

TEXAS A&M ENGINEERING



EXTENSION SERVICE

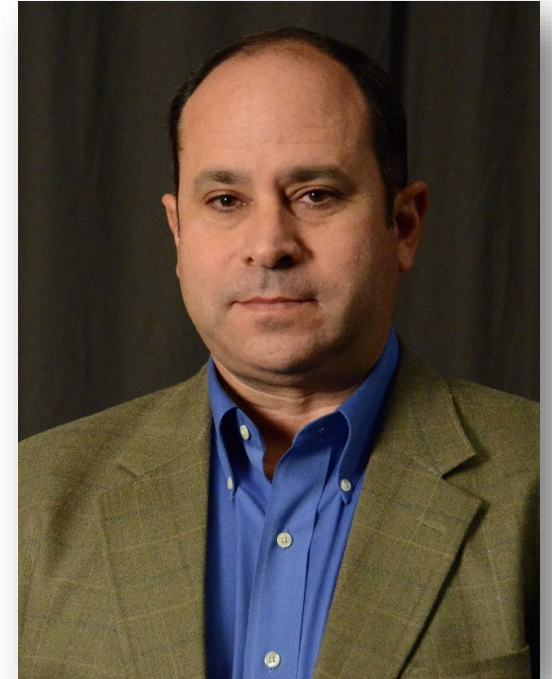
Lithium-Ion Batteries and All Things Energy

2025 TFCA Annual Conference

Gordon Lohmeyer, CFPS / PI

Gordon Lohmeyer is the Assistant Agency Director for the Texas A&M Engineering Extension Service, Responsible for Strategic Initiatives & Business Strategy. Gordon is a graduate of Blinn College, Sam Houston State University, San Jacinto College and the LBJ School of Public Affairs

Gordon's fire service career has spanned over 34 years, beginning in the Private Sector, where he served as the Fire Chief for Texas Petrochemicals at their Houston, Baytown and Lake Charles facilities. He is a past representative of Channel Industries Mutual Aid (CIMA), one of the largest industrial mutual aid organizations in the world. Gordon joined TEEEX in 2004 and has served in numerous roles during the past 20 years. Gordon serves on 12 NFPA Technical Committees, is the Vice Chair of the Texas Industrial Emergency Services Board and is a member of the IFSTA Executive Board.



Session Objective

During this session, we will discuss our Energy use and storage capabilities for the State, the future of energy, thermal runaway events, Battery Energy Storage Systems (BESS) case studies, legislation that has been introduced during is session and conclude with recent research TEEX conducted, where Li-Ion batteries were forced into thermal runaway and contamination was measure pre and post cleaning of protective clothing.

Li-Ion Consumer Products



**IDEAL FOR
MECHANICS**



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EEEX
EXTENSION SERVICE

Li-Ion Emergency Responder Products



How We Produce and Store Energy

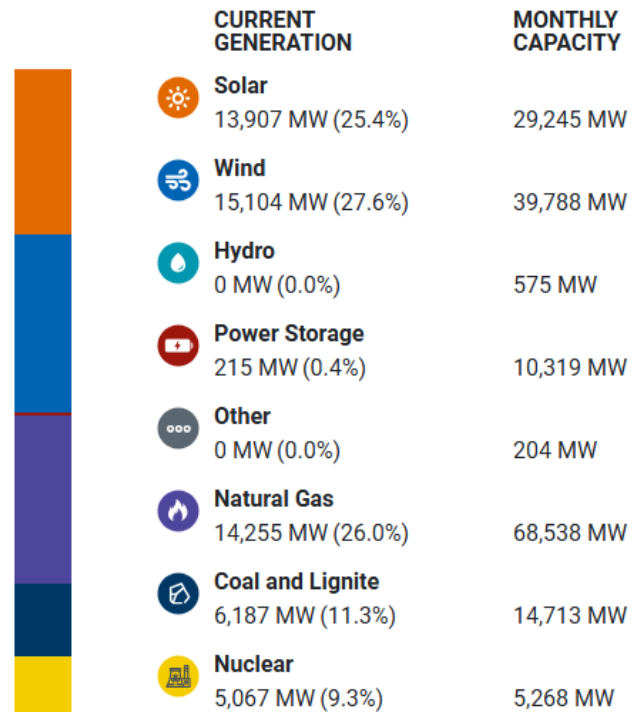
- 10 years ago, 80% of North Americas Electricity was produced by Natural Gas-fired turbines and Coal plants. That has changed
- Today, 60% of our Electricity comes from Fossil Fuels, including 43% from Natural Gas and 16% from Coal
- By 2030, Renewables could account for nearly 50% of all electricity produced. Net-Zero Carbon Emissions is the Goal.
- How Excess Energy is Stored (think batteries) and fed into the Grid before Consumer use will be a High-Focus Priority

ERCOT Energy Blend

Fuel Mix

Fuel Mix is a graphical representation of energy generation broken down by resource type in Real-Time as well as for the Previous Day and Current Day.

Last Updated: Mar 26, 2025 15:19 CT



The New Look of Utility-Scale Power



Texas is #1 in Wind Power

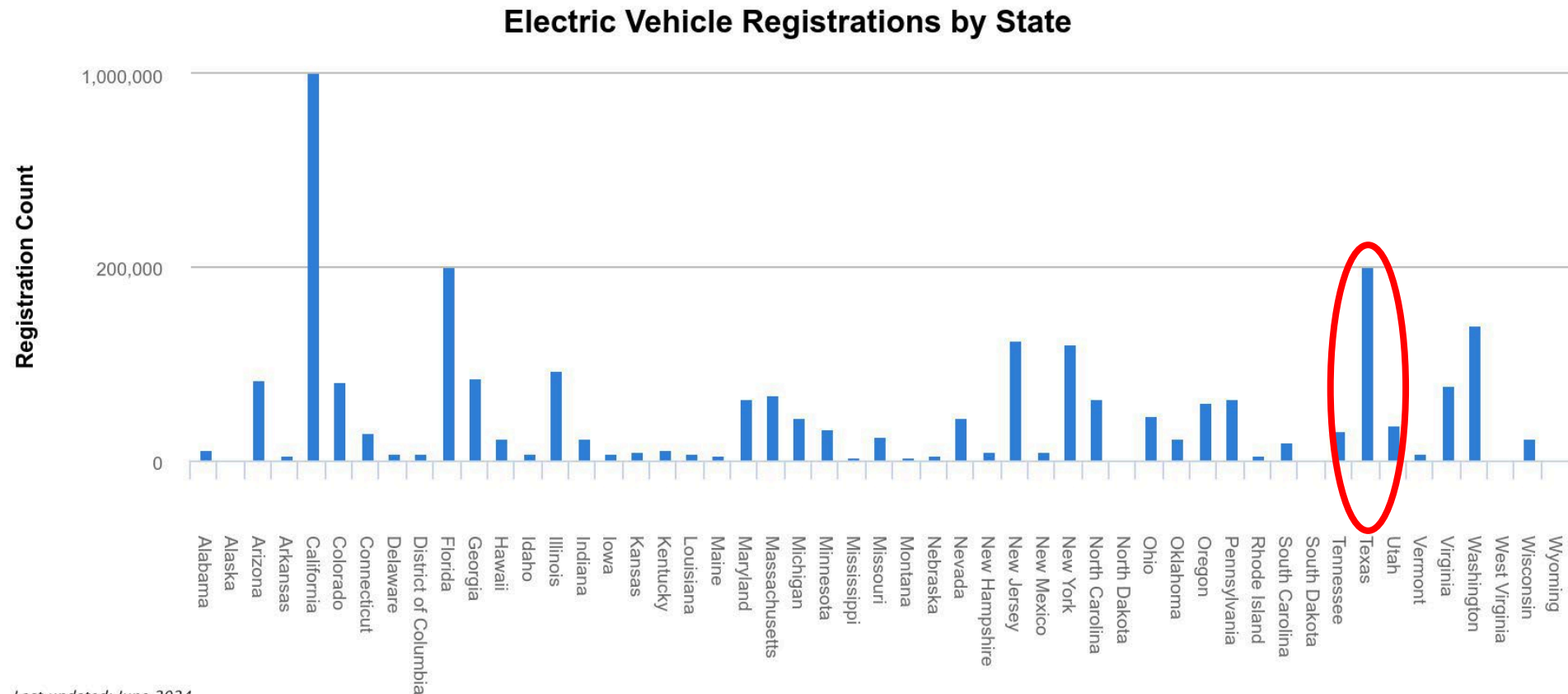


Batteries will play a big part in how energy is stored until needed



Texas is estimated to grow it's solar footprint by 400,000 acres in the next 10 years

EV Registrations by State



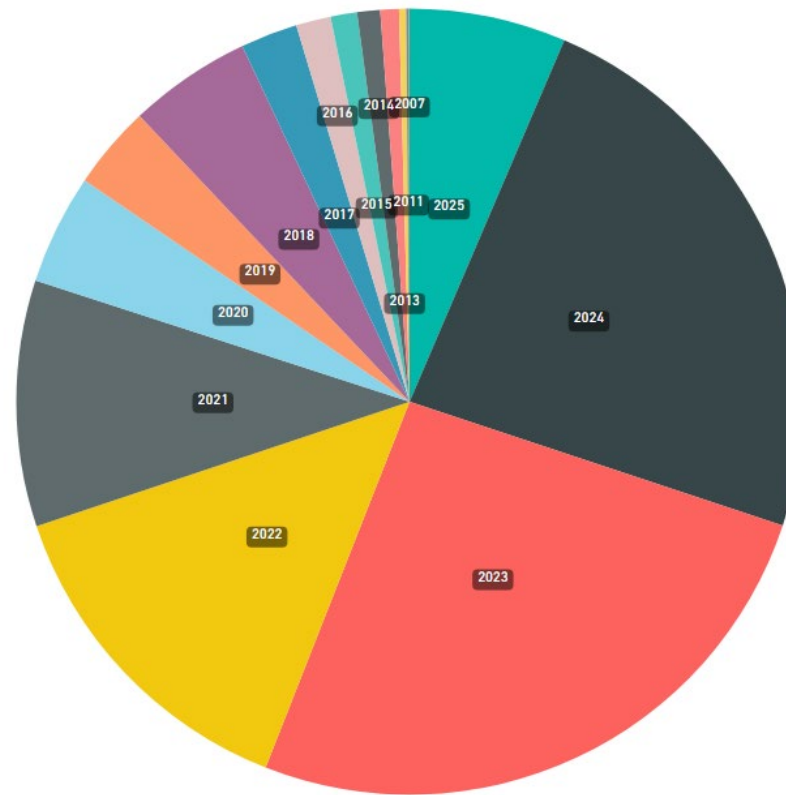
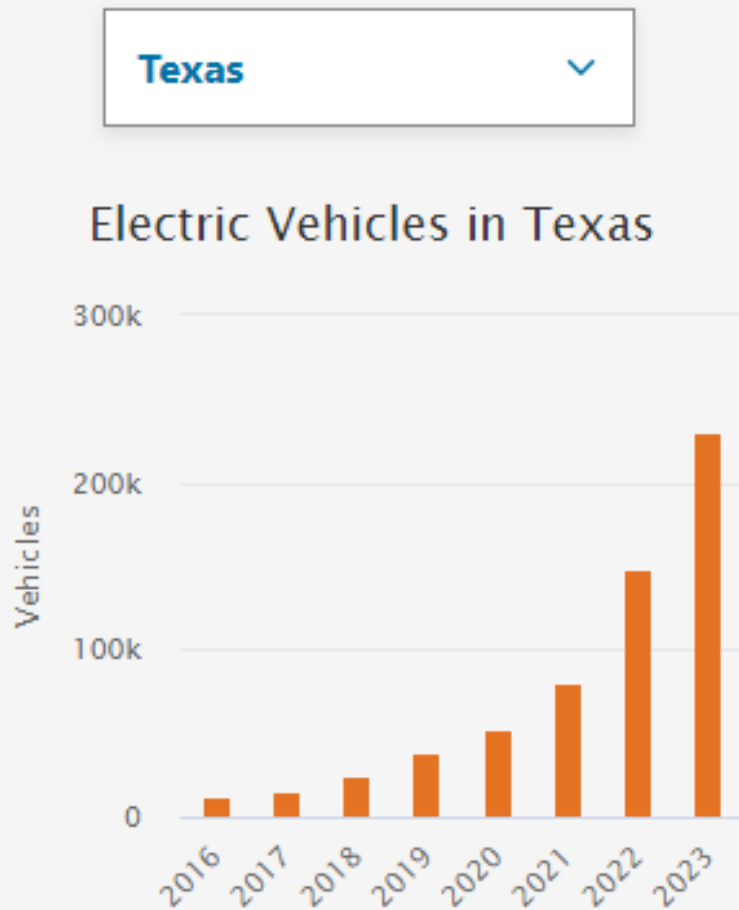
Last updated: June 2024
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California – 1.256M

Florida – 254k

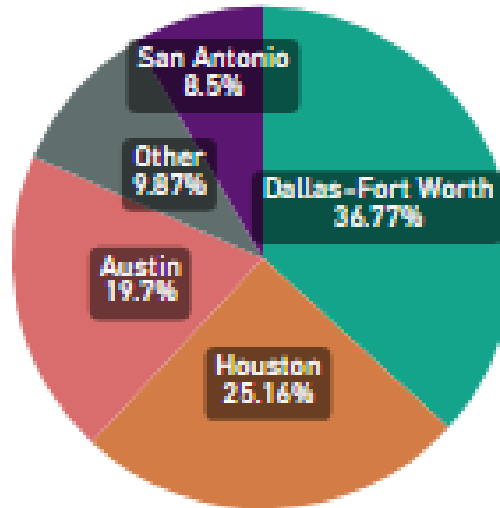
**Texas – 230k (0.9% of all registered vehicles in the state /
75 BEVs for every 10,000 cars sold)**

EV Growth in Texas



Texas EV Registration by Region and % of Total Registration

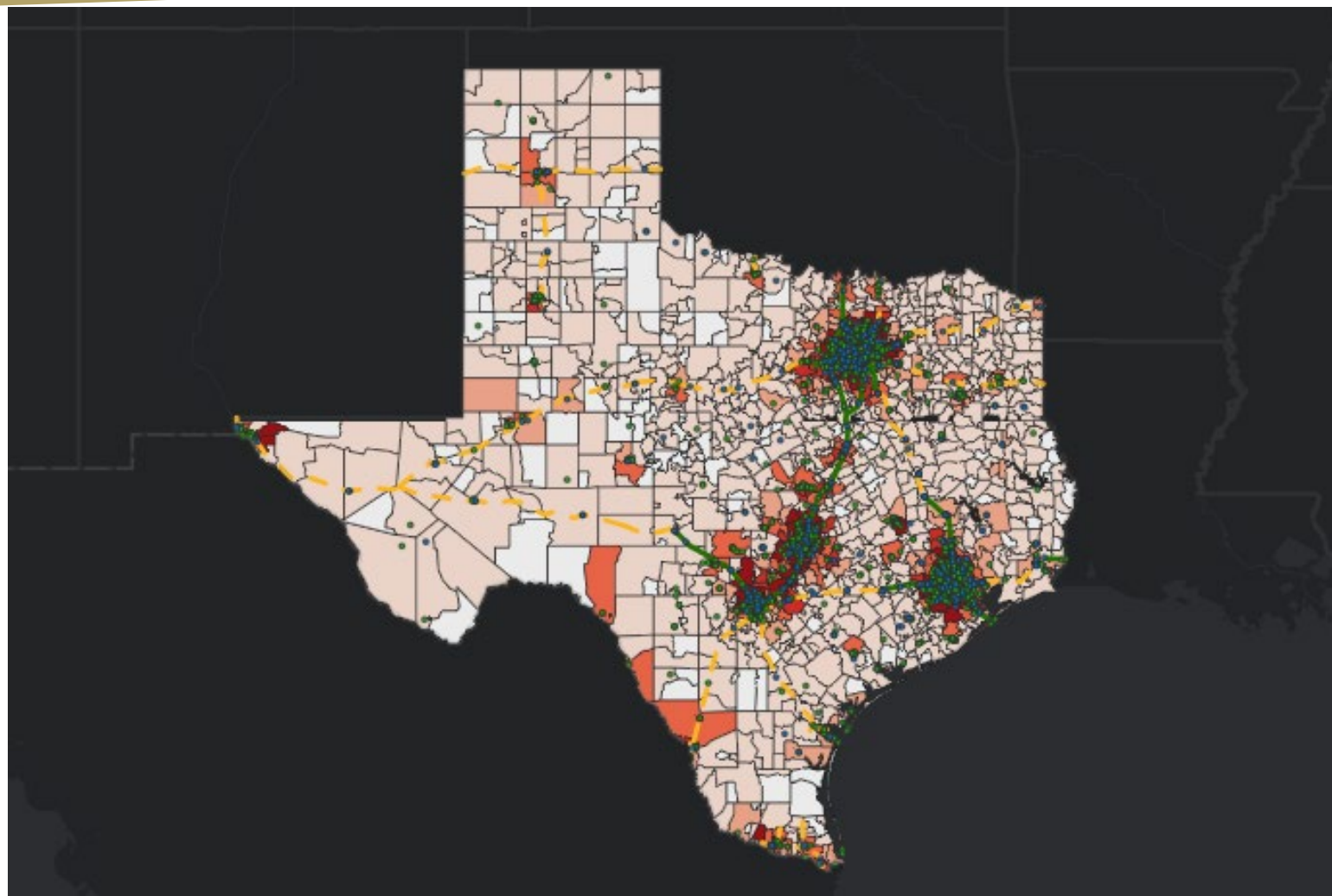
EV Registration by Region



EV Percentage of All Registered Vehicles by Region



Correlation between EV Ownership and Available Charging Locations



Lithium-Ion Battery Powered Electric Vehicles

- Electric Cars

- Typically, high-voltage – 300 to 400 volts
- Five manufacturers are producing 800-volt vehicles
- The GM '25 Hummer 205 kWh battery pack and Escalade uses a 200KWh battery pack
- Pierce Volterra 256 kWh battery pack
- TESLA Semi 850 kWh battery pack
- BESS 1-2 MW (each unit)



- Electric Scooters



- Electric Bicycles



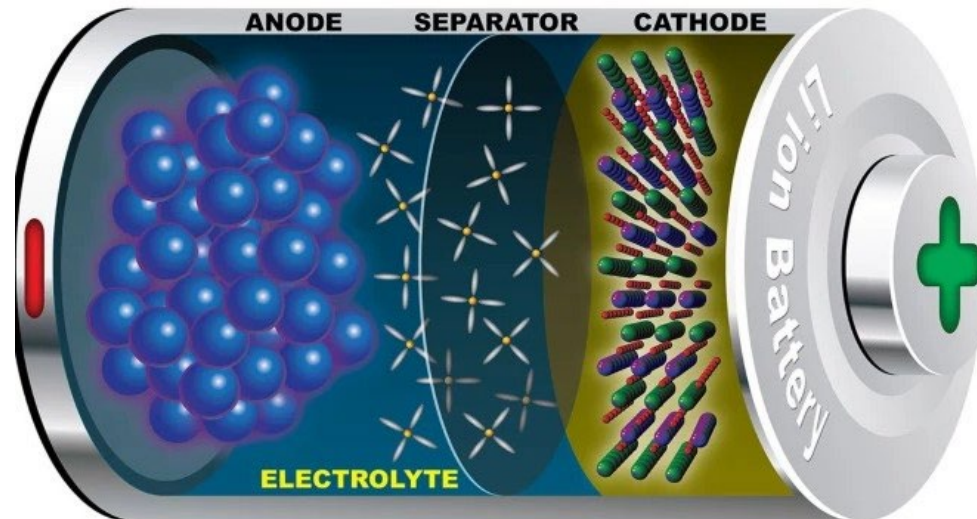
Lithium-Ion Battery Components

Separator:

Allows the lithium ions to move from the anode to the cathode while preventing a short circuit

Anode:

Stores lithium and releases lithium ions when the battery is discharging



Cathode:

Stores lithium and releases lithium ions when the battery is charging

Electrolyte:

A liquid which acts as a transporter of lithium ions within the cell

Popular Chemistries

LFP

Lithium Iron Phosphate (LiFePO_4)

NMC

Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO_2)

Batteries and Battery Packs

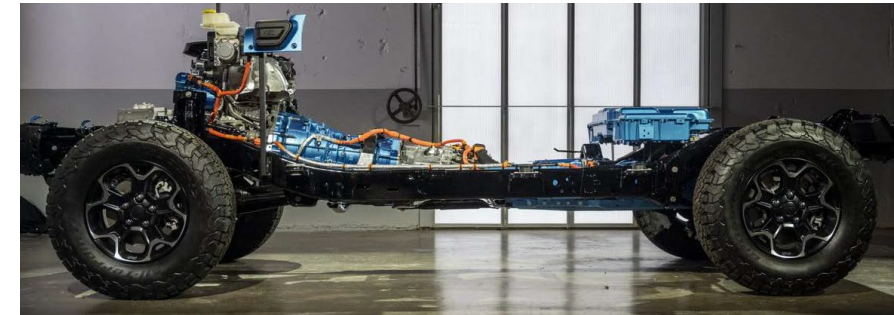
TESLA Model S Contains
8,256 individual cells
Each larger than a AA battery



16 modules
Each contain 516 cells



Plug in Hybrid Vehicle
17.3 kWh NMC battery



Thermal Runaway

- Occurs when excessive heat is generated in the lithium-ion cell (active and passive cooling). The protective layer covering the anode begins to break down. This is an exothermic reaction, so the temperature of the cell increases.
- As the temperature of the cell increases, the electrolyte starts to break down, releasing additional thermal energy. Eventually, the separator (thin film polymer) begins to melt.



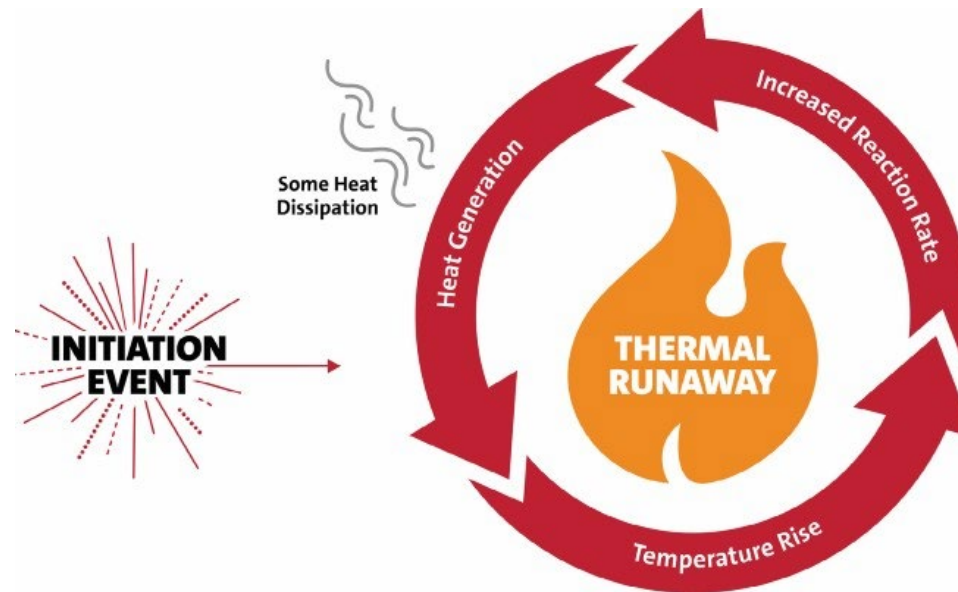
Thermal Runaway

- As the separator becomes compromised, an electrical short may be possible, between the anode and cathode. The electrical short adds even more heat to the system.
- Eventually, the cathode will begin to break down. This releases heat and bound oxygen, which can react with products from thermal decomposition and contribute to the combustion reaction that may occur once the cell catches on fire. Remember, the cells are linked.

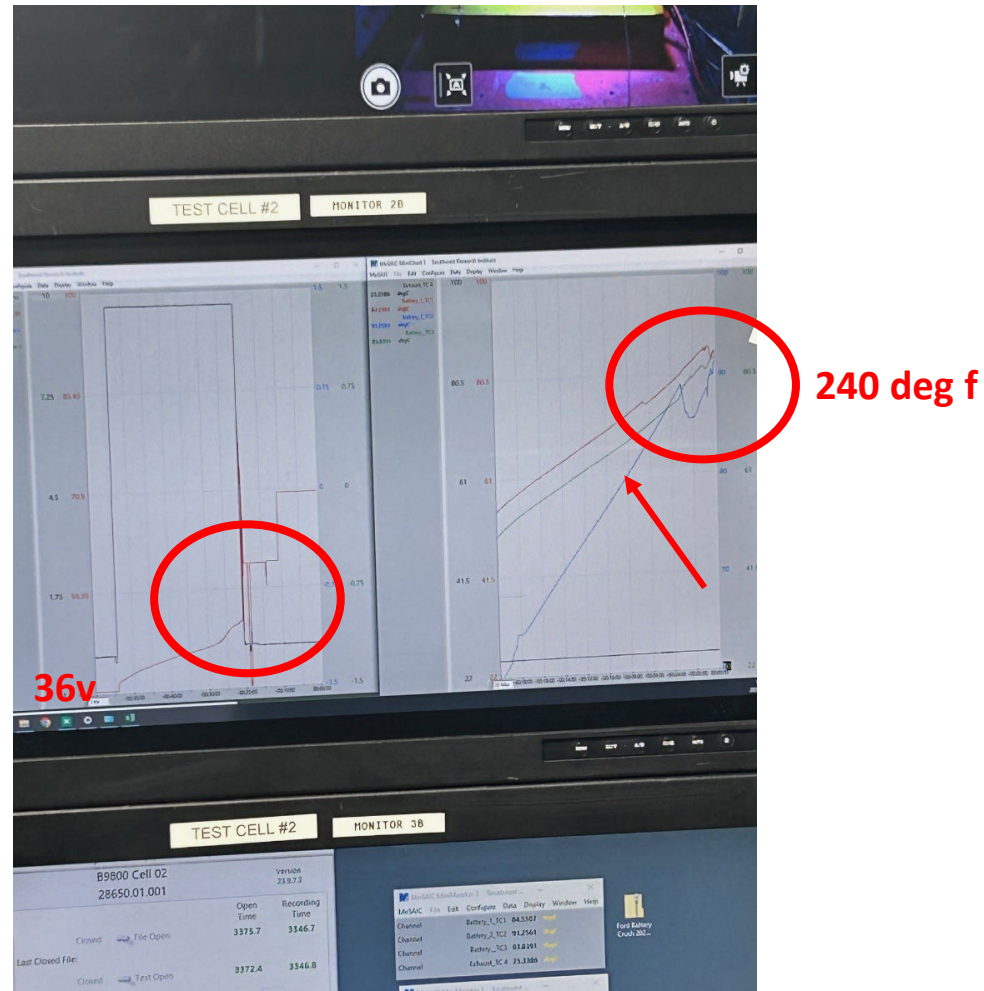


Causes of Thermal Runaway

- Environmental – i.e. flood damage
- Mechanical (puncture – bruise)
- Electrical Overcharge
- Electrical Over-Discharge
- Non-OEM Components
- Short Circuit
- Design and Manufacturing
- Aging



Voltage and Temperature in a Li Battery



Thermal Runaway Indicators

- Popping or hissing noises
- White or gray cloud forming around the battery area
 - This can be seen using a TI before temperatures rise.
- Small explosions or overpressure
- Projectiles flying from the battery casing (Heavy Metals)
- Fire or intense flames if thermal runaway is advancing rapidly



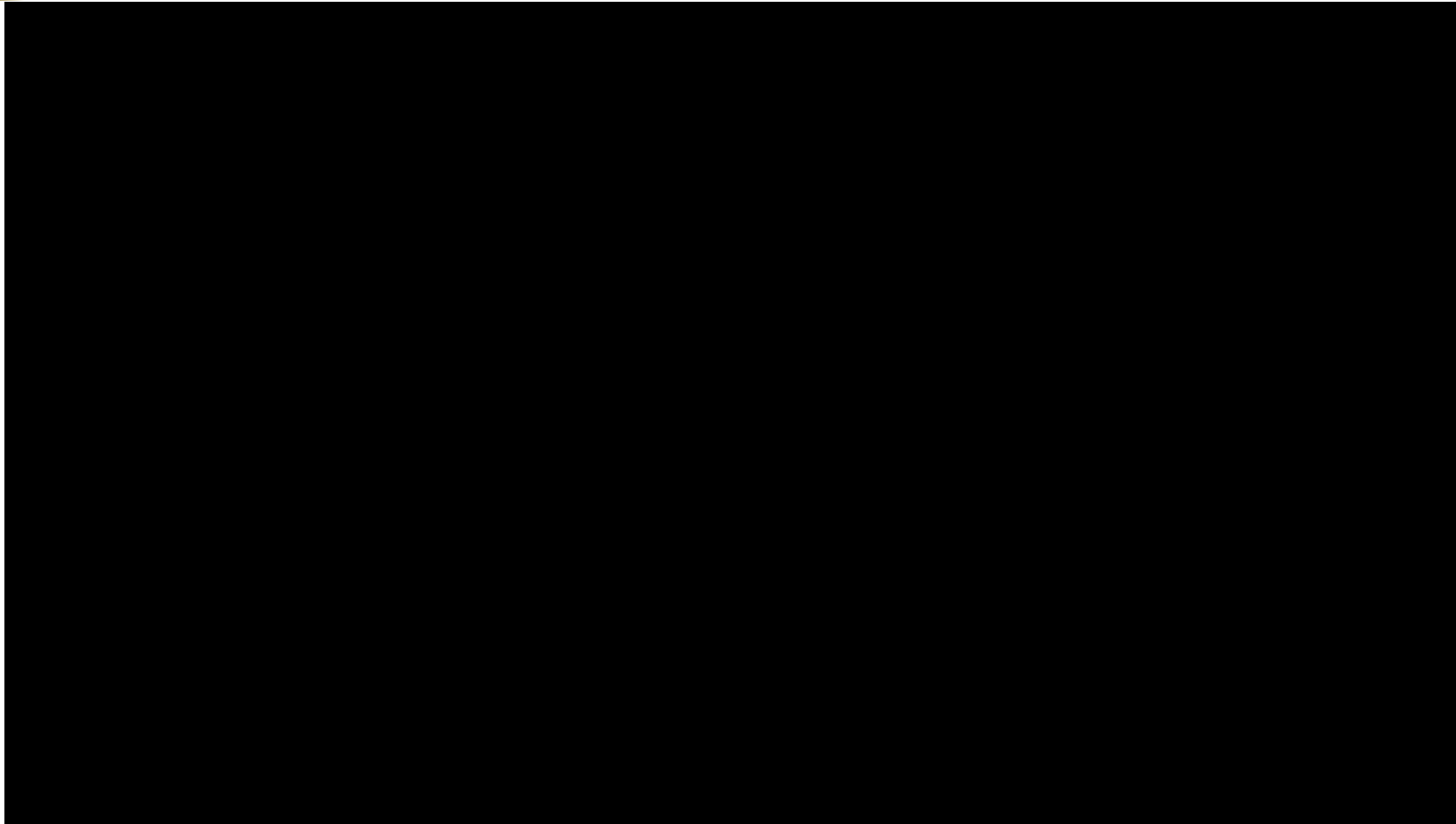
FDNY Li Battery Emergency Statistics

- 2019 – 13 Li Battery Fires
- 2020 – 40 Li Battery Fires
- 2021 – 104 Li Battery Fires, 4 fatalities
- 2022 – 220 Li Battery Fires, 10 fatalities
- **2023 – 268 Li Battery Fires, injuring 150 people and resulted in 18 fatalities**
- **2024 – 277 Li Battery Fires (133 were non-structural), resulting in 6 fatalities**

FDNY Commission Tucker “progress is the result of enhanced **public education, inspection efforts**, and greater community engagement”. The FDNY Li-ion Battery Task Force inspected 585 e-bike shops in 2024, a 25 percent increase from 2023. They issued 426 FDNY Summons, 138 violation orders, 32 criminal summonses, and issued seven vacate orders with the Department of Buildings.

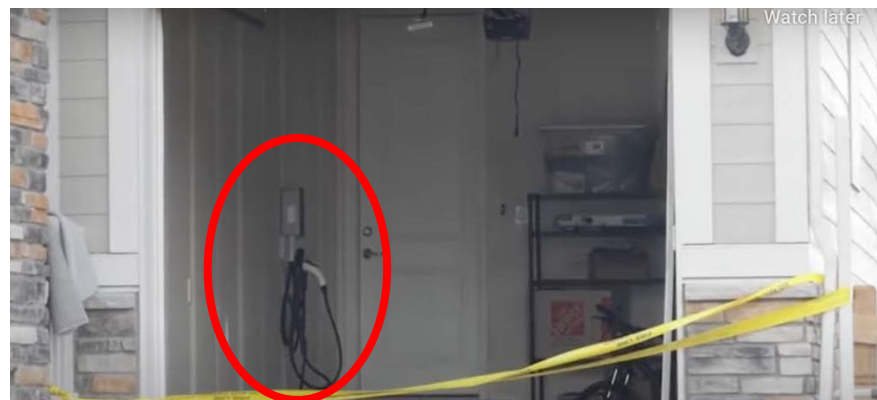
In 2023, Li-Ion batteries were the leading cause of fires and fire-related deaths in New York City

FDNY Li-Ion Battery Symposium



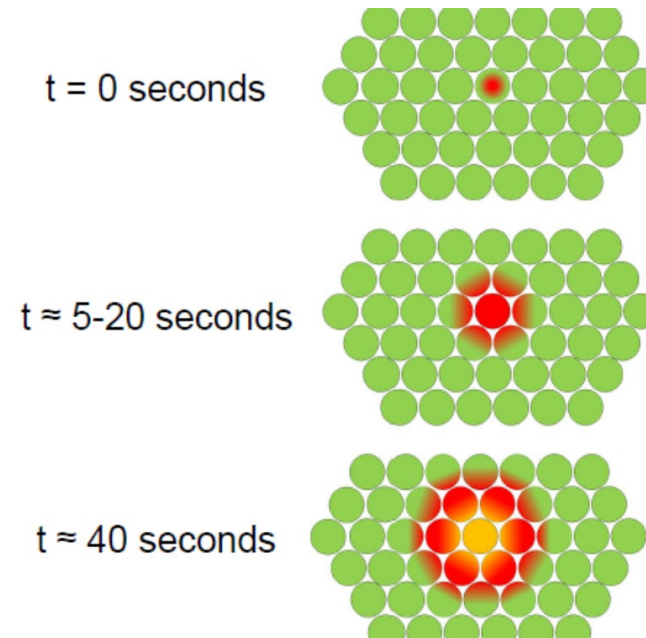
Gases Liberated during Thermal Runaway

- Gases produced from venting lithium- ion batteries:
 - Hydrogen Gas
 - Hydrogen Fluoride & Sulfide
 - Carbon Monoxide
 - Carbon Dioxide
 - Organic Solvent Vapors
- Gas production is flammable, explosive, toxic and a deflagration hazard
- Heavy Metal Exposure (*NANO PARTICLES*) – Cobalt, Manganese, Nickel, Copper, Chromium, Lead, Zinc, Barium, Cadmium



Thermal Runaway Propagation

- Thermal runaway usually begins when the heat generated within a cell exceeds the heat dissipated to its surroundings.
- If the cause of excessive heat generation is not remedied, the condition will worsen.
- The elevated heat causes chemical reactions that further release thermal energy.



Battery Energy Storage Systems (BESS)

Battery Energy Storage Systems (BESS) and Mega Packs

- They are intended to function as energy storage and to help stabilize the grid and prevent outages
- They help to prevent rolling brown outs during peak demand times
- They can “float on the grid” or can be connected to Solar Arrays, Wind Turbines, Gas-fired turbines/Coal power plants.
- Frequently located in rural areas with limited local protection capabilities or knowledge of the hazard
- NFPA 855, the Standard for the Installation of Stationary Energy Storage System
- UL 9540, the Standard for Safety of Energy Storage Systems and Equipment

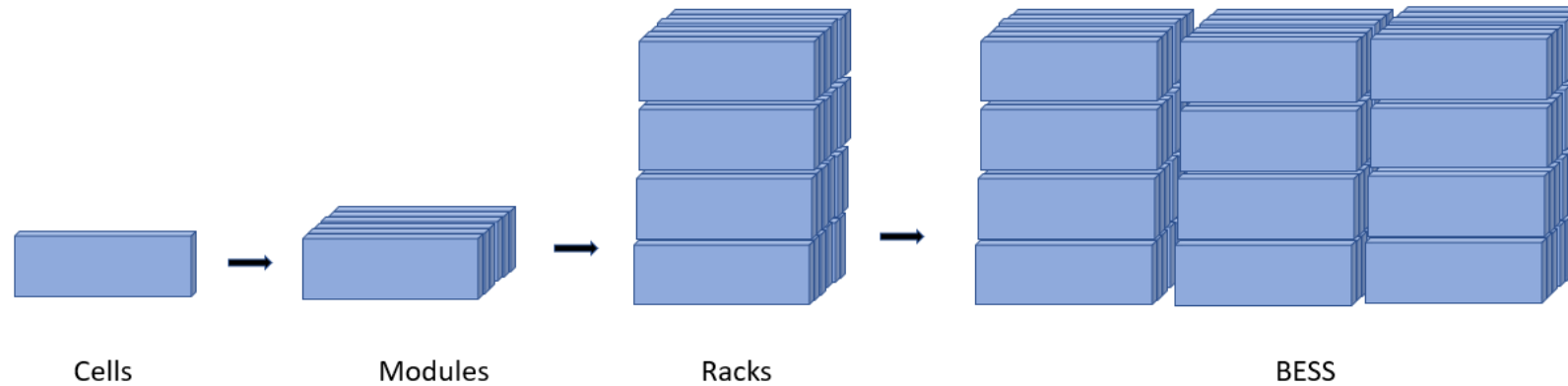


BESS Concerns

- When BESS can be connected to Solar Farms, the energy collected is Direct Current (DC), and then converted to Alternating Current, through an inverter.
- We have seen BESS storage banks capable of storing 2 megawatt of energy (free-standing connex box-style)
- Non-Entry style cabinets
- Just East of Bryan/College Station, we have a BESS connected to 535,000 solar arrays
- HUGE amounts of energy stored inside of BESS via batteries, battery chemistry....
- **An Upwind / Uphill Approach is Critical!**



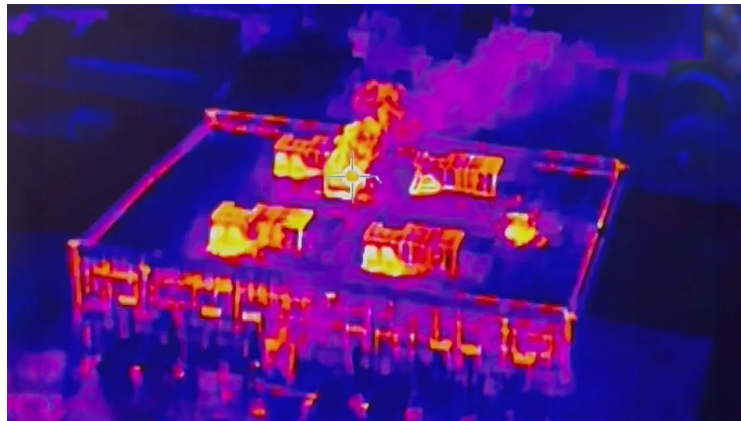
Battery Energy Storage Systems



May 15, 2024 Fire at BESS Facility

- **Gateway Energy Storage Facility – Otay Mesa** In San Diego County, California
 - Largest Energy Storage Facility in the world
- **250 Megawatts** of energy storage, LFP batteries are used
- Plans to expand this facility to 500 Megawatts
- 5 buildings under one roof
- 2-hour rated Fire stops between each building
- Suppression Systems - Clean agent system (which will not stop thermal runaway) extinguishment system, and water system (which will cause arc flashes, shorts and won't stop deep-seated fires)
- **19 days** of burning before the fire went out
- Fire Department flowed more than 1 million of gallons of water
- Runoff concerns....

Gateway Energy Storage Facility – Otay Mesa



January 16, 2025, Fire at BESS Facility

- Vistra Energy – Moss Landing Facility
- One of the Worlds largest Battery Energy Storage Facility
- 930 MW of Battery Energy Storage
- Expected to be deemed a “Complete Loss”
- Monitoring efforts have detected high concentrations of heavy metal nanoparticles — chemicals highly toxic to humans, animals and aquatic life — in the soil at the Elkhorn Slough Reserve
- Estimated Cleanup > 1 year



Current BESS House Bills

HB 1378 (Virdell)

- Would require BESS to be at least 500 yards from an adjacent property

HB 1343 (Troxclair)

- Would require battery storage projects to have permits if they want to sell energy on the state's main power grid, which is maintained by the Energy Reliability Council of Texas (ERCOT)
- Under HB 1343, permitted storage equipment or facilities must be "a sufficient distance from any other electric energy storage equipment or facility."

Current BESS Senate Bills

SB 1825 (Schwertner)

- This bill references UL 9540 and NFPA 855 as the basis for BESS design, safety and installation.
- The State Fire Marshal's office is the named Agency in this bill.
- If adopted, this will bring Texas into alignment with National Standards for BESS operations.

Recharging EVs and NFPA 70

Level 1 Charging

- Alternating Current, 120V
- Portable and designed to be plugged into a wall outlet
- To charge a medium size car– up to 24 hours



Level 2 Charging

- Alternating Current, 240V
- Hard-wired – dedicated charging station (public parking, parking garages, workplaces or residential)
- To charge a medium sized car - 2-6 hours



Level 3 Charging

- Direct Current (DCFC), 480V – 1,000V
- Typically located along major highways at conventional gas stations, restaurants, public garages, workplace parking lots
- To charge a medium sized car – around an hour

NFPA 70, the National Electrical Code

Problem - When an emergency occurs at an EV charging station, responders need a quick means to disconnect power.

- For all hard-wired charging stations, located at non-single/dual family dwellings, an e-stop will be required to be installed at the time of installation. Does not address current level 2 & 3 charges
- Mirrors language found in NFPA 30 – e-stops install not closer than 20 feet, and not greater than 100 feet from charging location
- NFPA 70 Technical Committee ballot to approve the language for inclusion of the '26 edition of the standard will take place in June '25

Recycling Facilities

- 2/17/24 Viviez, France (North of Toulouse)
 - Warehouse Fire Contained 900 tons of Li-Ion batteries
 - A security note for the site warns that in case of a major fire, products present there were likely to result in the emission of cadmium (highly toxic and dangerous to the environment) through fumes.
- 10/30/24 Frederickton, Missouri
- Redwood Materials – Sparks, Nv

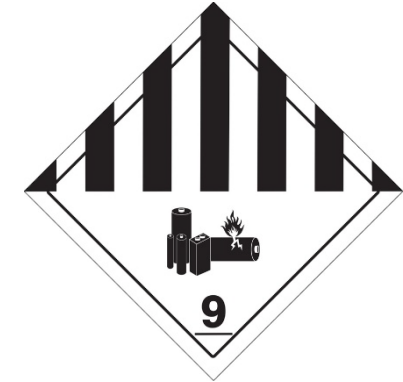
Former TESLA CTO JB Straubel, \$850m investment (several billions planned), will extract enough lithium and nickel this year to supply 20 gigawatt hours of Li-Ion energy, enough to power 250,000 BEVs



Damaged, Defective or Recalled (DDR) Li Batteries

Transporting DDR Li Batteries is becoming a HUGE problem.

- Lack of universal placarding and Enforcement (Class 9 hazard)
- These batteries are already “suspect”, transporting DDR batteries that are not properly packaged and separated
- When you arrive on the scene, what do you know?
- Shipping of DDR Li Batteries are regulated under the Hazardous Materials Regulations (HMR) (49 CFR Parts 171- 180), regardless of weight.
- All Hazardous Communication, Emergency Response, Training and Packaging requirements apply; including shipping papers, marking and Class 9 lithium battery label
- [July 9, 2024 - Semi-truck carrying lithium batteries catches fire, blocks traffic along I-90 near Issaquah – KIRO 7 News Seattle](#)
- Recycling of Li Batteries – If we don’t make it easy, LIB’s will find their way into Household Waste Streams. 10,000 fires annually at Australia’s waste management facilities & collection trucks



Sodium Batteries

- Cold resistant
 - Does not contain lithium or cobalt
 - Salt is readily available
 - China is coming on-line with 16 of the worlds 20 Sodium Battery Plants
 - Drawback – size of batteries
-
- ❖ TESLA is constructing a Lithium Hydroxide Refinery near Corpus Christi
 - ❖ Extensive work being conducted with Solid State Batteries



Emerging Technology

- Q-Container concept, a novel approach towards mitigating risks associated with EV batteries and the potential for thermal runaway following accidents
- Incorporates sensors and water mist plus automatic flooding of container
- Chief Parker (Aldine Fire & Rescue) – EV Tainer



Emerging Technology



What Some Fire Departments are Doing

- Let it Burn
- Remove it from Exposures – Homes and Critical Infrastructure
- Exposure Protection using Water
- Use of Fire Blankets
- Put the EV in a roll off dumpster (Isolation)
- Restrict EVs from being Charged Indoors (Hurricane Helen Florida)
- Restrict EV Charging at Access / Egress Points from Parking Garages
- Recharging Stations Emergency Shutoff Devices
(NFPA 70)

TEEX and Li-Ion Battery Research

Partners –

- National Laboratories
- Southwest Research Institute (SwRI)
- Federal Agencies
- Other Texas A&M University System Components

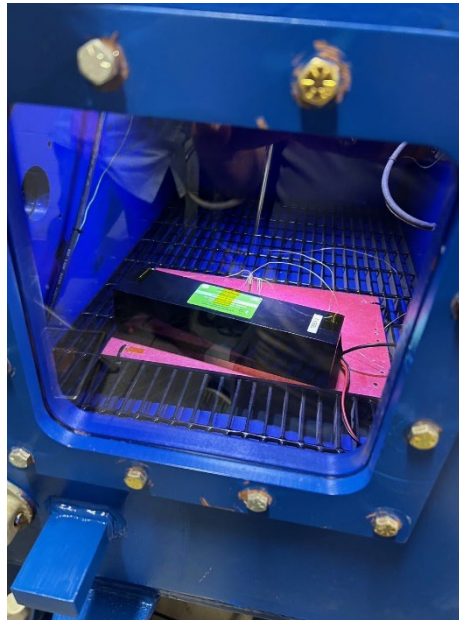
Why –

- Quantify Exposure to First Responders, the Community & Environment
- Poisonous, Dangerous and Explosive Gases
- Volatile Organic Hydrocarbons (VOCs)
- Polycyclic Aromatic Hydrocarbons (PAH) such as Benzene and Formaldehyde
- Heavy Metals
- These results will be the basis for Critical Decision-Making processes regarding Response Plans for Li-Ion battery response

Li-Ion Battery Testing at SwRI

- Basis for testing
 - 36v 12ah Li-NMC Chemistry Batteries, containing 50 cylindrical cells
 - Safety Components of the Battery - BMS and CID
 - Forced into Thermal Runaway via Overcharge
- PPE Exposed
 - Bunker Gear (Outer Shell, Moisture Barrier and Thermal Liner)
 - Apparatus Material (Clean Cab and Traditional Cab)
 - SCBA Straps
- Sample Collection and Analysis
- Cleaning of Bunker Gear
 - Water-based NFPA 1851 Extraction
 - Liquid CO2 Extraction

Batteries Tested



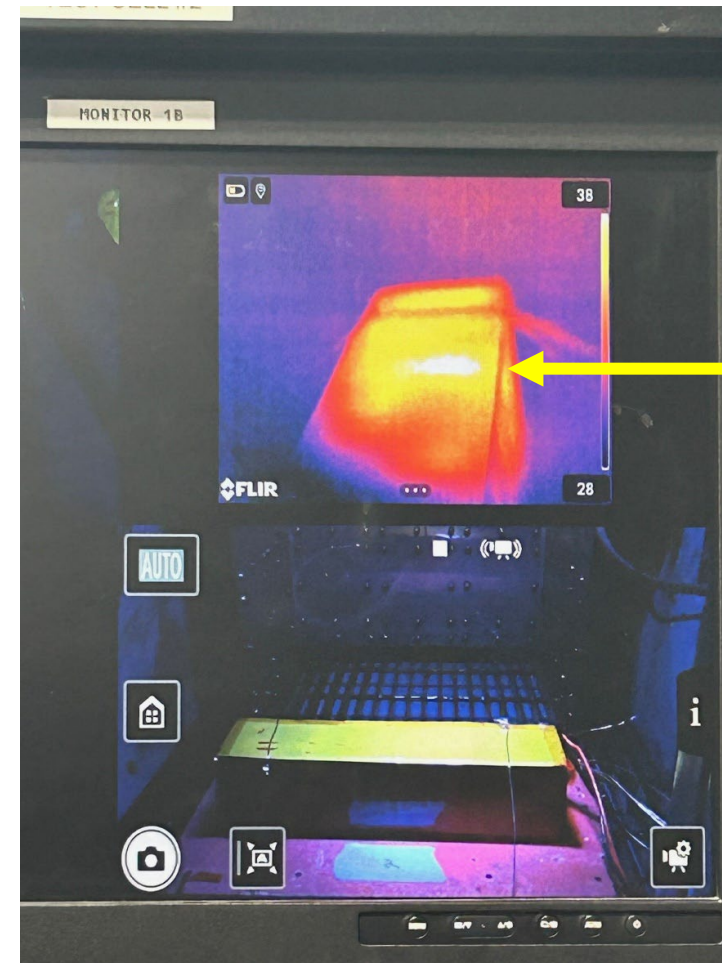
Battery
Management
System (BMS)

Current
Interrupter
Device (CID)

PPE Test Samples



Indicators of Thermal Runaway



Side-by-Side Thermal Runaway



Test Results

- Tests concluded that Li battery thermal runaway fire is **an extreme emissions event** of highly toxic gases and particles that are respirable and dominated by metallic compounds that well exceed the OSHA permissible exposure limits. High concentrations of **lithium, nickel, cobalt, manganese and copper** were detected in each test, with Lithium being the most dominant.
- **Particulate Matter (PM2.5)** in the dilute blast chamber was extremely high. It ranged from **12,000 to 17,000 times** higher than the new EPA ambient standard of $9 \mu\text{g}/\text{m}^3$. **Emissions were dominated by metallic particles, with the highest being Lithium. The concentration of metals ranged from 12 to 760 times their 8-hour OSHA limits, making them highly toxic, especially lithium.**
- **Positive pressure self-contained breathing apparatus (SCBA) is highly recommended** for use by all responders encountering Li battery emergencies. Due to the very high dilute particle concentration, even a very effective passive mask such as an N95 will not effectively protect the wearer in the vicinity of such fires. NFPA 1971-compliant protective ensembles will also be necessary to protect the user from direct dermal contact with contaminants.

Test Results

- In each test, peak temperatures were observed in the **2000+ deg F**. Temperatures increased each time a battery cell failed. There is a direct correlation between excessive voltage in a Li battery and an increase in internal battery temperature. In each test, batteries became unstable, leading to thermal runaway when temperatures reached **242 – 257 deg F**
- Significant battery weight loss, ranging from **44% to 63%** was observed post-thermal runaway.
- **Toxic gaseous species such as carbon monoxide, methane, hydrogen fluoride, hydrogen cyanide and formaldehyde** were all measured. Volatile organic compounds (VOCs) were dominated by electrolytes; **ethylene, acetylene and 1,3 butadiene**, besides unidentified species in the C5-C7 and C11-C13 ranges. **CO concentrations** can reach **500 times** the OSHA 8-hour 50ppm limit and formaldehydes can reach **150 times** the 8-hour 0.75 ppm limit and 56 times the 15-minute limit of 2 ppm. **Ethylene reached a level of 446 times** the OSHA 8-hour limit of 1 ppm, and 30 times the 15-minute limit of 5 ppm. **1,3 butadiene reached 26 times** the 15-minute limit of 1 ppm.

Cleaning Efficiencies

- Up to **75 SVOCs and 24 Heavy Metals (Metallic Particles)** were detected during testing, ranging from one ring to five ring PAHs. Tests that had increased dilution of air in the blast chamber greatly reduced the amount of SVOCs present.
- Penetration of **SVOCs** through the outer layer of the gear tested to the vapor barrier layer is possible. **Water-based cleaning efficiency ranged from 21% to 92%.** Many of the SVOCs penetrated the outer layer of the bunker gear, showing higher deposition in the vapor barrier. **CO₂-based cleaning was very effective showing many compounds as undetected after cleaning.**
- The penetration of metallic particles to the vapor barrier lever was very low. **The outer layer of bunker gear proved to be effective in stopping most metals.** All Thermal Liner values were near the detection limit.

Cleaning Efficiencies

- One cycle water-based and CO₂-based cleaning of the exposed swatches was very effective for removing metallic compounds deposited on the outer layer of the gear samples. **The cleaning efficiency was over 99% for most metals.** CO₂-based cleaning was slightly more effective than water-based cleaning. Using more than one cycle to clean could reduce some of the metals remaining on the surface of the gear outer layer.
- **Even after cleaning, metals such as cobalt, copper, manganese and nickel remain on the bunker gear swatches at levels above the unexposed sample.**
- The PM_{2.5} collection was dominated by metallic elements with a small fraction of soot. **Dominant elements were Lithium followed by Nickel, Manganese and Cobalt.**

Apparatus Fabric and SCBA Straps

- **Apparatus clean cab fabric** seems to have less metals sticking to it, when compared with the **traditional fabric materials**, showing roughly half of the contaminants entrained in the fabric once exposed to a Li battery fire. This is likely due to the smoother surface of these materials, resulting in less particles sticking to the surface. The sum of metallic deposition averaged **226 ug/cm² for clean cab materials** and **418 ug/cm² for traditional cab materials**.
- **SCBA straps** had the greatest amount of contamination of any of the tested materials. The heavy metals contained in the SCBA straps were twice that of traditional apparatus fabric. This is likely due to the porous material construction of SCBA straps, resulting in a great volume of particles entrainment. **The sum of metallic deposition averaged 780 ug/cm².**

The Facts

- EV fires are almost impossible to extinguish, especially at a state of charge > 30%
- Traditional Suppression methods are not effective (water-based, dry chem, foam)
- Develop a Response Plan
- “Stranded Energy” post-emergency is a problem
- Think Exposure Protection
 - Critical Infrastructure
 - Parking Garages
- When Possible, Remove EV from Exposures
- NFPA Guidance Standards - 30a, 70 & 855
- DDR Li-Ion Batteries are being transported daily, without standardized identification methods (ERG Guide 147)
- Poisonous Gases and Heavy Metals
 - Nano Particles of Heavy Metal fallout up to 100m downwind
 - Contamination of PPE and Transfer Contamination
 - Extraction Methods (Traditional NFPA 1851 Water-based Extraction and Liquid CO2)
- Case Studies –
 - Spokane, WA. Home Depot Arson
 - California Warehouse Fire
 - Baytown and Harlingen BEV events
 - TESLA 18-wheeler
 - Moss Landing (Vistra)

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ELECTRIC VEHICLE & STORED ENERGY SUMMIT 2025

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TEEX EV Resources & Training

EV Safety for the First Responder

New, No-Cost Online Training



E-Stops for EV Recharging Stations

Video Discussion with Chris Green, Seattle FD (Retired)



Current Practices, SwRI Report, Resources

