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Energy Storage for Bulk System Operations

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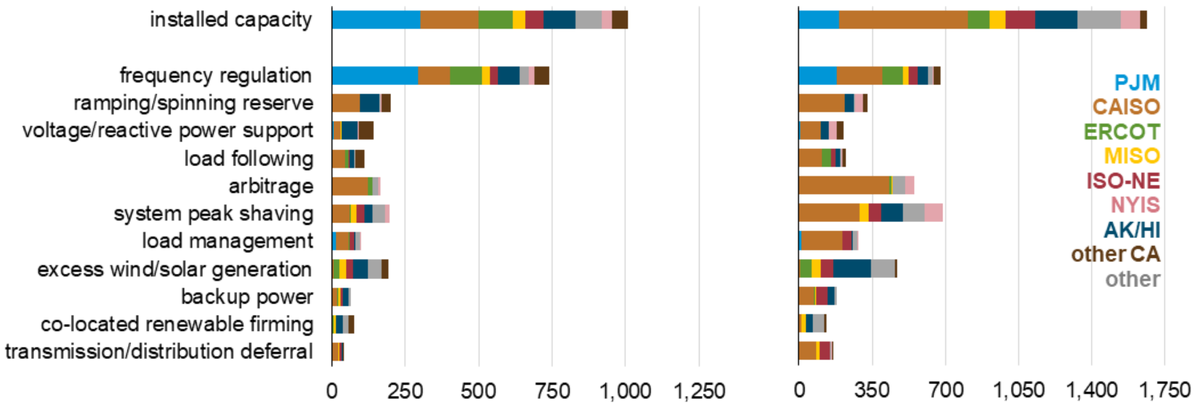
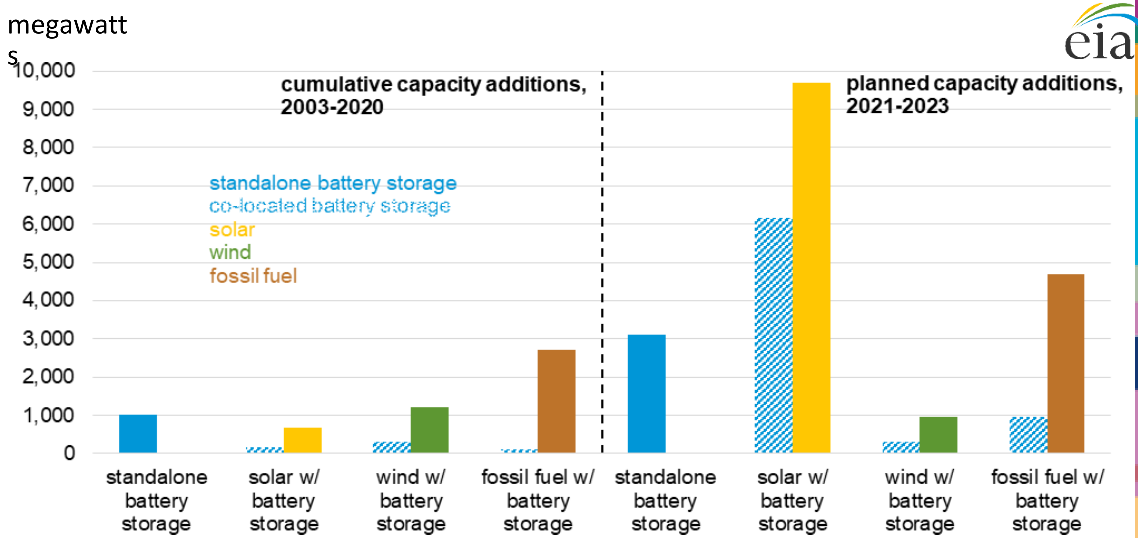
Where is Energy Storage Getting Deployed ?



Applications served by large-scale battery storage in the US (2019)



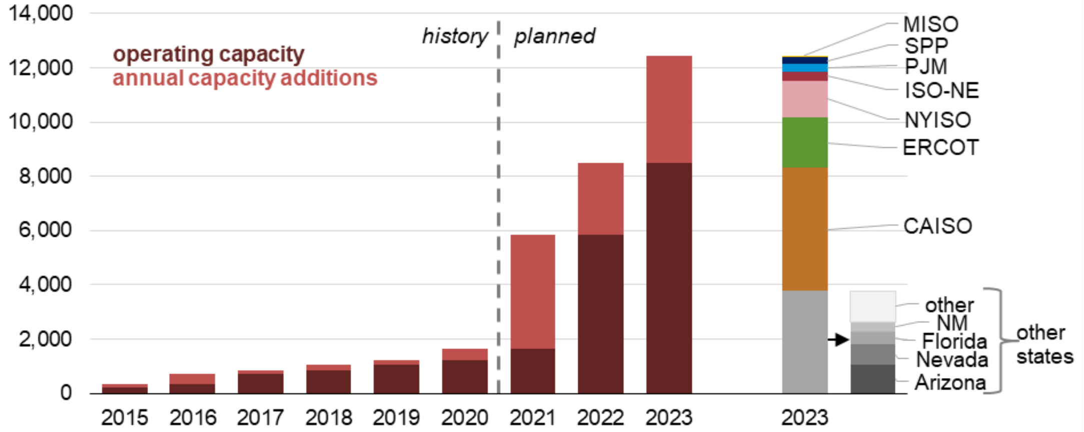
U.S. large-scale battery storage power capacity additions, standalone & co-located

Early deployments are all power applications

Planned new capacity in the pipeline is hybrids either with solar, wind or NG in selected markets

Energy markets beginning to open, energy storage is still expensive for many energy applications including bulk grid

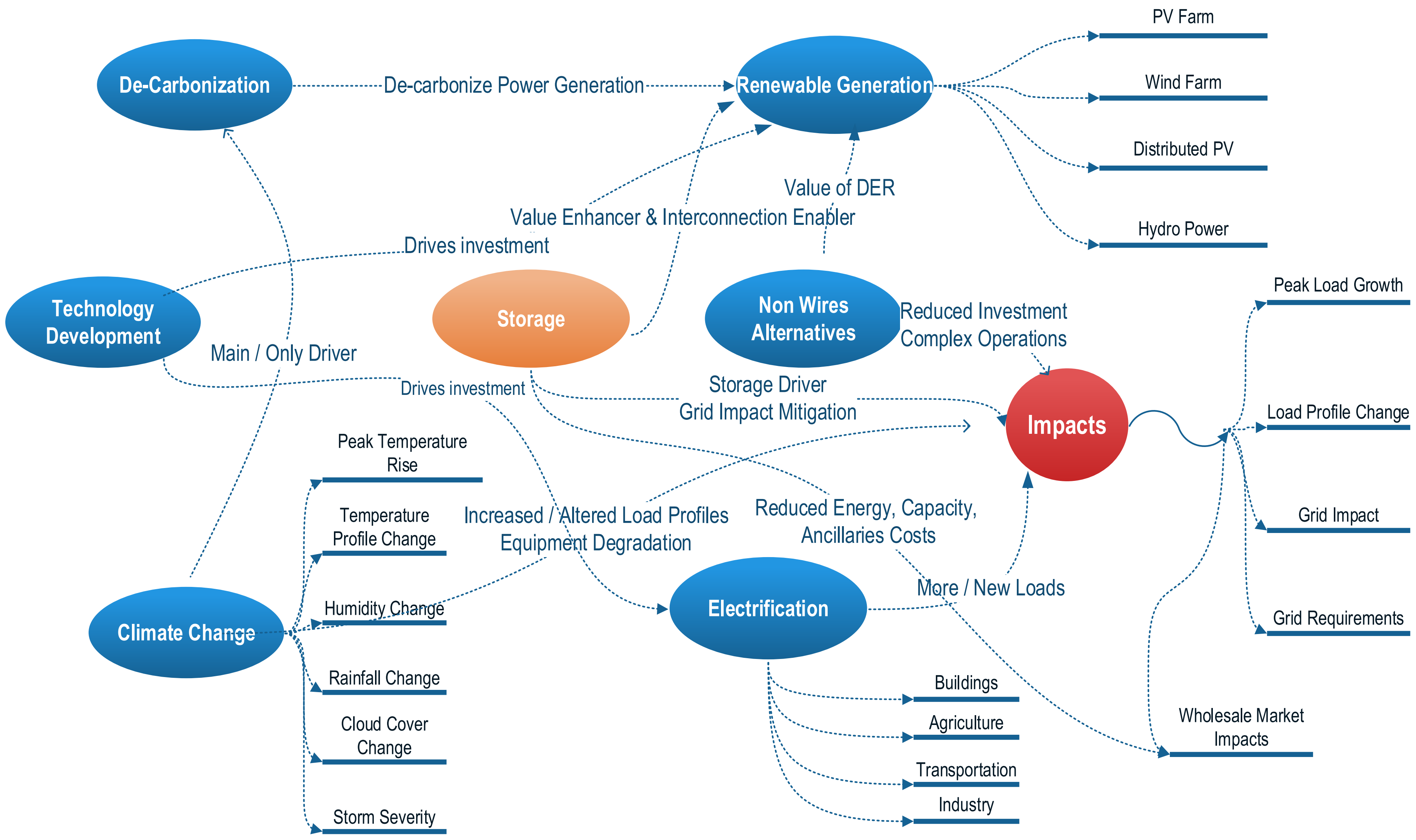
Battery energy storage systems are mostly using Li batteries



Large-scale battery storage cumulative power capacity in the US, 2015–2023

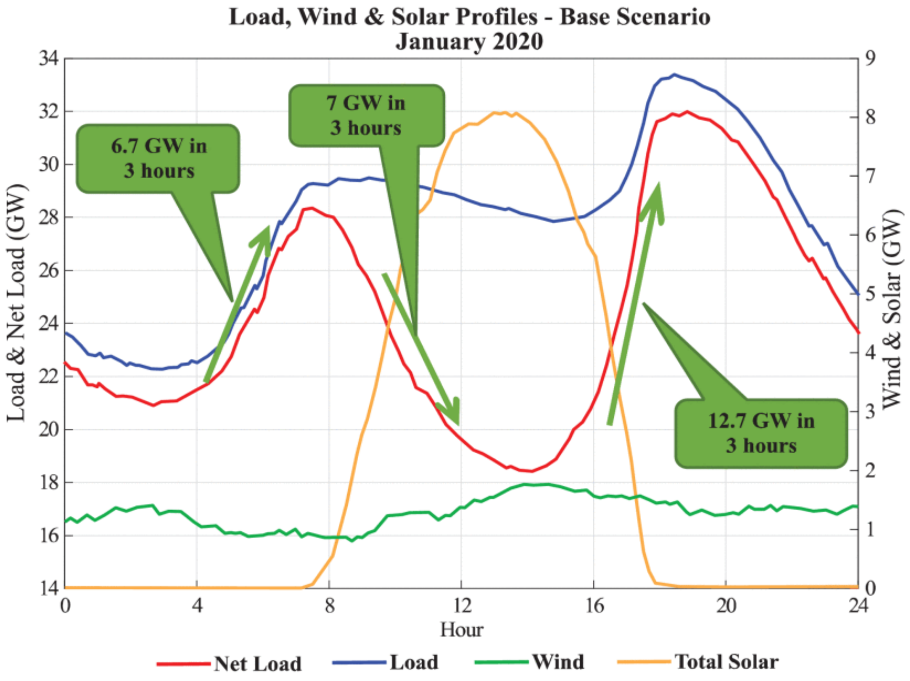
Source: U.S. Energy Information Administration, Dec 2020 Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*

Energy Storage in the Evolving Grid



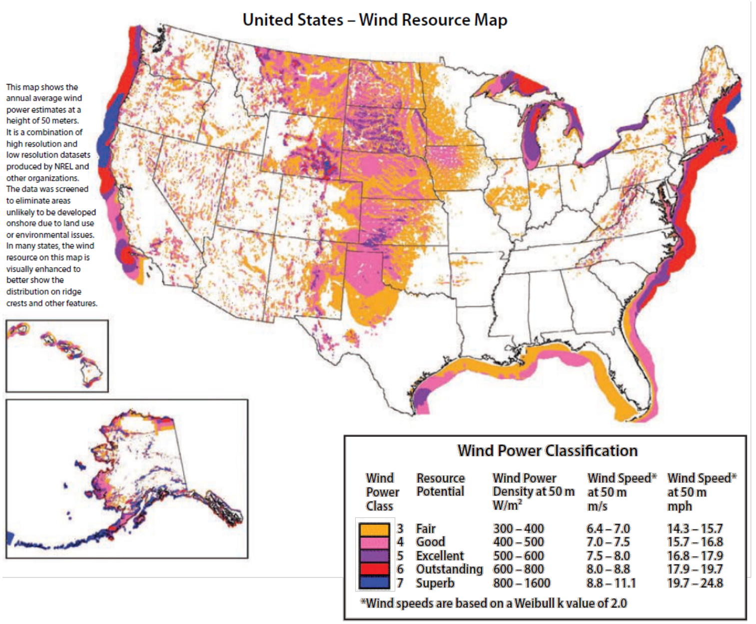
Source: R. Masiello, R. Fioravanti, B. Chalamala, and H. Passell, "Electrification, Decarbonization, and the Future Carbon-Free Grid: The Role of Energy Storage in the Electric Grid Infrastructure," Proc. IEEE, to appear (2021).

Grid Modernization - Challenges



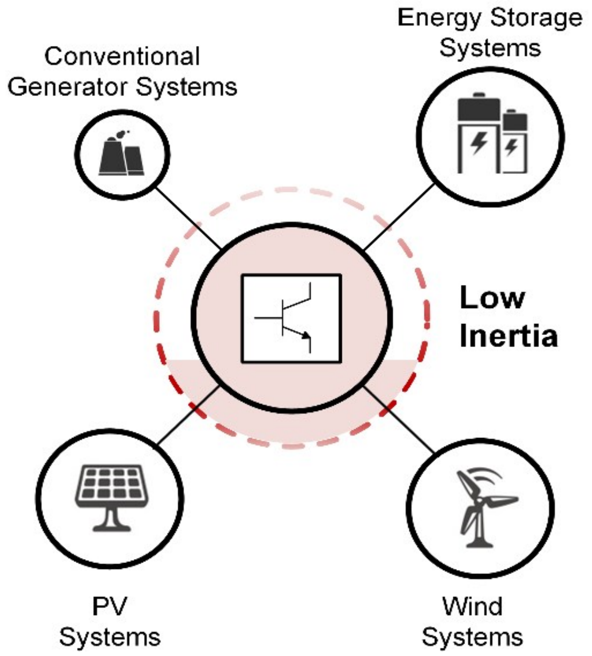
High Variability and Uncertainty

- Renewable sources derive from variable natural resources (e.g., wind & solar), which makes these resources more difficult to control, presenting challenges for grid operators.



Transmission Issue

- Transmission infrastructure is aging while new transmission lines is often time-consuming.
- Most attractive resources for wind and solar are located far from load center exploiting these resources requires enormous transmission expansion.



Low Inertia

- Power electronic dominated power system does not have enough rotating mass to deal with large disturbances.

Mitigating Climate Change

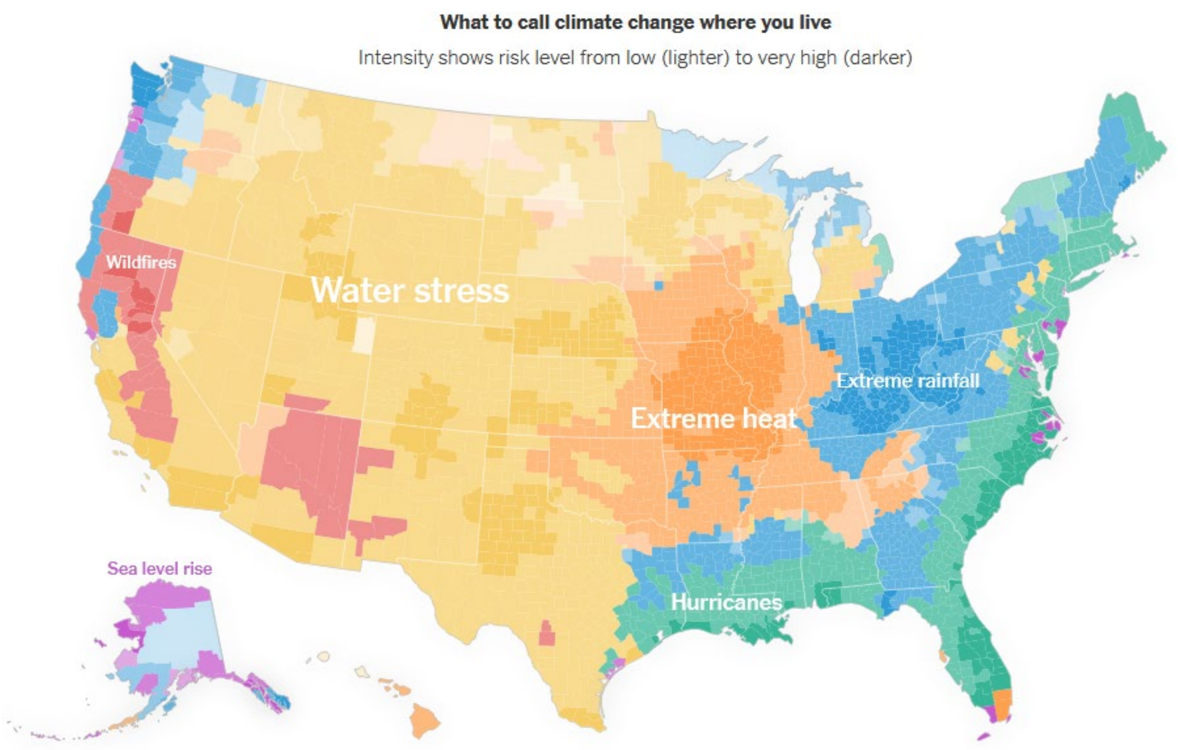


Image Credit – The NY Times

- Climate change forecasting as reported focuses on temperature, sea level, and severe weather, but cloud cover and wind speeds are also critical.
- How will renewable forecast accuracy change?
- How will T&D investment decisions and incentives factor into the relative adoption of different renewable technologies – PV versus wind, grid scale versus distributed, remote versus local?

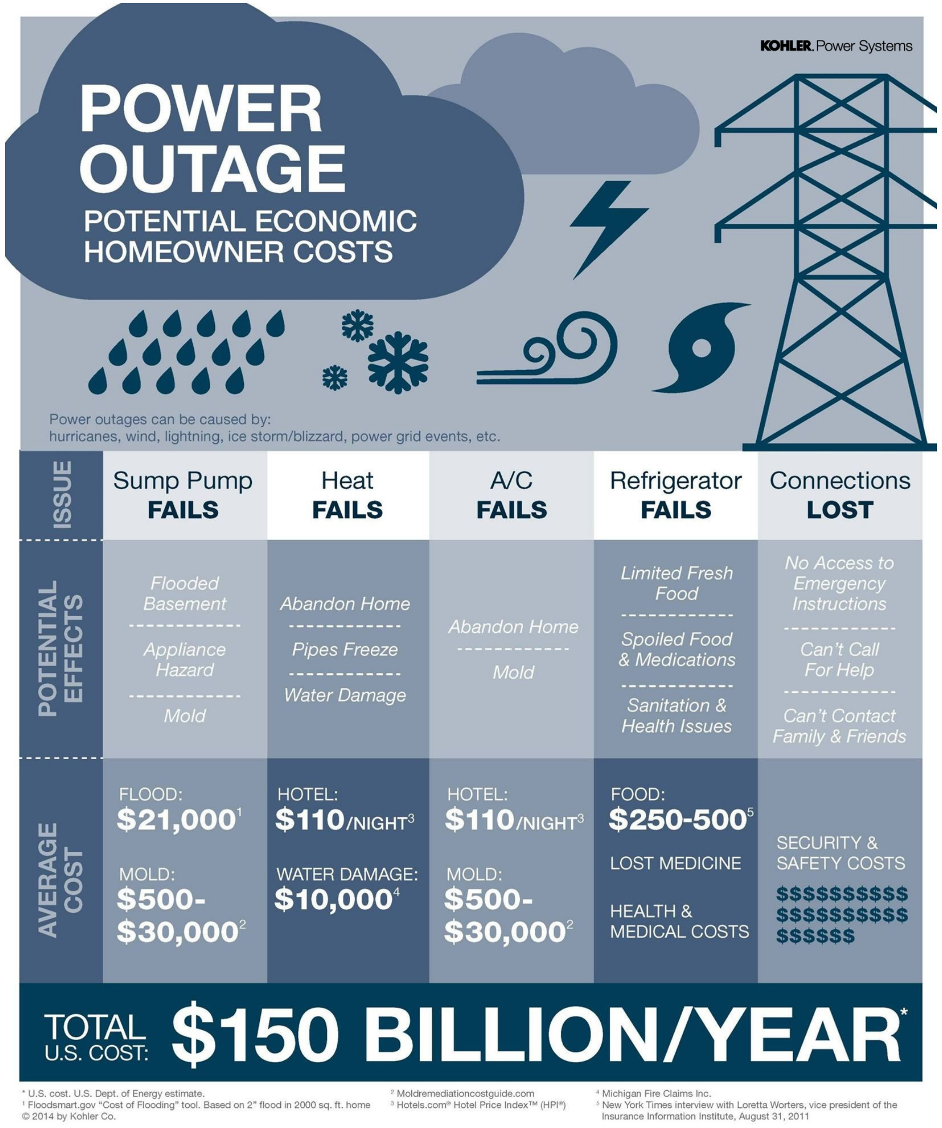
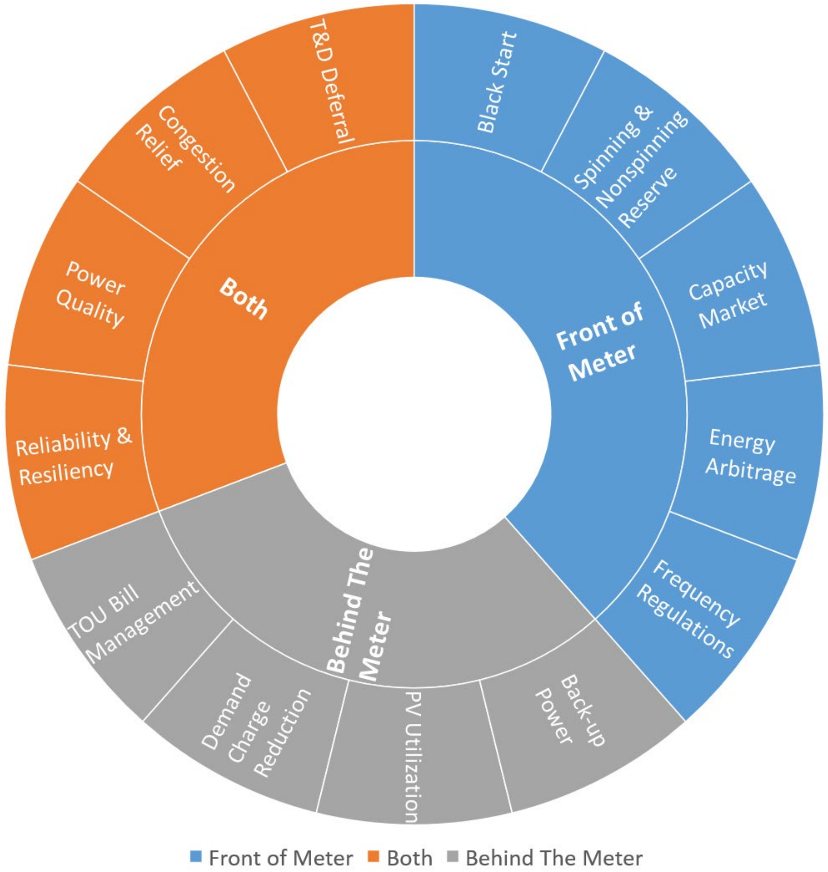
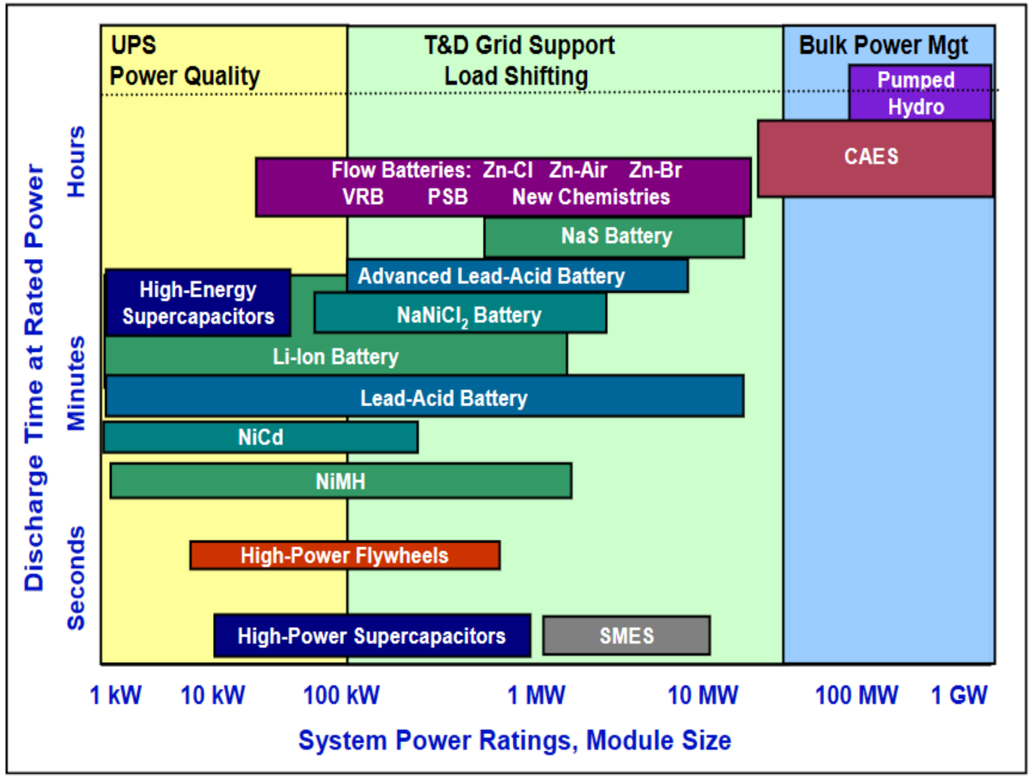


Image Credit – KOHLER Power Systems

Applications of Energy Storage





Source: DOE/EPRI 2013 Electricity Storage Handbook, Sandia National Laboratories, 2015

- Bulk energy applications are currently addressed by mostly pumped hydro storage
- BESS is beginning to find deployment

Need for Interconnection Standards

Diverse & different requirements across various jurisdictions

- *requires more effort and time to address*

Inverter-based resources (IBR) are different from synchronous generators

- *higher (and sometimes lower) capability*

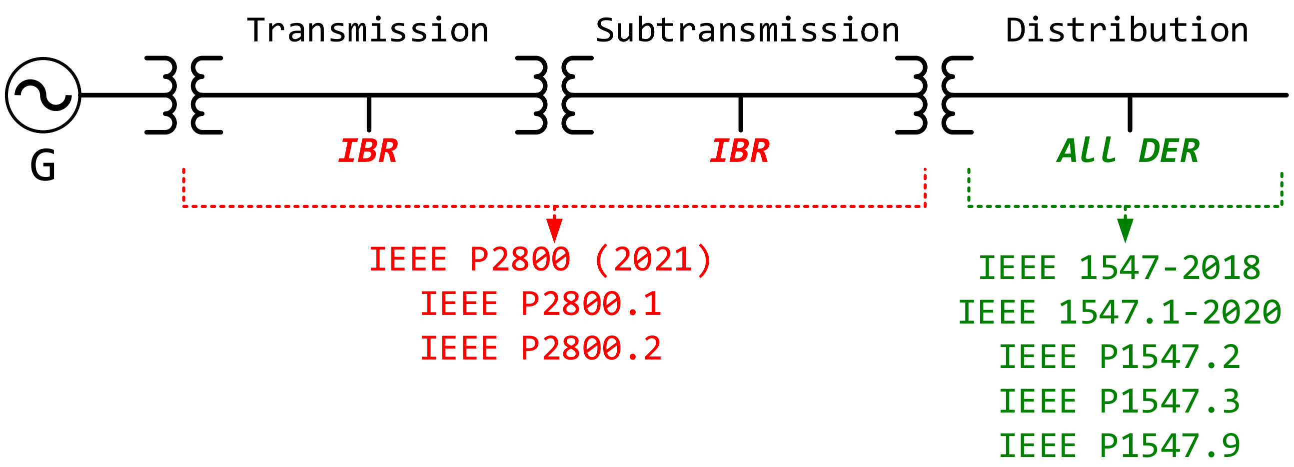
Requirements may not be balanced

- *some too stringent & not taking advantage of new capability*

Jurisdictions across the U.S. power system

Source: https://www.natf.net/

Need for Interconnection Standards



		Performance	Test & Verification & Model Validation
FERC / NERC?	**Transmission**	• FERC Orders • NERC Reliability Standards & Guidelines	• NERC compliance monitoring & enforcement
NARUC / State PUCs?	**Sub-Transmission**	• Not available	• Not available
	Distribution (for DER)	• IEEE Std 1547-2018 ✓	• IEEE 1547.1-2020 • UL1741 (SB) • IEEE ICAP ✓

IEEE P2800

IEEE P2800.1 and/or .x

Standards drive uniformity of requirements across jurisdictions

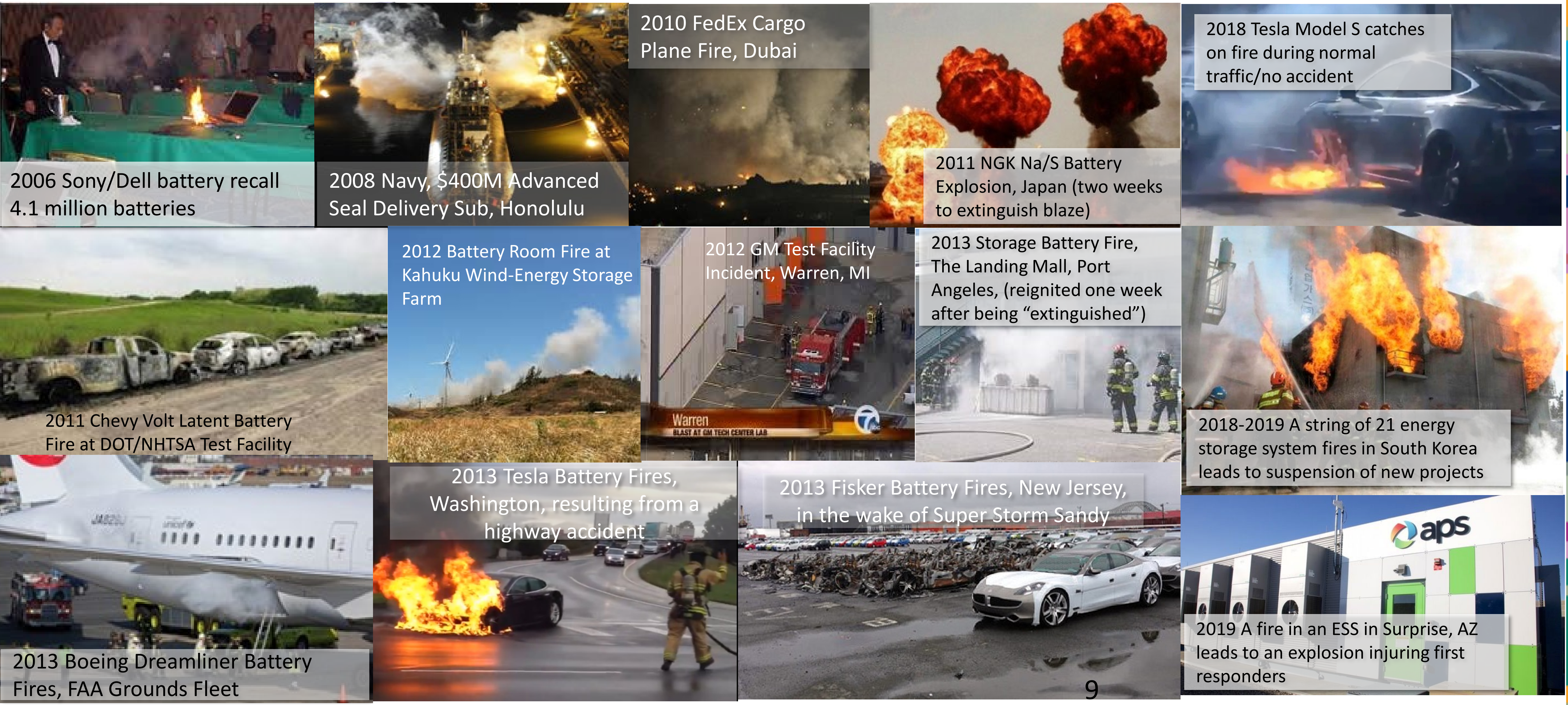
IEEE 1547 becoming widely adapted as the de facto DER interconnect standard

- IEEE 1547.9 new standard for energy storage interconnection

IEEE P2800 applies to interconnection of inverter based resources at the transmission and subtransmission levels

- Currently under development

Battery Energy Storage Systems – Safety Concerns



2006 Sony/Dell battery recall 4.1 million batteries

2008 Navy, $400M Advanced Seal Delivery Sub, Honolulu

2010 FedEx Cargo Plane Fire, Dubai

2011 NGK Na/S Battery Explosion, Japan (two weeks to extinguish blaze)

2018 Tesla Model S catches on fire during normal traffic/no accident

2011 Chevy Volt Latent Battery Fire at DOT/NHTSA Test Facility

2012 Battery Room Fire at Kahuku Wind-Energy Storage Farm

2012 GM Test Facility Incident, Warren, MI

2013 Storage Battery Fire, The Landing Mall, Port Angeles, (reignited one week after being “extinguished”)

2018-2019 A string of 21 energy storage system fires in South Korea leads to suspension of new projects

2013 Boeing Dreamliner Battery Fires, FAA Grounds Fleet

2013 Tesla Battery Fires, Washington, resulting from a highway accident

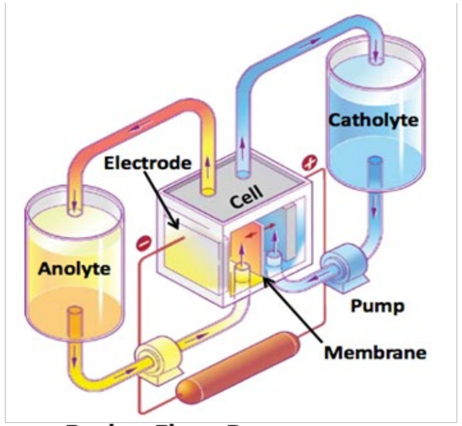
2013 Fisker Battery Fires, New Jersey, in the wake of Super Storm Sandy

2019 A fire in an ESS in Surprise, AZ leads to an explosion injuring first responders

Safety R&D is largely focused on Li-ion BESS

- Li-ion batteries: knowledge base mostly form consumer electronics, safety issued adequately addressed.
    - Safety issues for larger size (EV, grid) just beginning to be dealt with
- New technologies are being introduced
    - Is testing adequate to new technologies?
    - Li-ion – High energy anode materials
    - Li metal
    - Advanced aqueous batteries
    - Molten salt batteries
- Large storage systems targeting non-traditional locations, and areas near populations
- Grid-scale systems are complex, including not only a large battery but sophisticated power electronics
    - How do you qualify for safety? Is full-scale testing necessary?


Subway regen system, SEPTA



Redox Flow Battery


SAFT 10 MWh storage system


US Marine Corps FOB, Afghanistan

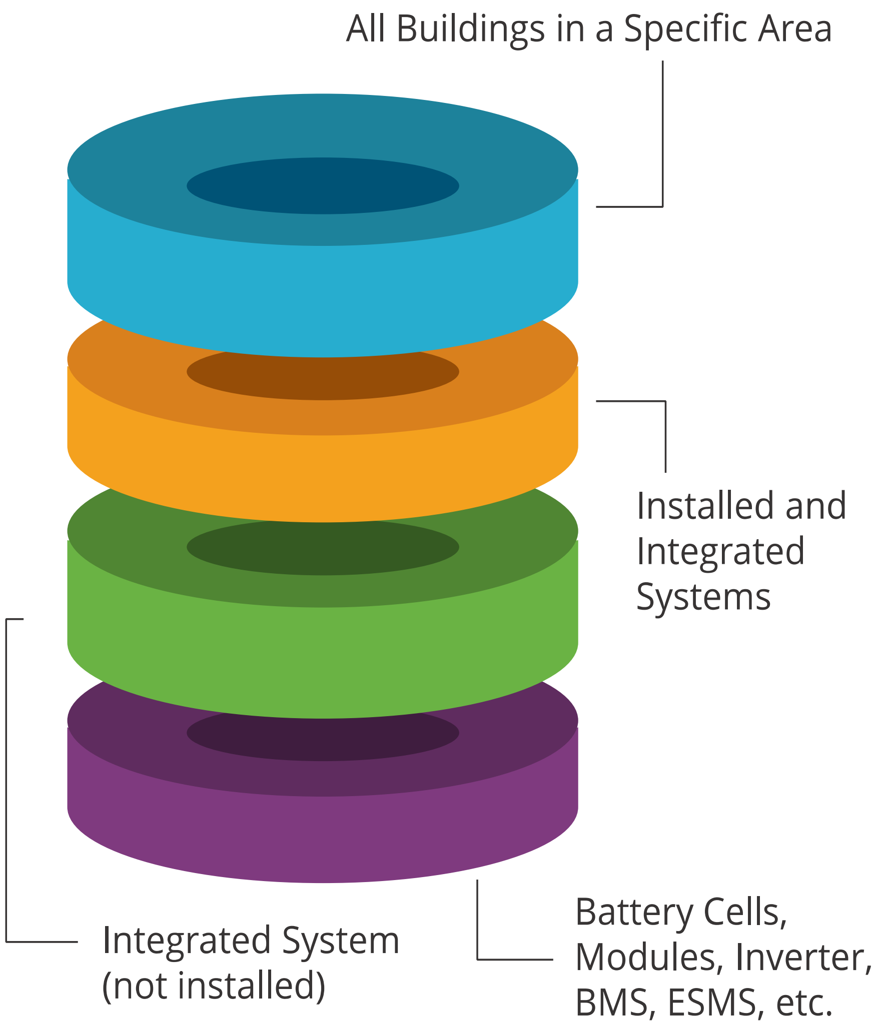
Standards to Ensure Energy Storage Systems Safety

4 Built Environment
International Codes – IFC, IRC, IBC
IEEE – C2, SCC 18, SCC 21
NFPA 5000, NFPA 1, ISA

3 Installation / Application
NFPA 855, NFPA 70, IEEE C2, IEEE 1635/ASHRAE 21, IEEE P1578,
FM Global 5-33, UL 9540A, NECA 416

2 Energy Storage Systems
UL 9540, MESA
ASME TES-1, NECA
NFPA 791

1 System Components
UL 1973, UL 1974, UL 810A, UL 1741,
CSA 22.2 No. 340-201, IEEE 1547, IEEE 1679



Categories for Energy Storage Codes and Standards

DOE Energy Storage Safety Codes and Standards Update
Publication released quarterly
[Available: https://www.sandia.gov/energystoragesafety-ssl/](https://www.sandia.gov/energystoragesafety-ssl/)

Operational and Regulatory Challenges

New forecasting tools that can adequately help to predict contingencies under different possible scenarios involving electrification of vehicles, ambient temperatures, and other resource availability

Development of appropriate computer models to drive simulations of integrated ES systems under a variety of grid scenarios

Further analysis of employing ES as an NWA to infrastructure upgrades.

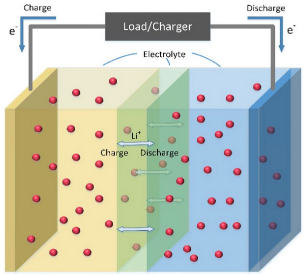
A regulatory and market framework that recognizes energy storage as a distinct asset class, rather than as part of the existing generation-transmission-distribution-load framework

Currently, there is a high level of uncertainty about how bulk ES will be treated by ISOs/RTOs, particularly within interconnection queues.

Making Energy Storage Mainstream to Grid Operators

Technology

- Lower cost, longer duration energy storage is a major gap
- Technologies that can scale from microgrids to large transmission applications
- **Further improvements in safety and reliability**



Manufacturing

- Industry needs cycles of learning – manufacturing scale through deployments
- Project finance – bankable, warrantees, performance guarantees, risk management
- **Standardization – equipment, permitting, construction processes**

Grid Operation

- Markets and Operations – business models and operational tools
- Analytics – economics and planning tools
- Appropriate Regulatory Policy – business models, asset classification

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