The values of centralized and distributed energy storage

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Deutsche Bank/Pillsbury Energy Storage Forum

New York, March 14, 2018

California storage—the drivers

- Ambitious legislative renewable mandates
- Forward-thinking ISO and agencies
- Stacking of services
- *2010* IOUs: 1325 MW by 2020 (PG&E, SCE, SDG&E)
- *2016* 500 MW more by 2024 including behind the meter (BTM)
- *2018* PUC rulemaking: 2000 MW more by 2030

California storage—the driven

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California storage—the driven

- Gas supply for 17 power plants, 10 GW
- California PUC fast-tracked 104.5 MW storage projects in 2016
- 4-hour duration prioritized
- Even so, permitting challenges over siting and chemical risks
- ***Location, meet technology***

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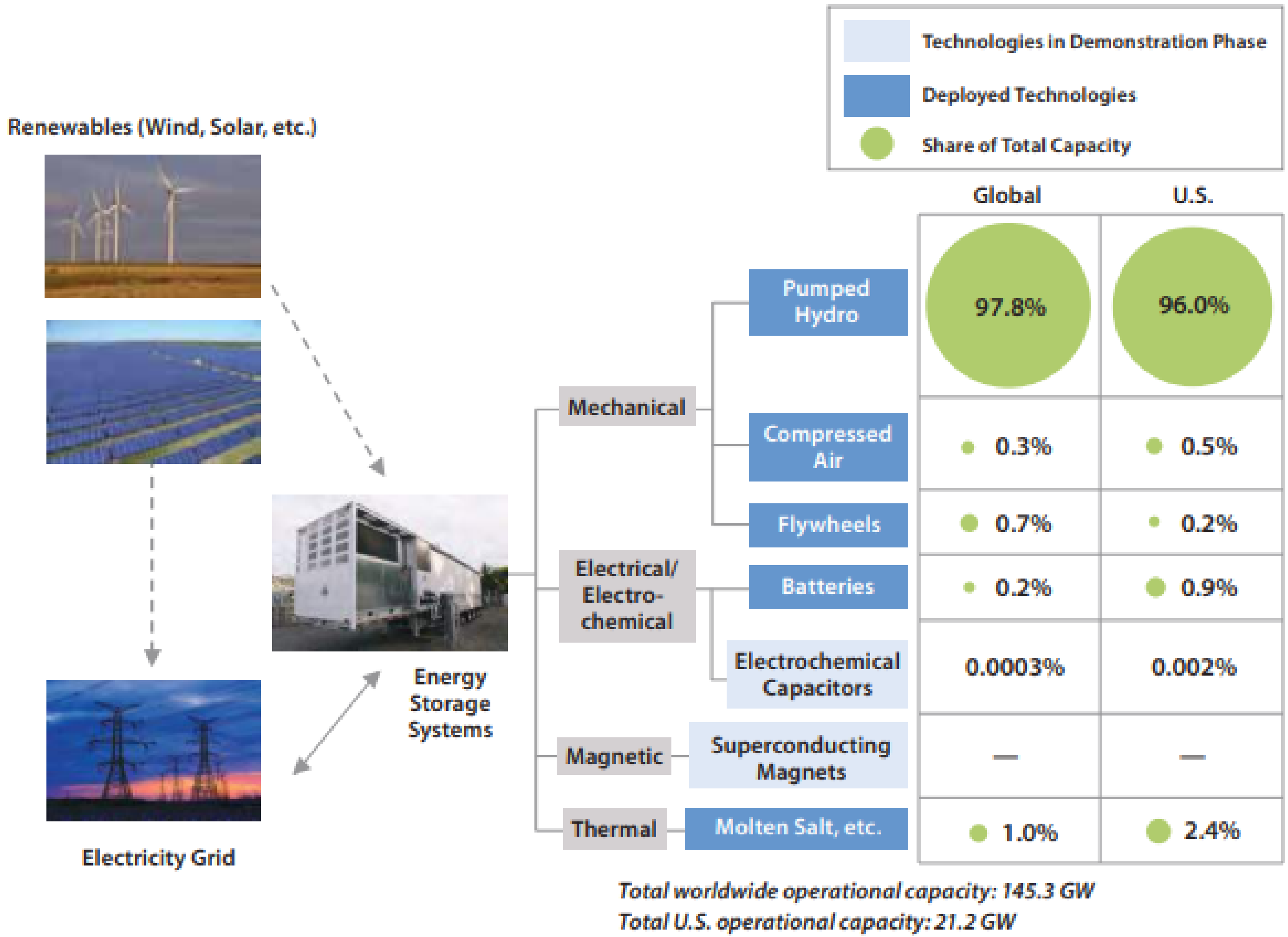
Storage in perspective, 2014



Source: MIT Energy Initiative. *The Future of Solar Energy: An Interdisciplinary MIT Study, Appendix C – Energy Storage Systems for the Electric Power Sector.* 2015. p. 289. <https://energy.mit.edu/wp-content/uploads/2015/05/MITEI-The-Future-of-Solar-Energy.pdf>

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Storage in perspective, 2014 → 2018

- US storage 21.2 GW → *24.2 GW (DOE 2017)*
- Storage other than pumped water 0.8 GW → *1.6 GW*
- Battery storage 200 MW → *715 MW (Pet Econ 2018)*

Storage technology trends

- **Lithium-ion expansion**
  - Versatile technology for standalone and co-located storage
  - Manufacturing costs down (EPC up)
  - Almost all capacity added in 2016 (GTM)

- **Lithium-ion constraints**
  - Degradation, warranties and O&M
  - Discharge depth and duration
  - Lithium and cobalt sourcing, commodity price swings
  - Volatility, safety, disposal

- **Pumped hydro's resilience**
  - FERC: 15 MW of pumped hydro permits, 2 MW more pending
  - Micro pumped hydro

- **Flow batteries, advanced thermal, emergent technologies**

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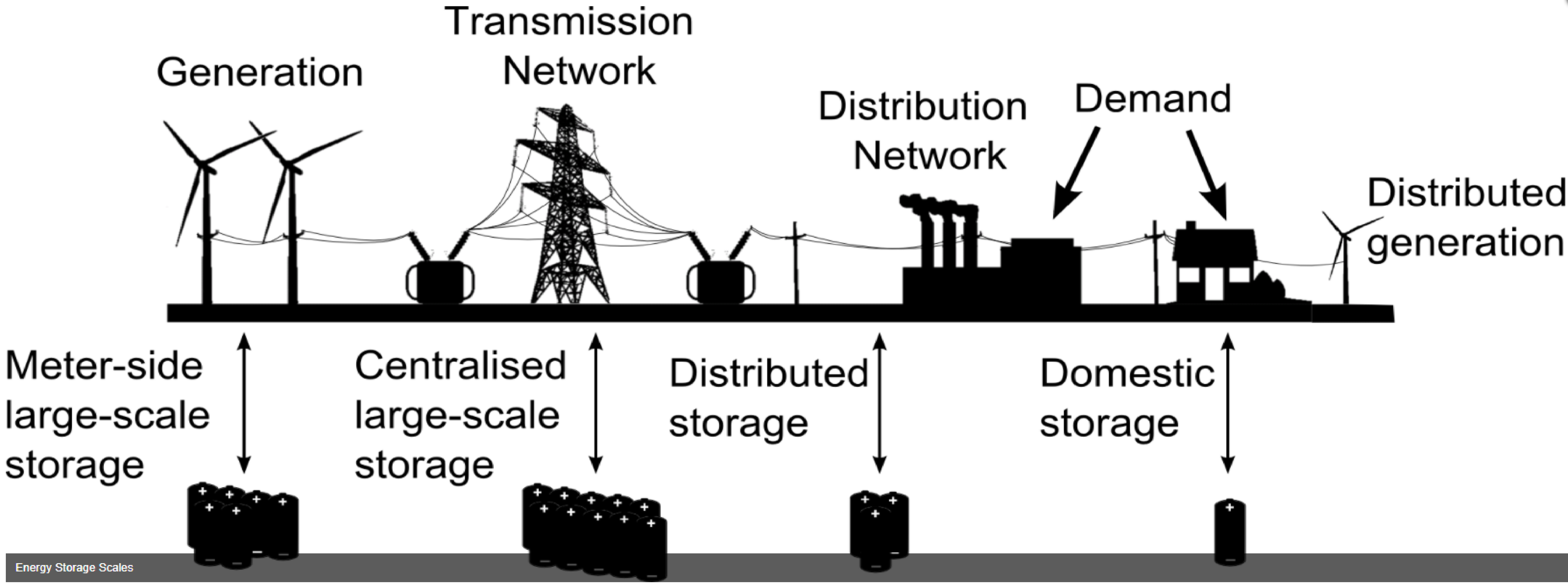
Storage on the grid



Energy Storage Scales

Storage off (or at) the grid

- Co-location with consumption
  - *Puerto Rico, 2018*
- Community choice aggregators
- Customer's side of the meter
  - Commercial & Industrial
  - Residential
  - Vehicles
- ***Why should the meter matter?***

Source: Tesla

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Values of energy storage

~~Values of energy storage~~

- **Discussions of "the values of energy storage" lead to confusion**

- Instead, distinguish the *possible benefits* of storage
- From the *actual benefits* delivered by storage
- And from being entitled by regulation to *seek chargeable compensation* for delivering those benefits
- And from being empowered by tariff or contract, in the unforgiving marketplace, to institute energy, capacity and ancillary service charges,

  and collect that actual compensation

Possible benefits: the customer level

- Time-of-use management: buy (and charge) at favorable rates and terms, discharge via net meter at higher rates and terms
- Increased PV self-consumption: in jurisdictions with rate structures unfavorable to distributed solar generation, utilize rather than export
- Demand charge reduction*: reduce peak grid usage and charge
- Backup power: power in the event of grid failure

Possible benefits: the utility level

- Resource adequacy: invest in energy storage rather than new or refurbished generation facilities
- Distribution deferral*: delay, reduce, or avoid investments in distribution system upgrades
- Transmission congestion relief: install storage downstream of bottlenecked transmission
- Transmission deferral: delay, reduce, or avoid investments in transmission system upgrades

Possible benefits: the ISO/RTO level

- Energy arbitrage: buy (and charge) low, sell (and discharge) high
- Frequency regulation*: respond to changes in locally sensed frequencies → grid stability
- Spinning and non-spinning reserve: serve load immediately (seconds or minutes) after outage; faster and less expensive than generation
- Voltage support: discharge to match power generation with power demand → grid reliability
- Black start: discharge to restore operation of large power plant

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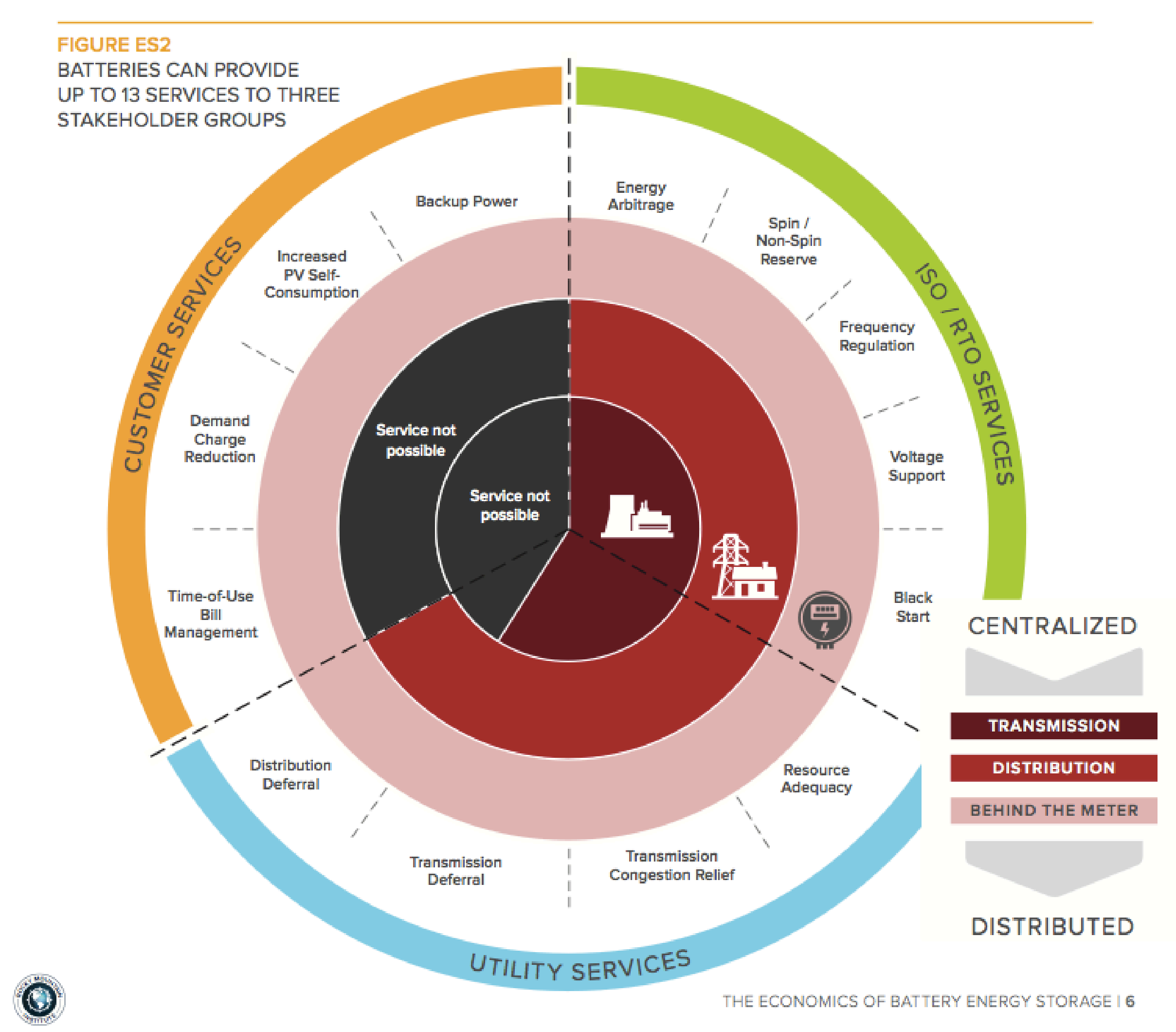
A wheel of possible benefits



Source: Rocky Mountain Institute (RMI)

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Benefits with broadly chargeable compensation

- Frequency regulation (PJM)
- Distribution deferral
- Demand charge reduction

Barriers to compensation (RMI 2015)

- Regulations inconsistent with compensation for multiple benefits, called “value stacking”

- ISOs/RTOs treating storage only as “transmission assets” or “distribution assets,” impairing participation in wholesale supply markets
- Limited market for black start and voltage control services
- Limited market for behind-the-meter storage for load management (some local experimentation)
- Tariffs/PPAs compensating storage insofar as power is discharged to grid
- Limited capability to dispatch remote storage, on or off grid

Regulatory challenges:
California today, elsewhere after FERC 841?

Table 1. Domains: Reliability Services and Non-Reliability Services

Domain	Reliability Services	Non-Reliability Services
Customer	None	TOU bill management; Demand charge management; Increased self-consumption of on-site generation; Back-up power; Supporting customer participation in DR programs
Distribution[7]	Distribution capacity deferral; Reliability (back-tie) services; Voltage support; Resiliency/microgrid/islanding	None
Transmission	Transmission deferral; Inertia*; Primary frequency response*; Voltage support*; Black start	None
Wholesale Market	Frequency regulation; Spinning reserves; Non-spinning reserves; Flexible ramping product	Energy
Resource Adequacy	Local capacity; Flexible capacity; System capacity	None

*Voltage support, inertia, and primary frequency response have traditionally been obtained as inherent characteristics of conventional generators, and are not today procured as distinct services. We include them here as placeholders for services that could be defined and procured in the future by the CAISO.

Practical challenges: Harnessing, maintaining and managing dispersed storage

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Where does "valued" storage belong today?

- The glib answer: everywhere that cash flow and tax/other government benefits can service investment
  - Renewables infrastructure, or security infrastructure?
- More nuanced answer: *scale, technology, and regulation will tell*
  - Transmission system storage in bulk and scale and for long discharges
  - Distribution system storage for local system upsets and investments
  - Generation co-location for uninterruptible power supply
  - Consumption co-location benefitting customers, utilities, the ISO/RTO, and the grid (RMI), but dispersed and at small scale

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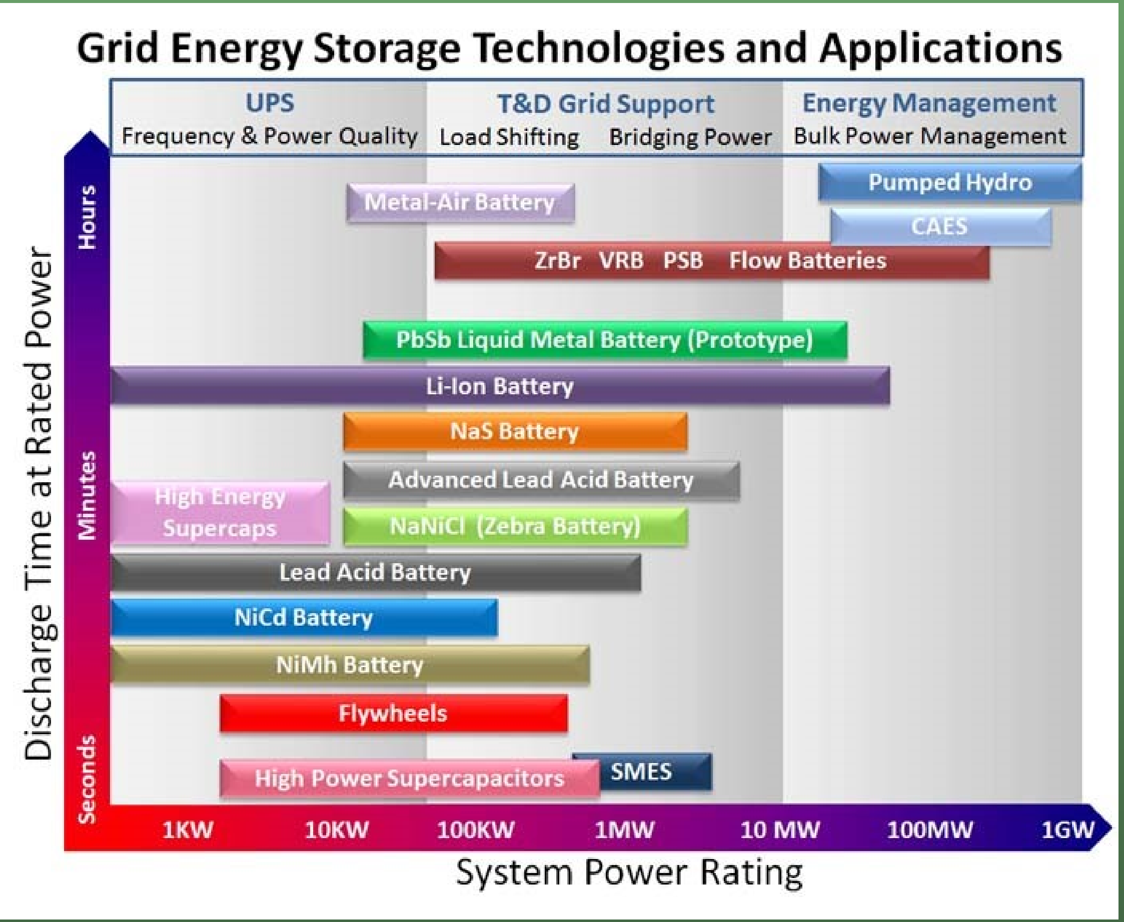
Where will "valued" storage belong tomorrow?



- *We have come full circle to the storage technology trends*

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Unleashing storage

- Project development/finance, regulation, and technology: listen to one another
- Projects: develop capacity charges and alternative measures of benefits that can be simply enforced
- Regulation: finish the job, ISO/RTOs;
  don’t limit behind-meter storage to demand reduction
- Technology: target advancement of benefits most likely to be compensated, viewed over a long life cycle (decommissioning)

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Get over the meter!

- It’s a measurement point and device, not a Wall

Thanks!

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