

**Minnesota
Power
Systems
Conference
2018**



Battery Storage: “Swiss Army Knife” of the Grid

**Jeff Plew – Director of Development
NextEra Energy Resources, LLC
November 8, 2018**





NextEra Energy is comprised of two primary businesses utilizing a common platform and supported by several key subsidiaries



- Fortune 200 company
- \$76.6 B market capitalization
- \$97.8 B in total assets
- Ranked #1 “Worlds Most Admired Companies”
- Partnership with NEXTera energy™ PARTNERS



- ~5.0 million customer accounts
- One of the largest electric utilities in the nation by electric sales
- 25 GW in operation including over 17 MW of battery storage



- The world leader in electricity generated from the wind and sun
- 149 operating assets in 33 states and Canada
- 18 GW in operation including over 125 MW of battery storage

Core Values

Commitment to Excellence / Do the Right Thing / Treat People with Respect





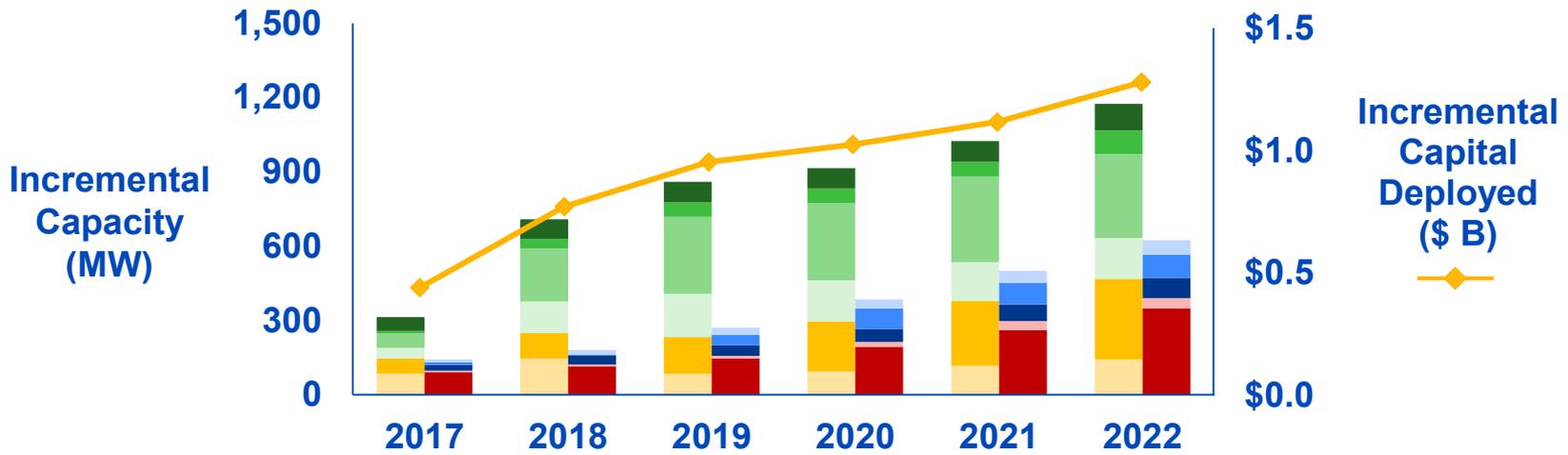
Agenda

- 
- **Market Overview and Technology Trends**
 - T&D Grid Applications
 - Storage Project Examples
 - Additional Considerations



Industry estimates are that 4.7 GW of utility-scale storage and 2 GW of behind-the-meter storage will be installed in 2018-2022

Energy Storage Market (annual)⁽¹⁾



Utility-Scale – Primary Application

- Long-Duration Peaking Capacity (8+ hours)
- Regular, Cycling Peaking Capacity (4-8 hours)
- Peaking Capacity (1-4 hours)
- Occasional Peaking Capacity (1-4 hours)
- T&D Deferral
- Frequency Regulation



Behind-the-Meter – Primary Application

- Grid Services (Utility contracted)
- Capacity (Utility contracted)
- Coincident Peak Management
- Demand Response
- Demand Charge Management

Energy Storage is poised for a rapid acceleration of installed capacity over the next 5 to 7 years, driven by flexibility in design and applications

1) Greentech Media





Unprecedented tax credit visibility past 2020 in wind and solar driving increased renewable build-out; Storage can be a key part of this growth and maturity

ITC and PTC Extension

Wholesale Energy Prices

- Cheap wind and solar will create economic demand
- Customer desire for green energy may also be a driver



Storage Opportunities Created

- Arbitrage
- Curtailment and congestion relief
- Increase need for frequency regulation (but a limited 2-3 GW market)

Capacity Products

- Renewables are cost efficient in many jurisdictions, but intermittent
- Capacity applications will happen with cost improvements, just a matter of “when” (4-8 hour peakers)

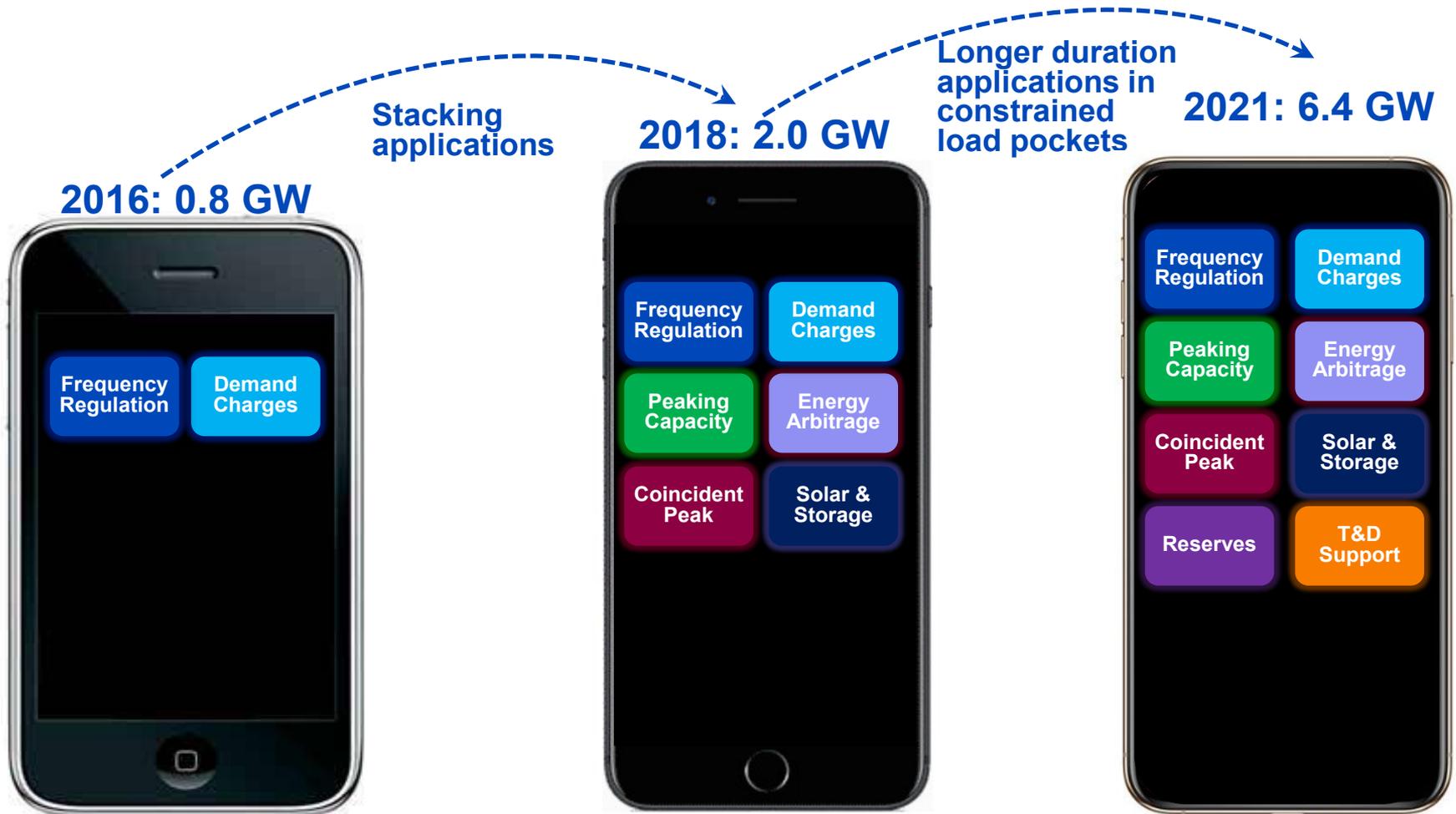


Storage Markets to Pursue

- Base load energy through storage and renewable joint dispatch
- Flexible capacity opportunities with distributed storage applications (1-100 MW)

While ancillary services markets drove initial growth in storage, longer duration applications are expected to grow significantly through 2021 and beyond

The iPhone is Analogous to Storage Disruption



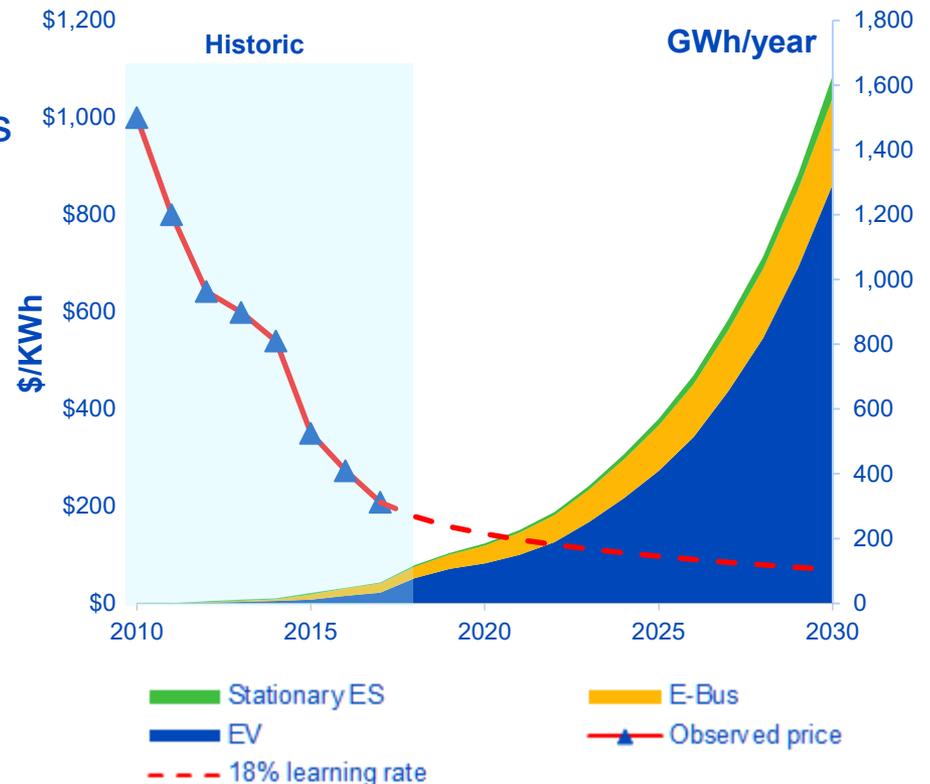
Eleven years ago, no one owned an iPhone; 11 years from now, cheap storage will disrupt how we consume electricity

Energy storage is poised to become an integral part of the energy sector, due to cost declines associated with manufacturing scale and continued R&D efforts

What is Driving Energy Storage Growth?

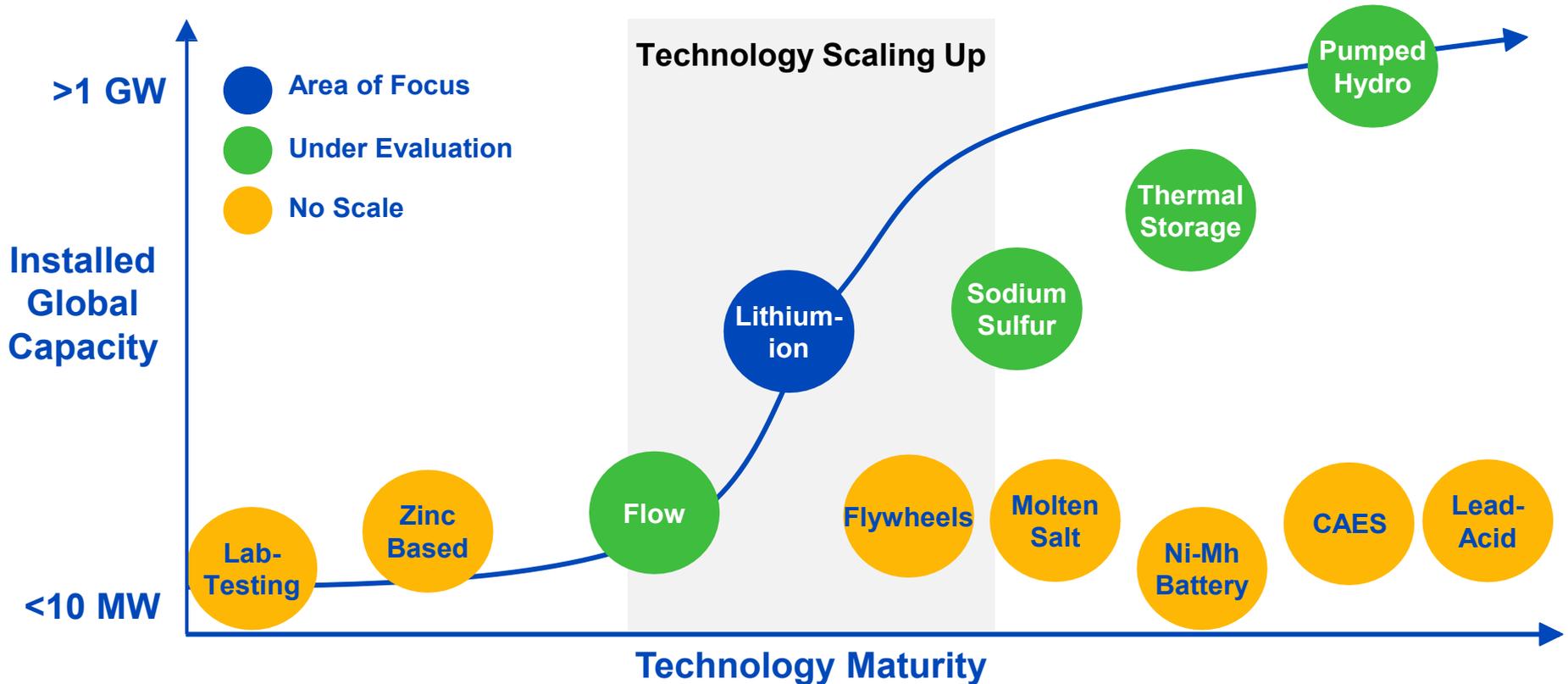
- **Storage provides customized and adaptable solutions**
 - Highly flexible resource capable of performing multiple roles
 - Regulatory policy advancements along with fast ramping capability will help enable integration of more renewables
 - Simpler siting makes storage a viable alternative to new fossil generation and transmission
- **Declining costs through continuously improving technology and scale of manufacturing**
 - New technologies and controls play a large role in driving demand for energy storage

Scale Driving Down Costs⁽¹⁾



Lithium-ion storage technology continues to be the market's preferred technology for today's grid applications

Market Maturity of Grid Storage Technologies⁽¹⁾

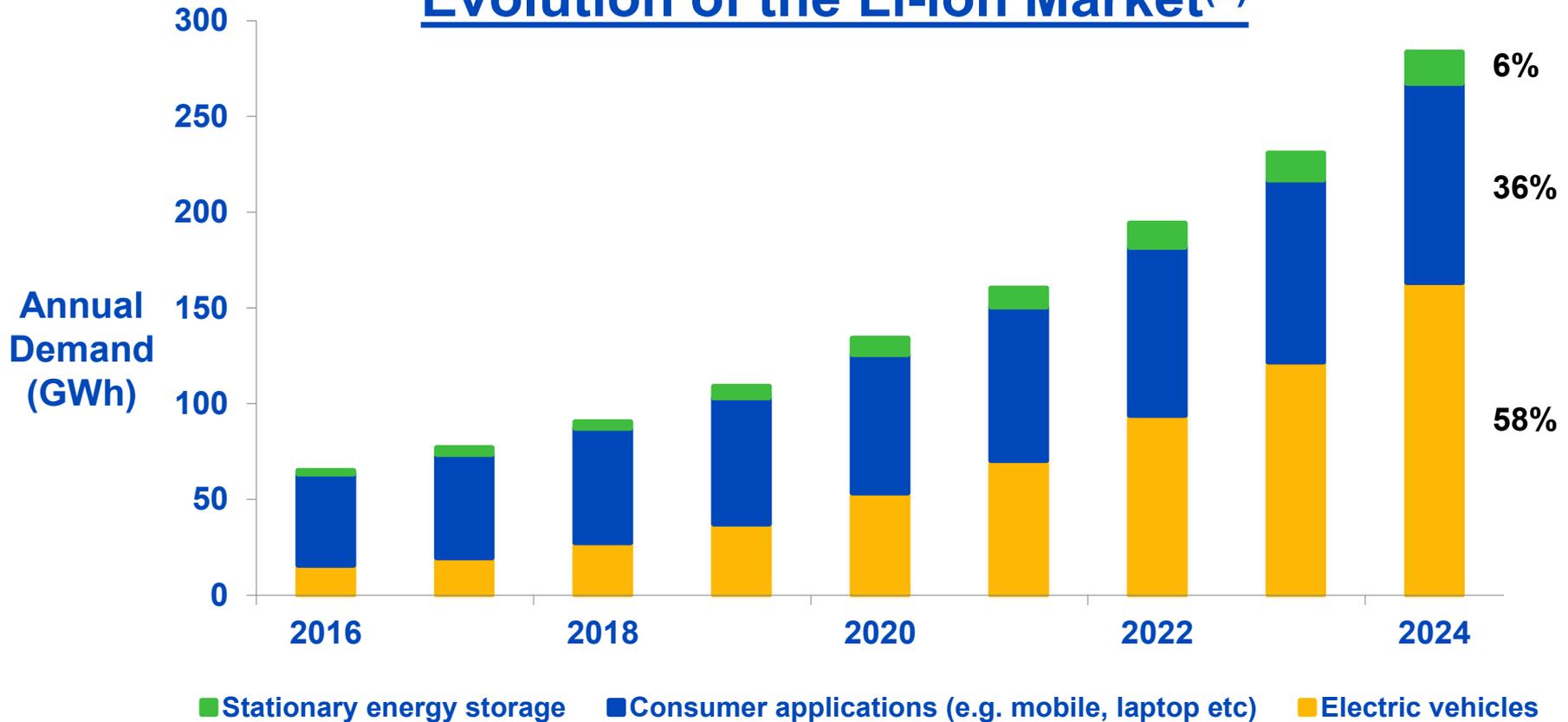


Evaluation of traditional technologies and alternative technologies (sodium sulfur, flow) for longer duration applications will continue



In 2015, electric vehicles accounted for 35% of lithium-ion consumption versus 2% in 2005⁽¹⁾

Evolution of the Li-ion Market⁽²⁾

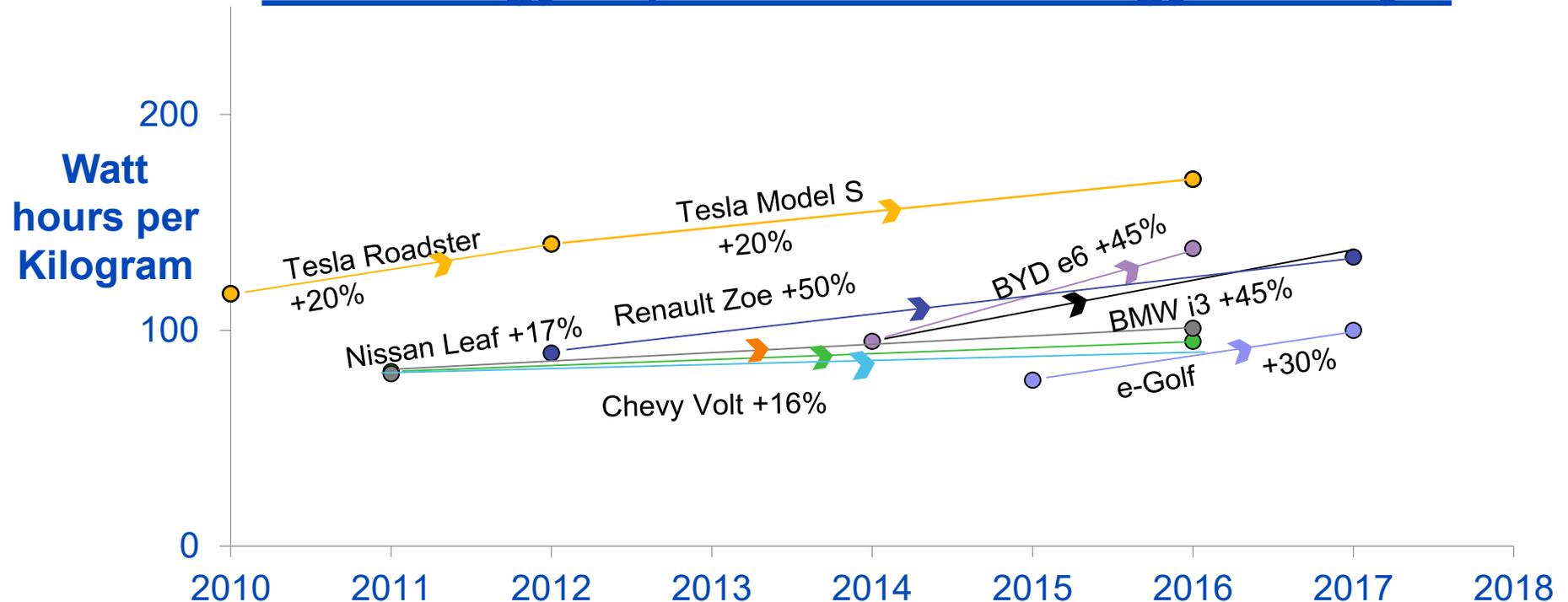


The electric power industry will be a secondary beneficiary of the electric vehicle demand for lithium-ion batteries

1) The Battery Series Part 3: Explaining the Surging Demand for Lithium-Ion Batteries, Visual Capitalist
 2) Energy Storage Deployment by application, Bloomberg New Energy Finance

Significant R&D amounts invested by the automotive sector has led to on-going battery density improvement

Technology Improvements – Energy Density⁽¹⁾



Energy density improvements are primarily attributable to the redesign of batteries and addition of new chemistry variations

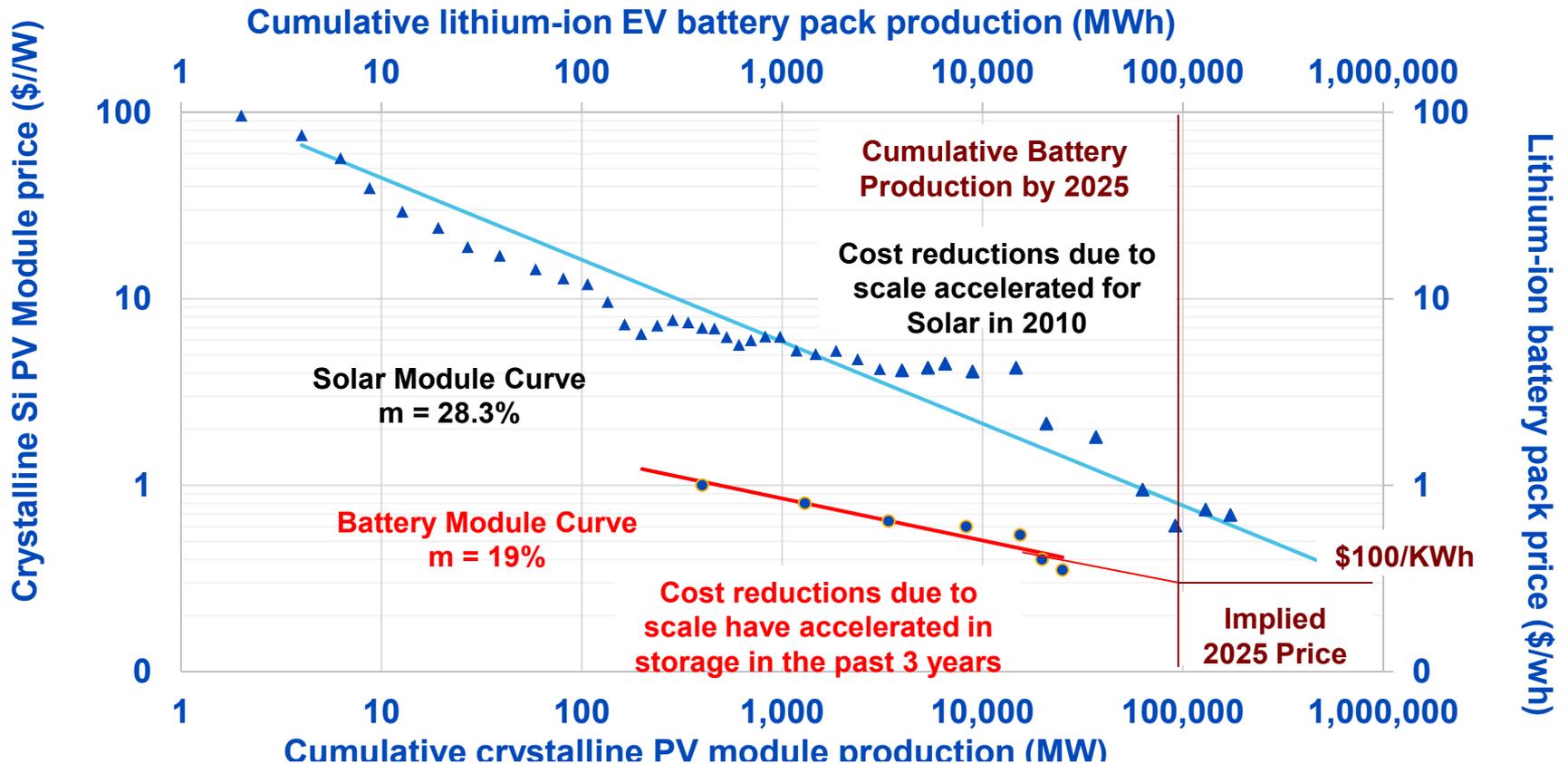
Higher density both improves the battery cost and reduces the total system footprint

1) Bloomberg New Energy Finance - Battery energy density improvements (July 2017)



The battery module cost declines we are seeing are similar to that seen in solar technology in recent years

Cost Learning Curve with Scale⁽¹⁾⁽²⁾



Under current projections based on public data, the \$100/KWh module cost mark may be reached by 2025

1) Bloomberg New Energy Finance (BNEF), "Global EV Sales Outlook to 2040," (February 2017)
 2) m represents the historical cost decline for every cumulative doubling of produced module capacity





Two recent FERC rulings will contribute to efforts in opening up additional market participation and interconnection opportunities for energy storage

Energy Storage Opportunities- FERC Order 841 and 845

- **FERC Order 841 requires ISO's to wholesale participation models that account for the unique physical and operational characteristics of energy storage**
 - Allows storage to more effectively participate in all ISO market products, increasing revenue potential while contributing to overall reliability
 - ISO/RTO compliance filing with FERC by 12/2/2018; implementation expected by December 2019
- **FERC Order 845 includes key provisions to allow storage to be integrated into existing projects easier than they can be today**
 - New "Surplus Interconnection" provisions may enable expansion of an existing generating facility nameplate without an interconnection request
 - Reduced study time and costs, lower network upgrade costs when adding storage to existing wind, solar or fossil sites
 - Effective date in early 2019

FERC activities related to storage should support additional projects and opportunities in the near future



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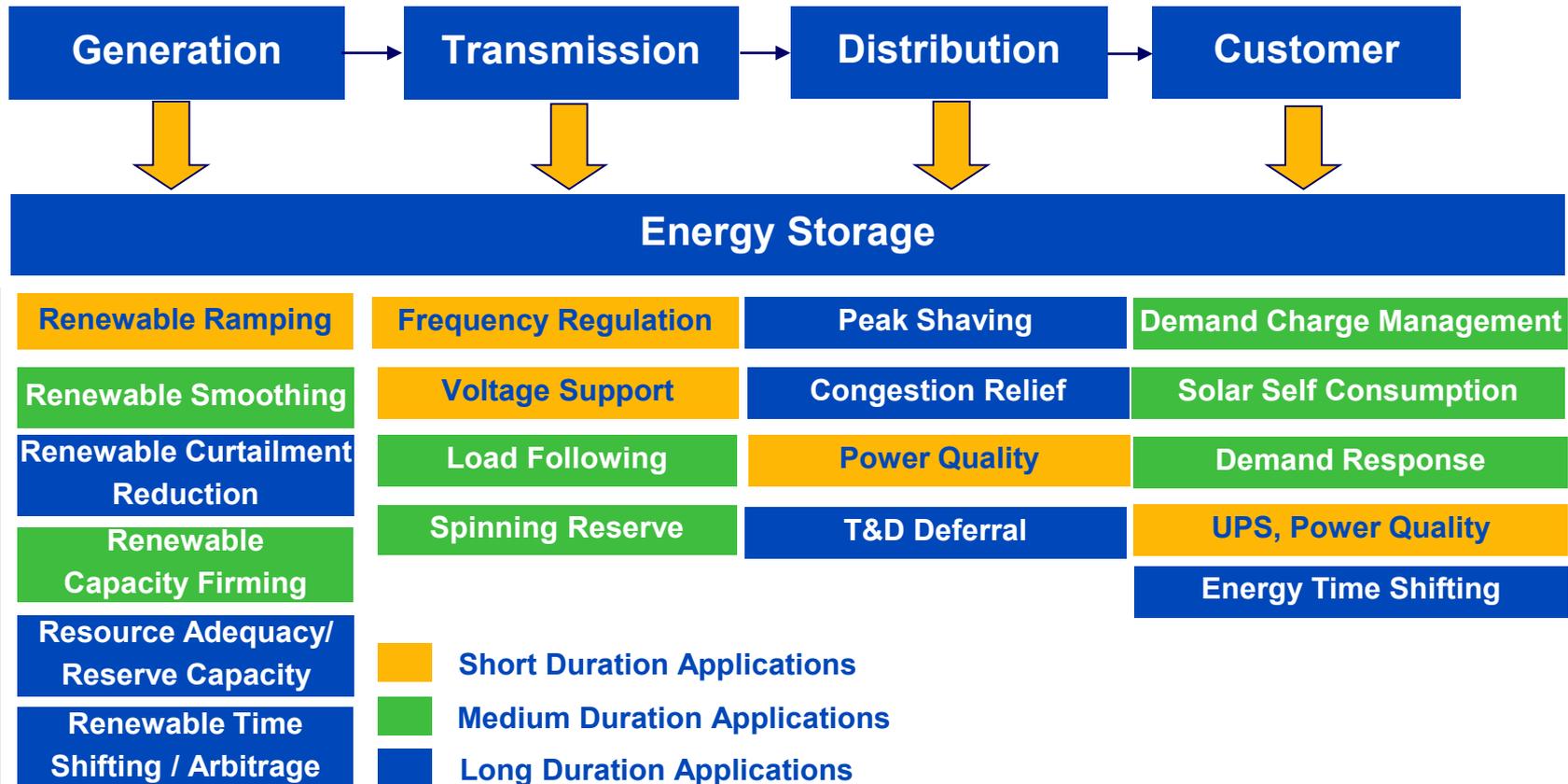




Energy storage applications span multiple disciplines across the grid, but use case stacking is key to unlocking the full value of storage



Energy Storage - Grid Applications



Storage can do many different things, but not necessarily all at once; design and location are key factors

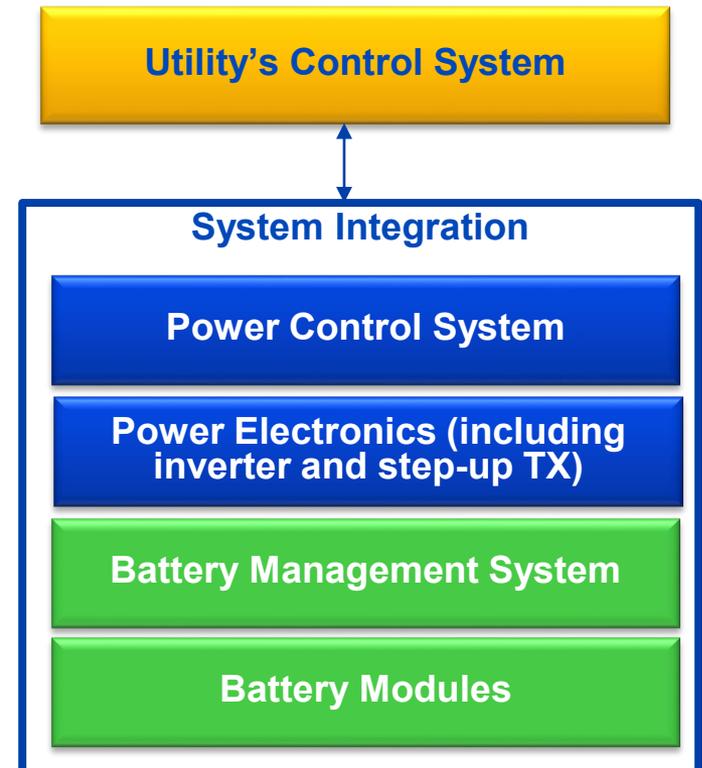




A seamless integration of the various components is critical to meet unique application requirements and realize cost effective operations and reliability value

Energy Storage – System Integration

- Integration is a combination of hardware and software components, joined together to provide a seamless interface between the energy storage system and the grid
- This includes:
 - Determining the optimal battery, inverter and transformer configuration
 - Optimizing the containerization design of the system, HVAC and fire suppression systems design
 - Developing software and communications to optimally dispatch the system while maintaining the system health and state of charge
 - Includes the controls and design need for storage use-case “stacking” when providing multiple value streams

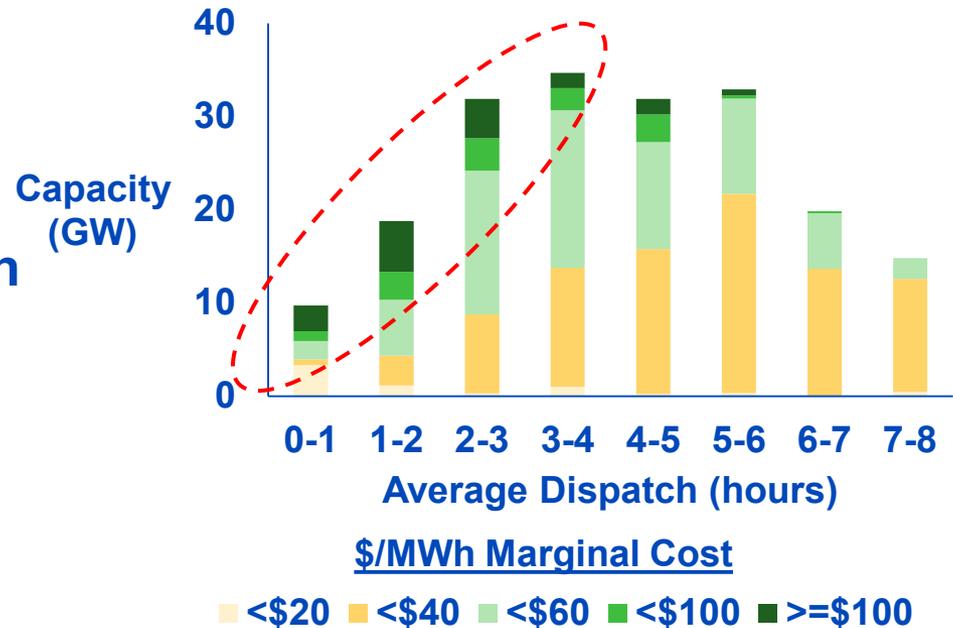


Storage could displace a large portion of the sub-4 hour, >\$40/MWh peaker market

Peaker Replacement⁽¹⁾

- **Replacing existing peakers**
 - Solar + storage or standalone Storage can offer a peaker replacement product competitive with the marginal cost of some expensive peakers
- **Storage should compete with new-build combustion turbine peakers as storage costs continue to decline; NYISO and CAISO in particular show near-term promise**

Total U.S. Peaker Market
(capacity by average dispatch time with marginal cost data)



There is 100 GW of sub-4 hour peaker capacity with a marginal cost above \$40/MWh; 40 GW of that has a marginal cost above \$60/MWh

1) Velocity Suite/EIA 2016; all daily dispatches of fossil fuel units above an annual heat rate of 9,000 Btu/kWh for sub-8 hour dispatches

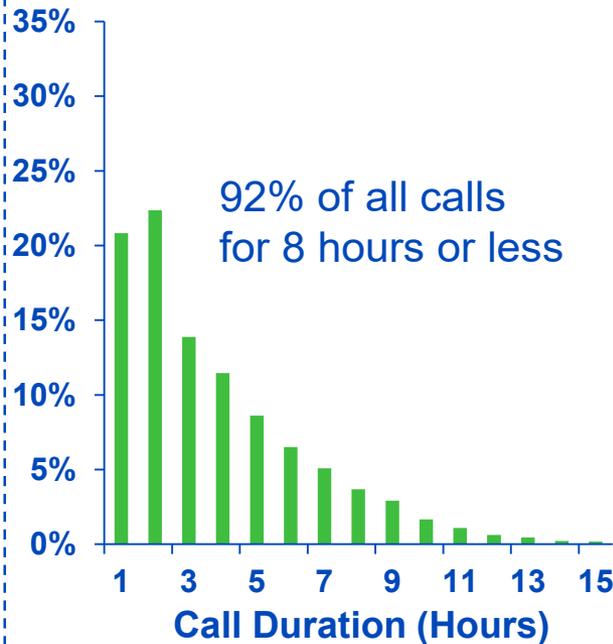
Storage has the greatest opportunity to provide peaking capacity in areas with high load, transmission congestion, or high permitting costs

Storage as a Peaking Resource Alternative

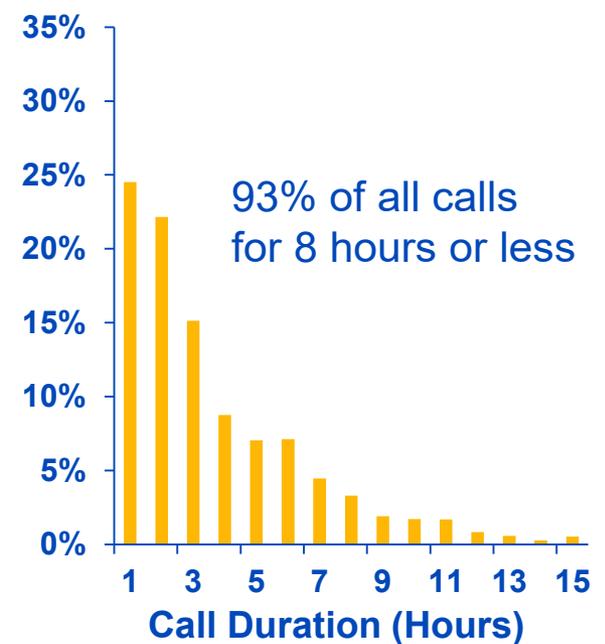
NYISO



CAISO



PJM



More than 92% of all calls in three congested markets are for eight hours or less, creating an opportunity for storage to provide peaking capacity

Velocity Suite, EPA Continuous Emission Monitoring (CEMS); trailing twelve months on 3/1/2016 for all fossil plants in CAISO, PJM, and NYISO with annual NCF less than or equal to 10%

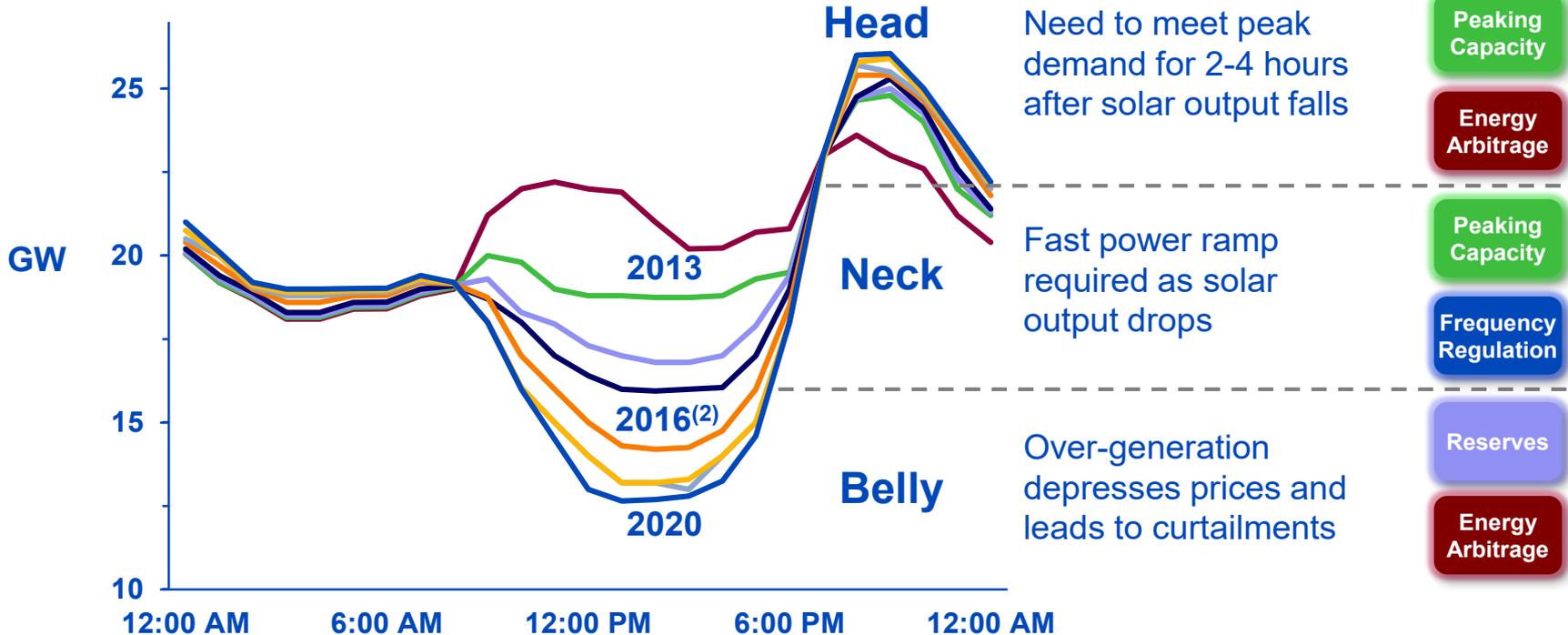




As renewable penetration continues to increase, resource flexibility and enhanced capabilities are becoming key for grid operators to manage the grid

Opportunity for Renewable Integration

CAISO Net Load⁽¹⁾



Storage can enhance electric grids that have a large penetration of renewables by providing both ramping, firming and peaking products

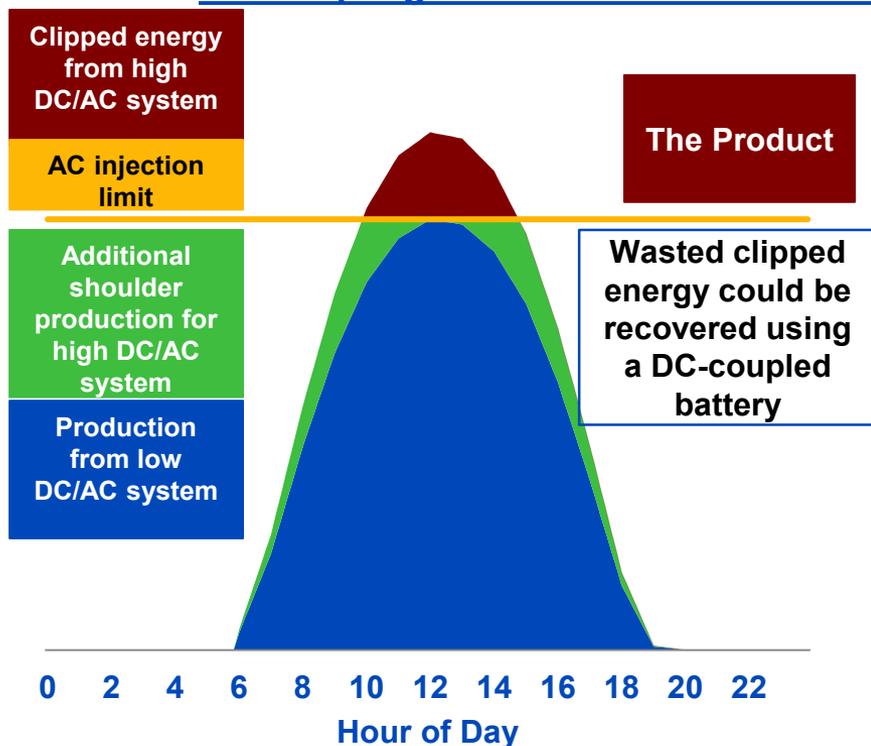
1) California ISO, "What the duck curve tells us about managing a green grid," (2016)
 2) Renew Economy, "California's duck curve has arrived earlier than expected," (July 2016); Windpower Engineering, "CEO of California ISO sees 50% renewable energy penetration," (June 2016)



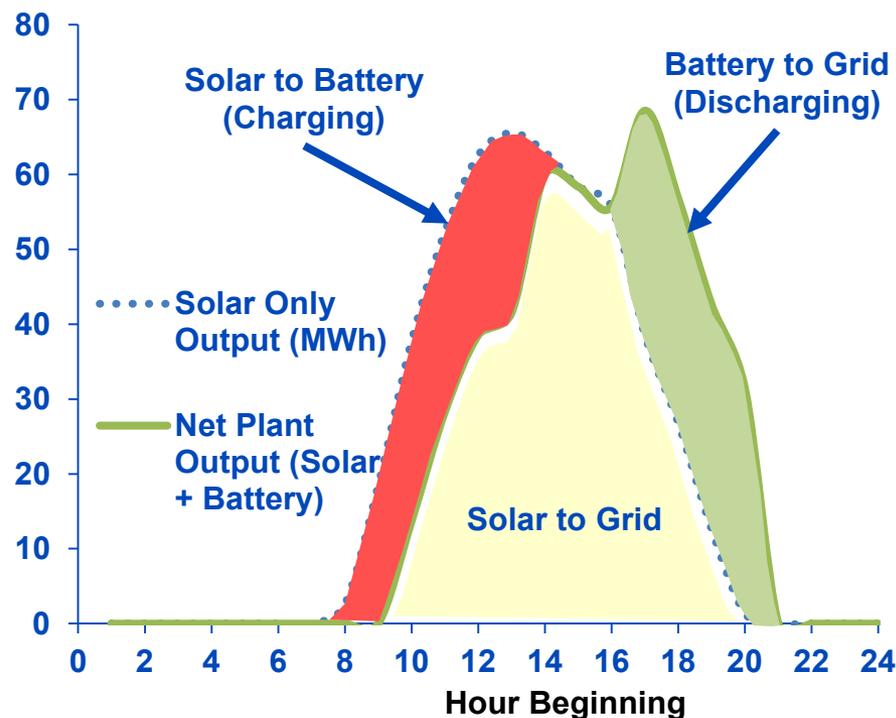
Storage and solar can deliver more energy at peak price periods and in some cases, capture otherwise lost solar energy due to system design constraints

Solar + Storage – DC Coupling & Energy Shifting

DC Coupling – Boost Solar Farm NCFs



Shifting Solar output to Peak Hours⁽¹⁾



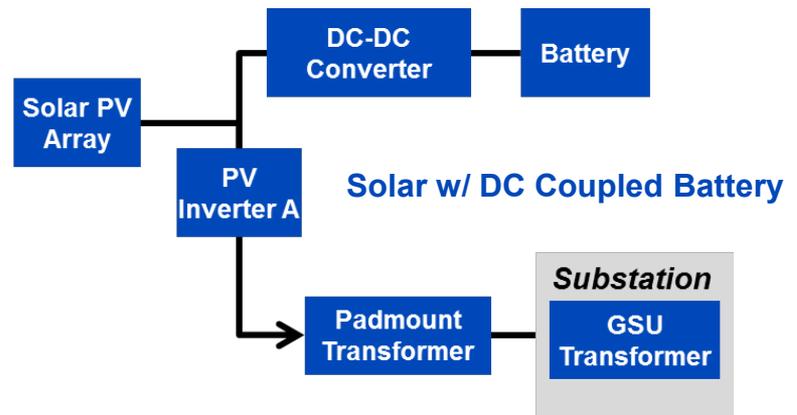
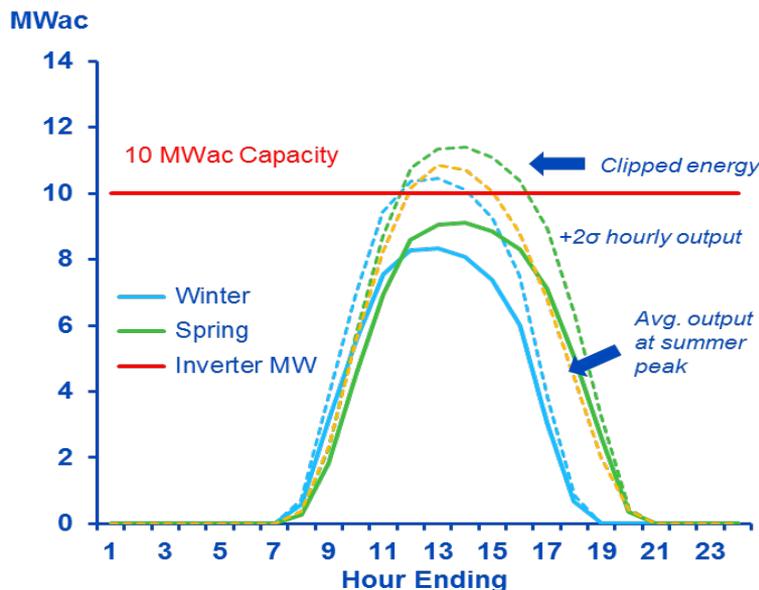
Both of these use cases become increasingly valuable at higher renewable penetration levels, while ITC eligibility improves economics



Storage paired with solar is price advantaged due to ITC eligibility, provides incremental capacity value and depending on design can increase solar production

Solar + Storage: What's better...AC or DC coupling?

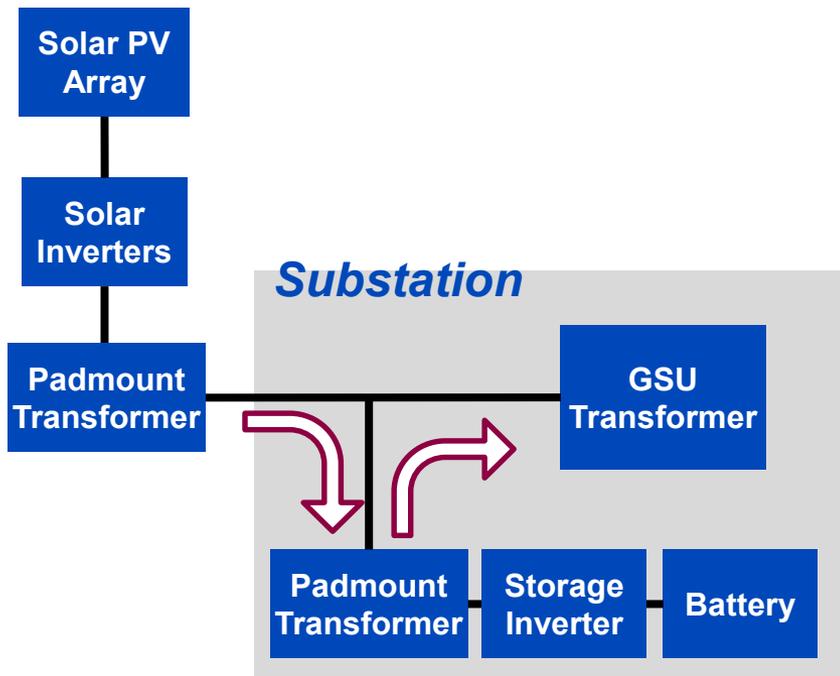
- Storage can be coupled with solar in two ways: on the AC side of the facility using separate inverters, or on the DC side (i.e. PV panel side) using a DC-DC converter
 - Overall capital and O&M costs will vary based on the selected design
- DC coupled design captures incremental solar production that would normally be lost due to typical solar facility design of DC oversizing
 - Energy Arbitrage/shifting and peak firming for capacity are additional benefits



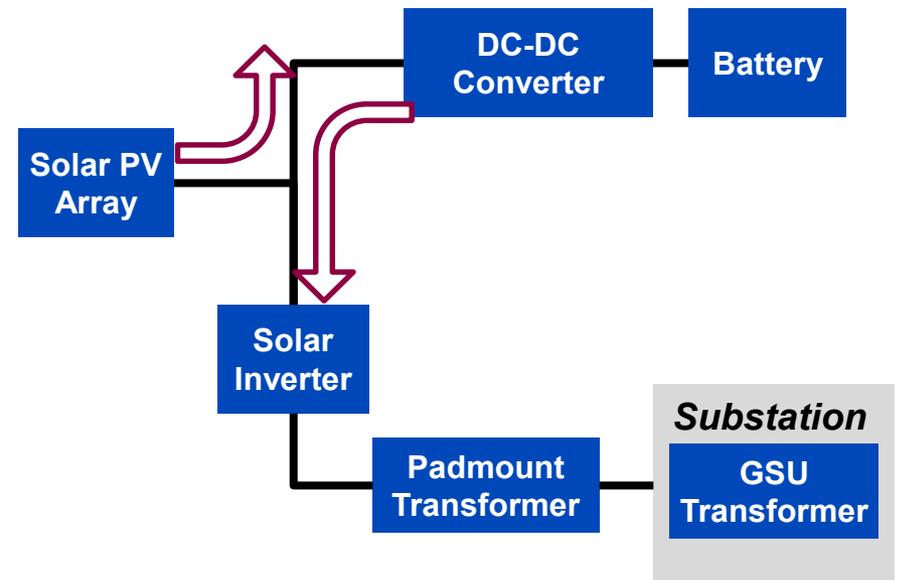
Overall efficiency for a solar + storage system varies with the design and configuration

Efficiency Difference Between AC and DC Coupling

AC Coupled System

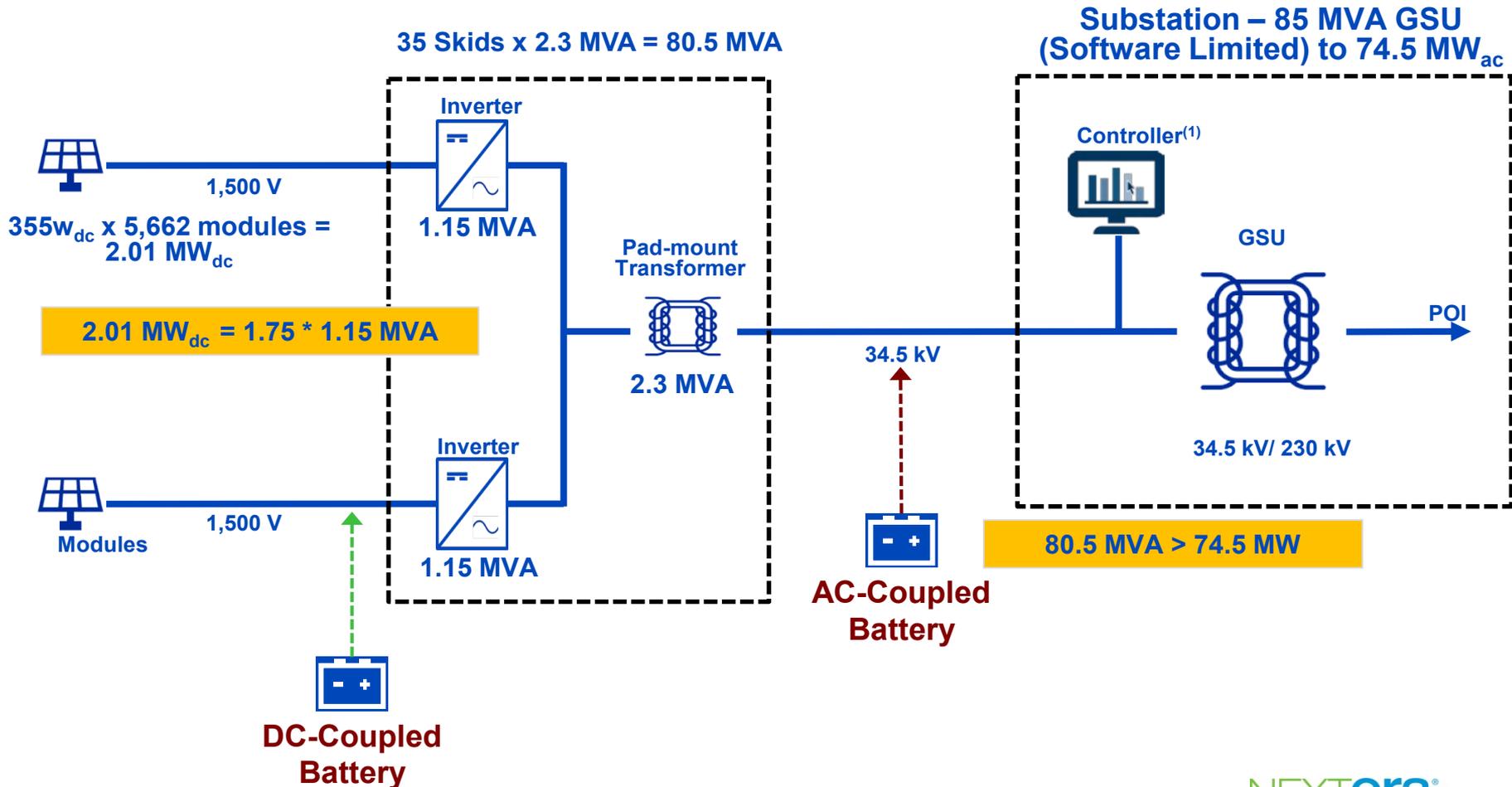


DC Coupled System



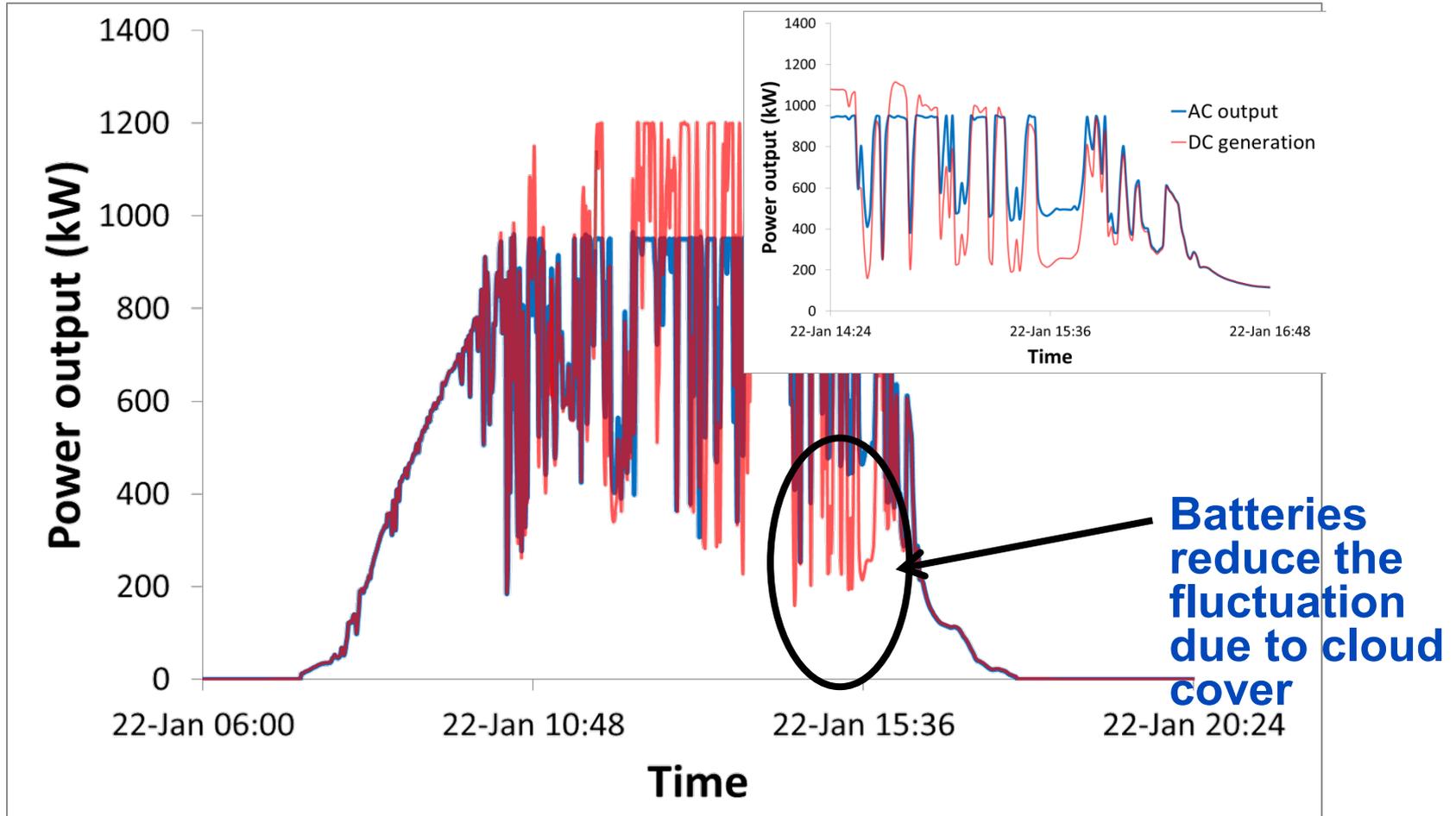
Batteries can be added to solar on the AC or DC side of the inverter, each configuration has benefits and drawbacks

AC vs DC Coupled Batteries – 1.75 DC/AC Example



Mitigating solar variability using co-located storage can provide some value on the distribution grid

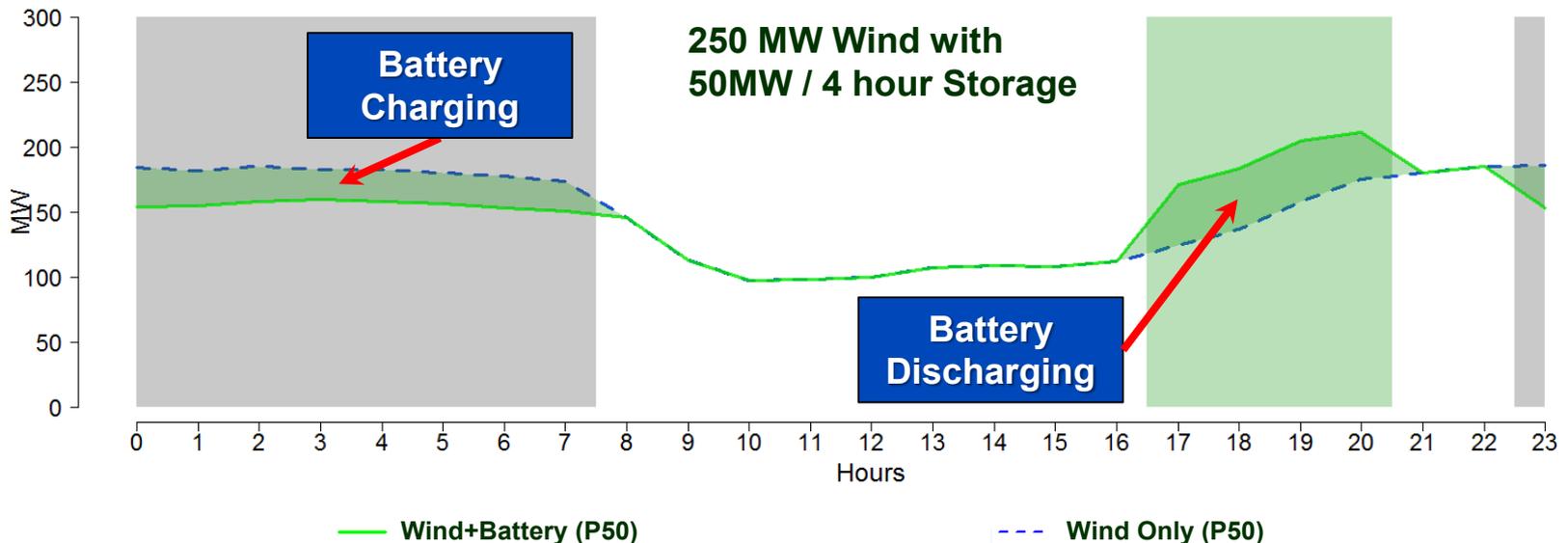
Solar Smoothing via Energy Storage



Storage paired with wind can mitigate impacts of off peak price suppression while firming output during peak hours to provide incremental capacity value

Wind + Storage: Price Arbitrage and Firming

- **Storage can allow flexible contractual structures, such as firm peak hour energy deliveries and limiting must take energy during off peak**
 - Smoothing intermittent wind output and load following services may provide value, depending on market participation strategy used to offer generation and load, as well as ancillary service participation



Pairing storage with PTC advantaged, low priced wind energy can provide several use cases that are value add

Storage connected at the substation and distribution feeder level can increase customer reliability, and provide system level benefits as a load reducer

Battery Storage as a T&D reliability tool

- **Distributed Generation (DG) Energy Storage (i.e. connected at substation or feeder level) can provide a variety of benefits**
 - Reduction in customer outages thru islanding/micro-grid applications
 - Localized voltage support, reserves and capacity when aggregated
 - T&D investment deferral
- **DG Energy Storage is an ideal location for pilot projects due to flexibility and smaller scale**

Resource Adequacy

Reserves

Frequency Response

T&D Deferral

Energy Arbitrage

Florida Bay BESS – 1.5 MW



Pima BESS– 10 MW



When deployed strategically, battery storage interconnected into the T&D grid can provide both economic and reliability benefits



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The Citrus BESS project is a DC coupled solar + storage facility, providing increased solar facility NCF, while also firming summer peak hour deliveries

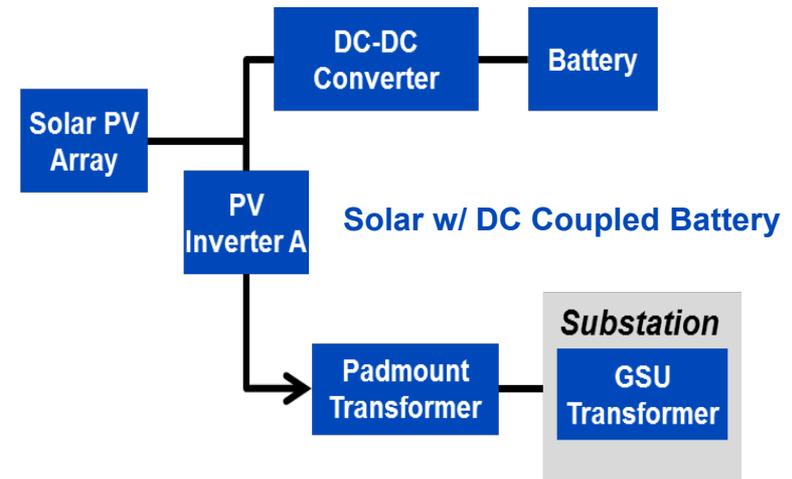
Project 1: DC Coupled Storage w/ Solar

- **Overview**

- Solar facility consists of multiple individual solar inverters rated at 1 MVA each
 - Various DC-DC converter sizes
- Use Cases: Capture clipped solar production while performing solar shifting and peak firming during summer periods

- **Design / Operational Considerations**

- Retrofitting a PV inverter to include battery input (software and hardware)
- Controls required to capture clipped energy w/out impacting solar output
- Optimization of site design including DC/AC ratios for maximum value

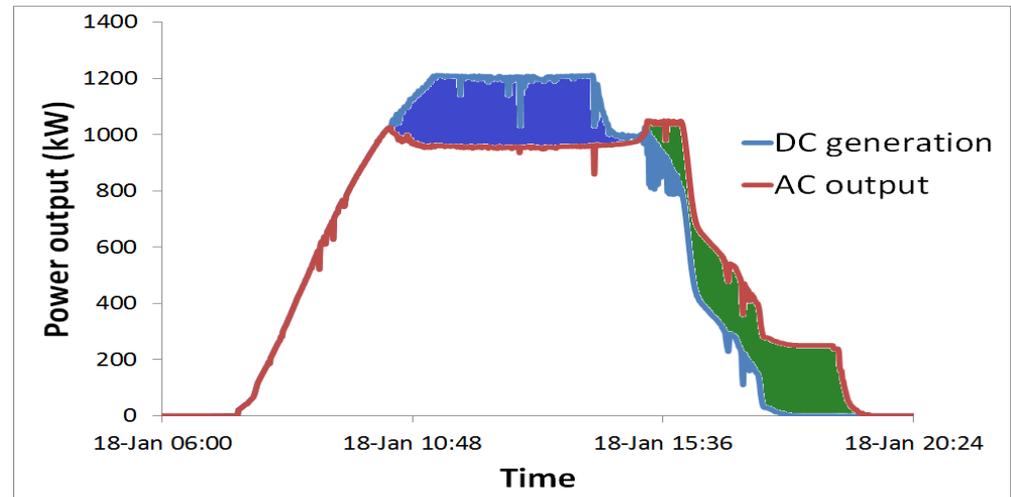


DC Coupled storage is a promising new design approach but requires more complex software controls to optimize performance

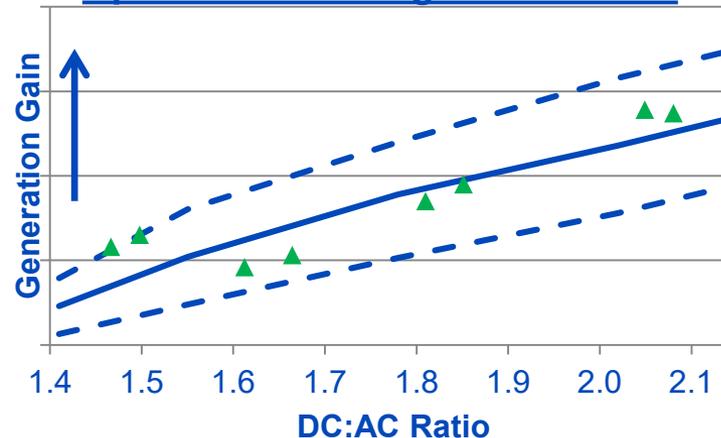
DC Coupling Example: Clipped Energy Capture

- **Additional solar generation captured will vary based on several design factors**
 - DC/AC ratio, solar prediction, battery sizing, etc.
 - Non-clipped energy may be used at times to maximize peak hour deliveries
- **Careful consideration of overall site design on the front end will allow maximum value add from storage**

Generation Profile: Jan 18th



Operational Testing vs. Predicted





The Southwest BESS project incorporates 2nd life EV batteries; system designed to utilize storage in a Peaker / T&D deferral application

Project 2: DG Storage for Deferral and Ancillary Value

- **Overview**

- Capacity: 1.5 MW / Energy: 4 MWh
- Interconnection: 13kV distribution feeder
- Use Cases: Peak shaving, frequency response, voltage control, T&D deferral

- **Design / Operational Considerations**

- Design for both automated and manual control algorithms as a “mini-peaker” via AGC
- Evaluate costs and complexities of integrating 2nd life batteries vs. new modules
- Control logic when performing use case “stacking”; ensure proper prioritization
- Value of T&D deferral vs. avoidance based on expected load growth and other system factors



The Florida Bay BESS project supports a 45 mile radial feeder during outages, as an alternative to a traditional reliability solution

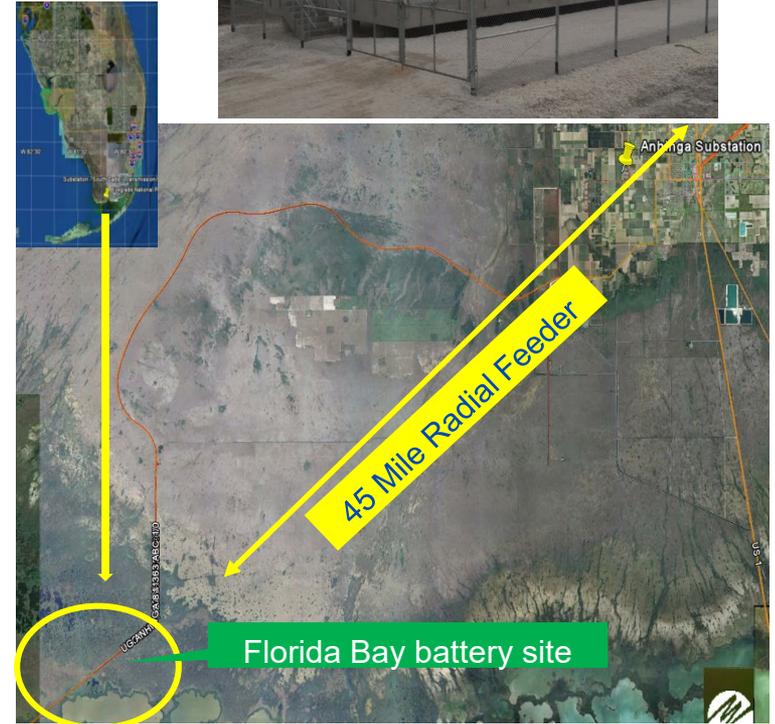
Project 3: “Grid Edge” Storage for Outage Support

- **Overview**

- Capacity: 1.5 MW / Energy: 1.5 MWh
- Interconnection: 13kV radial distribution feeder (45 miles)
- Use Cases: Electrical Islanding (Microgrid) for outage support, voltage control, short term peaking

- **Design / Operational Considerations**

- Planning and operating an electrical island with dynamic loads is complex
- Controls and switching equipment needed to provide seamless transition to and from islanded configuration should be carefully selected



Florida Bay Project: Microgrid Overview

Anhinga
Substation

45 Mile
Radial Feeder

Sewage Plant

FL BAY
BESS

Water
Treatment
Plant

Flamingo
Marina

New
Restaurant

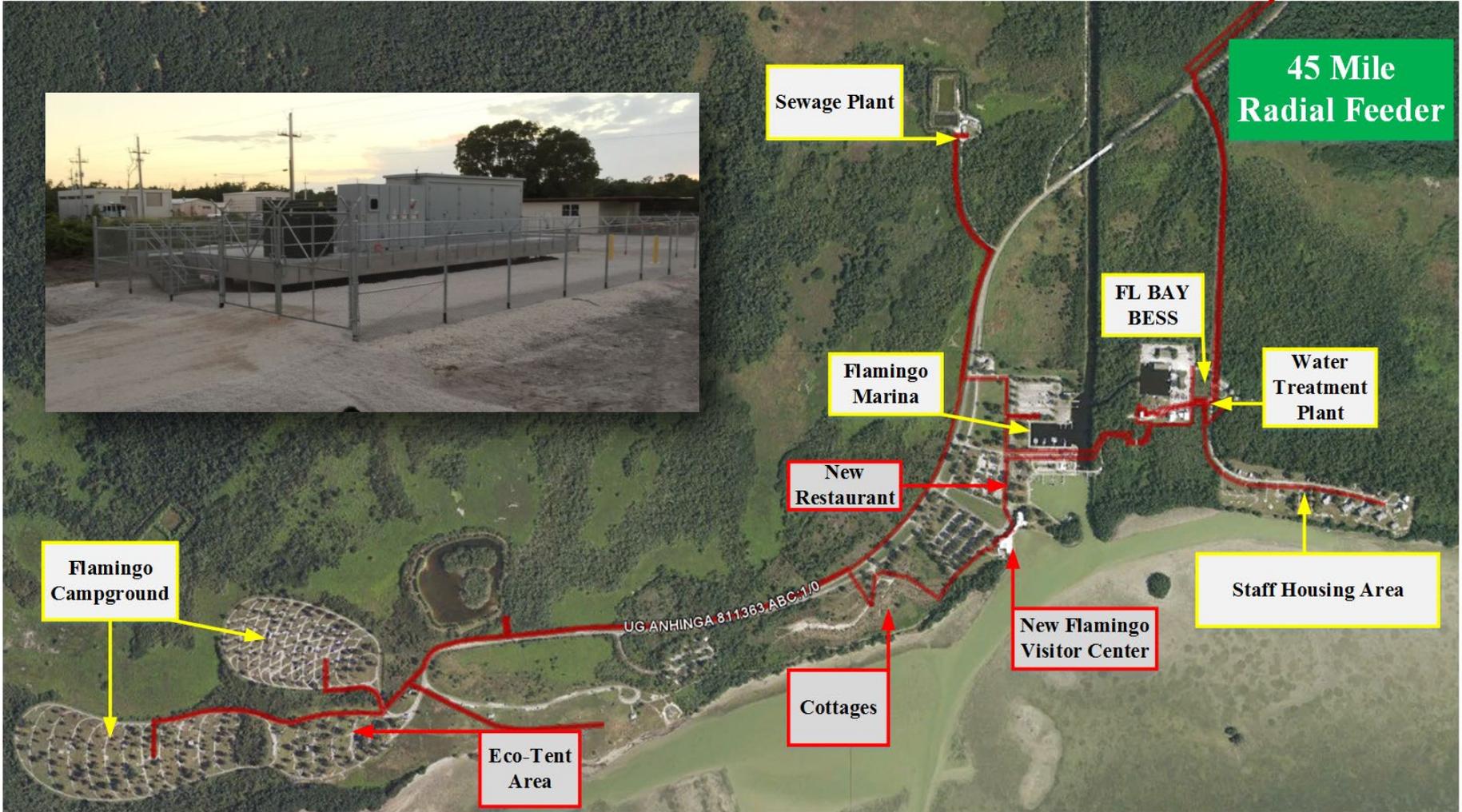
Staff Housing Area

New Flamingo
Visitor Center

Cottages

Flamingo
Campground

Eco-Tent
Area



Hurricane Irma made landfall in South Florida in 2017 with sustained wind speeds of 115 mph

Florida Bay Project – Designing for the Storm

- **Design Considerations**
 - BESS's platform and battery module building are designed for 180 MPH ultimate wind speed
 - Designed to mitigate the risk of flooding
 - Incorporated anticipated storm surge into design
- **Performance during Irma**
 - Projects were ready to operate and deliver energy during and after the hurricane



Water reached the fourth step.



No wind borne debris affected the physical plant.



Mobile Battery storage systems can provide premium UPS service to critical loads such as sporting events and manufacturing while also providing utility benefits

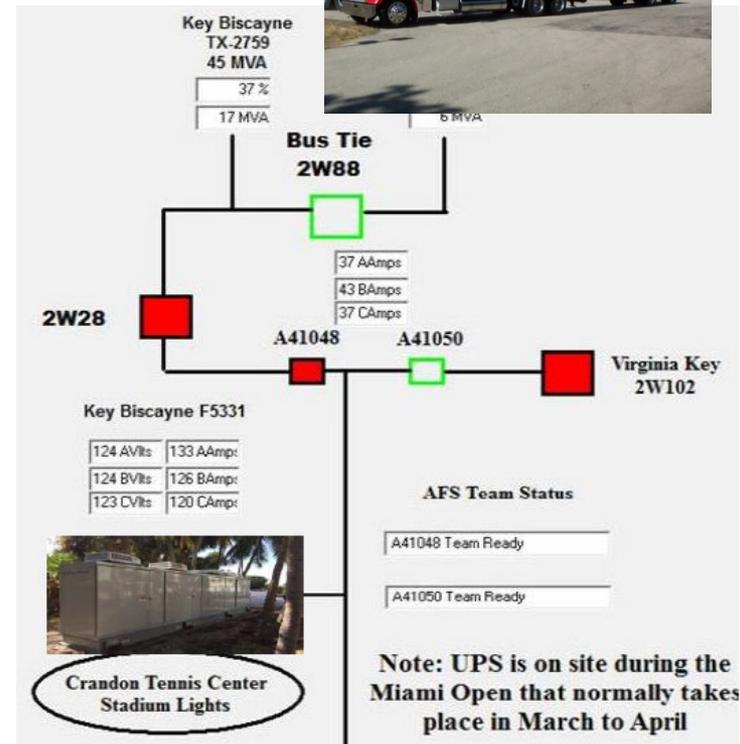
Project 4: Mobile UPS Battery Storage System

- Overview**

- Capacity: 500 kW / Energy: 50 kWh
- Interconnection: 480V / secondary
- Use Cases: Reliability (eliminate momentaries and CME), future expansion for longer duration backup under evaluation

- Design / Operational Considerations**

- Grid-BESS transfer speeds must meet load requirements (e.g. stadium lighting reliability)
- Similar transfer speed requirements must be met for critical manufacturing facility loads
- Long duration expansion to couple premium service with grid benefits can be considered

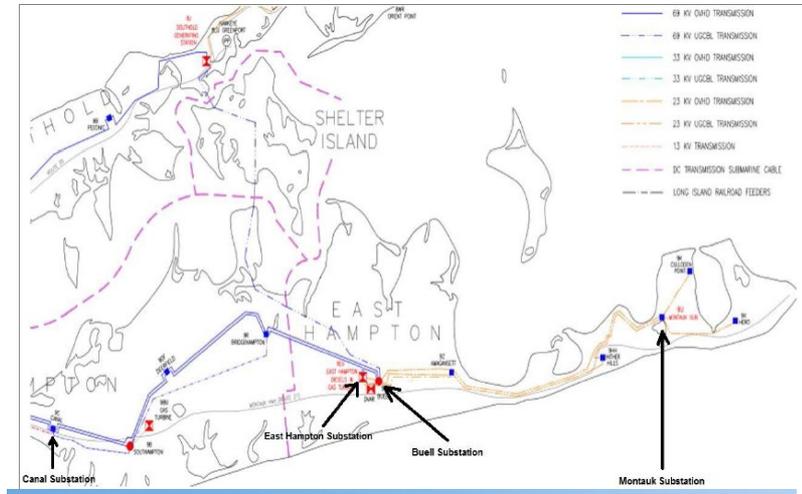




Storage, located strategically on the grid, can provide summer peaking capacity while improving transmission reliability during N-1 conditions

Project 5: Storage for Transmission Contingencies

- **Overview**
 - Capacity: 10 MW / Energy: 80 MWh
 - Interconnection: 13kV distribution substation (two sites)
 - Use Cases: Peaking Capacity / Load Reduction, voltage support, and occasional frequency regulation participation
- **Design / Operational Considerations**
 - Refine overall system design including duration requirements to provide targeted, seasonal transmission load relief
 - Local permitting requirements may vary by location



Beyond reliability benefits, DG connected storage paired with solar can provide economic benefits to utility customers when dispatched strategically

Project 6: DG Solar + Storage for Peak Shaving

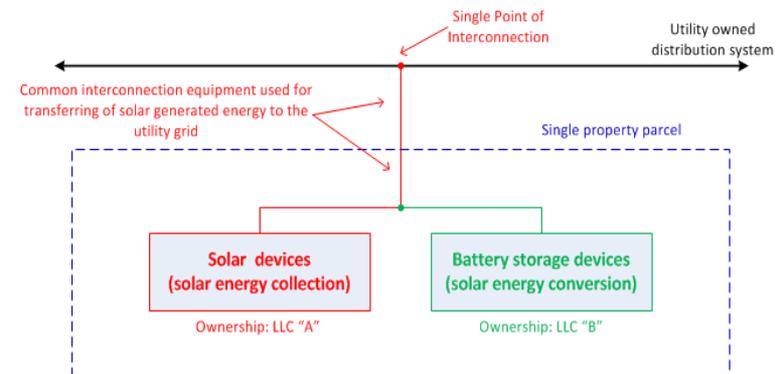
• Overview

- Capacity: 15 MW / Energy: 30 MWh
- Three projects, each interconnected on a separate 12.47kV load serving feeder
- Use Cases: solar shifting for targeted peak shaving, voltage and reactive power control

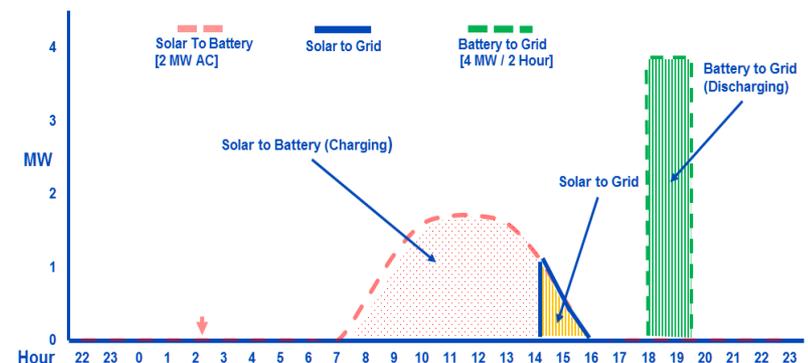
• Design / Operational Considerations

- Interconnection requirements and operational procedures for solar + storage on load serving distribution feeders
- Customized voltage and backfeed prevention control schemes, dynamic curtailments

Conceptual One-Line



Typical Peak Shaving Day





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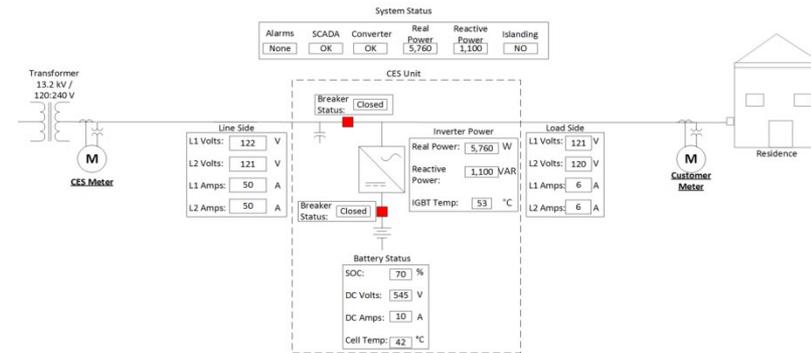
Energy Storage is a new technology; the pre-existing utility processes and business practices used for day to day operations may need to be refreshed



Energy Storage – Integration into Utility Processes

System/Stakeholder	Potential Considerations
Safety/Switching Committees	Switching procedures and clearance processes
Asset Management Systems	In the System
SCADA/Communications Team	SCADA points, Remote Access
Control Center Operations	Control Center screens and Training
Information Management (IM)	Data bandwidth requirements
Customer Information System (CIS)	Outage/SAIDI tracking for microgrid applications
Trouble Call Management System	Alarm Response Guidelines for field technicians
Environmental	Environmental review and policies for battery disposal

Diagnostic Center Screen



Operator Screen

The Operator Screen displays the following information:

- User:** ALEXANDER (677)
- Date/Time:** 26-Apr 17:04:34
- System:** FEEDER 8565
- Control Options:**
 - ENABLE REQUEST: DISABLED
 - INHIB ISLANDING: OFF
 - REQST ISLANDING: OFF
 - RESET ALARMS:
- CES Status:** BATTERY SOC%: 70 %, CONNECTION MODE: GRD, INHIBIT ALARM: TRIP OFFLINE: NORMAL, LOAD POWER kW: 6, LOAD Vars kVAr: 1.

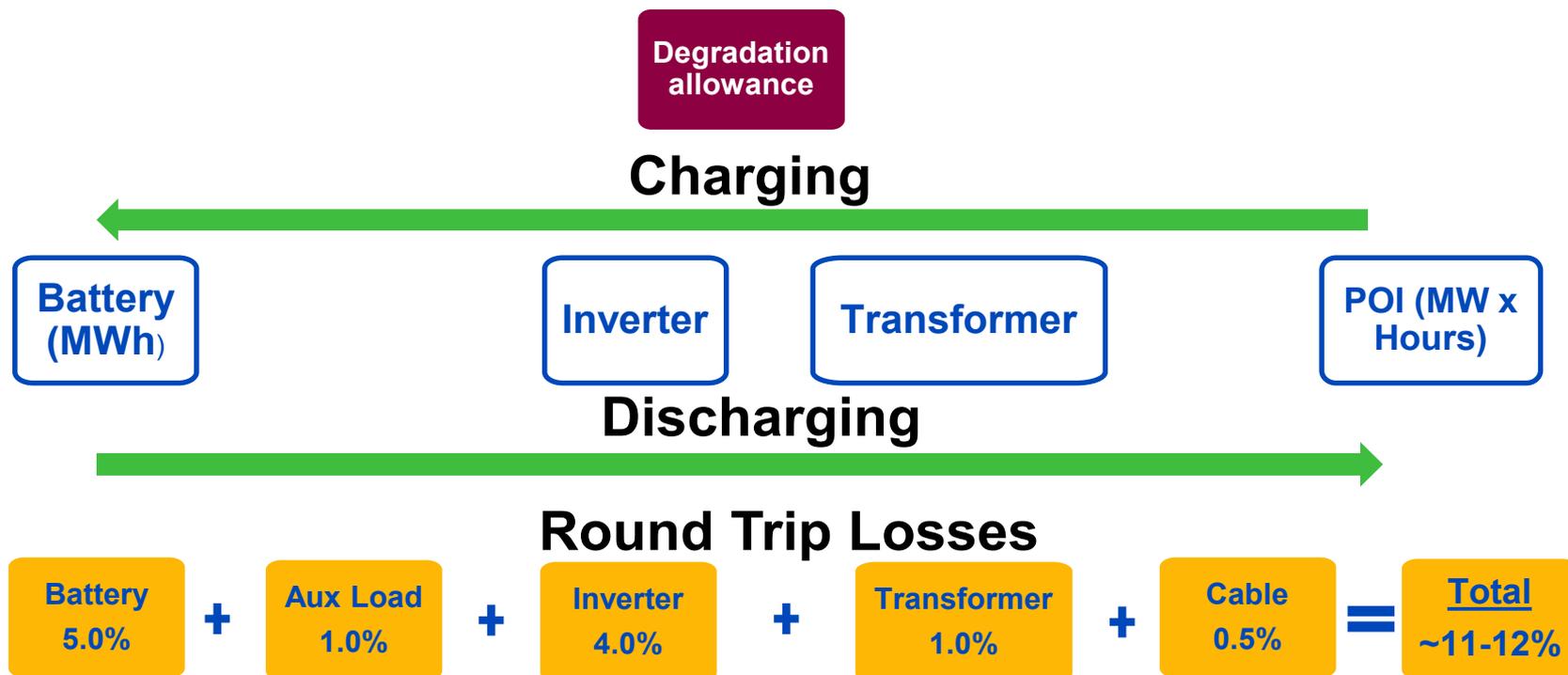
Significant back office effort may be needed to define how battery storage systems are integrated into utility business and operational processes





Battery storage capacity (MWh) has to be sized to account for DC and AC losses to meet the delivery requirement at the Point of Interconnect

Designing for Round Trip Losses⁽¹⁾



Sizing Battery Capacity to deliver constant AC Power for a defined duration requires grossing up for all losses

(1) Shown for Li-ion batteries. Round trip losses vary by technology



Application versatility, declining capital costs and low maintenance costs have made lithium-ion the front runner vs other battery technologies

Battery Technologies – Pros and Cons

Chemistry	Dominant Companies	Advantages	Disadvantages
Lithium Ion	    	Synergies with EV, Strong balance sheets to support equipment warranties, R&D budgets	Versatile product up to 4-6 hrs but potential degradation at low or high State of Charge idle periods
Lead Acid	   	Low cost	Cycle life, Energy density, restricted state of charge operation
Sodium Based	  	Good over long duration (NGK's sodium sulphur commercial at 8 hours)	High temperature operation results in high aux load, safety risk
Flow Batteries	   	Cost effective in long duration applications	Lifetime costs, round trip efficiency, leaks, component failure mode risk
Thermal Storage	 	Half the price of lithium ion for 4hr durations; no degradation	Compressor replacements required within 20-year life





Lithium-ion battery technology continues to improve, but few systems across the globe have been operating long enough to validate true life-cycle

Battery Degradation Validation

- **Battery's life span is impacted by various factors (full or partial cycling, resting state-of-charge, internal temperature, etc.)**
 - Battery degradation is a key risk factor in long term battery storage applications
- **NextEra commissioned a new battery test facility in 2014 to build institutional knowledge around battery design and degradation characteristics**
 - Experiment with varying duty cycles, state of charge, and temperatures
 - Predictive modeling of battery degradation curves, end of life, and long term O&M costs
 - Validate manufacturer stated performance characteristics



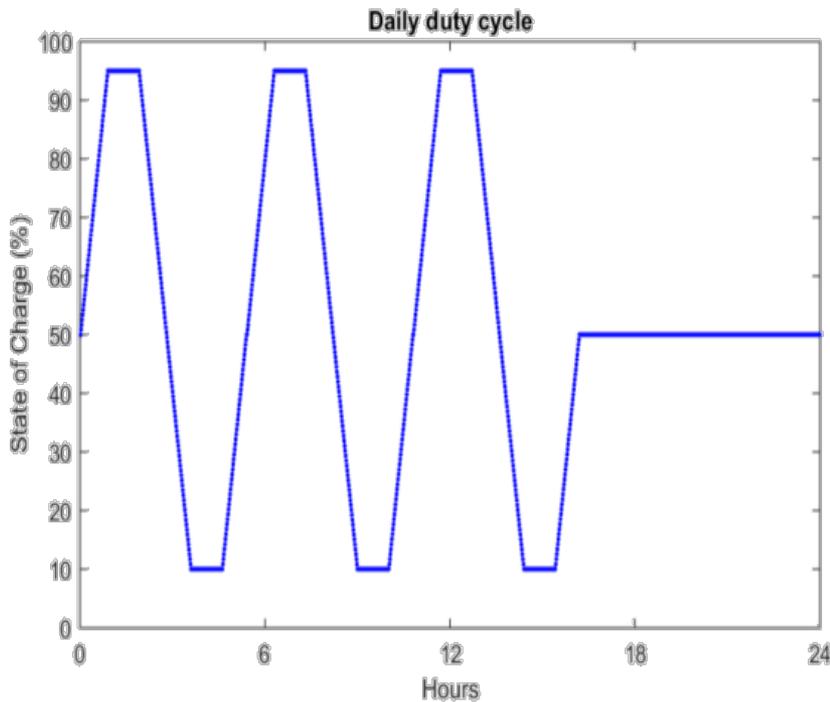
Battery application and use-cases will effect the long term degradation of the system and must be considered



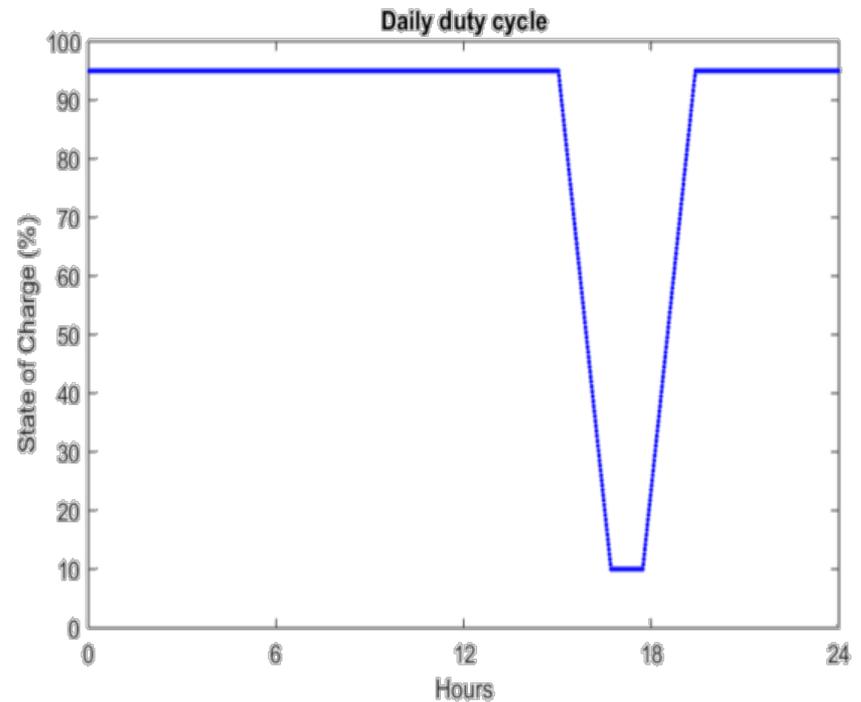
Which of the two use cases below will result in higher battery degradation (i.e. lower capacity) over 10 years?

Battery Storage Degradation – Pop Quiz

Option A



Option B

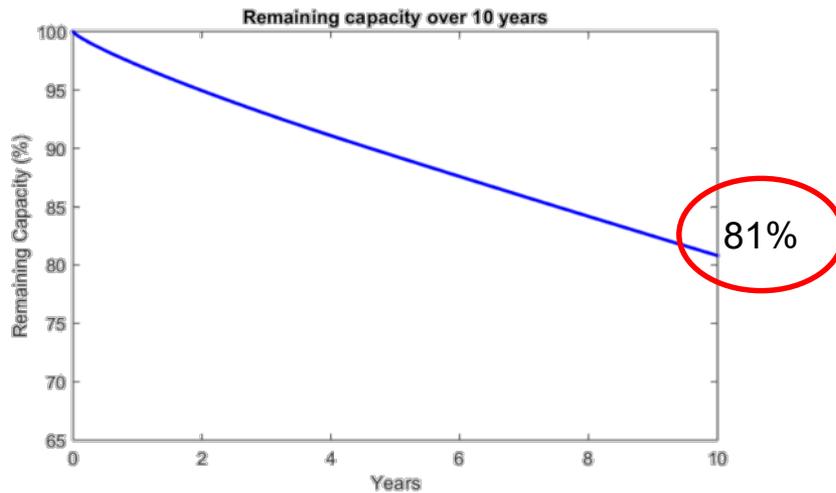
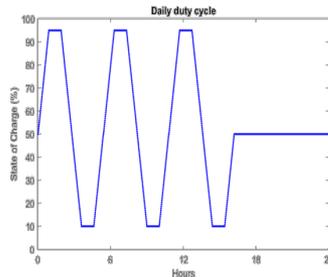




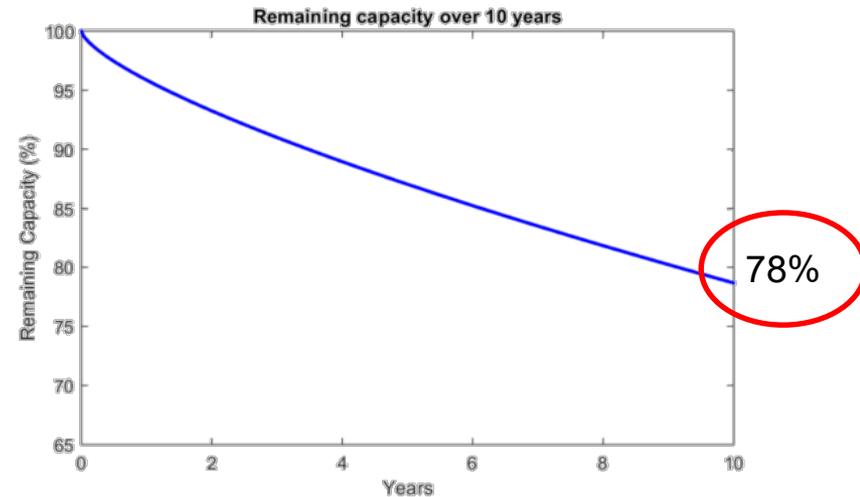
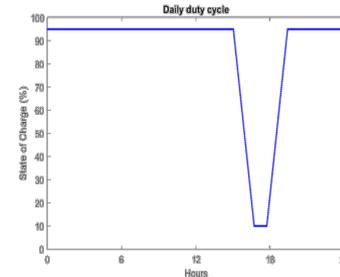
Predicting long term degradation accurately can be challenging, as there are a variety of factors that all impact the battery life cycle

Battery Storage Degradation – Pop Quiz Results

Option A



Option B





Batteries degrade over time and need to be replenished over the life of a project in order to maintain the same level of MWh energy output at POI

Select Factors Impacting Battery Degradation

Number of Cycles

Number of times the battery is charged and discharged (e.g. 255 annual cycles = 1 full cycle per day on all non-holiday weekdays)

Depth of Discharge

How deep is the battery charged and discharged between 0% and 100%

Idle Time & Rest SOC

How often is the battery idle; battery also degrades in idle state (also known as “calendar degradation”); resting SOC when idle is a key driver in degradation

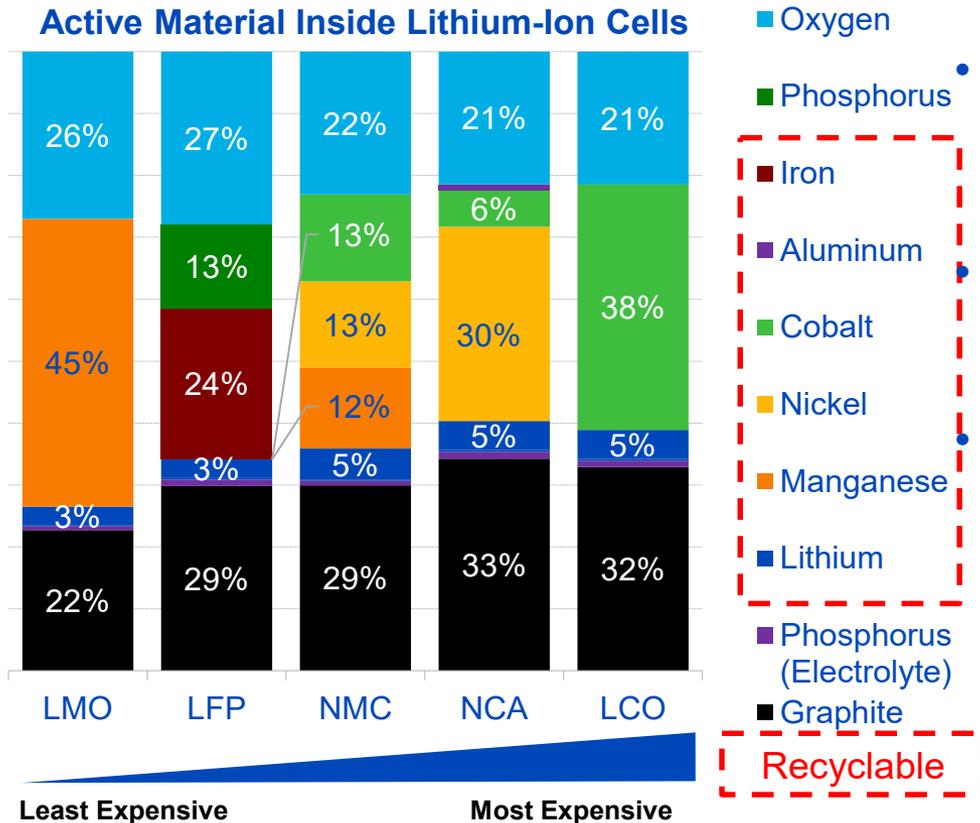
Chemistry

Different combinations of anode, cathode and electrolyte material have varying degradation profiles

Validation battery degradation profiles provided by OEMs via independent testing can provide more certainty in asset life

Not all lithium-ion batteries are created equal; the specific chemistry selected for each project should be dependent on the intended use cases

Battery Chemistry⁽¹⁾⁽²⁾



Battery Life

Typical consumer electronic battery life is ~4 years⁽³⁾

- Typically select the highest density battery without significant regard for cost

Typical electric vehicle battery life is 8 years⁽⁴⁾

- EV battery has a long single charge range

Typical stationary battery storage life is 7-15 years

- Lifespan is highly dependent on thermal management and cycling
- Continual refurbishment to extend lifespan to 25 years is possible with proper initial design of power electronics

1) Bloomberg New Energy Finance - Lithium-Ion Battery Materials Supply and Demand

2) LMO – Lithium Manganese Oxide, LFP – Lithium Iron Phosphate, NMC – Nickel Manganese Cobalt, NCA – Nickel Cobalt Aluminum, LCO – Lithium Cobalt Oxide

3) Implied Cycle Life from Apple iPhone Warranty

4) Tesla Model S Limited Warranty; Tesla's Model S can swap only the battery pack for performance upgrades



There are several important factors that need to be considered in designing the battery system for safety

Important Considerations in Battery Safety

Battery Chemistry

Select battery chemistry based on use case

Battery Management System

Battery Management System monitors the battery's state of health (voltage, current, temperature)

Battery Cooling

HVAC system needs to be properly designed and sized to provide optimal cooling to batteries and to avoid excessive battery heating

Fire Suppression System

Fire suppression agent should be carefully selected for given battery chemistry

Local Fire Department

Local fire department should be made aware of the battery chemistry and response protocols

Safety must be a top priority in design, construction and operation of a battery system

Energy Storage is not a net generation resource; as a result, power purchase pricing is often stated in \$/kW-month rather than in \$/MWh

Contracting Mechanisms for Energy Storage

- **Pricing based on storage nameplate rating (in kW)**
 - Longer duration systems will have a higher \$/kw-month rate
 - Contract terms may include guarantees on storage capacity/duration, or alternatively may cap the annual degradation
- **Storage is not a net generator, as it withdraws more energy from the grid (or from co-located renewables) than it discharges**



Energy Storage pricing methodology is in some ways similar to a Fossil Peaker – payment for the ability to use when desired

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RESOURCES