

E-STORAGE ENERGY STORAGE SOLUTION

Fire Safety Design Overview

Apr 2025

- Product overview
- PowerBlock integration and system design
- Codes, standards and UL9540A
- Project specific fire safety design (ERP, HMA and HFA)
- Emergency response on site

Product Evolution

Navigating Our Technology Roadmap

- Product overview
- PowerBlock integration and system design
- Codes, standards and UL9540A
- Project specific fire safety design (ERP, HMA and HFA)
- Emergency response on site



SolBank1.0
3 MWh

SolBank3.0
5 MWh

2022

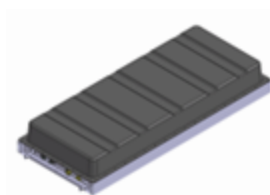
2023

2024

2025



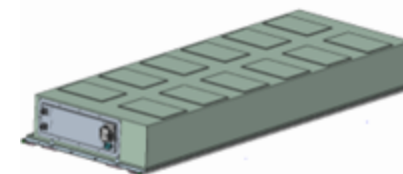
280 Ah



1P69S Pack



314 Ah



1P104S Pack

SolBank 1.0

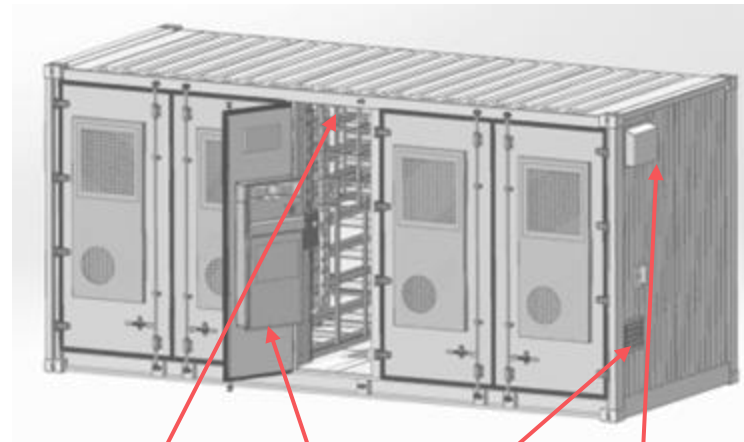
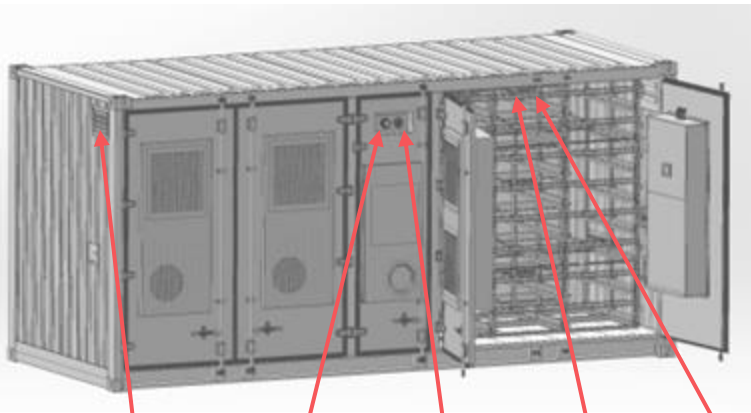
3MWh Containerized Product



Model	4-hour (0.25P)	2-hour (0.5P)	1.5-hour (0.67P)
Battery	280 Ah Lithium Iron Phosphate (LFP) Prismatic Cells		
Rated DC Voltage Range	1159.2V~1490.4 V		
Configuration	8P414S (8 Strings)	8P414S (8 Strings)	6P414S (6 Strings)
Rated DC Power	700 kW	1375 kW	1300 kW
Nominal Energy Capacity (Nameplate)	2967 kWh	2967 kWh	1950 kWh
Usable Energy Capacity (FAT)	2800 kWh	2750 kWh	1950 kWh
DC Round-Trip Efficiency (RTE)	94%	93%	90%
Thermal Management System	Liquid cooling for battery system, air cooling for electrical components and humidity control		
Enclosure	20 ft ISO Container NEMA 3R 6058L x 2438Wx2896H (mm)		
Weight (Battery Included)	29,800kg (65,700 lbs.)	24,900kg (54,895 lbs)	

SolBank 1.0 FSS

Fire Safety System Design



Safety features

- Fire detection (smoke + heat detectors)
- Fire alarm (remote and local)
- Explosion prevention (combustible gas detection, active ventilation)
- Fast Stop (F-Stop)
- Non-walk-in container design with open door sensors

Redundancy designs

- Two sets of smoke, heat detectors, trigger of any will report fire alarm
- Two gas detectors, trigger of any will report gas alarm
- DMC UPS for battery monitoring, ventilation, fire detection and alarming
- Dedicated FACP UPS for fire safety system (fire sensors, alarms)

SolBank 3.0

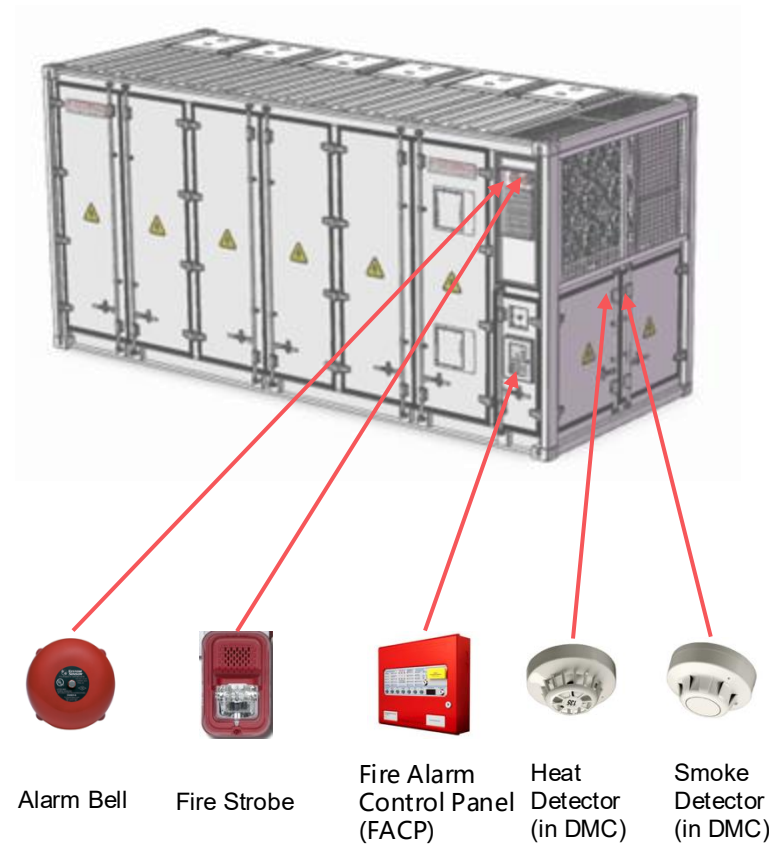
Leading in Performance, Energy Density and Safety



Model	4-hour (0.25P)	2-hour (0.5P)
Battery Cells	314 Ah Lithium Iron Phosphate (LFP) Prismatic Cells	
Configuration	12P416S (12 Racks)	12P416S (12 Racks)
Rated DC Voltage Range	1164.8V~1497.6 V	
Rated DC Power	1200 kW	2350 kW
Nominal Energy Capacity (Nameplate)	5016 kWh	5016 kWh
Usable Energy Capacity (FAT)	4800 kWh	4700 kWh
DC Round-Trip Efficiency (RTE)	94%	93%
Thermal Management System	Smart liquid cooling (integrated within the container)	
Enclosure	20 ft ISO Container NEMA 3R 6058L x 2438Wx2896H (mm)	

SolBank 3.0 FSS

Fire Safety System Design



Safety features

- Fire detection (smoke + heat detectors)
- Fire alarm (remote and local)
- Explosion prevention (combustible gas detection, active ventilation)
- Fast Stop (F-Stop)
- Non-walk-in container design with open door sensors
- Separate fire sensors for electrical system (in DMC)

Redundancy designs

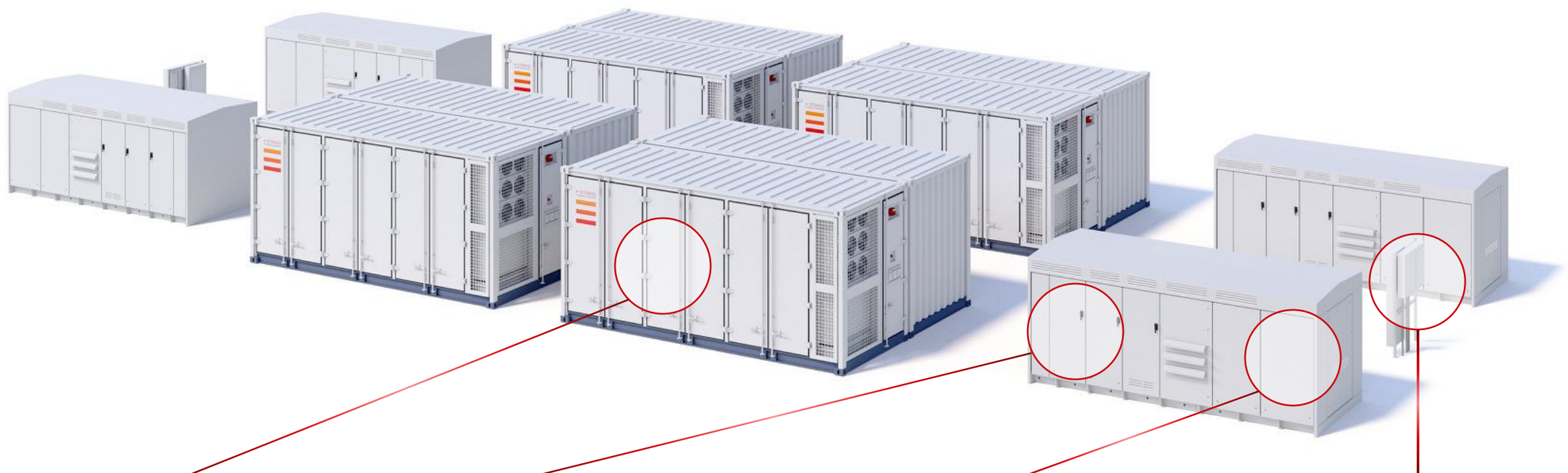
- Two sets of smoke, heat detectors in battery cabinets, one set of smoke, heat detector in DMC, trigger of any will report fire alarm
- Two gas detectors in battery cabinets, trigger of any will report gas alarm
- DMC UPS for battery monitoring, ventilation, fire detection and alarming
- Dedicated FACP UPS for fire safety system (fire sensors, alarms)

PowerBlock Design

Solution Tailored to Project Requirements

- Product overview
- PowerBlock integration and system design
- Codes, standards and UL9540A
- Project specific fire safety design (ERP, HMA and HFA)
- Emergency response on site

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BESS Enclosure (SolBank)
LFP battery, integrated BMS, auxiliary system to maintain performance and safety of the product

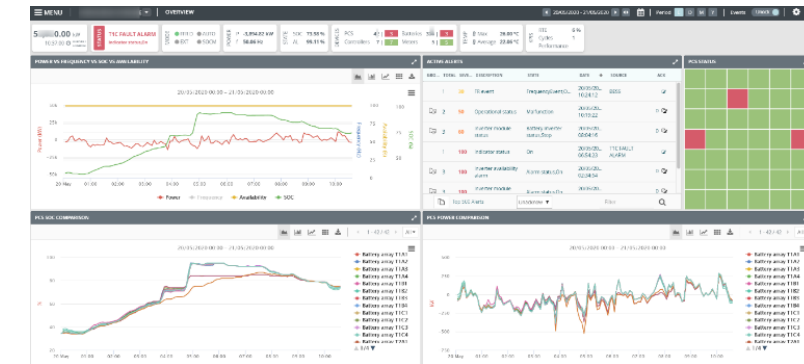
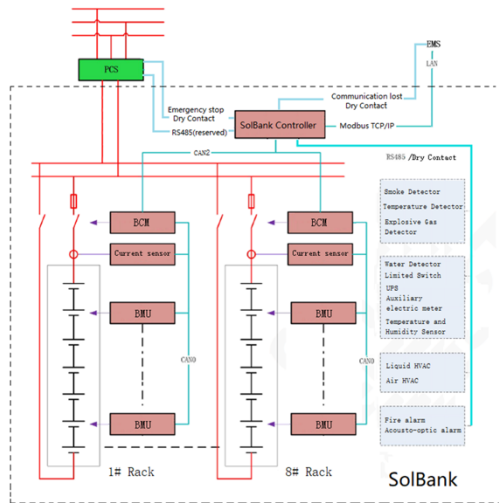
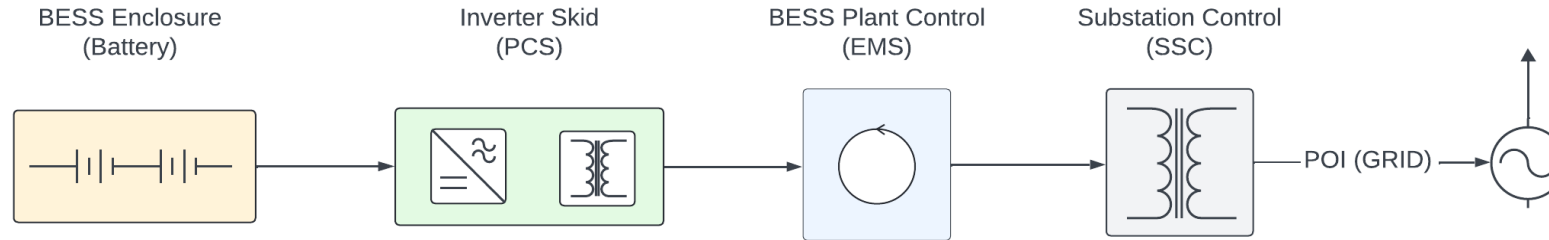
Inverter (PCS)
Convert power between AC-DC for charging and discharging, with integrated battery controls and grid support functionalities

Medium Voltage Transformer (MVT)
Skidded with PCS or separated. Step up for interconnection with the grid

Energy Station Controller (ESC, part of EMS)
Monitoring equipment status onsite and optimize power commands between different PowerBlocks.

PowerBlock Layers of Controls

Vertically Integrated Control and Monitoring



Battery Management System (BMS)

- Monitor and track critical parameters of battery and auxiliary system
- Report operating limits, alarms, rapid fault isolation on rack and enclosure level

Battery Control Interface (BCI)

- Act as the control hub for controlling and fine-tuning the power output of each PowerBlock
- Coordinate behaviors of equipment during normal operation, maintenance mode or fault condition

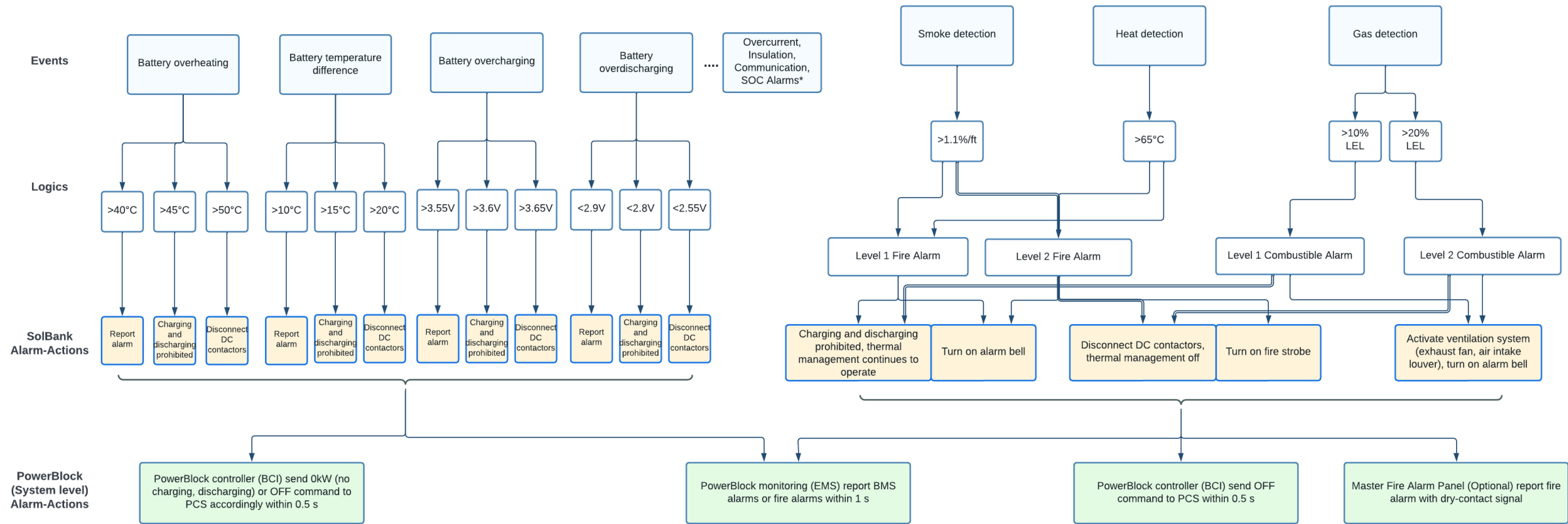
Energy Management System (EMS)

- Monitors status of all BESS equipment and report any fault detected to the operator
- read and analyze operating data of the equipment, to optimize system health and identify issues from early stage

BMS Alarm and Fire Alarm Overview

Coordinated alarms between BMS and FACP

Fire Safety Alarms and Protections Overview



Note: *This overview has included examples for BMS alarms, for complete list of alarms and monitoring datapoints please refer to BMS alarm list and modbus map

Primary BESS Codes & Standards

BESS safety standards (Will vary on location)

- NFPA 855 Standard for the Installation of Energy Storage Systems (2023 Edition)
- 2024 International Fire Code (IFC) Chapter 12 – Section 1207

**Required code / standard and editions may vary based on state or jurisdiction.*

Listings / Certifications for ESS and Associated Equipment:

- **UL 9540:** Standard for Energy Storage Systems and Equipment

Includes:

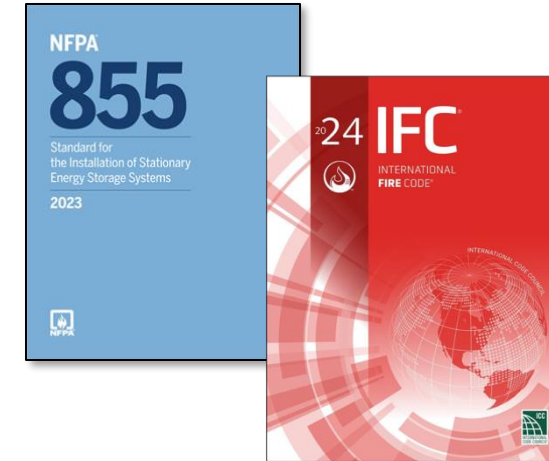
- UL 1973 for cell, battery, rack
- UL 1741 for inverters

Large-Scale Fire Testing:

- **UL 9540A:** Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

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UL9540A Large-scale Fire Testing

Purpose of the test and key criteria

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

Developed to better understand safety risks, demonstrate compliance with codes and standards

▪Testing performed at multiple levels:

- Cell
- Module
- Unit
- Installation*

▪Test results inform system design and installation requirements

- Fire mitigation and protection
- Ventilation
- Incident management

Test Level	Reported Information / Performance Criteria
Cell	• Can cell exhibit thermal runaway? • Thermal runaway characteristics • Flammability / composition of vent gas
Module	• Thermal runaway containment / characteristics • Flammability / composition of vent gas • Heat and gas release rates
Rack / Unit	• Evaluation of fire / thermal runaway spread • Heat and gas release rates • Deflagration and re-ignition behavior
Installation	• Effectiveness of fire protection systems • Heat and gas release rates • Deflagration and re-ignition behavior

UL9540A Report Examples

Cell-Module-Unit level testing

Test Result high level summary

UL9540A – Unit level

- Cell to cell thermal runaway propagation was observed.
- No module-to-module thermal runaway propagation.
- No flying debris or explosive discharge of gases during the test.
- No electrical arcs, or other electrical events during test.
- No external flaming was observed.

Note: Please refer to the reports for more details.

GProdukte Products		TÜVRheinland®	
Prüfbericht-Nr.: Test Report No.: CN22Y931 001	Auftrags-Nr.: Order no.: 16835050	Seite 1 von 31 Page 1 of 31	
Kunden-Referenz-Nr.: Client Reference No.: 2347845	Auftragsdatum: Order date: 2022.01.10		
Auftraggeber: Client: Xiamen Hithium New Energy Technology Co., Ltd. 201-1, Comprehensive Building 5, No. 11, Butang Middle Road, Industrial Base Of Xiamen Torch High Tech Zone (Tongxiang), Xiamen, P.R. China			
Prüfgegenstand: Test item: Rechargeable Li-Ion Cell			
Bezeichnung / Typ-Nr.: Identification / Type no.: LFP71173207/280Ah			
Auftrags-Inhalt: Order content: Test report			
Prüfgrundlage: Test specification: UL 9540A: 2019 (Fourth Edition)			
Wareneingangdatum: Date of receipt: 2022.01.10			
Prüfmuster-Nr.: Test sample No.: Engineering sample			
Prüfzeitraum: Testing period: Refer to clause 1.1 of main report			
Ort der Prüfung: Place of testing: Refer to clause 1.1 of main report			
Prüflaboratorium: Testing laboratory: TÜV Rheinland (Shenzhen) Co., Ltd.			
Prüfgebnis: Test result: See main report			
geprüft von / tested by: Zack Su	kontrolliert von / reviewed by: Cory Zhang		
Datum: Date: 2022.03.15	Unterschrift: Signature: Zack Su	Datum: Date: 2022.03.15	Unterschrift: Signature: Cory Zhang
Sonstiges / Other:			
Zustand des Prüfgegenstandes bei Anlieferung: Condition of the test item at delivery:		Prüfmuster vollständig und unbeschädigt Test item complete and undamaged	
Legende: 1 = sehr gut 2 = gut 3 = befriedigend 4 = mäßig 5 = mangelhaft Legend: 1 = very good 2 = good 3 = satisfactory 4 = fair 5 = not good Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht ausgewertet veröffentlicht werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens. This test report only relates to the above mentioned test sample as. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.			
TÜV Rheinland (Shenzhen) Co., Ltd. 1801 1802 Room, 1802-1804, 17-18F, Building 7 Site C, Vantage Cloud City Phase 1, Jangle First Street, Xixi Street, Xixi Community, Nanshan District, Shenzhen 518052, P.R. China Mail: shenzhen@tuv.com Web: http://www.tuv.com			

UL9540A-Cell level

GProdukte Products		TÜVRheinland®	
Prüfbericht-Nr.: Test report no.: CN22XU98 001	Auftrags-Nr.: Order no.: 24439902	Seite 1 von 37 Page 1 of 37	
Kunden-Referenz-Nr.: Client reference no.: 2371109	Auftragsdatum: Order date: 2022-08-30		
Auftraggeber: Client: CSI Energy Storage Co., Ltd. 199, Lushan Road, SND, Suzhou City, Jiangsu, P.R. China			
Prüfgegenstand: Test item: LFP battery module			
Bezeichnung / Typ-Nr.: Identification / Type no.: CSI-SolBank-P-61.8-1.5h-H, CSI-SolBank-P-61.8-2h-H, CSI-SolBank-P-61.8-4h-H			
Auftrags-Inhalt: Order content: Test report			
Prüfgrundlage: Test specification: UL 9540A: 2019 (Fourth Edition) Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems			
Wareneingangdatum: Date of sample receipt: 2022-10-14			
Prüfmuster-Nr.: Test sample no.: #2022101801			
Prüfzeitraum: Testing period: 2022-10-18 - 2022-11-02			
Ort der Prüfung: Place of testing: See clause 1.1 of main report			
Prüflaboratorium: Testing laboratory: See clause 1.1 of main report			
Prüfgebnis: Test result: See main report			
geprüft von: tested by: Simon Wang	genehmigt von: authorized by: Bowen Dong		
Datum: Date: 2022.11.05	Unterschrift: Signature: Simon Wang	Datum: Issue date: 2022.11.05	Unterschrift: Signature: Bowen Dong
Stellung / Position: Project Engineer			
Sonstiges / Other:			
Zustand des Prüfgegenstandes bei Anlieferung: Condition of the test item at delivery:		Prüfmuster vollständig und unbeschädigt Test item complete and undamaged	
Legende: 1 = sehr gut 2 = gut 3 = befriedigend 4 = mäßig 5 = mangelhaft Legend: 1 = very good 2 = good 3 = satisfactory 4 = fair 5 = not good Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht ausgewertet veröffentlicht werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens. This test report only relates to the above mentioned test sample as. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.			
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UL9540A-Module level

GProdukte Products		TÜVRheinland®	
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Kunden-Referenz-Nr.: Client reference no.: 2371109	Auftragsdatum: Order date: 2022-08-30		
Auftraggeber: Client: CSI Energy Storage Co., Ltd. 199, Lushan Road, SND, Suzhou City, Jiangsu, P.R. China			
Prüfgegenstand: Test item: Battery Rack			
Bezeichnung / Typ-Nr.: Identification / Type no.: CSI-SolBank-R-370-1.5h-H, CSI-SolBank-R-370-2h-H, CSI-SolBank-R-370-4h-H			
Auftrags-Inhalt: Order content: Test report			
Prüfgrundlage: Test specification: UL 9540A: 2019 (Fourth Edition) Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems			
Wareneingangdatum: Date of sample receipt: 2022-10-14			
Prüfmuster-Nr.: Test sample no.: #2022102001			
Prüfzeitraum: Testing period: 2022-10-20 - 2022-11-05			
Ort der Prüfung: Place of testing: See clause 1.1 of main report			
Prüflaboratorium: Testing laboratory: See clause 1.1 of main report			
Prüfgebnis: Test result: See main report			
geprüft von: tested by: Simon Wang	genehmigt von: authorized by: Bowen Dong		
Datum: Date: 2022.11.05	Unterschrift: Signature: Simon Wang	Datum: Issue date: 2022.11.05	Unterschrift: Signature: Bowen Dong
Stellung / Position: Project Engineer			
Sonstiges / Other:			
Zustand des Prüfgegenstandes bei Anlieferung: Condition of the test item at delivery:		Prüfmuster vollständig und unbeschädigt Test item complete and undamaged	
Legende: 1 = sehr gut 2 = gut 3 = befriedigend 4 = mäßig 5 = mangelhaft Legend: 1 = very good 2 = good 3 = satisfactory 4 = fair 5 = not good Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht ausgewertet veröffentlicht werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens. This test report only relates to the above mentioned test sample as. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.			
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UL9540A-Unit level

Other Standards Overview

Related to BESS safety

Certification-Standard

- Battery Cell, Module and Rack – **UL1973, IEC62619, UL1642**
- SolBank - **UL9540, UL9540A** (cell, module, unit level), **UN38.3**
- SolBank Explosion Prevention System – **NFPA69, NFPA68** (Optional)
- Inverter – **UL1741**
- Integrated system – **UL9540**

Independent Engineering Report

- SolBank product DNV IE report



Owner Support under Long Term Service Agreement (LTSA)

- 24*7 monitoring of the system through CSI remote operation center
- O&M service with preventive maintenance and corrective maintenance of the equipment
- Onsite and remote training to ensure adequate professionalism of O&M team members

Site Specific Documents

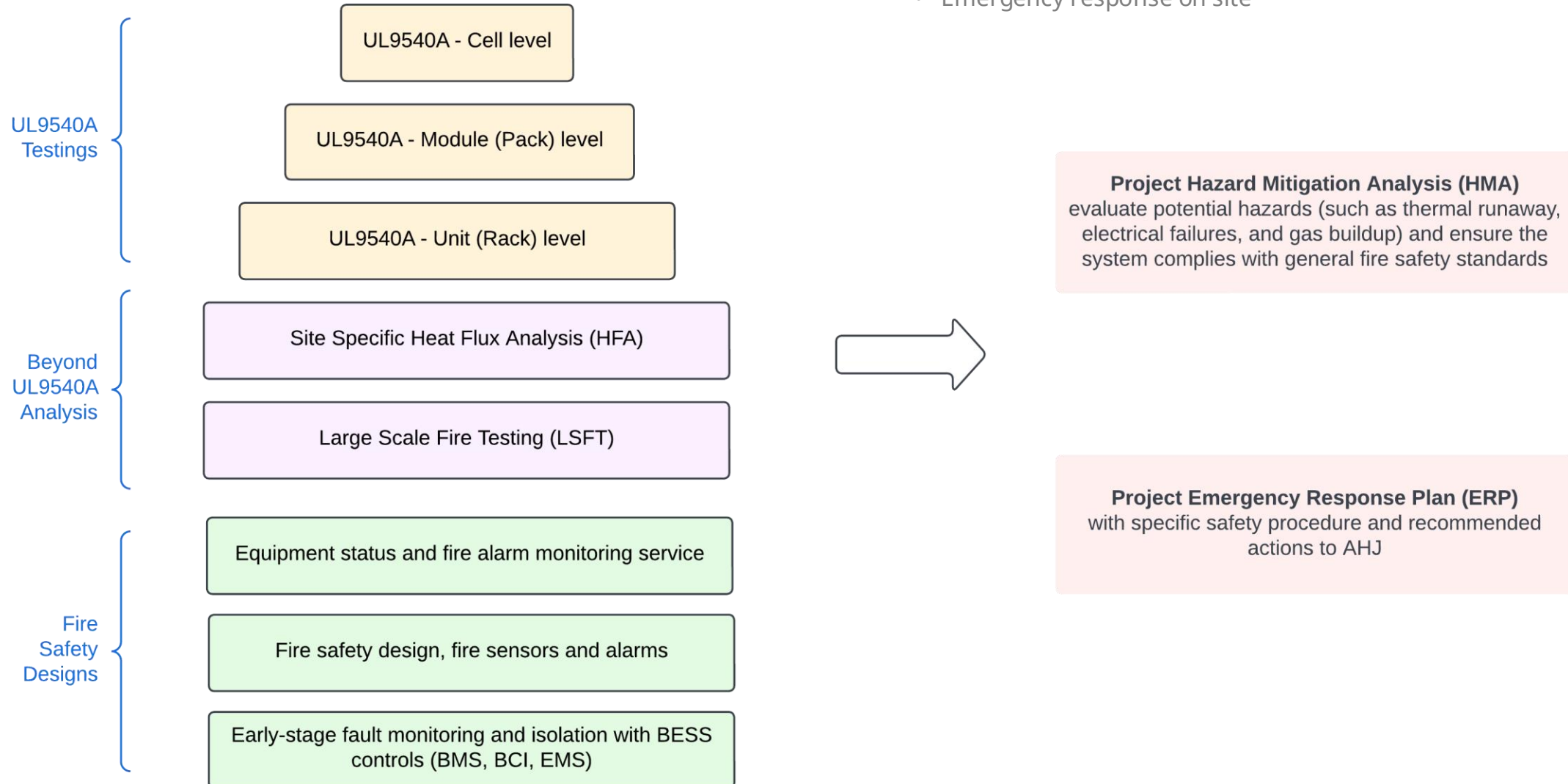
- Site specific Emergency Response Plan (ERP)
- Site specific Hazard Mitigation Analysis (HMA)
- Site specific Heat Flux Analysis Report (HFA)



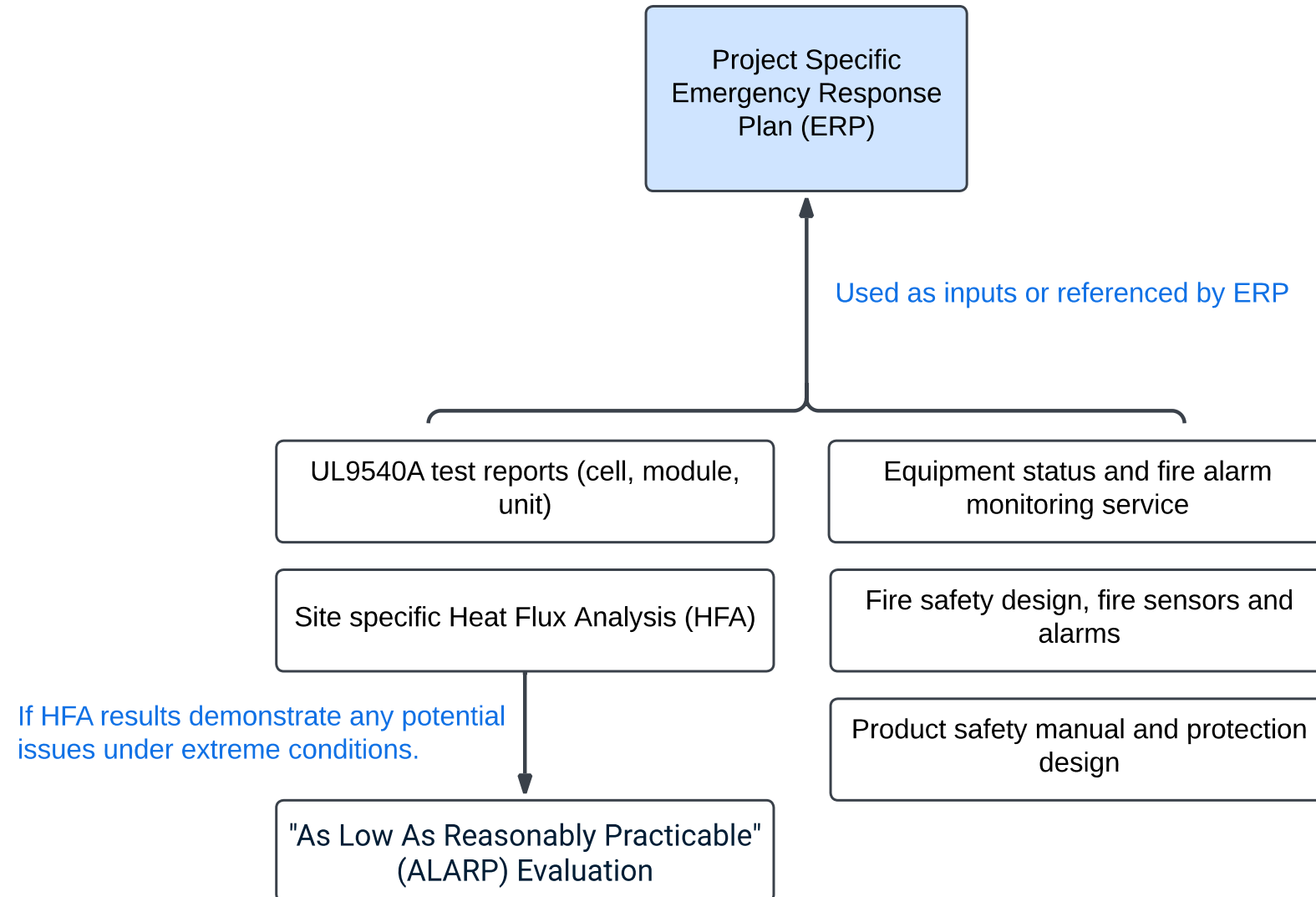
Project Specific Fire Safety Design

Related to BESS safety

- Product overview
- PowerBlock integration and system design
- Codes, standards and UL9540A
- Project specific fire safety design (ERP, HMA and HFA)
- Emergency response on site



ERP Inputs and Structure



Emergency Response Plan (ERP)

Prior to completion and COD of the unit, a proper emergency response plan (ERP) should be developed -
ESRG Typically kicks off ERP Development at 30%.

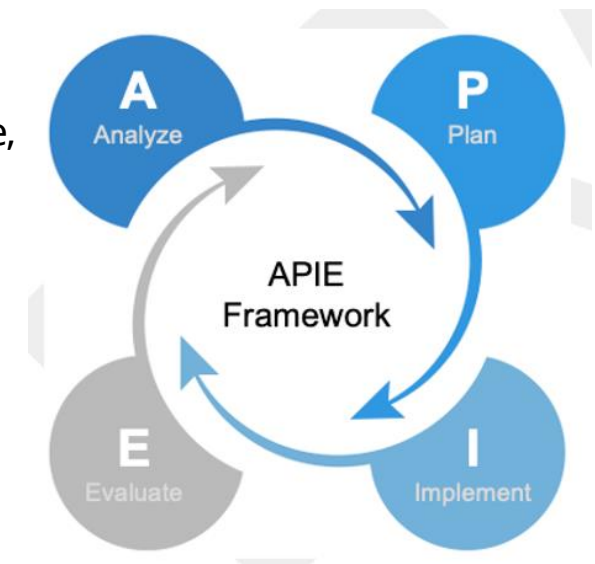
- Requires site plans and layouts
- FD access points and staging areas
- Sensitive occupancies or exposures in the area

This differs from the overall site safety plans typical corporate safety policies mandate

An ERP for the fire service is not the EAP (Action) or EOP (Operations) plans that will be used internally

- An ERP should clearly focus on issues related to a fire or failure in the battery and should clearly state, for all stakeholders, but particularly the fire department
- All safety considerations to keep the fire department safe
- Clear and concise guidance on how to manage events like, electrical failure, fire, explosion
- Guidance on PPE, shutoffs (if relevant), additional site and environmental considerations
- Contact info for all public safety and stakeholders in the area

Site-Specific ERPs are delivered in “Draft” form – Finalized during ESRG Site Familiarization with the local First Responders to include site-specific pictures and layouts



Emergency Response Plan (ERP)

8.2 Fire Incident

Upon activation of smoke and/or heat detectors in an affected SolBank enclosure – indicating a possible fire incident – a signal will be sent to the Fire Command Center and audible and/or visual notification devices on the exterior of the enclosure will alarm. Smoke and flames may be visible from the outside of the ESS enclosure. Fire growth may be slow, fast, or ultra-fast (e.g., during a deflagration event) in nature.

A safe stand-off distance shall be maintained between individuals and the ESS enclosure(s) exhibiting fire conditions. Staging of personnel and equipment shall be located at angles relative to the ESS enclosure(s) to stay out of the potential blast radius of any enclosure doors or other possible projectiles. Attempt to extinguish the fire only if imminent threat to life safety exists.

If there is no immediate threat to life safety:

1. Allow the ESS to burn in a controlled fashion until all fuel sources inside are depleted.

2. A defensive approach should be considered, utilizing water to cool and protect adjacent exposures and to mitigate the spread of fire to areas outside of the fenced installation.
3. Manage the fire incident by utilizing the reach of the hose stream to protect exposures and control the off-gassing and smoke from the enclosure.
4. Remember that, even after the ESS is isolated from the electric grid, there may still be considerable stored energy in the batteries that poses a potential electric shock hazard to anyone in the nearby vicinity.

Hazard Mitigation Analysis (HMA)

The Hazard Mitigation Analysis creates a more holistic view of system failure can be developed originating with component and cell failures. This full analysis is called a hazard mitigation assessment.

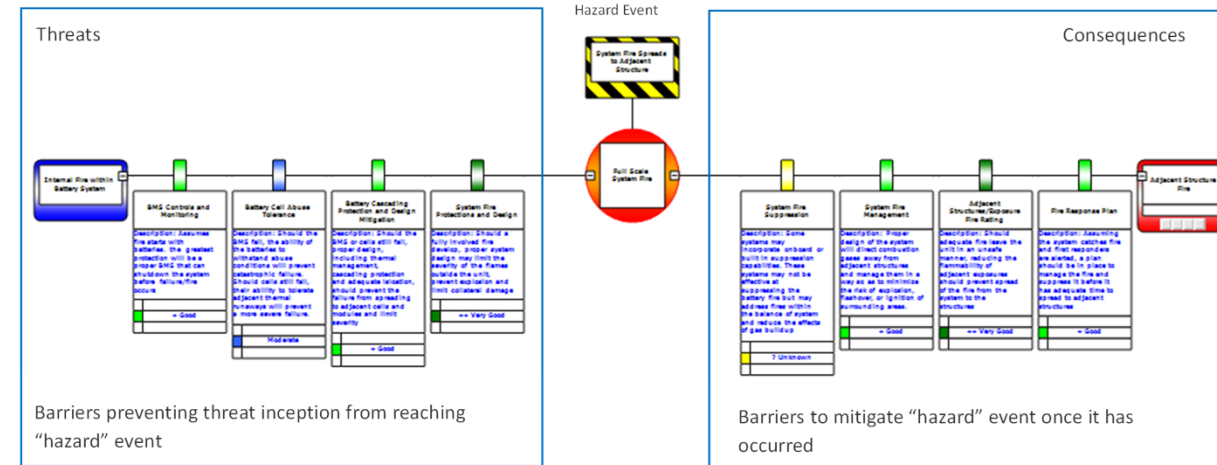
This analysis is required in NFPA855 as well as in California fire code and NY fire code. Has been increasingly required for permitting for more locations (Arizona, etc.)

In the CFC, the analysis criteria is clearly laid out, while in the NY code, a full spectrum analysis must be done and then verified by a qualified third party

ESRG uses the bowtie format for HMA's along with a comprehensive report template to explain findings

Recommend kicking off at 30% design. Information to conduct HMA includes:

- Site Layout
- UL 9540A Test Results
- Product Safety Features (Fire Protection and Electrical)
- FMEA



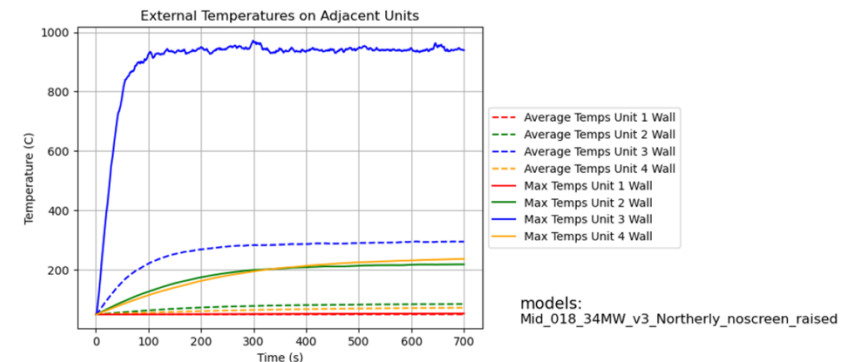
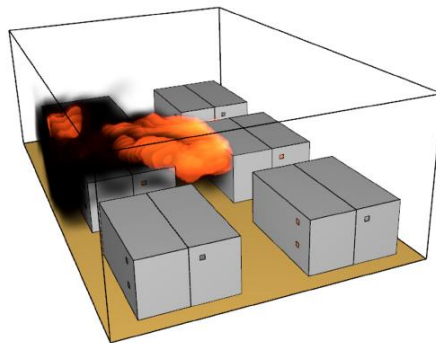
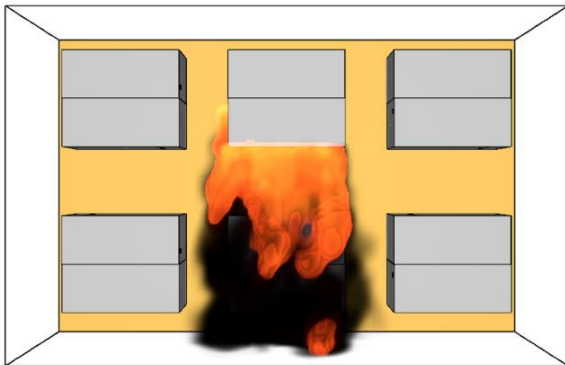
Heat Flux Analysis (HFA)

Heat Flux Analysis is not mandatory or prescribed by Codes and Standards, but has been increasingly asked for by AHJs – Often required when there is no availability of “bespoke” fire testing (more aggressive than UL 9540A)

Utilizes UL 9540A test data (mostly heat release and products of combustions). Extrapolates that module/cell level data to assume either entire rack or entire system fire consumption.

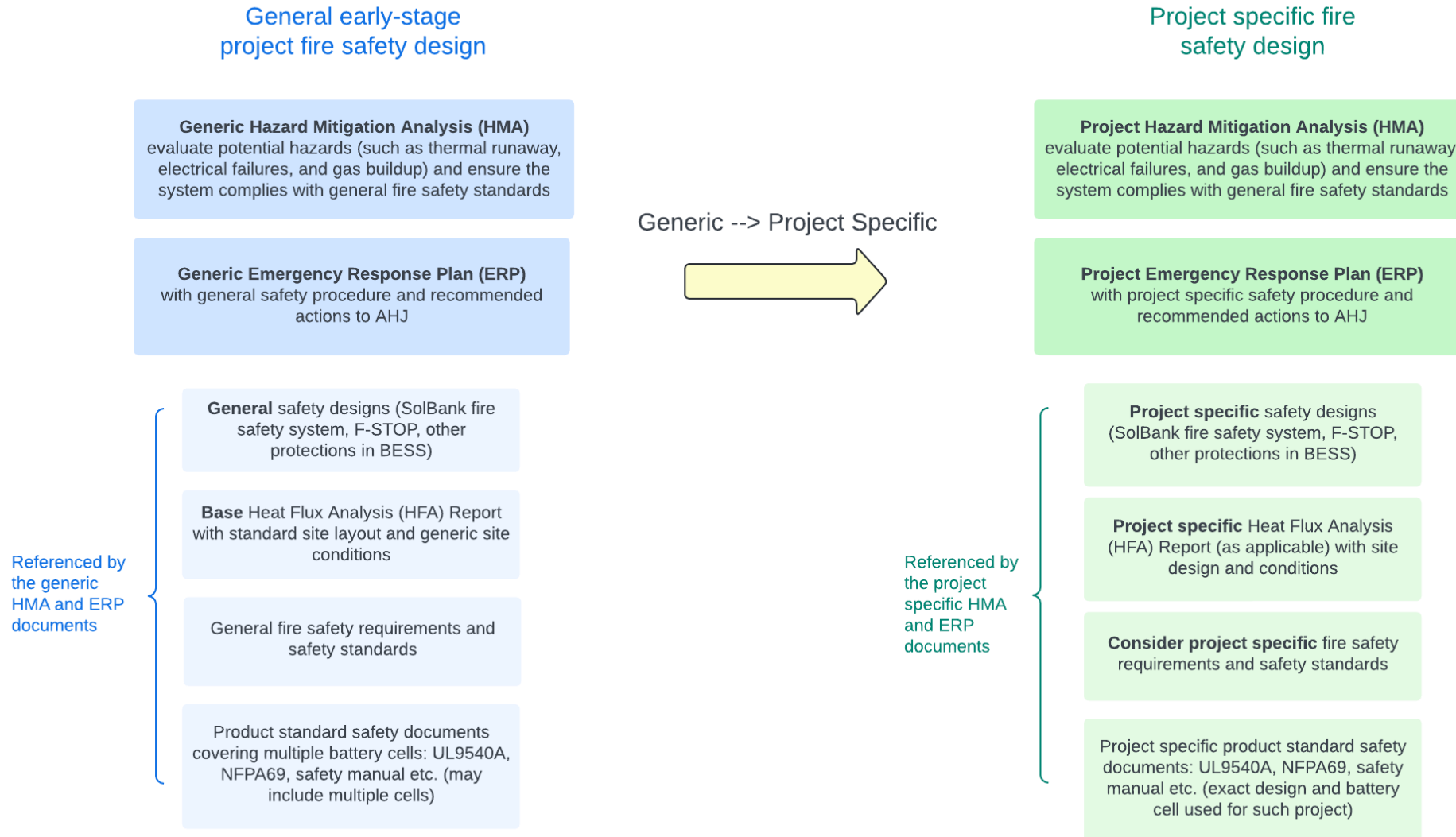
Assesses the possibility of a full-burning system propagating to adjacent systems.

- Requires UL 9540A test results, local weather conditions (wind rose) and product construction (external gaskets, internal thermal barriers, etc.)
- Recommended to start early (30% design). May require multiple re-runs of situations. Computer modeling is time and resource intensive.
- Results of Heat Flux Analysis will determine if propagation is possible. Most often, the highest risk of propagation is through burning of external combustible materials (door seals, HVAC, etc.).
- If propagation is possible – Incorporate methods in ERP to manage situation (e.g. using hand lines to cool exposures).



Generic vs. Site Specific Documents

From early-stage communication to project specific design



Fire Safety Training and Subject Matter Expert Service

e-STORAGE
A subsidiary of Canadian Solar

First responder training and site familiarization

- Product overview
- PowerBlock integration and system design
- Codes, standards and UL9540A
- Project specific fire safety design (ERP, HMA and HFA)
- **Emergency response on site**



Available service from e-STORAGE through fire safety expert:

- On-site First Responder Training and Site Familiarization Drills
 - Industry best practices based on Emergency Response Plan and Full-Scale Fire Test experience
 - Developed by former/current First Responders and Engineers
- Subject Matter Expert (SME) availability
 - Providing direction and support to Incident Commander (IC) during event

BESS Failure Response and Firefighting

Standard procedure to follow

Follow site specific Emergency Response Plan (ERP)

Attempt to extinguish the fire only if imminent threat to life safety exists.

A defensive approach should be considered utilizing water to cool and protect adjacent exposures and mitigate the spread of fire.

- Water is the best agent!
 - Foam is more conductive, has not performed well in the field
 - Other water-based agents have not shown they perform better than water
 - Alternative agents (non-water based) don't provide the cooling of water
- Suppression, however, will likely be defensive in nature, protecting adjacent enclosures while the effected system burns itself out
 - Testing has not shown electrical leakage to be an issue at the voltages ESS operates for fire fighting safety
 - Testing on water runoff is on-going but has so far not been overly negative



THANK YOU

Questions, Thoughts, Suggestions

