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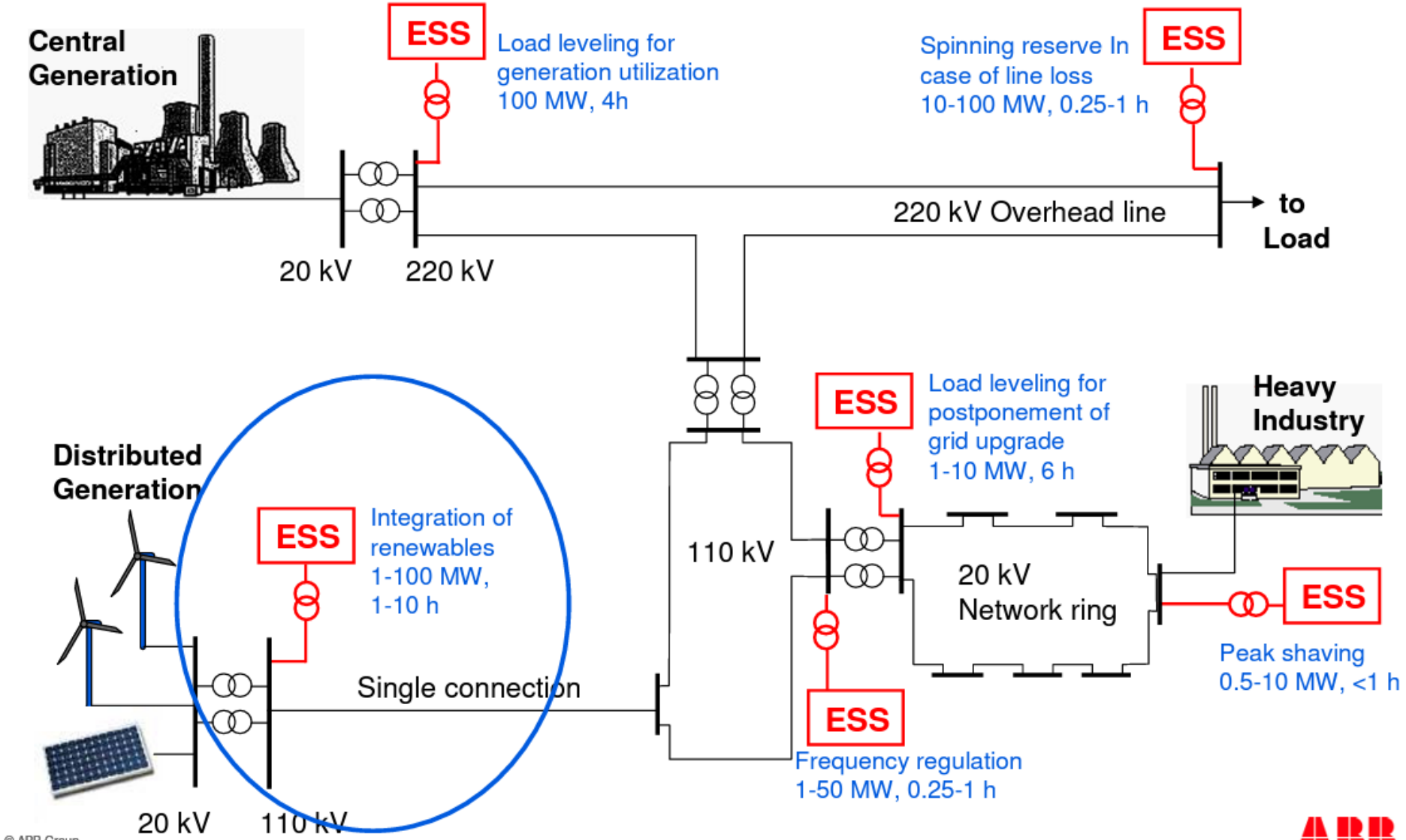
Battery Energy Storage Systems

What is BESS?

Battery Energy Storage Systems (BESS)



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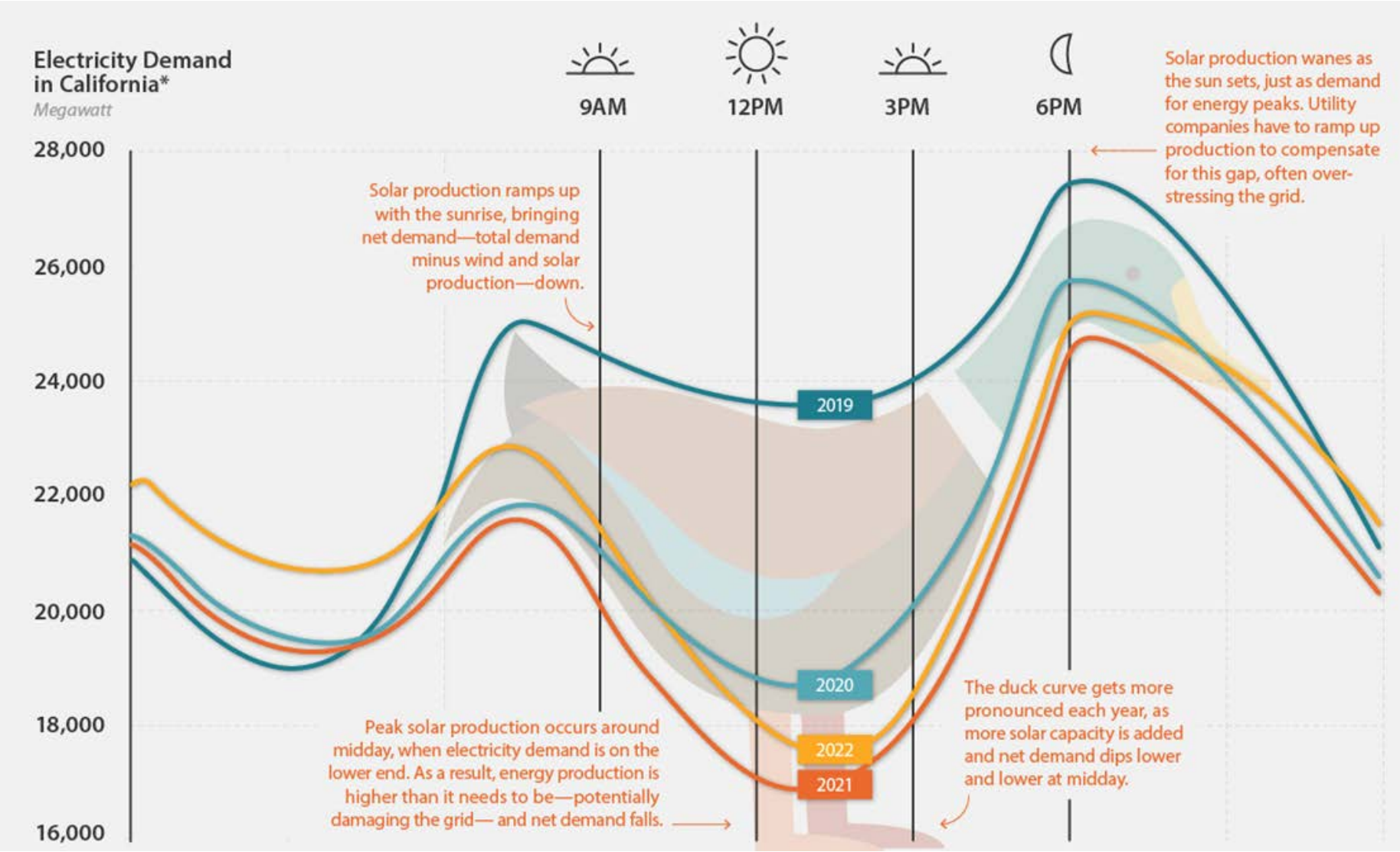
Why is Battery Storage needed?



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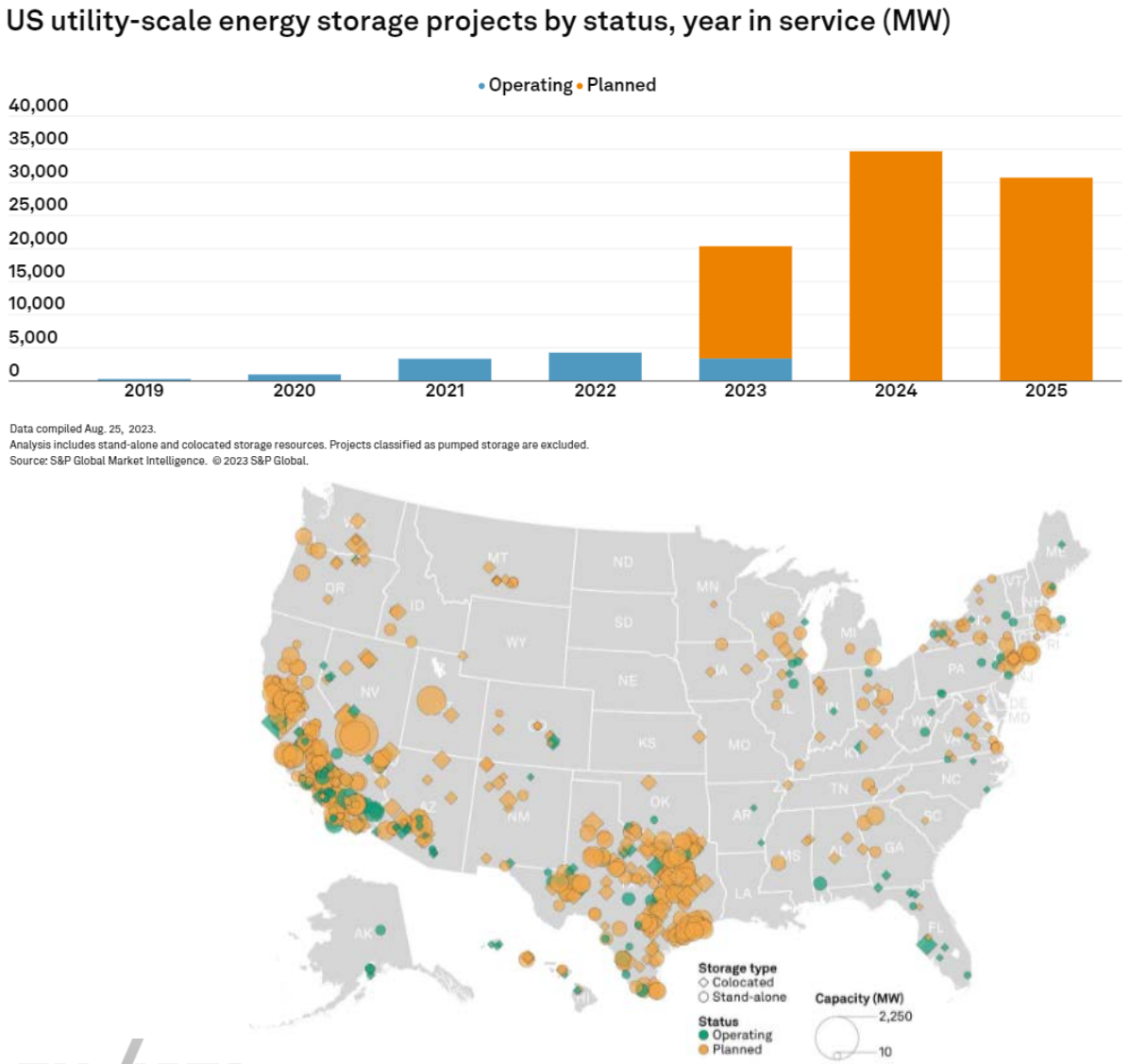
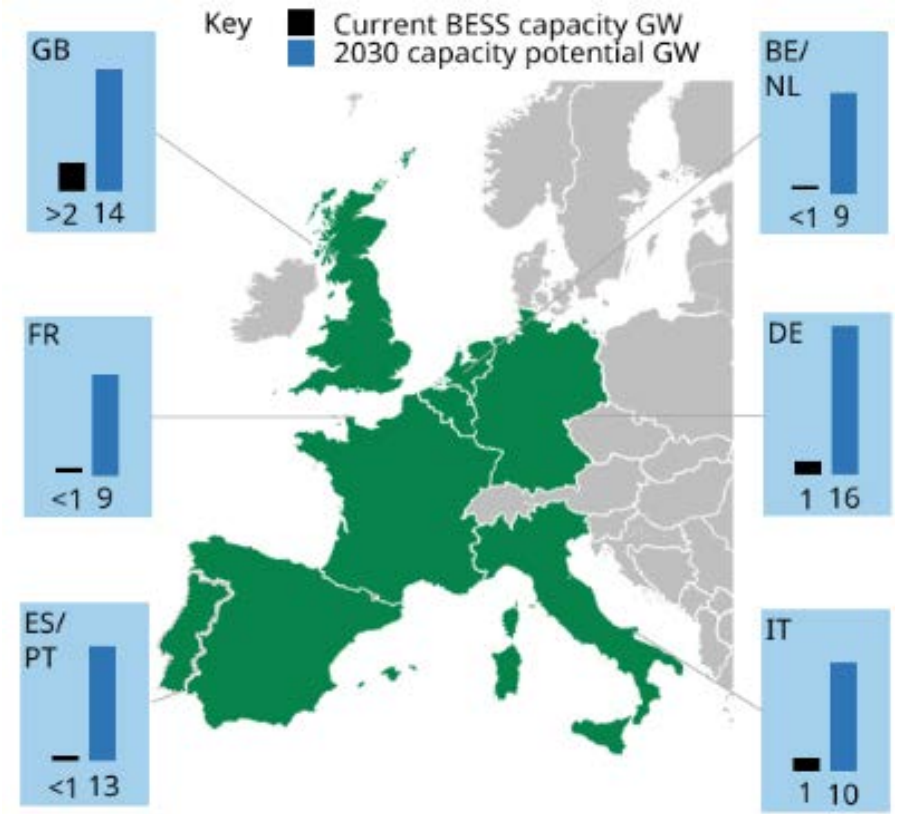
Growth of BESS Installations





Source: Timera Energy

Inflation 2022 Inflation Reduction Act (IRA): Stand-alone BESS

- The IRA creates technology-neutral Clean Energy Production Tax Credit (CEPTC) and Clean Energy Investment Tax Credit (CEPTC) starting in 2025, while also extending current PTC and ITC credits until these new incentives come into effect
- There is an additional 10% increase for projects meeting domestic content requirements for steel, iron and manufactured components as well as for projects located in an “energy community” or commonly known as brownfield sites (20% additional bonus potential)
- The value of the ITC for a BESS is calculated as a percentage of the eligible cost of the equipment. The base rate of 6% increases to 30% if the asset was under construction before 29 January 2023, or if certain prevailing wage and apprenticeship requirements are satisfied.

BESS Design

Warehouse Assembly

- Physically restricted sites or the need for greater energy density favor the building solution. A container solution will have a footprint 50% greater than a building.
- Customized HVAC for the BESS.
- Higher cost of loss in fire (generally)

Containerized

- Single containers can generally be manufactured and assembled more quickly than a building which represents a cost savings.
- Containers are a more standardized construction and likely to meet published standards and testing.
- Cost of loss may be limited to one container.

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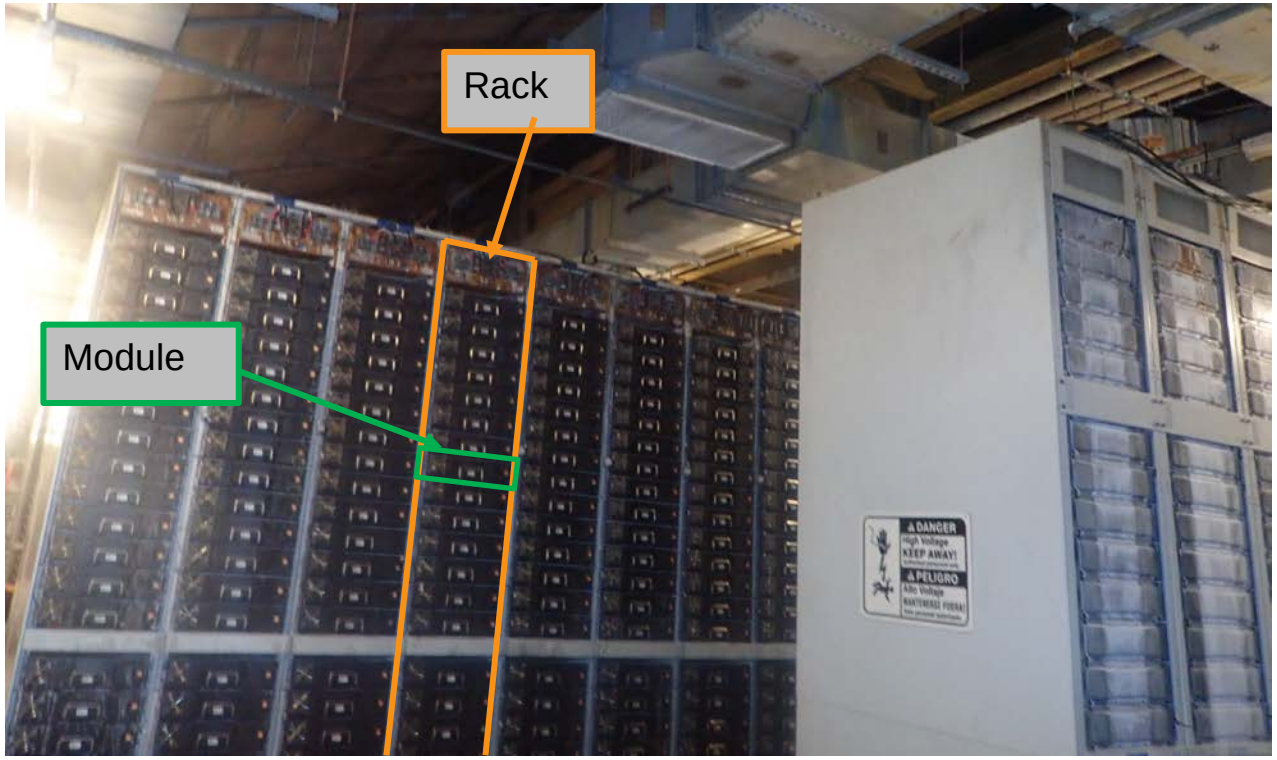
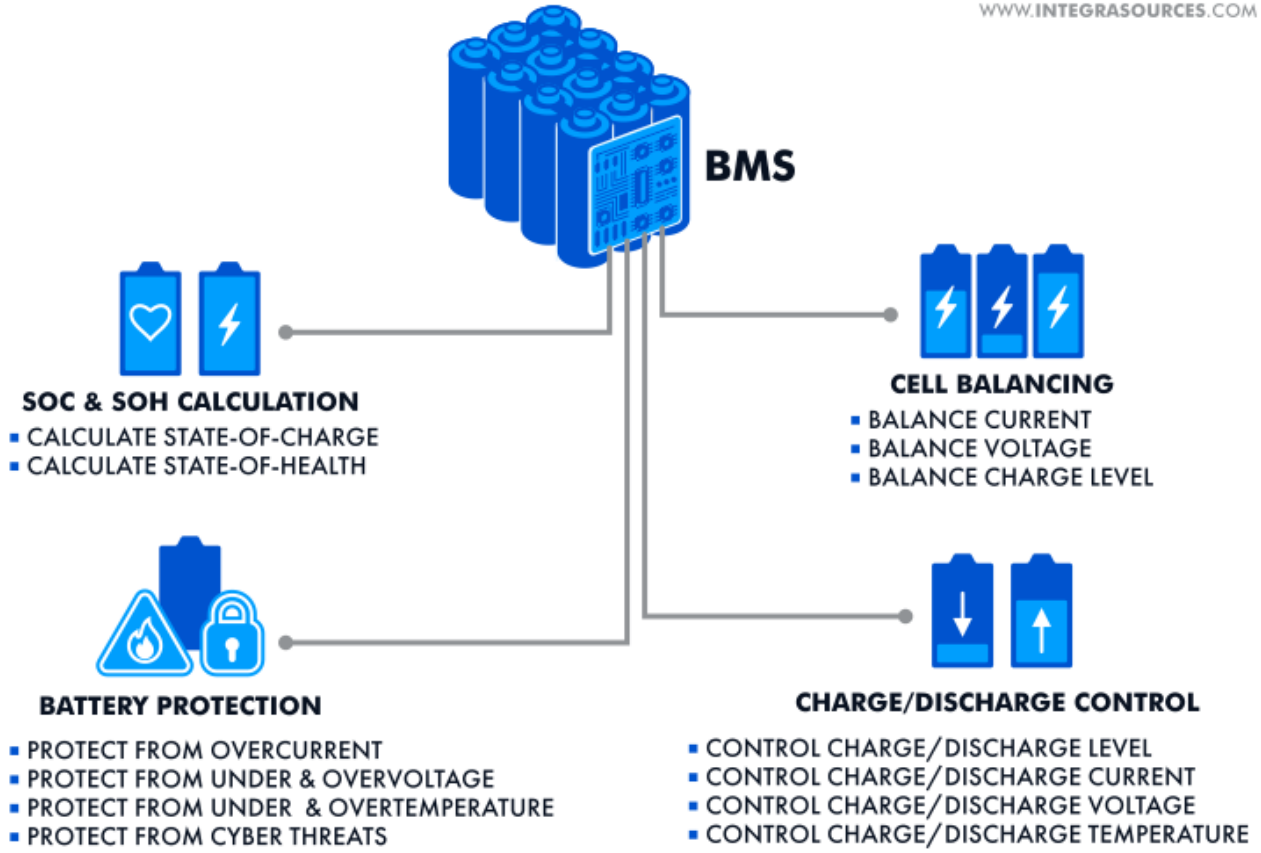
BESS Battery Management Systems (BMS)

- There are Thousands of Cells in a BESS
  - Cells are organized into modules
  - Modules are organized into racks
  - Racks are organized in containers
- These Cells MUST be connected to and controlled by a BMS



BESS Battery Management Systems (BMS)

- These Cells MUST be connected to and controlled by a BMS
- The BMS:
  - Controls and monitors both charging and discharging
  - Monitors each cell and maintains it within a high and a low voltage
  - Controls voltage balancing
  - Can perform impedance checks
  - Must perform temperature monitoring
  - Tracks charge/discharge depths and cycles
  - Can monitor other things like smoke detection in a facility and the suppression system
  - Designed to maximize power output of batteries



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Who Governs BESS Installations?

Energy Storage Systems - Standards

NFPA 855

- NFPA 855: Standard for the Installation of Stationary Energy Storage Systems.
- The standard applies to an ESS that meets/exceeds the Aggregate Capacity of the ESS technology per "fire area"

Pin Header

Table 1.3 Threshold Quantities per Each Fire Area or Outdoor Installation

ESS Technology	Aggregate Capacity[a] kWh	MJ
Battery ESS		
Lead-acid, all types	70	252
Ni-Cad, Ni-MH, and Ni-Zn	70	252
Lithium-ion, all types	20	72
Sodium nickel chloride	20 (70[b])	72 (252[b])
Flow batteries[c]	20	72
Other battery technologies	10	36
Batteries in one- and two-family dwellings and townhouse units	1	3.6

UL 9540

- Energy Storage Systems and Equipment
- UL 9540A - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

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Energy Storage Systems – NFPA 855

- NFPA 855 (2023) shall apply to almost any system that is described as an energy storage system.
- The following information shall be provided with plans and specifications for an ESS:
  - Fire and explosion testing data
  - Hazard Mitigation Analysis
  - Calculations/modeling showing compliance with NFPA 68 and 69 (explosion prevention)
  - Other data required by NFPA 855
- Battery Energy Storage Systems (BESS) now require fire and explosion testing according to **UL 9540A** (Test Method for Evaluating Thermal Runaway Fire Propagation in BESS)
- Existing Lithium-Ion ESS that are NOT UL 9540 listed shall now require a Hazard Mitigation Analysis (HMA)
- Maximum stored energy of ESS in non-dedicated use buildings is **600kWh for Li-Ion**
- ESS shall be comprised of groups of **50kWh "blocks**" separated by at least **3 feet**, UNLESS supporting test documentation says otherwise.

How Do Batteries Fail?

What Can Go Wrong With a Battery?

Overvoltage

- Charging problems
  - One battery failure mode is for it to simply not hold a charge.
- System failures
  - Undercharging or low voltage can cause sulfate crystals to form on the battery plates causing failure.

Overcurrent

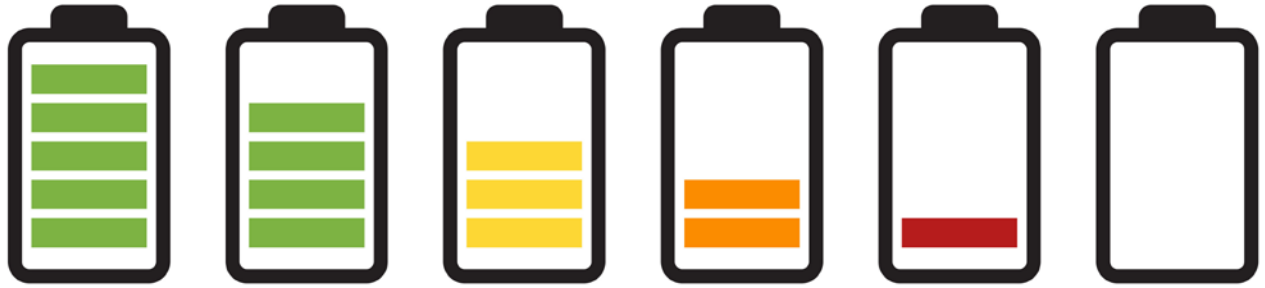
- Battery terminals are the electrical contacts used to connect a load or charger to a single-cell or multiple-cell battery

Temperature

- Failure to control ambient temperature can lead to thermal runaway.

Manufacturing Defects

- Each BESS module contains hundreds (1000+) cells, each rack contains dozens of modules (e.g., 24), and each segment or container contains tens of racks. This leaves many failure points on a high-quality system.



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What Can Go Wrong With a Battery?

Operational Parameters

- Low Temperature Operation: Chemical reaction rates decrease in line with temperature leading to reduction in the current carrying capacity of the cell both for charging and discharging
- High Temperature Operation: Can result in the destruction of the cell as start it will initiate a positive temperature feedback and unless heat is removed faster than it is generated the result will cause thermal runaway of the battery
- Mechanical Fatigue: Electrodes of Lithium cells expand & contract during charging and discharging. Cyclic stresses on electrodes lead to cracking of the particles making up the electrode resulting in increased internal resistance as the cell ages leading to overheating & cell failure
- Cycle Life: Operating outside of recommended operating window causes irreversible capacity loss in the cells

What Can Go Wrong With a Battery?

Thermal Runaway

Definition – A positive feedback loop where a lithium-ion battery enters and uncontrolled, self-heating state.

When lithium-ion batteries undergo thermal runaway and catch fire, they release toxic gases which are highly combustible

The main mitigation measures that are adopted are to use:

- A gas sensing system within the battery container to detect trace amounts of hydrogen
- A venting system that can be operated when the measured explosive LEL limits exceed 25% of the atmosphere within the container
- Gaseous fire extinguishing systems, while installed in numerous battery containers to put out electrical fires, when activated can accelerate a deflagration event

BESS – Fire Suppression

- NFPA 855 recommends the use of water and overhead sprinklers with coverage of at least 0.3 gallons per square foot to dissipate heat from cells in a thermal runaway event.
- FDNY protocol (abridged): stay 50ft back, use external lines to cool adjacent BESS containers
- Dry chemicals may work on specific battery chemistries, but this data is anecdotal at best

Battery Failure Under Water

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Where are the Challenges in a BESS Loss?

Battery Storage Systems - Augmentation

Augmentation Example

- In the context of energy storage, “augmentation” refers to the process of adding storage capacity to a project over time and is typically seen in the context of battery energy storage projects. This happens during initial construction and at scheduled periods throughout the life expectancy of the BESS (e.g., 5 years)
- Lithium-Ion batteries decay approximately 2-3% annually.
- A 5MW battery with a 40 MWhr capacity might be originally built as a 6.1MW battery with a 49 MWhr capacity.

	PPA "nameplate"	2018 design +augmentation	2023 restoration	2023 augmentation	2023 total
Power output (MW)	5	6.17	6.3085	0.491625	6.800125
Capacity (MWhr)*	40	49.35	50.468	3.933	54.401
Racks		138	154	12	166
Modules/rack		24	22	22	22
Total modules		3312	3388	264	3652

*8-hour discharge cycle

Growth projection is USD 31 billion by 2030 – CAGR 16%

Whilst BESS is most commonly linked to solar, potential issues are similar to offshore wind -

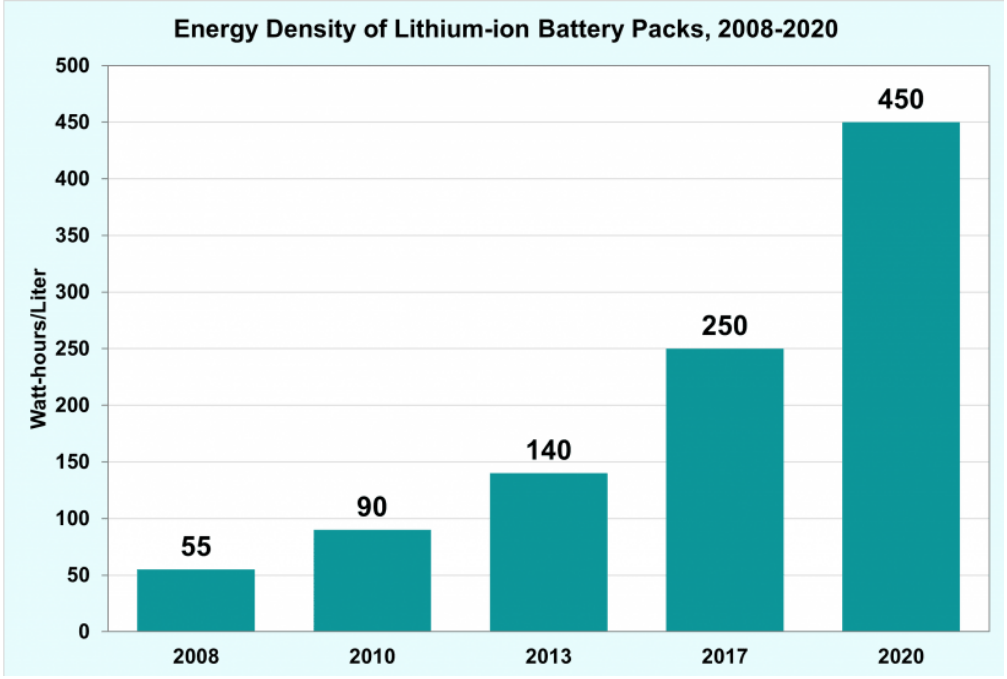
- With rising scale giving rise to prototype concerns?
- Are underwriter's wordings sufficiently robust?

MIT Technology Review

What's next for batteries

Expect new battery chemistries for electric vehicles and a manufacturing boost thanks to government funding this year.

By Casey Crownhart January 4, 2023



Underwriter's Checklist

- Use of lithium ion-batteries with Lithium Iron Phosphate (LFP) battery chemistry
- UL9540A module/unit/installation level test showing none/low propagation & explosive risk
- Use of liquid cooling technologies for battery cooling & environmental control
- Deflagration vents incorporated into battery enclosure design + internal H2 sensor (applicable only to battery containers not cabinets) & fire detection
- External access panels to each battery rack
- 3m separation distance between battery enclosures or battery strings (applicable for pairs of Tesla Mega Packs as they are configured to be placed back-to-back with a separation distance of 15cm)
- Battery enclosures divided into multiple groups with a separation distance >7.5m
- 1.5m separation distance between battery enclosure and inverter (PCS) + MV transformer
- >10m separation distance between battery enclosure & switchgear + HV transformer substation
- Site characteristics - located in flood zone 1 and no concerns identified from Hawkeye
- Fire response plan developed, site familiarisation by local fire service & onsite fire hydrants
- For CAR reputable EPC who has extensive experience in constructing BESS sites
- For OAR reputable O&M service provider who has extensive experience in maintaining BESS

Good

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BESS – Technical Takeaways

- Limit the storage energy contained in one space – Hazard Mitigation Analysis
- Toxic gas build-up must be managed and may occur before fire.
- How does the BMS handle Thermal runaway signatures? (e.g. temperature, voltage, etc.)
- When reviewing the hazards of a newer installation, ask for the fire/explosion analysis studies and documents
- Maintenance and fault resolution should be well documented; unaddressed faults can lead to larger failures.
- 13% of losses within Construction, 22% within the first year and 42% in within two years = over half (57%) of losses fall within CAR / extended maintenance. Reduction over the last 12 months (63%) which is to be expected as operational life extends.

Thank you!

Please don’t hesitate to contact us with any questions.

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