# Energy Storage Breakout Session
# AIEC CTC, October 2018

PRESENTED BY ENGIE

IN PARTNERSHIP WITH NRTC

**October 4, 2018**

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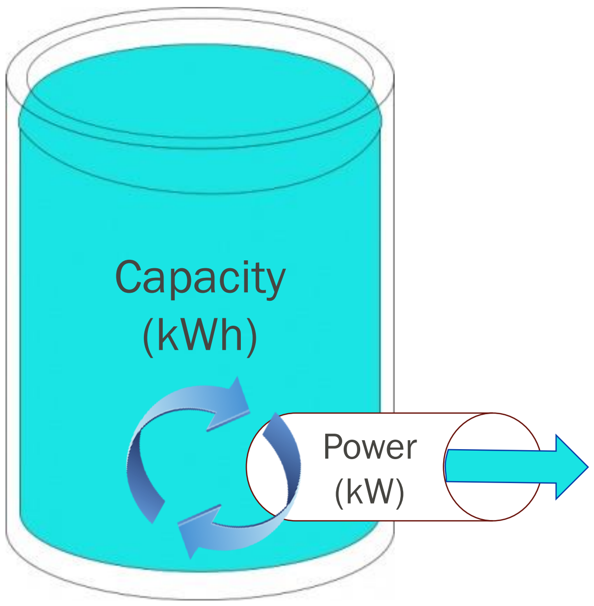
# Energy Storage – The Basics

**Capacity** rating: The amount of **kWh** that can be stored in the battery system

> Determined by the batteries

**Power** rating: The maximum **kW** that can be dispatched at any time

> Determined by the inverter(s)




**Important terms for Battery Energy Storage Systems (BESS)**

Losses are incurred during charging and discharging due to battery (in)efficiency (chemical reaction) & inverter (in)efficiency. The "**round trip efficiency**" (RTE) of a storage system reflects the total AC -> DC -> AC efficiency of the system during a full charge/discharge cycle, and depends greatly on the technology. Modern lithium-Ion systems can have RTE of ~85-90%.

The **duration** of a storage system is the length of time a system can dispatch at Rated Power before all Rated Energy is depleted. Simply, this is the Rated Energy divided by the Rated Power. Typical Li-Ion battery systems range from 15 minutes to about 6 hours.

The **C-Rate** of a storage system is defined as 1/h, where h is the duration (in hours) of the energy storage system. For example, a "two-hour" ESS may be 250 kW / 500 kWh. The c-rate of this system would be C/2 or 0.5C.

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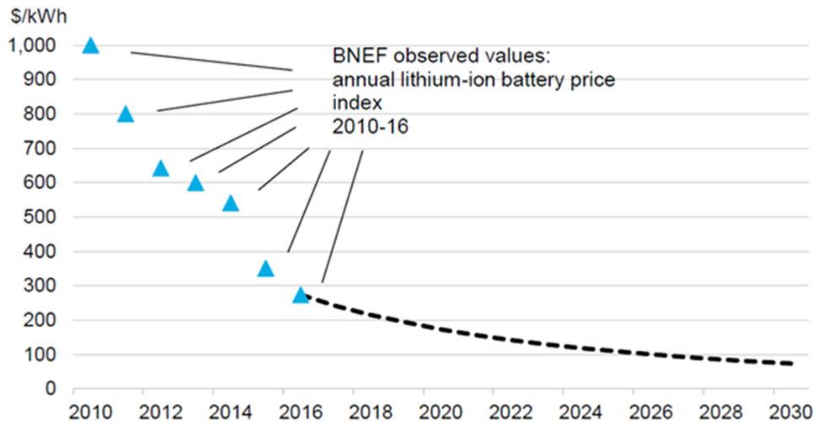
# Energy Storage – Why Now?




- Manufacturing Capacity (EV Market)
- Battery Prices (Li-Ion)
- Markets & Applications
- Renewables Integration

# Energy Storage Technologies - Overview

- Energy Storage Systems
  - Solid State Batteries
    - Electrochemical Capacitors
    - Lithium-ion Batteries
    - Nickel-Cadium Batteries
    - Sodium Sulfur Batteries
  - Flow Batteries
    - Redox Flow Batteries
    - Zinc-Manganese Oxide Batteries
    - Zinc Hybrid Cathode
  - Flywheels
  - Pumped Hydropower
  - Other
    - Rail
    - Compressed Air Energy Storage
    - Thermal

The BESS market has primarily focused on Lithium-Ion and a limited number of flow (or quasi-flow) products. These represent the most reliable and competitively priced commercially available technologies.

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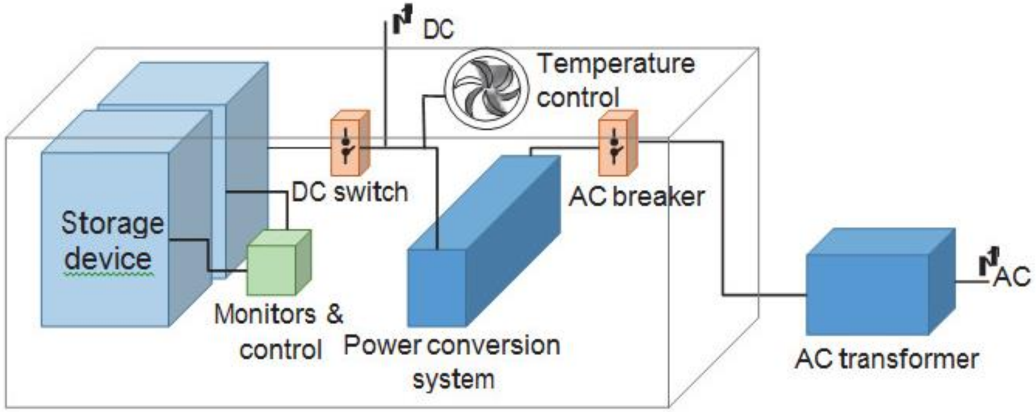
# BESS: Major Components

- **Battery system**: gives the system the capacity to store energy
- **Bi-directional inverter(s) (PCS)**: used to charge / discharge the ESS
- **"Balance of System" (BOS)**: the rest of the major physical equipment: containers, HVAC, transformers, etc.
- **Site control software/hardware**: used to control / manage dispatch of the system (can be autonomous, scheduled, or manually dispatched).




**Integration** of these various components (especially batteries and inverters) is a key concern

- Batteries and inverters must be compatible (voltage range, c-rate limitations, etc.)
- Most OEMs make only batteries or only inverters
- Integration of components across various OEMs is common, but adds risk (e.g. warranty disputes). Ideal structure is a warranty that "wraps" the batteries, inverters, and some critical BOS (containers, controls).

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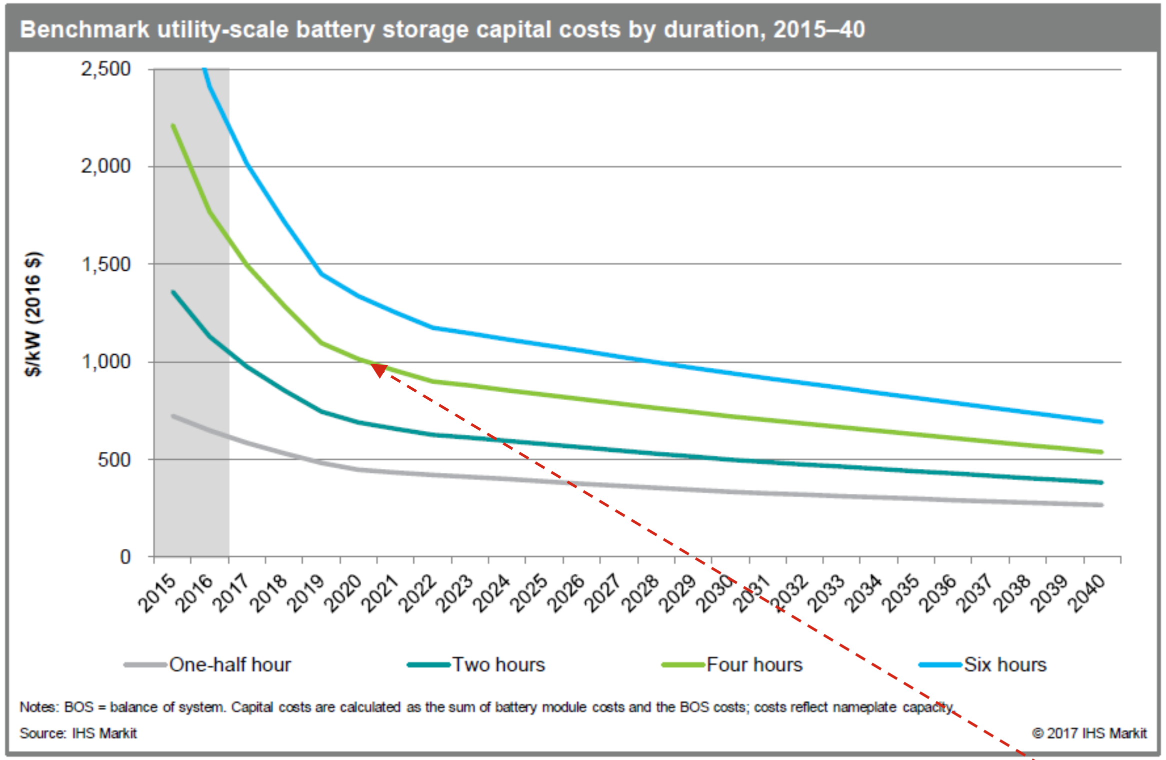
# Market Trends

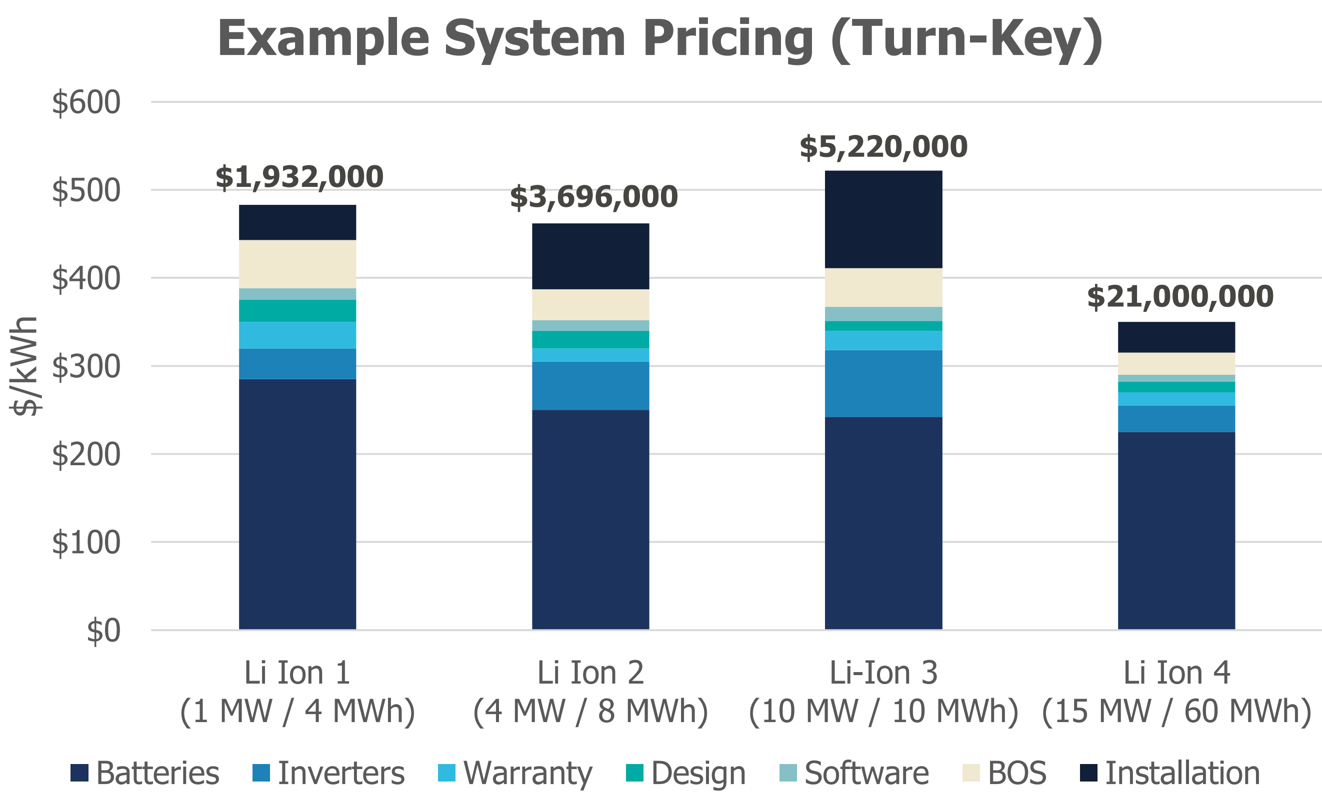


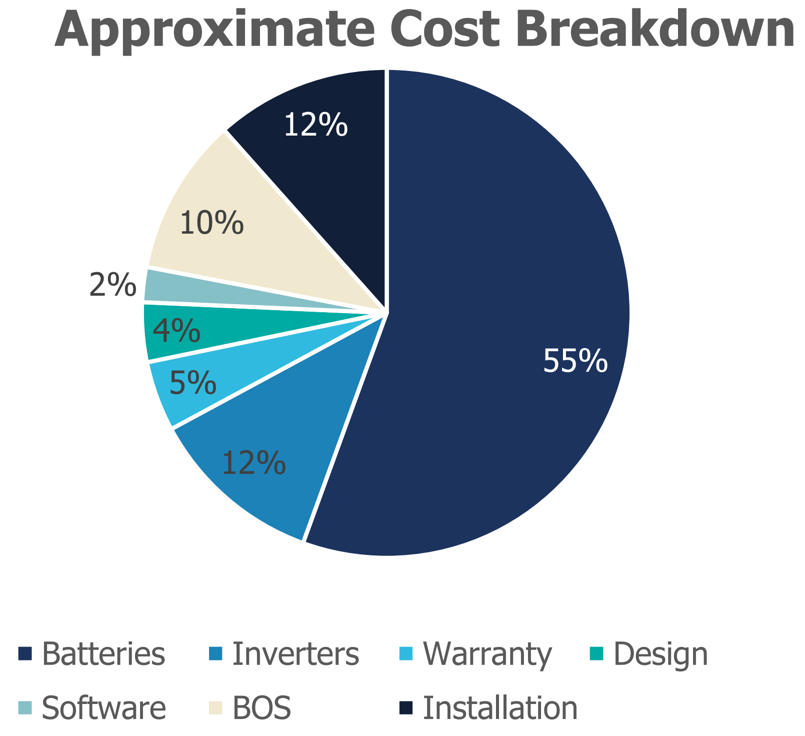

**Highlights:**

- Li-Ion battery prices have been trending down due to manufacturing scale (for EV market) and increased density & efficiency
- Theoretical limit on Li-Ion battery pricing (can the enclosure-level price breach $100/kWh?)
- Future price declines will come from improved inverters (PCS), more efficient installation, higher energy density, and improved containerization (lower BOS cost).
- Current lithium-ion market is constrained: Korean suppliers are focusing on domestic market, Cobalt is a concern. This is causing divergence between OEMs and renewed interest in Chinese suppliers.

**Ultimately, the industry is driving to breach $1,000/kW installed cost at utility-scale for 4-hour systems ($250/kWh) – this is believed to be competitive with conventional peaking resources with lower overall operational expenses (compare to fuel cost).**

# BESS Cost Breakdown



# Battery Capacity Degradation

Li-Ion battery systems experience **capacity degradation** based on three factors:

1. **Throughput/Cycling**: Each effective "cycle" of a BESS results in a small amount of degradation of the remaining capacity.
2. **Duty Cycle:** Certain use cases can result in more rapid degradation (frequency regulation) – slower charging / discharging and shallow cycling promote longer life.
3. **Shelf Life**: Regardless of use, a BESS will experience some capacity degradation each year it is in operation, even when kept at optimal state of charge.

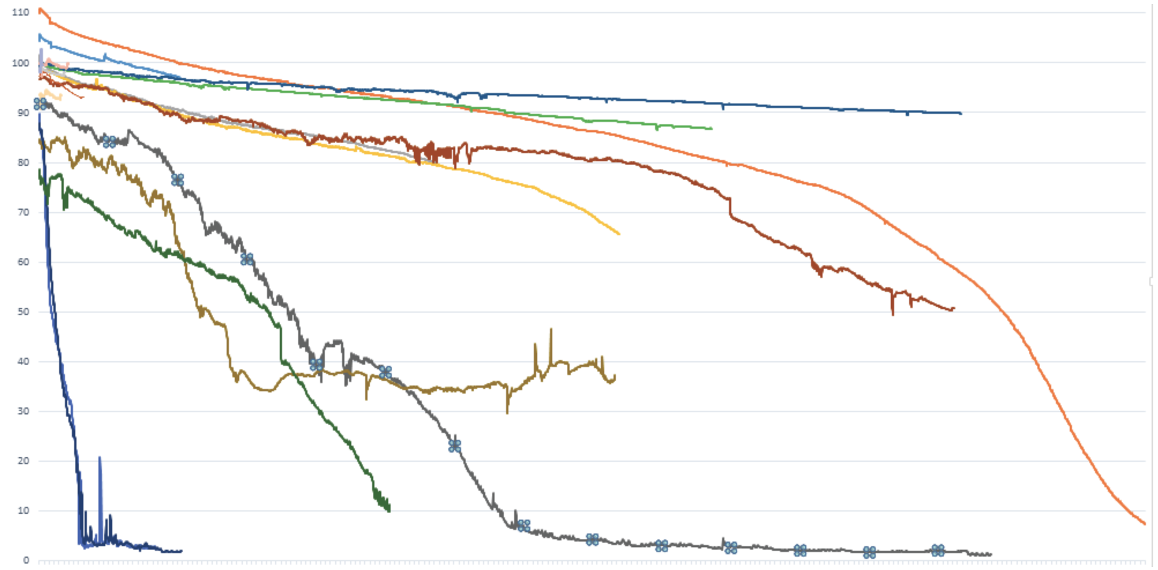



Image above: one battery OEM's Li-Ion chemistry degradation comparison … not without bias! Testing conditions (among other factors) vary.

Rule of thumb: 60%+ capacity retained at year 15 if used <150 full cycles per year.

- Capacity degradation is Li-Ion chemistry **dependent** – certain sub-chemistries have more favorable degradation profiles (at the expense of density or other metrics).
- Third-party engineering services (like DNV-GL's BatteryXT) are beginning to test, simulate, evaluate, and model degradation for real-world applications. The industry is still immature in this respect – seek appropriate warranties!

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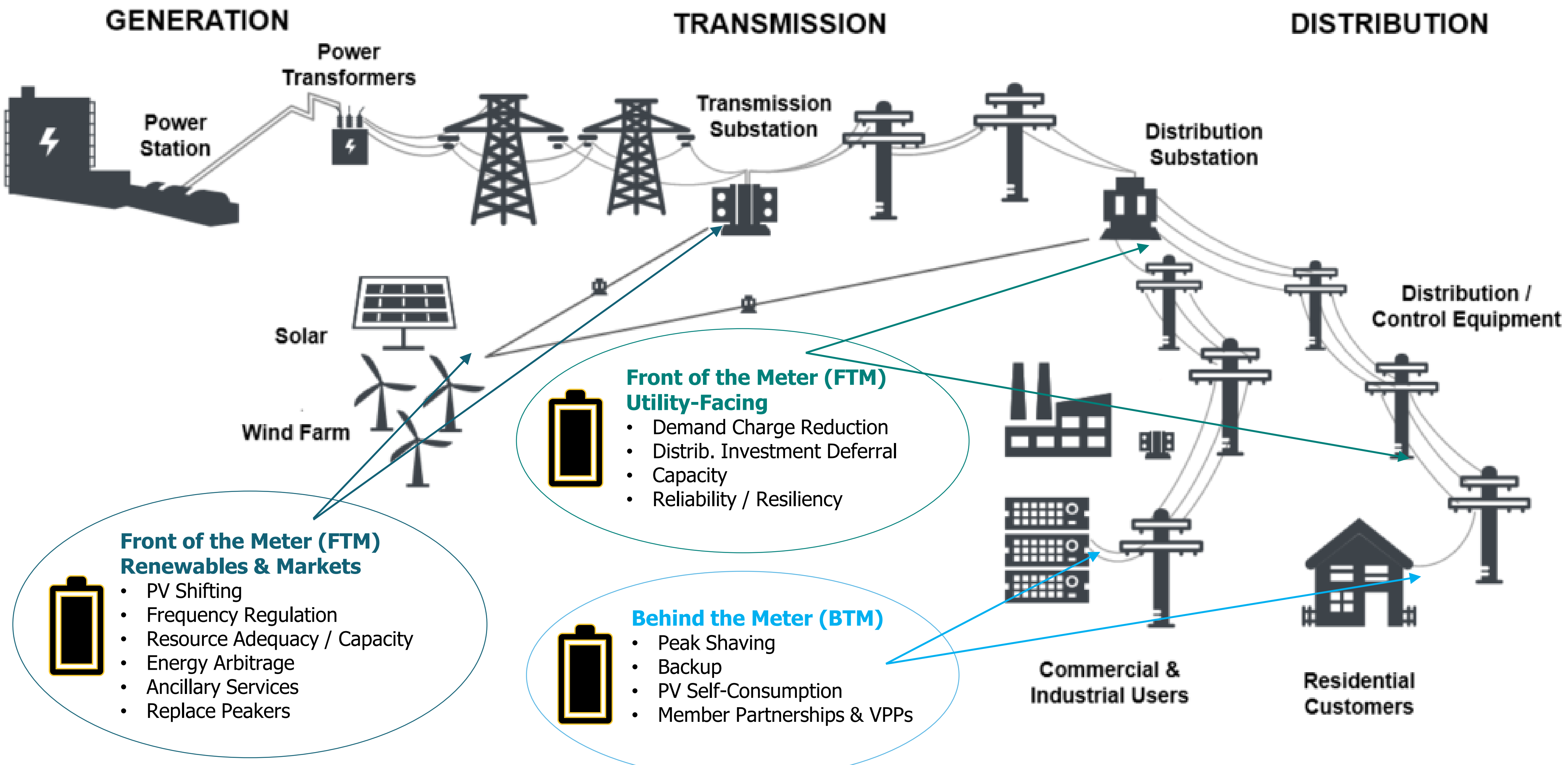
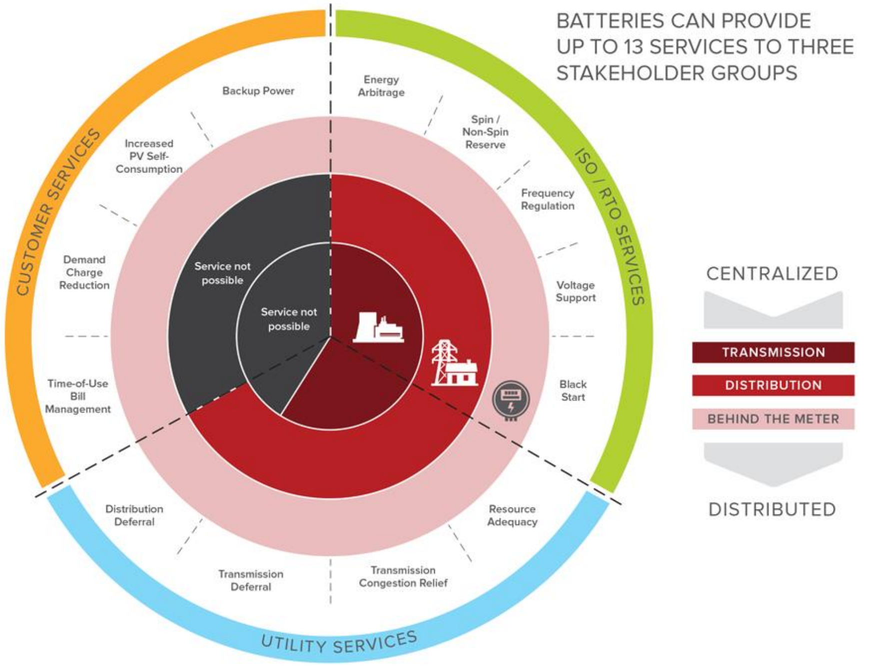
# Many Levels of BESS Deployment



# Decreasing Cost, Increasing Reliability

| Value Proposition | Value Stack | Comments |
|---|---|---|
| Demand Charge Reduction / Capacity Value | 30-70% | What do you pay for coincident / non-coincident peaks? Do you have a capacity need? |
| Frequency Regulation | 0-70% | Is there an FR Market? |
| Customer Partnerships | 0-25% | Are there customers/members of the distribution system with unique challenges addressable by storage? |
| Voltage Regulation (VAR Support) | 0-15% | Are there voltage or power factor issues on feeder? |
| Distribution & Transmission Costs Deferred | 0-15% | What are proposed distribution and/or transmission augmentation plans? |
| PV Ramp Rate Control | 0-15% | Is there concern with PV variability? |
| Distribution Line "Black Start" | 0-15% | Can the feeder be sectionalized? |
| 24-Hour Microgrid Capability | 0-15% | What fuel, maintenance, and other costs deferred? |

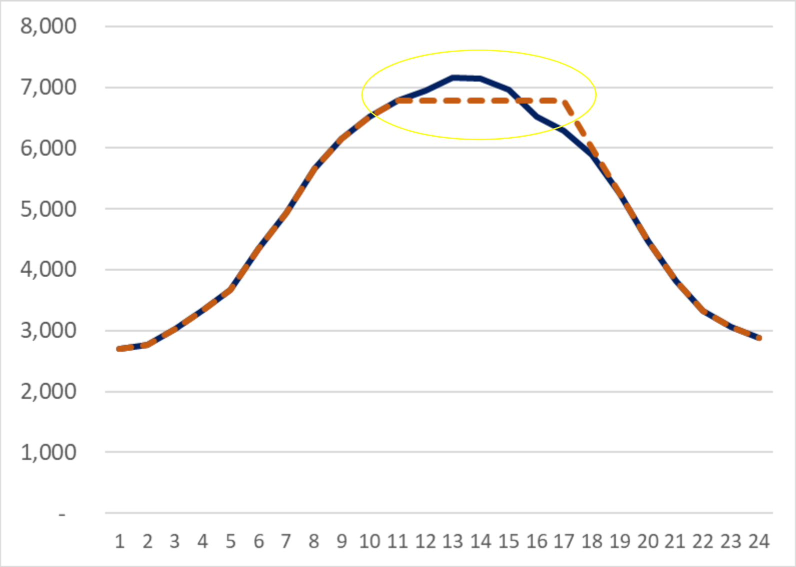



Rocky Mountain Institute: "The Economics of Battery Energy Storage" (October 2015)

Electric Cooperatives are uniquely positioned to capture multiple values from energy storage.

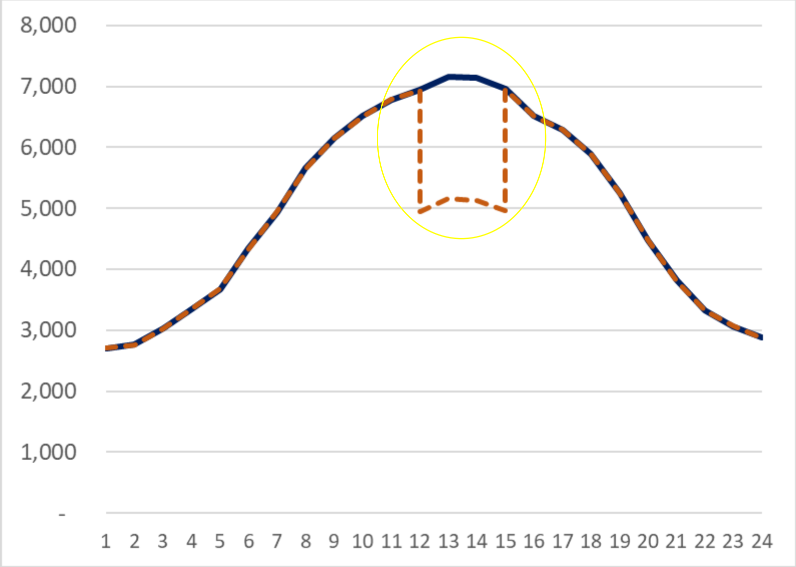
# Peak Management & Demand Charges

- Using storage for peak reduction is generally economic at demand charges at or above $12/kW-mo.
- Opportunities exist BTM (tariffs) and FTM (demand & transmission charges) applications.
- Improved dispatch software has led to various new opportunities (autonomous peak shaving, RTO/ISO peak prediction, etc.)
- **Coincident** peaks are easier to reduce:




"Peak Shaving"
Limited by load shape
Peak reduction: ~ 400 kW

Coincident demand reduction
Not constrained by load shape
Peak reduction (e.g.): 2 MW




Use case: Demand charges, transmission operator charges, ISO/RTO charges (e.g. PJM PLC & NITS)

# T&D Investment Deferral

Under certain conditions, deploying BESS can defer transmission and/or distribution investments. Examples include:

- **ConEd BQDM**: $1 billion substation along the Queens-Brooklyn border deferred indefinitely by 52 megawatts of BTM and FTM solutions by 2018 (much of which is BESS).
- **Electric Co-op**: Analysis shows $1 million distribution substation can be deferred for over 20 years by using 1 MW BESS; additional value / savings possible from demand reduction and PV shifting (co-located with PV).
- **Distribution Utility:** The owner of an aging distribution system's analysis shows strategically placed BESS (1-2 MW each) could remove the need for a whole-system overhaul (re-build of significant portion of network) to address power quality & reliability (outages).

Use case: Defer distribution / transmission system upgrades, defer substation investment, improve reliability on aging / challenged / remote portions of networks.

# Customer Partnerships

## Case Study: United Power Cooperative, Brighton CO | "Community Battery"

Value Proposition:

- Analysis shows 25 MW (on a 450 MW peak utility) could be shaved over each of the 12 months with a duration of 4 hrs. Chose a 4 MW / 4 hr. BESS
- Dispatch ~100 times per year to mitigate peak demand charges
- 100% capacity guarantee for 10 years, 15-year overall wrapped warranty

**Community Battery:**

- United's members cannot reduce their peak (kW) charges very effectively, especially those with high load factor
- United structured the community battery program like community solar: members can purchase a "share" of kW reduction from the BESS which will turn into a reduction on their retail kW charges
- Allows United to partner with members for BESS savings without restructuring tariffs or waiting for significant BTM "peak shaving" penetration against their tariffs – overall, a more economic and effective approach.

Use case: Create programs behind or in front of the meter for critical customers/members of the distribution system. Allow members to participate actively in BESS deployment, reducing utility capital investment and mitigating tariff risk.

# Renewables Integration

Integrating BESS with renewables can unlock several benefits for projects owners and offtakers

- Increase Energy and Capacity value of renewable generating asset
  - PV Capacity value in various markets determined by generation on several specific "peak" hours
- Address duck curve
  - PV energy value is rapidly decreasing in markets with significant PV penetration (like CA) – using storage to shift PV energy to more valuable time periods can be economic today
- Self-consumption of PV
  - System offtakers can use storage to overbuild PV and consume additional kWh in non-generating hours (in lieu of net metering) – this works only in niche markets today (Hawaii)
- Address transmission or demand charges with PV
  - Example: Co-ops can address ERCOT 5CPs with their PV assets more readily with energy storage co-located with PV rather than PV (trackers) alone.
- Monetize the Federal ITC
  - BESS qualifies for the Federal Investment Tax Credit (ITC) if charged >75% from renewables. To fully monetize the ITC, you must charge 100%.

Use case: Contract for more valuable energy / capacity from PV+BESS resources, contract for additional services from BESS paired with PV, deploy BESS on distribution system to monetize cheap renewables.

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