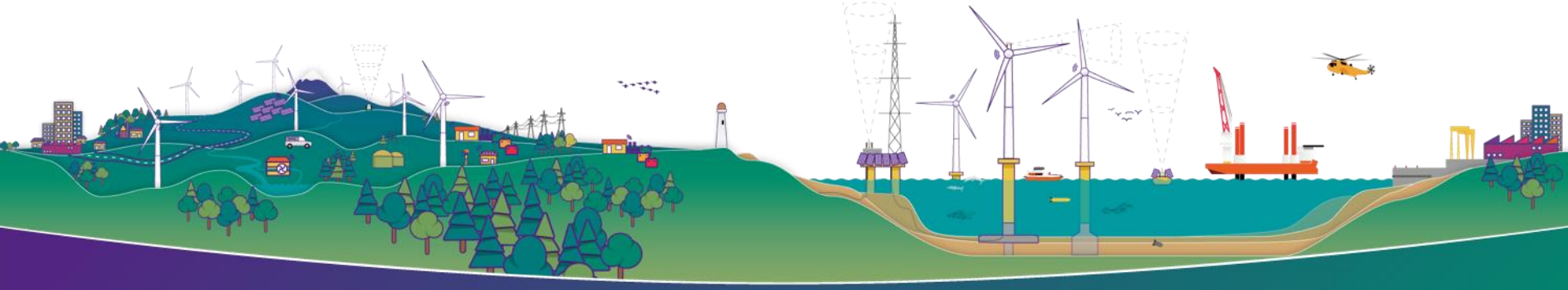
Dissecting the Silver Bullet

Key Considerations in Energy Storage Hybrid Projects

Clean Power, June 2021

Presented By: Shawn Shaw PE, Head of Solar and Energy Storage



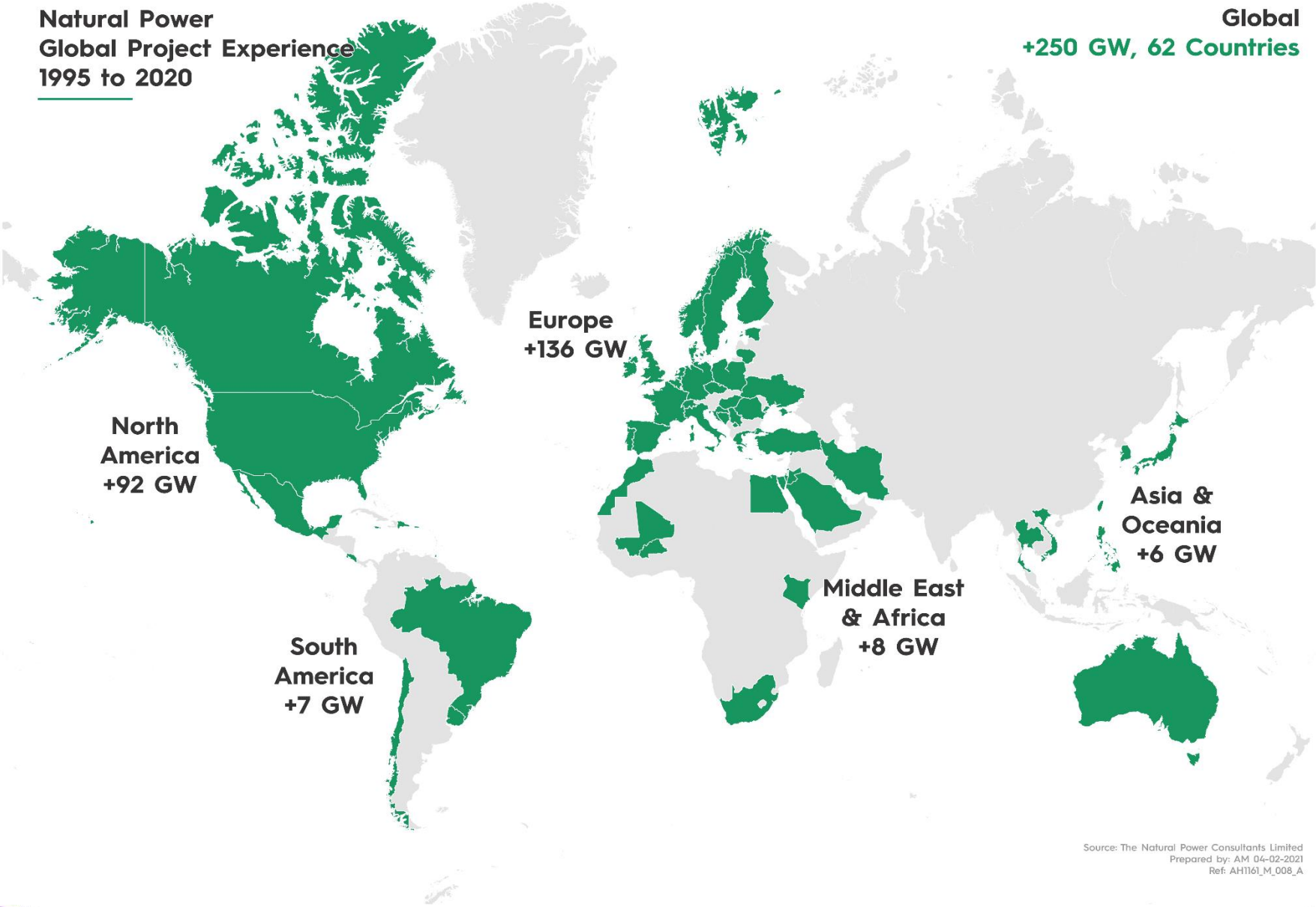
Shawn Shaw, P.E.

Head of solar and energy storage

- Joined Natural Power in autumn 2018
- Leads global team of industry experts
- 17 years in industry with expertise in:
  - Technical design reviews & inspections
  - Performance analyses & testing
  - Quality assurance codes & standards
  - Microgrids & energy resilience
  - Due diligence & independent engineering
- Member of ESIC, NY-BEST, and SEIA Quality Assurance Working Group
- Background in applied physics, economics, and electrical engineering

Natural Power Global Project Experience 1995 to 2020

Global
+250 GW, 62 Countries



Source: The Natural Power Consultants Limited
Prepared by: AM 04-02-2021
Ref: AH1161_M_008_A

Energy Storage Project Experience Summary

2+ GWh Global Experience in Portfolios and Projects from C&I to 400MWh Scale

Technical Due Diligence (1+ GWh)

- Design & technology
- Major agreements
- Market and financial risks

Independent and Owner's Engineering (1+ GWh)

- Testing and commissioning
- Construction monitoring and inspections
- Commissioning, codes, and standards

Other Storage Experience

- Hybrid projects and portfolios
- Feasibility studies
- Fire safety and risk assessment

Why is Storage the Silver Bullet?

- Falling costs
- Expanding value proposition
- Co-location options

What to Know Before Adding Storage to a Project

- How to make your ESS pay
- Safety is key
- Not all batteries are created equal

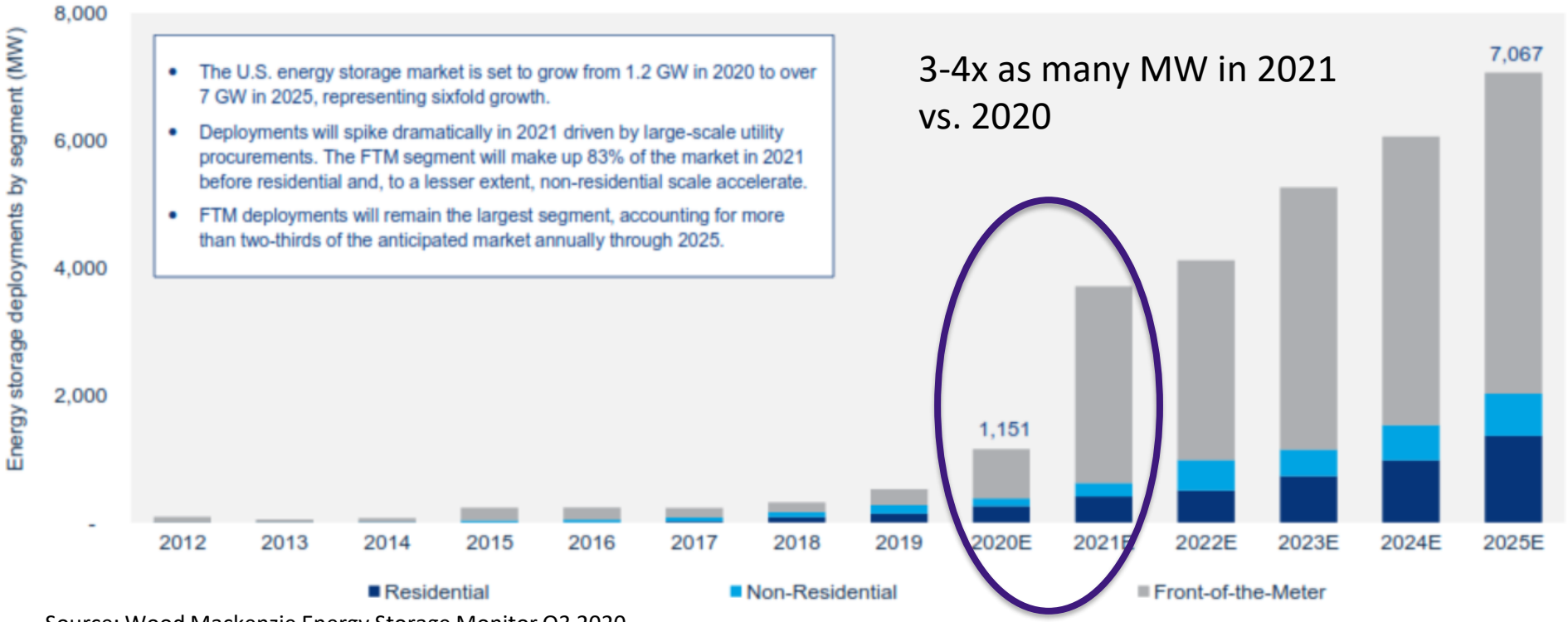
Energy Storage

The Silver Bullet

Energy Storage Market Expanding

2021 is the Year to Move

U.S. energy storage annual deployment forecast, 2012-2025E (MW)

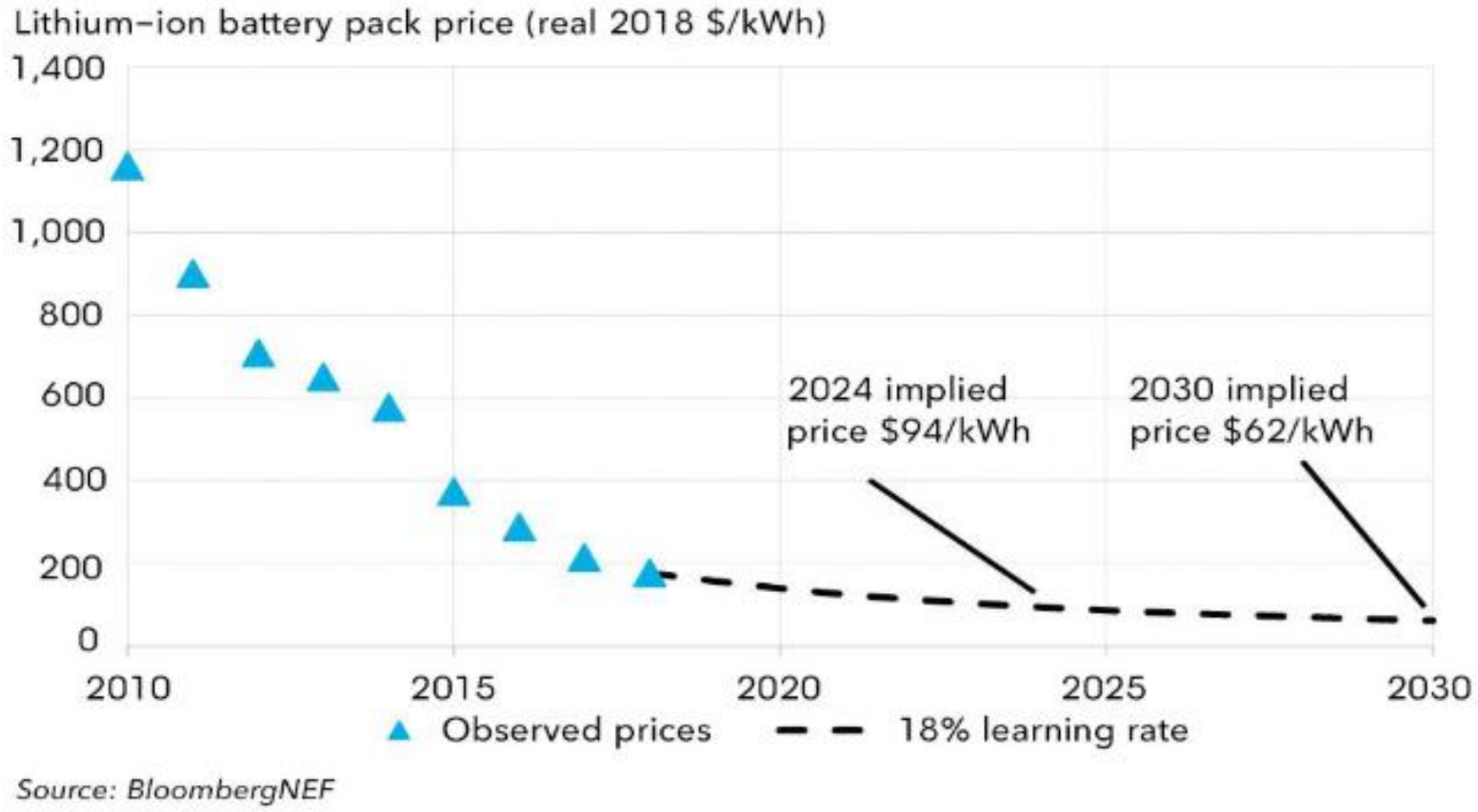


Source: Wood Mackenzie Energy Storage Monitor Q3 2020

Over 60GW of storage in US interconnect queues and 25%-67% of PV projects in interconnection queue include storage.

Why have Lithium-ion batteries dominated global markets?

Lithium-ion battery prices have fallen dramatically over the last decade and now offer a cost-effective method of large-scale storage.



Source: BloombergNEF

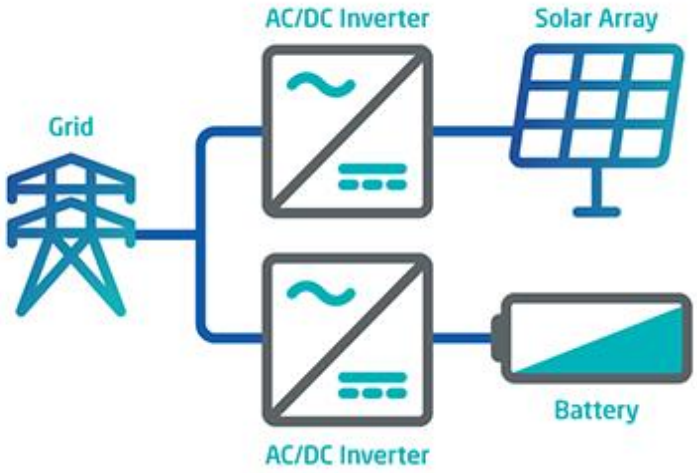
Know your revenue streams

A few of the things that an ESS can do

Revenue Stream	Typical Value	Typical Tenor	Volatility	Benefits	Risks
Arbitrage	Variable	Open	Medium	Dynamic battery schedule	Day ahead/ RT pricing
Frequency Regulation	High	0-5 Years	High	High revenue	Penalty payments, Market cannibalization
Spinning Reserve	High	1 month	Low	High price per MWh	Day time action Closes other markets
Capacity/ RA	Medium	1 Year	Low	Pay for availability	Decreasing revenue – derating

ESS is also frequently paired with renewables to capture clipping, curtailment, and arbitrage opportunities

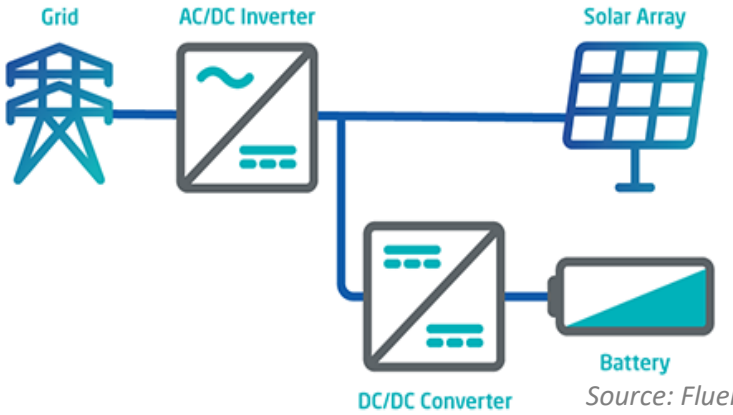
AC coupled system



Pros:
Easier to retrofit
Can participate in more grid services

Cons:
More complex interconnection
System will not recover from low battery if there is no backup generator

DC coupled system



Source: Fluence

Pros:
Better for charging batteries
More efficient if most energy needs to be stored
Can capture “clipping” losses from PV

Cons:
Market participation limited by inverter size and current mode

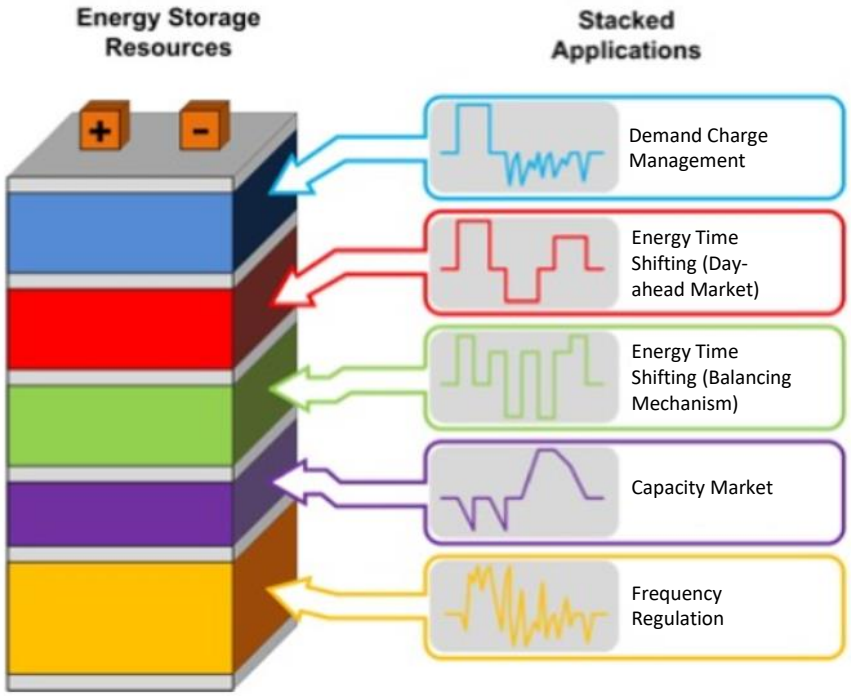
Things to Know About Energy Storage

More than just “adding a battery” to your existing project

Revenue Stacking is Key to ESS Value

Energy Storage's #1 Buzz Term

- ESS dispatch profile can be tightly controlled
- Each time step has a value:
  - Day ahead energy
  - Real-time energy
  - Ancillary services
- But we don't always know that value perfectly
- Don't forget-ESS can provide value by discharging AND charging, so cleverly optimizing is key



California Standalone Utility Scale BESS

Typical for a Large Utility Scale ESS with COD in 2020-2022

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System Information

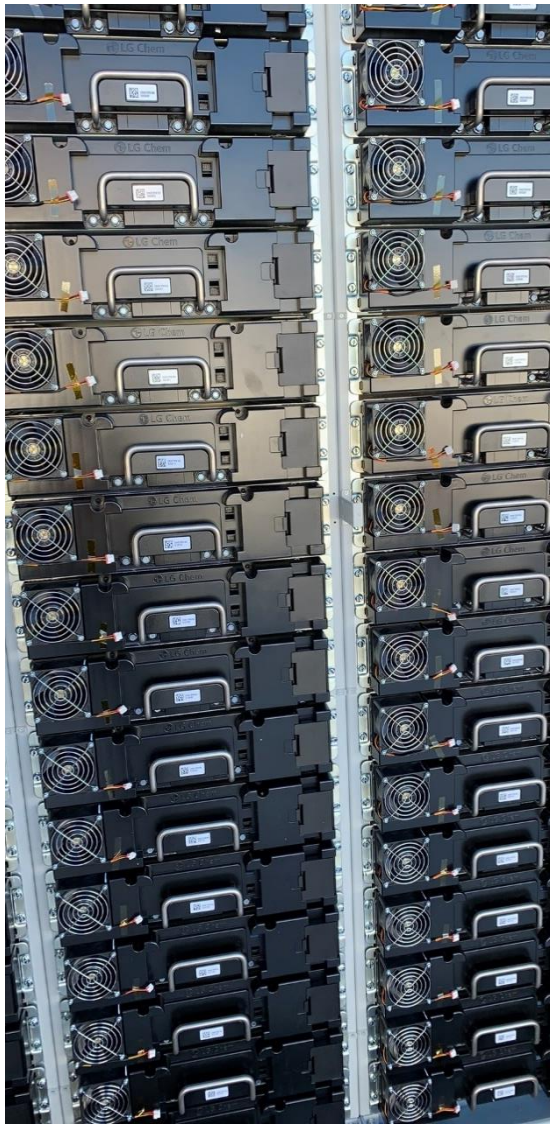
- 300-500 MWh, 100 MW Li-Ion BESS (a “4 hour” battery)
- Located in Southern CA

Markets and Annual Revenue Estimates (Years 1-5)

- Resource Adequacy: $6M-$8M
- DA-RT Energy Arbitrage: $8M-$16M
- Regulation Up/Down: $5M-$8M
- Spinning Reserve: $1M-$3M

Typical Costs

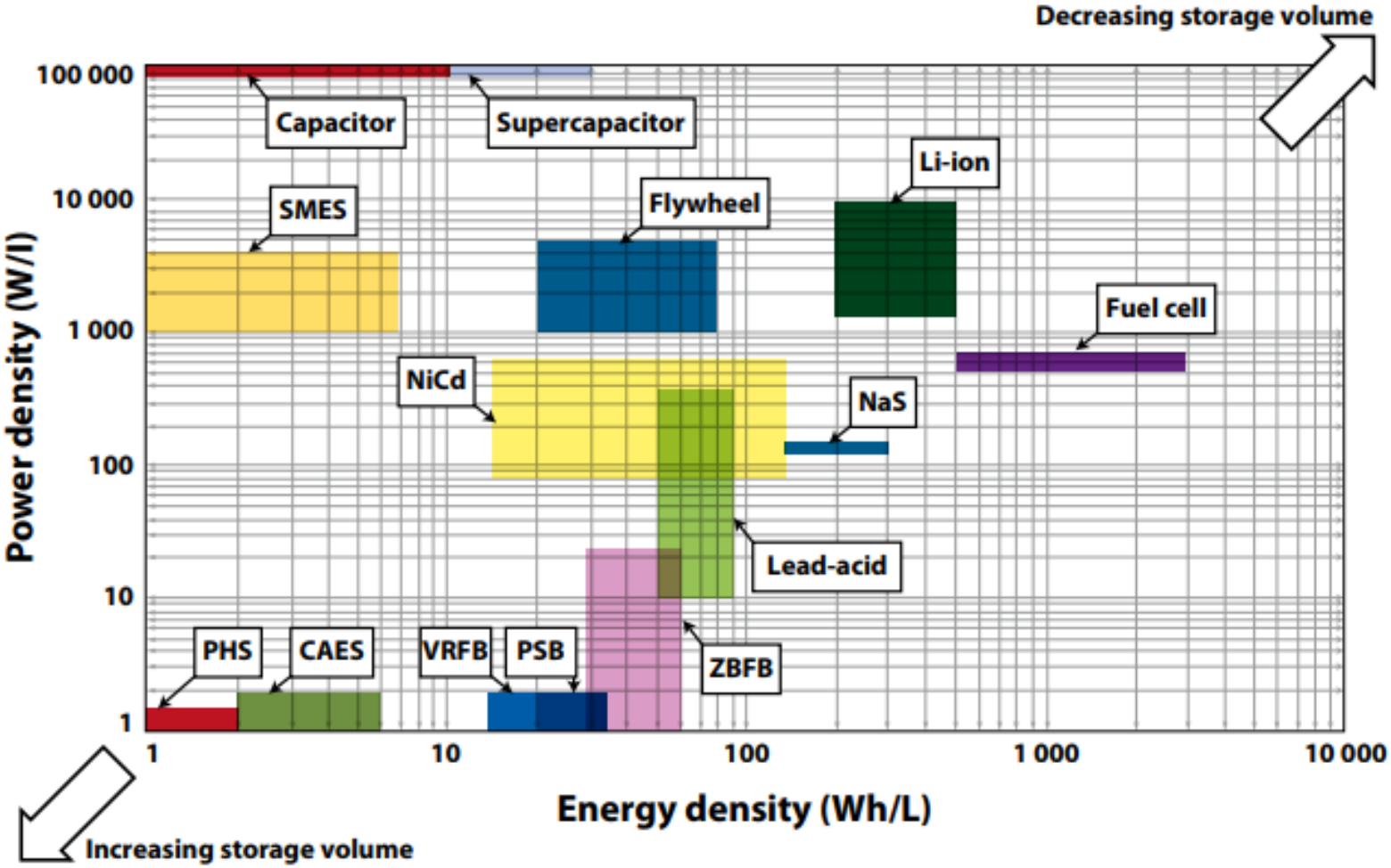
- CAPEX: $200-$400 per kWh
- OPEX: $5-$8 per kWh



Storage Technologies Overview

Lithium-Ion Energy Storage

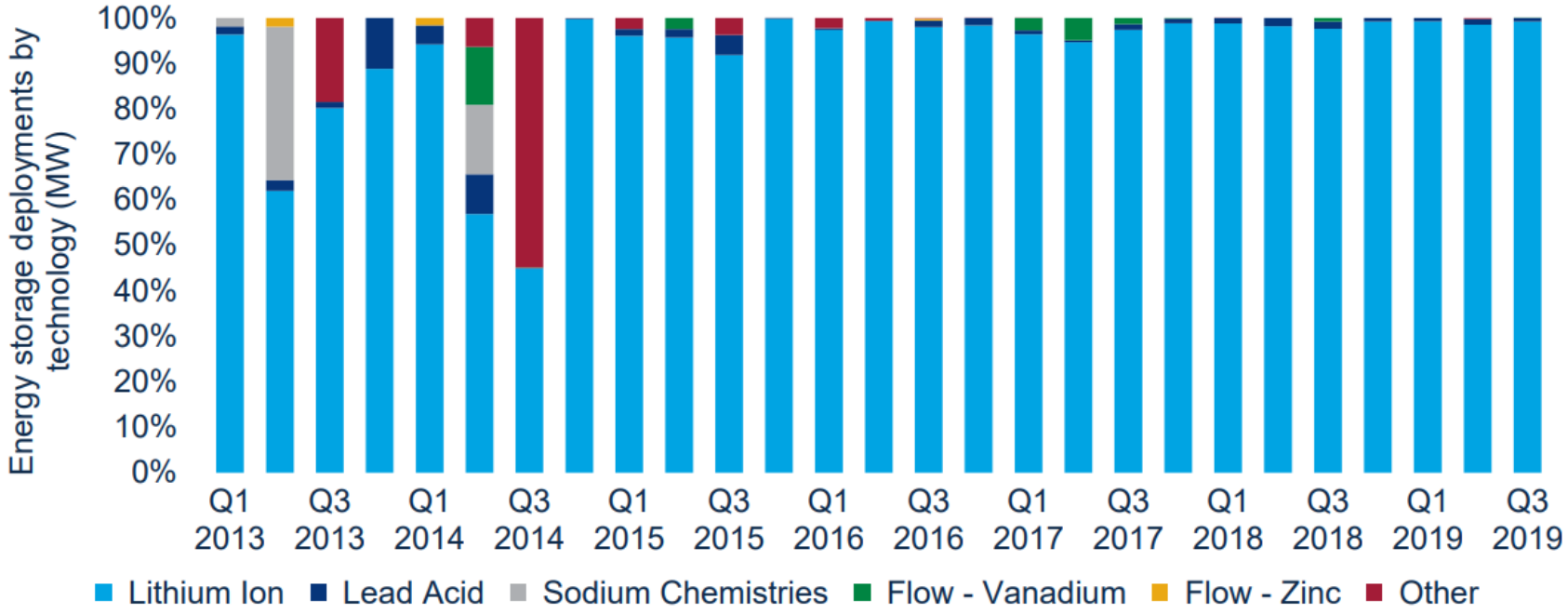
Li-ion batteries offer one of the most energy dense forms of storage. Few other storage technologies can offer the same energy density at the price of Lithium-ion.



Lithium-ion still dominates the market, accounting for 99.2% share in Q3 2019

Lead-acid hovers around 0.8%; a single vanadium flow battery project in Q3 accounts for roughly 0.01% share

Quarterly energy storage deployment share by technology (MW %)



* "Other" includes flywheel and unidentified energy storage technologies.

Source: Wood Mackenzie Power & Renewables

The process of producing electricity remains broadly the same in all Lithium-ion batteries. However, changing the materials used for the anode and cathode can produce batteries with varying characteristics.

Short Name	Name	Anode	Cathode	Energy density Wh/kg	Cycles	Sample Manufacturers
NMC	Lithium Nickel Manganese Cobalt Oxide	Graphite	Li Ni0.6 Co0.2 Mn0.2 O2	120-300	3000-10,000	BYD, Samsung, LG Chem, CATL
LFP	Lithium Iron Phosphate	Graphite	Li Fe PO4	50-130	6000-8000	BYD, Saft, CATL
LTO	Lithium Titanate	LiTO2	Various	70-80	15,000-20,000	Toshiba, Kokam, Leclanche
LMO	Lithium Manganese Oxide	Graphite	LiMn2O4	100-150	300-700	Saft, AESC
NCA	Lithium Nickel Cobalt Aluminium Oxide	Graphite	LiNiCoAlO2	200-260	500	Tesla (Panasonic)

Fire Safety Risks

Is Lithium-Ion Safe?

ESS safety is a key factor in permitting and insurability

- ESS have been subject to scrutiny over risks:
  - Thermal runaway
  - Fire
  - Explosion
- Typical considerations include:
  - Ventilation
  - Explosion control
  - Gas/fire/smoke detection
  - Suppression system(s)
  - Fire-testing and spacing of battery racks
  - Materials and construction of containers/enclosures
- Proper system design requires large-scale fire testing to UL 9540A or equivalent
  - Provides key data on smoke output and composition
  - Key flame spread characteristics needed for spacing/layout
  - Some chemistries, as deemed to have minimal explosion risk, are exempted (e.g., lead acid)

New Technology Trends

Lots of Innovation to Do in Li-Ion but Other Options Exist

- Shift to potentially safer chemistries
- Liquid cooling systems
- From “containers” to “enclosures”
- More advanced fire safety systems
- Wrapped performance guarantees/ long-term service agreements
- Modular architecture

Great opportunities for adding storage to renewables but bear in mind:

- Falling Costs and increasing revenue opportunities create opportunity
- AC or DC coupling tradeoffs must be considered
- Technology is changing quickly and not all Li-Ion systems are comparable
- Safety is a critical consideration for protecting people and also for insurability and permitting of the project

Thank you