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Battery Energy Storage Solutions (BESS)

The concept, the technology, the risks and the future..

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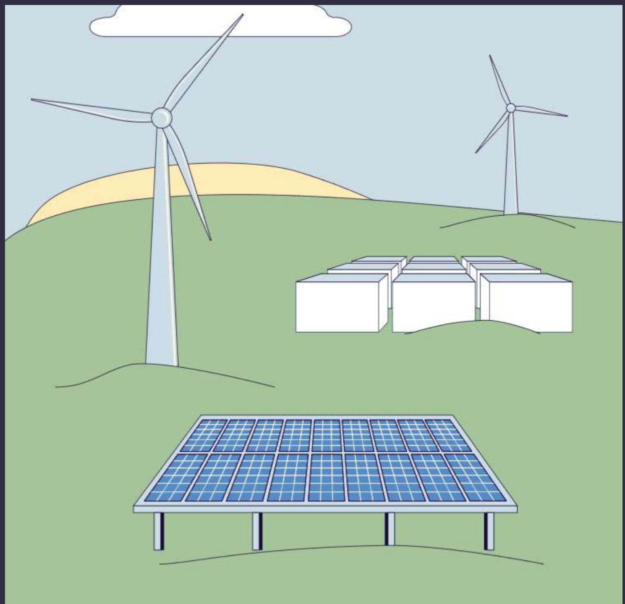
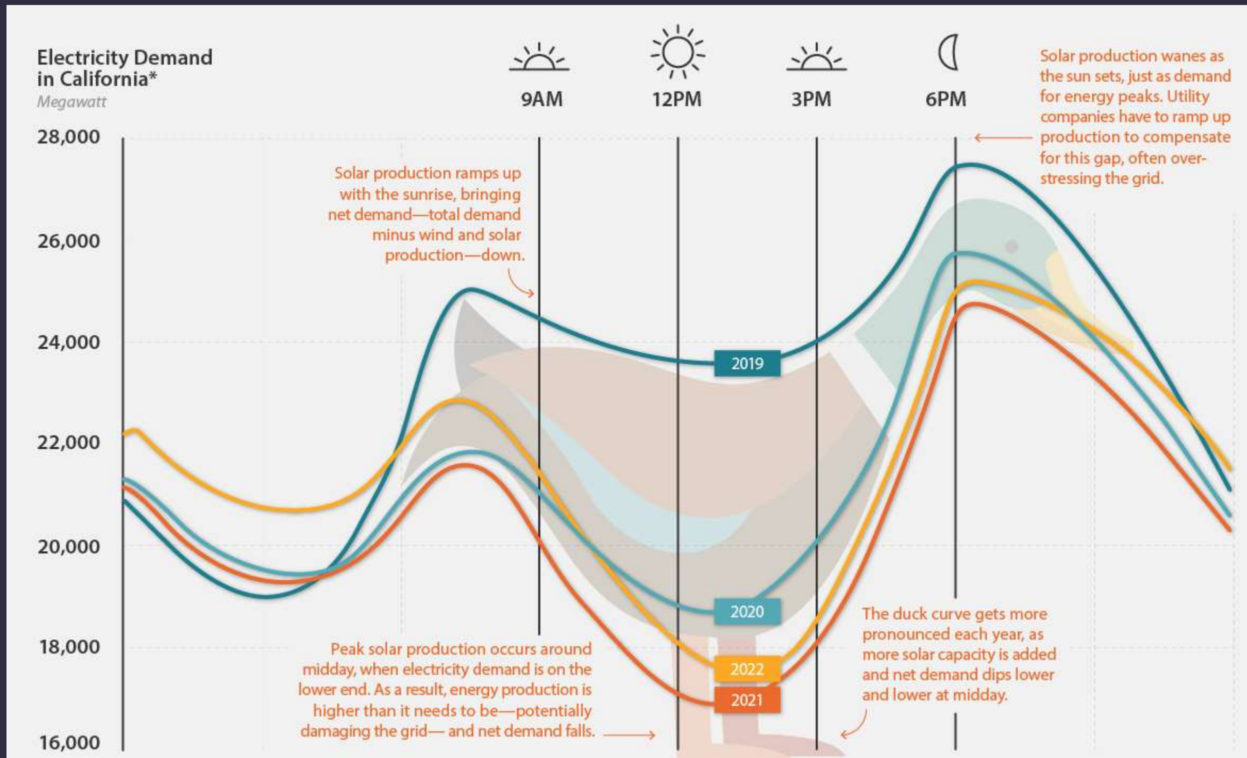
Why?

Battery storage plays a key role in grid management & the integration of renewable energy into the grid.

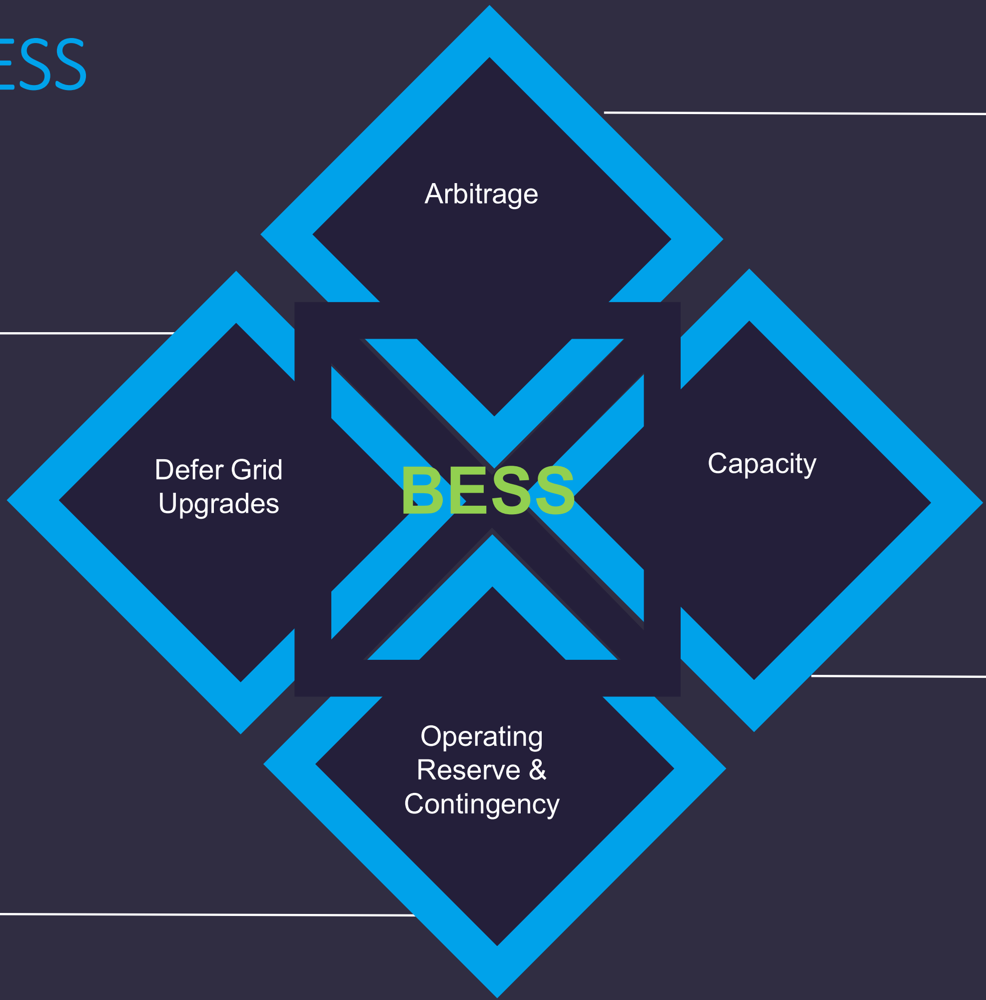


Sources: Neoen.com & visualcapitalist.com



Benefits of BESS

Extend existing grid capacity by meeting peak demand with energy stored from lower demand periods



Taking advantage of energy price fluctuation, reducing curtailment of renewable energy and load-levelling

Provide response to unpredictable demand variations, contingency in the event of generation failure. Response to total system failure (Black-start)

Providing peaking capacity, helping renewable source contribute to firm generating capacity

Key Characteristics of BESS

- Rated power capacity (in kW or MW) – maximum rate of discharge from a fully charged state
- Energy capacity (in kWh or MWh) – maximum amount of storage energy
- Storage duration / Duration of discharge – time taken to discharge stored energy to depletion (e.g. 1MW battery with 5MWh of capacity = storage duration of 5 hours)
- Cycle life – number of cycles BESS can charge / discharge provide before performance degradation
- Round-trip efficiency - the percentage of electricity put into storage that is later retrieved. The higher the round-trip efficiency, the less energy is lost in the storage process.

Battery Energy Storage Technologies (Electrochemical)

- Lithium-ion Batter Energy Storage
- Flow Battery Energy Storage
- Lead-Acid Battery Energy Storage
- Sodium Sulphur Battery

Electro Chemical Batteries	Lithium-ion	Widely commercialized	1,408-1,947 ($/kW) 352-487 ($/kWh)†	Minutes to a few hours	Subsecond to seconds	86-88%	10 years
	Flow	Initial commercialization	1,995-2,438 ($/kW) 499-609 ($/kWh)†	Several hours	Subsecond to seconds	65%–70%	15 years
	Lead-acid	Widely commercialized	1,520-1,792 ($/kW) 380-448 ($/kWh)†	Minutes to a few hours	Seconds	79-85%	12 years
	Sodium-sulfur	Initial commercialization	2,394–5,170 ($/kW) 599–1,293 ($/kWh)††	Several hours	Subsecond	77%–83%	15 years

Sources: https://greeningthegrid.org/energy-storage-toolkit/energy-storage-decision-guidebook/technologies#section-1

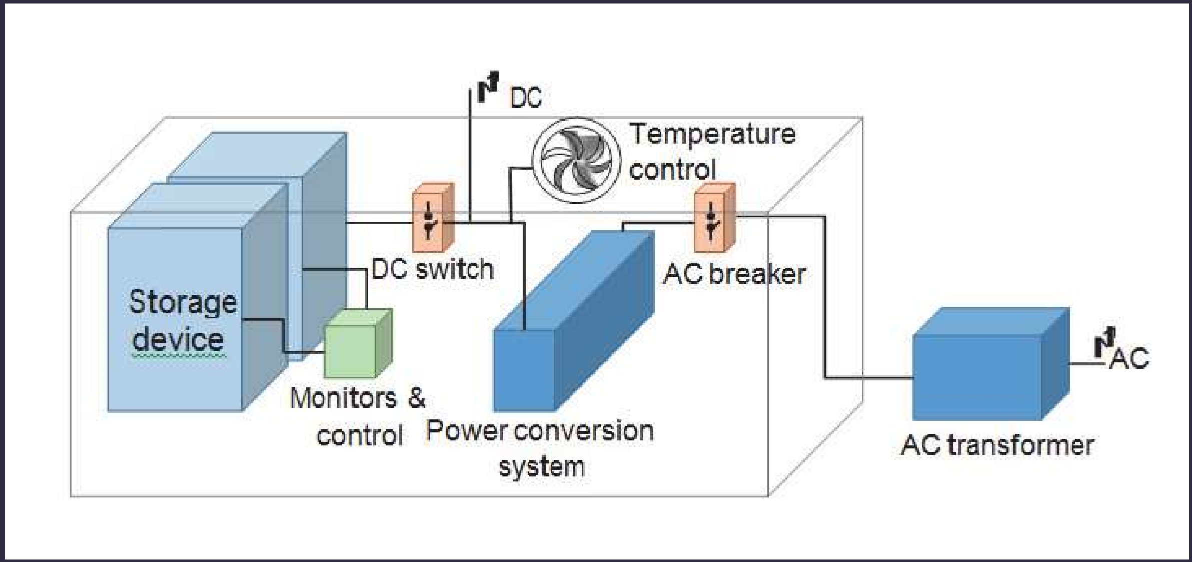
Lithium-ion cells

- Li-ion technology comprises a family of different chemistries where main reaction is transport of lithium ions between electrodes
- Common anode (negative) material is graphite or hard carbon and titanate
- Cathode is a metal oxide, such as NMC (lithiated nickel manganese cobalt oxide)
- Anode & cathode separated by a porous film – separator – comprising several layers of polymers
- Electrode and separator soaked in an electrolyte (organic solvents with dissolved lithium salt (LiPF6)
- Three forms of cells: cylindrical, pouch cells and prismatic – sealed and unvented
- Cells connected in series and parallel & grouped into sub-packs called modules

Cylindrical cell Pouch cell Prismatic cell

Sources:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/923611/domestic-battery-energy-storage-systems.pdf

Typical architecture of BESS



Locations:

- In the transmission network
- Near load centres in the distribution network
- Co-located with renewable energy generators, e.g. wind farms

Sources: Wartsila.com & amdcenergy.com/battery-energy-storage-system.html

Case Study 1 – Energypark Haringvliet, Rotterdam, NL

- Developed by Vattenfall
- 20km south of Rotterdam
- Combines 6 wind turbines 22MW) , 115,000 solar panels (38MW) & **12MWh of battery storage**
- Used for flattening supply and grid balancing
- Comprises 288 batteries of type which are used in BMW i3
- Investment of €61 million

The Energypark Haringvliet in the Netherlands. Image: Vattenfall.

Sources: https://group.vattenfall.com/

Case Study 2 – Carnegie Road, Liverpool, UK

- Developed by Ørsted
- 20MW battery in 3 battery containers
- Batteries and power conversion equipment provided by NEC Energy Solutions
- Used for grid balancing
- Fire in 2020

Sources: https://orsted.com/en/media/newsroom/news/2019/01/orsteds-first-standalone-battery-storage-project-now-complete

Case Study 3 – Victorian Big Battery, Geelong, AUS

- Developed by Neoen at a cost $160m
- 300 MW / 450 MWh
- Consists of 210 Tesla Megapacks
- Located nr Moorabool Terminal Station, in area size of football oval
- Support increasing number of solar and wind projects & increase transfer capacity for VI-NSW Interconnector (VNI) of 250MW at peak times
- 10 month to build; operational end 2021; 20 year lifespan
- Fire July 2021

Sources: https://victorianbigbattery.com.au/wp-content/uploads/2021/05/Neoen_VBB_A4_web.pdf & https://www.tesla.com/en_gb/megapack

What are the risks that insurers face?
Loss Scenarios – Recent GBESS Battery Fires

Korea Battery Fires

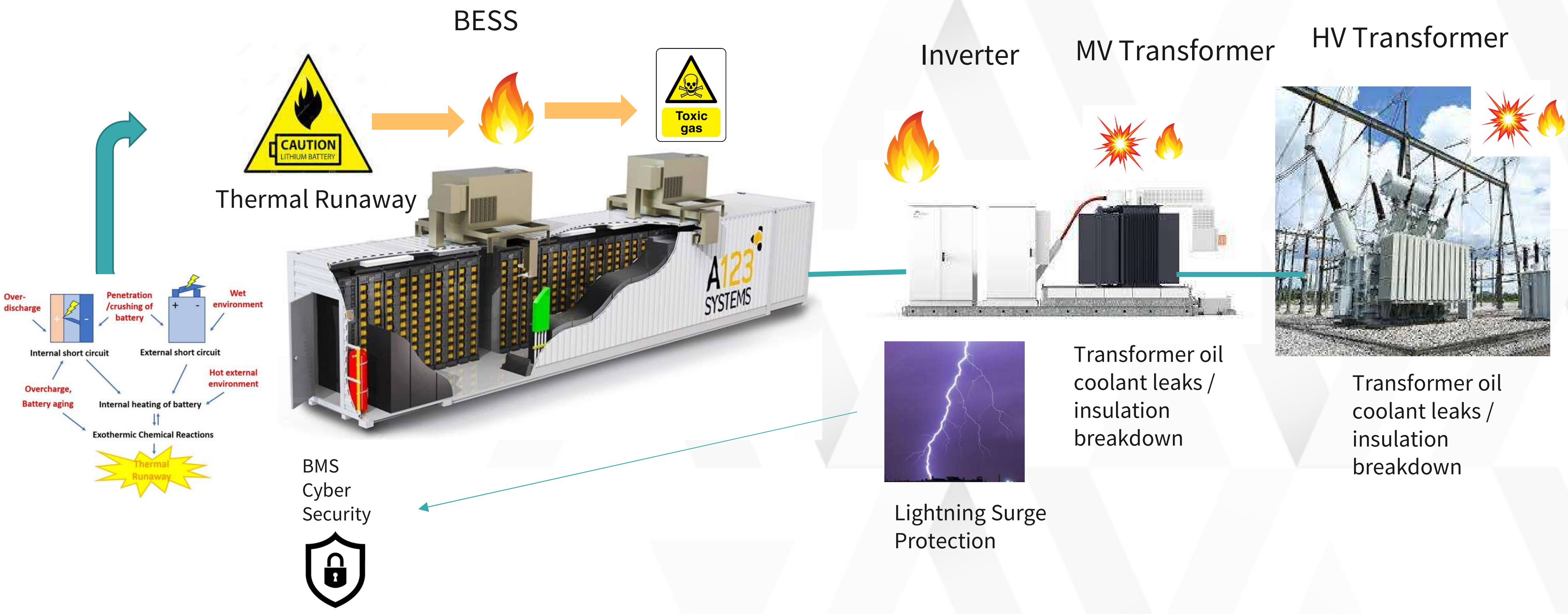
McMicken Battery Fire

15% of losses during CAR
25% within first year
48% within two years
= 63% first two years

Victoria Big Battery Fire

Carnegie Rd Battery Fire

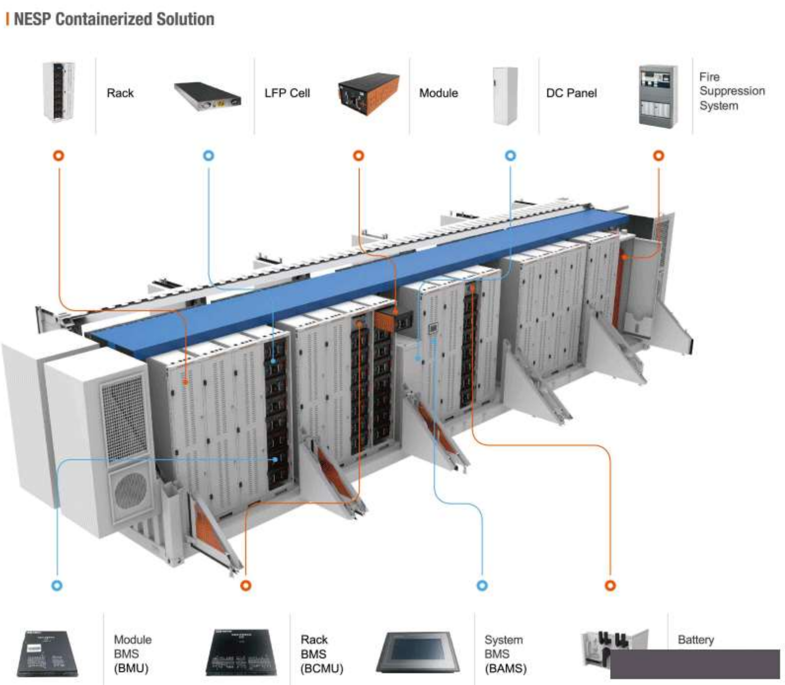
Loss Scenarios – Root Causes

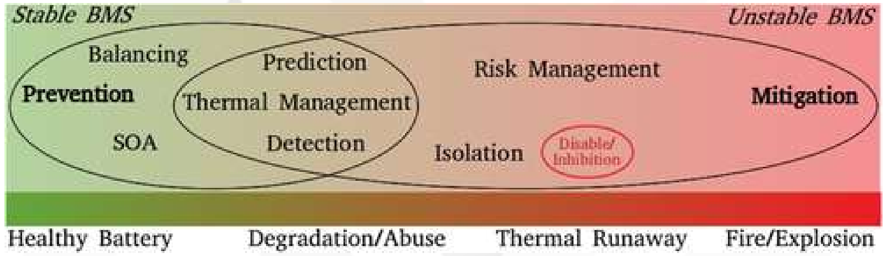


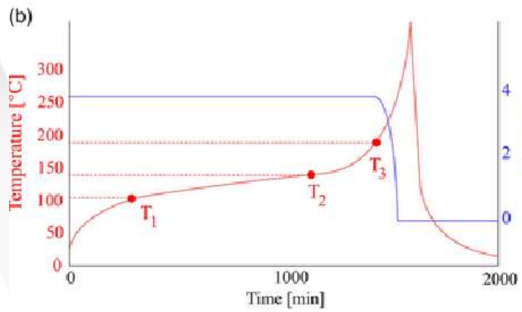
*BMS – Battery Management System ^BESS – Battery Energy Storage System

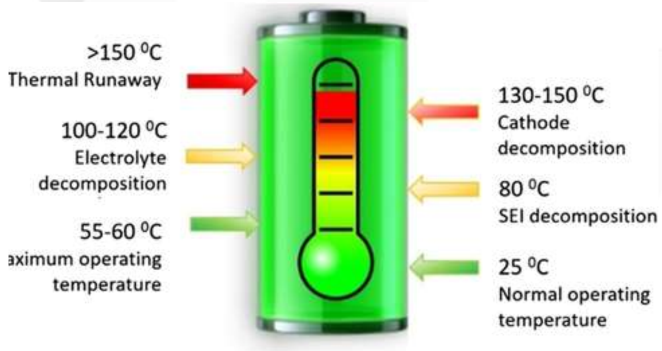
GBESS Thermal Runaway & Fire – Technology & Configuration

Lithium Ion Battery – heat is the major issue









T1 – Solid Electrode Interface starts to decompose
T2 - Melting process of electrode separator begins
T3 – Thermal runaway trigger temperature
- T1 increases and T3 decreases as the cell ages

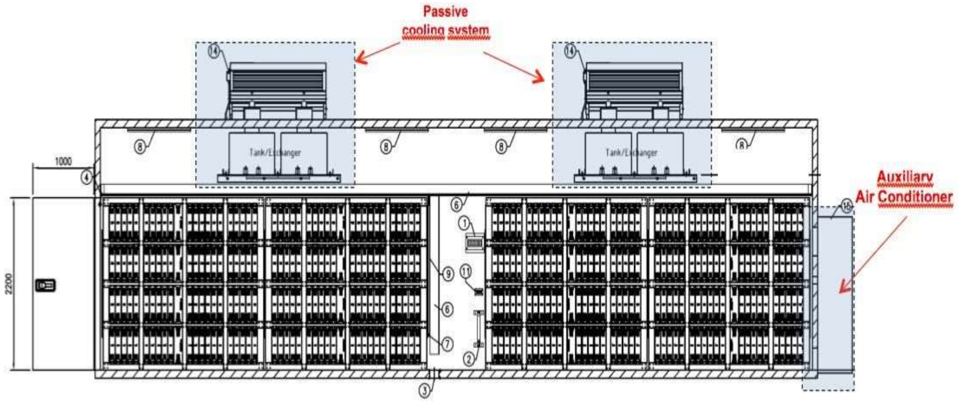
T2 is critical for evaluating battery safety because a cell with a higher T2 will most likely pass abuse tests such as puncturing, penetration or other mechanical abuse

GBESS Thermal Runaway & Fire – Cooling & Ventilation

- Lithium Ion battery life is strongly dependent on operating temperature & temperature variation that occurs within each individual cell
- Two main cooling approaches to maintain overall battery temperature

Air Cooled - HVAC

- Simple, light, cheap and easy to maintain
- To achieve a similar cooling performance to liquid cooling systems, higher volumetric flow of air is needed
- Could induce condensation within BESS container
- Fans can get blocked reducing cooling efficiency



Liquid Cooled

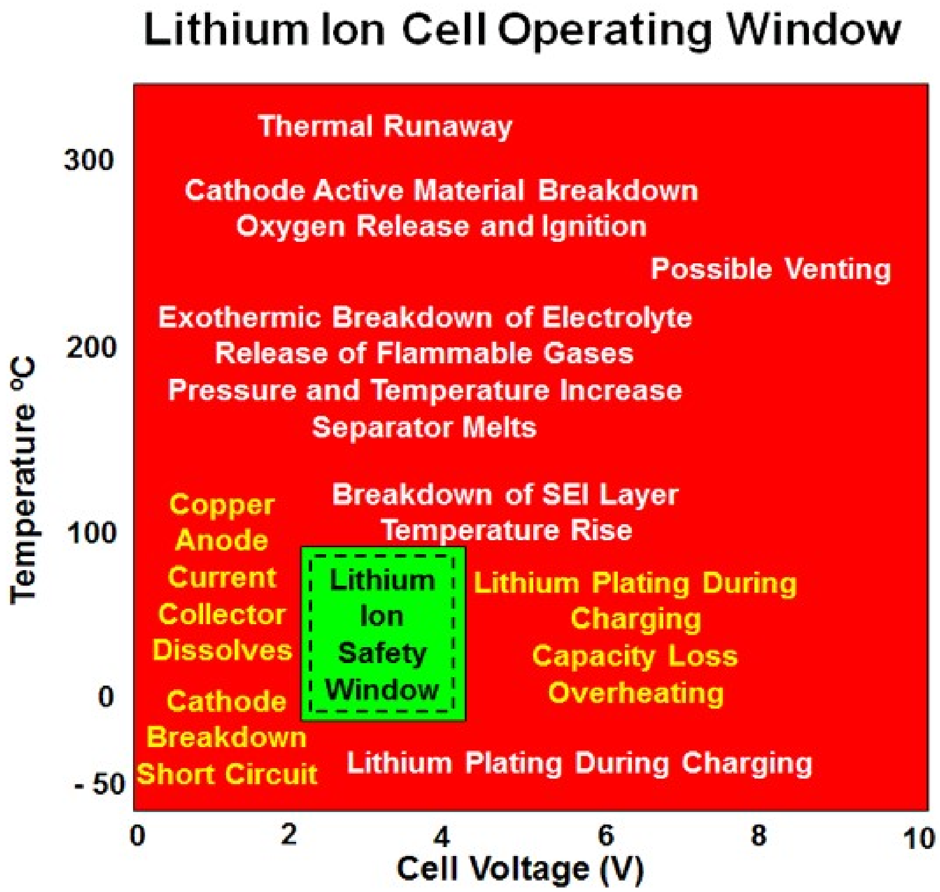
- Liquid cooling is very effective in removing substantial amounts of heat with very low flow rates
- Requires a pressurised system with pump and tank which requires periodic top-up while potential being prone to leaks
- Regular pressure testing of system is required

GBESS Thermal Runaway & Fire – Summary

Deflagration explosive risk is always present during a lithium battery fire

- When lithium ion batteries undergo thermal runaway and catch fire they release toxic gases which are highly combustible
- These gases are also released as a result of other materials within the battery container catching fire
- When the environment exceeds a specific explosive threshold limit and deflagration event can occur causing an explosion that can rupture the battery container and cause shrapnel to be released at high speed
- The main mitigation measures that are adopted is 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

Lithium Ion Batteries – Failure Scenarios



Heat is a major battery killer, either excess of it or lack of it, and Lithium secondary cells need careful temperature control

- 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

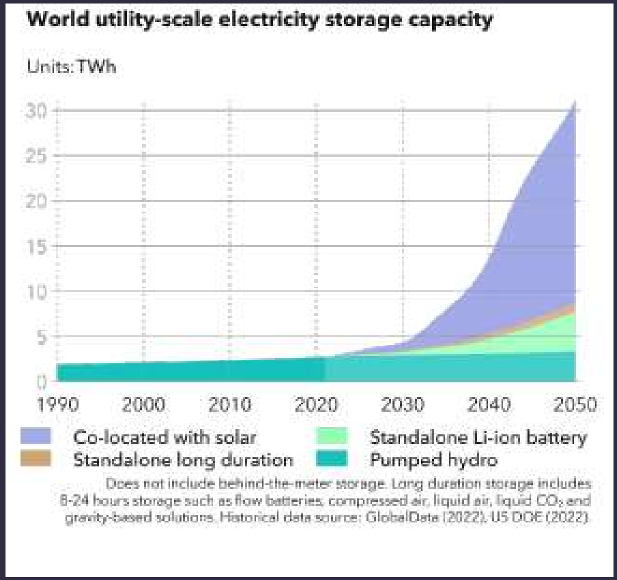
What does a good GBESS Project Look Like?

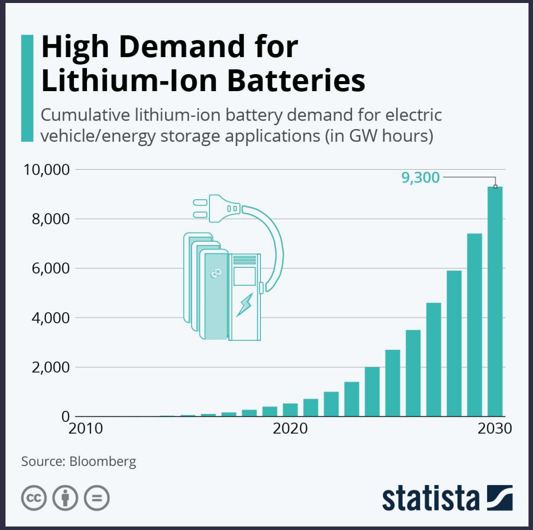
- Use of lithium ion-batteries with Lithium Iron Phosphate (LFP) battery chemistry
- UL9540A module/unit/installation level test showing none/low propagation & explosive risk
- Use of liquid cooling technologies for battery cooling & environmental control
- Deflagration vents incorporated into battery 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

Market Projections

- USD10.88 billion in 2022
- Projected to grow to USD31.20 billion by 2030, representing CAGR of 16.3%
- Rising penetration of Lithium-ion batteries to enable growth.
- Growth driven by grid expansion to cater for infrastructure projects and transportation sector e.g. EVs
- BESS co-located with solar power seeing largest growth

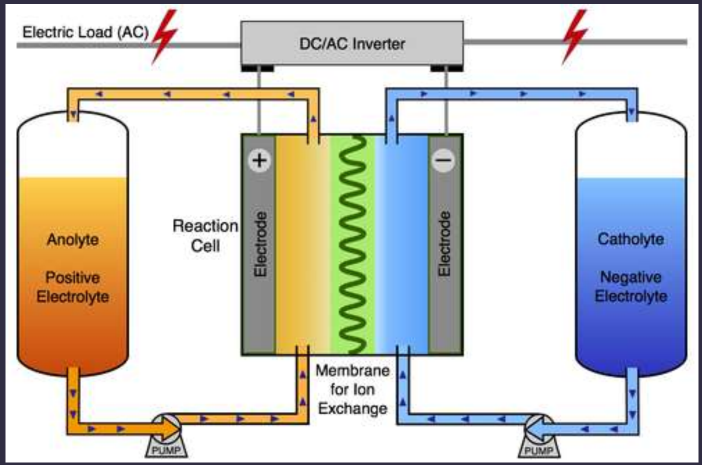




Sources: DNV Energy Transition Outlook 2022 & https://www.globenewswire.com

Future of BESS

- Shift to VRES will require increased flexibility and response to variations in power demand
- Better energy prediction, and management, e.g. smart grids and more interconnectors
- Increased prevalence of EV storage
- Strain on supply of lithium could force shift to other battery chemistries
- Trending for longer duration batteries, e.g. flow batteries, compressed air, gravity energy storage
- Seasonal storage to accommodate annual cycles, e.g. hydrogen production and storage in salt caverns and depleted O&G fields



Sources: https://wernerantweiler.ca/blog.php?item=2014-09-28 & https://www.energyvault.com/ch-castione charlestaylor.com

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