Electricity Storage for the Provision of Flexibility in Power Systems

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Power system flexibility has become a global priority

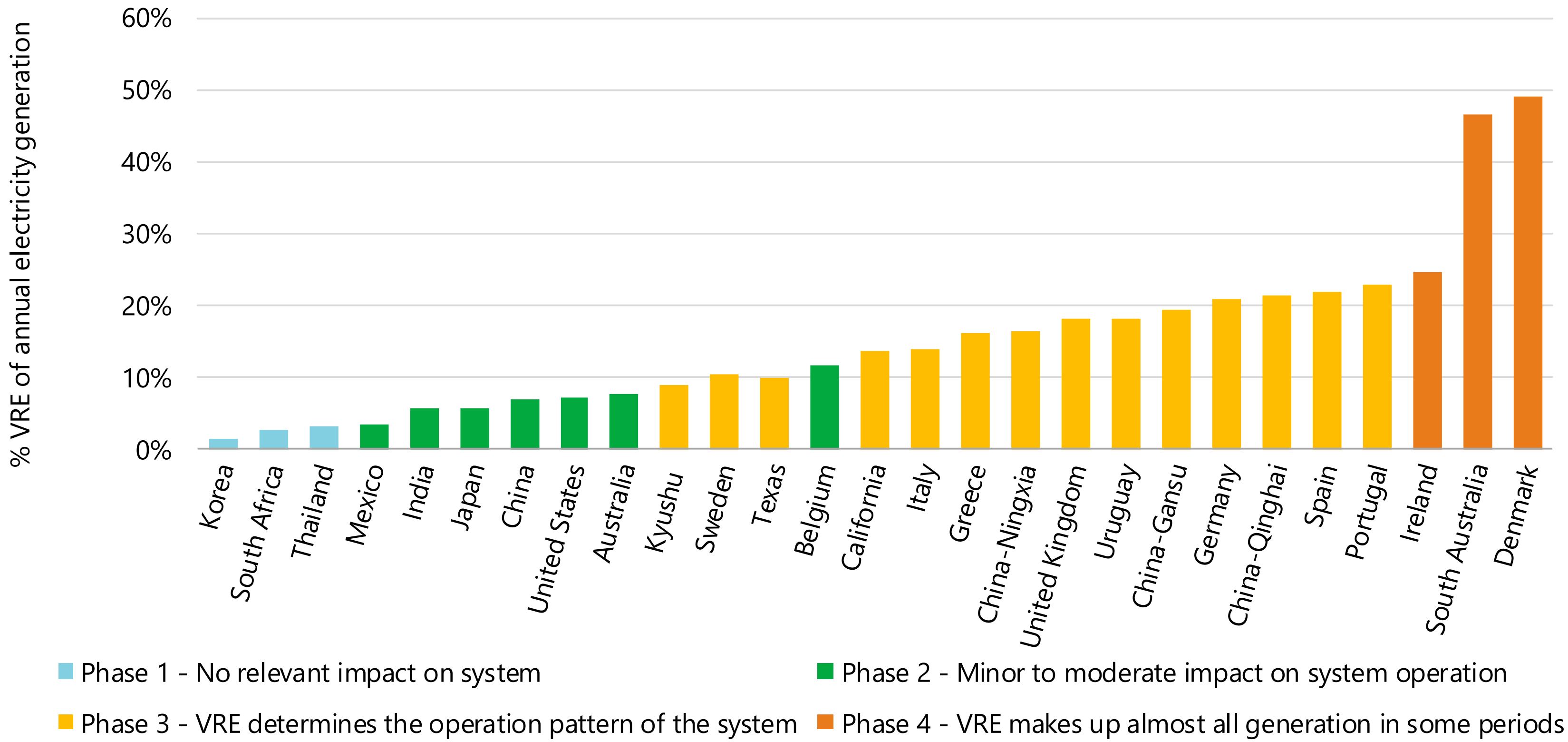
The ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply.

	Short-term flexibility			Medium-term flexibility	Long-term flexibility	
Timescale	Subseconds to seconds	Seconds to minutes	Minutes to hours	Hours to days	Days to months	Months to years
Issue	Address system stability, i.e. withstanding large disturbances such as losing a large power plant.	Address fluctuations in the balance of demand and supply, such as random fluctuations in power demand.	Manage ramps in the balance of supply and demand, e.g. increasing electricity demand following sunrise or rising net load at sunset.	Decide how many thermal plants should remain connected to and running on the system.	Manage scheduled maintenance of power plants and larger periods of surplus or deficit of energy, e.g. hydropower availability during wet/dry season.	Balance seasonal and inter-annual availability of variable generation (often influenced by weather) and electricity demand.

Source: 21st Century Power Partnership and International Energy Agency. (2018). Status of Power System Transformation 2018: Advanced Power Plant Flexibility.

Power system flexibility requirements are primarily driven by variable renewable energy (VRE) deployment

Different levels of VRE penetration require an evolving approach to providing power system flexibility



Source: 21st Century Power Partnership and International Energy Agency. (2019). Status of Power System Transformation 2019.

Flexibility is primarily considered to help meet “residual load”

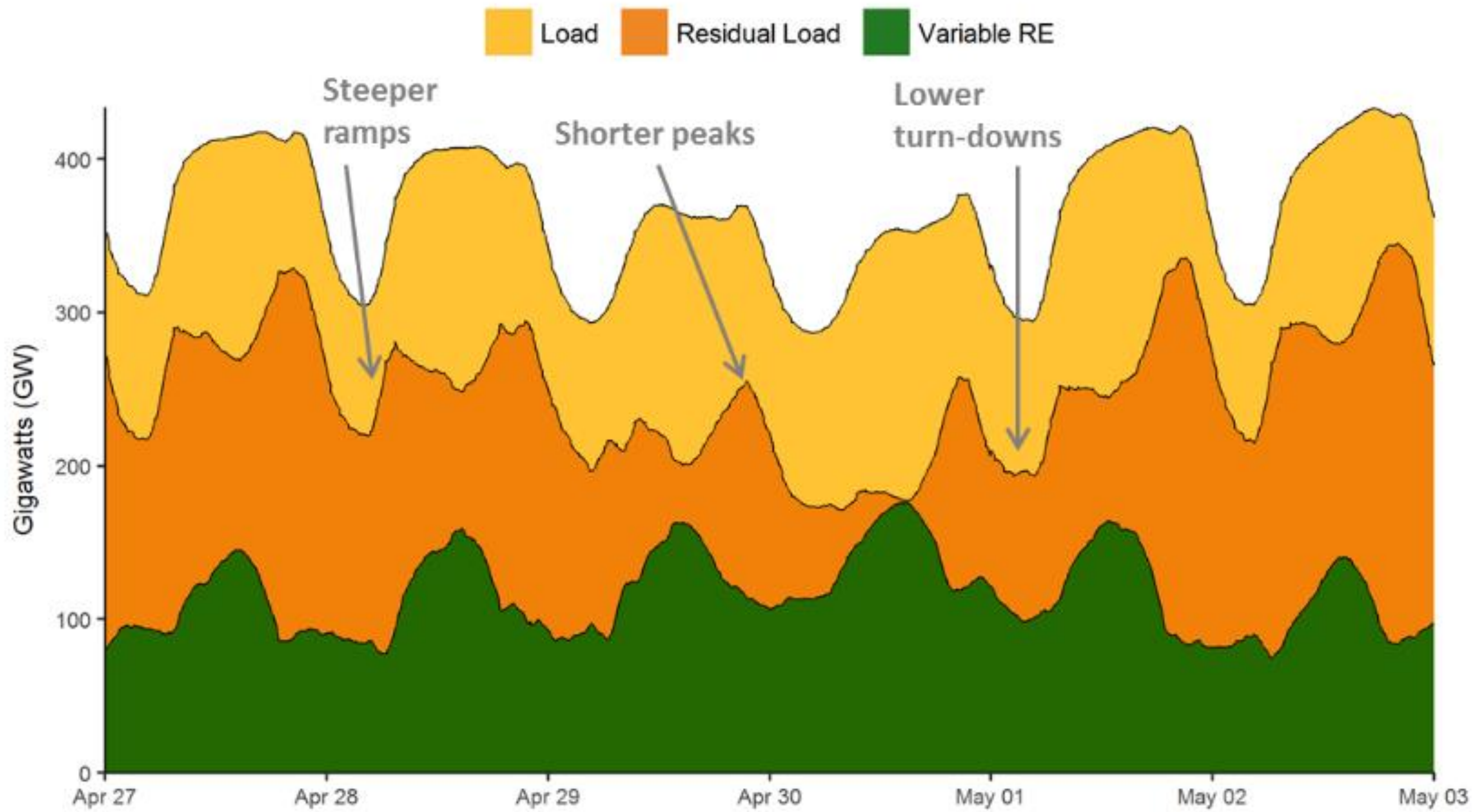
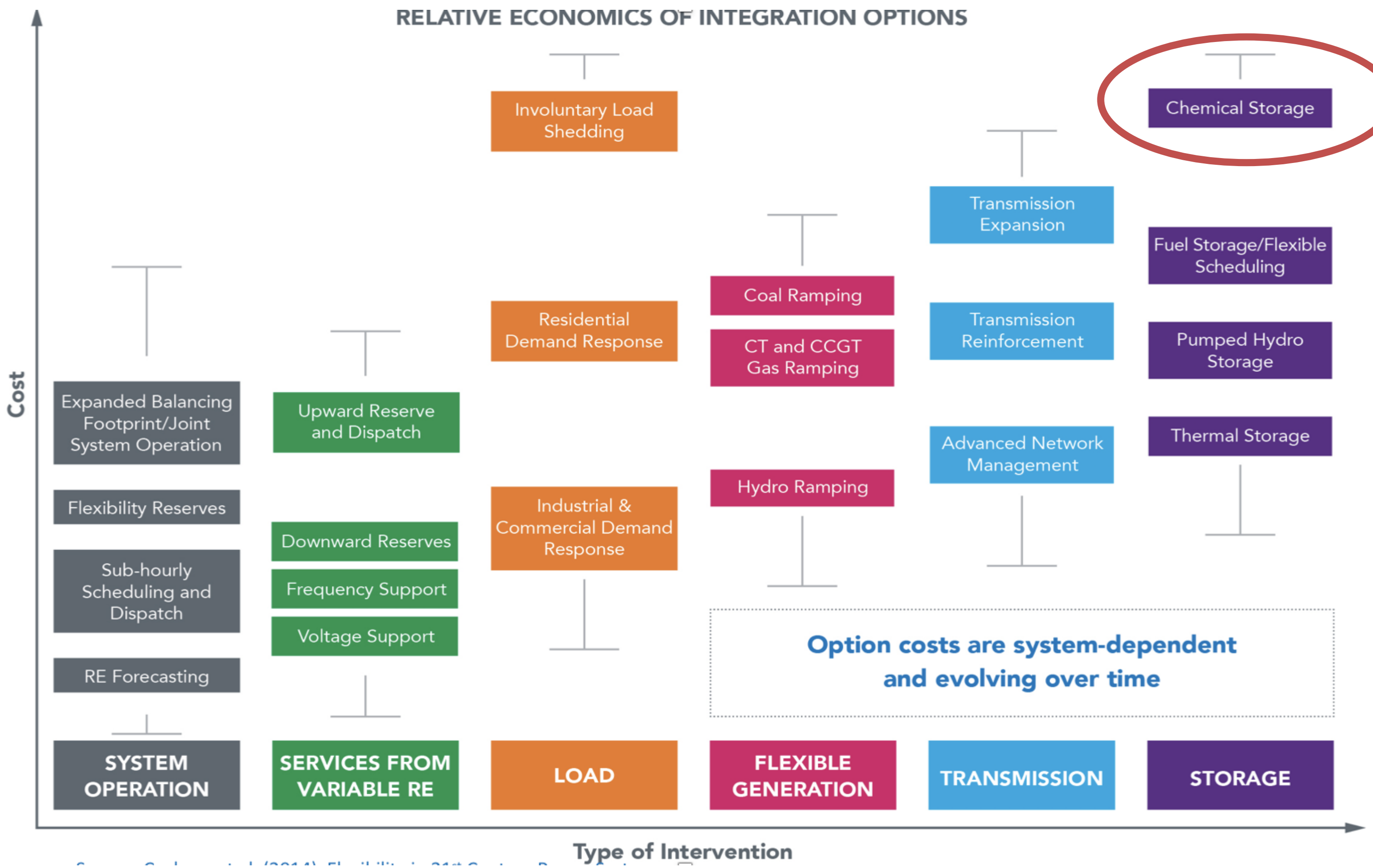


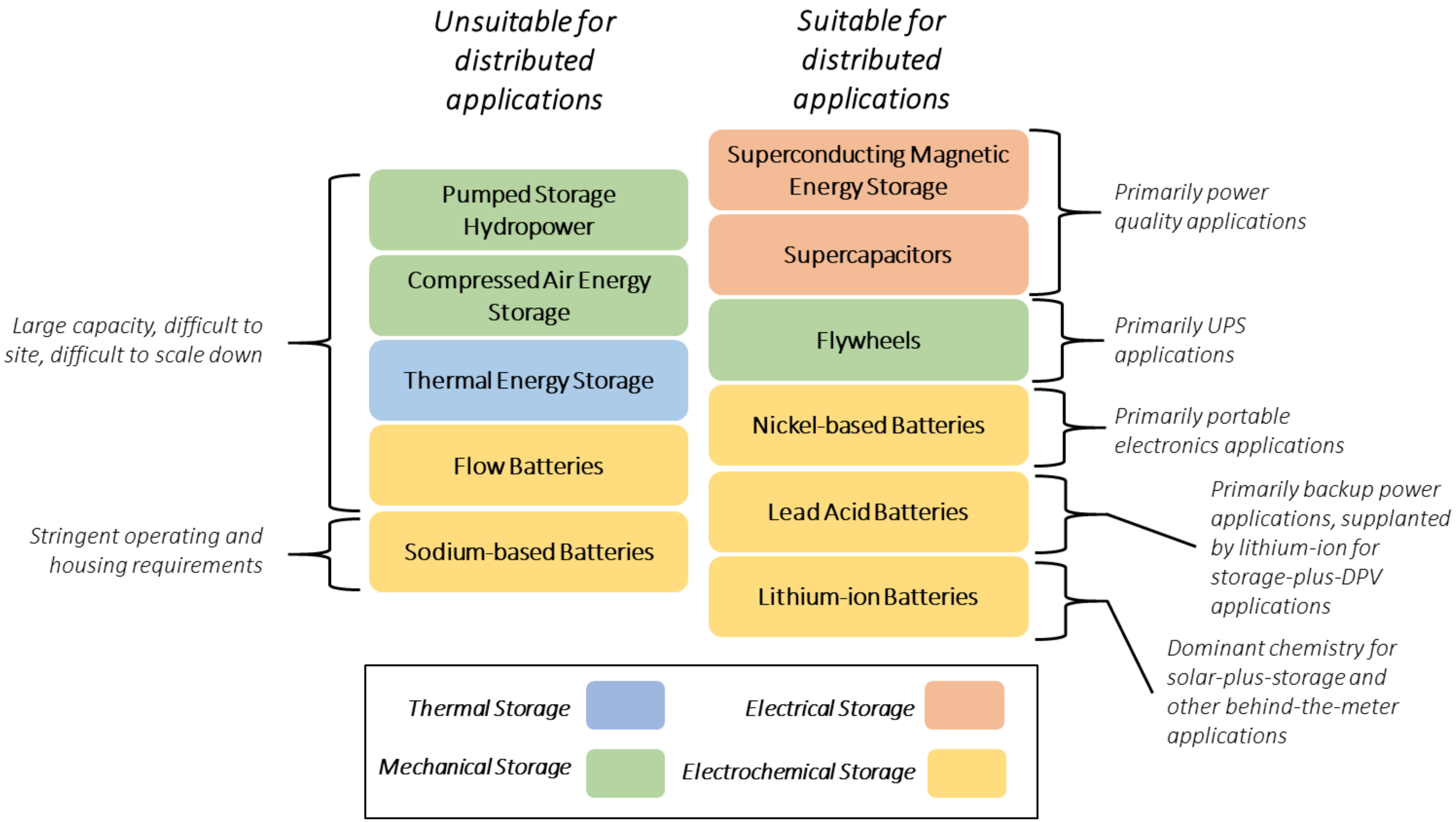
Figure source: NREL Report No. FS-6A20-63039

All power system assets can provide flexibility services if enabled by proper policy, market and regulatory frameworks



Source: IEA-RETD. (2016). RE-TRANSITION.

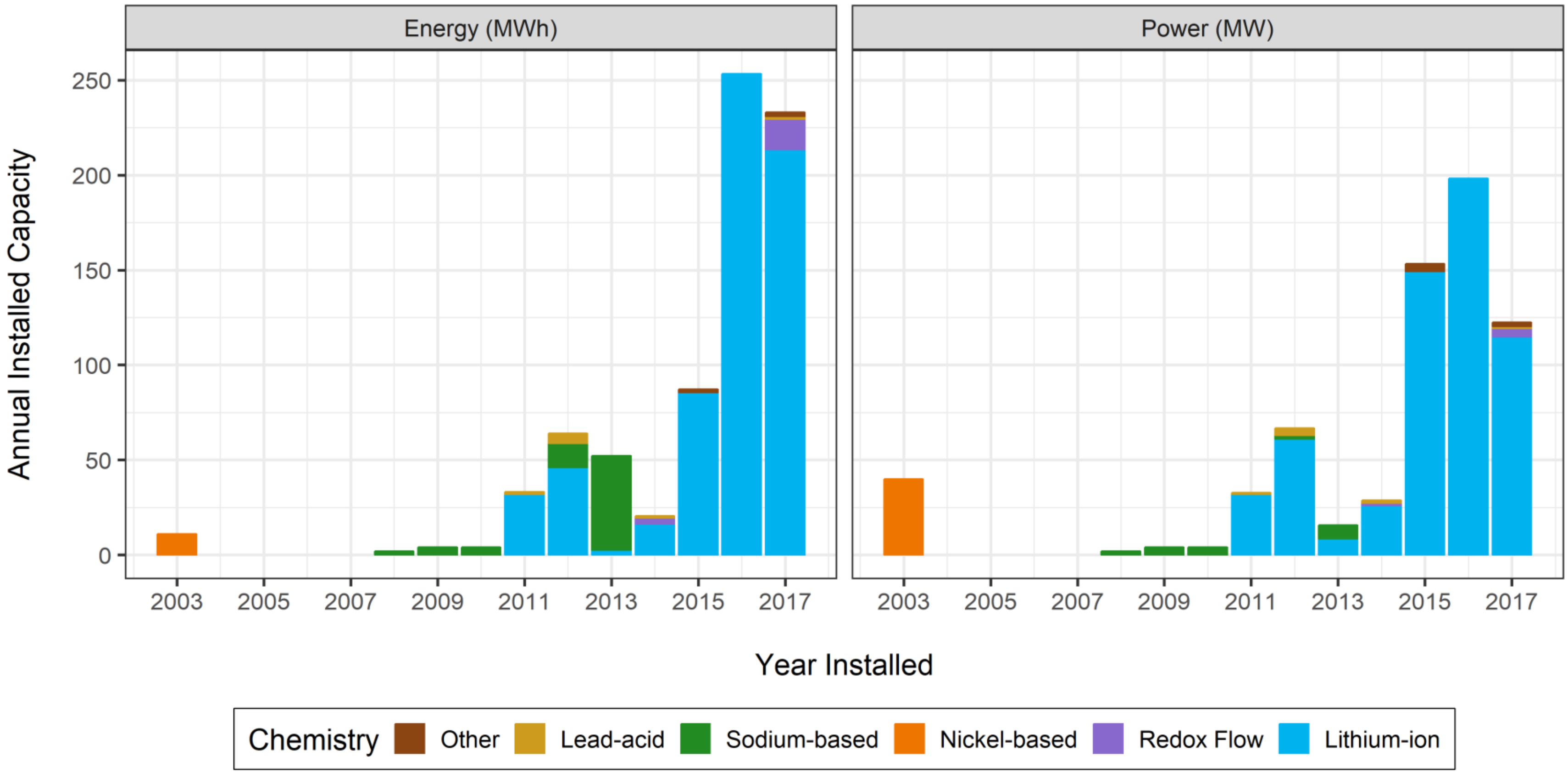
The Broader Storage Ecosystem



Source: Zinaman et al. (Forthcoming). An Overview of Behind-the-meter Storage-plus-DPV Regulatory Issues. NREL Technical Report.

Lithium-ion battery deployment dominates the electrochemical energy storage market in the U.S.

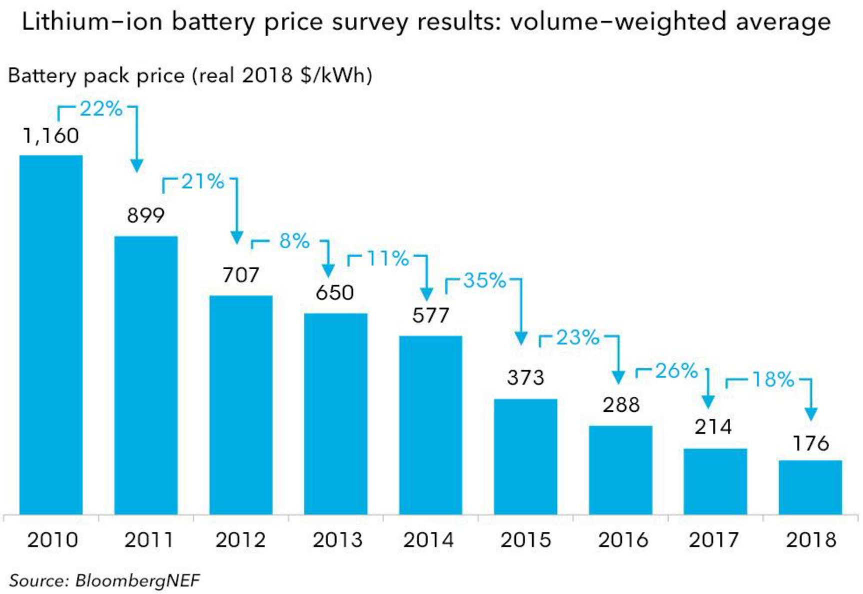
Annual utility-scale electrochemical storage deployments in the U.S., by chemistry



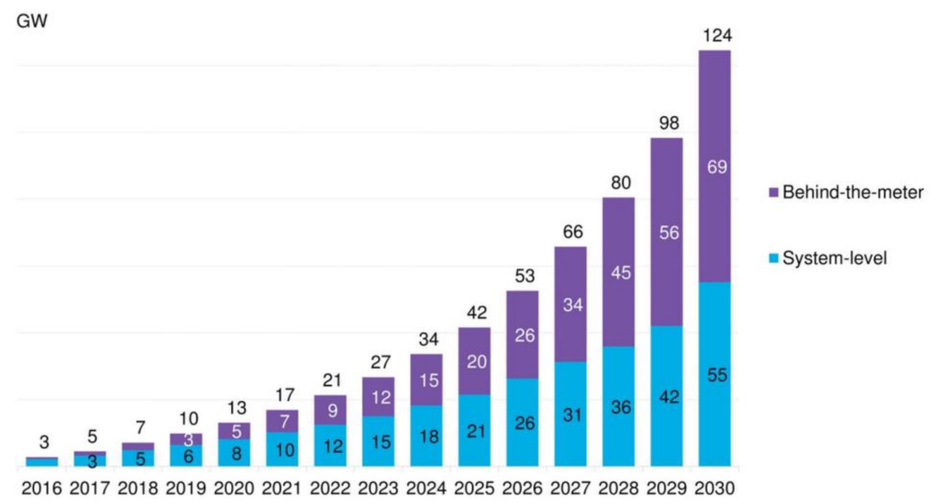
Source: U.S. Energy Information Administration, Form EIA-860, *Annual Electric Generator Report*

Lithium-ion Batteries: Why all the hype?

Lithium-ion battery price survey, 2010-18 ($/kWh)
Source: Bloomberg New Energy Finance (March 2019)



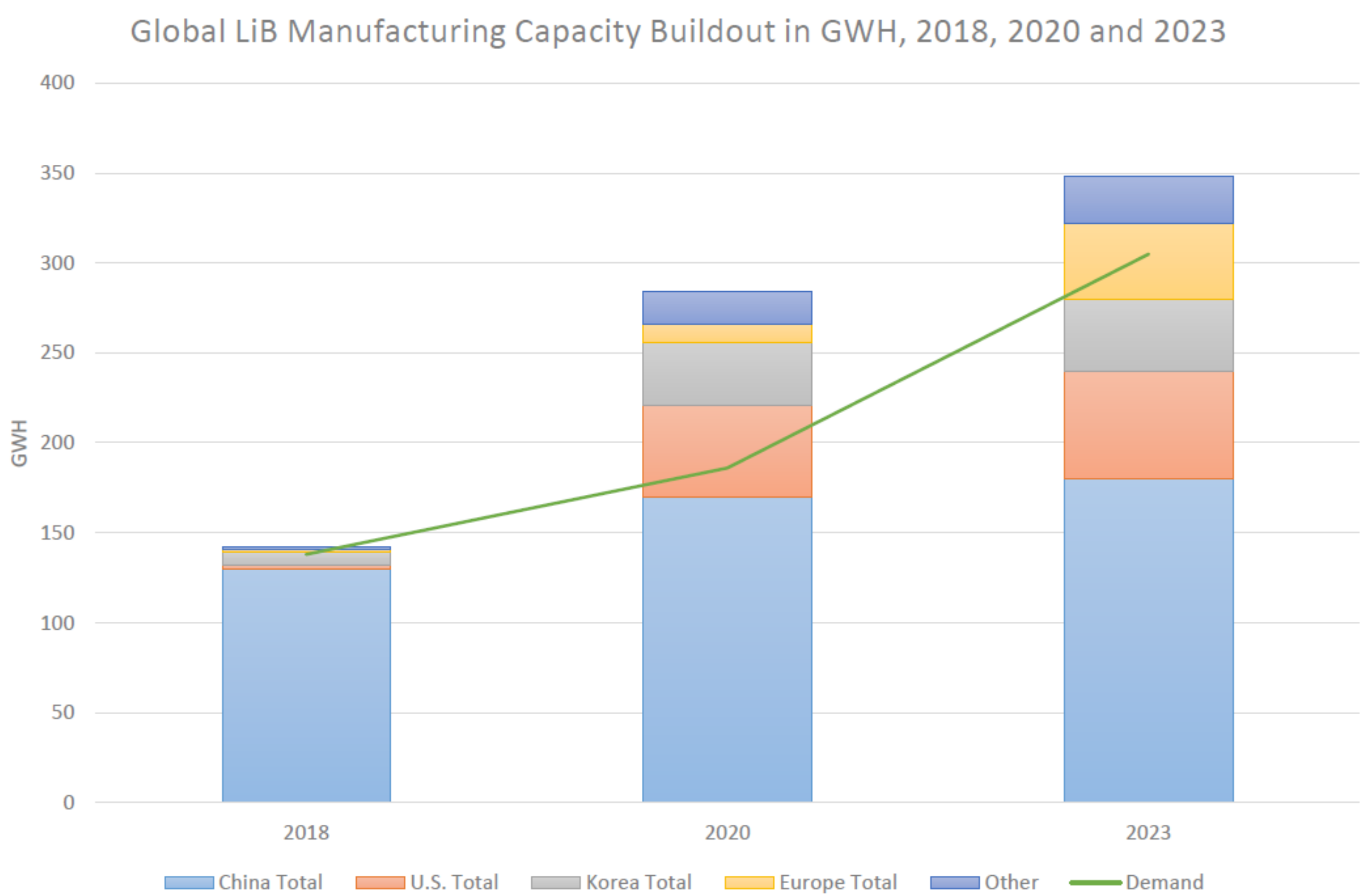
Projected Cumulative Global Storage Deployment 2016-30 (GW)
Source: Bloomberg New Energy Finance (November 2017)



85% cost reduction since 2010 due to technology improvements, economies of scale, manufacturing competition

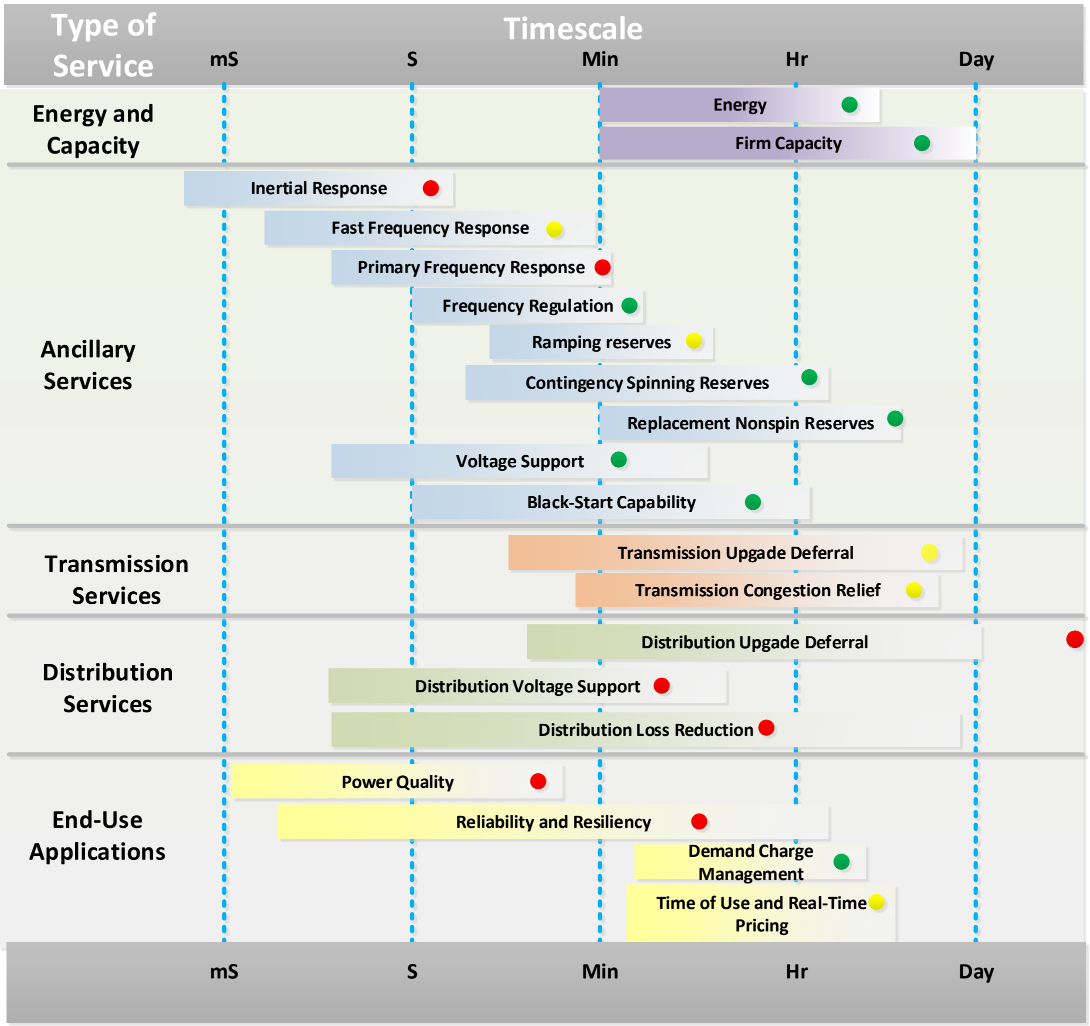
Similar trajectory to PV deployment in early 2000s

Global manufacturing capacity is expected to more than double in the near-term



Source: Cairn ERA.

Battery energy storage applications and value streams



- Many possible business cases
- **Value stacking** can be an important strategy
- Services must be monetizable
- Market/regulatory barriers tend to constrain use cases

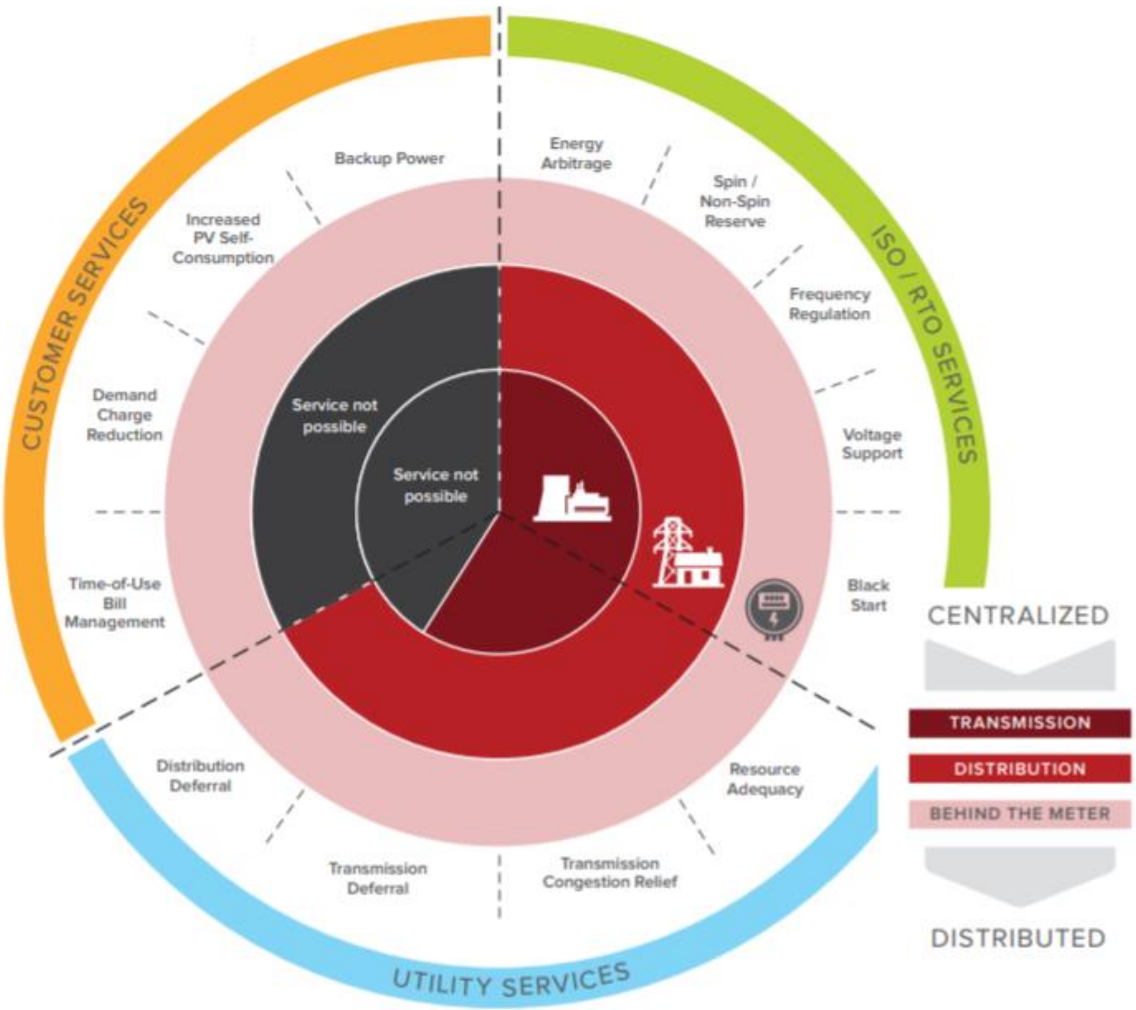
Services currently valued in some markets

Proposed or early adoption services

Currently not valued services

Source: Denholm, P. (2019). *Utility-Scale Battery Storage: When, Where, Why and How Much?* Greening the Grid Webinar.

Location matters!



Source: Rocky Mountain Institute.

COMMON STORAGE USES CASES FOR THE PROVISION OF FLEXIBILITY

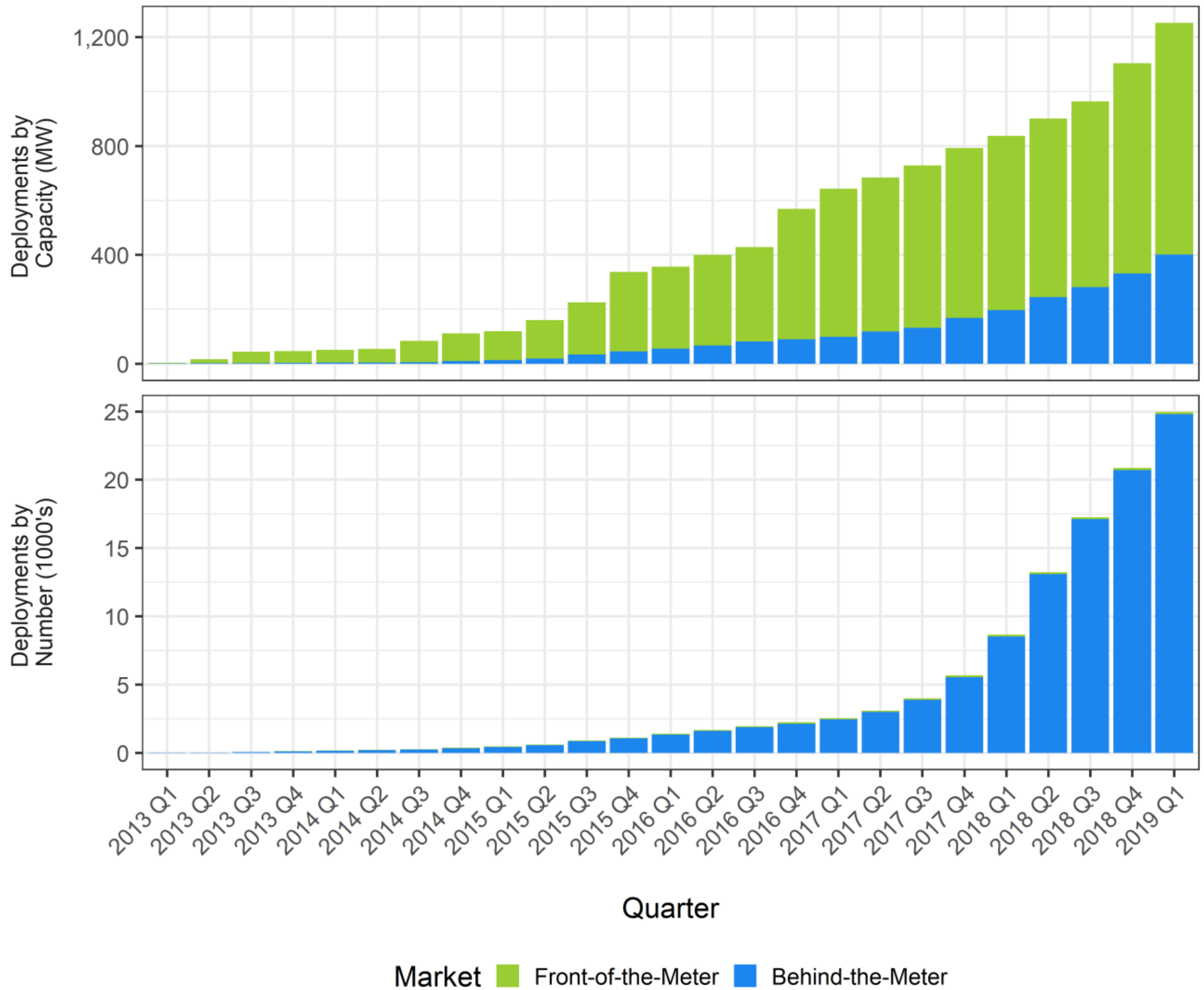
Storage is increasingly cost-competitive for:

- individual retail customer bill reductions
- short-duration ancillary services
- longer duration applications that include a combination of capacity, energy and transmission services
  - Key Concept: "Value Stacking"

Use Case: Behind-the-Meter Storage

Source: Sun Valley Solar

U.S. Behind-the-Meter Storage Deployment

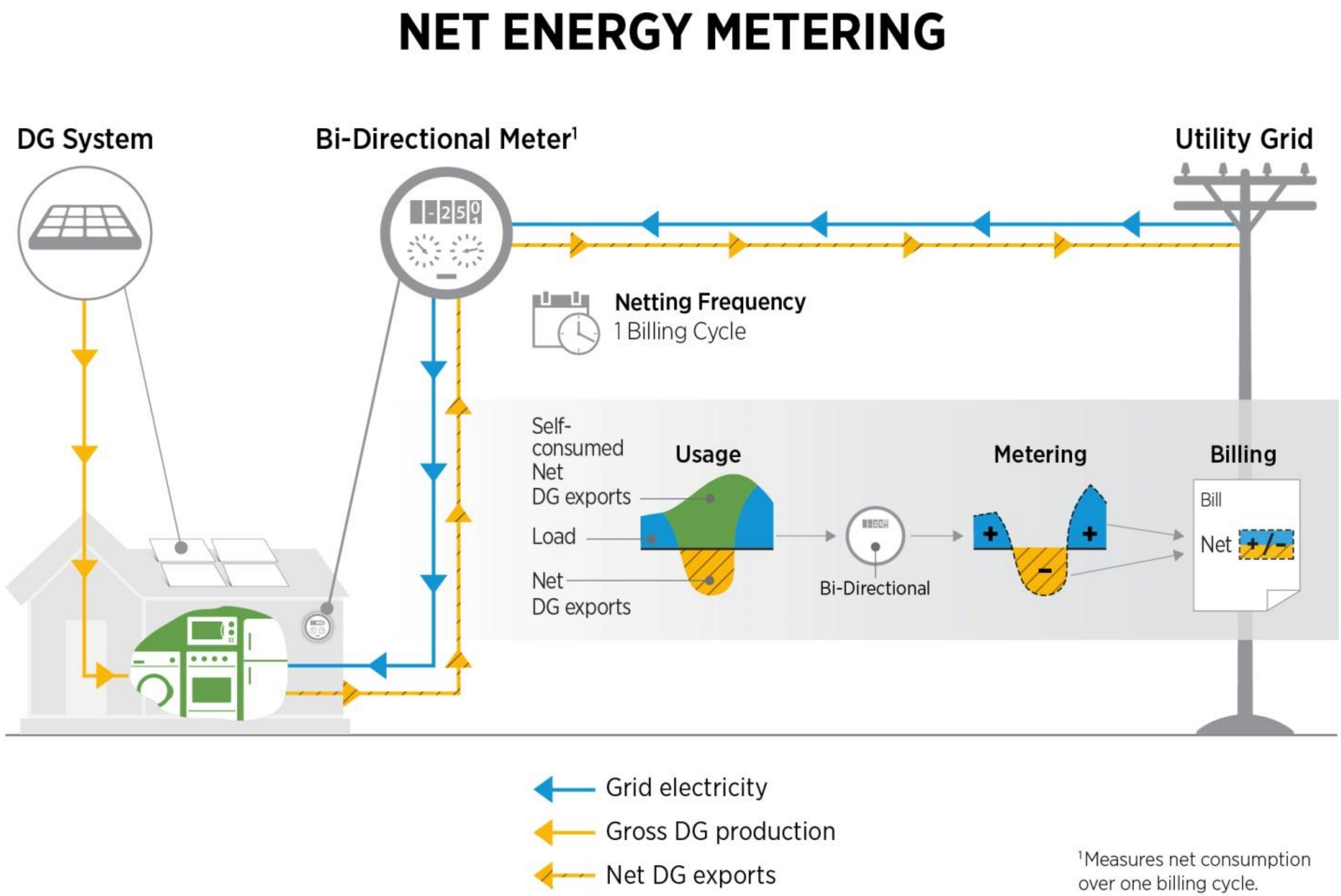


Source: Wood Mackenzie U.S. Storage Monitor. (2019).

Are behind-the-meter batteries providing flexibility services?

- Today: Activating flexibility from BTM batteries requires smart retail tariff design
  - Use of **Time-of-Use Rates** or **Demand Charges** introduces economic signal to shift load
    - Rates must be well-designed to reflect real-time conditions (advanced metering infrastructure and billing required)
    - Tension between a desire for tariff simplicity and tariff cost-reflectivity (i.e., complexity)
- Tomorrow: Aggregation schemes hold promise but are still being piloted (more later)

Net Energy Metering Review



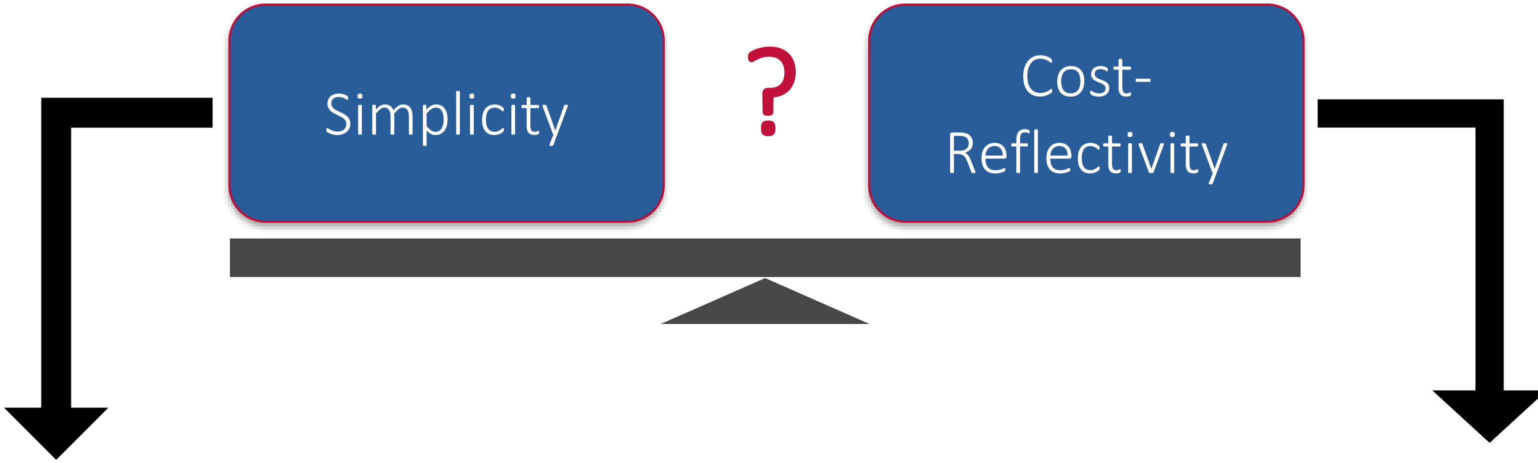
Source: Zinaman et al. (2018). Grid-connected Compensation Mechanism Basics. NREL Technical Report.

The Economics of Storage-plus-DPV under NEM

- NEM with typical time-invariant rates:
  - **grid is effectively a free-to-access financial battery**
  - minimal economic benefit for storage-plus-DPV
  - some reliability benefit, if valued

- NEM with Time-of-Use or Demand-based charges
  - **may be significant incentive** to install storage by exporting / avoiding consumption during peak periods
  - This is valuable to power system to provide flexibility if retail rates are sufficiently granular

More cost-reflective retail tariffs can promote equity and innovation – but how much is too much?



Needs:

AMI
Complex
Billing

– ***Less Price Volatility and Risk*** Granularity ***More Price Volatility and Risk*** +

Time-energy	Flat tariff	Seasonal time-of-use (summer/winter)	Daily time-of-use (weekday/weekend)	Intra-daily time-of-use (peak/off-peak hours)	Real-time pricing
Time-demand	No demand charge	Customer peak	Expected system coincident peak, annual	Expected system coincident peak, monthly	Real-time coincident peak
Location	Single price	Zonal disaggregation	Nodal disaggregation	Locational marginal price (LMP)+Txlosses	LMP +Tx/Dx losses

Amended from: Status of Power System Transformation 2017. 21st Century Power Partnership and International Energy Agency.

“Net Metering Integrity” and Grid Interactivity

- For behind-the-meter storage-plus-DPV systems, regulators in leading U.S. states expressing concern with so-called **“Net Metering Integrity”**

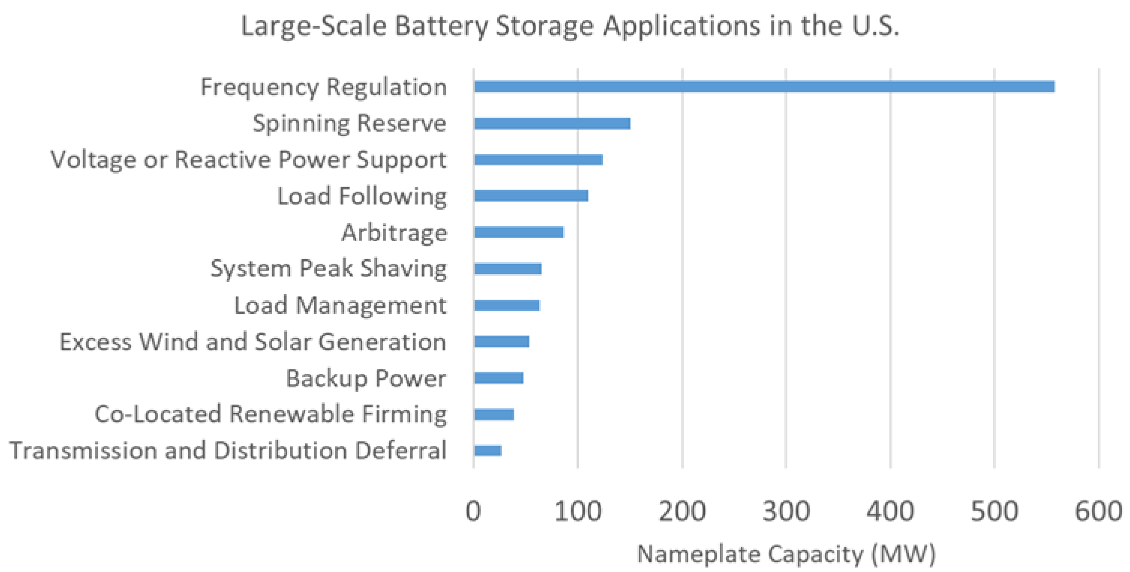
- Net Metering is theoretically granted to eligible generation resources only, not stored grid-supplied electricity that is later exported
  - How do we ensure that NEM kWh credits are only granted to NEM-eligible?

- Related concerns around “arbitrage” activities via time-of-use rates
  - When is arbitrage desirable or undesirable?

- Strategies to ensure Net Metering integrity sometime limit storage charging/export capabilities
  - This may have serious implications for “grid interactivity” and flexibility provision in the future

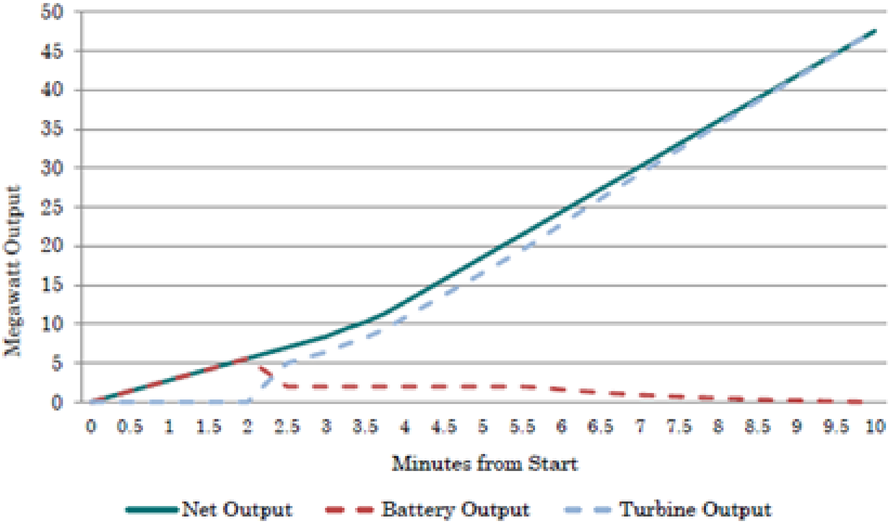
Use Case: Frequency Regulation (Transmission-level)

- Significant deployment for frequency regulation (regulating reserves/ secondary frequency response)
- Often most cost effective early application
  - Short duration requirements
  - High utilization of storage assets



Source: US Energy Information Administration. (2017).

Battery hybridization with conventional power plants



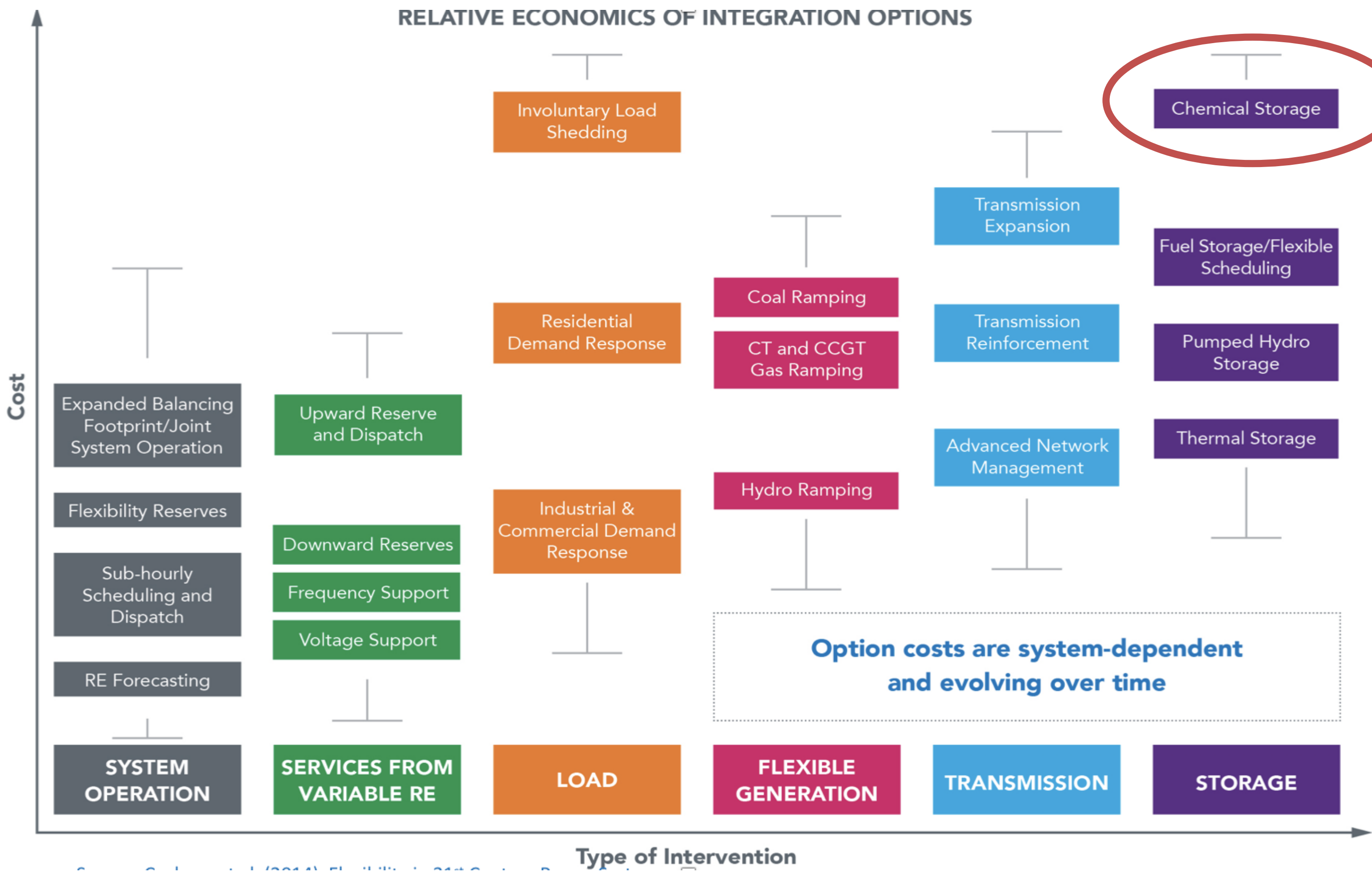
Quick-start capability of hybrid facility

Source: International Energy Agency

Southern California Edison hybrid battery storage, gas turbine peaker system

Pairing battery electricity storage systems with peaking plants can allow for the provision of spinning reserves without the power plant actually running.

Myth: Storage is needed to integrate renewables in all cases

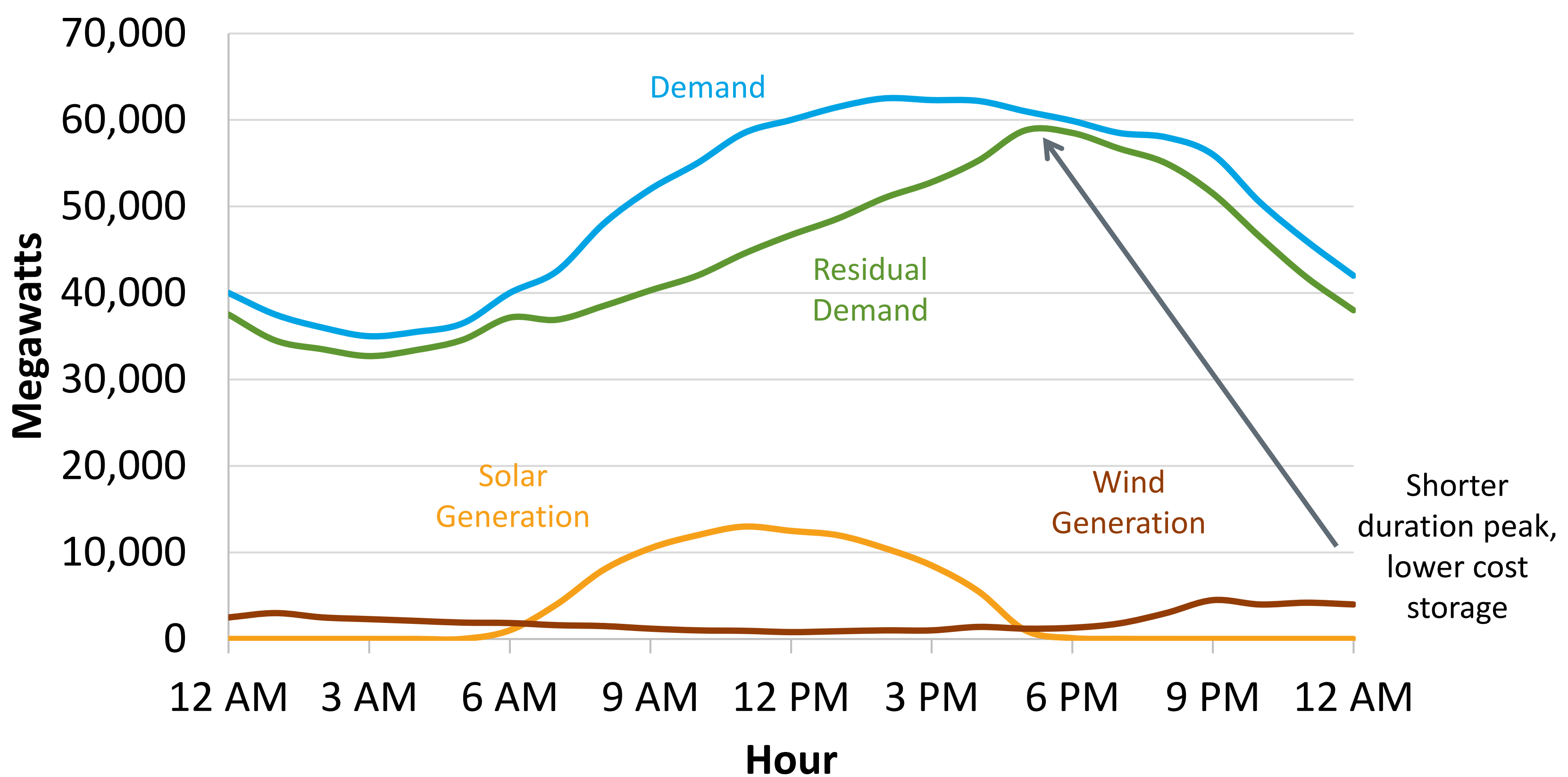


Source: IEA-RETD. (2016). RE-TRANSITION.

Energy storage is a growing threat to peaking capacity in many U.S. states

- Short duration storage projects (e.g., 2 hours) are nearly at parity
- Regulators in leading U.S. states (e.g., CA & NY) state that storage with 4-hour capacity is eligible for providing system capacity
- Emergence of “Clean Peak Standards”

A Virtuous Cycle: Higher penetrations of wind and solar may increase the market potential for peaking batteries



Some power systems are nearing a tipping point for 4-hour storage providing capacity services instead of conventional generators

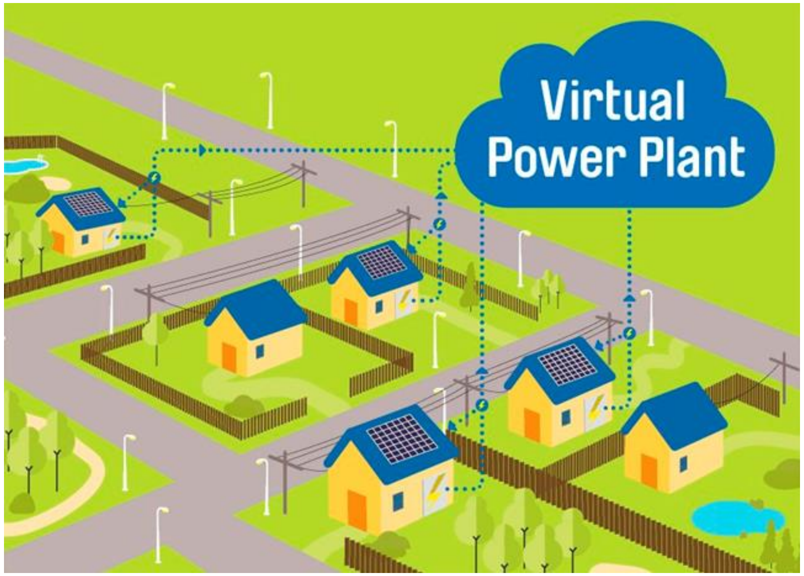
Source: Denholm, Paul. *Utility-Scale Battery Storage: When, Where, Why and How Much?.* Greening the Grid. 2019.

EMERGING STORAGE USES CASES FOR THE PROVISION OF FLEXIBILITY

Trend: Emergence of DER Aggregation

Example: South Australia's AGL Virtual Power Plant

1000 residential BTM storage-plus-DPV customers
(5 MW, 12 MWh)



Intended Use:

- Voltage support for distribution feeders with high solar penetrations
- Capacity and frequency regulation at wholesale market level

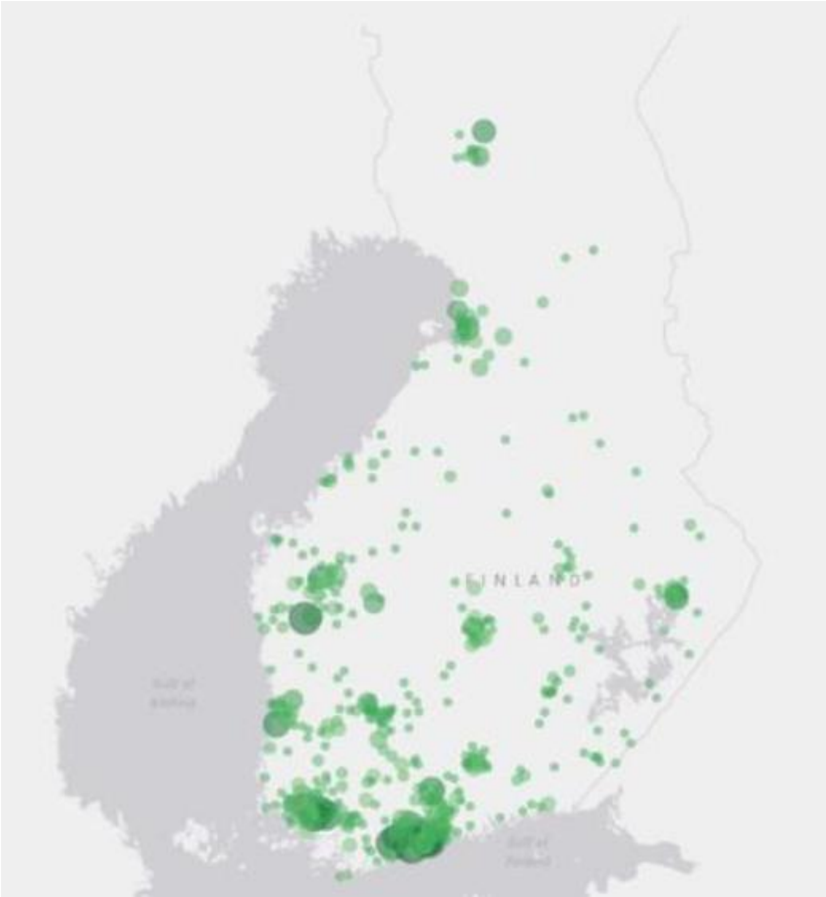
Customer Compensation:

- $1,000 incentive to install storage
- 1-year contract: $100 signing bonus, $45 / 3 months (bill credit)

Image credit: twitter.com/aglenergy

Related Example: Fortrum Virtual *Thermal* Energy Storage Plant

- Pilot program: ~2,000 residential water boilers aggregated
- Fixed bill credit for customer
- Staggered use



Innovative business models come with innovative technology

Example: GI Energy + ConEd

- Four 1 MW / 1MWh batteries located in front-of-the-meter at customer sites throughout NYC area
- Located in constrained network areas
- Customer receives lease payment
- **Regulated:** ConEd granted priority dispatch during peak local demand
- **Competitive:** GI Energy can otherwise sell flexibility services on NYISO
- **Innovation:** <u>Value stacking</u> across regulated and competitive market segments

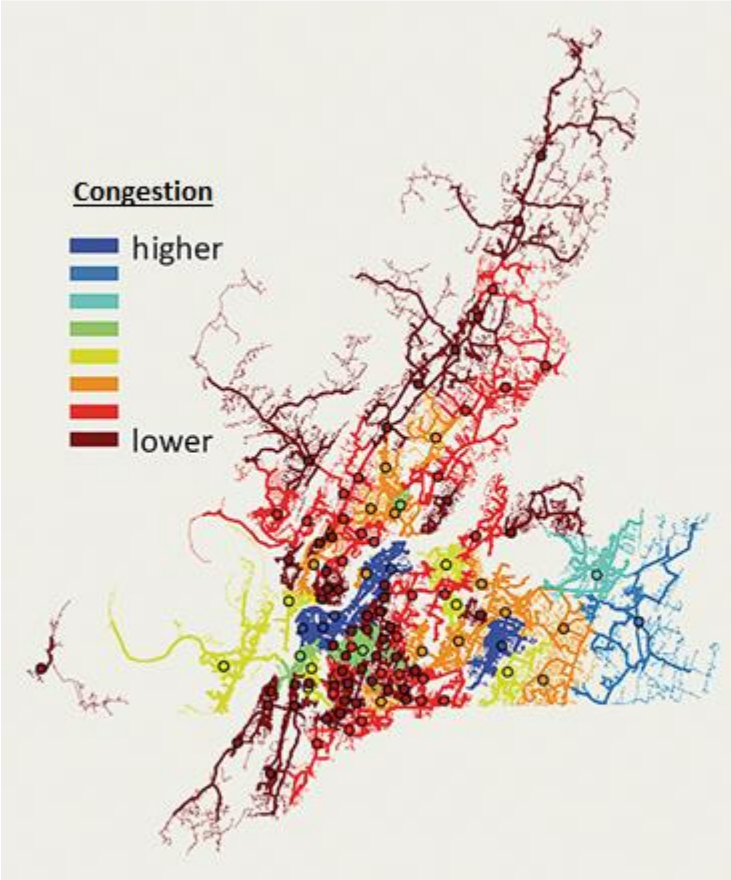
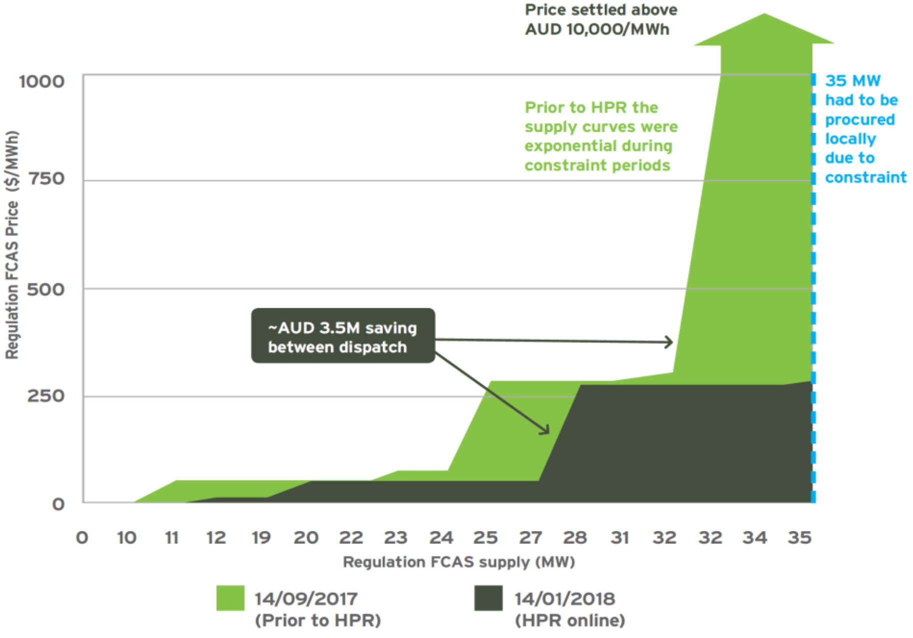


Image Source: T&D World

Dual Participation in Regulated and Competitive Markets

- **Example: Hornsdale Power Reserve in South Australia**
  100 MW, 129 MWh – Largest battery currently operating
  – Context: Isolated power system with ~50% VRE; security of supply and reliability issues; extremely high frequency control and ancillary service (FCAS) prices

Purpose	Battery capacity	Services provided
Capacity contracted by South Australia Government	70 MW, 10MWh	• Participation in System Integrity Protection Scheme (SIPS) • Fast frequency response • Contingency frequency control • Back-up reliability measure
Capacity open for market participation	30 MW, balance of energy	• Energy arbitrage • Regulation FCAS • Contingency FCAS



Trend: evolving regulatory frameworks for distribution companies accelerating DER investments

- Regulatory incentives are driving distribution utilities to weigh traditional grid capacity upgrades against emerging alternatives
- Examples:
  - New York – *Non-wires Alternatives*
  - Australia – *The $5M Rule*
  - California – *Demand Response Auction Mechanism*
  - U.K. – *Network Innovation Competition*

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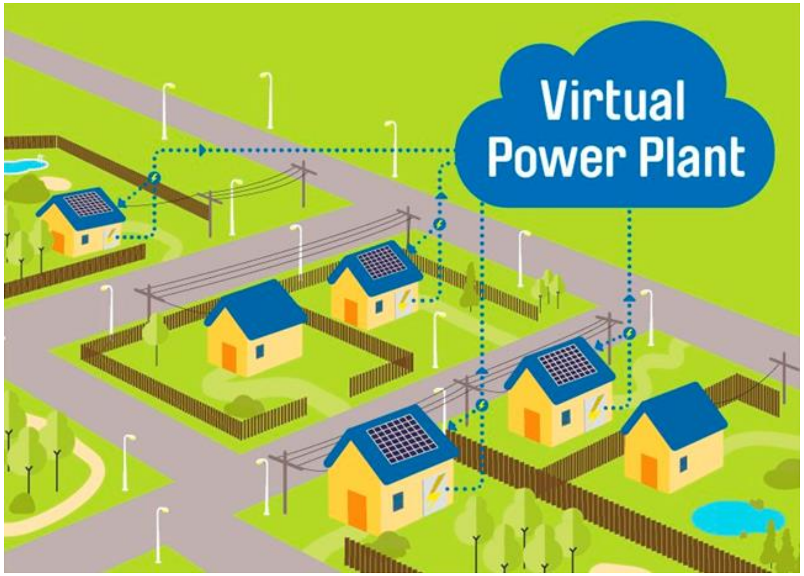

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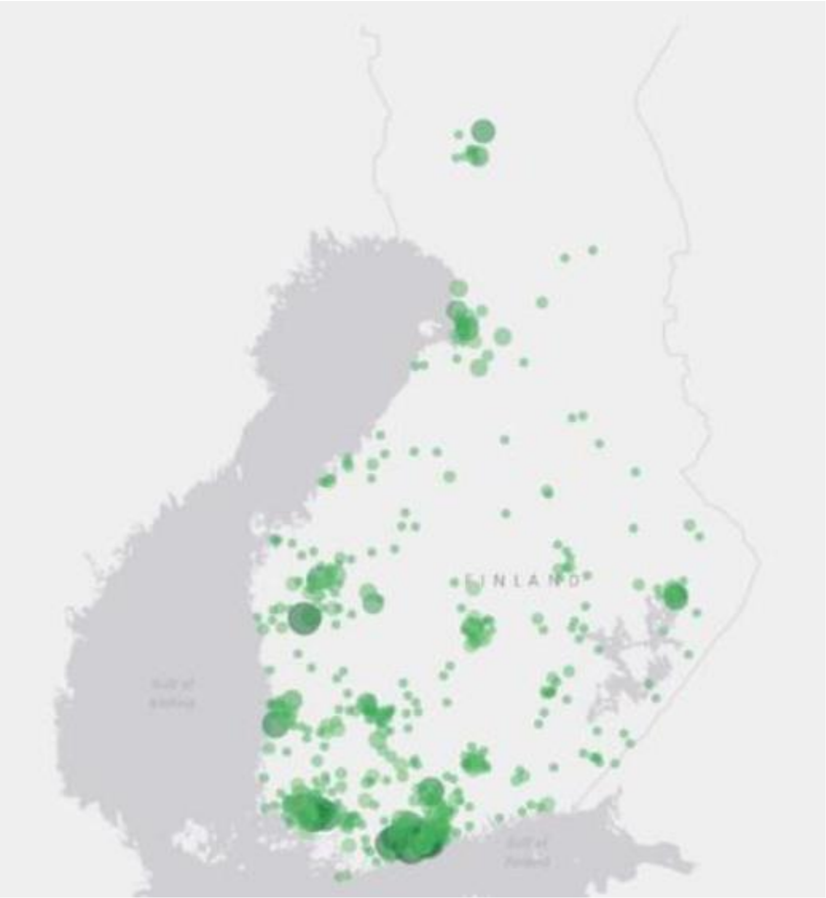

Closing Thoughts

- Storage can still be considered in as in a "familiarization" phase with utilities, regulators and planners as costs continue to decline.
- Deployment patterns and cost reductions appear to be following a similar story as photovoltaics
- Regulatory innovation can unlock multiple value streams of storage through "value stacking"
- The market for storage grows as wind and solar penetrations increase
- Participation hinges on changes to connection codes and market/procurement rules

QUESTIONS?

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