BATTERY ENERGY STORAGE SYSTEMS

Fire Safety Symposium

For Local Fire Departments & Officials

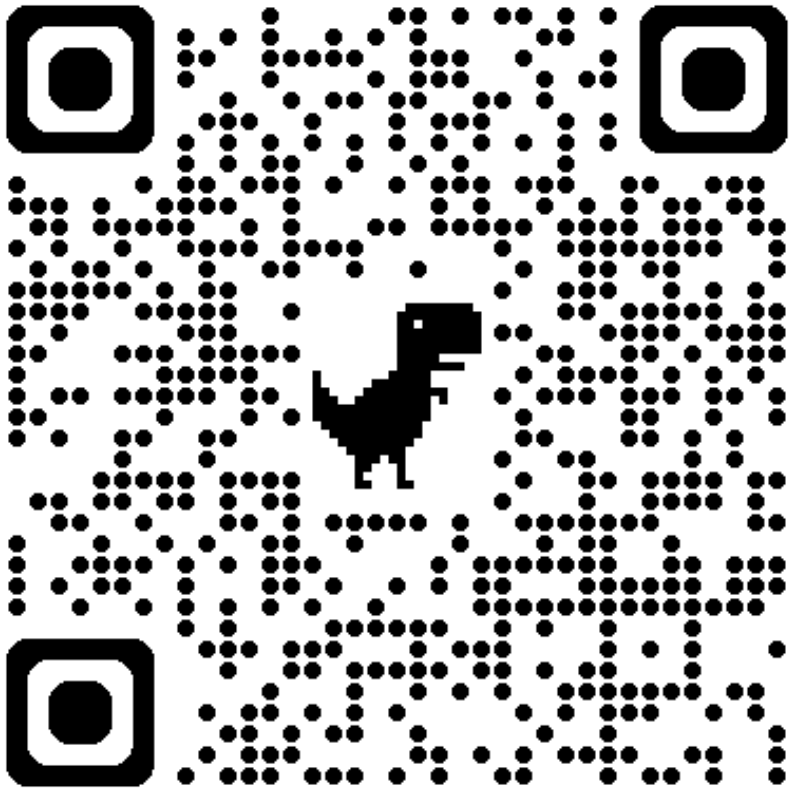
JULY 24, 2025

Keynote Speaker

Michael O’Brian

Fire Chief

Brighton Area Fire Authority



CODE
CONCEPTS
GROUP

Join our Email List

Michael O’Brian

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Discussion on Codes and Standards

Moderator – Robert Marshall, Underwriters Laboratories

- **Robert J Davidson** – Davidson Code Concepts, LLC
- **Crystal Sujeski** – CAL FIRE – Office of the State Fire Marshal
- **Christine Reed** – International Code Council (ICC)
- **Brian O'Connor** – National Fire Protection Association (NFPA)

Your Moderator

ROBERT MARSHALL- SENIOR REGULATORY ENGINEER

UL SOLUTIONS

Panelists

CRYSTAL SUJESKI- OSFM

CHRISTINE REED- INTERNATIONAL CODE COUNCIL

PAUL HAYES- HILLER

BRIAN O’CONNOR- NFPA

CAL FIRE / Office of the State Fire Marshal

Protects life and property through the development and application of fire prevention, engineering, training and education, and enforcement.

- Authority: HSC 13100-13146
- Adopting and amending Title 24, Part 9, the California Fire Code
- Coordination with local AHJs, CPUC, and CEC
- Leads training and guidance for local fire departments
- Participates in the national development code process

Baseline Requirements

- System Thresholds & Classification
- Location, Access & Spacing
- Fire Suppression & Detection, Ventilation & Hazardous Gas Management
- Safety Analysis, Hazard Mitigation Analysis, Emergency Response Plan
- Signage & Labeling
- Construction & Structural
- Monitoring, Controls & Shutdown
- Plan Review, Inspections, Pre-Fire Planning

Statewide response to incidents

- Moss Landing (2002 & 2023)
- San Diego/ Otay Mesa (2024)

- These events prompted
  - New California Public Utility Commission safety rules
  - Increased State Fire Marshal engagement
  - Focus on fire code consistency, incident reporting, and cross-agency coordination (Cal Fire, EPA, CARB, Environmental Health)

Moving forward

- Updating the Fire Code to the latest available codes and standards
  - Early adoption of the latest editions of:
    - UL9540/ 9540A
    - NFPA 855
    - International Code Council model codes
- SB 1152 (2024) and SB 38 (2023), and GO-167-C for incident oversight
- Hosting training programs
- Improving data collection of BESS fires and incidents
- Early engagement in project development
- Increased alignment with California Energy Commission certification, permitting

Contact Information

- Crystal L. Sujeski

  Chief, Code Development & Analysis

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  crystal.sujeski@fire.ca.gov

  510-846-1276

Battery & Energy Storage Systems
International Code Council

Batteries in The I-Codes

- 2006 - introduced in the IFC
- 2015 - expansion in the 2018 IFC began
- 2021 - large expansion from 2018 IFC
- 2024 - updated exceptions & NFPA 855 adjustments
- 2027 - current code cycle
  - New IFC Chapter 43 on Batteries
  - IFC Chapter 12 Section 1207
  - IRC R330

Battery & Energy Storage Systems Committee

- Explore how building safety is impacted by batteries and ESS
- Code officials, manufacturers, fire organizations, researchers
- Identify increased risks and gaps in codes and standards
- Workgroups with focus areas
- Comprehensive report

ICC's Continued Efforts

- Technical Services
- Fire and Disaster Mitigation
- Content and Product Development
- Government Relations

Christine Reed
Fire & Disaster Mitigation Program Manager
Email: creed@iccsafe.org
Phone: (714) 983-9591

Energy Storage System: Discussions of Codes and Standards – NFPA 855

Paul Hayes, FPE
VP Energy Infrastructure

Fire Safety Symposium

LEGAL DISCLAIMER

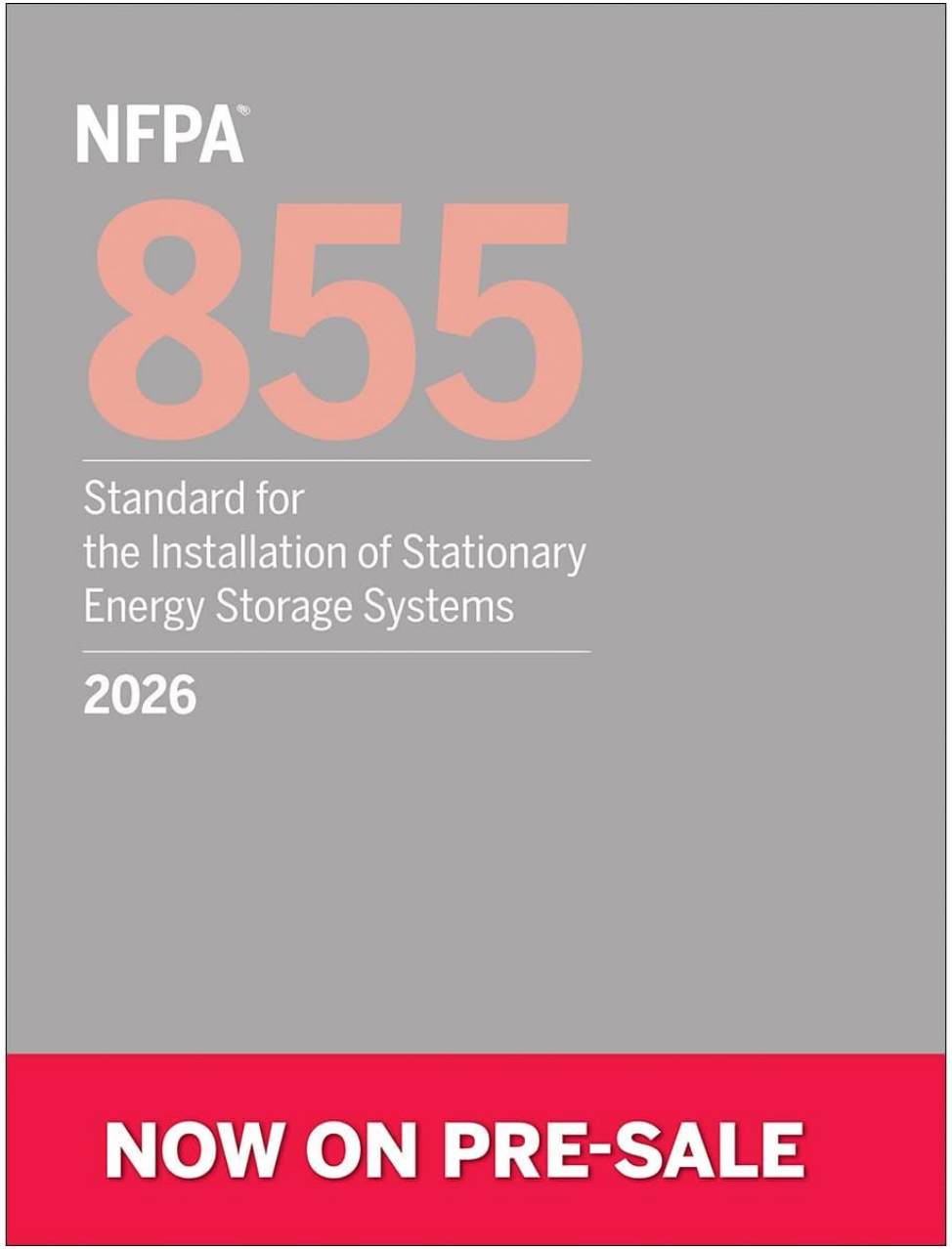
The information provided is my opinion, and I do not represent the NFPA or the 855 Committee.

Information details may be subject to NDA's or legal complications

Any reliance on this information is at your own discretion.

NFPA 855

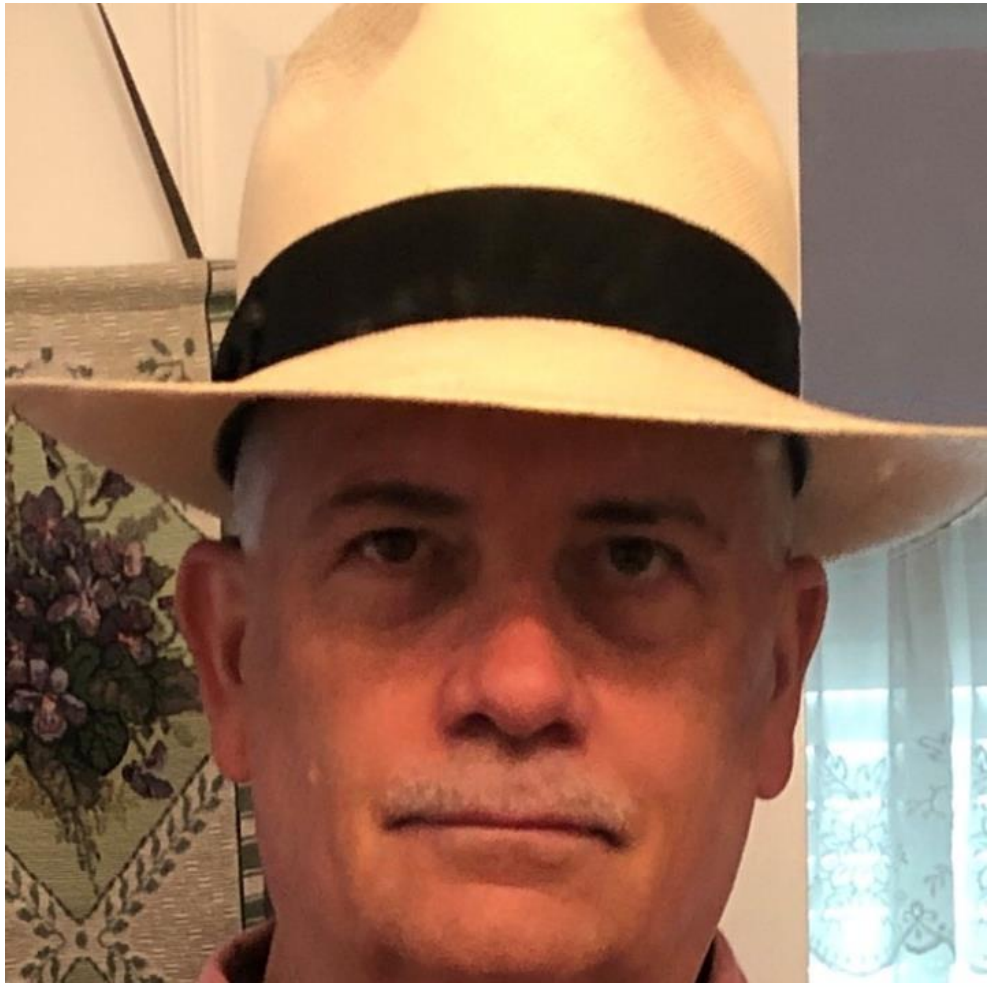
Should be published in September 2025



Bob Davidson

Code 

Extraordinaire



2023 TO 2026 CYCLE

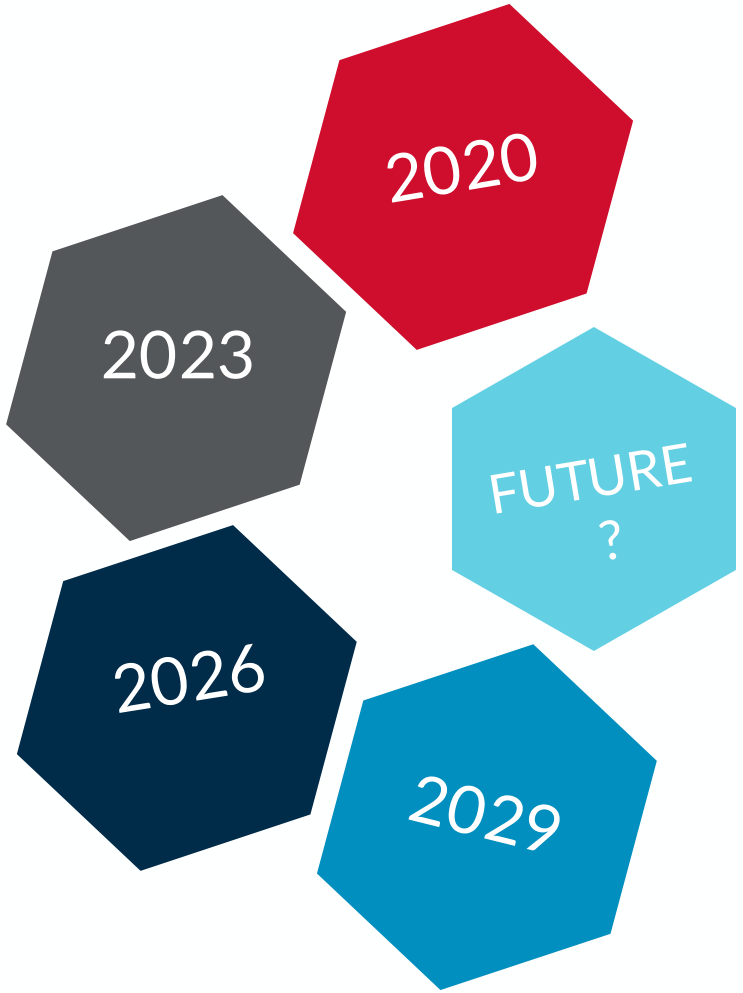
- No true major changes
  Better Clarity and definition of the requirements

- 28+ Task groups
  Involved significant input from industry experts outside of the Technical Committee.

- Focused on Explosion vs Fire

- Most of the failures we reviewed and provided input to the code.

- Represent the Best practices
  But Codes will always be behind.



THE OVERARCHING ASSUMPTIONS

- An Event can happen that overwhelms the inherent safety systems.
- Control propagation between units
- Insure listings, Reliability, and survivability
- Protect Life and Safety

ALL ROADS LEAD TO A CLIFF

Let it burn – Observe and Contain

Events are over quicker
No reflash
No Stranded energy
No runoff
Doesn’t jeopardize life and safety.

An Asset is not worth a Life!

CHANGES TO 2026

- HMA – Just Required
- Critical Safety Systems
- 9540 Listing
- Power backup
- Data/Reliability
- No Suppression in Containers only for Exposures
- LSFT
- Integrated Testing
- Explosion Control- better explosion control requirements
- Contain propagation

THANK YOU

PAUL HAYES, VP-ENERGY INFRASTRUCTURE, FPE
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www.HillerFire.com

855 AND TOXICS – TG RECOMMENDATIONS

Responses and evacuation should be left to the indecent commander

Plume Studies provide limited values – too many variables and true understanding of Fate and Transport

All fires pose a toxicity risk, including those of lithium-ion batteries, Though utility scale battery fires are rare, their novelty draws attention and raises important questions about how to keep firefighters safe.

Lithium-ion batteries contain many of the same materials common throughout the built environment, including metals, plastics, and insulation, and industry best practice is for firefighters to protect themselves when responding to them as they would during any other fire exposure.

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Discussion

AND QUESTIONS

State Agency Updates

Le-Quyen Nguyen – California Collaborative

Drew Bohan – Energy Commission

Lee Palmer – California Public Utilities Commission

State Agency Updates:
Battery Storage Collaborative

Le-Quyen Nguyen
Deputy Secretary for Energy

CALIFORNIA
NATURAL
RESOURCES
AGENCY

Battery Storage Collaborative Overview

What: Convening of state agencies to examine battery storage technologies and safety considerations.

Who: CNRA, GO-Biz, CARB, CPUC, CEC, CalFIRE OSFM, CalOES

Purpose:

- Review the battery storage landscape for opportunities to improve battery safety, technology development and best practices for outreach and education, permitting and installation of battery projects, inspection and monitoring practices, and first responder training and safety.
- Increase coordination between state agencies.

CALIFORNIA NATURAL RESOURCES AGENCY

Battery Storage Collaborative Actions

Coordinating Actions to Date

- Updated Codes and Standards for BESS
- CPUC General Order 167-C
- Data Inventory of Facilities
- Facilities Inspection Plan
- Energy Reliability Analysis
- GO-Biz Permitting Resources
- BESS Webpage

Edwards Sanborn Project in Kern County

Future Actions

- Identify and explore additional risk-reduction measures.

CALIFORNIA NATURAL RESOURCES AGENCY

Battery Energy Storage Systems Agency Initiatives

Lee Palmer

Director

Safety and Enforcement Division

California Public Utilities Commission

Overview of Recent BESS Activities at CPUC

Safety Related

- **Updated General Order 167-C**

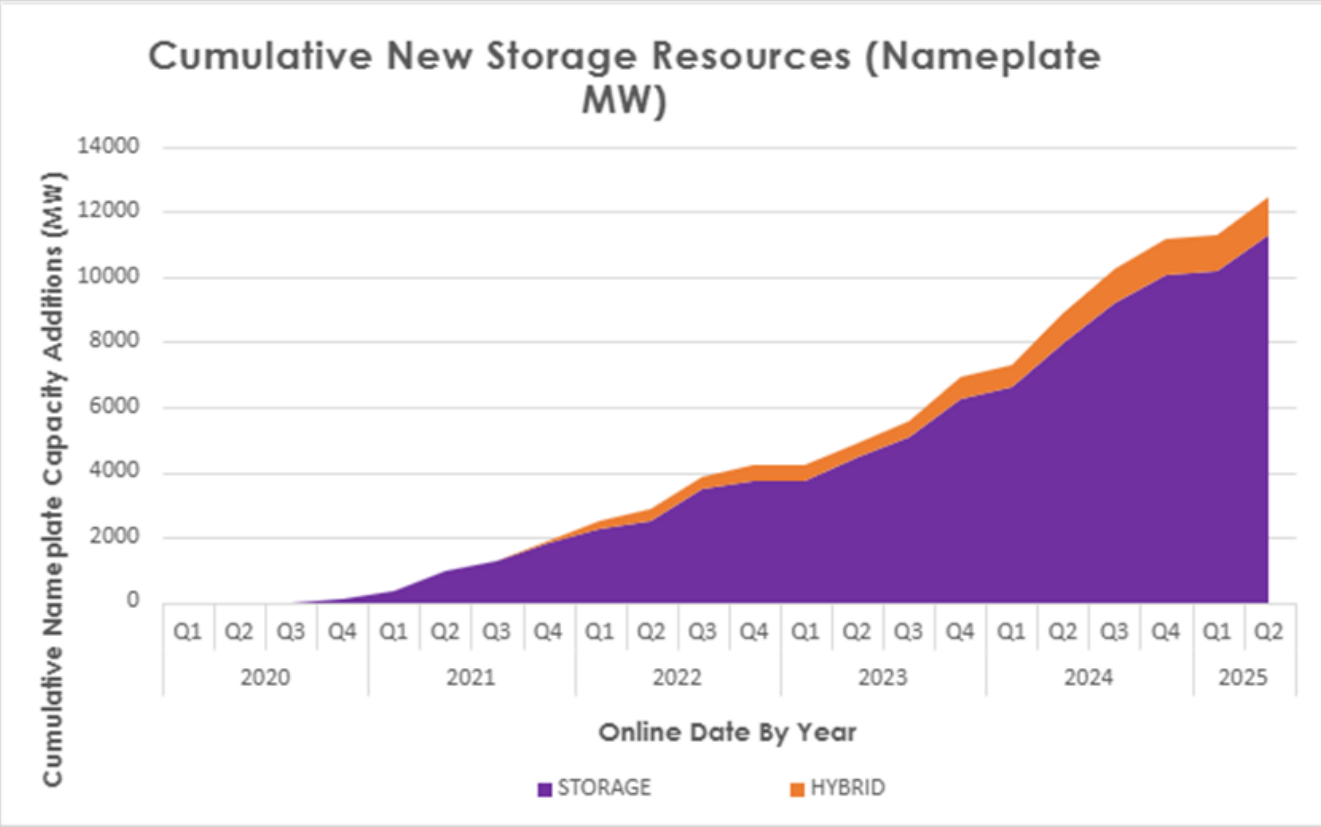
  In March 2025, CPUC revised regulations for storage safety "Enforcement of Maintenance and Operation Standards for Electric Generating Facilities and **Energy Storage Systems (ESS)"**
- **Conducted BESS Survey**
- **Initiated 10 Incident Investigations**
- **Established Risk Based Methodology for Audits**
- **Started Auditing Facilities**

Procurement Related

- **Ordered large quantities of new reliability capacity since 2019**
- **CA Installed over 26,000 MW new capacity since 2020, including over 12,500 MW new BESS**
- **Expect over 12,000 MW additional installs by 2028**
- **BESS supports State's transition to clean energy**

Total Storage Online
By Year

Data includes projects online as of May 6, 2025



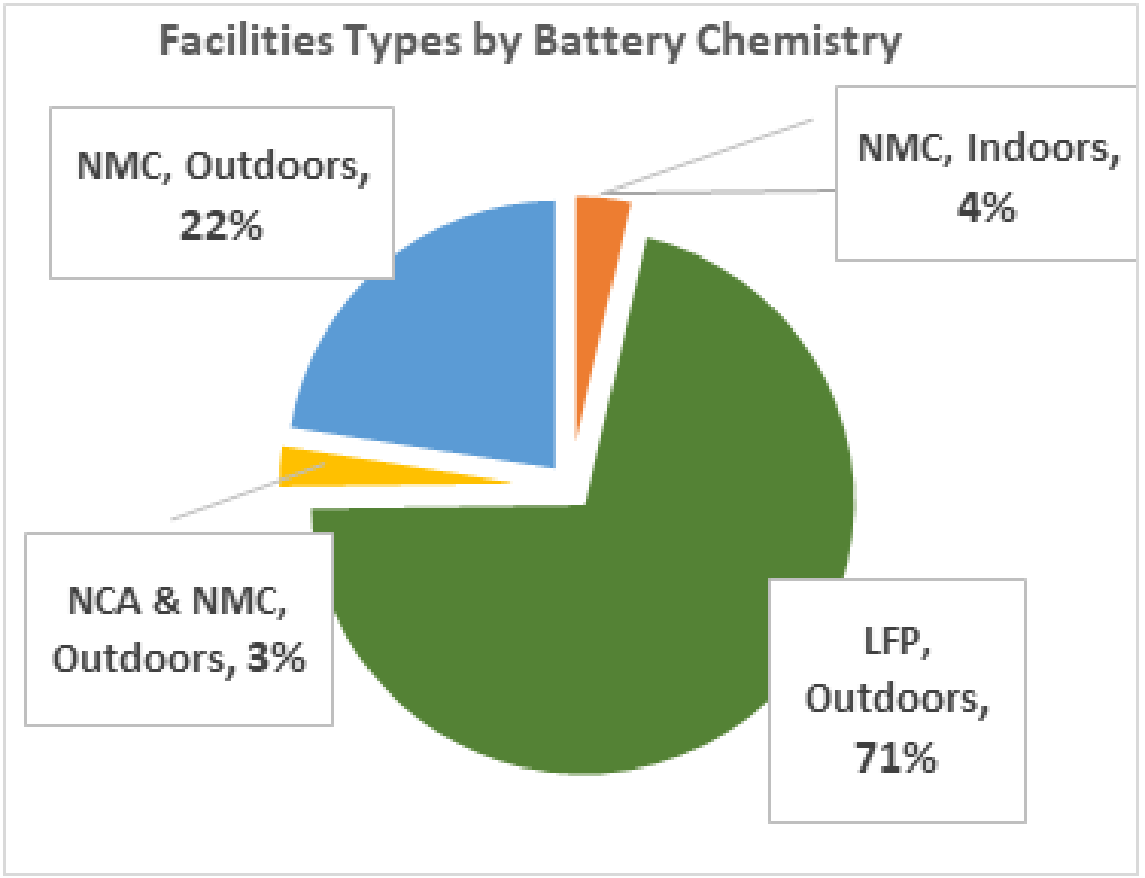
- **Installed to date:** Roughly 12,500 MW of storage nameplate capacity is online
  - Includes standalone battery storage and the storage component of hybrid resources
- **Expected future installs:** Over 12,000 MW nameplate capacity of additional storage resources are under contract and expected to come online by 2028.

www.cpuc.ca.gov/trackingenergy

Note: Data shown here shows a snapshot of new resources added to the CAISO grid Q1 2020 – Q2 2025, including specified CAISO imports. Hybrids include some storage, and some other (usually solar) technology. MW shown here only include the storage portion of hybrids.

High Level BESS Survey Results – Jan. 2025

- Most - 96% - facilities are outdoor/containerized installations
- All BESS are lithium-ion based chemistries
  - Most use lithium iron phosphate (LFP)
  - Remaining use nickel manganese cobalt (NMC) or nickel cobalt aluminum (NCA) cathodes



Interagency and Industry Collaboration

- **CPUC Lead Actions**
  - Memorandums of Understanding (MOU) with CEC and CALFIRE
  - Active collaboration with other agencies and NGOs
  - Engagement with battery Original Equipment Manufacturers (OEM) and other industry experts
- **Tracking Energy Development (TED) Task Force**
  - Joint interagency effort between the CEC, CPUC, CAISO and GO-Biz
  - Provide project development support for new energy projects to come online in the near-term
  - Identify challenges that may impact clean energy development and coordinate actions to address those barriers
- **For more information: SED website:** Battery Energy Storage Facilities in California and **www.cpuc.ca.gov/trackingenergy**

California Public Utilities Commission

Lee Palmer
leslie.palmer@cpuc.ca.gov

BESS Permitting (GO-Biz)

Moly Rohimah

Deputy Director Energy & Climate

Go-biz

CALIFORNIA
BUSINESS AND ECONOMIC DEVELOPMENT

Clean Energy Permitting Initiative

CalFIRE - OSFM BESS Fire Safety Symposium
07.24.2025

AGENDA

- Overview of the GO-Biz Clean Energy Permitting Initiative
- Key Findings (including BESS)
- Permit Accelerator Tool: Sample BESS Model Ordinance
- Q&A

GO-Biz Clean Energy Permitting Initiative

Drivers for Improved Process Efficiencies

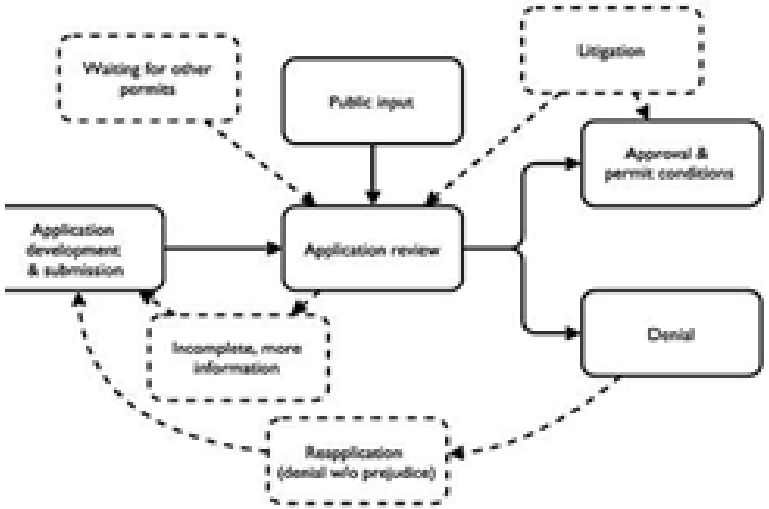
California's Energy and Climate Goals

- Decarbonize the state's electrical grid by 2045
- SB 100 estimates ~7,000 new MWs per year needed to achieve carbon-free electric grid

Expected Growth of Clean Energy Projects

- 2025 | ~6,800 MWs
- 2026-2028 | ~17,000 MWs

GO-Biz Clean Energy Permitting Playbook & Toolkit



PERMITTING ISSUES & DELAYS

- Local, state and/or federal
- Long environmental reviews
- Staff capacity/turnover
- Community opposition

OBJECTIVES & OUTCOME

- **Playbook:** compilation of information and best practices for components of the permitting process
- **Toolkit:** set of tools and resources for local permitting authorities to accelerate renewable development across California

Permitting Playbook & Toolkit | Process & Timeline

Phase	*Jan - Apr 2025*	*Apr - Aug 2025*	*Sept - Nov 2025*
	Complete	**In Progress**	**In Progress**
	Discovery & Data Collection	**Playbook Development**	**Playbook & Toolkit Publication**
Activities	• Evaluate barriers in local permitting process • Engage stakeholders to understand permit “accelerators”	• Compile & develop permit accelerator best practices • Stakeholder feedback on playbook, tools, templates, guidance & reference material	• Launch Playbook & Toolkit

Stakeholder Outreach

Surveys, Interviews, Webinars, Focus Groups & Other Outreach

In Progress

SURVEYS | 170+ completed

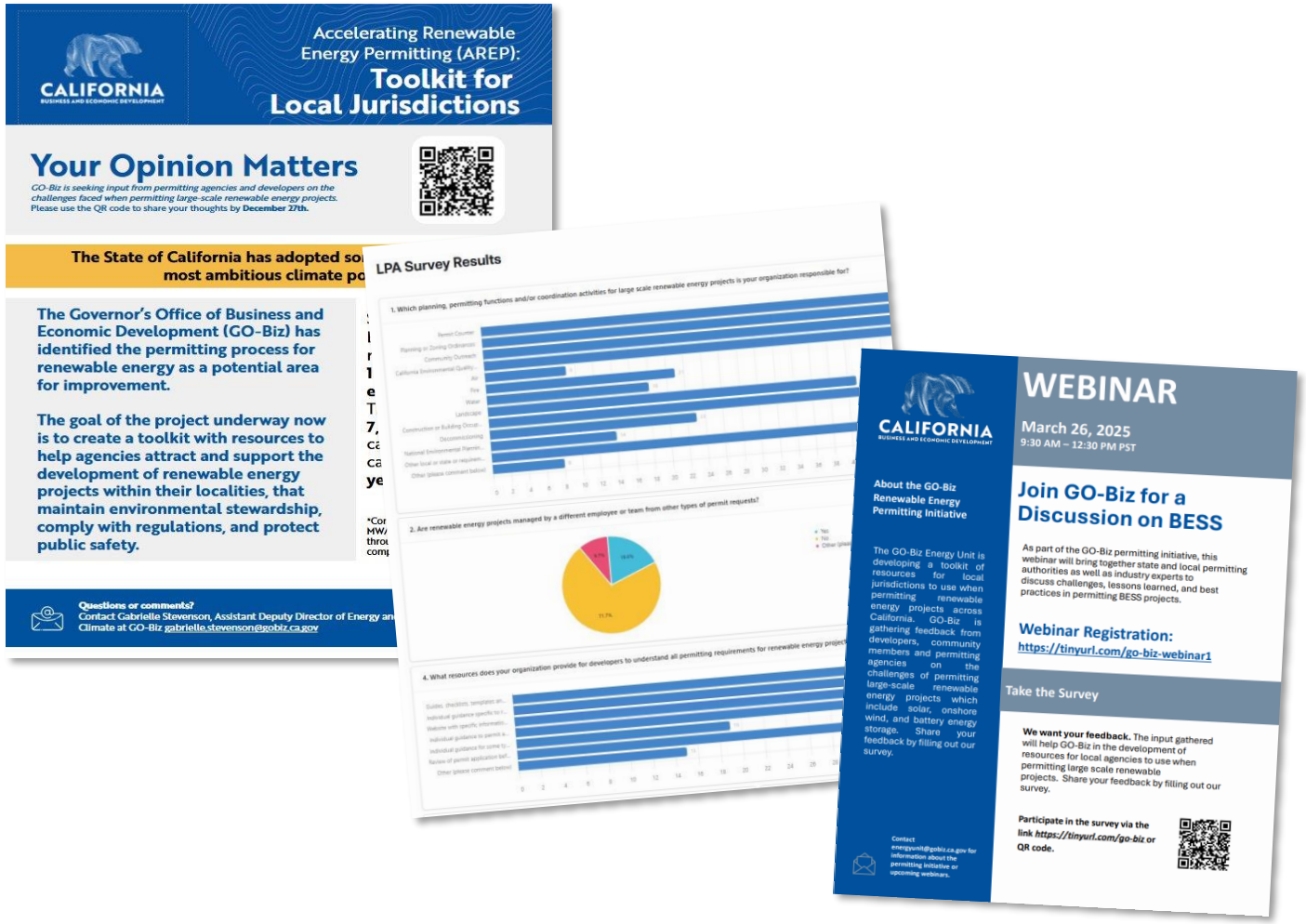
- Local Permitting Authorities
- Developers
- Community-Based Organizations
- Native American Tribes

INTERVIEWS, FOCUS GROUPS & CONSULTATIONS | 50+ completed

- Local Permitting Authorities
- Developers
- Trade Associations
- Native American Tribes
- Community-Based Organizations
- Fire Safety SMEs & Officials

WEBINARS & CONFERENCES

- REACH Inland Empire Conference (Dec 2024)
- GO-Biz BESS Webinar (Mar 2025)
- GO-Biz Playbook & Toolkit Webinar (Jun 2025)



Key Findings (including BESS)

Findings: Pain Points for Permitting Authorities

45% of local planners feel equipped to handle an influx of permit applications

Local Permitting Authorities

Workload & Experience

Planners:

- Have responsibilities across all types of projects (not just clean energy) permitting
  - Handle inquiries
  - Planning & zoning
  - Review applications
  - Procure 3rd party experts
  - Regulate construction
  - Coordinate across-agencies
  - Monitor building occupancy
  - Hold public hearings
  - Recommend projects to the Board

Technical Assistance

- Perform time intensive permit reviews - including multiple iterations for incomplete permits
- Experience varies on the power system and technical clean energy knowledge (e.g. BESS)
- Seek assistance to develop ordinances, codes, & standards (e.g. BESS fire safety)
  - Some counties have enacted temporary moratoria until ordinances addressing BESS safety can be developed

Stakeholder Navigation & Coordination

Largest impacts to project development & timelines:

- Assessing the project's wildlife, habitat, environmental impacts and mitigation determined by the state
- Community concerns including negative media coverage (e.g. BESS fires)
- Navigating and coordinating with other local (e.g. fire department) and state entities (e.g. CDFW)

Findings: Pain Points for Developers

87% of respondents indicated that “unnecessary delays could have been avoided”

Developers

Developers:

Risk-Minimized Projects

- Transmission access is a key factor in site selection
- Likelihood of permitting approval and clarity of permitting process and timeline are also key factors
  - 79% of developers avoid localities with unclear permitting processes
- File applications in multiple localities to maximize success given CAISO interconnection process and sites are often selected in advance of LPA notification

Environmental Review, Policy & Agency Navigation

- CEQA
- CDFW
- Williamson Act
- Local renewable project fees
- Expiry of state solar property tax exemption (2027)
- Community benefit agreements (offered by 61% of developers)

Largest barriers to project development & timelines:

Local Permitting Barriers

- Local permitting staff shortages & process delays
- Restrictive zoning ordinances and moratoria
- Inconsistent, changing, and/or unclear permitting guidelines
- Community opposition to local development
- AB205 CEC opt-in permitting process is additional mechanism to address local permitting barriers

Findings: Planners & Developers have similar needs on BESS

Survey and interviews with local permitting authorities, developers and other organizations

Local Permitting Authorities

Developers

Other Organizations

A top barrier to permitting BESS is community concern about **health and safety, including fire risk.**[1, 2]

Consistent and defined standards on BESS siting, such as a **BESS-specific zoning ordinance,** would be helpful for permitting BESS.

BESS projects were reported to be the **most time-consuming** clean energy projects to permit, over utility-scale solar and onshore wind.[3]

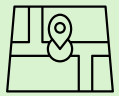
Communication of BESS safety information to the general public, such as fact sheets, could support BESS permitting & media (mis)information

[1] *Q15. Using a scale of 1 (no barriers) to 5 (significant barriers), which of the following are barriers to accelerating renewable energy project permitting*
[2] *Q15. Using a scale of 1 (no barriers) to 5 (significant barriers), which of the following are barriers to accelerating renewable energy project permitting?*
[3] *Q9. Which types of renewable energy projects are most time consuming to permit and why?*

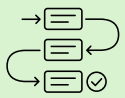
The Local Permitting Process and Best Practice Recommendations

Priority

1 Pre-Permit Application



Siting



Pre-Application Coordination

2 Permit Application

Local Permitting Authority Review & Decision

Environmental Review

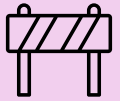
Community Engagement & Benefits

Other Permitting Process Support

3 Permit Issue & Approval

Building Permits & Construction

Final Inspection & Commission



De-Commissioning

Fire / Building Department Involvement

Early coordination on siting

Use of model ordinances

Site-specific list of sensitive & protected species

Land use compatibility strategies

Pre-application submittal meeting

Application resources & checklist

Alignment on application completion requirements for by-right permits

Clean energy guidebook

Education / Training

Online application system with e-signature

Automatic completeness check of submittal

Coordination of CEQA documentation for discretionary permits

Compliance with state and federal protected species regulations

Community benefits guidance

Clear communication of project's economic & environmental benefits

State and local contact lists for planners & developers

Fact sheets for general public & media

Best practices forum for planners

Interagency facilitation & "ombudsman"

Planning Department Focus

Alignment with siting application requirements

Technical/Departmental coordination (Fire, Building, Electrical, ...)

Development of approved site plans aligned to codes and standards

Coordination with interconnecting utility and system operator on commissioning requirements

Fire / Building Department Focus

Local Planners and Fire Officials

Complementary & linked roles

	Pre-Application Coordination	Zoning & Land Use Review	Environmental Review (CEQA)	Application Intake & Completeness	Building & Site Plan review	Emergency Response Planning	Permit Approval
Planner	Early meetings with applicants for zoning compliance & permit application requirements	Reviews for zoning compliance & land use compatibility	Leads CEQA process, including mitigation measures	Verifies completeness of applications (site plan, mitigation requirements met, etc.)	Coordinates plan checks (safety, environmental safety, community compatibility..)	Coordinates with public safety officials for local requirements	Issues conditional and/or “by right permits
Fire Official	Confirm fire safety considerations are integrated early	Zoning/ordinances should support fire/emergency safety needs, including access and fire safety buffers	Includes fire risk mitigation	Includes safety & fire-specific documents	Fire code review (battery enclosures, suppression systems, ventilation, spacing…)	Emergency response plans and site-specific technical risk analyses	Conducts safety inspections before operation; enforces local fire code, including applicable standards

Permitting Activities Timeline

Planners and fire officials can align land use and construction permitting processes through early coordination

Permitting Accelerator Tool: BESS Model Ordinance

Localities are developing BESS ordinances to align land use and fire safety regulations in one streamlined permitting framework

- Benefits localities with high developer interest
- Reduce potentially conflicting fire & planning code
- **Requires coordination to properly integrate all perspectives (planning, fire, legal, engineering, community..)**
- One framework to align fire safety conditions in planning / land use code with fire code requirements

A. Introduction
B. Definitions
C. Applicability
D. Application Requirements
   - Review Timeline
   - Permit Fees
E. Design Standards
   - Location
   - Setbacks
   - Security
     - Physical Security
     - Cyber Security
   - Signage
   - Vegetation Management

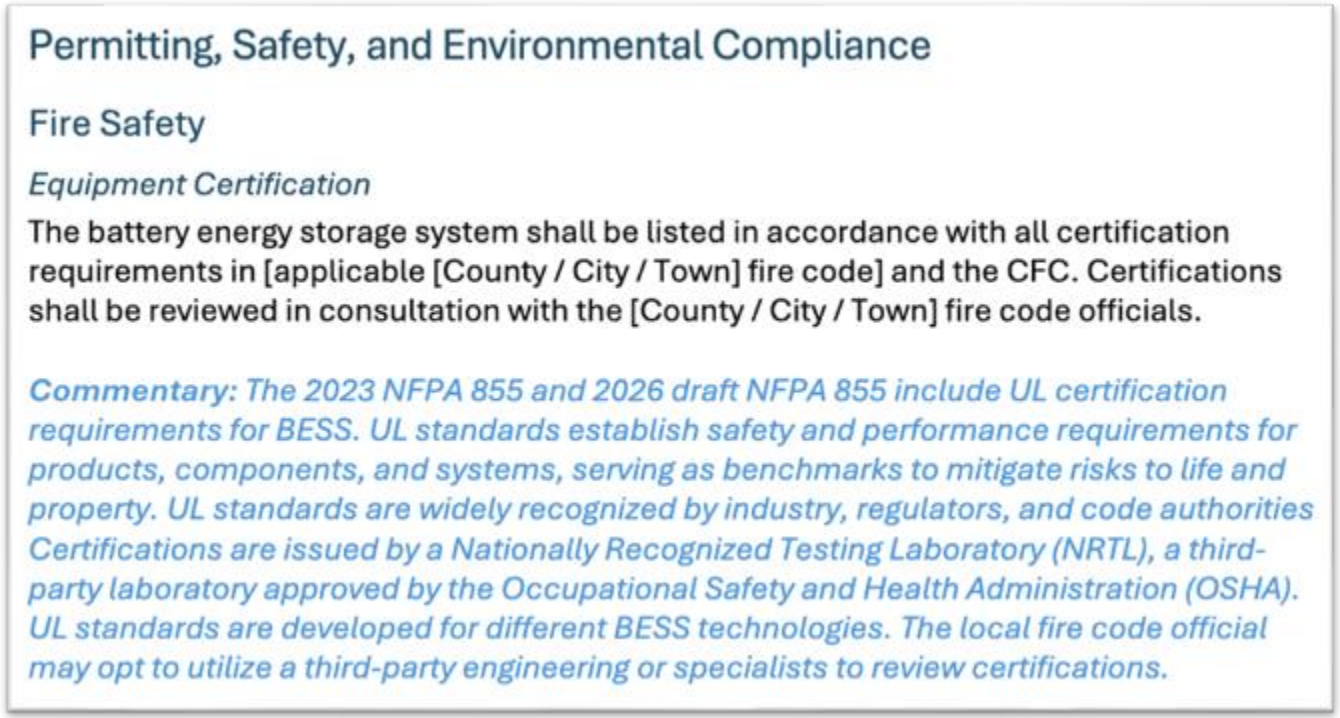
- DRAFT -

F. Permitting, Safety, & Environmental Compliance
   - Fire Safety
   - Environmental Compliance
   - Commissioning Plan
   - Operations & Maintenance
G. Decommissioning
H. Additional Considerations
   - Lighting
   - Sound
   - Visual
I. Resources

Sample Ordinance Language: Fire Safety Equipment Certification

Example with “low risk of conflict” between planning, fire code and developers…

- **Sample ordinance language** →
- *Sample Commentary text* →



Permitting, Safety, and Environmental Compliance

Fire Safety

Equipment Certification

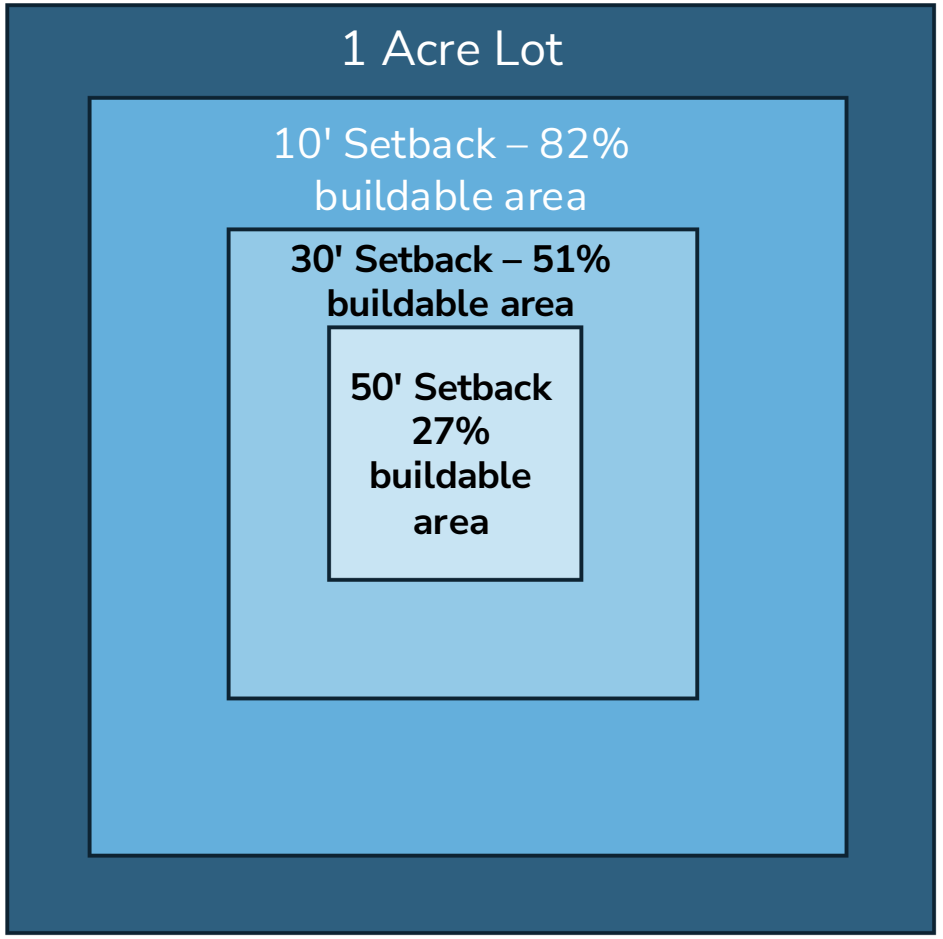
The battery energy storage system shall be listed in accordance with all certification requirements in [applicable [County / City / Town] fire code] and the CFC. Certifications shall be reviewed in consultation with the [County / City / Town] fire code officials.

Commentary: *The 2023 NFPA 855 and 2026 draft NFPA 855 include UL certification requirements for BESS. UL standards establish safety and performance requirements for products, components, and systems, serving as benchmarks to mitigate risks to life and property. UL standards are widely recognized by industry, regulators, and code authorities Certifications are issued by a Nationally Recognized Testing Laboratory (NRTL), a third-party laboratory approved by the Occupational Safety and Health Administration (OSHA). UL standards are developed for different BESS technologies. The local fire code official may opt to utilize a third-party engineering or specialists to review certifications.*

Sample Ordinance Language: Setbacks for Land Use

Example with “higher risk of conflict” between planning, fire code and developers

Setback Requirement (ft)	1 Acre Lot	5 Acre Lot	20 Acre Lot
	Buildable Area (% of Lot)		
10'	82%	92%	96%
30'	51%	76%	88%
50'	27%	62%	80%
100'	0.2%	33%	62%
300'	0%	8%	13%



Setbacks
Options benchmarked in BESS ordinances

	10'	30'	50-100'	101 – 300'	Hazard Mitigation Analysis (HMA)
Setback description	Minimum (CA Fire Code, NFPA 855)	Common "default" setback	Common in recent CA BESS ordinances	Can create "de facto" moratorium for developers	Setback determined by engineering analysis
Examples	• Rancho Cucamonga	• BESS projects often build in 20-30 ft of buffer where applicable for internal access	• University of Michigan Model Ordinance (50-100 ft) • San Diego (100 ft) • San Marcos (100 ft)		• Orange County • San Marcos
Ordinance Considerations	• Typically appropriate for smaller systems in residential or commercial areas • Demonstrates no fire spread • Demonstrates emergency access	• Flexibility for larger systems in commercial or industrial areas, although may be too rigid for urban sites • Close to public road rights-of-way for emergency vehicle access • Minimum clearance for most fire apparatus access roads	• Project distance from nonparticipating residences, public infrastructure, and rights-of-way • May limit development in commercial and industrial areas • Distance from hydrant can become additional risk factor	• Addresses community's low tolerance for safety risks • Restricts development to very large sites in less developed areas, potentially limiting access to grid connection points.	• Custom setbacks may be difficult to implement due to timeline for procuring equipment relative to permit approval process

Permitting Acceleration Recommendations – BESS & Fire Safety

What are your thoughts & best practices?

Early & collaborative engagement between parties (developer, planner, fire & building officials)

Aligned zoning and local fire code criteria

Public information on BESS & Fire Safety

Same testing to address land use & fire permit testing & evaluation

Engage in discussion of local community needs

- Specialized training & equipment
- Impact on local emergency responders

Next Steps & Q&A

Share your best practices!

Stay Connected

Sign up for the GO-Biz Climate & Clean Energy newsletter for updates, webinars and other announcements

https://business.ca.gov/climate-clean-energy-sign-up/

Feedback on the Clean Energy Permitting Initiative & Findings

Send your comments to energyunit@gobiz.ca.gov

Discussion on Emergency Response

Moderator – Michael O'Brien, Brighton Area Fire Authority

- **Paul Hayes** – The Hiller Companies
- **Rex Pritchard** – California Professional Firefighters (CPF)
- **Dustin Hail** – Fresno County Fire
- **Sean Decrane** – IAFF/UL FSRI

Improving Emergency Response

UNIQUE CHALLENGES AND LESSONS LEARNED

FROM BATTERY ENERGY STORAGE SYSTEM INCIDENTS

Robert Rezende

BATTALION CHIEF - SAN DIEGO FIRE-RESCUE

CAMINO INCIDENT - GATEWAY FACILITY
DEDICATED USE BUILDING - BESS
SAN DIEGO COUNTY, CA
MAY 2024

LESSONS LEARNED (1/4)

Preplanning and familiarity of the facility by the first-in resources were key. Early involvement of operator improved communication and planning.

Large LiBESS fires should be treated as a hazardous materials incident.

Hazmat brought in specialists that assisted in the planning process and monitoring equipment to determine hazards.

Proximity to population impacts number of resource needed.

LESSONS LEARNED (2/4)

Dedicated use BESS designs are extremely challenging to firefighters.

Limits or eliminates any offensive options.

Building collapse/failure should be considered a high possibility.

BESS projects approved prior to 2020 have significantly less safety and redundant systems.

The building did not have redundant power systems for HVAC and built-in atmospheric monitoring.

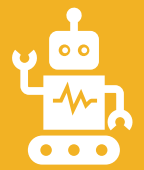
LESSONS LEARNED (3/4)

Water prolonged the incident. Batteries could not completely burn and caused additional batteries to arc and start fires.

Expect reignition and propagation

Plan for multiple operational periods.

Units maintained a flow of 5000+ gpm for 20 hours during prolonged thermal runaway event. Firefighters should work with local water departments and be familiar with techniques to maximized water systems.



Access to robots and UAS with thermal imaging, provided critical information and enhanced firefighter safety.

LESSONS LEARNED (4/4)

Environmental protection should be considered early in the incident. Water and air monitoring should be maintained throughout the incident.

Early notification to EPA was critical for preparing and planning for recovery phase.

Recovery: Unified Command continues, and battery mitigation and removal are ongoing (Over 12 months and counting)

On site hazardous materials processing - only allowed due to EPA involvement.

Off site transportation potential to impact jurisdictions along the route.

I-15 INCIDENT
TRANSPORTATION BESS INCIDENT
SAN BERNARDINO COUNTY
JULY 2024

LESSONS LEARNED (1/2)

UN 3536 does not differentiate between Lithium-Ion and Lithium Metal batteries.

- May influence fire extinguishment techniques if necessary.

Operations in a hazardous materials environment require specialized training, PPE, and certification:

- Firefighters – FRO, defensive capabilities
- Industry – HAZWOPER
- Hazmat – Tech/Spec, offensive capabilities

Container weighed 79,370 lbs.

- Movement of container was extremely difficult and required heavy equipment and certified operators.

LESSONS LEARNED (2/2)

Moving active/off-gassing container:

Agencies with jurisdiction in the area: BLM, DOD, Cal Trans.

Early involvement of EPA enhanced federal agency coordination.

Environmental Considerations: Desert Tortoise Habitat

Significant life hazard with high temperatures and stranded vehicles.

Major impact to commerce.

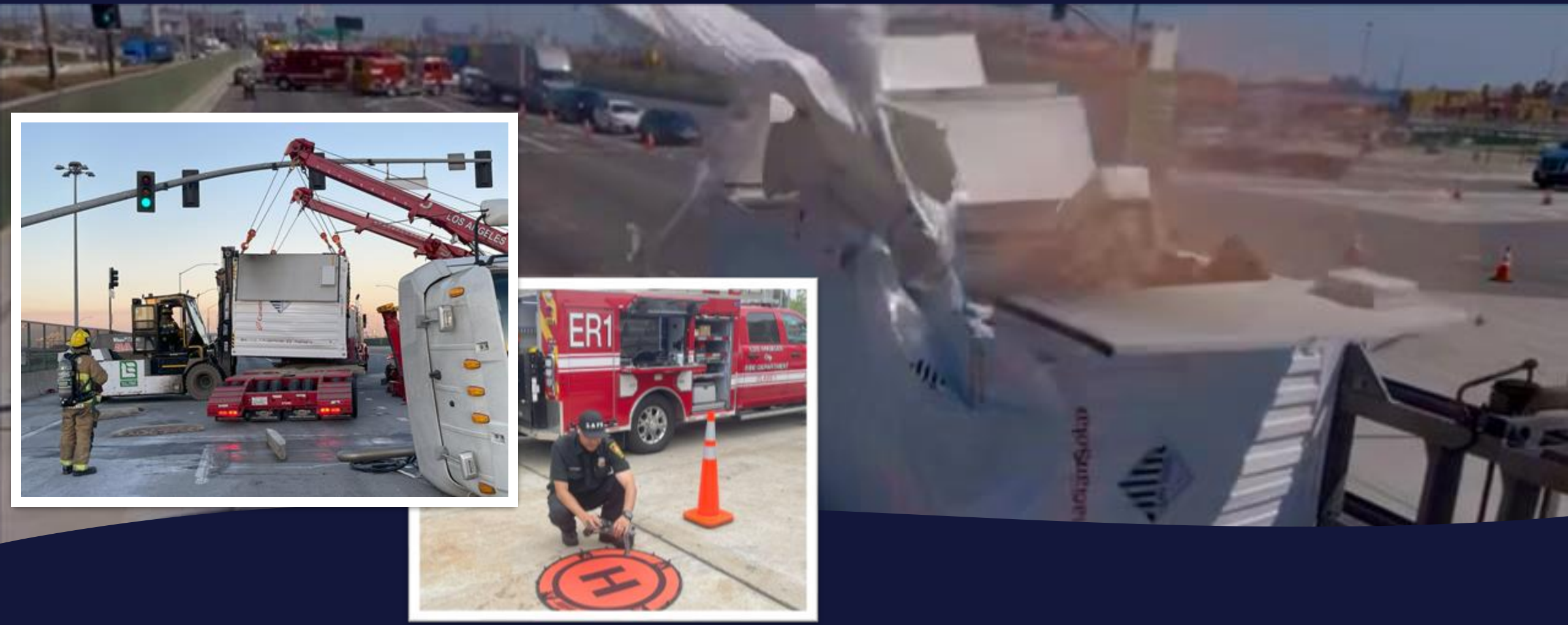
Recovery: Container was not removed until October 1, 2024

ENTERPRISE INCIDENT
Lithium-Ion Battery Energy Storage System (LiBESS)
ESCONDIDO, CA
SEPTEMBER 2024

LESSONS LEARNED

- Low state of charge does not equal no fire potential.
- Unified Command with site operators is critical.
- Early public safety messaging and elected official involvement assists in reducing concerns.
- Recovery: Container is wrapped up, on site, awaiting removal plans.

SEASIDE INCIDENT - PORT OF LOS ANGELES
BESS TRACTOR TRAILER ROLLOVER
LOS ANGELES, CA
SEPTEMBER 2024



LESSONS LEARNED (1/2)

Drone usage increased firefighter safety.

We CAN operate in an offensive manner.

Provided a proper risk assessment has been completed by trained personnel.

Provided proper PPE, monitoring, and specialized equipment are present.

LESSONS LEARNED (2/2)

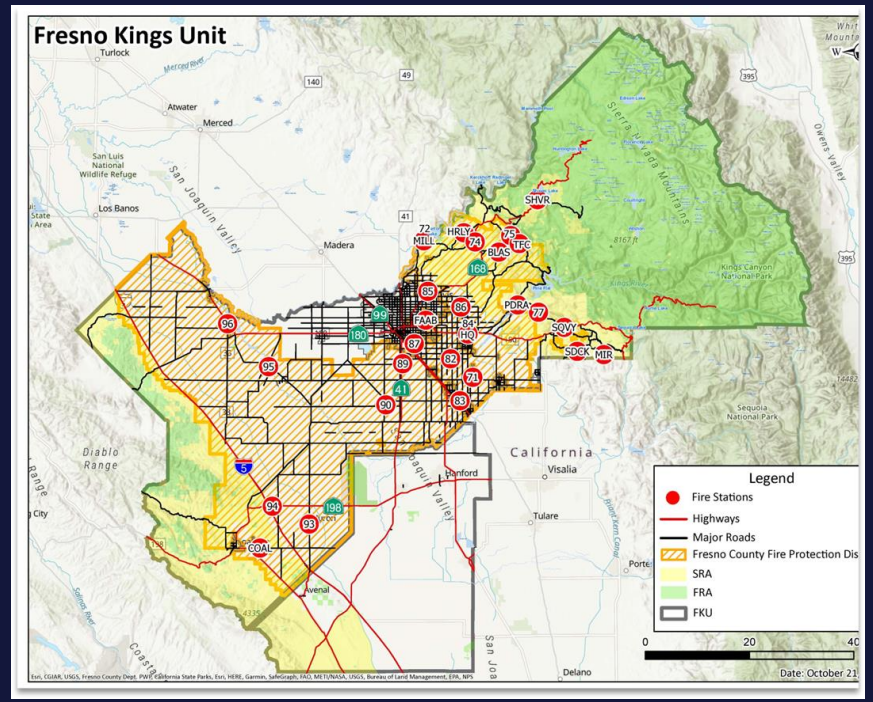
Firefighter Hazmat Technicians/Specialists are well suited to operate and coordinate operations in these environments.

Utilizing fire department resources expedited the removal and stabilization of the incident.

Impact to commerce must be considered as part of incident priorities (Life, Property, Environment, Impact to Commerce).

Recovery: Battery was considered no longer energized on October 10, 2024.

Fresno County Fire Protection District (FCFPD) Overview



- FCFPD provides protection to 4,213 square miles within the County of Fresno. <50% of Fresno County
- Provides protection to the cities of:
  - Huron*
  - Mendota*
  - Parlier
  - San Joaquin*
  - Fowler

FCFPD Funding Sources

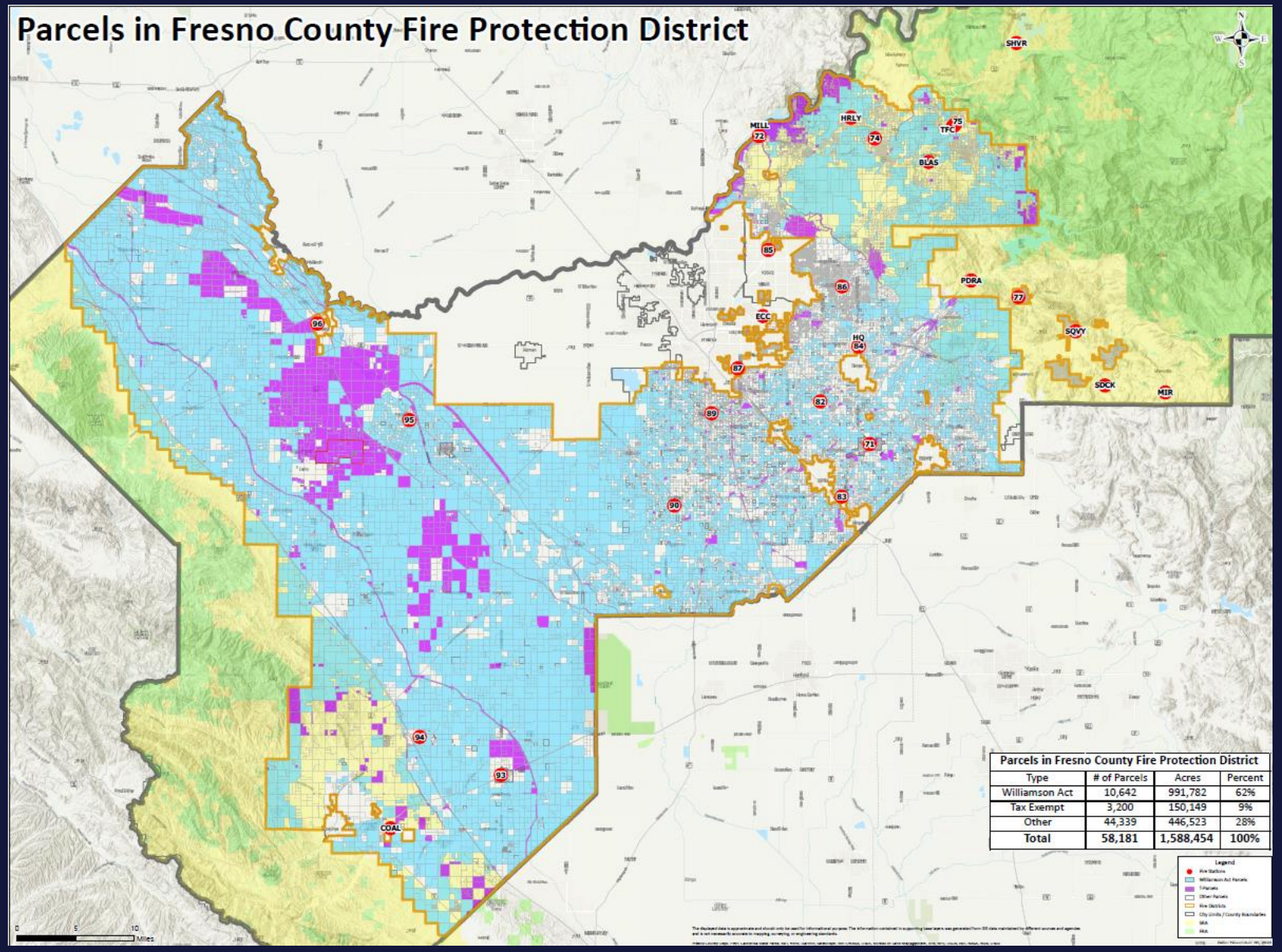
- FCFPD is a California Special District predominantly funded through ad valorem property taxes
  - Base Tax Rate Area (TRA) is .00078 (ex. $1,000,000 Assessed Value x .0078 =$780.00 of property tax FCFPD receives from that property for fire protection services)
- Fire Service Agreements
- Grants
- Community Facility Districts (CFD, Mello-Roos)

Threats to FCFPD Funding (1/2)

- Williamson Act Properties
  - Suppression of Property Taxes to provide tax relief of agricultural properties and open-space lands for long-term commitment to keep land in agricultural or related uses.
  - 62% of FCFPD jurisdiction is under Williams Act
  - 9% of FCFPD jurisdiction is 100% Tax Exempt
- BESS and Solar PV Developments in western Fresno County being tax exempt or leased property keeping them within property value of 1975-1976 without reassessment (California Proposition 13)

Threats to FCFPD Funding (2/2)

- Light Blue shading are Williamson Act Parcels
- Pink shading are Tax Exempt Parcels



2024 Fresno County General Plan Policy Document (1/3)

- PF-H.2 Adequate Fire Protection Facilities -Prior to the approval of a development project, the County shall determine the need for fire protection services. New development in unincorporated areas of the county shall not be approved until such time that fire protection facilities and services acceptable to the Public Works and Planning Director in consultation with the appropriate fire district are provided.
- PF-H.3 Fire Station Location -The County shall require that new fire stations be located to achieve and maintain a service level capability consistent with services for existing land uses.

2024 Fresno County General Plan Policy Document (2/3)

- PF-H.5 Minimize Fire Hazard Risk -The County shall require that new development be designed to maximize safety and minimize fire hazard risks to life and property.
- PF-H.6 Long Response Areas -The County shall limit development to very low densities in areas where emergency response times will be more than 20 minutes.

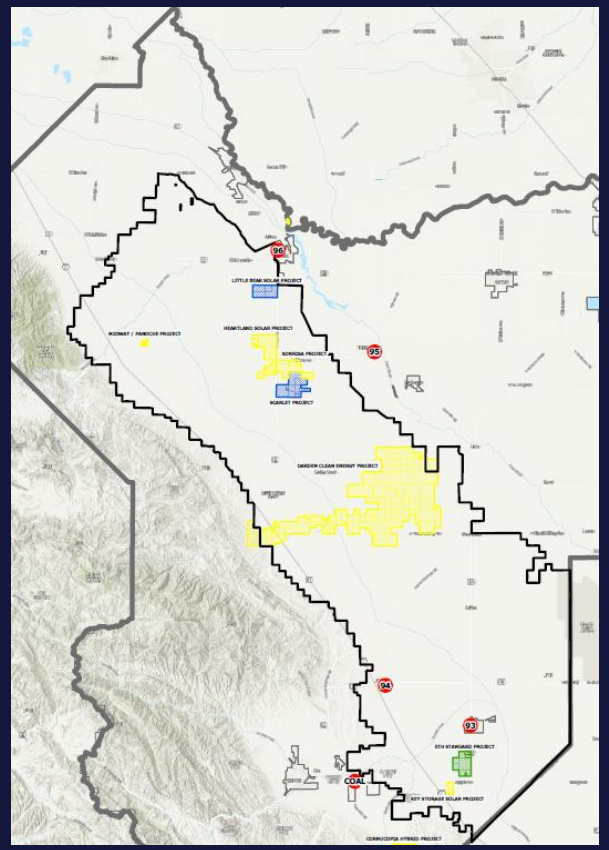
2024 Fresno County General Plan Policy Document (3/3)

- PF-H.8 Minimum Response Times -The County shall encourage local fire protection agencies in the county to maintain the following as minimum standards for average first alarm response times to emergency calls:
  - a. 5 minutes in urban areas
  - b. 15 minutes in suburban areas
  - c. 20 minutes in rural areas

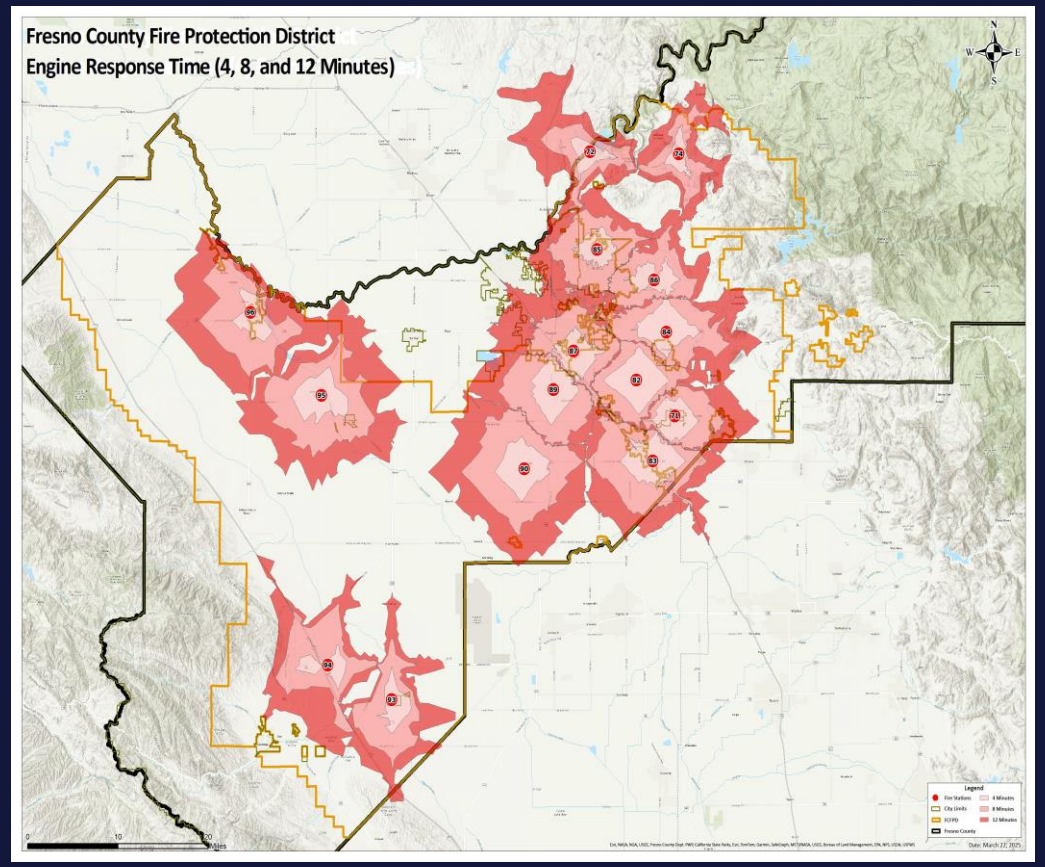
Proposed Solar Developments and Response Times of Current FCFPD Engines

130,000+ Acres of Planned Solar/BESS Development

Proposed Solar/BESS Developments



Engine Response Time Intervals



Authorizing Agencies for Solar Developments within Fresno County

Authorizing Agencies

- County of Fresno
  - Department Public Works and Planning
- California Energy Commission (CEC)
- Westlands Water District
  - Valley Clean Infrastructure Plan (VCIP)

Known Solar/BESS Project List

Project Name	BESS MW	Solar MW	Acres	Parent Energy Co.	Authority
IP Darden	4600	1100	9500	Intesect Power	California Energy Commission
San Luis West	30	125	770	CSI Electric	County of Fresno
Scarlet/Sonrisa	184	200	1730	EDP Renewables	County of Fresno
Heartland Solar	200	0	2371	????	County of Fresno
Key Storage	300	0	318	NextEra Energy	County of Fresno
Cornucopia	300	300	2446	BayWa r.e Solar Projects LLC	County of Fresno
Midway/Panoche	177	0	91.33 (Leased 24.7)	Middle River Power	County of Fresno
VCIP	20000?		130000	????	Westlands Water District

Call Type Impacts of Solar/BESS Developments

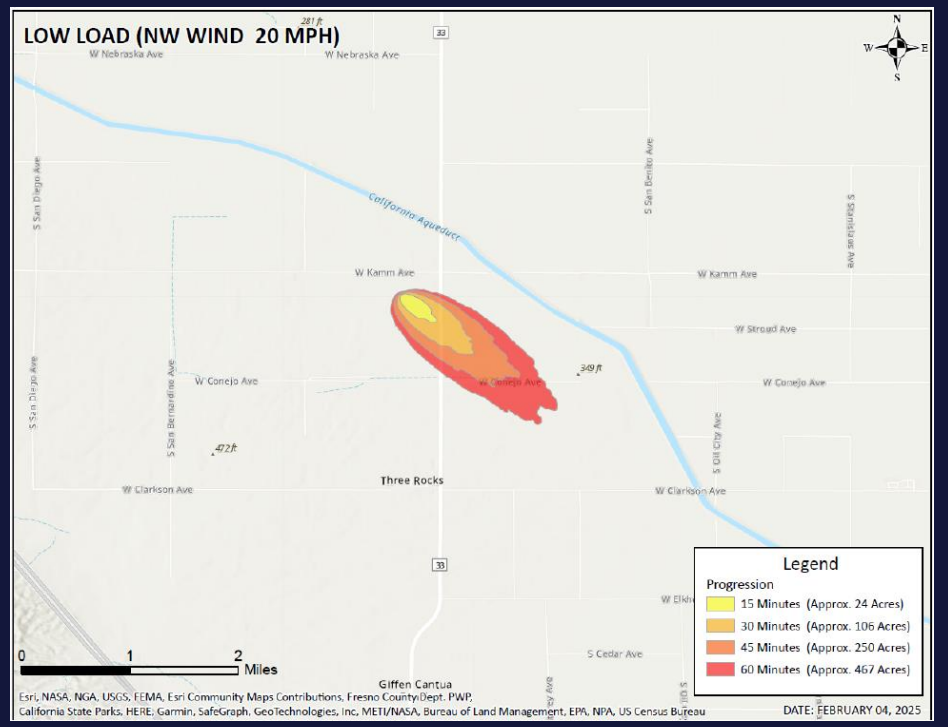
- On-Site Medical Aids
- Motor Vehicle Accidents
- Technical Rescues
- HAZMAT
- Fire/Trouble/Nuisance Alarms
- Vegetation Fires
- Solar Array/Inverter Fires
- BESS Fires
- Commercial Structure Fires

Solar Array Fire Spread Example (Low) (1/2)

Fire Growth Projections in 6” fuel

- Normal prevalent winds are 20 MPH daily
  - Gusts between 25-35 often
- Closest Engine response time to this fire is between 20-25 minutes for first arriving engine.
- Fire Progression:
  - 15 Minutes (Approx. 24 Acres)
  - 30 Minutes (Approx. 106 Acres)
  - 45 Minutes (Approx. 250 Acres)
  - 60 Minutes (Approx. 467 Acres)

Fire Example Starting where IP Darden (9,500 Acre) site is proposed

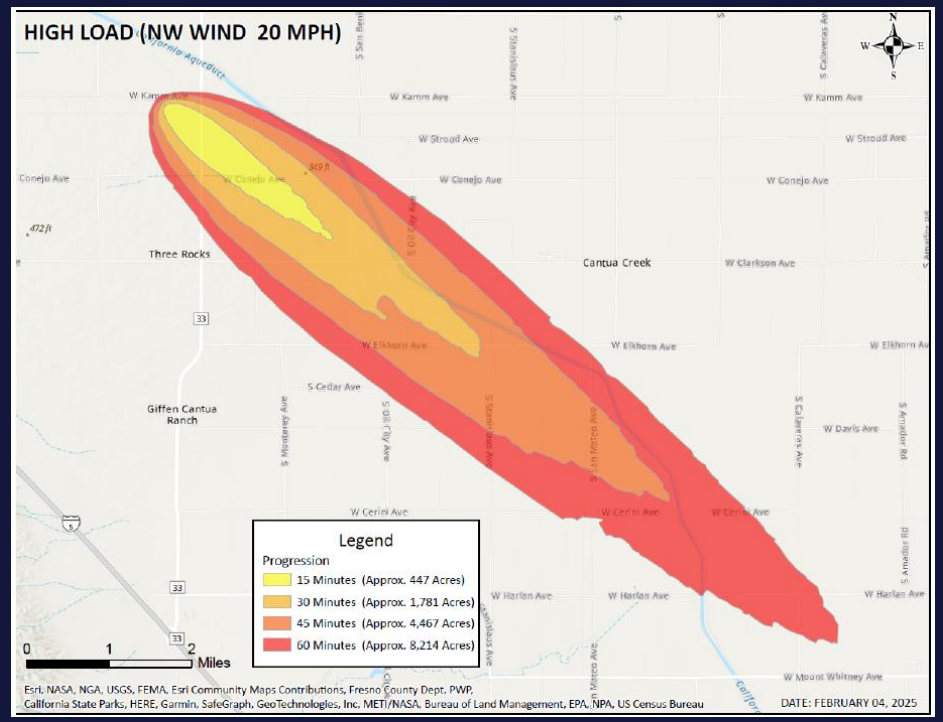


Solar Array Fire Spread Example (High) (2/2)

Fire Growth Projections in 12” fuel

- Normal prevalent winds are 20 MPH daily
  - Gusts between 25-35 often
- Closest Engine response time to this fire is between 20-25 minutes for first arriving engine.
- Fire Progression:
  - 15 Minutes (Approx. 447 Acres)
  - 30 Minutes (Approx. 1,781 Acres)
  - 45 Minutes (Approx. 4,467 Acres)
  - 60 Minutes (Approx. 8,214 Acres)

Fire Example Starting where IP Darden (9,500 Acre) site is proposed

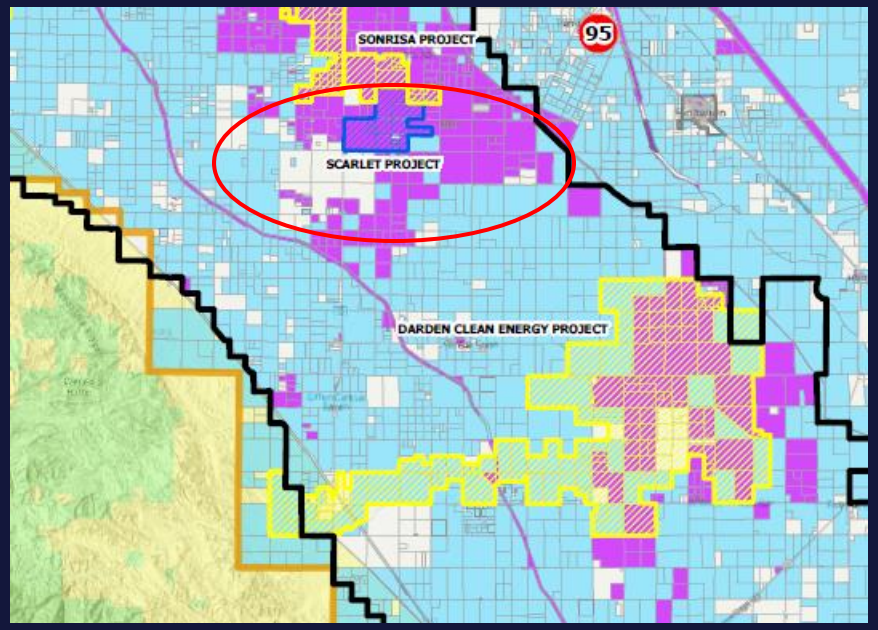


Scarlet Solar Project Vegetation Fire 5/8/2025 (1/3)

Incident Information

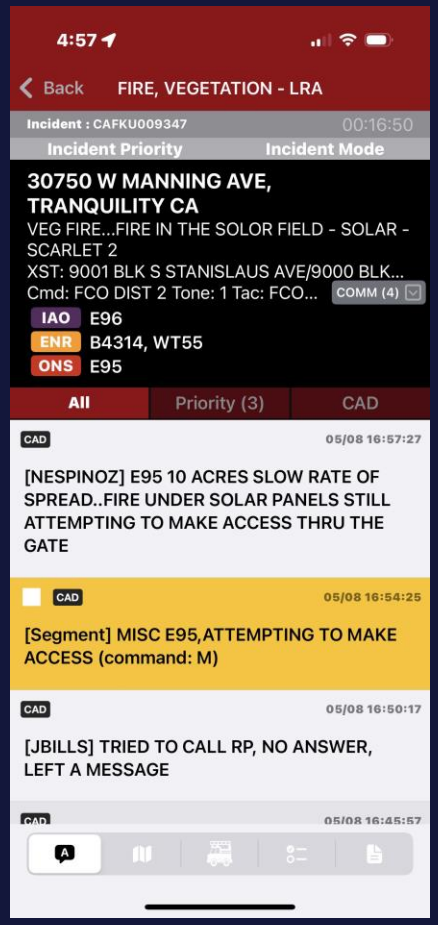
- Site is approx. 15 minutes away from FCFPD Station 95
- Weather at time of Dispatch:
  - 91° F
  - Winds out of Northwest 8-11 MPH
- Annual Grass 6”-8” tall
- 4 Stations Responded to this single incident

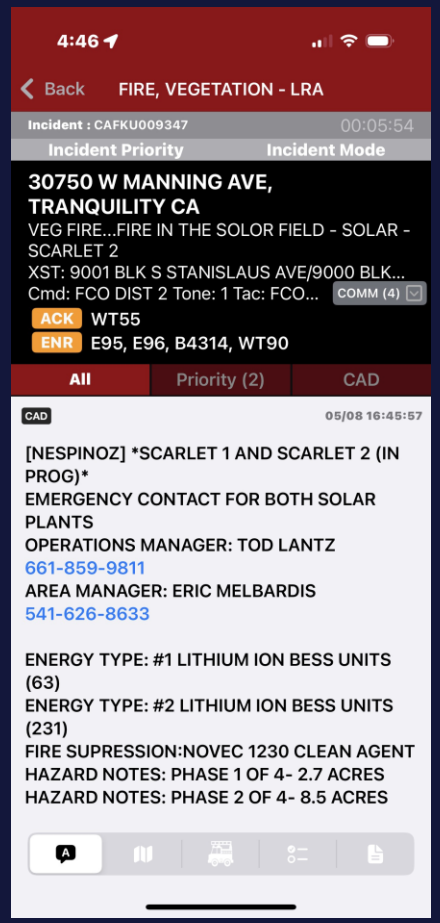
Scarlet Solar Project

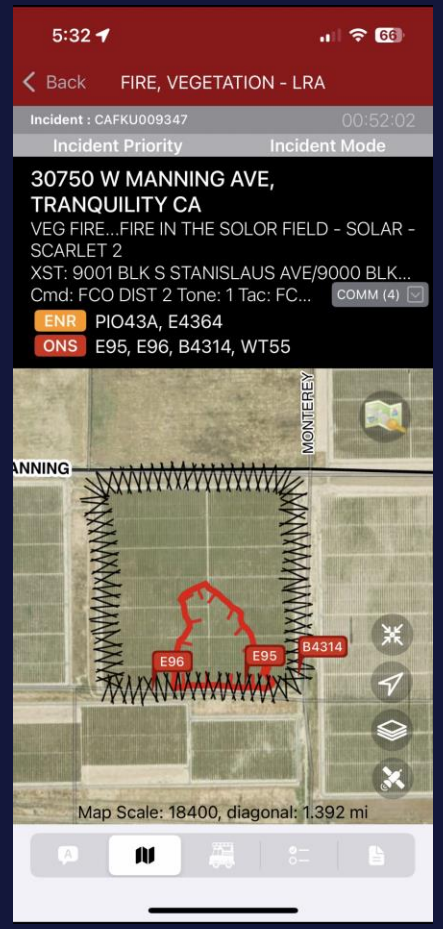


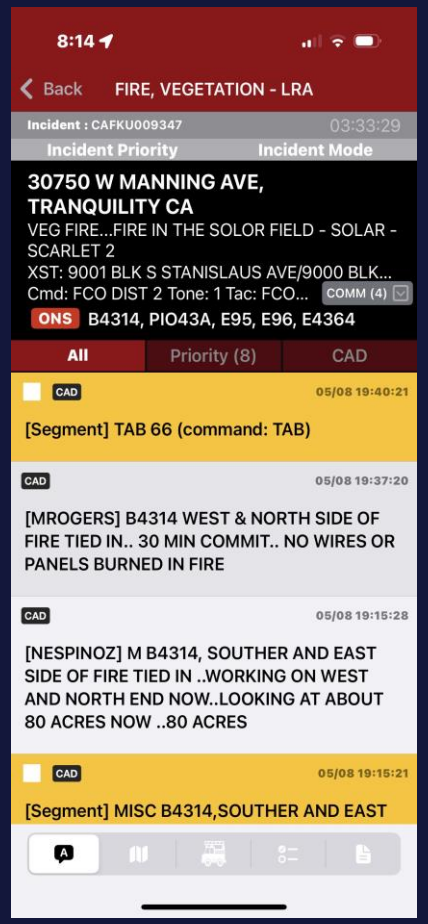
Scarlet Solar Project Vegetation Fire 5/8/2025 (2/3)

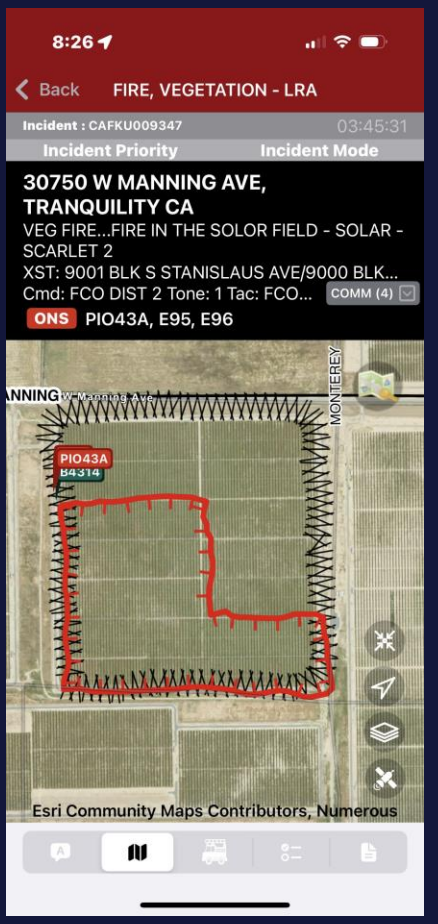
Tablet Command Incident Information











Scarlet Solar Project Vegetation Fire 5/8/2025 (3/3)

- Limited access for Type 1 Engines
- Typical vegetation fire mitigation tactics (Mobile Attack, Defensive Firing, Progressive Hoselays, etc.) cannot be utilized due to configuration of solar arrays and electrical distribution lines/wiring crossing lanes.

Compiling the Information (1/2)

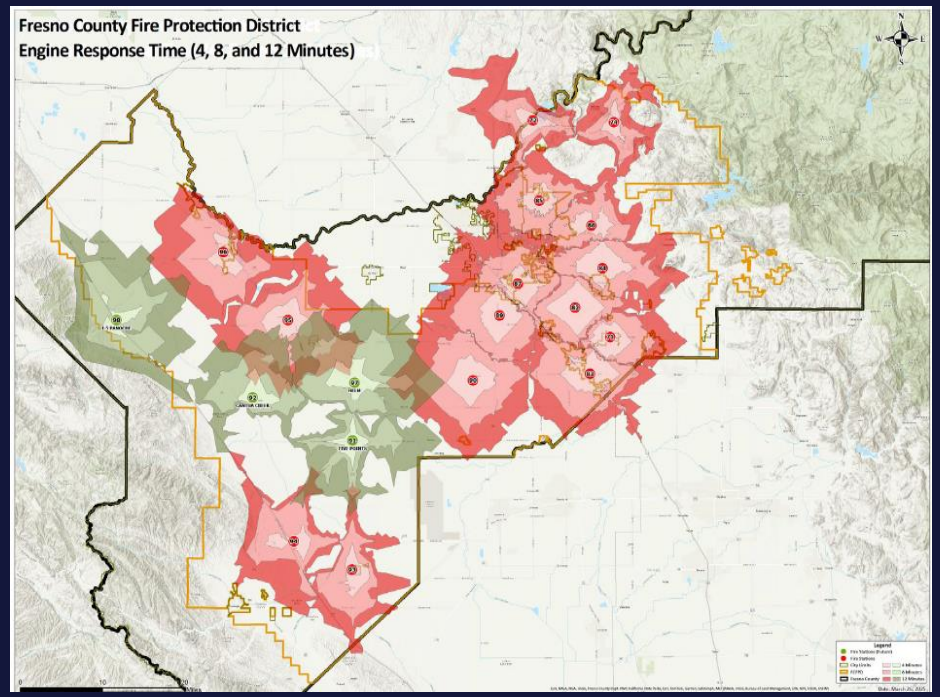
- Board of Directors for Fresno County Fire Protection District confirmed that new construction Solar/Bess projects should not reduce current service levels
- Fresno County Board of supervisors echoed the same sentiment very strongly
- Using known projects, impacts were determined
- Created maps validating response times
- Created maps for future station buildout and response coverage

Compiling the Information (2/2)

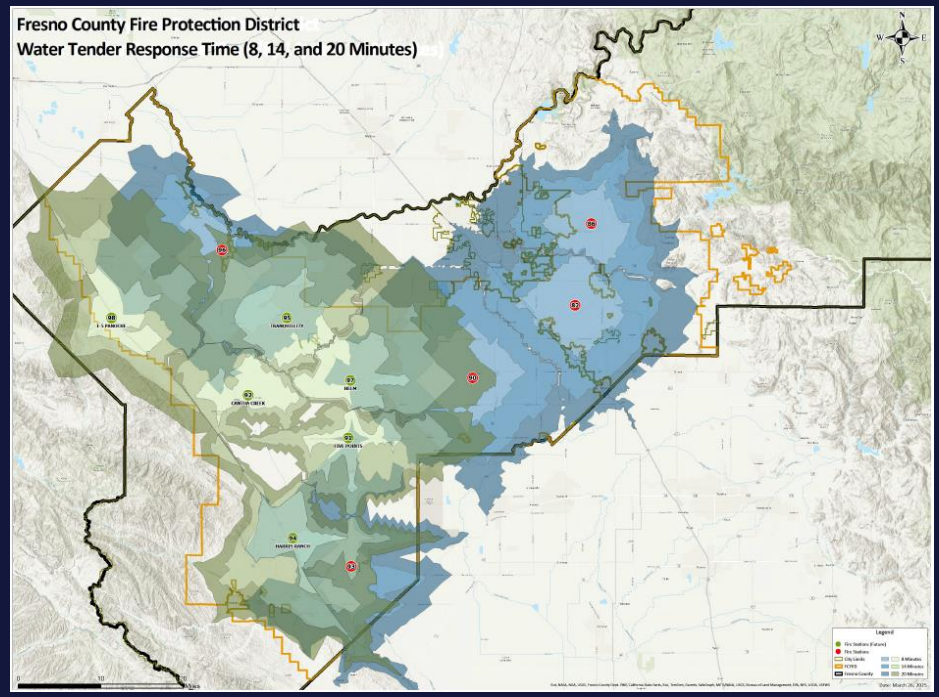
- Operational needs to meet the impact
  - 4 new stations
  - Enhancements to 4 existing stations
  - Upstaffing of additional equipment at existing stations
  - Upstaffing support positions for daily fire department operations
- Line by line budget assessment
  - Adjusted by ratio each impact
  - Determined First Year Cost Impact
  - Determined Annual On-Going Cost Impact for life of the projects
  - Hired third party financial consultant to review funding methodology

Proposed New FCFPD Station Locations

FCFPD Proposed New Station Locations Engine Response Coverage



FCFPD Proposed New Station Location Water Tender Response Coverage



Funding Methodology for BESS and PV Projects (1/2)

- The bulk of existing and proposed PV Projects exist in the western part of Fresno County. The west side of Fresno County requires additional resources to respond to fire, rescue, and emergency medical services to the proposed PV Projects in an appropriate response time while maintaining the current level of service to existing towns and energy facilities. District stations on the western side of the County are presently staffed and equipped to handle emergency responses to the growing population of communities on the west side of the County including Mendota, Tranquility, San Joaquin, Coalinga, and others.

Funding Methodology for BESS and PV Projects (2/2)

- The District's resources in the western portion of the County require enhancement to maintain and provide the current level of service to existing communities and to the proposed PV Projects. New and expanded fire stations, personnel, water tenders, engines and other capital and operating costs have been identified by the District to adequately serve the proposed PV Projects.
- The Funding Methodology allocates the estimated amount of costs needed to serve the estimated buildout of PV Projects in the District's boundaries to the megawatts produced/stored by type of project. The Funding Methodology is based on the industry standard 4-hour megawatt system and may be converted in a fractional amount as needed.

Future Needs Cost Summary

- The total additional personnel, capital facilities, equipment and apparatus to adequately serve the fire and emergency medical service demands of the existing and proposed PV Projects in the District, are summarized in this table.

Summary of Future Needs Costs		
Type	**First Year Cost**	**Annual Cost**
Safety Personnel	$29,610,549	$31,091,077
Non-Safety Personnel	$1,757,829	$1,757,829
Repairs and Maintenance	$415,096	$415,096
Supplies, Equipment & Services	$1,182,106	$1,182,106
Capital Equipment	$20,597,467	$2,349,667
Capital Facilities	$71,320,000	$2,020,000
Total Future Needs Costs	**$124,883,047**	**$39,202,009**

Project Cost Calculation Formula

- To ensure the funding of personnel, new facilities, apparatus and equipment as well as an enhancement to existing facilities, we have allocated the identified personnel, capital facilities, equipment and apparatus with the proposed PV Projects. This results in a one-time initial payment and an adjustable annual cost on a per Mega Watt basis by Solar and BESS, for the PV Projects within the District's boundaries.

Cost per Megawatt		
Type	**First Year Cost**	**Annual Cost**
BESS Cost per Megawatt		
BESS Future Needs Allocated Costs	$70,171,784	$22,027,609
BESS Projected Megawatts Produced	11,058	11,058
BESS Future Needs Costs per Megawatt	**$6,346**	**$1,992**
Photovoltaic Cost per Mega Watt		
Photovoltaic Future Needs Allocated Costs	$54,711,263	$17,174,400
Photovoltaic Projected Megawatts Produced	17,275	17,275
Photovoltaic Future Needs Costs per Megawatt	**$3,167**	**$994**
Total Future Needs Costs per Megawatt	**$9,513**	**$2,986**

Conclusion

- The addition of PV Projects will result in a reduction of service to the communities served by the District without an appropriate increase of firefighting resources. The purpose of the Funding Methodology is to ensure that new PV Projects within the District pays its share of future personnel and capital costs, which are necessary to provide fire protection, fire suppression and other fire safety services adequate to accommodate these highly specialized projects.

INTERNATIONAL ASSOCIATION OF FIRE FIGHTERS

IAFF: Lithium-ion Battery Research and Response

Cal Fire Battery Symposium

July 2025

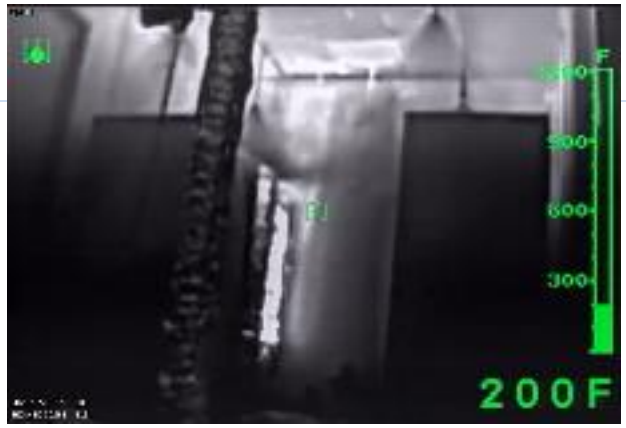
Background

- 2 MW/2.16 MWh lithium-ion battery ESS
  Average home in Arizona consumes 1 MWh/month
  ESS owned by local electric utility (APS)
  Batteries manufactured by LG Chem
  ESS designed by the integrator (Fluence)
  ESS maintained by contractors to the
- Four firefighters (Peoria HAZMAT team) seriously injured
- Four firefighters (Surprise E304) held overnight for suspected exposure to HCN

Courtesy of APS

Results — Test 3, timeline of major events

Ignition, sustained flaming
[TR + 00:08:49]



Waterflow @ 0.5 gpm/ft^2
[TR + 00:10:13]

TR propagation after water flow off
[TR + 01:13:05]

TR propagation continues after water flow restart [TR + 01:49:54]

Deflagration
[TR + 00:42:02]

TR notes the time of the first cell thermal runaway.

Safe Response to Renewable Energy Hazards

June-July 2022

Results – Test 2 (batteries as first item Ignited)

- Smoke appearance similar – few differences (low-hanging clouds, lower vent velocity)
- Deflagration observed – Self-ignited. Many variables affect severity (gas chemistry, release volume, concentration, temp, enclosure strength)

Interior view, 16 minutes of TR & gas accumulation before ignition

Exterior view, deflagration

Fire Service Size-up and Tactical Considerations

A significant explosion hazard can develop before any exterior indicators (visual or measured) are shown.

Reality Check: Comparison to Mountain View Incident

- Simulated ESS battery gas buildup (FSRI)

- Battery gas buildup from Hybrid Jeep
- Video courtesy of Mountain View Fire Department

Residential ESS Report

FIRE RESEARCH AND DEVELOPMENT TECHNICAL REPORT

Considerations for Fire Service Response to Residential Battery Energy Storage System Incidents

December 4, 2023

Alex Schraiber, PE
Adam Barowy*
Ben Gaudet, PE
Veronica Kimmerly, PhD
*UL Fire Safety Research Institute

Prepared for the International Association of Fire Fighters

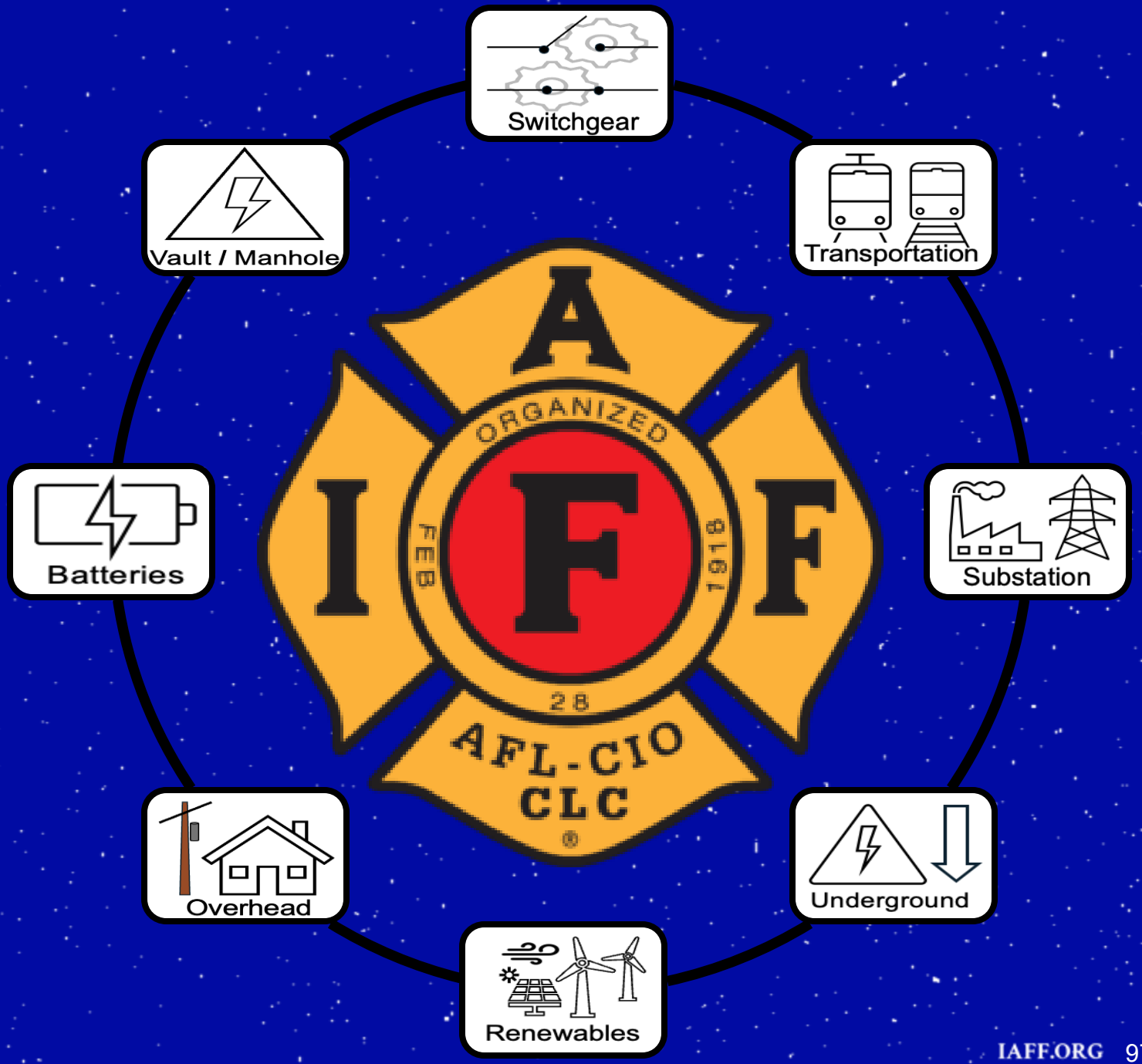
UL Solutions

IAFF Lithium-ion Research and Reports

- IAFF Safety Advisory

Responding to Residential ESS

Energy Hazards Categories



Energy Hazard Guide – How to Get It

IAFF Learning Management System

WWW.IAFF.ORG

Fire Blanket Alert

- As a result of EV testing the IAFF issued a Safety Advisory on the use of fire blankets in response to an EV fire.
- Possible Explosion Hazard

IAFF SAFETY ADVISORY

USE OF FIRE BLANKETS ON ELECTRIC VEHICLE FIRES

JUNE 2025

The IAFF recommends members do not use fire blankets on EV fires involving the battery.

Electric vehicle (EV) fires have presented unique suppression challenges to the fire service. Anecdotal information describes these fires as burning hotter and for longer periods than gasoline-powered cars, with an additional threat of reignition that can last for months.

In response to these challenges, numerous products claim to improve suppression efforts involving EVs. Many of these claims have not been substantiated through independent scientific testing. Appropriate product standards have not yet been updated to address these products, and in some cases, new standards have yet to be proposed or developed.

Two major research initiatives, UL Fire Safety Research Institute (FSRI) and the NFPA Fire Protection Foundation (FPRF), are conducting experiments that simulate fire department responses to EV fires and evaluate the effectiveness of various suppression tactics and products. The IAFF is actively involved in both projects.

While it will take time for the researchers to develop the final reports, we have learned critical information that needs to be shared immediately before the final publications of these reports.

- The IAFF strongly urges fire service members NOT to deploy a fire blanket for suppression efforts when responding to an EV fire.
  - This recommendation is based on the experiences resulting from both projects and shared in this joint statement issued on May 30, 2025.
  - While deploying a blanket can control a fire by eliminating oxygen – a smothering effect – it does not stop the battery from experiencing thermal runaway and releasing flammable gases, including hydrogen. Although eliminating oxygen may stop flaming, the ongoing release of flammable gases can build up beneath a fire blanket and create an explosion hazard.
  - Determining if the EV's battery is involved is a multi-step process, but it must begin with life safety of the driver, occupants, and responders as the top priority.
  - When encountering a fire involving an EV, fire fighters should use water to initially knock down the body of fire and then assess for battery involvement. Indicators include persistent flaming from the wheel wells and from underneath the vehicle that resist hose stream extinguishment, jetting flames accompanied by hissing and popping sounds, and reignition. Refer to the IAFF Energy Hazard Guide for additional information.

iaff.org • @IAFFOfficial 1

THANK YOU!
ANY QUESTIONS?

Sean DeCrane

Assistant to the
General President, IAFF
sdecrane@iaff.org

Discussion on Research & Technology

Moderator – Greg Rogers, National Fire Protection Association

- **Alexandra (Klieger) Schraiber** – UL Solutions
- **Noah Ryder** – Society of Fire Protection Engineers
- **Ray Byrne** – Sandia National Laboratories
- **Xiaoliang Wang** – Desert Research Institute and University of Nevada, Reno

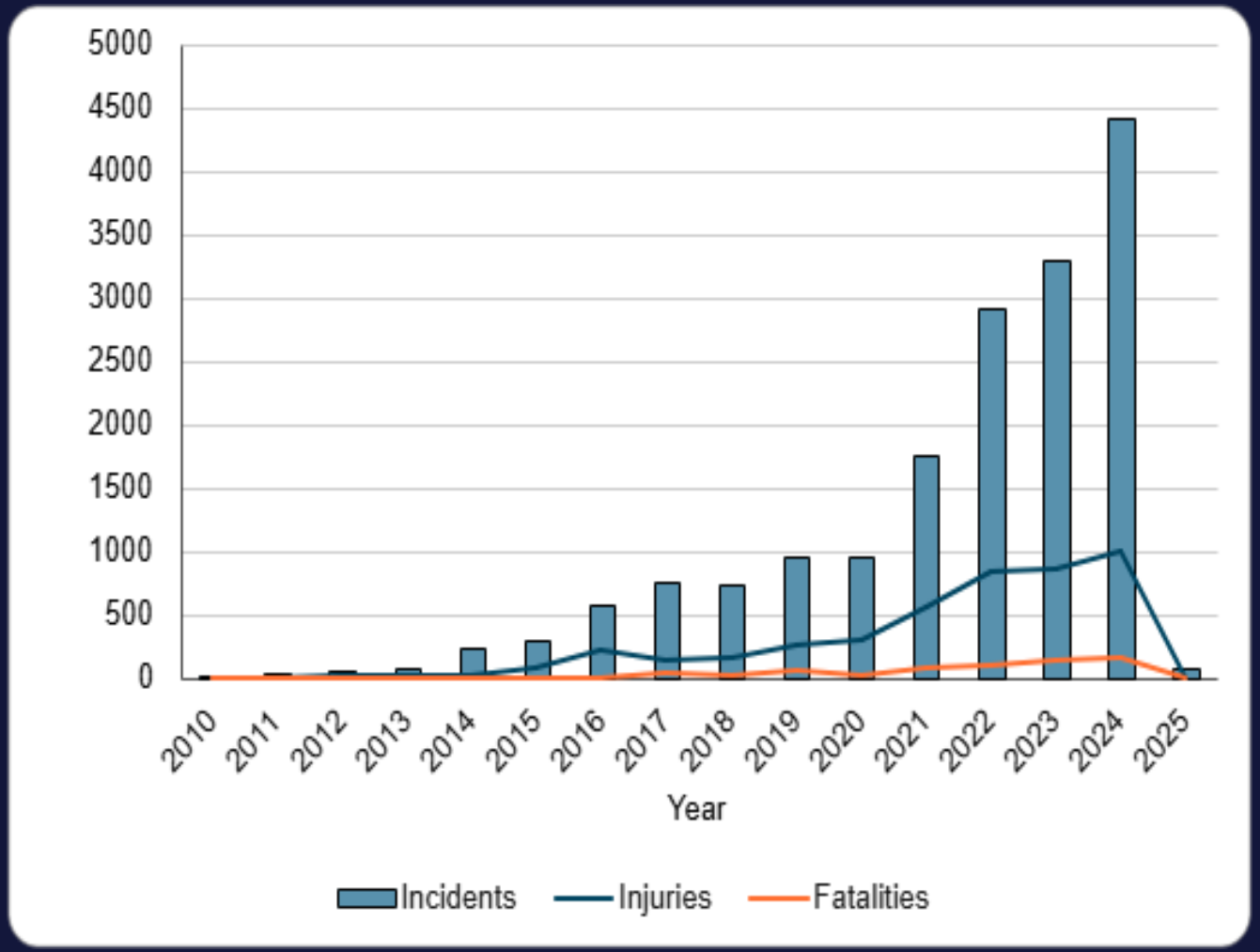
Research for ESS safety and standards development

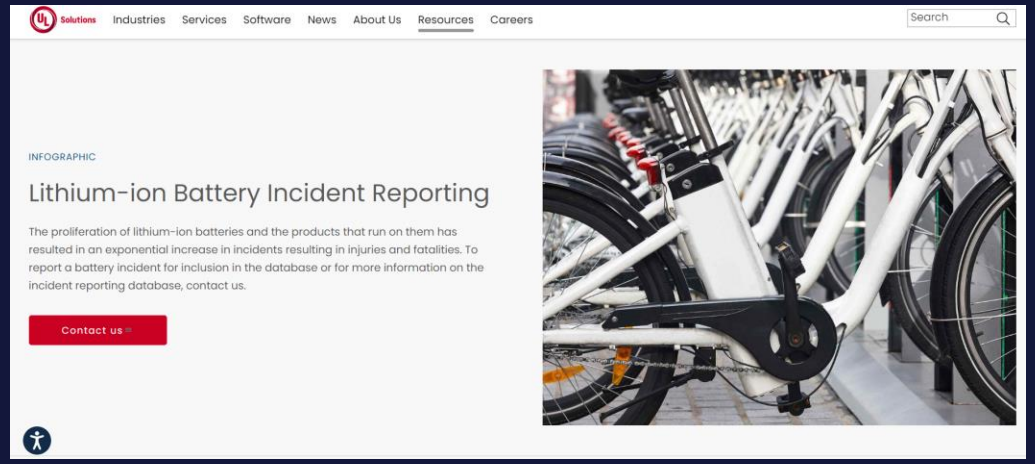
Alex Schraiber, P.E.

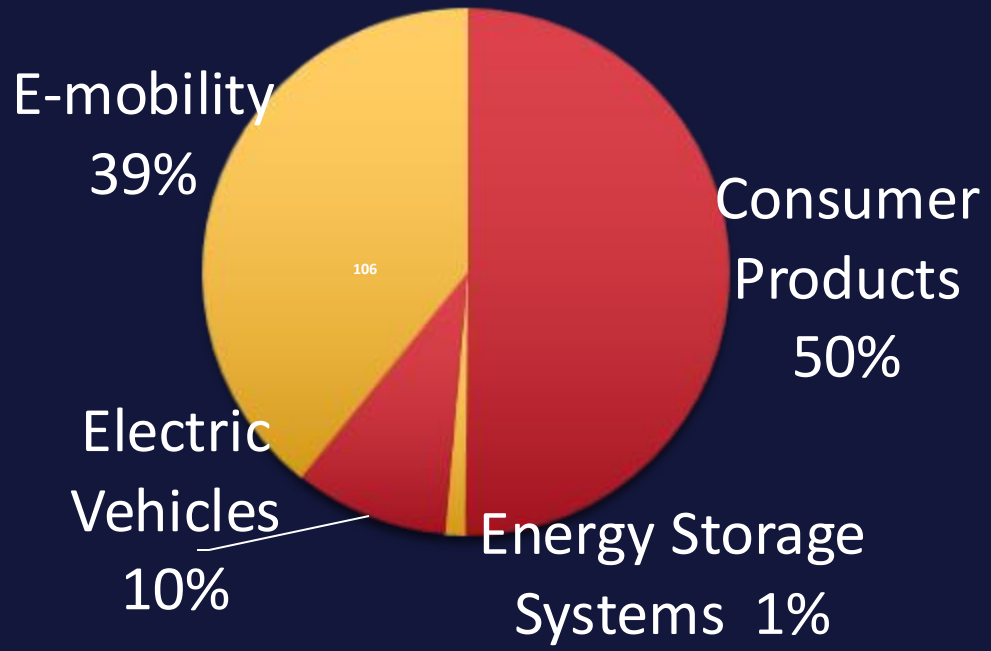
Where is R&D focusing for BESS fire and explosion hazards?

- Incident tracking
- Fire department response
- Fire and explosion testing
- BESS construction
- Simulations
- New chemistries, re-use

Battery incidents are proportional to market size

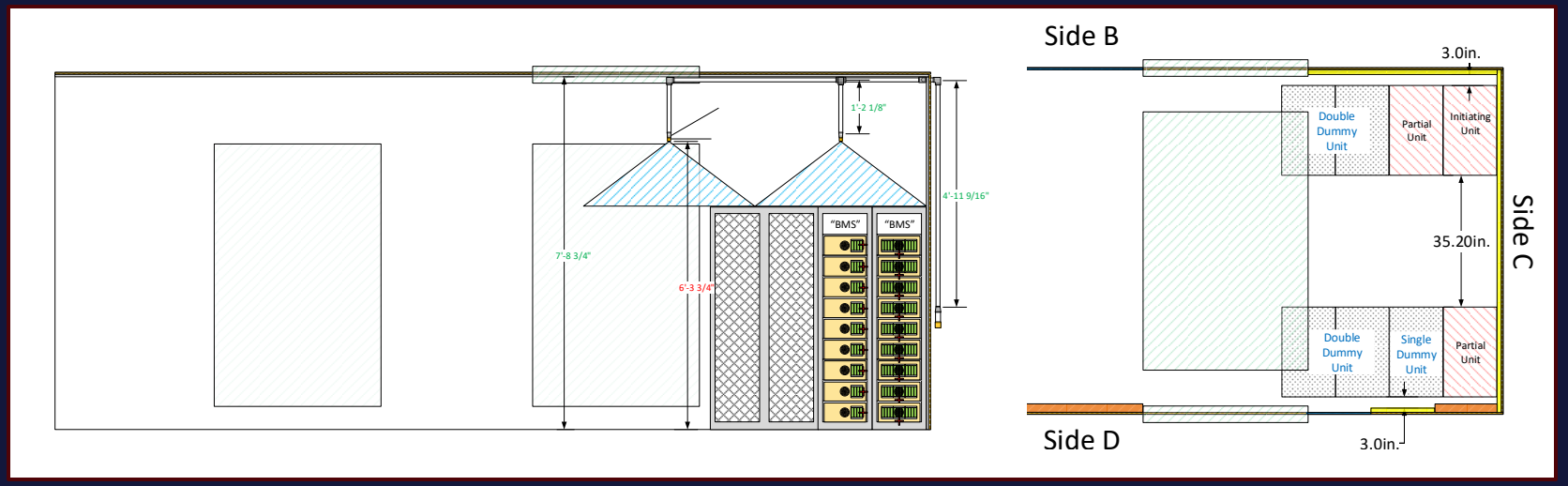






https://www.UL.com/insights/lithium-ion-battery-incident-reporting

Installation-level container tests



FIRE RESEARCH AND DEVELOPMENT TECHNICAL REPORT

UL 9540A Installation Level Tests with Outdoor Lithium-ion Energy Storage System Mockups

April 12, 2021

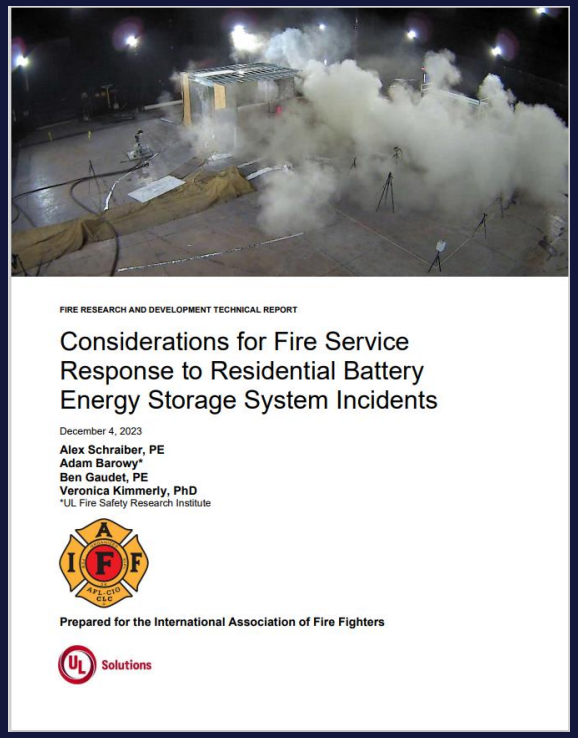
Adam Barowy
Alex Klieger
Jack Regan
Mark McKinnon, Ph.D., P.E.

Empowering Trust®

Residential ESS incident response

Impact of Li-ion residential ESS on incident response:

- Determine whether Li-ion battery gas impacts compartment fire dynamics.
- Develop size-up and tactical considerations for first responders to Li-ion residential energy storage system fire incidents.



FIRE RESEARCH AND DEVELOPMENT TECHNICAL REPORT

Considerations for Fire Service Response to Residential Battery Energy Storage System Incidents

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UL Solutions

U.S. DEPARTMENT OF ENERGY

UL Solutions

UL Research Institutes

FSRI

Disclaimer: The views expressed herein do not necessarily represent the views of the U.S. Department of Energy or the United States government.

Source:

Outdoor testing: Representative garage

An explosion hazard is dependent on the release duration, quantity and flammability of thermal runaway gases.

109

Research collaboration:

UL Research Institutes

FSRI

Large Scale Fire Test – Method Development/Revision

- Proposed Revisions to UL 9540A Installation Level Testing
- Ballot period June 27 to August 11, 2025
- Industry innovation and testing experience of the last several years have identified need for revision of UL 9540A
- Example of fire following explosion

Photo courtesy of Merseyside Fire & Rescue Service Headquarters

Liverpool, U.K. — September 2020

Testing with Sandia National Laboratories

UL – Garage Explosive Testing

Test 4

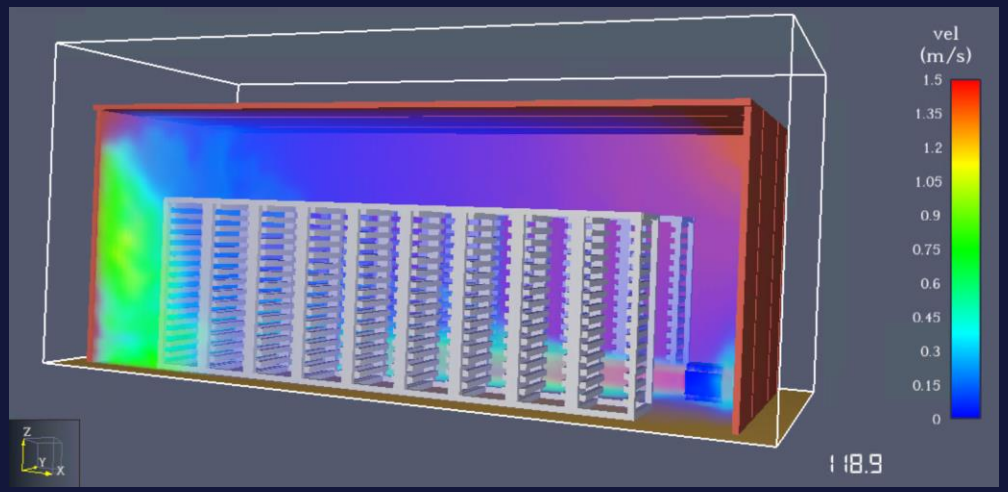
Garage Door

October 4th, 2023

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia. LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.

SAND2024-03631O

Simulation


vel
(m/s)
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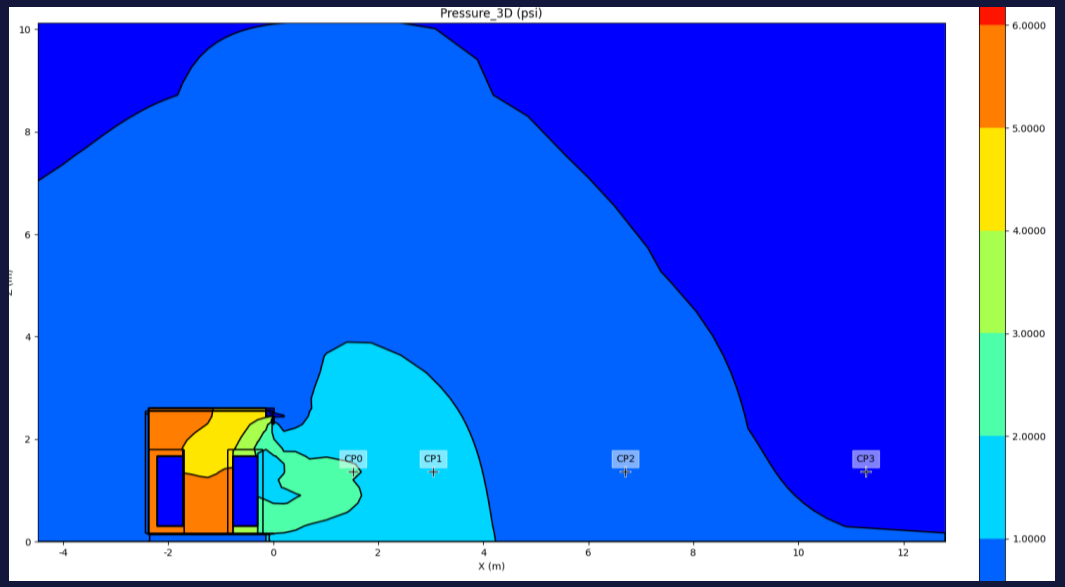
1.35
1.2
1.05
0.9
0.75
0.6
0.45
0.3
0.15
0
118.9


Pressure_3D (psi)
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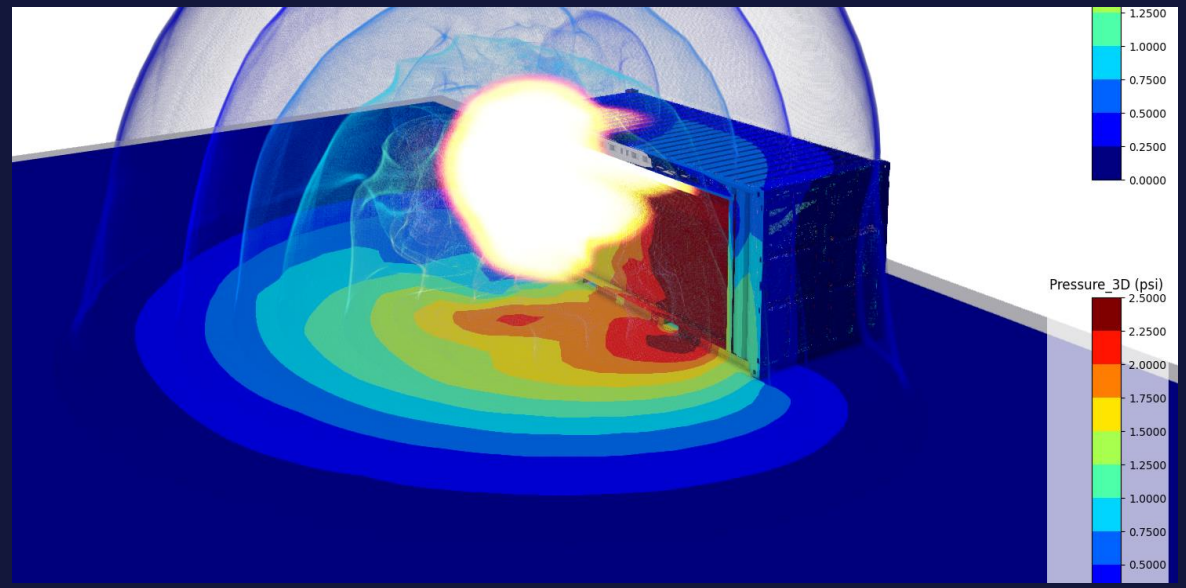
5.0000
4.0000
3.0000
2.0000
1.0000
CP0
CP1
CP2
CP3
X (m)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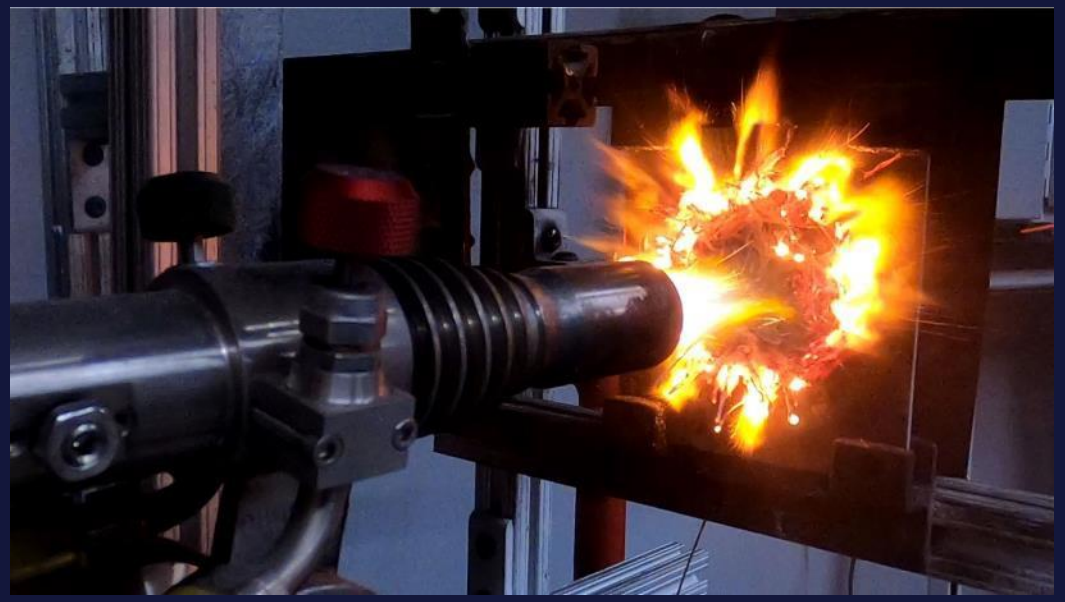
1.0000
0.7500
0.5000
0.2500
0.0000
Pressure_3D (psi)
2.5000
2.2500
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000

New Test Methods

- UL 2596, Battery Enclosure Material Screening



- UL 1487, Battery Containment Enclosures

Thank you!

Alex Schraiber
alex.schraiber@UL.com
Senior Manager, Fire R&D

Discussion on Research & Technology

Noah L. Ryder
nryder@fireriskalliance.com

CALFIRE BESS Fire Safety Symposium

CHIEF OPERATING OFFICER

NOAH RYDER, PHD, PE

- ~25 years in fire safety, Licensed FPE
- BS and MS in Fire Protection Engineering (UMD), MBA (UMD)
- PhD in Mechanical & Mechatronics Engineering (U. Waterloo)
- Adjunct/Associate professor at University of Maryland and University of Waterloo
- Lead FRA's Risk, Modeling, PBD, Forensics, and Applied Research Groups
- Principal on NFPA 855, UL9540, CSA 800/801
- FRA is founding member of the NFPA Energy Storage Research Consortium
- Over 250 GWh of ESS projects commissioned or in the pipeline

RESEARCH & TECHNOLOGY: CHALLENGES

Categories

- Cake analogy (chemistries)
  - Chocolate, Vanilla, etc.
- Gaps in basic knowledge
- Improper scaling or use of available inf
- Rapid development of new products
- Gap from published research to latest pro
  - Academia vs Industry

RESEARCH & TECHNOLOGY: ADVANCES

Categories

- "Safer" chemistry advancements and technologies
- Improved safety at the product design level
  - Reduced fuel loads in a single "compartment"
  - Deflagration protection improvements and understanding
- Progress on BESS fire comparison to non-BESS fires
  - NFPA Research Foundation Work
  - ACP Work
  - SFPE Research Foundation Work
- Better understanding of "risk" and exposures
- Improved ERP/training that implements the latest knowledge

WHY IS THIS IMPORTANT

This is What's Coming

- Stacke
- In buil
  appli
  - C
    b
  - R
  - D
  - P

Codes, standards, and guidance rely on Research and Technology and for a rapidly evolving industry they are often out of sync, that is the case here. Need more research

QUESTIONS?

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www.bess-sdk.com
www.fireriskalliance.com

Research & Technology Panel

RAY BYRNE, SANDIA NATIONAL LABORATORIES

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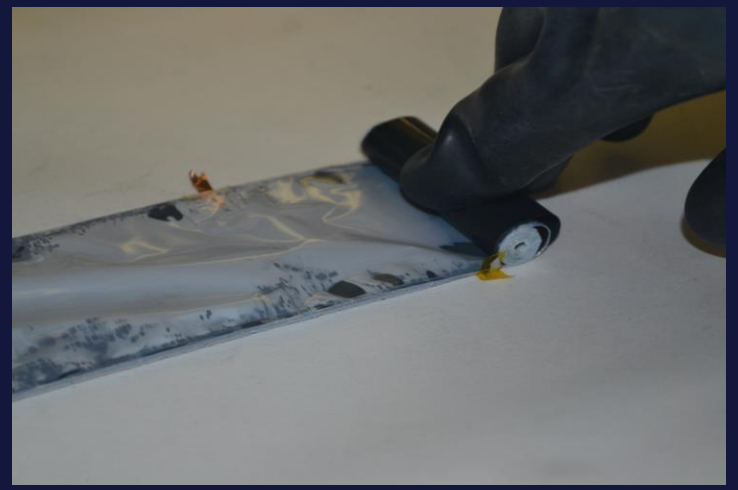
U.S. DEPARTMENT of ENERGY

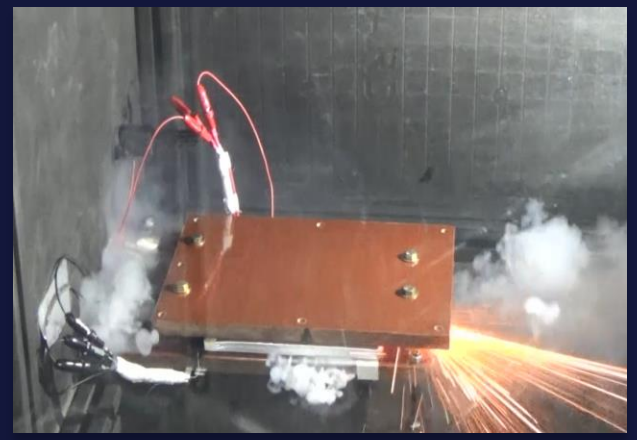
Sandia Addresses All Aspects of Battery Safety and Reliability 1 of 3

- Materials R&D
  - Thermal stability
  - Gas evolution
  - Degradation
  - Manufacturing defect evaluation



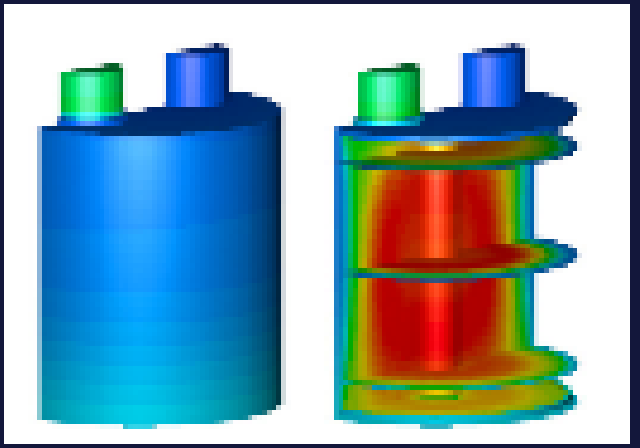
Sandia Addresses All Aspects of Battery Safety and Reliability 2 of 3

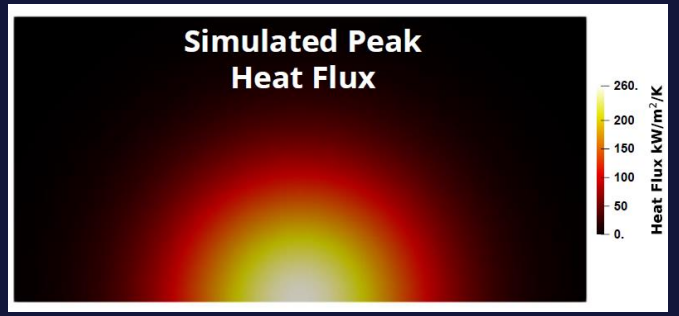
- Cell and Module Testing
  - Aging
  - Diagnostics
  - Abuse testing
  - Thermal propagation

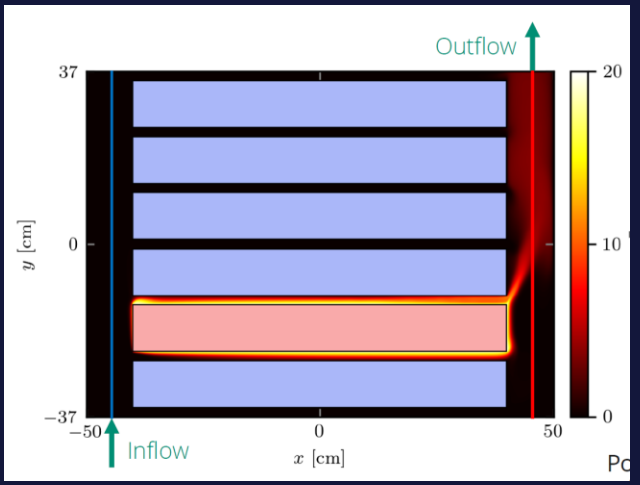


Sandia Addresses All Aspects of Battery Safety and Reliability 3 of 3

- Simulations and Modeling
  - Multi-scale models
  - Fire dynamic simulations
  - Predictive simulations
  - Machine learning





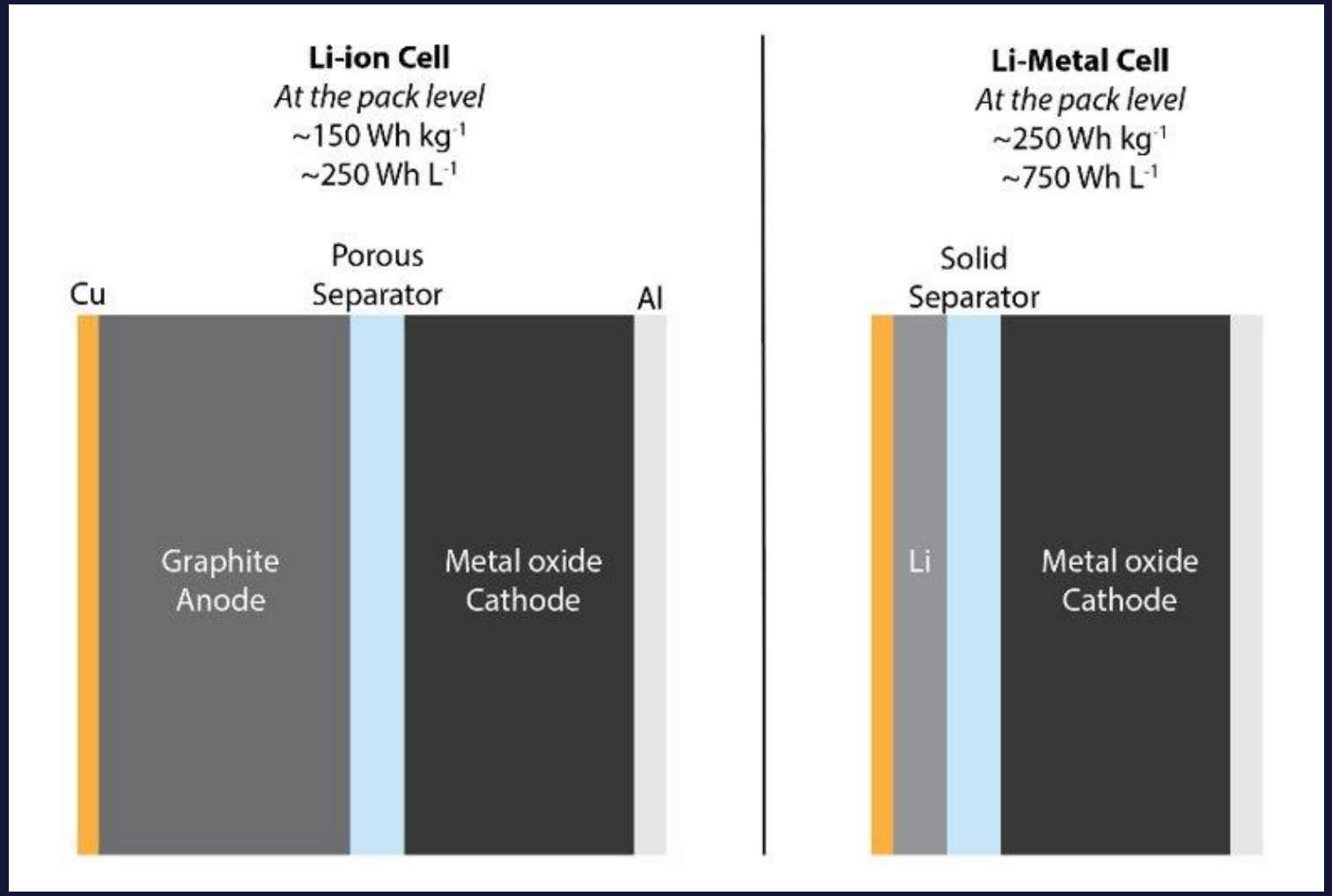


Sandia Outreach Activities

- Energy storage safety working group
- IEEE standards
  - IEEE 1547.9-2022, IEEE Guide for Using IEEE Std 1547 for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems
  - P2686, Recommended Practice for Battery Management Systems in Energy Storage Applications
  - P2688, Recommended Practice for Energy Storage Management Systems in Energy Storage Applications
  - P3434, Guide for the Project Development, Facility Design, Installation, Operations and Maintenance (O&M) for Grid Connected Energy Storage Systems (ESSs)
  - NFPA 855 Technical Committee Member
  - NFPA 800 Technical Committee Member
- EPRI energy storage data guidelines

Recent Results – Solid State Batteries 1 of 3

- Solid state batteries are proposed as a “safer” solution



Recent Results – Solid State Batteries 2 of 3

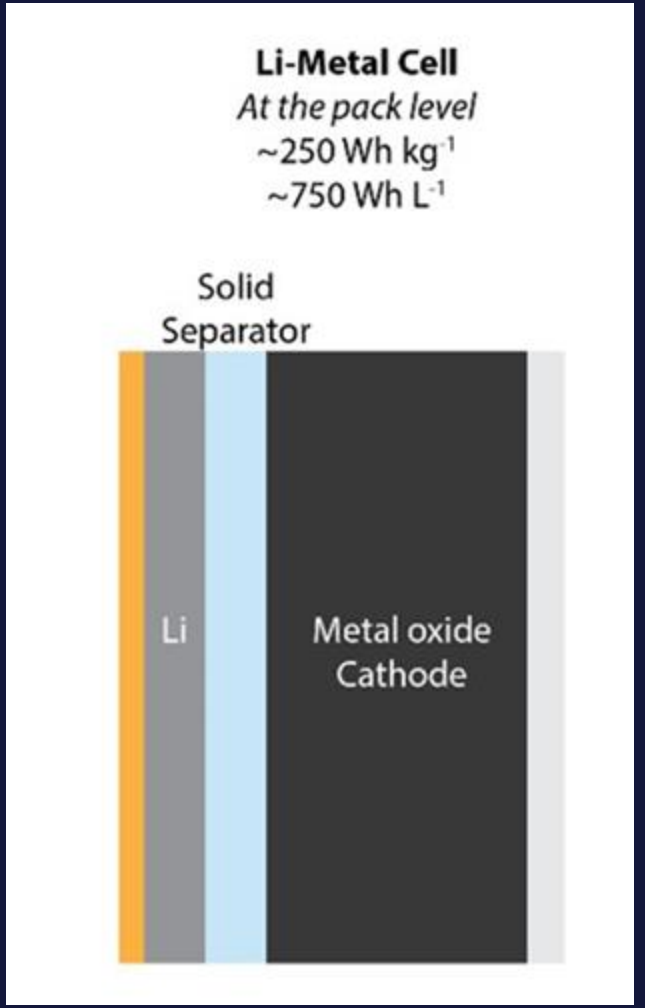
- Thermite: exothermic reaction between a metal and an oxide
- Known thermite:
  - $2Al + Fe2O3 \rightarrow 2Fe + 2Al2O3$
  - ΔH= -3.98 KJ/g
- With lithium:
  - $6Li + 2Fe2O3 \rightarrow 2Fe + 3Li2O$
  - ΔH= -4.82 KJ/g
- Discharged LFP Cell:
  - $9Li + LiFePO4 \rightarrow 2/3\ Li3P + 1/3\ Fe3P + 4Li2O$
  - **Δ**H= -4.29 KJ/g
- Charged LFP Cell:
  - $10Li + FePO4 \rightarrow 2/3\ Li3P + 1/3\ Fe3P + 4Li2O$
  - **Δ**H= -5.92 KJ/g

Recent Results – Solid State Batteries 3 of 3

- Sandia has performed initial experiments to evaluate if contact between the anode and cathode material can result in a thermite reaction
- LFP powder with ~100mg of lithium metal

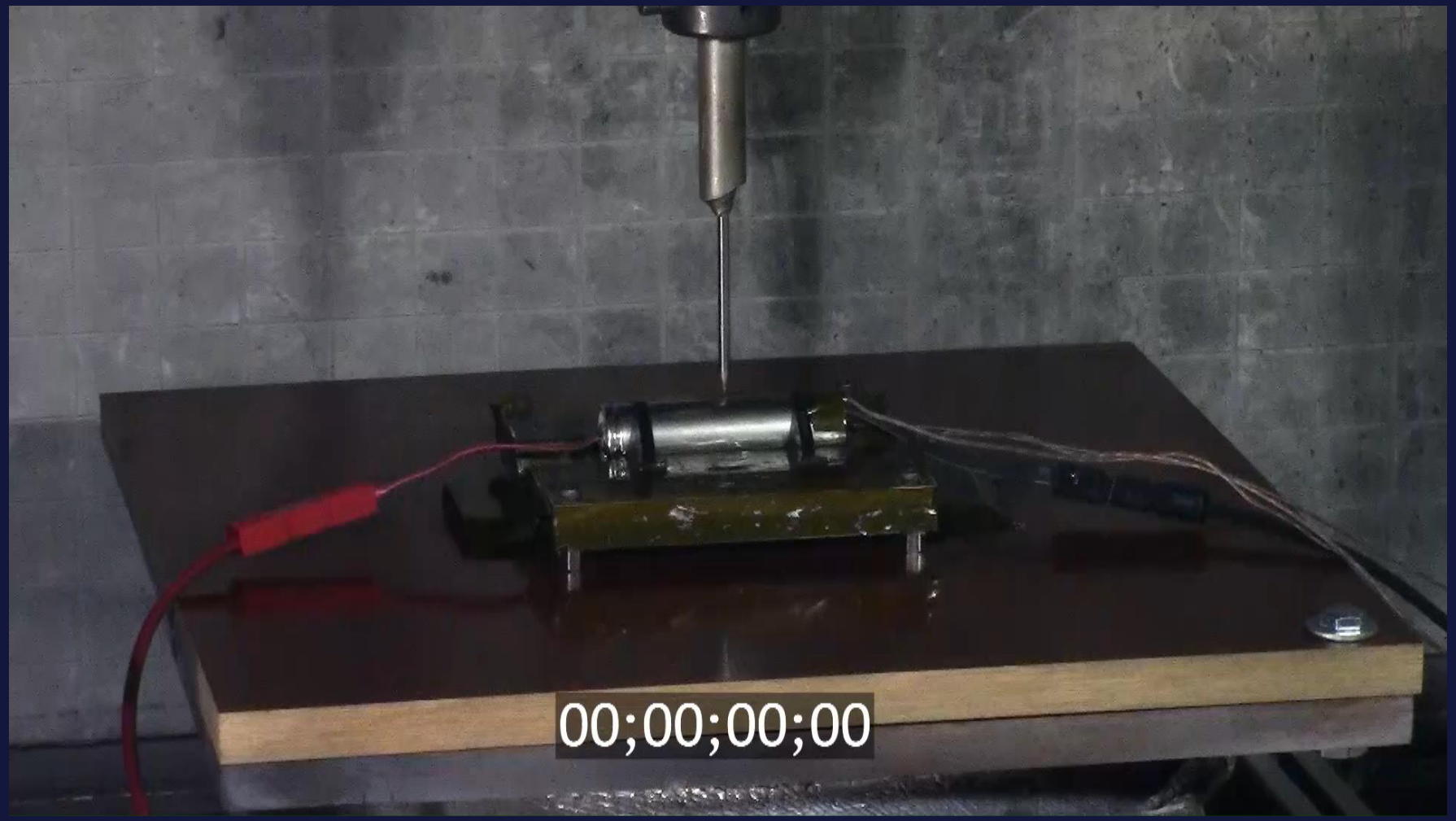
Solid State Batteries – Safety Concerns

- Anode to cathode contact can result in a thermite reaction
- A crushed cell should be treated with caution
  - Vehicle batteries in an accident
  - Grid batteries after physical damage
- Sandia plans to conduct additional testing on solide state batteries



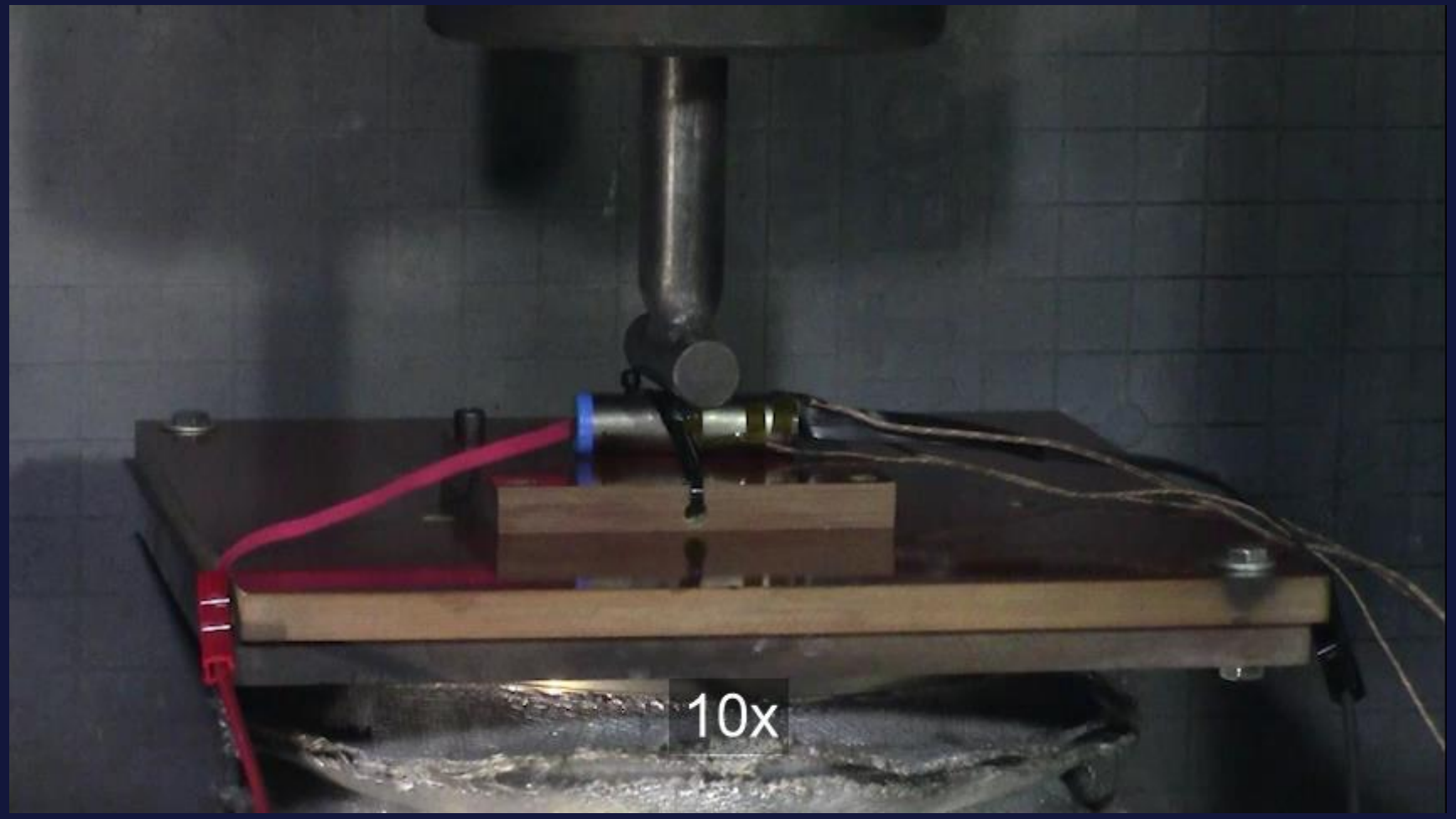
For more information: Bertrand, M., Johnson, N.B, Jin, L., Bates., A.M., Chartrand, P., Torres-Castro, L., Dollé, M. Joule. 2025, 9(5), https://doi.org/10.1016/j.joule.2025.101953

Sodium Ion Nail Penetration



For more information:
Alex Bates
ambates@sandia.gov

Sodium Ion Mechanical Crush



For more information:
Alex Bates
ambates@sandia.gov

Summary

- For more information on Sandia's energy storage safety and reliability research:

  www.sandia.gov/ess

- Some takeaways for firefighters and first responders:
  - Always work with the proposed energy storage developer to be aware of any technology specific hazards prior to construction
  - For existing deployments, keep aware of the evolution in safety standards and the differences between the deployed system and the latest standards
  - There are non-fire hazards, like highly acidic electrolytes, stored mechanical energy, etc., that still can pose serious safety hazards for first responders

Air Quality Impacts of Battery Energy Storage System (BESS) Fires

Xiaoliang Wang

Desert Research Institute, Reno, NV

Li-ion battery thermal runaways emit a wide range of air toxics

OEHHA Reference Exposure Level

Air toxics	Hazards	Acute (1-hour)	8-hour	Chronic
Carbon monoxide (CO)	Headache, fatigue, dizziness, drowsiness, vomiting, confusion, collapse, and death	20 ppm		
Hydrogen fluoride (HF)	Eye and respiratory tract irritation, skin burn, bone changes, and death	0.3 ppm		0.017 ppm
Hydrogen chloride (HCl)	Respiratory tract irritation, cough, choking, shortness of breath chest pain, and eye and skin burns	1.4 ppm		0.006 ppm
Hydrogen cyanide (HCN)	A metallic taste, headache, fatigue, confusion, vomiting, gasping, suffocation, and thyroid, blood changes	0.3 ppm		0.008 ppm
Nickel (Ni)	Skin allergies, nausea, vomiting, diarrhea, headache, asthma, pneumonitis	0.2 $\mu g/m^3$	0.06 $\mu g/m^3$	0.014 $\mu g/m^3$
Cadmium (Cd)	Breathing difficulty, cough, chest tightness, headache, muscle aches, vomiting, diarrhea, loss of smell, cancer			0.02 $\mu g/m^3$

Bugryniec et al., 2024; NIOSH Pocket Guide to Chemical Hazards

OEHHA: California Office of Environmental Health Hazard Assessment

Limited data from past BESS failure incidents show low air quality impacts

Location	Capacity	Start Date	Description
US, CA, Moss Landing	300 MW/1200 MWh	1/16/25	Levels of HF in and around the fire perimeter and across Monterey County remained below acute Reference Exposure Levels. Elevated levels of Ni, Co, and Mn were found in soil samples at concentrations roughly 100 to 1,000 times higher than normal.
US, CA, Escondido	30 MW/120 MWh	9/5/24	Air quality and water runoff were well below acceptable exposure limits and considered expected readings during a routine structure fire.
USA, CA, San Diego	25 MW/250 MWh	5/15/24	High level of H_2 was detected. A drone and unmanned robot were used to measure air quality.
USA, ID, Melba	2 MW/8 MWh	10/2/23	No detected analytes above health-based action levels.
US, NY, Chaumont	5 MW/15 MWh	7/27/2023	No or low CO, VOC and HCN were measured near the containers.

EPRI BESS Failure Incident Database; Zhao 2024

Air quality was “typical” during the Moss Landing Battery Fire, but residents reported health issues

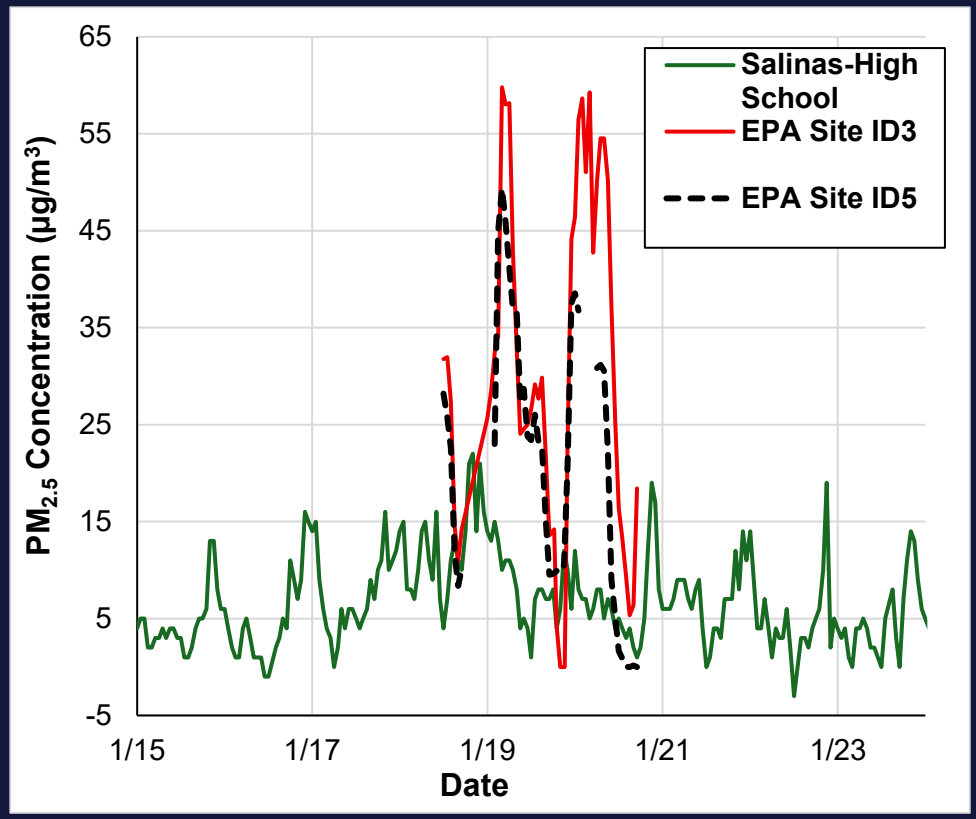
- Fire at Vistra's 300 MW / 1200 MWh Phase I BESS on 1/16/2025.
- Highway 1 closure and ~1,500 residents evacuated.
- EPA monitoring reported:
  - Max HF 71.2 ppb (well below 300 ppb threshold)
  - $PM_{2.5}$ within typical regional levels.
- Residents reported symptoms: headaches, sore throats, and metallic taste.

(Shmuel Thaler – Santa Cruz Sentinel)

https://www.readymontereycounty.org/emergency/2025-moss-landing-vistra-power-plant-fire/testing/air

There are gaps in the monitoring data

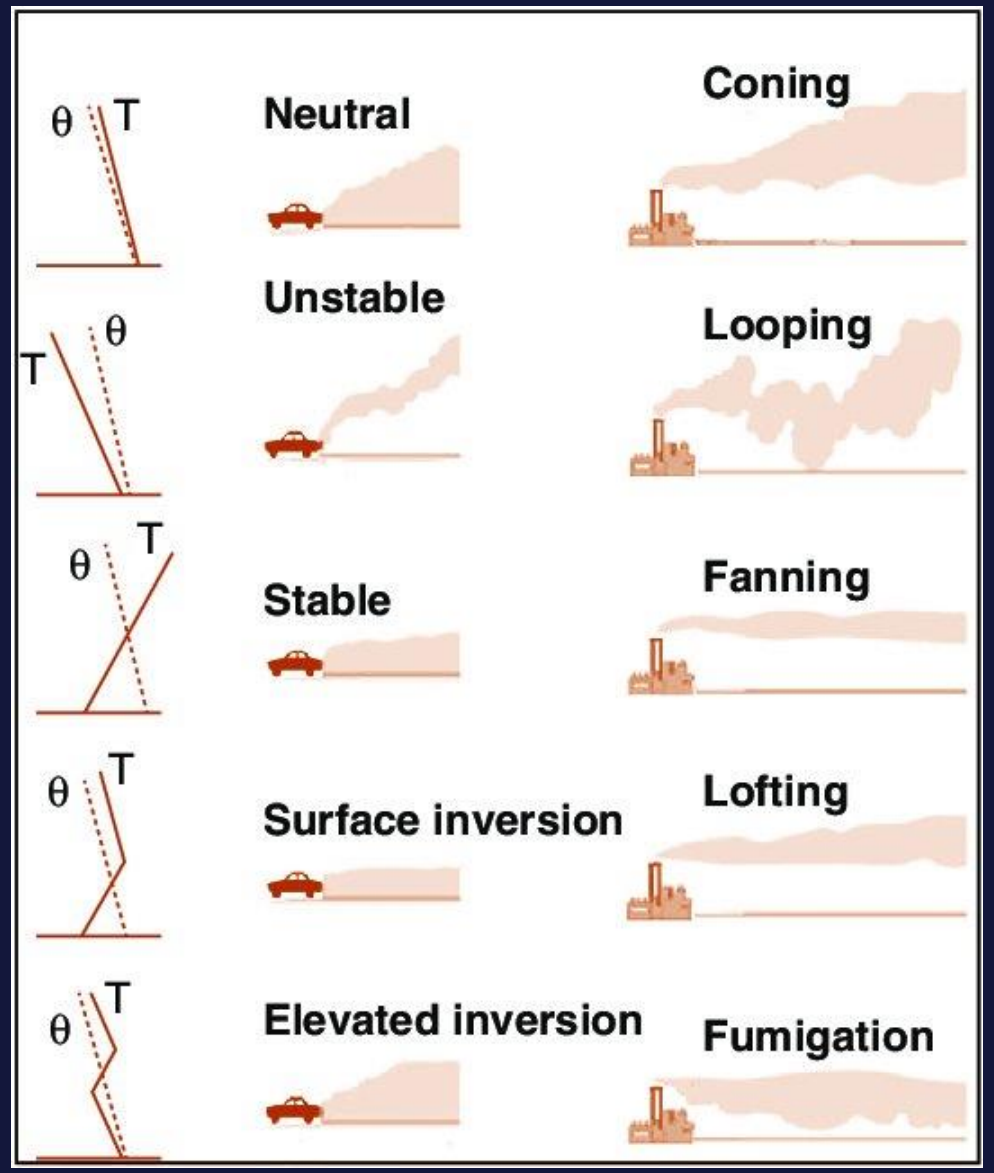
- $PM_{2.5}$ near Moss Landing may have exceeded regional norms.
- EPA monitoring did not measure particle size (e.g., nanoparticles) or chemical compositions (e.g., heavy metals).
- Soil samples ~2 miles from the site showed elevated heavy metals (Ni, Mn, Co).
- Additional data are needed to assess impacts on air, water, and soil.



https://www.readymontereycounty.org/emergency/2025-moss-landing-vistra-power-plant-fire/testing/air

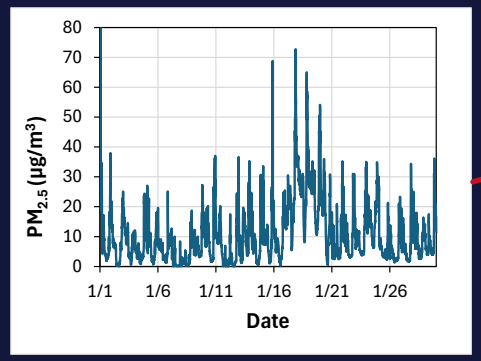
Broader gaps exist

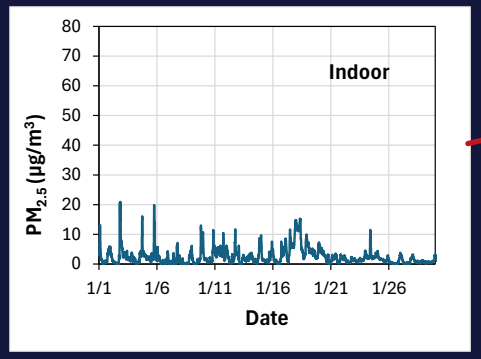
- Many BESS fires lacked real-time air quality monitoring.
- Instruments not always calibrated to federal reference/equivalent methods.
- Delayed measurements limit understanding of real-time exposure.
- Air quality index (AQI) does not capture toxic compounds unique to battery fires.
- Plume dispersion varies by fire behavior, wind, and atmospheric conditions.
- Distributed monitoring + dispersion modeling needed for community impact assessments.

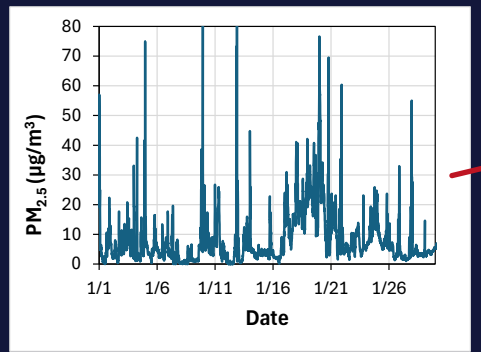


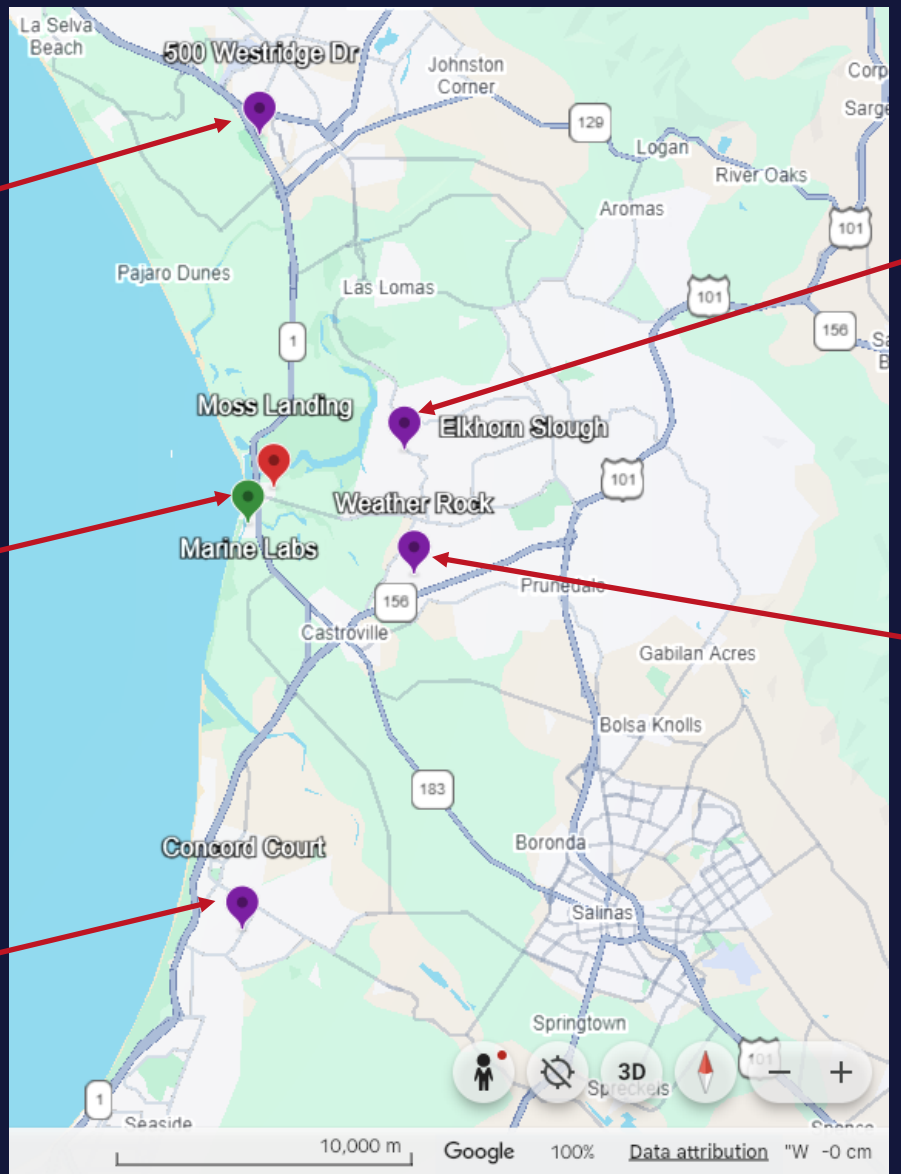
Chakraborty et al., 2018

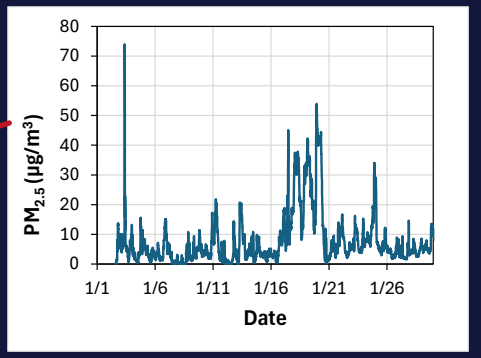
$PM_{2.5}$ from PurpleAir indicate fire impact.

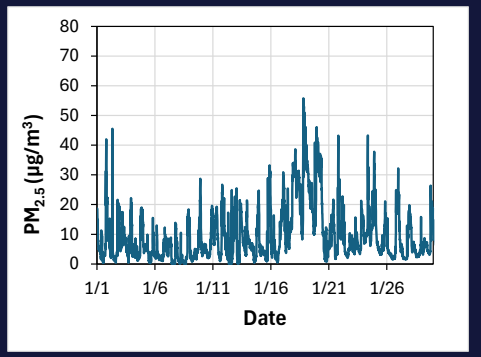












https://map.purpleair.com/

Are Li-ion battery fire emissions more toxic than other fires?

Average Emission Factors (mg/g fuel)

Fuel Type	HF	CO	CO_2	HCN	HCl	NO_2	SO_2	$PM_{2.5}$
LFP Flaming	24.8	35.1	1463		0.7	1.9	3.5	56
NMC Flaming	8.2	42.6	420	0.06	0.4			52
Furniture		41	890	1.3	0.37		6	
Polyurethane	0	30	1500	1.8	0	90	0	
Polyethylene	0	24	2800	0	0	1.7	0	
Electrical cables	8.3	180	560	22	54	8.8	9.7	
Municipal waste	0.02	32	1417		0.5	2.4	0.9	7.3
OEHHA REL (ppm)	0.3	20		0.3	1.4	0.25	0.25	

Notes:

1. Wide variability in emission factors.
2. The toxicity of many species (e.g., lithium compounds, fluoride gases) have not been evaluated.

Wang et al., 2023; Zhao 2024

Several factors affect health outcomes of air pollution

- Type and concentrations of pollutants
  - HF, CO, HCl, HCN, volatile organic compounds, $PM_{2.5}$, nanoparticles, metals
- Duration and frequency of exposure
  - Short-term: acute responses
  - Long-term: chronic diseases
- Individual Susceptibility:
  - Age and pre-existing health conditions

Additional considerations for Li-ion battery fires

- First responders face highest exposure risks.
- Fire suppressants may produce harmful byproducts (e.g., HF and per- and polyfluoroalkyl substances [PFAS]).
- Vulnerable populations (e.g., elderly, children, and pre-existing conditions) should take extra precautions.
- Particulate filters do not protect against toxic gases.

Summary

- Li-ion battery thermal runaways release a complex mix of toxic compounds, many with unknown health risks.
- While past incidents show low air quality impacts, more comprehensive data are essential.
- Rapid deployment of air monitors to detect key contaminants of concern around the fire site and in downwind communities, combined with dispersion modeling, can better inform emergency responses.
- First responders and vulnerable populations should take extra precautions with respiratory protection.

Contact: xiaoliang.wang@dri.edu

Thank you!

Complete After Event Survey