FIRE & RISK ALLIANCE

Indoor BESS Case Study & Fire Protection Design Considerations

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10/17/2024

INTRODUCTION

Karli Steranka, P.E.

- B.S. Fire Protection Engineering (UMD)
- M.S. Fire Protection Engineering (UMD)
- 5+ years fire protection experience
    - Li-ion Battery Hazards
    - Computational Fluid Dynamics Modeling
    - Industrial Hazards

Agenda

01. Introduction

02. Lithium-Ion Battery Uses & Hazards

03. Codes and Standards

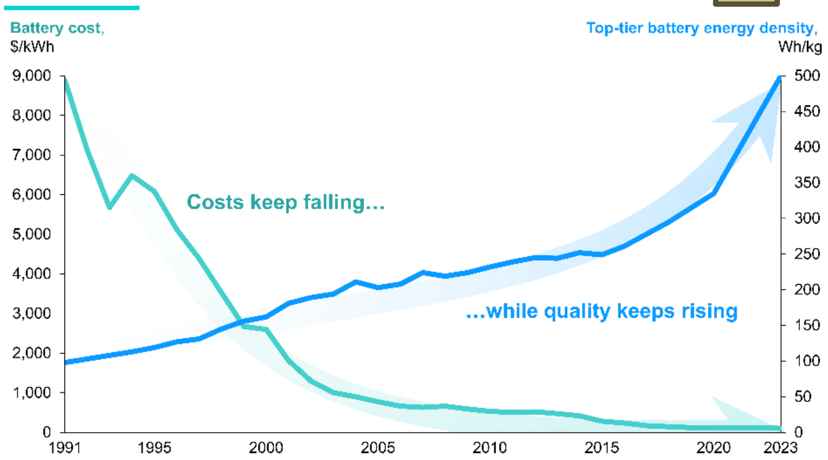
- UL9540A Overview

04. Case Study

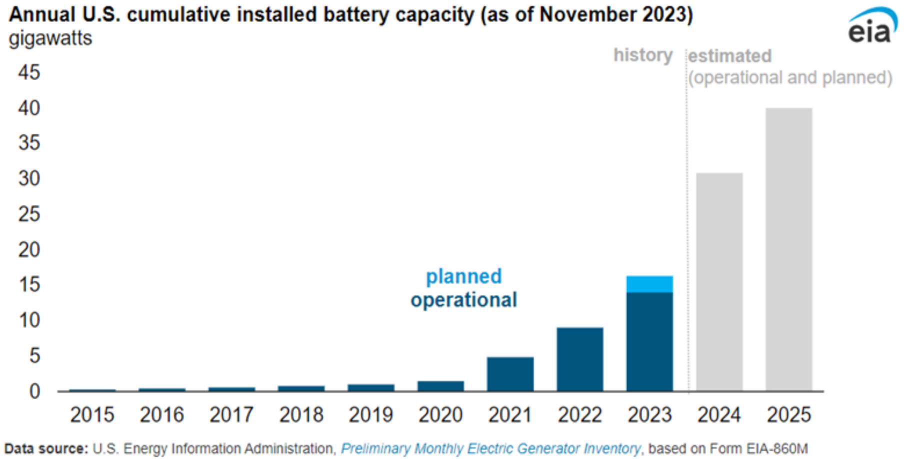
- Original Installation Fire Protection Features
- Failure event and consequences

WHY NOW?

High Energy Density Creates Demand



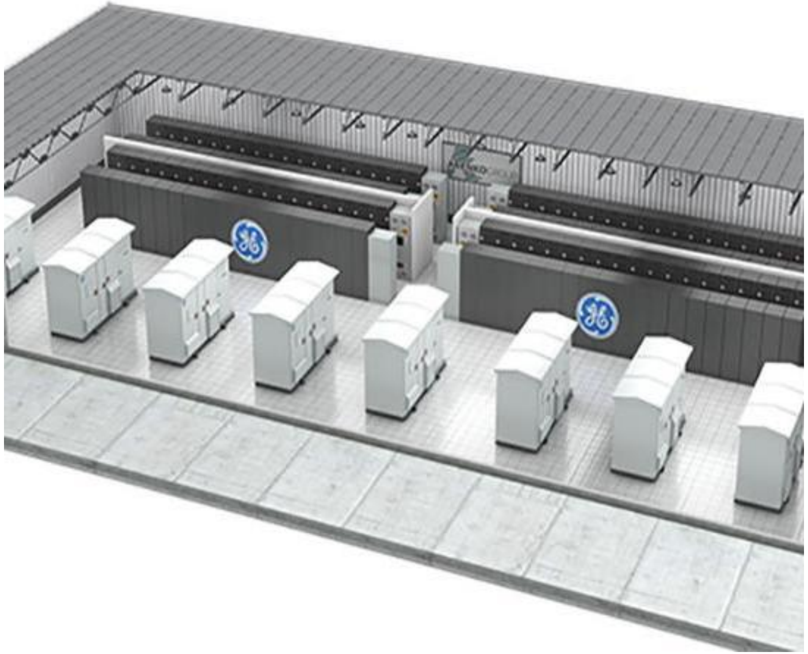
Source: Ziegler and Trancik (2021), Placke et al. (2017) for 1991-2014; *BNEF Long-Term Electric Vehicle Outlook* (2023) for 2015-2022 and the latest outlook for 2023 (*) from the BNEF Lithium-Ion Battery Price Survey (2023)



Scaling Lowers Cost

BESS USE CASES

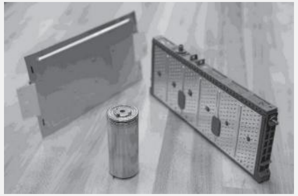
- Uninterruptable Power Supply (UPS) / back-up power
- Store energy from PVs
- Charge EV's
- Peak shavings
- AND MORE



Dedicated Use Building

Non-Dedicated Use Building

BESS INFORMATION: CELL → SYSTEM



Cell

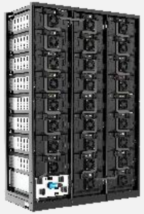
Cell-level integration

Cell testing and screening

Module

Module-level integration

Module testing



Unit

Unit-level integration

Unit testing

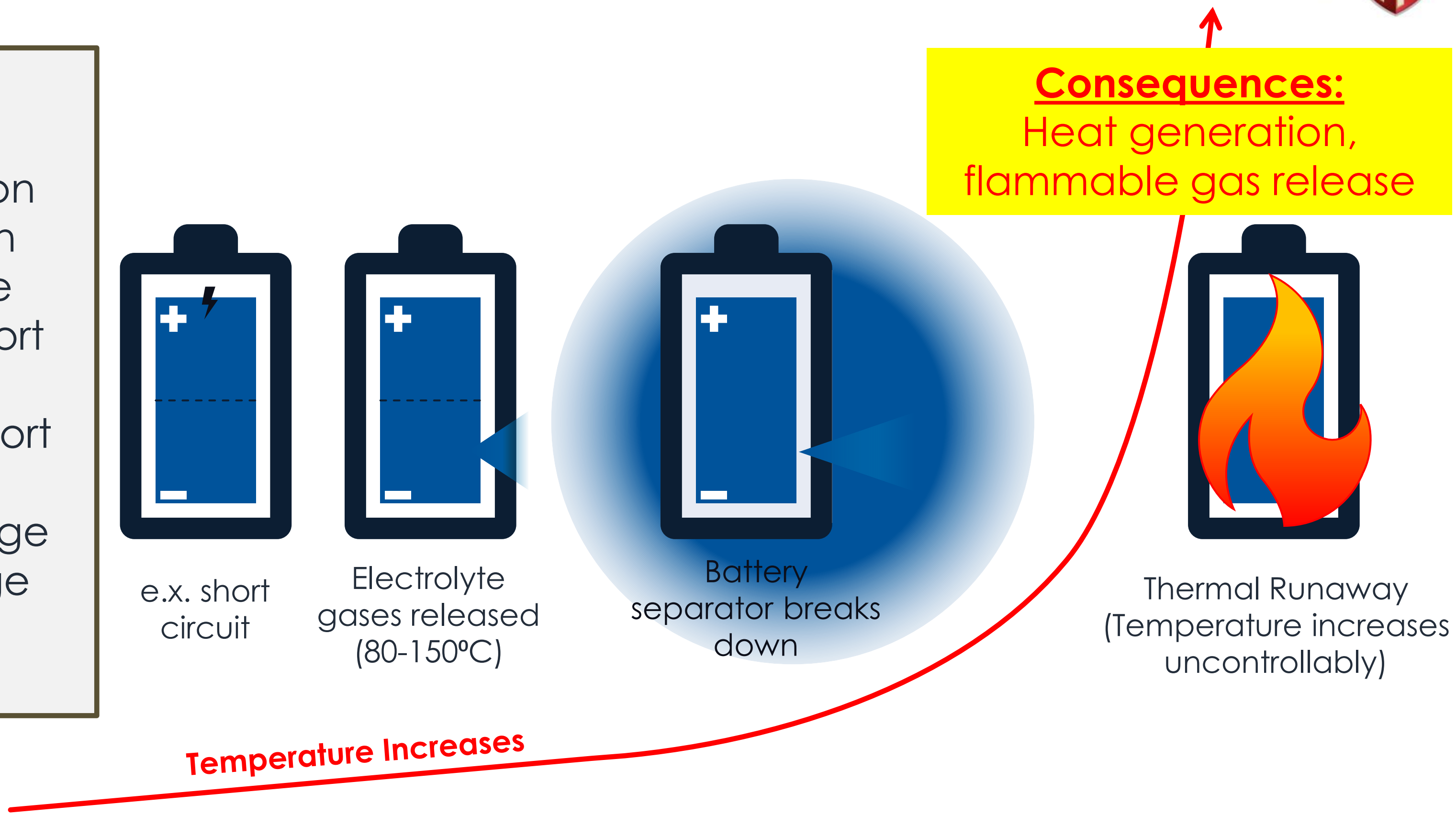
Battery System

Includes BMS, detection, suppression

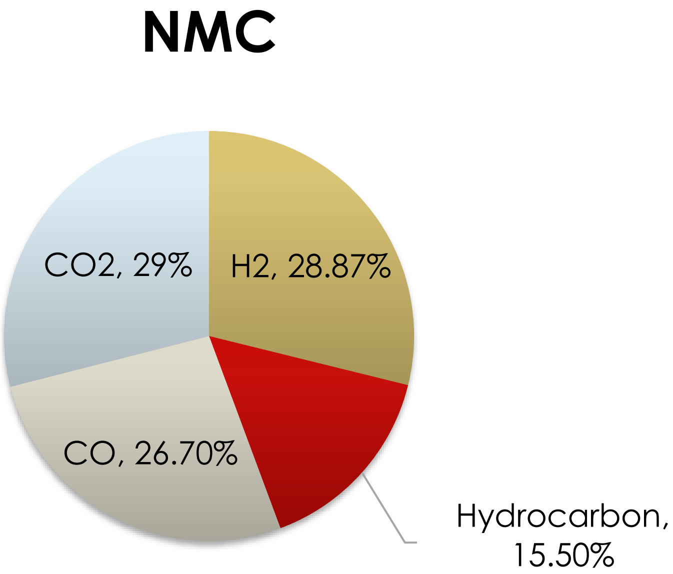
THERMAL RUNAWAY

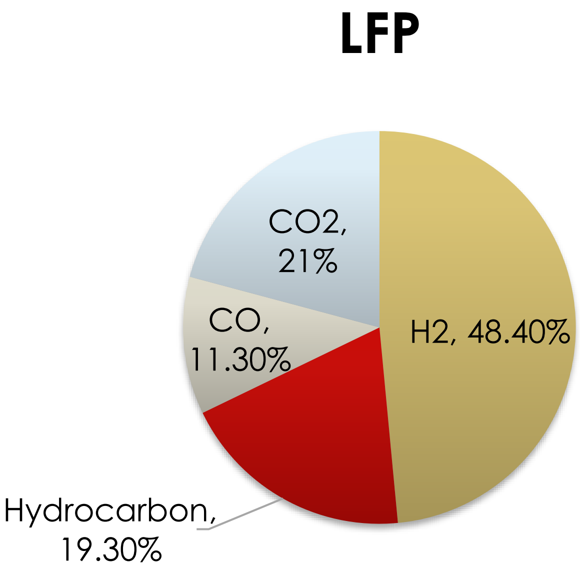
Causes:

- Physical Abuse
  - Deformation
  - Penetration
- Electrical Abuse
  - Internal Short Circuit
  - External Short Circuit
  - Over voltage
  - Overcharge
- Manufacturing Defects



BATTERY GAS COMPOSITION

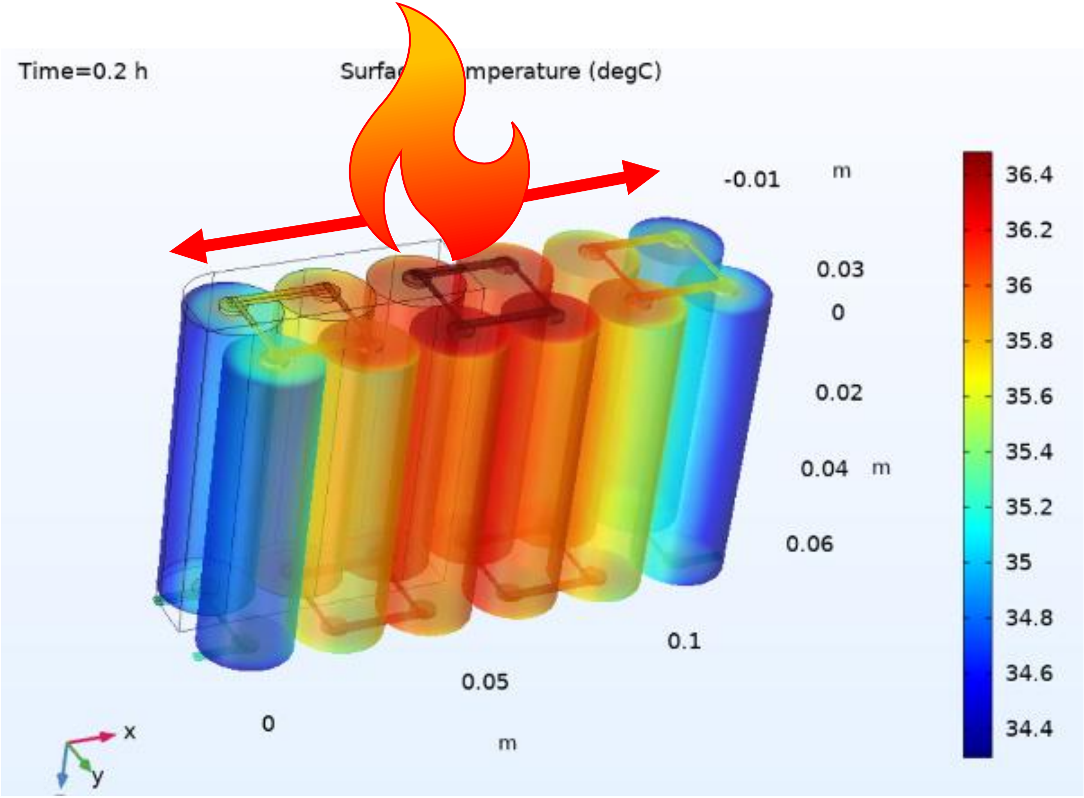




Varies between cell chemistry and form factor

THERMAL PROPAGATION

Cell-to-Cell temperatures can increase without combustion of flammable gasses and in oxygen deprived environments



LI-ION BATTERY HAZARDS

INSTALLATION CONDITIONS IMPACT

Unenclosed

Enclosed

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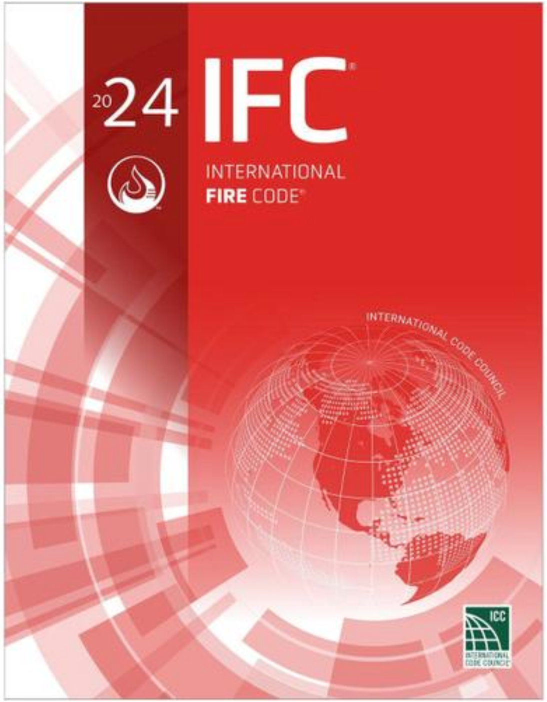
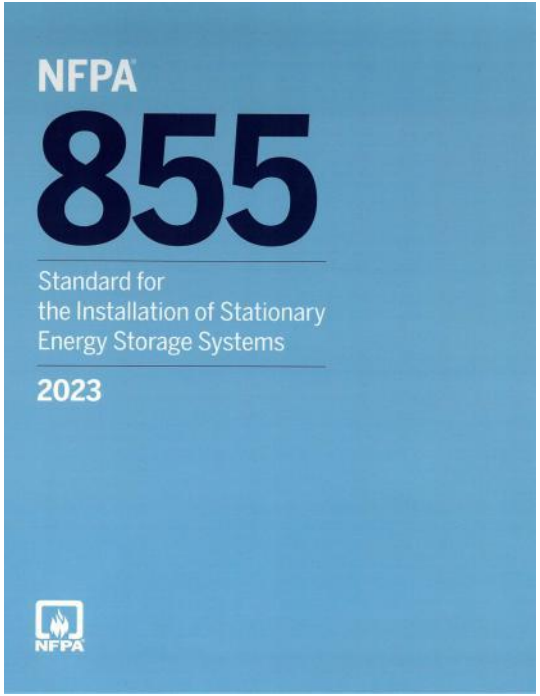
BESS IN THE FIRE CODES





technology development far outpaces codes and standard development

BESS INFORMATION: STANDARDS


UL 1642

STANDARD F

Lithium Batte

STANDARD FOR

ANSI/CAN/UL-19
in Stationary, Vel
Light Electric Rai

ANSI/UL 1973-2018

ANSI/CAN/UL
9540A:2019

JOINT CANADA-UNITED STATES
NATIONAL STANDARD

STANDARD FOR SAFETY

Test Method for Evaluating Thermal
Runaway Fire Propagation in Battery
Energy Storage Systems

ANSI/UL 9540A-2019

Standards Council of Canada
Conseil canadien des normes

- Cell certified to IEC 62619 (UL 1642)
- Module Certified to UL 1973
- Rack Certified to UL 1973
- BMS Certified to IEC 61508
- System Certified to UL 9540
- Cell, Module, Rack, Installation tested to UL 9540A

UL9540A Overview

STEP 1

BATTERY CELL

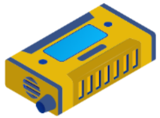
Key Results

- Thermal Runaway Temperature
- Venting Temperature
- Vent Gas Composition
- Vent Gas Volume
- Lower Flammability Limit
- Max. Explosion Pressure
- Gas Burning Velocity

Performance Criteria

- Thermal runaway not induced
- Vent gas not flammable

STEP 2



MODULE

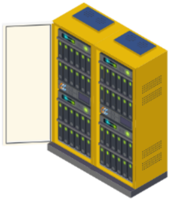
Key Results

- Propagation
- External Venting/Flaming
- Heat Release Rate
- Smoke Release Rate
- Gas Composition
- Gas Volume
- Mass Loss

Performance Criteria

- Thermal runaway is contained
- Vent gas not flammable

STEP 3



UNIT

Key Results

- Propagation
- External Venting/Flaming
- Heat Release Rate
- Smoke Release Rate
- Gas Composition
- Surface Temperatures
- Heat Flux

Performance Criteria

Varies depending on the intended application/test configuration

STEP 4

INSTALLATION

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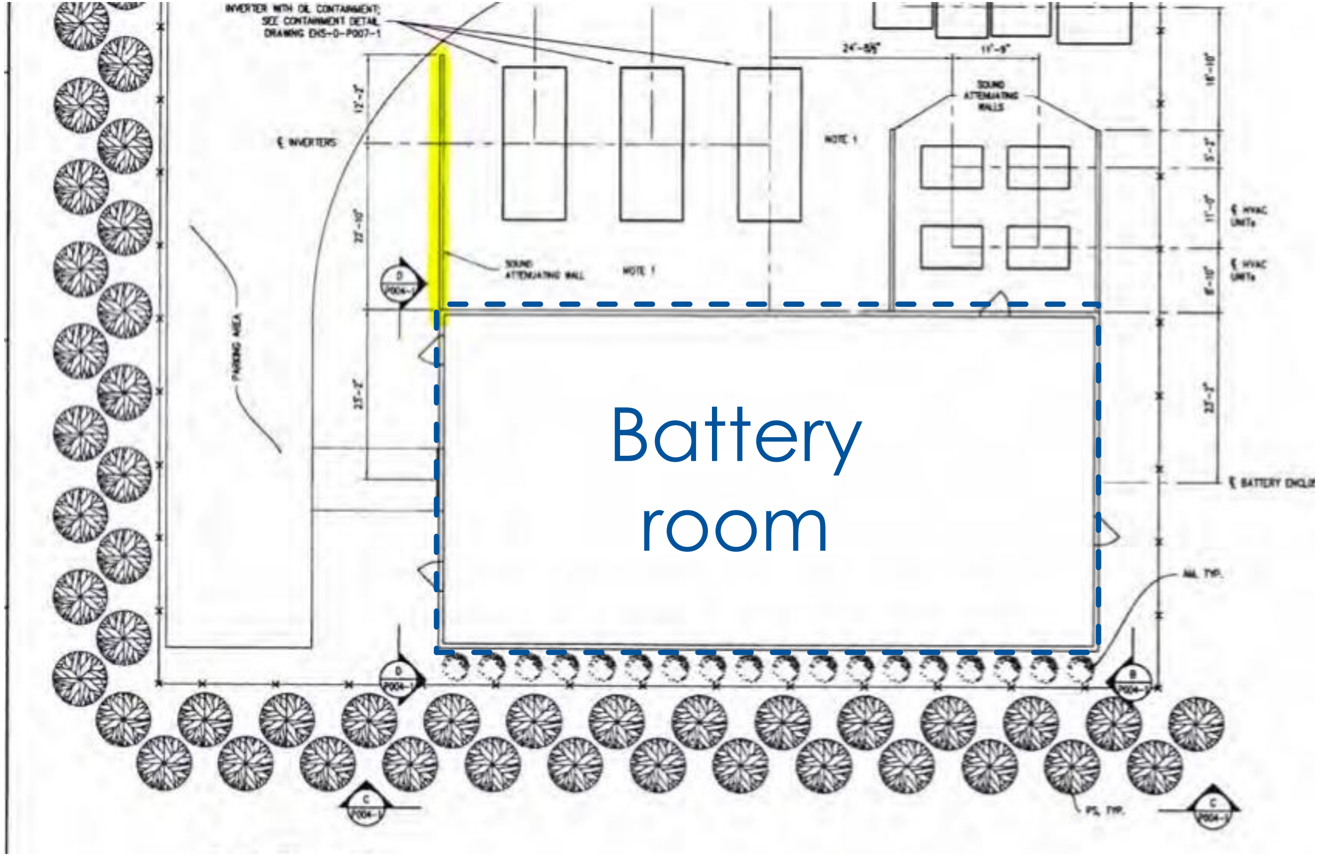
CASE STUDY: INDOOR 5MW BESS; ~4,000 SF



FIRE PROTECTION DESIGN STRATEGY

Monitor & Prevent

- BMS monitors cell conditions (voltage, temp, etc.)
- BMS automatically keeps the system within safe operation range (e.g. charging, discharging)

Control Fire & Explosion

- Pre-action sprinkler System
- Explosion prevention (NFPA 69 mechanical exhaust)

Alert & React

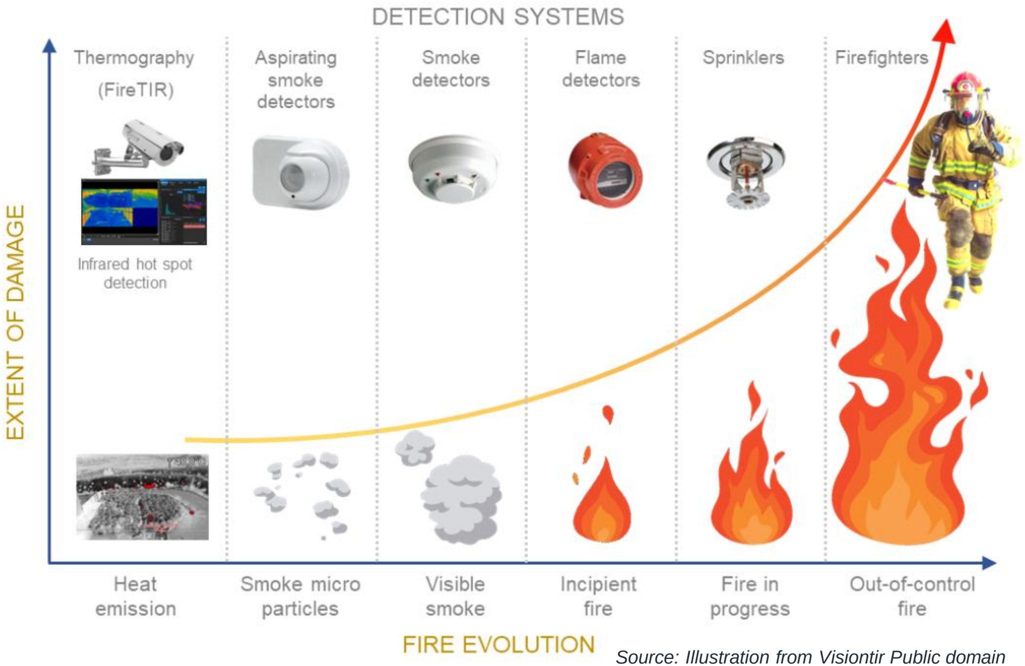
- Alarm upon detection (vesda & gas detection)
- Automatic shutdown and disconnect

Limit Exposures

- Fire rated walls
- Emergency response
- Limit combustible

ALERT & REACT

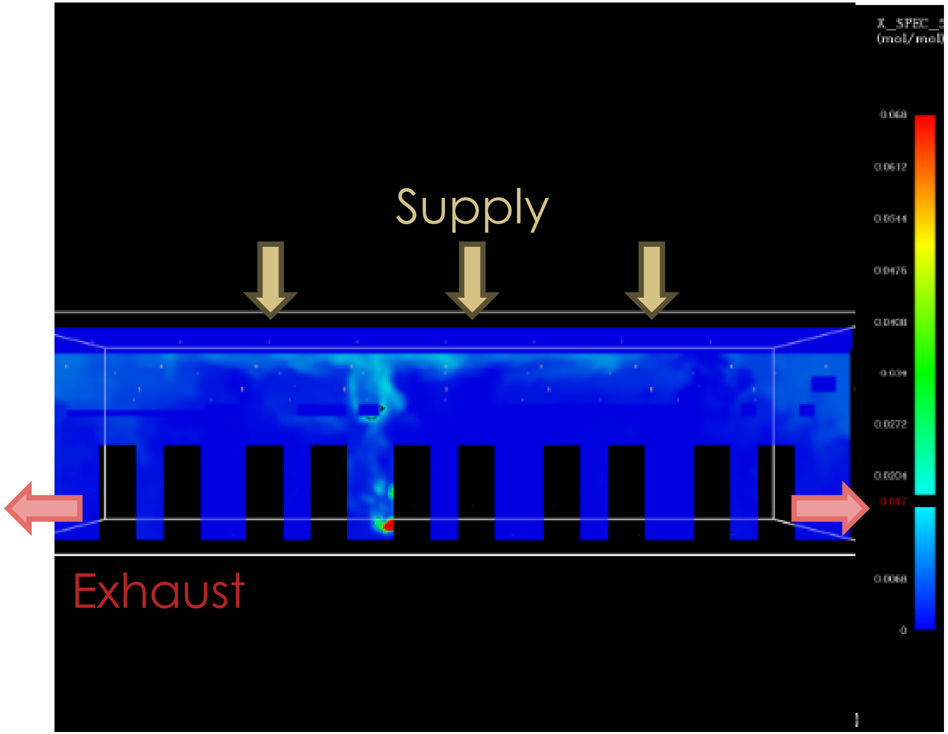
- Smoke and Heat Detection
  - Air aspirated smoke detection (large spaces)
  - Spot-type smoke detector
  - Heat detection (integrated into battery packs)
  - Radiant Heat/ IR (outdoor applications)
- Gas Detection



Source: Illustration from Visiontir Public domain

Early warning gives time for defensive response tactics

EXPLOSION CONTROL DESIGN



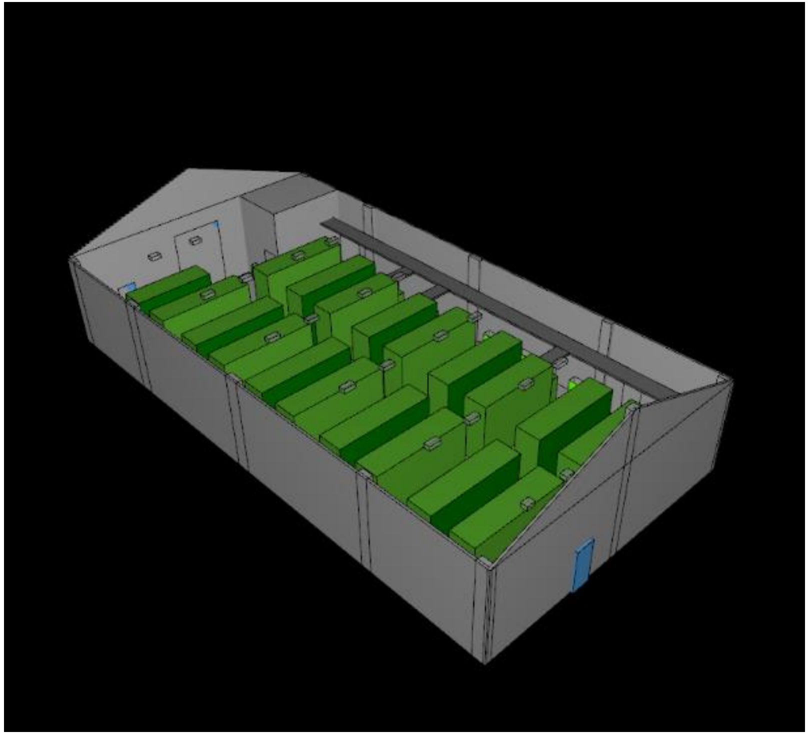
Room equipped with emergency ventilation system (NFPA 69)

Design:
- ~10 CFM/sqft airflow

Initiation:
- Gas detection system

Design Performance:
- maintain combustible concentration of gas within the room < 25% of LEL
- Average gas concentration < 3% LEL
- Local concentration > 25% LEL
- Partial volume deflagration analysis showed no damage to room

FIRE CONTROL DESIGN



Room equipped with pre-action closed head sprinkler system

Design*

- Ordinary hazard 0.2 GPM/sqft
- Standard response

*newer systems we typically recommend extra hazard design

Initiation:

- Vesda gas detection activates solenoid
- Heat/ temperature actives sprinkler link

Design Performance

- Sprinkler system activates sufficiently early to limit fire spread
- Plastic module coverings
- Adjacent module thermal runaway

FIRE EVENT MAY 2023

Detection Performance:
- VESDA and gas detection system successfully activated
  - Detection lines compromised during event

Explosion Protection Performance:
- Successfully mitigated explosion hazard

Actual Sprinkler Performance:
- Likely caused propagation
  - Non-IP rated battery cells
- Entire room sprinkler operation
  - < 0.2 GPM/ft^2

A battery energy storage system caught fire in May at the electrical substation

FIRE EVENT MAY 2023

"have extensive fire protection systems, which responded immediately to an incident"

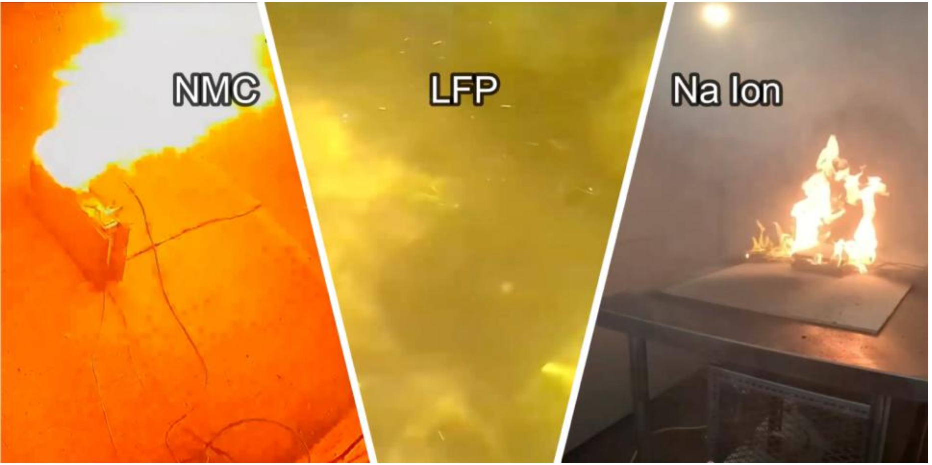
Event Key Takeaways:

- Damage limited to the room of origin
- Fire was successfully detected
- Entire room sprinkler system operation
- No explosion occurred

A battery energy storage system caught fire in May at the electrical substation

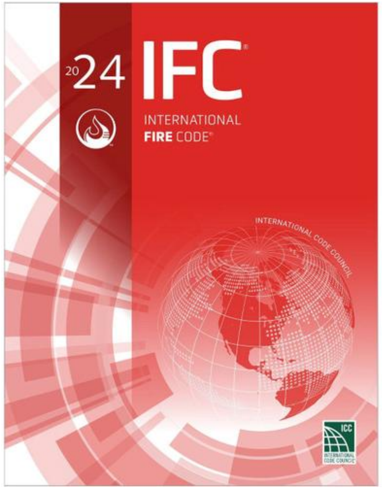
Suffolk County Tax Map Viewer

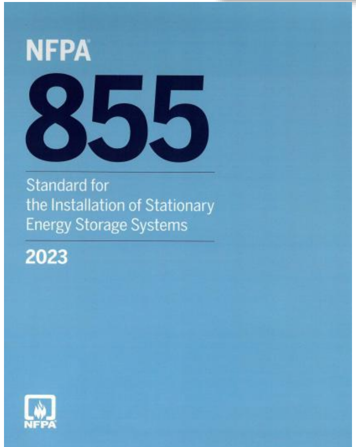
KEY TAKEAWAYS



- **Thermal runaway is the uncontrollable increase in temperature in a battery cell**
  - Thermal runaway can release flammable & toxic gases
  - Propagation can occur in the absence of oxygen & without flaming combustion

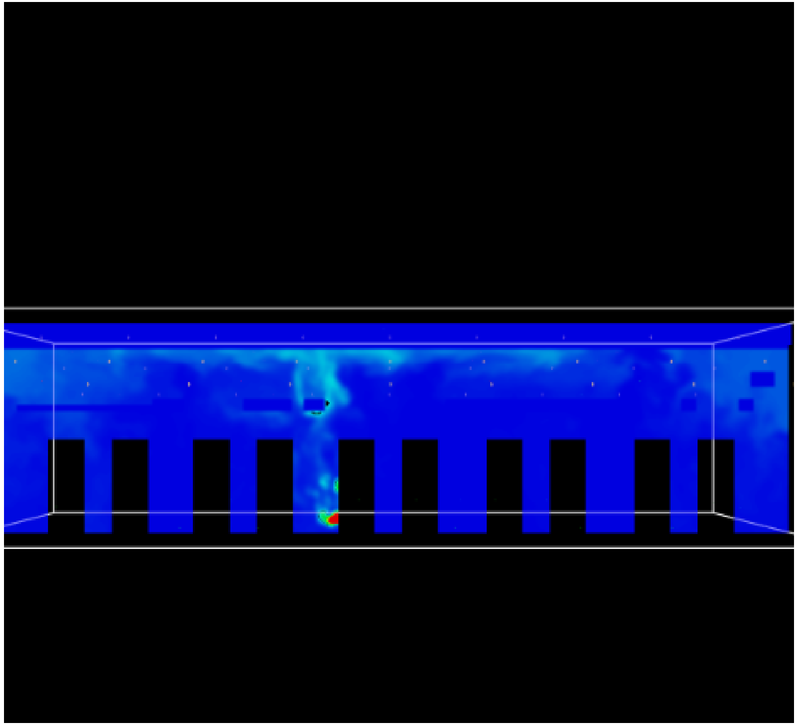
KEY TAKEAWAYS





- **Codes & standards are still being developed to properly protect these hazards (recommend using most recent editions)**
    - Certifications are important to ensure quality of batteries

KEY TAKEAWAYS



- **Wholistic fire protection design is important to mitigate the consequences of a thermal runaway event**
  - Prevention, detection, notification, fire control, explosion control
  - Proper design, implementation & maintenance can limit damage

FIRE & RISK ALLIANCE

Questions?

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