Electrification Impacts on Fire & Life Safety: Research Progress

4th EU Fire Safety Day, Zagreb, Croatia

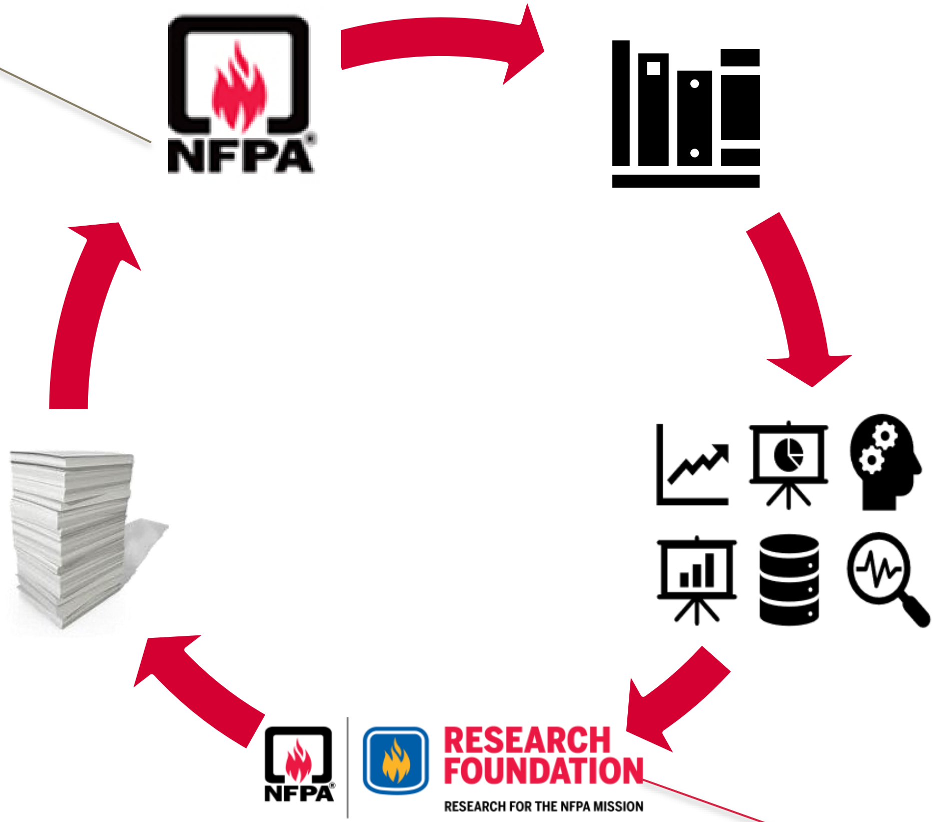
May 21, 2024 | Victoria Hutchison, Fire Protection Research Foundation

NFPA | RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

Who is FPRF? Our connection to NFPA

NFPA vision: Be the leading global advocate for the elimination of death, injury, property, and economic loss due to fire, electrical and related hazards.

NFPA mission: To help save lives and reduce loss with information, knowledge, and passion.



Mission: The Research Foundation's mission is to plan, manage and communicate research in support of the NFPA mission.

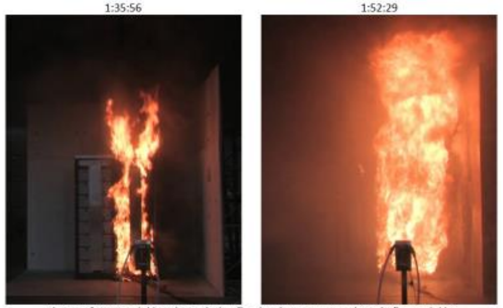
Vision: To be the premier global research delivery organization for the elimination of death, injury, property and economic loss due to fire, electrical and related hazards.

FPRF

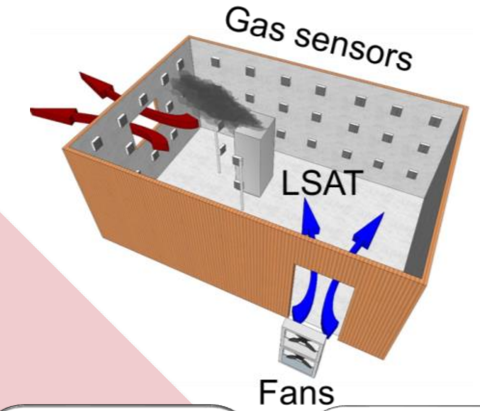
- Independent non-profit organization
- Formed by NFPA in 1982
- Intended to provide data to support the needs of NFPA codes & standards
- Research funds come primarily from:
  - Private/public sector consortia
  - Grants/gov't sources,
  - Other sources (including NFPA)

FPRF Battery Research & Resources

ENERGY STORAGE & SOLAR SYSTEMS
SAFETY TRAINING PROGRAM



Photos of NMC sprinklered test during fire development on main rack: first sprinkler operation (left) and peak heat release rate (right).



2011…
Li-ion Battery Hazard & Use Assessment Phase I & II
Emergency Response to Incidents involving EV Li-ion Battery Hazards
Workshop on Energy Storage Systems and the Built Environment

… 2016
Li-ion Battery Hazard & Use Assess. Phase III
Hazard Assess. of Li-ion Battery ESS – Full-scale Testing

2019
Sprinkler Protection Guidance for Li-ion Based ESS
&
SUPDET ESS Research & Design Challenge Proceedings

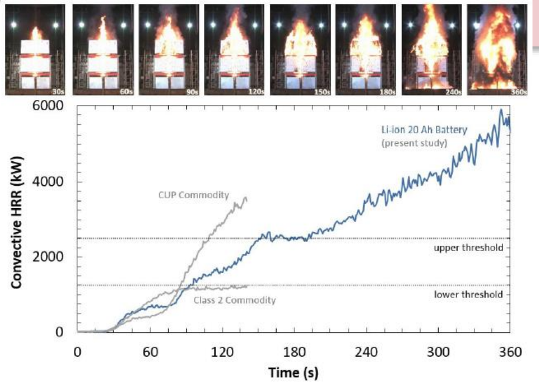
2020
FF Safety for Battery ESS
Lead Acid Batt Hazard Assessment
Modern Vehicle Hazards in Parking Garages & Vehicle Carriers – Phase I

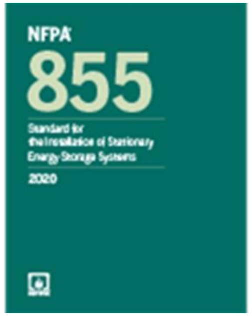
2021
Landscape of battery ESS hazards & mitigation strategies
Firefighter Safety for Firegrounds involving LIBs
ESS Landscape Workshop

2022
Assessment of EV FF Tactics and Techniques & the impact on Stranded Energy
Marine Transport of Battery Energy Storage Systems: Regulatory and Hazard Assessment

2023
Classification of Modern Vehicle Hazards in Parking Structures/Systems – Phase II
Environmental impact of LIB fires compared to other common fires
PPE contamination from LIB fires and cleaning best practices

2024
Development of Explosion control/prevention guidance for ESS installations
EV infrastructure near gas stations: risk assessment (upcoming)
Protection of battery manufacturing facilities (upcoming)





Launch of FPRF Energy Storage Research Consortium (ESRC)

 |

Battery Research at FPRF

Battery Focused Research

- **Battery manufacturing storage & assembly**
  - LIB Hazard & Use Assessment – Storage Protection
  - Protection Guidance for battery manufacturing/ assembly plants
- **Transport of ESS, EV, or other battery products**
  - Modern Vehicle Hazards on Marine Vessels - Ph I
  - BESS Marine Transport: Hazard Assessment & Regulatory Analysis
- **Electric Passenger Vehicles/Bus Fleets**
  - Hazard quantification/ spread characteristics
  - Protection Guidance for EV's (or mixed fuels) in parking garages and car stackers
  - Firefighting response tactics & impact on stranded energy (with training modules)
  - Characterization of E-Bus Fire Hazards & Bus Depot facility protection
- **Stationary Energy Storage Systems**
  - ESS sprinkler protection guidance
  - ESS Firefighter Safety
  - Landscape of BESS Hazards & Mitigation Strategies
  - Explosion Control Design Framework for ESS Installations
- **Battery Infrastructure**
  - Risk assessment of charging station placement near gas stations
- **LIBS/ESS on the Fireground**
  - FF Safety on Firegrounds involving LIBs
  - Environmental impact of LIB fires compared to other fuels
  - Improved PPE Cleaning Best Practices/Exposure Assessment (Ph 3) – LIB gear contamination

Green	**Active FPRF Project**
Yellow	**Proposed/Pending**
Red	**Recently Completed**

Battery Research at the Research Foundation

General Hazard Characterization

Heat Release Rate (HRR)

Fire load/ Fire behavior

Gas Release / Toxicity

Vapor Cloud Explosion

Fire Spread Potential

Impact on Infrastructure

Commercial Environments
(e.g., parking garages, warehouses, manufacturing plants)

Residential Environments
(e.g., home garages, etc)

Marine Environments
(e.g., RoRo's, containerships, ferrys)

Emergency Response Considerations

Tactical considerations
(e.g., various suppression strategies, cooling efficiency, impact on stranded energy risk)

Training

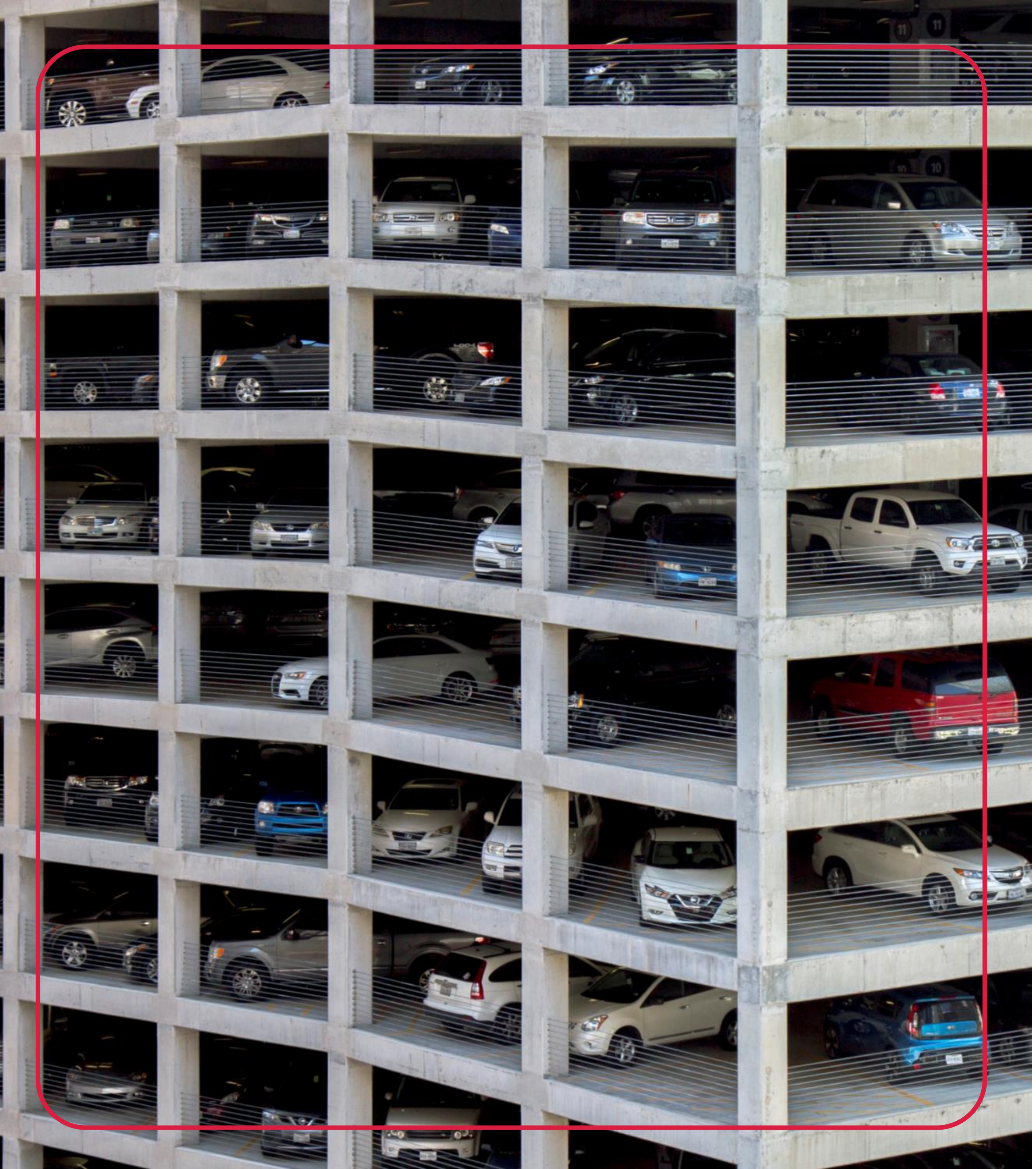
Frequently Asked Questions

- Are EV's more hazardous than ICE's? Do EVs and their charging infrastructure introduce greater risk to parking garages?
- What tools/techniques are available to the fire service for fighting EV fires; What is the impact on stranded energy? What are the recommended best practices?
- What is the environmental impact of li-ion battery fires compared to common fuels?
- Guidance for designing an ESS explosion control system?

EV’s in Parking Structures

Are EV’s more hazardous than ICE’s?

Do EVs/charging stations pose greater risk to parking structures?

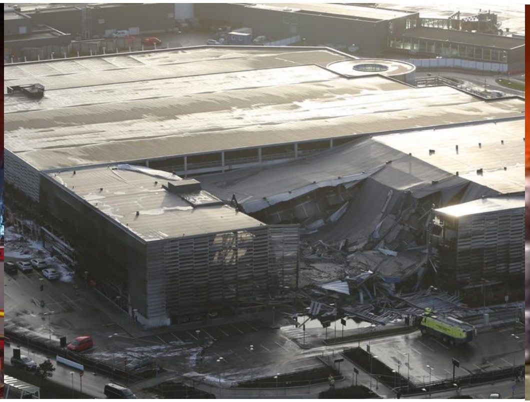


Parking Structures

- Historically,
  - Codes & standards assumed that: “In an open car park, a vehicle fire is likely to be constrained to the burning car or at most spread to one or two adjacent cars, before fire department response, and be able to be extinguished by the fire service”
  - Enclosed car parks were sprinklered, with successful performance experience
  - Open car parks did not require sprinkler protection
  - Had minimal loss history (deaths, injuries, economic loss)

Parking Structure Fire Experience

Liverpool, UK 2017



Stavanger, Norway 2020

Luton Airport, London, 2023

Felicity Ace RoRo Fire Incident

Electric Bus Depot Fire

Parking Garage fires are **relatively rare**. But have huge potential for **significant consequences** and **large economic losses** if left unmitigated.

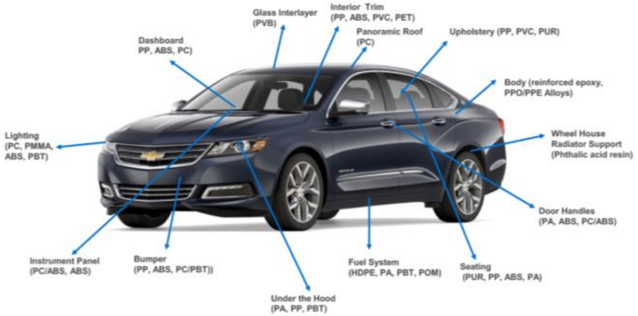
What's changing?

Larger vehicles

Denser Configurations

Less Vehicle Spacing

More Plastics



Alternative Fuels


Administration Priorities COVID Plan

BRIEFING ROOM

FACT SHEET: The Biden-Harris Electric Vehicle Charging Action Plan

DECEMBER 13, 2021 • STATEMENTS AND RELEASES

Vice President Kamala Harris to Announce Action Plan that Fast Tracks Bipartisan Infrastructure Law Investments

President Biden has united automakers and autoworkers to drive American leadership forward on clean cars, and he set an ambitious target of 50% of electric vehicle (EV) sale shares in the U.S. by 2030. Now, the Bipartisan Infrastructure Law will supercharge America's efforts to lead the electric future, Building a Better America where we can strengthen domestic supply chains, outcompete the world, and make electric cars cheaper for working families.

 |

Phase II Research: Has the hazard of modern vehicles changed?

FPRF recently:

- Conducted a comprehensive literature review changes in modern vehicles, parking garage design trends, and fire tests of modern vehicles, capturing all relevant data and aspects of the test that influence results
- Analyzed the test results in the context of parking structures/systems and developing protection guidance
- Created a database of all test data – available to the public to support design guidance
- Identify knowledge gaps or testing needs
- Develop a Research Plan for Full-scale Vehicle Fire Tests to fill identified gaps

Testing Information Table for each Reference

Vehicle ID	1	2	3	4
Reference No	1	1	1	1
Number of Tests	4	4	4	4
Testing Facility Information	RISE	RISE	RISE	RISE
Objective	Water spray fire suppression comparison of gasoline fueled and electric vehicles involved in fire			
Vehicle ID	1	2	3	4
Fuel Type	Gasoline	Electric	Gasoline	Electric
Vehicle Condition	New	New	Used	Used
Ventilation Conditions	Large Scale Calorimeter Lab			
Target Vehicles	Heat Flux and Temperature Measured			
Number of Target Vehicles	Sensors on all 4 sides	Sensors on all 4 sides	Sensors on all 4 sides	Sensors on all 4 sides
Ignition Type	Fuel Leak-Ignited	Battery Damaged-Ignited	Fuel Leak-Ignited	Battery Damaged-Ignited
Ignition Location	Leaked Fuel on the Floor	At the Battery	Leaked Fuel on the Floor	At the Battery
Ignition Source	Electronic	Electronic	Electronic	Electronic
Testing Time (min)				
Testing Conditions				
Burn Time	90	90	90	90
Sprinlers On (min)	1	13	1	17
HRR Chart	Link	Link	Link	Link
HRR Measurement Method	Calorimeter	Calorimeter	Calorimeter	Calorimeter
Peak HRR (kW)	7978	2944	5324	1975
Time to Peak HRR (min)	3	20	4	17
Total Heat Released (MJ)	5241	4510	4765	4474
Mass Loss Rate Chart				
Mass Loss Total				
Heat Flux (at Targets)	98-138	6-7	44-59	5-6
Heat Flux Curve	Link	Link	Link	Link
CO Curve	Link	Link	Link	Link
Oxygen Curve	Link	Link	Link	Link
CO2	Link	Link	Link	Link
Other Species				
Temperature Curve	Link	Link		
Temperature Location				
Flame Height				
Sprnklers	Yes	Yes		
Sprinkler Flow Rate (LPM)	372	372		

Resources available at:
www.nfpa.org/foundation

What does the data show?

ALL vehicle fires are NOT EQUAL…
challenging the hazard characterization and protection scheme recommendations

Latest Data Insights: EV vs ICE

1. **Impact of Ignition Methods on Heat Release Rates (HRR):**
   - **Internal Combustion Engine Vehicles (ICEVs):**
     - Typically ignited by puncturing and igniting fuel tanks, leading to high initial HRR due to a large pool fire.
     - This method creates a large spike in HRR.
   - **Battery Electric Vehicles (BEVs):**
     - Generally ignited inside the battery compartment, resulting in a lower initial HRR (slow growth).
     - Despite different peak HRRs, total heat release (HR) for ICEVs and BEVs is similar.
2. **Impact of Ignition Location:**
   - Ignition location significantly influences fire growth and HRR.
   - Example: Ignition at the driver’s seat with open windows can lead to fire spreading to adjacent vehicles, while closed windows can lead to self-extinguishment due to lack of oxygen.

 |

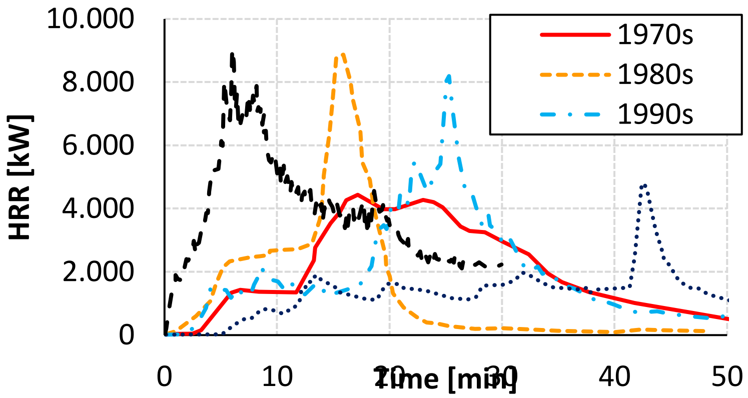
Latest Data Insights: EV vs ICE

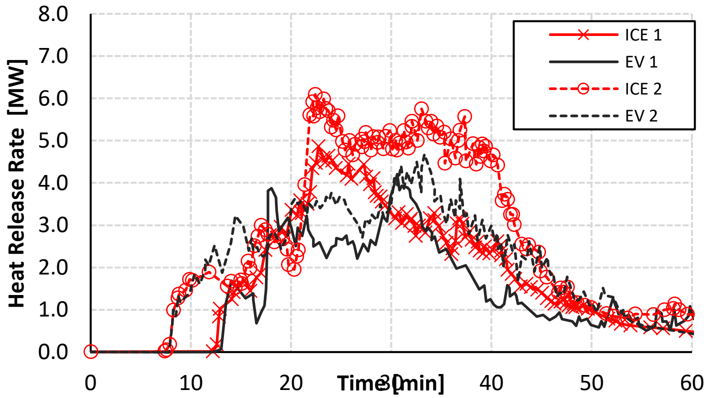
3. Heat Flux Measurements:

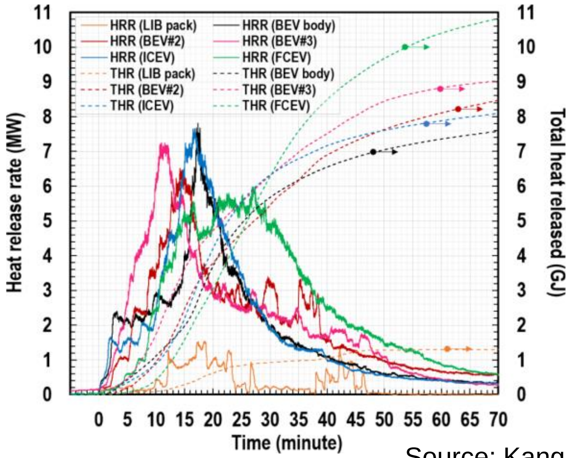
- Heat flux exceeding **25 kW/m²** can ignite nearby combustible materials.
- Vehicle fires, both ICEVs and BEVs, **often exceed this threshold**, suggesting a high risk of fire spread to adjacent vehicles.

4. Peak HRR and Total HR:

- Peak HRR varies widely across studies due to different test conditions. However, total HR and HR per unit mass showed **similar values** when comparing ICEVs and BEVs.
  - BEVs demonstrated **higher heat released per unit mass** compared to ICEVs when tested individually.







Source: Kang, 2023

Latest Data Insights: EV vs ICE

5. **Vehicle Composition and Fire Behavior:**
   - Older vehicles used in some tests might not fully represent modern vehicles, which have higher plastic content.
   - This difference may impact how test results apply to current vehicle fires.
6. **Fire Spread and Structure Impact:**
   - **Exposed Structures**: Studies showed vehicle fires could cause extensive spalling of concrete surfaces in structures like parking garages.
   - **Road Tunnels**: Tests indicated that BEVs might produce higher total HRRs, with the potential to cause structural damage in road tunnels.
   - **Steel Members in Parking Garages**: Tests suggested that vehicle type (ICEV, BEV, LPGV, NGV, FCEV) does not significantly impact the stability of unprotected steel members in fire scenarios.

 |

Latest Data Insights: EV vs ICE

7. Toxic Gas Emissions:

- Vehicle fires release various toxic compounds that may pose health risks to occupants and firefighters, including:
  - Heavy metals (cobalt, lithium, manganese, nickel)
  - Gases (carbon monoxide, carbon dioxide, hydrogen fluoride, hydrogen chloride, hydrogen bromide)
  - Etc.
- Toxic emissions come from both ICE and EV; concentrations of the specific emissions just differ.

 |

Latest Data Insights: EV vs ICE

8. **Sprinkler Systems**
   – Few tests included sprinklers, but those that did include sprinklers **shows that they can control the fire and prevent spread to adjacent vehicles**, although they likely will not achieve final extinguishment without fire service intervention.
   – Effective sprinkler design density to prevent vehicle-to-vehicle fire spread in parking garages is **not well-established**, indicating a need for further research and testing.
9. **Fire Spread in Stacker Configurations:**
   – Limited tests with and without sprinklers showed significant differences in fire spread. Sprinkler systems (OH2 equivalent) managed to control the fire and prevent it from spreading to an upper vehicle in a stacker setup.

EV vs ICE: Similarities and Differences

EV

- ✓ Potential toxic gas release
- ✓ Possible vapor cloud explosion
- ✓ Intense jet like, highly directional flames, can burn for extended period of time
- ✓ High temp. flames (~1000+ C)
- ✓ High HRR: can be up to 8 MW
- ✓ **Battery cell debris** projectiles possible during **thermal runaway**
- ✓ **Reignition Risk**

ICE

- ✓ Potential toxic gas release
- ✓ Possible deflagration risk (from fuel)
- ✓ Intense flames – often short lived following suppression
- ✓ High flame temperatures (~1000+ C)
- ✓ High HRR ~ can be up to 8 MW
- ✓ Risk of releasing debris during fire

 |

Hazard Comparison Summary: EV vs ICE

	EV	ICE
Fuel Source	Lithium-ion Batteries	Gasoline
Fire Causes	Puncture, overheating, overcharging, over-discharging	Fuel or oil leak, overheating, worn out parts, loose electrical components
Likelihood	*** 25.1 fires/100,000 cars sold ***	1,529.9 fires/100,000 cars sold
Suppression Time	~ 60 – 90+ min	~ 30 min
Water Usage	Reports of up to thousands of gallons; Sustained water supply needed	~500 gallons
Reignition Potential	Likely, and very common	Rare
Fire Size	Can be large if propagation occurs, Avg HRR: 1.5 – 8^{+} MW Avg THR: 5.9 GJ	Typically limited to 1 vehicle; propagation is less common Avg HRR: 6.5 MW – 8 MW Avg THR: 5.9GJ

** not based on national statistical data

 |

Hazard Characterization Summary: EV vs ICE

	Electric Vehicles (EV)	Internal Combustion Engine (ICE)
Toxicity of Runoff	Water runoff had a pH of **7.3 - 7.7** copper, antimony, and higher concentrations of manganese, nickel, cobalt, hydrogen fluoride, and lithium	Water runoff had a pH of **2.6 - 2.8** Higher concentrations of lead, copper, polycyclic aromatic hydrocarbons, and volatile organic compounds, testing showed higher toxicity towards aquatic species
Special Post-Fire Considerations	Often towed and recommended to be placed **50 ft away** from all surroundings (due to reignition risk)	Vehicles/engines should be inspected to see how much damage was done to determine if repairs can occur
Additional Hazards	**Stranded energy**, electrocution, second responders, projectiles and explosions, propagation, toxic gas release	Toxic gas release, lots of combustible fuel still accessible to the fire (i.e., a full gas tank)

Vehicle Type	Ignition Scenario	Sprinkler Density (mm/min)
ICE	Fuel Tank Rupture	0
~~ICE~~	~~Fuel Tank Rupture~~	~~4.1 (light)~~
ICE	Fuel Tank Rupture	8.1 (OH2)
ICE	Fuel Tank Rupture	6.1 (OH1) or 12.2 (EH1)
BEV	Battery Puncture	0
~~BEV~~	~~Battery Puncture~~	~~4.1 (light)~~
BEV	Battery Puncture	8.1 (OH2) or 12.2 (EH1)
~~BEV~~	~~Battery Puncture~~	~~8.1 (OH2)~~
ICE	Compartment	0
~~ICE~~	~~Compartment~~	~~4.1 (light)~~
~~ICE~~	~~Compartment~~	~~6.1 (OH1)~~
~~ICE~~	~~Compartment~~	~~8.1 (OH2)~~
BEV	Compartment	0
~~BEV~~	~~Compartment~~	~~4.1 (light)~~
BEV	Compartment	8.1 (OH2)
BEV	Compartment	6.1 (OH1) or 12.2 (EH1)

Next Steps

- 3 Critical Gaps Identified:
  - Most critical variables for fire growth/spread;
  - Sprinkler Hazard Classification; and
  - Protection for Stacker and Automated Parking Structures.
- Next Step: Full-scale Testing
- Goal: To better characterize vehicle fire hazard and spread potential; develop sprinkler protection guidance.
- Proposed to test 9 vehicles (ICE and EV)
- Ignition Locations
  - ICE: 1 in compartment; 1 fuel tank rupture
  - EV: 1 in compartment; 1 battery puncture
- Sprinkler Density:
  - Start with 0.2 gpm/ft2 or 8.1 mm/min/m2 (aligned with current requirement in NFPA 13 – OH Group 2)
  - Based on results, in future tests, consider a sprinkler hazard class higher or lower depending on whether the performance of the initial density is "successful" in preventing fire spread or not.

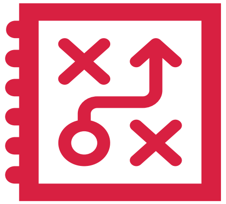
Emergency Response for EVs

Current FF Practice for EVs

Current best practice for EV fires:

Apply copious amounts of water onto the battery/source of the fire for an extended period of time.

Water remains the primary suppression method because it is simple, effective, and easy to access/use.



Some challenges exist:

Required amount of water typically exceeds the amount stored in the tank of a fire truck.

Thousands of gallons of water may be required; can be difficult to get this quantity of water from hydrants/other source

This traditional suppression method can take several hours to fully put out an EV fire and has been shown to still result in reignition.

Using copious amounts of water on EVs can cause water runoff, which can be highly toxic and hazardous due to the chemicals leached from the batteries.

FPRF Research on EV FF Tactics to Address Critical Gaps

DHS/FEMA AFG Award: EMW-2021-FP-00948

RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

ESRG ENERGY SAFETY RESPONSE GROUP

FIRE & RISK ALLIANCE

Research/Testing Focus:

- Are the traditional approaches optimal?
- What other options are available?
- How do they perform in comparison, in terms of damage reduction, fire extension, resources required, etc?
- What is the impact of various suppression tactics on post-incident reignition risk?

Assessment & Expected Outcome

The analysis identified several utilized/proposed approaches to extinguishing EV fires:

Water	Fire Blankets	Specialized Equipment	Flood Barriers and Submersion	Experimental Techniques	Letting it Burn

Outcome = Assessment of each FF strategy on:

Extent of Fire Propagation; Fire/Incident Duration; Resources needed (e.g., quantity of water or other tools); Risk to Fire Service by Applying Tactical Approach; Impact on Stranded Energy Risk; Etc.

 |

Cell Level

21 cell-level Tests

- Cells from 3 unique manufacturers
- Measurements of critical cell parameters, e.g., **venting and thermal runaway temp**, **gas production** and **composition**, **SOC**, etc. will be used to rank cell specific hazards based on quantitative results.
- Repeatability of test outcomes

Module Level

22 module-level tests:

- Cell to cell propagation rate
- Scaled effects of SOC
- Thermal runaway propagation control approaches.
- Impact of fire blanket on gas production/ failure propagation

Pack Level (cold flow)

9 pack-level cold flow tests

- Pre-test assessment of OEM battery enclosures
- Cold flow tests using battery pack shells and vehicles mock-ups. Define assessment of FD tactics by:
  - Approach orientation
  - Height & Distance
  - Stream type
  - Pressure/Flow rate
- Comparison based on total water delivery and penetration efficiency

Pack Level (hot flow)

13 pack-level hot flow tests

- Baseline measurements of unsuppressed fire
- Two suppression approaches selected from cold-flow tests, and a transitional/ combination attack plan
- Post test analysis
  - Structural failures
  - Thermal runaway propagation/damage
  - Flame extension
  - HRR, heat flux
  - Stranded energy
  - Effect of fire blanket

Full-Scale

4 full-scale vehicle tests

- **Test 1**: Free Burns
- **Test 2**: Water-only suppression approach developed per suppression efficiency analysis in Series 2 tests.
- **Test 3**: Direct injection/submersion, using best performing flow from Series 2 tests.
- **Test 4**: Fire blanket, based on best performing application approach from Series 2 tests.

\+ Post Test Stranded Energy Assess.

Environmental Impact of Li-ion BESS incidents compared to other fires

- **The overarching goal** of this research program is to evaluate the environmental impact (air, water, and soil) of a lithium-ion ESS fire compared to other types of fires.

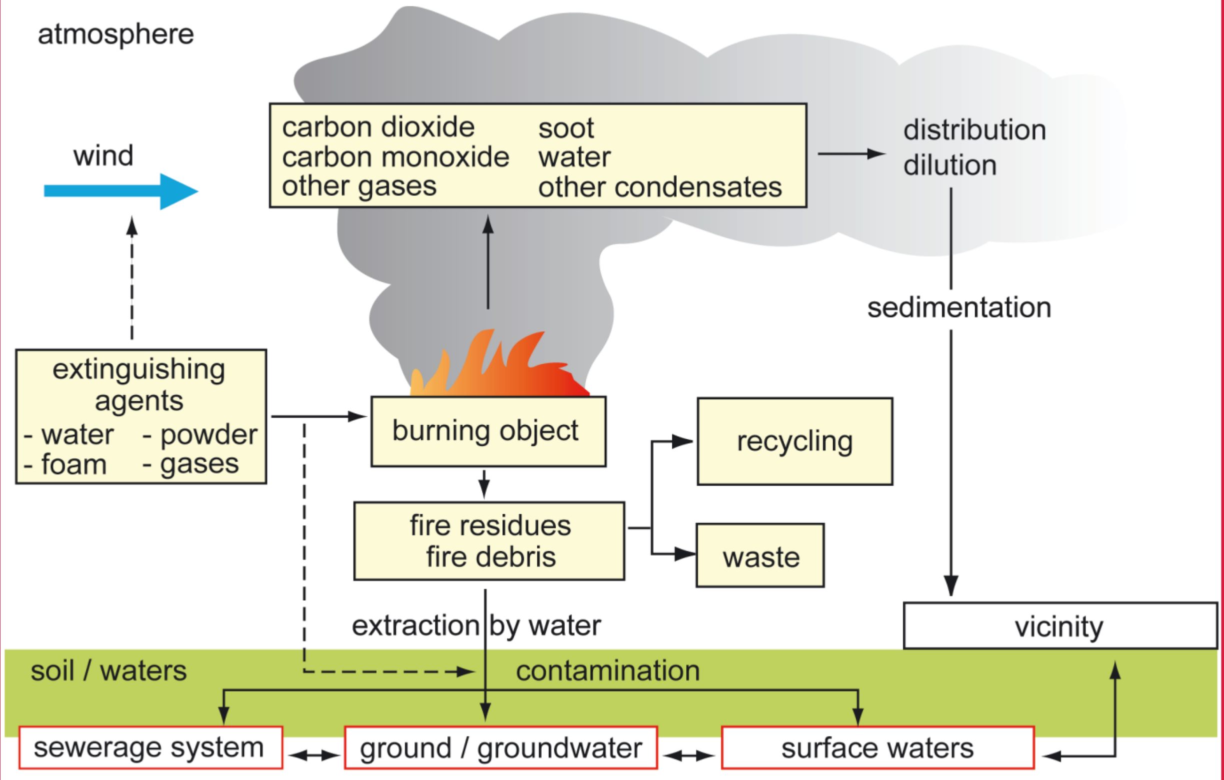
- **This phase will** develop a report that provides an overview of the existing literature on the environmental impact of lithium-ion battery ESS fires compared to other common fires and document the knowledge gaps.

Tasks

(Part 1) Task 1.1: Literature Review
• Identify pathways of toxic contamination from fire to air, water, soil
• Characterize material composition of ESS systems
• Scenario Identification (LIB scenarios, other common scenarios)
• Review literature and compile available test data on toxic gas products, concentrations, emissions, and particulates to the air, water and soil from
    • Li-ion battery ESS
    • Other common fire scenarios

Task 2: Data collection (build on emissions database)
Task 3: Gap Analysis/Research Plan
(Part 2): Experimental Testing/Analysis

Environmental Hazards of Li-ion Battery Fires



Environmental impact

Fires can cause wide-ranging pollution through air transport (smoke plume) and local contamination through fire residues.

Environmental Impact of Firefighting

Extinguishing efforts can spread pollutants further, contaminating nearby areas, water and soil.

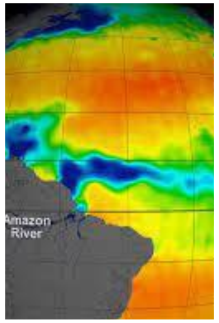
Lithium-ion Battery Failure to AIR

Toxic Emissions

Battery fires release dangerous gases, like hydrogen fluoride, which is highly toxic and can severely harm the respiratory system when inhaled.

Particulate Matter.

Battery fires emit fine particulate matter that harms respiratory and cardiovascular health and can degrade air quality over wide areas.



Planetary Impact.

Battery fires release greenhouse gases, contributing to global warming, with the gas composition varying by battery type and fire conditions.

 |

LIB Plume Activity Data - Limited

Lithium-ion battery warehouse fire in Morris, IL, USA, 2021

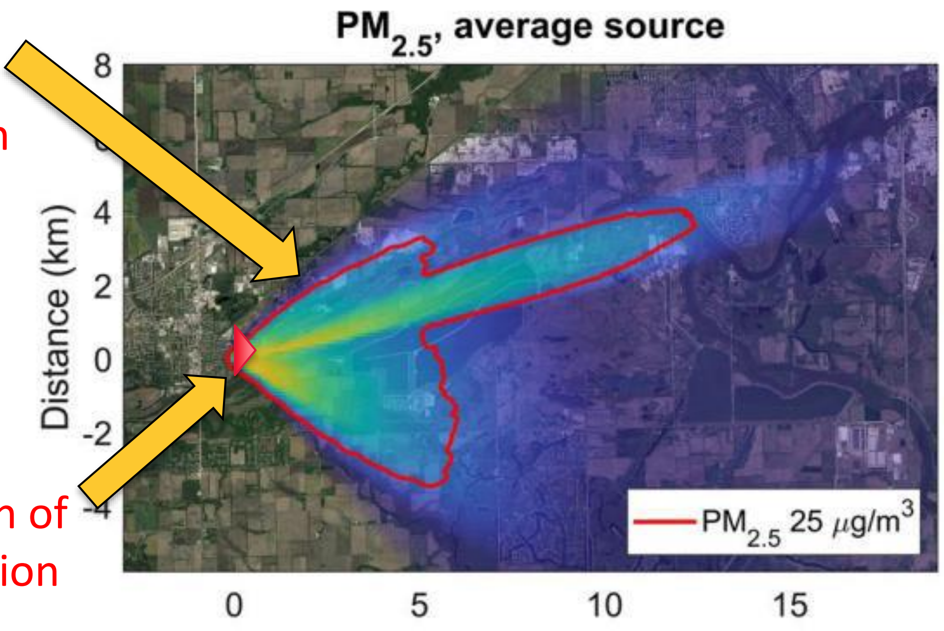
"In June…a warehouse…with roughly 184,000 pounds of lithium [ion] batteries caught fire."

Takeaway: First Responders reacting to Air Contamination may underestimate the impacted area.

Data Gap: There are limited studies with field experimental data for plume activity and analysis of gas present prior to visible plume particulates.

Red Line is Action Level Concentration from plume rise and dispersion model

Approximation of Event Evacuation Area



Lithium-ion Battery Failure to SOIL

Soil Contamination

Battery debris and firefighting water can lead to soil contamination, harming ecosystems and reducing fertility.

Bioaccumulation

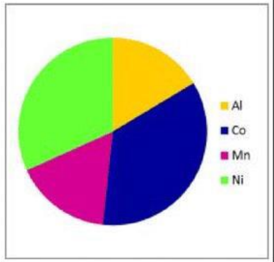
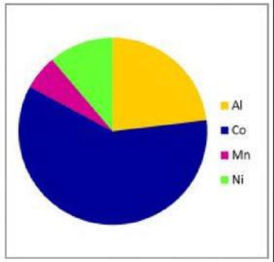
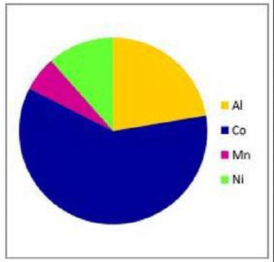
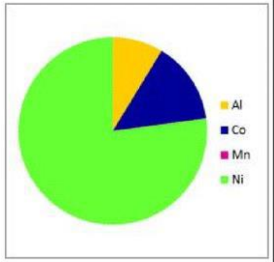
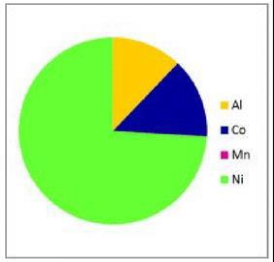
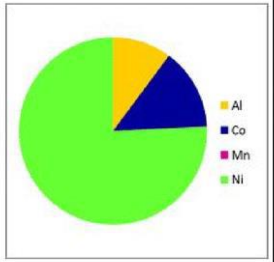
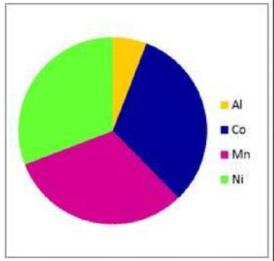
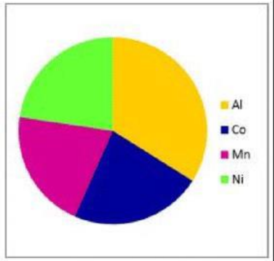
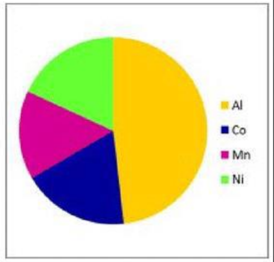
Toxic substances from batteries can build up in soil, enter the food chain, and cause health issues in wildlife and potentially humans through bioaccumulation.

Remediation

Soil remediation can be costly, requiring removal of contaminated soil, chemical treatments to neutralize toxins, or barriers to halt further spread.

 |

Lab experiments show metals in the smoke

	Metal from smoke particulate collected on the filter via the air sample pump	Metal Residues from swabbing the most obvious residues near the positive end of cell	Metal Residues from swabbing elsewhere
Cell A			
Cell B			
Cell C			

Al
Co
Mn
Ni

https://pubs.rsc.org/en/content/articlehtml/2023/ya/d2ya00279e


ROYAL SOCIETY OF CHEMISTRY

Check for updates

View PDF Version | Previous Article | Next Article

DOI: 10.1039/D2YA00279E (Paper) Energy Adv., 2023, 2, 170-179

Experimental determination of metals generated during the thermal failure of lithium ion batteries†

Jonathan E. H. Buston *, Jason Gill, Rebecca Lisseman, Jackie Morton, Darren Musgrove and Rhiannon C. E. Williams
HSE Science and Research Centre, Harpur Hill, Buxton, Derbyshire SK17 9JN, UK. E-mail: jonathan.buston@hse.gov.uk

Key takeaway: Metals generated during thermal runaway can contaminate the surrounding areas, and finer particulate can be easier inhaled posing health hazards.

Data Gap: There are no published studies with field experimental data for soil contamination, this study is the closest approximation

Lithium-ion Battery Failure to WATER

Runoff

Using water to put out battery fires can create runoff contaminated with heavy metals, acids, and toxins, which may harm aquatic life and risk entering the human water supply.

Immersion

Hazardous chemicals like lithium and cobalt can leach into water, contaminating it for drinking, agriculture, and wildlife.

Long Term Pollution

Contaminants settling in sediments can disrupt water body ecosystems, making cleanup difficult and costly through extensive water treatment.

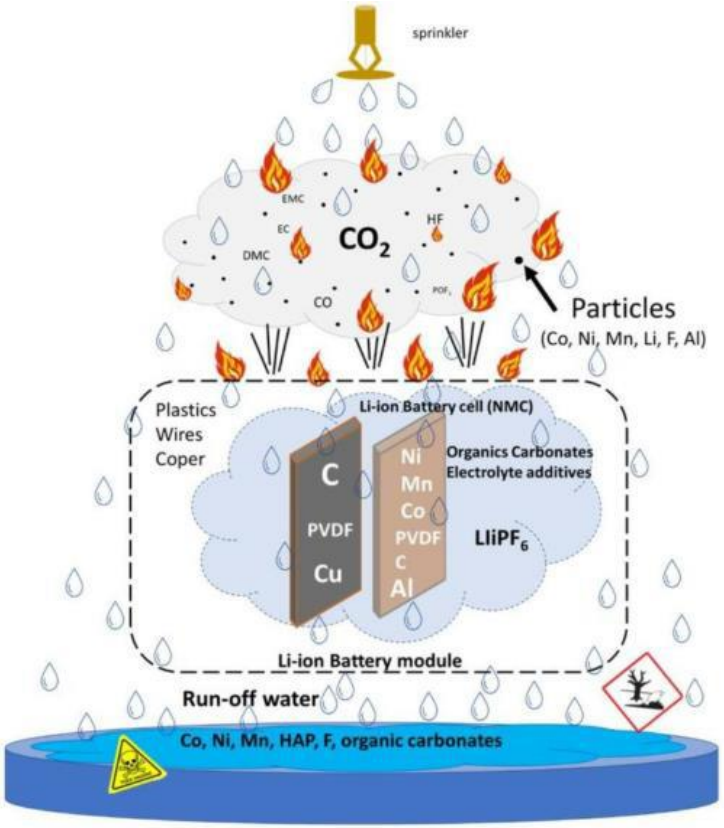
 |

batteries MDPI

Article

Assessment of Run-Off Waters Resulting from Lithium-Ion Battery Fire-Fighting Operations

Arnaud Bordes, Arnaud Papin, Guy Marlair *, Théo Claude, Ahmad El-Masri, Thierry Durussel, Jean-Pierre Bertrand, Benjamin Truchot and Amandine Lecocq



Batteries 2024, *10*(4),118;
https://doi.org/10.3390/batteries10040118

Contaminants in FF Water

INERIS in France analyzed the composition of run-off waters of NMC Li-ion modules under thermal runaway

No Ignition vs. Ignition

- Firefighting water contained:
  - Ni, Mn, Co, Li and Al from electrode composition
  - Liquid compounds from the electrolyte
  - Polycyclic Aromatic Hydrocarbons (PAH) gaseous species

- When there is ignition, the water is highly concentrated in PAH, and cathode metals.
- When there is no ignition, there are more liquid organic compounds.

LIB ESS Environmental Impact Research Program

Outcome

- Assessment of the environmental impact (to air, water, and soil) of a lithium-ion ESS fire (including runoff from suppression activities) compared to other common types of fires.
- Phase II testing effort to fill knowledge gaps

Final Report, forthcoming (Late Summer 2024)

Lead by:

NFPA | RESEARCH FOUNDATION Research for the NFPA Mission

INERIS maîtriser le risque pour un développement durable

Sandia National Laboratories

Funded by: FPRF Energy Storage Research Consortium (ESRC) Members

ESRG ENERGY SAFETY RESPONSE GROUP

FIRE & RISK ALLIANCE

FM Global

Southern Company

TESLA

Fike

gm

Pacific Northwest NATIONAL LABORATORY

UL Research Institutes

WÄRTSILÄ

Explosion Control Guidance for BESS Installations

Background

- Deflagration hazards in general have existed for a long time and have been extensively researched.

- **Challenge applying to BESS:** Explosions involving lithium-ion batteries are different because they typically involve a more complex mixture of gases, smaller very obstructed geometry, different mechanisms for gas release, and random hard-to-avoid ignition sources.

- **Gap in Guidance:** The standards most commonly used for explosion control (NFPA 68 and NFPA 69) were written before BESS deflagration hazards were known and do not provide adequate guidance for practitioners to take a consistent approach to provide for BESS explosion mitigation.

Project Overview

- **Overarching Goal and Scope of Research Program**: To develop guidance on how to design an explosion prevention/control system to prevent or minimize an explosion hazard for li-ion battery ESS applications.
- **Phase Goal**: This phase will focus on compiling the available information, establishing a design framework and identifying key knowledge gaps for future testing needs.

Tasks
Task 1: Literature Review • Review of ESS installation types needing explosion prevention/control • Review of international codes/standards • Summarize explosion prevention/control system strategies for BESS applications • Summarize available calculation methods • Review of literature/test data of li-ion ESS explosion hazards
Task 2: Data collection and database development (e.g., data needed for applicable calculations)
Task 3: Establish a framework for Explosion Prevention/Control Design Considerations for BESS installations
Task 4: Gap Analysis / Research Plan

- **Design Framework Considerations:**
  - Categorization of ESS Designs
  - Design Strategies
    - Passive/Active/Fail-Safe
  - Benefits/Limitations/ Applicability of chosen strategy
  - Framework Development
    - Parameters for analysis
    - Thermal management
    - Structural integrity considerations
    - Data/Info Sources
  - Implementation Strategy
    - Integration, monitoring, evaluation
  - Regulatory Compliance and Best Practices

LIB ESS Explosion Control Design Guidance Research Program

Outcome

- Report that provides guidance on how to design an explosion prevention/control system to prevent or minimize an explosion hazard for li-ion battery ESS applications.
- Standalone Design Framework
- Database for testing framework, or validation purposes
- Research plan for Phase II testing effort to fill knowledge gaps.

Final Report, forthcoming (September 2024)

Lead by: NFPA | Research Foundation – Research for the NFPA Mission

ESRG Energy Safety Response Group; The Hiller Companies; Hazard Dynamics

Funded by: FPRF Energy Storage Research Consortium (ESRC) Members

ESRG Energy Safety Response Group; Fire & Risk Alliance; FM Global; Southern Company; Tesla; Fike; GM; Pacific Northwest National Laboratory; UL Research Institutes; Wärtsilä

Thank You!

Victoria Hutchison
Fire Protection Research Foundation | Research Project Manager
vhutchison@nfpa.org | +1 617 984-7741 | www.nfpa.org/foundation

RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION