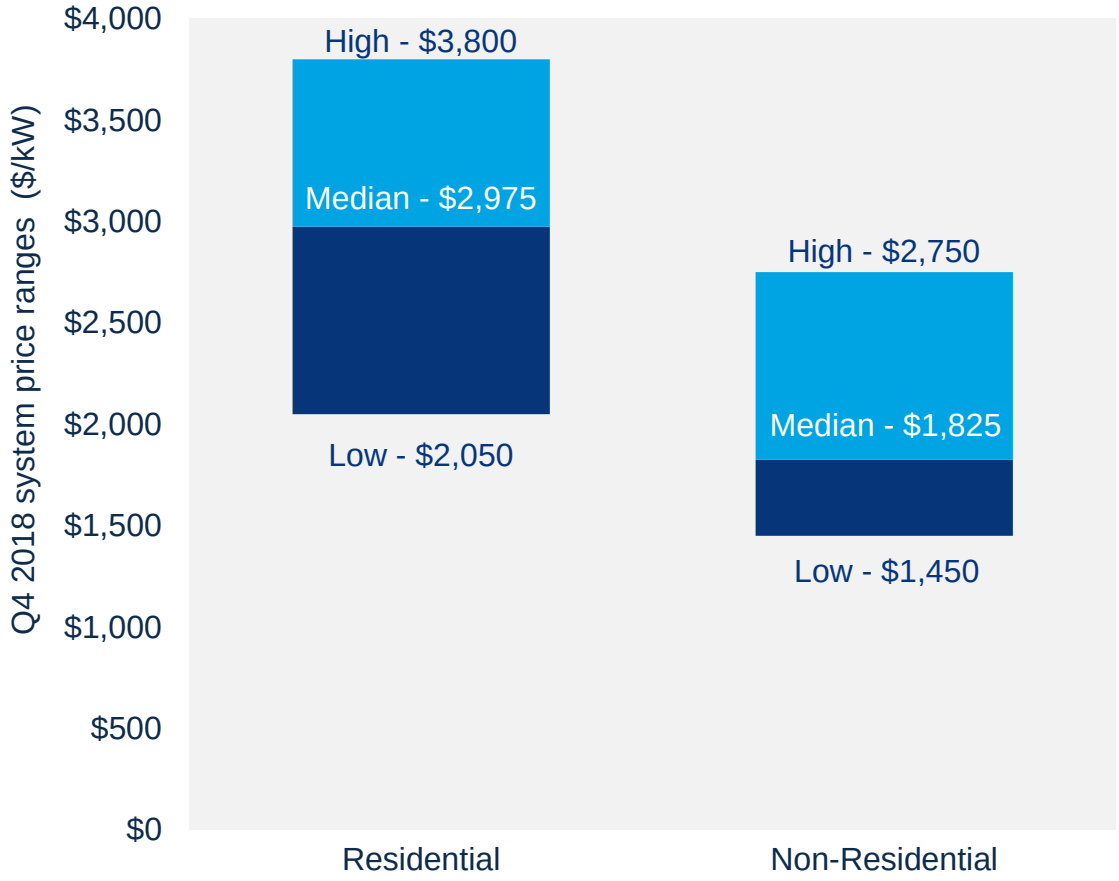
Year-Over-Year Decline in Battery Price and BOS Cost, 2013 – 2022E (%)



Source: Wood Mackenzie Power and Renewables

High and low BTM prices remain mostly flat in Q4 2018

Behind-the-meter fully installed system price trends Q4 2018, 2-hour ($/kW)



Source: Wood Mackenzie Power & Renewables

3. Market drivers

Front-of-the-meter policy and market developments, Q4 2018

Nevada

Nevada Energy's latest renewable energy RFP includes the opportunity for energy storage to be paired as a capacity asset. Voters rejected deregulation of the market, while increasing the state's renewable portfolio standard.

California

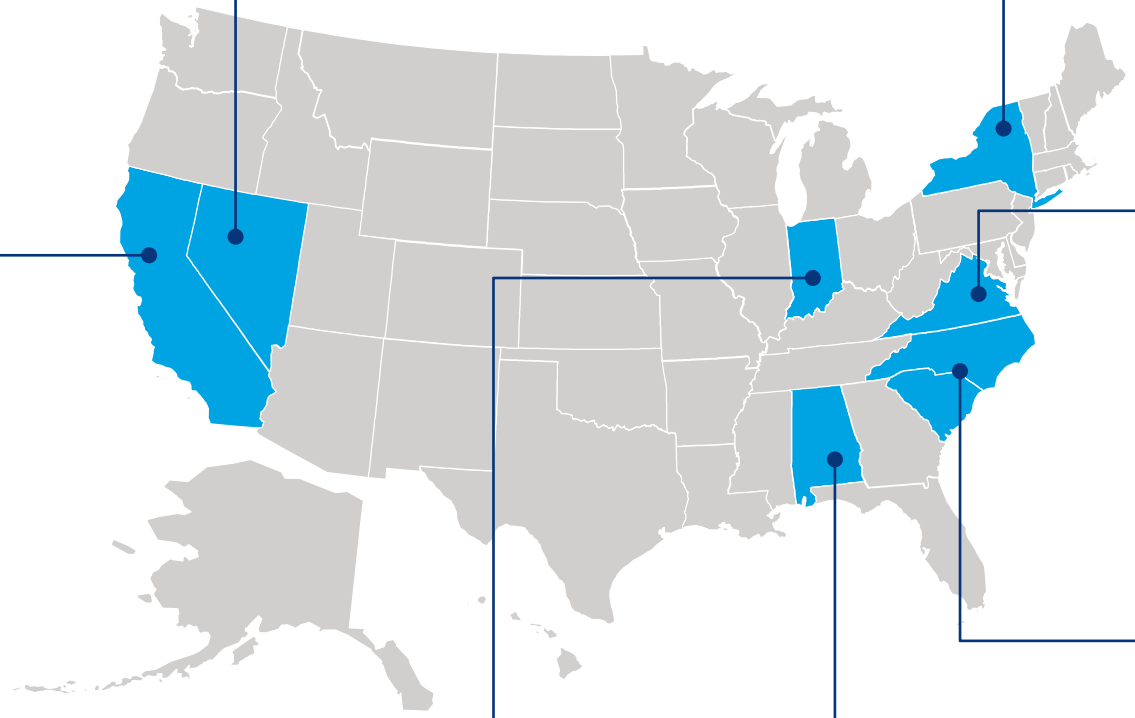
CPUC approved 175 MW worth of storage contracts split between SCE and PG&E. **CAISO** continued market participation rulemaking for energy storage. **FERC** rejected portions of SCE's wholesale distribution tariff.

Federal

The **Department of Energy** announced the selection of 10 projects through the ARPA-E Duration Addition to Electricity Storage program. **Senators Scott and Bennet** sent a letter to Treasury Secretary Mnuchin asking him to clarify Investment Tax Credit eligibility for storage systems.

ISO proceedings

Market design committees at CAISO, SPP, MISO, ISO-NE, NYISO and PJM continue to tackle issues related to FERC Order 841 compliance.



Indiana

Northern Indiana Public Service Company launched its latest integrated resource plan, including potential energy storage.

New York

Governor Cuomo announced $40 million under the NY-Sun program to support storage deployment. **NY PSC** accepted environmental review of the state's storage roadmap. **NYISO** is considering storage participation and capacity market eligibility.

Virginia

Virginia Department of Mines, Minerals and Energy issued an RFP to evaluate the benefits of storage for the state.

New Jersey

PSE&G announced its $4 billion Clean Energy Future program, including $180 million for energy storage.

North/South Carolina

Duke Energy will invest $500 million in energy storage over the coming years, with total deployments expected at 300 MW.

Alabama

Alabama Power's latest capacity RFP shows energy storage is increasingly being recognized across the Southeast.

Source: Wood Mackenzie Power & Renewables

Behind-the-meter policy and market developments, Q4 2018

Nevada

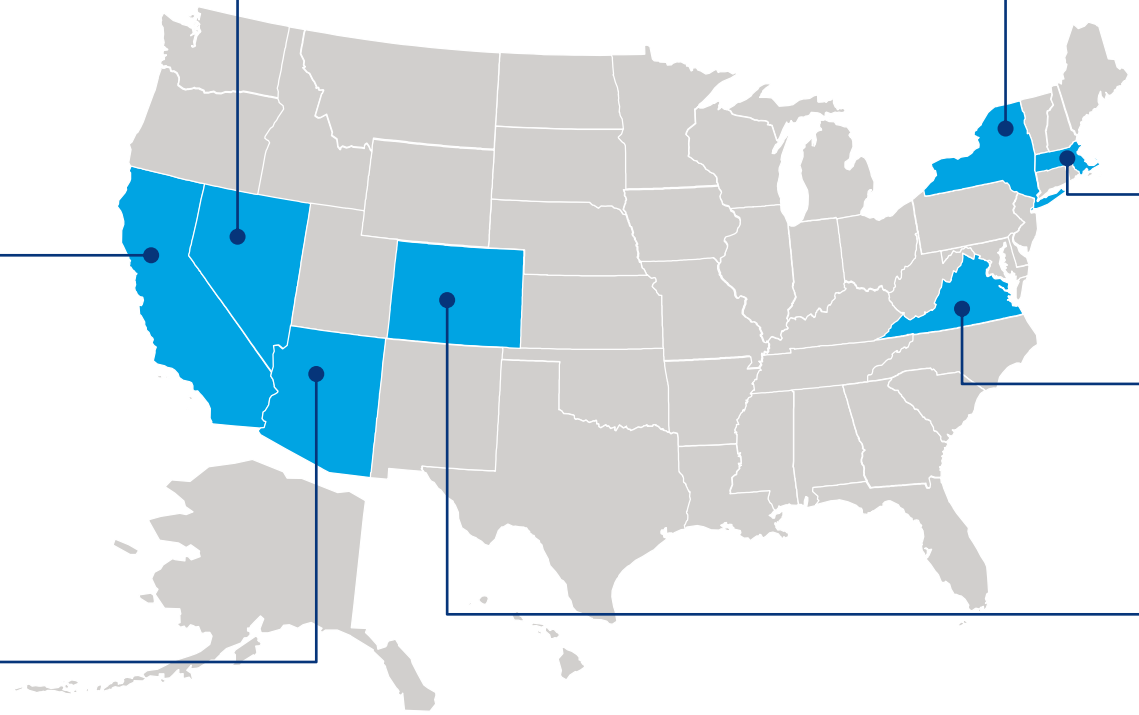
NV Energy launched a storage incentive for both residential and non-residential systems.

California

The **California Building Standards Commission** issued new fire code regulations that greatly impact non-residential storage deployments. The **GHG Working Group** issued a report outlining proposals for the GHG signal under SGIP. **CPUC** denied a proposal for changes to metering requirements of NEM generating facilities with paired storage; it also approved 175 MW worth of storage contracts split between SCE and PG&E. **Governor Brown** signed SB 700 into law, which reauthorizes the Self-Generation Incentive Program through the end of 2025.

Arizona

APS announced its Storage Rewards program to support adoption of residential storage in its territory.



New York

Governor Cuomo announced $40 million under the NY-Sun program to support storage deployment. **NY PSC** accepted environmental review of the state's storage roadmap.

Massachusetts

The state's **Department of Public Utilities** issued the order finalizing the SMART program..

Virginia

Virginia Department of Mines, Minerals and Energy issued an RFP to evaluate the benefits of storage for the state.

Colorado

Xcel Energy published its 2019/2020 Demand-Side Management Plan, which includes a residential storage demand response pilot.

Federal

Senators Scott and Bennet sent a letter to Treasury Secretary Mnuchin seeking additional clarity on Investment Tax Credit eligibility for storage systems.

Source: Wood Mackenzie Power & Renewables

FERC 841 compliance requirements

The foundational elements of the order were designed to ensure a level playing field for storage

FERC order 841, required ISOs and RTOs to modify their participation rules to ensure energy storage is eligible to participate in all organized electricity markets. The new rules, with four key areas highlighted below, ensure that storage will be competing without a market handicap, as was identified by FERC. The requirements ranged from the relatively simple, such as requiring minimum size requirements lower at 100 kW than is common, to the complex, primarily designing or defending participation models for energy storage and ensure tariffs accommodate the technology directly while acknowledging the ways storage is different. ISOs generally adopt a “technology agnostic” approach, which they say underpins the foundation of their competitive markets by not giving any technology a leg up, but FERC rules that this approach, when applied too broadly to energy storage, does not take into account the technologies unique nature, and must be changed, at least in this one specific example.

Ensure that a resource using the participation model for electric storage resources in an RTO and ISO market is **eligible to provide all capacity, energy and ancillary services** that it is technically capable of providing

Ensure that a resource using the participation model for electric storage resources can be **dispatched and can set the wholesale market clearing price as both a wholesale seller and wholesale buyer** consistent with rules that govern the conditions under which a resource can set the wholesale price.

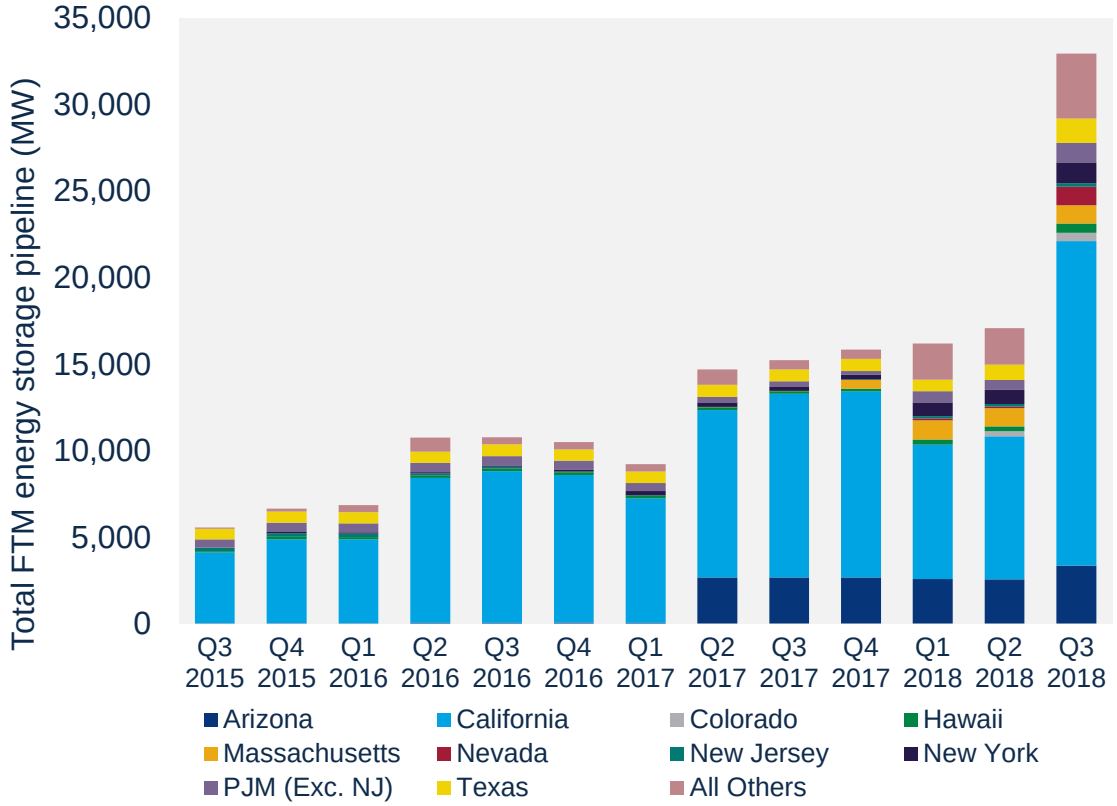
Account for the **physical and operational characteristics** of electric storage resources through bidding parameters or other means.

Establish a minimum size requirement for participation in ISO markets that does **not exceed 100 kW**. Also requires that the sale of electric energy from ISO markets to an electric storage resource that the resource then resells back to those markets must be at the **wholesale locational marginal price**.

U.S. front-of-the-meter pipeline nearly doubles

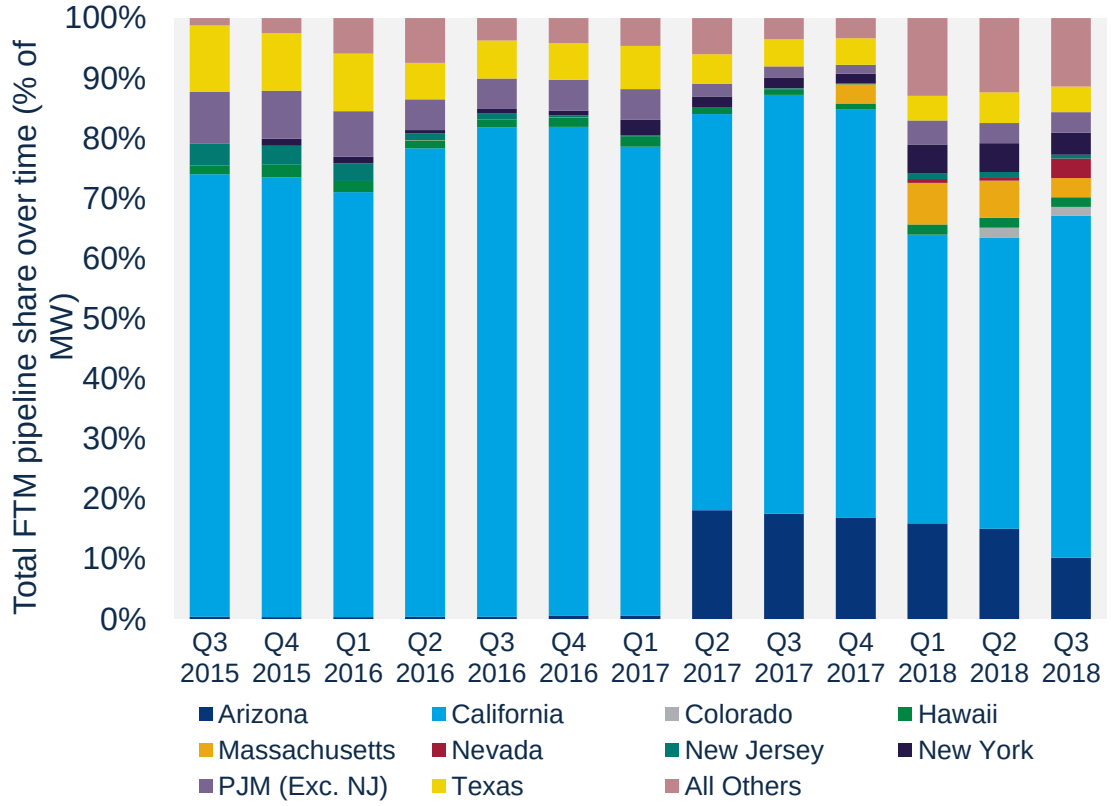
CAISO and SPP interconnection queues drive the lion's share of new speculative projects

U.S. front-of-the-meter energy storage pipeline by market, Q3 2015-Q3 2018 (MW)



Source: Wood Mackenzie Power & Renewables

U.S. front-of-the-meter energy storage pipeline market share, Q3 2015-Q3 2018 (%)



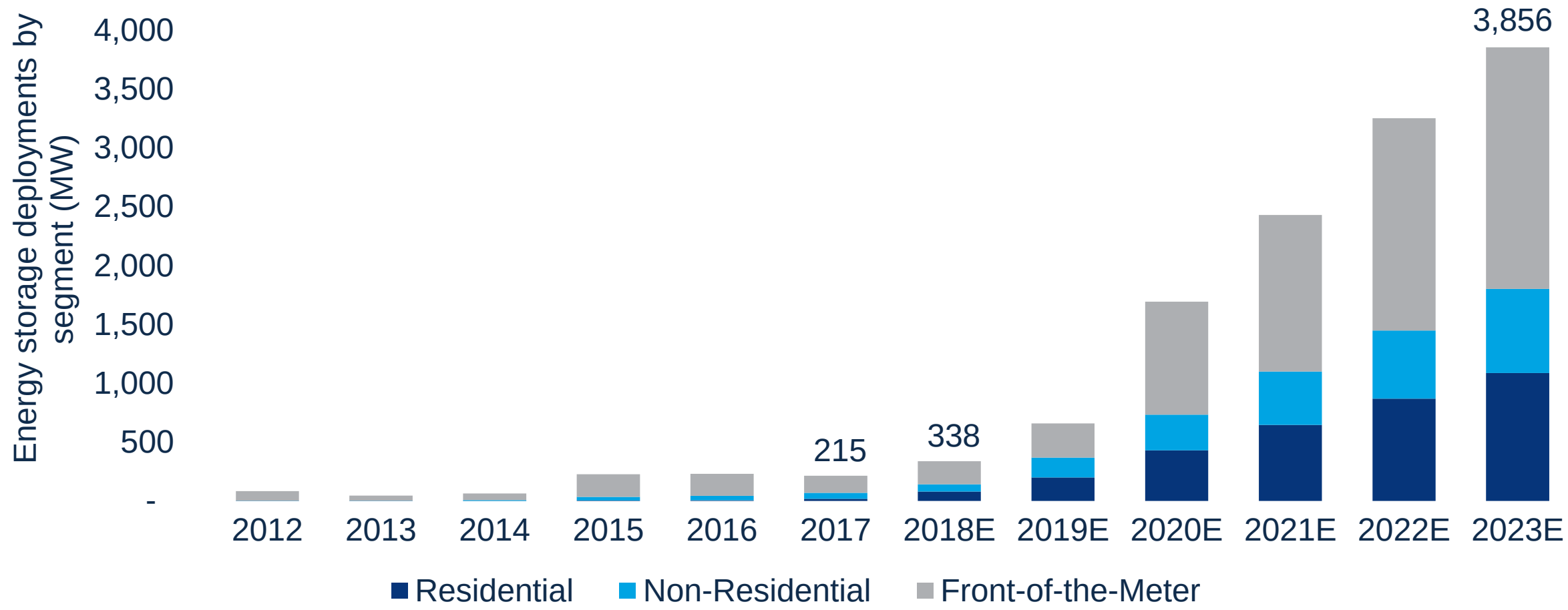
Source: Wood Mackenzie Power & Renewables

4. Outlook

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)

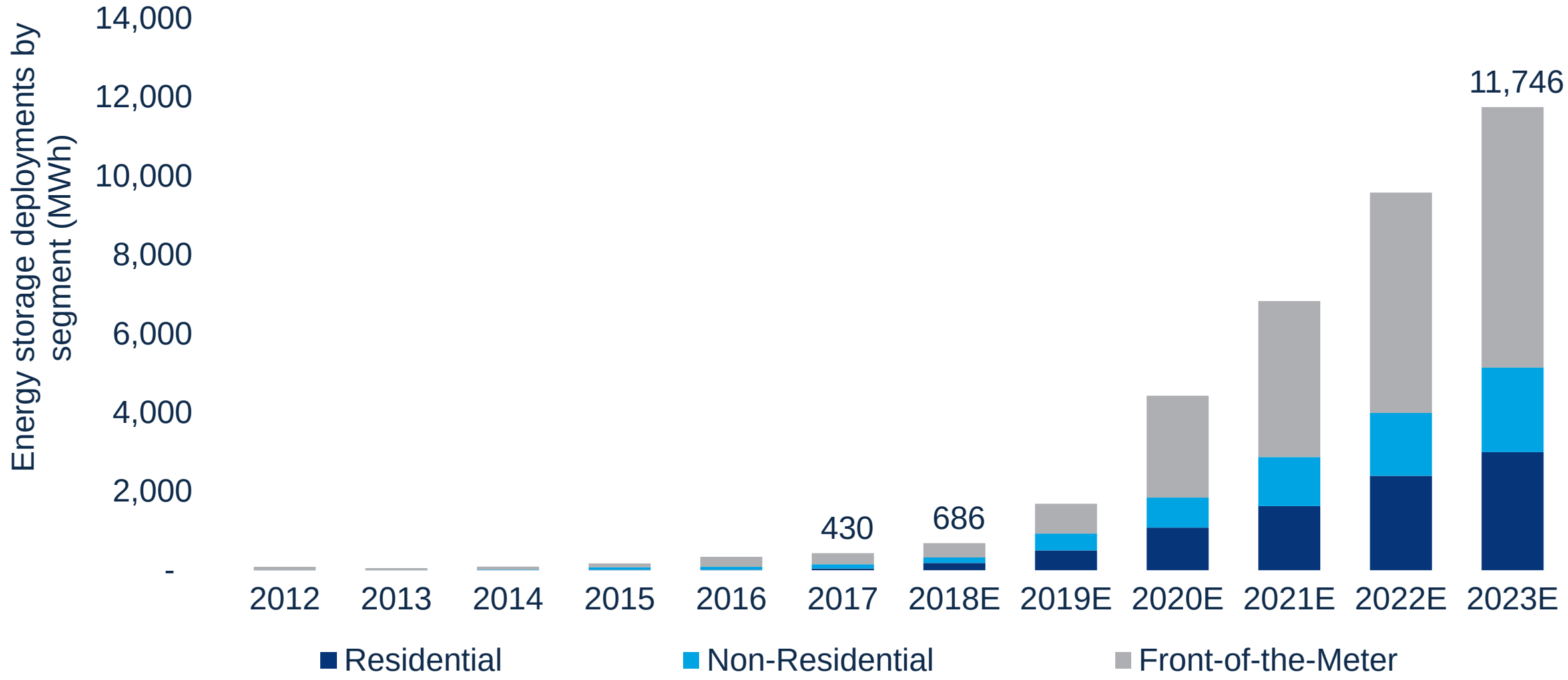


Source: Wood Mackenzie Power & Renewables

U.S. market will reach nearly 12 GWh in annual deployments by 2023

4-hour systems becoming the norm for front-of-the-meter systems; average BTM durations inch toward 3 hours

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

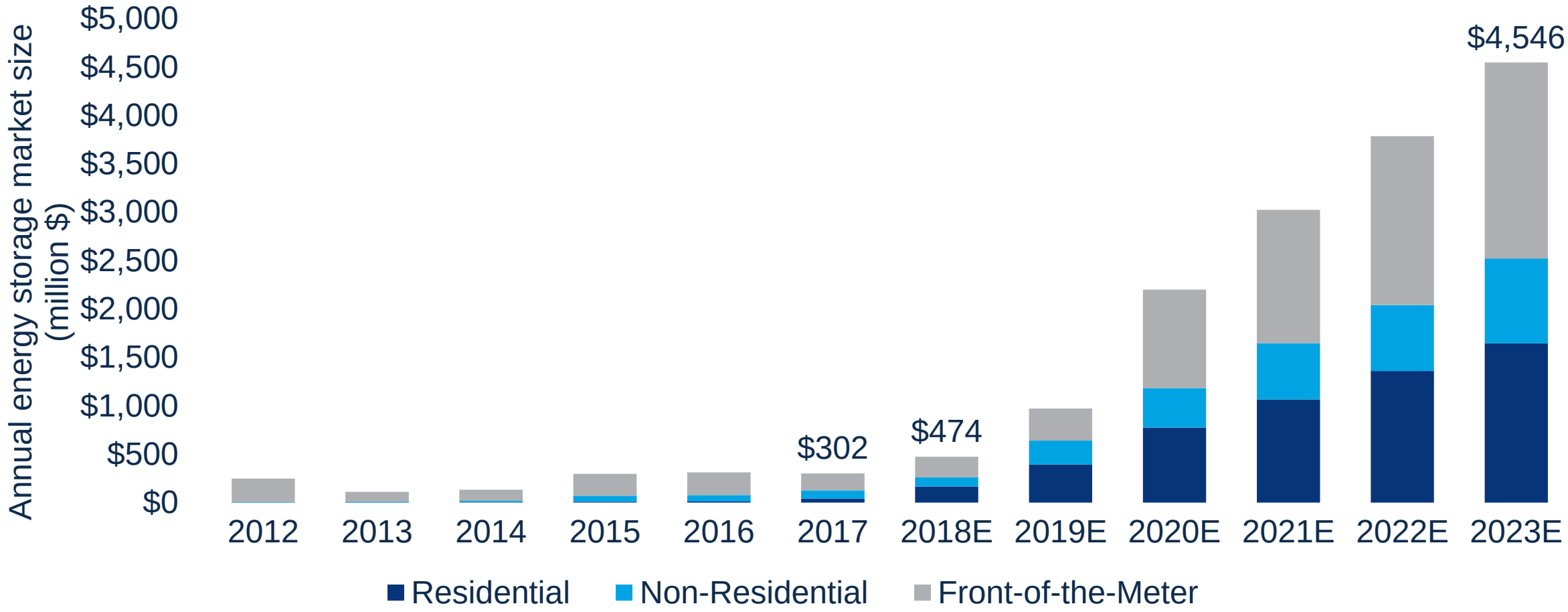


Source: Wood Mackenzie Power & Renewables

U.S. energy storage will be a $4.5 billion market in 2023

Value set to double between 2018 and 2019 and then again from 2019 into 2020

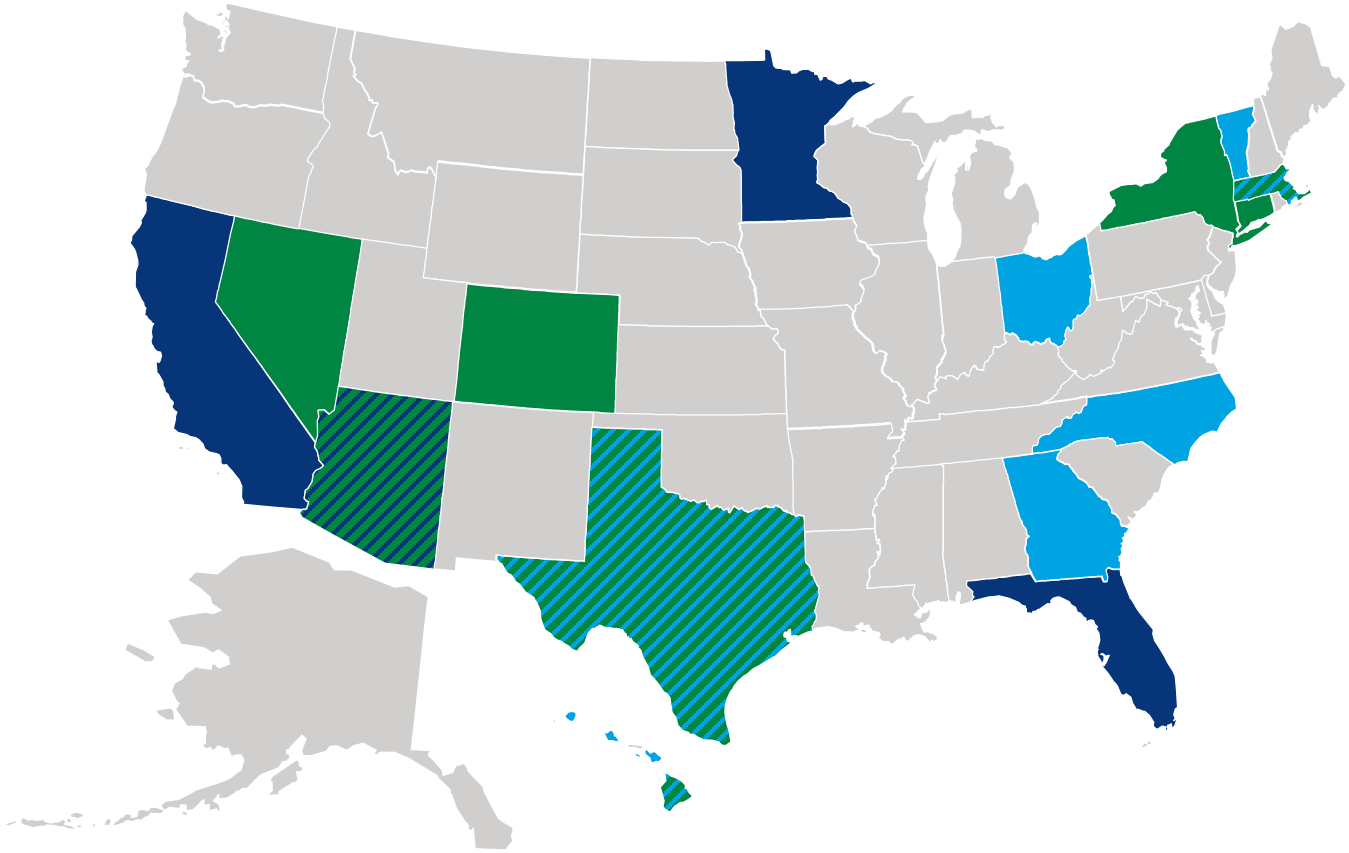
U.S. annual energy storage market size, 2012-2023E (million $)



Source: Wood Mackenzie Power & Renewables. Note: Market size is reported as energy storage system deployment revenues (product of deployments and installed system prices).

5. Trends to watch for 2019 and beyond

Solar-plus-storage deployments driven by utilities in the front-of-the-meter space and incentives behind-the-meter



135 MW of FTM energy storage in the US is solar-paired.

- 6 states (including Puerto Rico) have more than **10 MW** of solar-paired storage.
- 6 more have **1 MW** or more.
- Eight states have more than **547 MW** of solar-paired storage contracted or under procurement

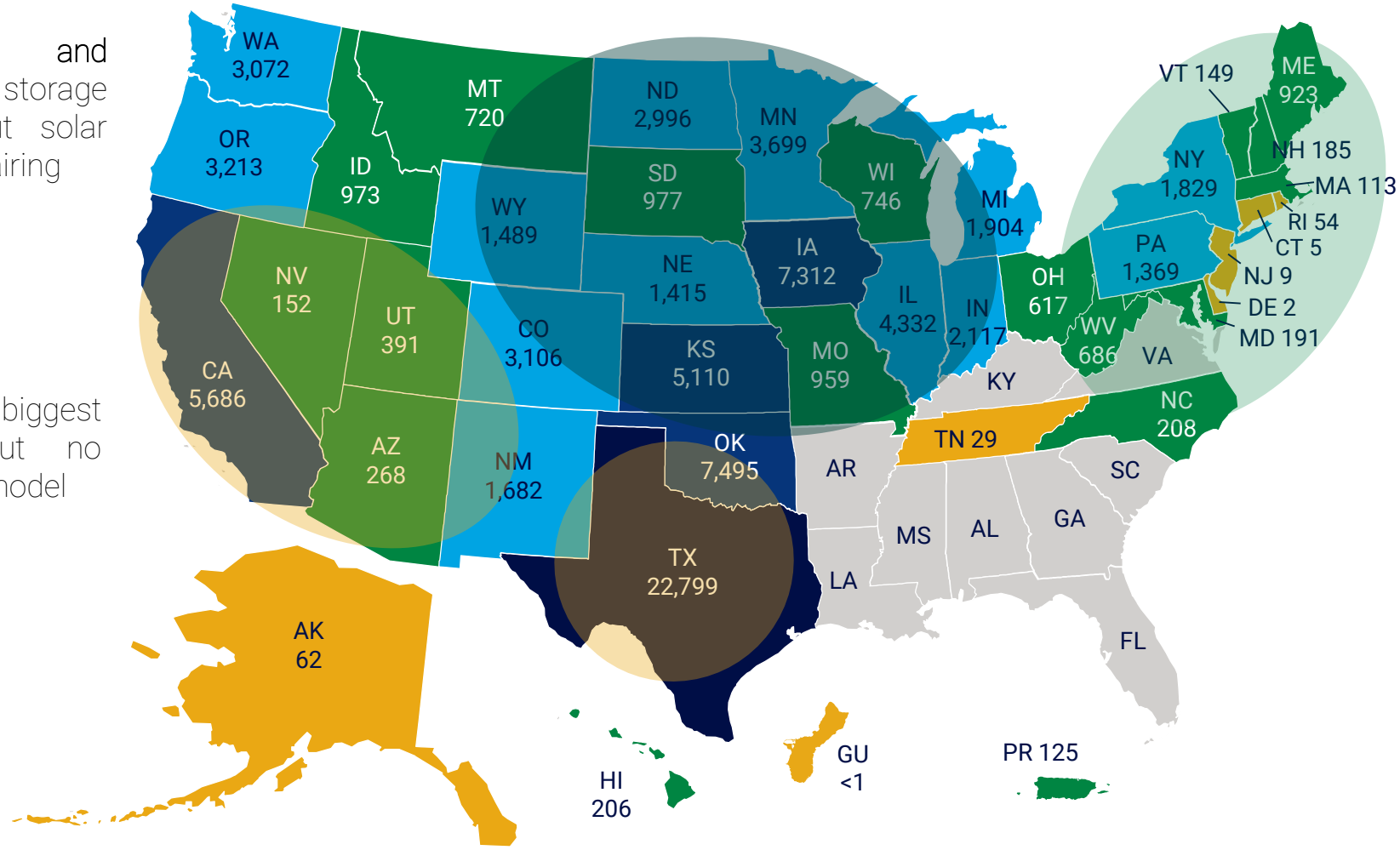
Solar-plus-storage's reach is widening, but much of its value outside incentive states is contingent on the ITC

Source: Wood Mackenzie Power & Renewables

Where will the opportunity emerge for wind-plus-storage?

California and Southwest – storage investment, but solar remains best pairing

Texas – biggest opportunity, but no clear business model



Northeast – storage mandates, clean peak, new offshore wind, large opportunity

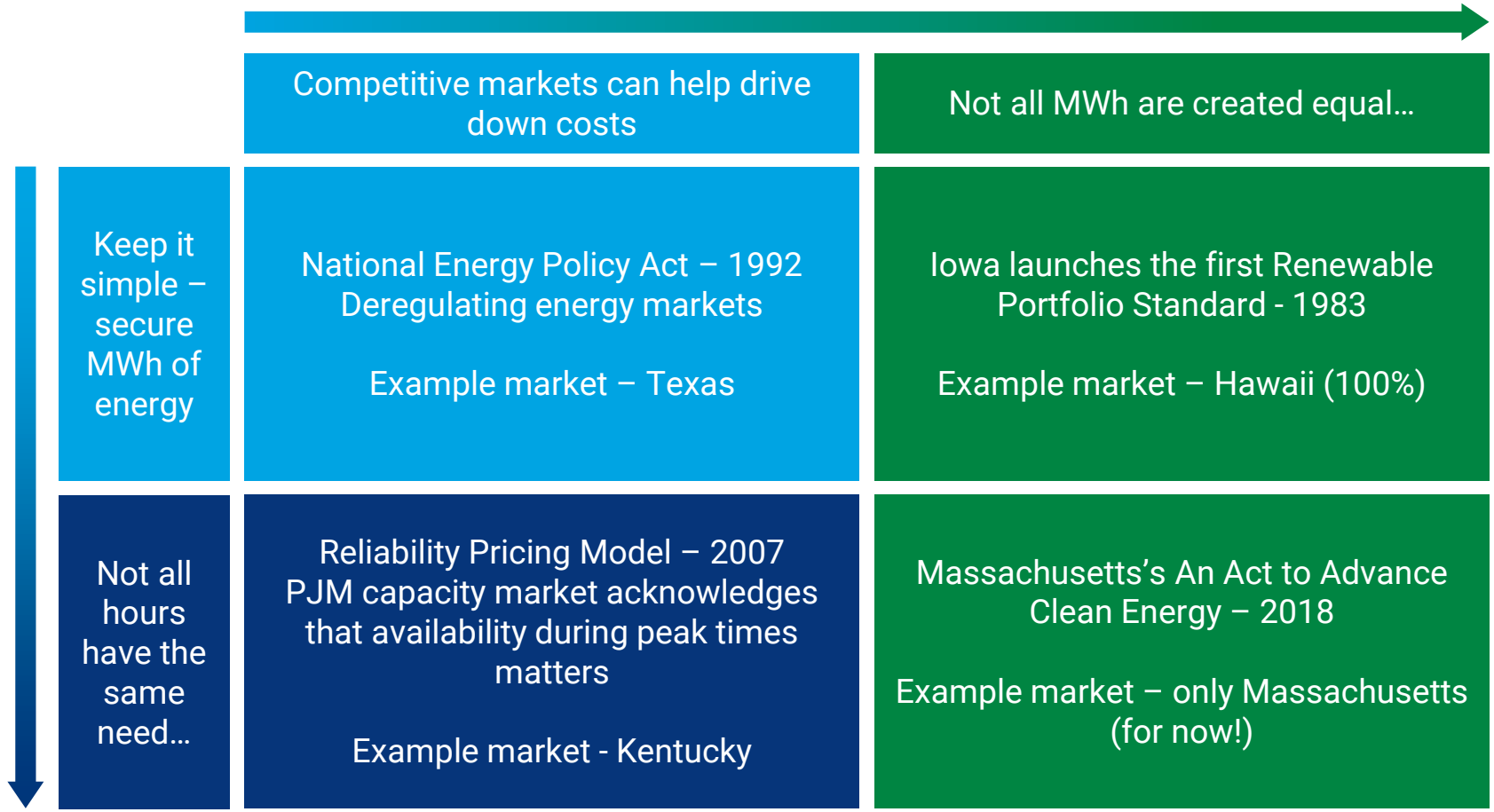
Midwest – excellent wind resource, few incentives for storage

- 0 to 100MW
- > 100MW to 1,000MW
- > 1,000MW to 5,000MW
- > 5,000MW to 10,000MW
- > 10,000MW

Source: Wood Mackenzie Power & Renewables, installed wind data AWEA

The new foundation for hybrid energy storage systems – recognizing value

True value for hybrid storage systems lies at the intersection of green policy and system needs



- **As you move in either direction, either towards valuing renewables, or valuing delivery during peak hours, storage's value increases.**
- **As you move in *both* directions, valuing renewables during certain hours, storage's value increases exponentially.**
- **The clean peak standard, if it becomes a model as capacity markets and the RPS did, could drive massive storage growth.**

Q&A

Thank you for attending our webinar

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