BESS manufacturing defect overview

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INTERTEK CEA HAS CONDUCTED QUALITY AUDITS ON OVER 65 GWH OF LITHIUM-ION BATTERY ENERGY STORAGE PROJECTS SINCE 2018

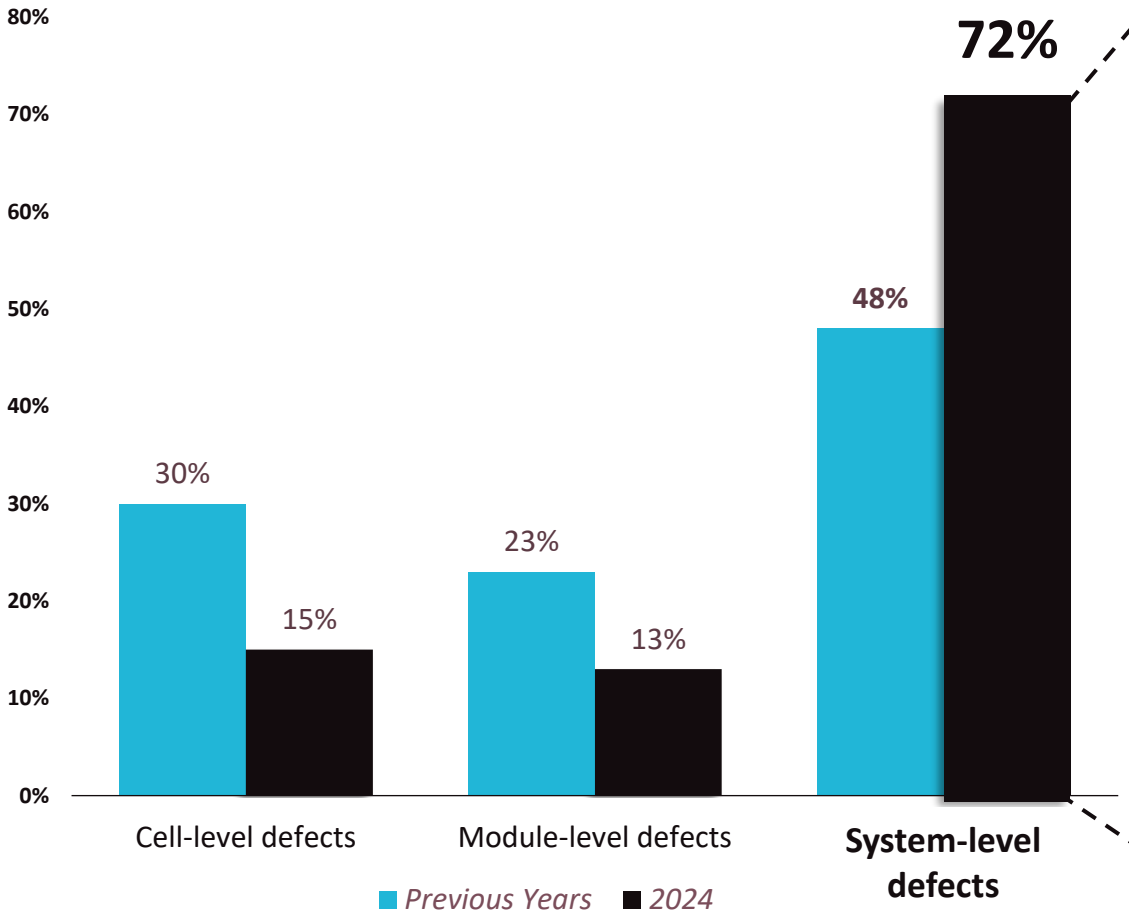
- 700+ inspections in 70+ BESS factories
- 70% of tier 1* BESS cell manufacturers audited worldwide
- 3000+ total manufacturing issues identified

Locations of factory audits

Here are our key findings from our 2024 inspections...

*Tier 1: definition is based on BMI (Benchmark Mineral Intelligence)

IN 2024 THE MAJORITY OF IDENTIFIED QUALITY ISSUES WERE AT THE SYSTEM LEVEL



Safety-critical failures:

28% of systems had defects in **fire detection and suppression**, which are critical for preventing runaway fires.

19% of systems had faulty **auxiliary circuit panels**, increasing the risk of control system failure.

15% of systems had **thermal management defects,** raising the risk of overheating and accelerated degradation.

Performance failures:

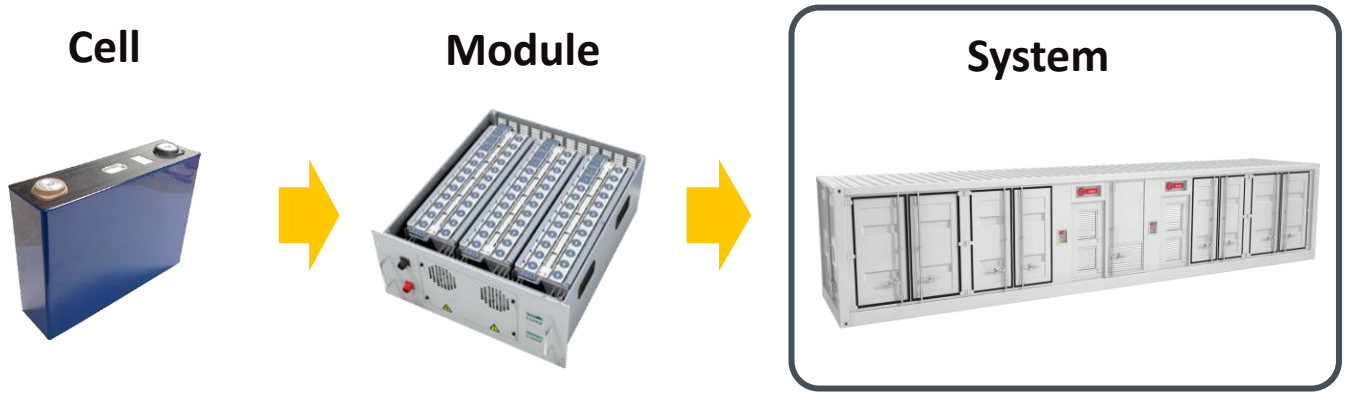
6% of systems failed capacity tests — directly impacting energy delivery and project performance.

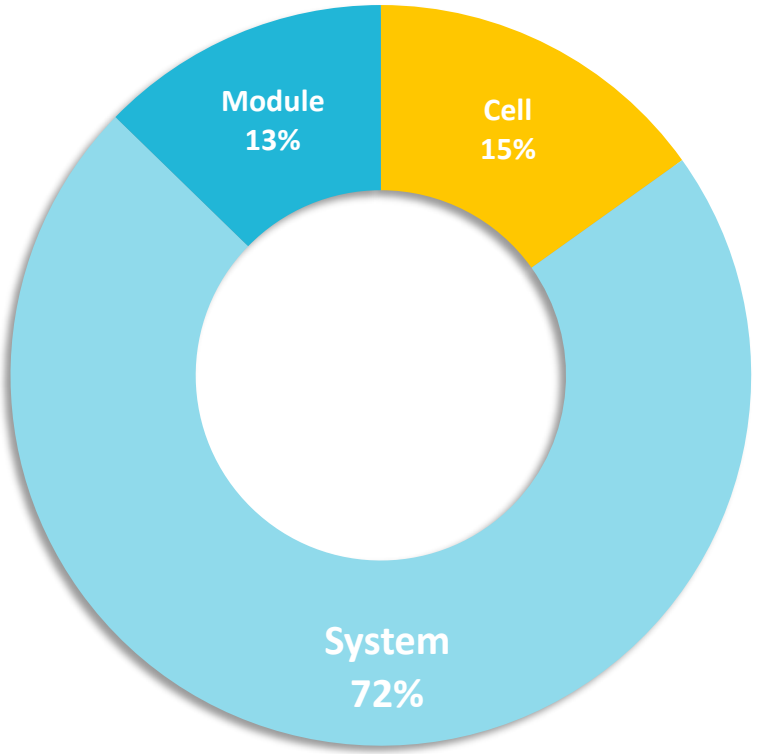
Distribution of Total Findings

As the industry continues to scale, quality problems at the integration stage continue to be challenging to fix.
System-level defects accounted for 72% of our QA findings.

The large number of system-level issues is mainly caused by the following contributors:

- *The BESS integration process is* **highly manual** *and labor-intensive, with weaker quality control often carried out by outsourced integration companies who have little incentive to ensure long-term performance.*
- *The rapid product iteration puts* **time constraints** *on the development of mature production practices.*
- *Systems are* **very complex** *and are vulnerable to underlying problems originating from defects in upstream components that were not caught during earlier quality checks.*





Distribution of all BESS Findings

BREAKDOWN OF SYSTEM-LEVEL FINDINGS

Most system-level findings occurred in the **Balance of System** *and* **Enclosure**.
Performance test *findings usually indicate larger or more complex problems.*

64% of system-level findings are Balance of System related

Why/How Does It Happen

Component defects and improper system integration procedures.

Examples

- **Liquid coolant leakage** *due to deformed flange plates, defective valves, loose pipe connections within the coolant circulation system*
- **Malfunctioning** *temperature, smoke, gas sensors, sound and visual alarms due to internal mis-wiring*
- **Live conductor** *exposed within the AC/DC distribution*

30% of system-level findings are enclosure related

Why/How Does It Happen

Defects from enclosure manufacturing process and mishandling during transportation.

Examples

- *Poor* **strength** *and rigidity: lifting provision test, structural deformation, etc.*
- *Poor* **wiring** *and cabling arrangement*
- **Grounding** *mechanism defects*
- **Water** *ingress issue*
- **Appearance** *defects: painting specifications, markings, nameplate, openings, etc.*

6% of system-level findings are performance test related

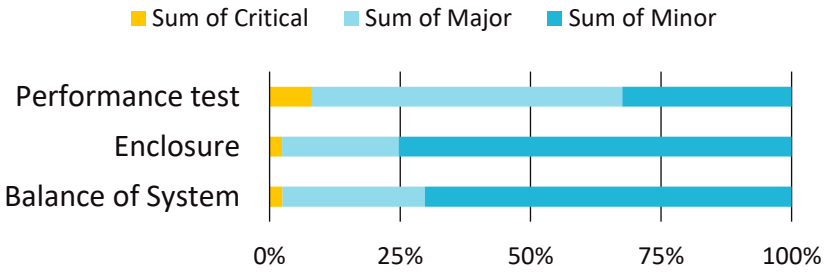
Why/How Does It Happen

A wide variety of manufacturing defects and/or improper system integration.

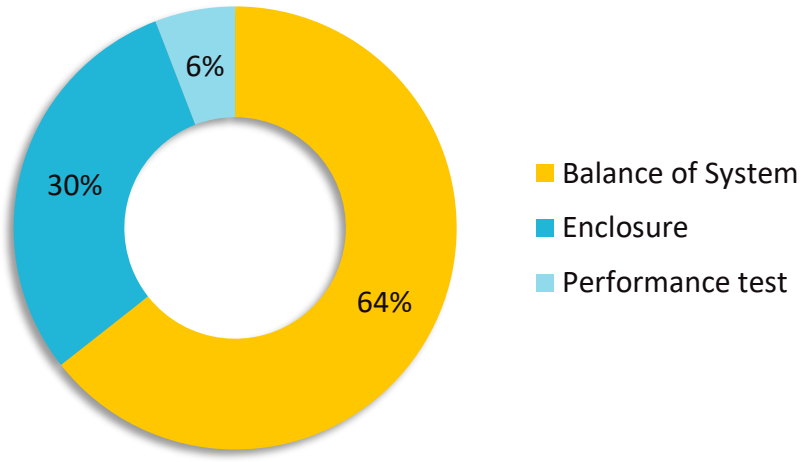
Examples

- *Underachieving* **capacity** *and Round-Trip* **Efficiency** *results from abnormally* **large temperature and voltage variations** *among battery cells within a module, due to high impedance from poorly* **welded** *wiring connections*
- *Charging/discharging failure due to* **wiring** *issues in battery rack high voltage boxes*

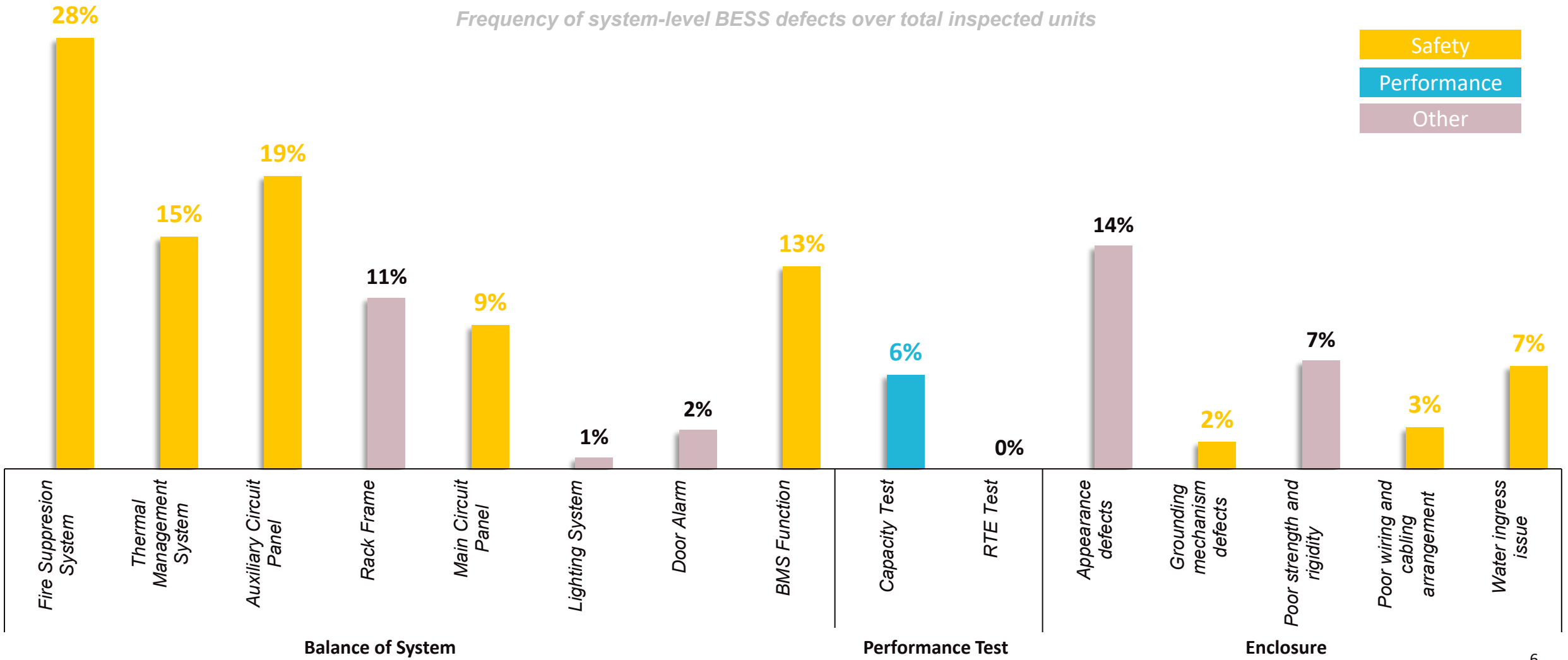
Severity Scale of System-Level Findings



Distribution of System-Level Findings



MOST SYSTEM-LEVEL DEFECT TYPES HAVE A SAFETY IMPACT; 6% FAILED PERFORMANCE TESTS



COMMON FIRE DETECTION AND SUPPRESSION SYSTEM FINDINGS

28% of inspected BESS units had fire detection and suppression system defects

Non-responding release actuator for the fire extinguishing agent

Why/How Does It Happen

Faulty **diode** *within the actuator.*

Risk

A malfunctioning **actuator** *will not respond to the command of releasing a fire extinguishing agent, potentially allowing the fire to further propagate.*

Example

Fire alarm abort button was not functional

Why/How Does It Happen

The fire **alarm** *abort button was not responding to the user commands due to incorrect wiring.*

Risk

The abort **button** *allows user to deactivate an improperly triggered fire alarm; failure to deactivate can lead to unwanted fire extinguishing agent or sprinkler system activation which can cause serious damage to equipment.*

Example

Non-responding smoke & temperature sensors

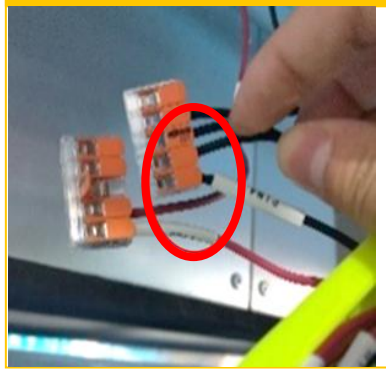
Why/How Does It Happen

The smoke **sensor** *was incorrectly wired, and a temperature sensor was reversely connected to power source.*

Risk

An incorrectly **wired** *smoke sensor cannot detect the presence of smoke. A reversely connected temperature sensor can have a false reading. Malfunctioning sensors risks fire and explosion or inadvertent activation of fire suppression system.*

Example



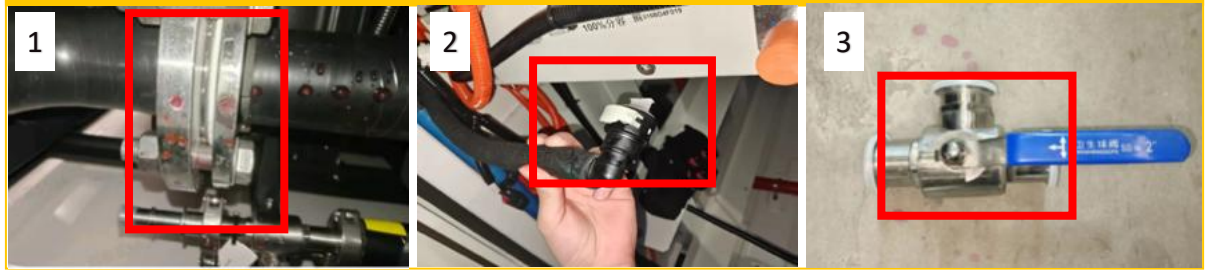
COMMON THERMAL MANAGEMENT SYSTEM FINDINGS

15% of inspected BESS units had thermal management system defects

Circulation System Components Failure

Why/How Does It Happen		
1. Flange plates are **deformed** *from overtightening due to a loosely defined screw mounting Standard Operating Procedure (SOP).*	*2. Loose pipe connection: the fastener was not fastened from operator's erroneous installation and not following SOP.*	*3. Defective incoming material:* **valve** *with loose stem.*
Risk		
1. **Internal short circuiting** *and thermal runaway initiation from continuous coolant leakage.*	*2. Severe* **short-circuiting** *events and thermal runaway initiation from potential massive coolant leakage.*	*3. Faster battery* **degradation** *from insufficient coolant flow control and internal short circuiting and thermal runaway initiation from continuous coolant leakage.*

Example



Compressor mainboard short circuiting

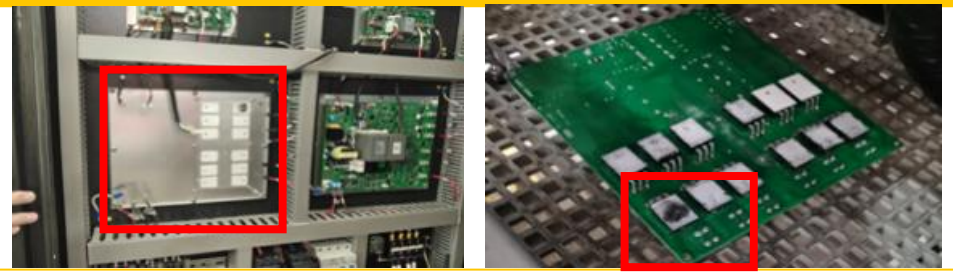
Why/How Does It Happen

Defective **mainboard** *with a burned MOS (Metal Oxide Semiconductor) tube for compressor control.*

Risk

1. *Faster battery* **degradation** *from dysfunctional liquid cooling system.*
2. *Initiating thermal* **runaway** *or explosion with sparking from burned components.*

Example



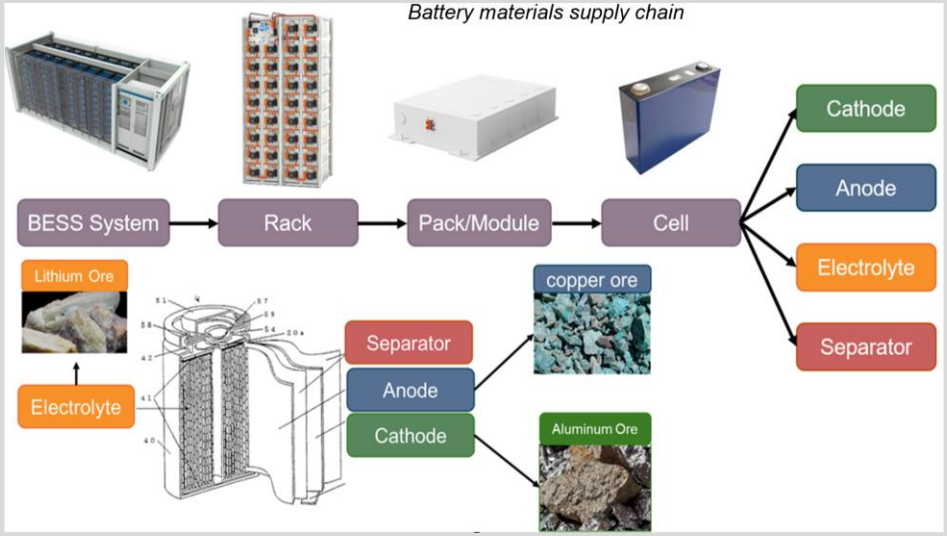
ESG & TRACEABILITY FOR BESS HAS ITS OWN CHALLENGES

Battery manufacturers are not ready for the EU battery regulation

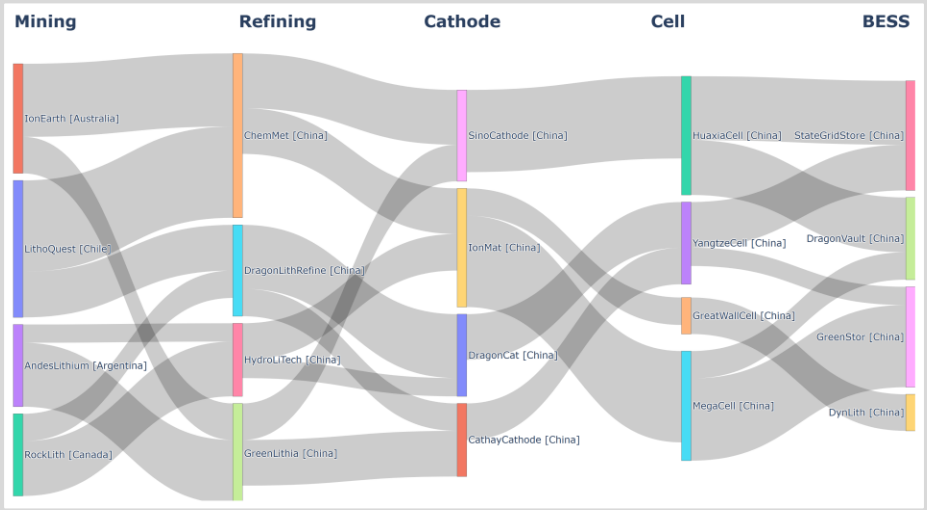
Battery manufacturers have less control of the upstream supply chains than in PV

It’s all about the BESS cell: cell suppliers are very large and powerful organizations, primarily focused on the EV business

But there is progress, as large buyers with strict ESG requirements demand transparency and BESS suppliers compete to win multi-GWh portfolio business



Anonymized lithium supply chain map

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