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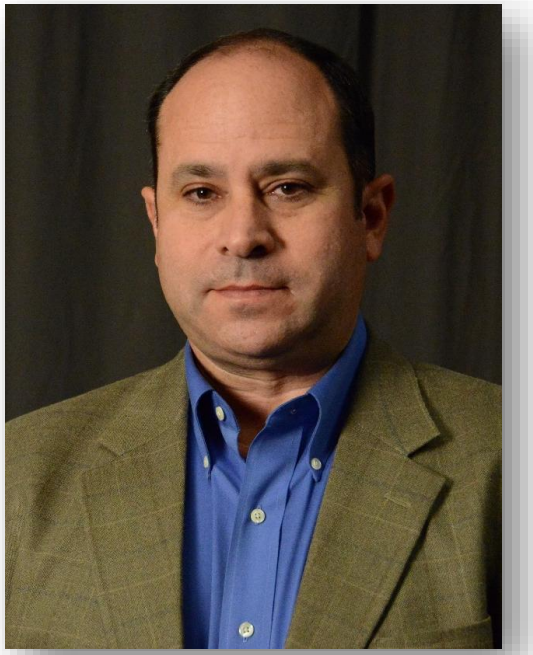
Electric Vehicles and Li-Ion Batteries – All Things Energy

Gordon Lohmeyer, CFPS/ PI

Assistant Agency Director, Texas A&M Engineering Extension Service, TEEX

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 TEEX 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.

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Session Objective

Battery Electric Vehicles (BEV), Micro Mobility Devices, Battery Energy Storage Systems (BESS) and their related Lithium-Ion (Li-Ion) battery fire potential pose a significant risk to the First Responders, the community and potentially to the environment. This session is intended to increase your awareness and overall knowledge base.
I will also share the results of a recent research project, where we forced Li-Ion batteries into thermal runaway and measured contamination to Fire Fighters PPE.

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Li-Ion Consumer Products

IDEAL FOR MECHANICS

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Li-Ion Battery Powered Emergency Response Products

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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
- 18% from Nuclear Energy and **21% from Renewable Energy –** Wind Energy 10%, Hydropower 6%, Solar Photovoltaic and Solar Thermal 4%, Biomass 1%.
- 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

Last Updated: Jan 16, 2025 08:19 CT

	CURRENT GENERATION	MONTHLY CAPACITY
Solar	4,486 MW (7.5%)	29,180 MW
Wind	5,729 MW (9.6%)	39,533 MW
Hydro	0 MW (0.0%)	575 MW
Power Storage	1,024 MW (1.7%)	10,407 MW
Other	51 MW (0.1%)	174 MW
Natural Gas	32,662 MW (54.7%)	68,657 MW
Coal and Lignite	10,611 MW (17.8%)	14,713 MW
Nuclear	5,121 MW (8.6%)	5,268 MW

Previous Day | Real-Time | Current Day

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Electric Vehicle Data

- There are currently 3.5M registered Battery Electric Vehicles (BEVs) on the road in the United States. In comparison, there are 288.5M registered Internal Combustion Engine vehicles (ICE) (US DOE)

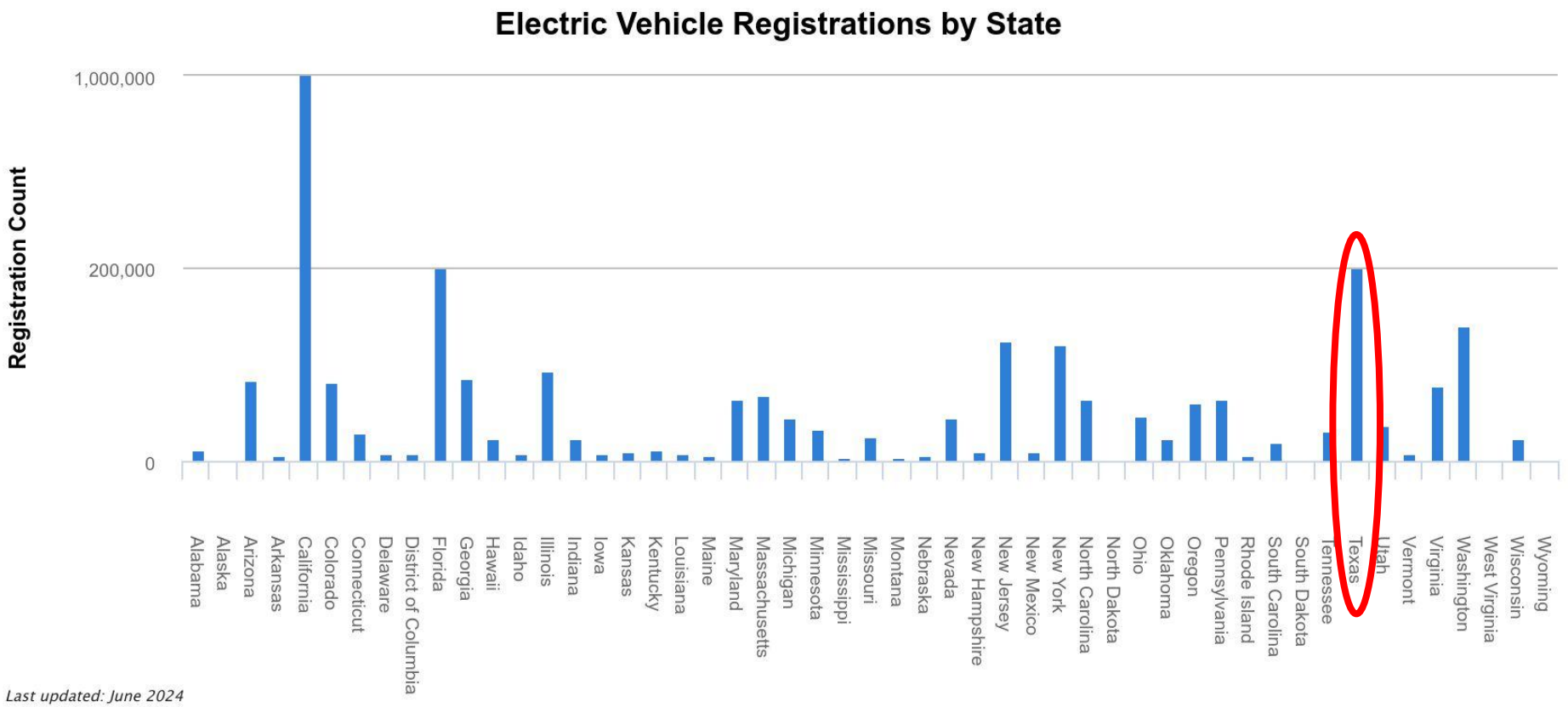
- It is estimated that by 2030, there will be 30-42M EVs on the road (Edmonds.com)

- Battery-electric vehicles (BEV) are only .03% likely to ignite, compared to 1.5% for gas-powered vehicles and 3.4% for hybrid vehicles (Carsmetric.com)

Sales Volume of all US Registered Vehicles

Sales volume	EV	Hybrid	Plug-in hybrid	Internal combustion engine (ICE)
2015	54,179	318,878	12,530	17,086,650
2016	70,466	346,816	16,984	17,124,945
2017	94,626	369,729	38,595	16,727,920
2018	206,365	430,421	54,519	16,620,333
2019	225,741	590,445	56,482	16,186,224
2020	233,330	577,803	38,658	13,705,565
2021	389,410	757,433	78,883	13,790,304
2022	713,145	754,772	113,743	12,200,411
2023	1,077,138	1,242,608	177,081	13,061,153
2024 (Jan-May)	454,670	579,038	110,902	5,409,757

EV Registrations by State



Last updated: June 2024
Printed on: August 12

California – 1.256M
Florida – 254k
Texas – 230k (0.9% of all registered vehicles in the state / 75 BEVs for every 10,000 cars sold)

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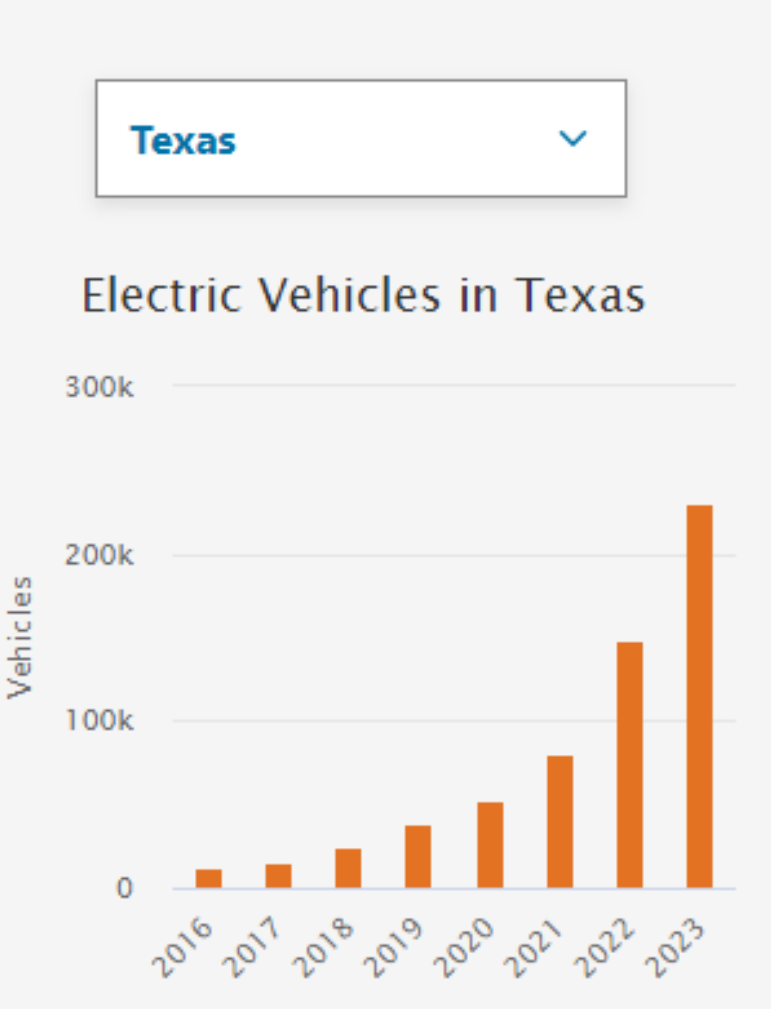
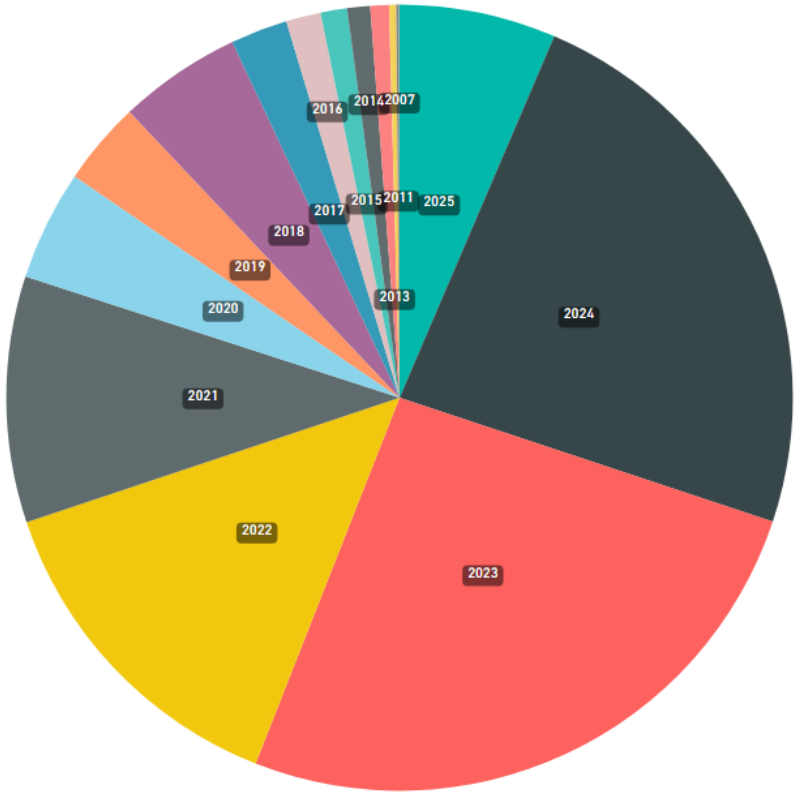
EV Growth in Texas





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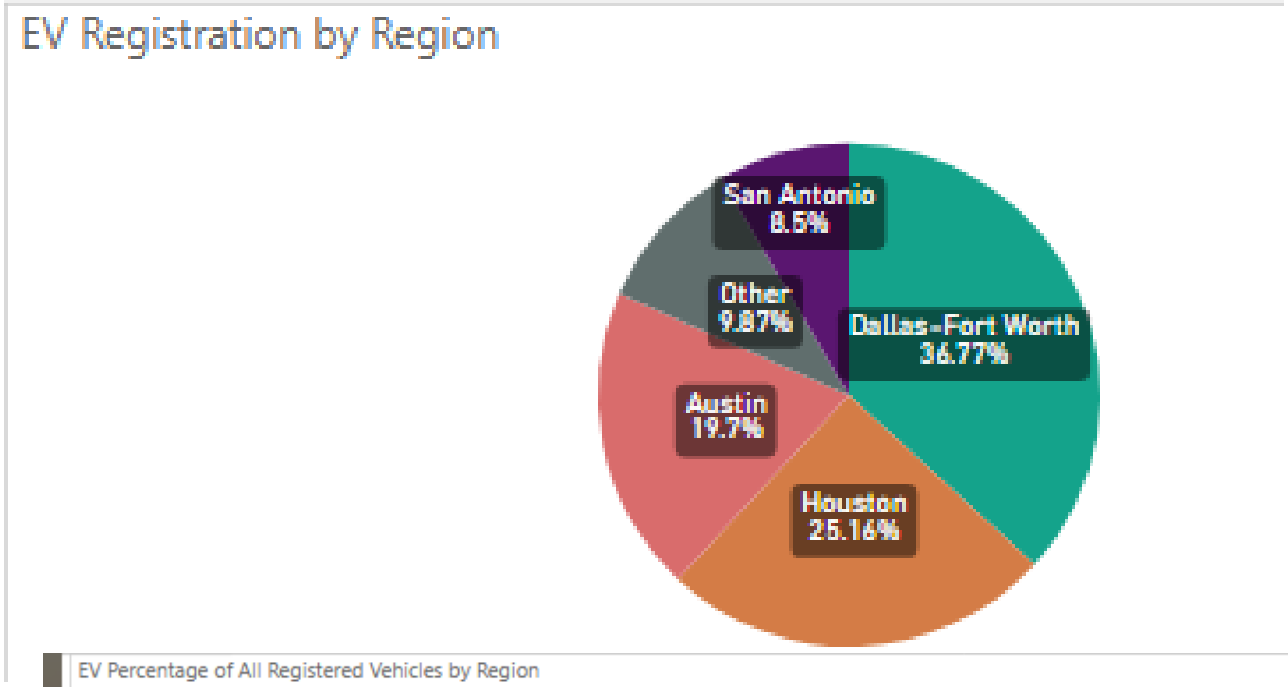
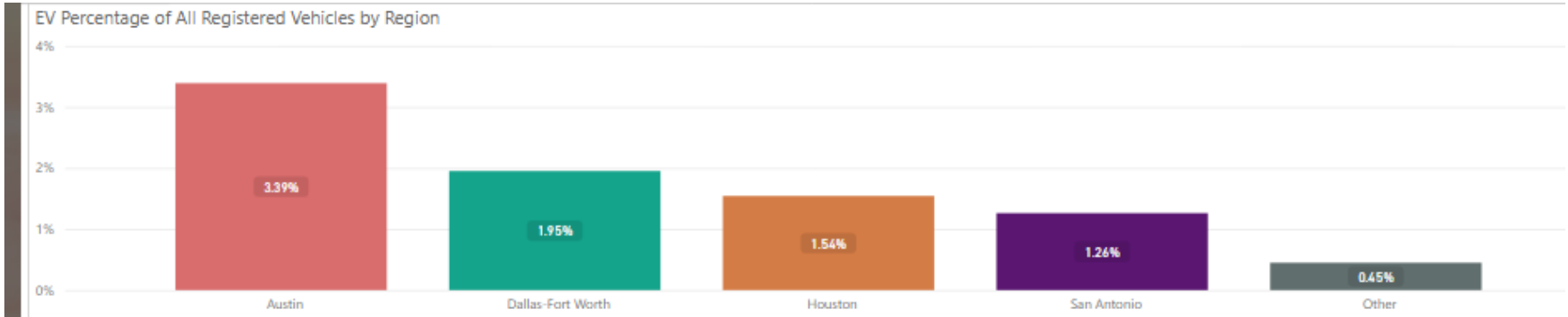
Texas EV Registration by Region and % of Total Registration





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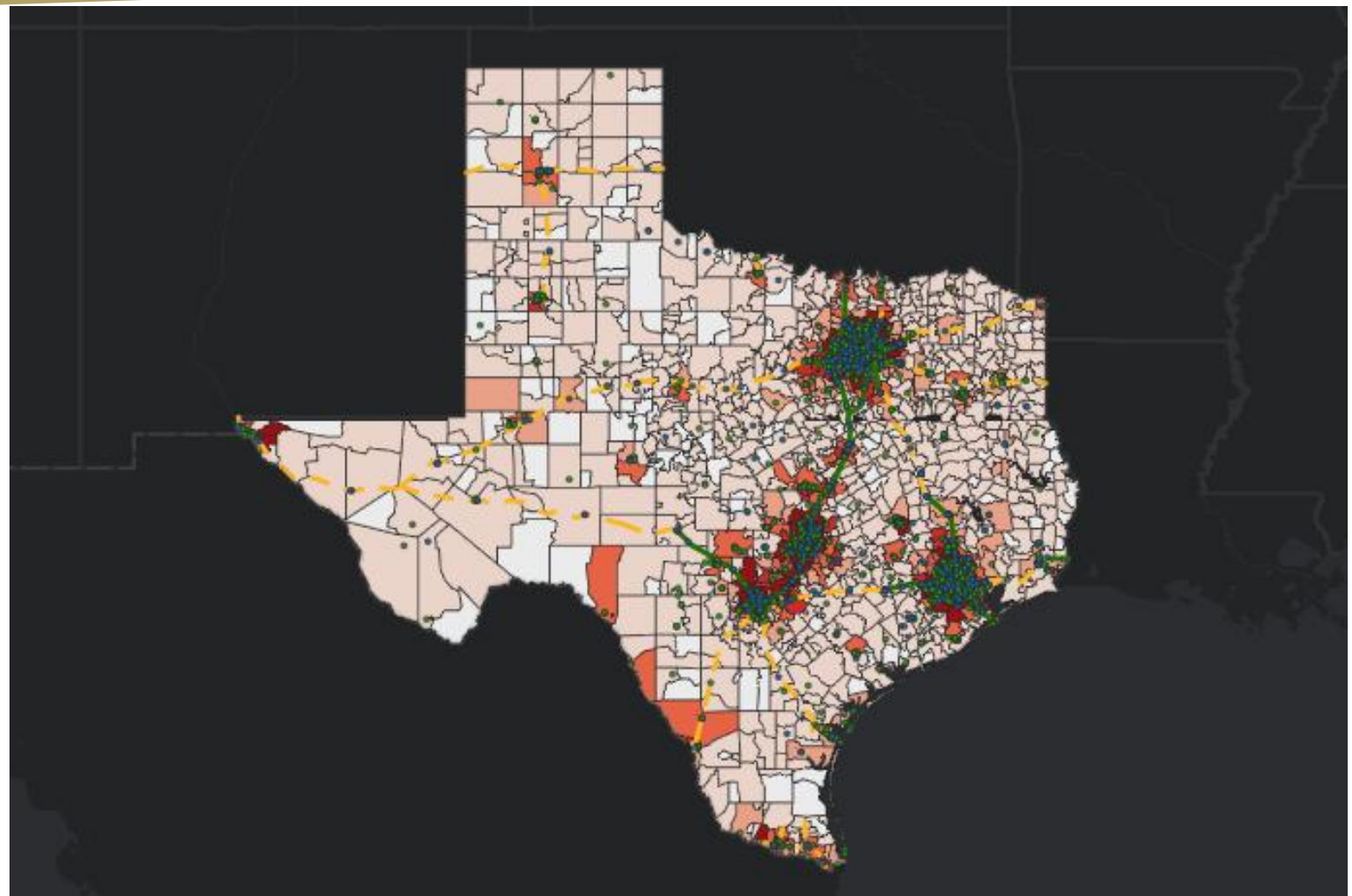
Correlation between EV Ownership and Available Charging Locations



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Lithium-Ion Battery Powered Electric Vehicles

- Electric Vehicles
  - 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)
- Electric Scooters
- Electric Bicycles

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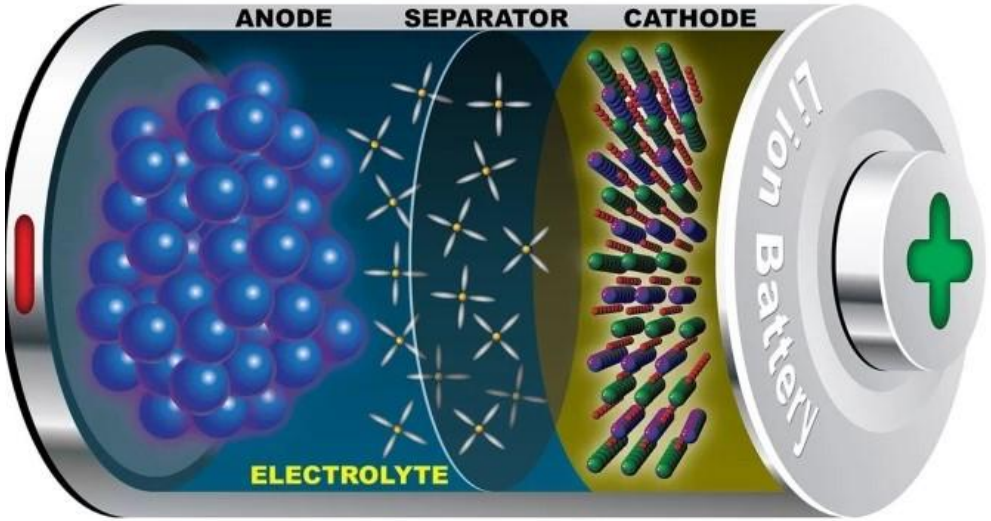
Lithium-Ion Battery Components

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

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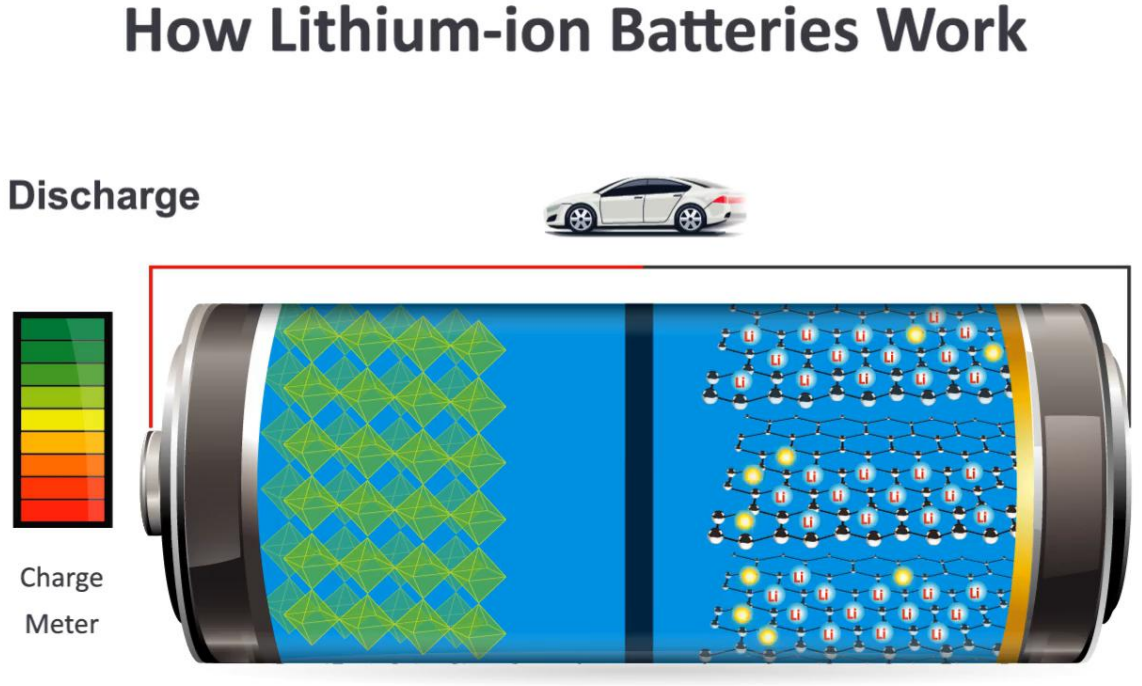
Lithium-Ion Battery Operation



U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

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Popular Li-Ion Battery Chemistries

LFP

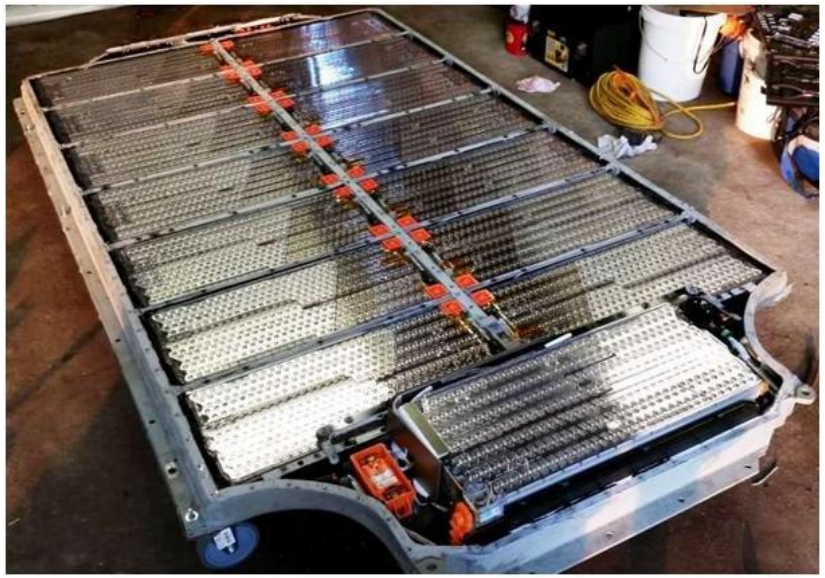
Lithium Iron Phosphate ($LiFePO_4$)

NMC

Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$)

Tesla Model S Battery Pack

- **Contains 8,256 individual cells.**
  - Each larger than a AA battery



- **16 modules**
  - **Each contain 516 cells**

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TESLA Model Y – Foam Filled Voids

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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.

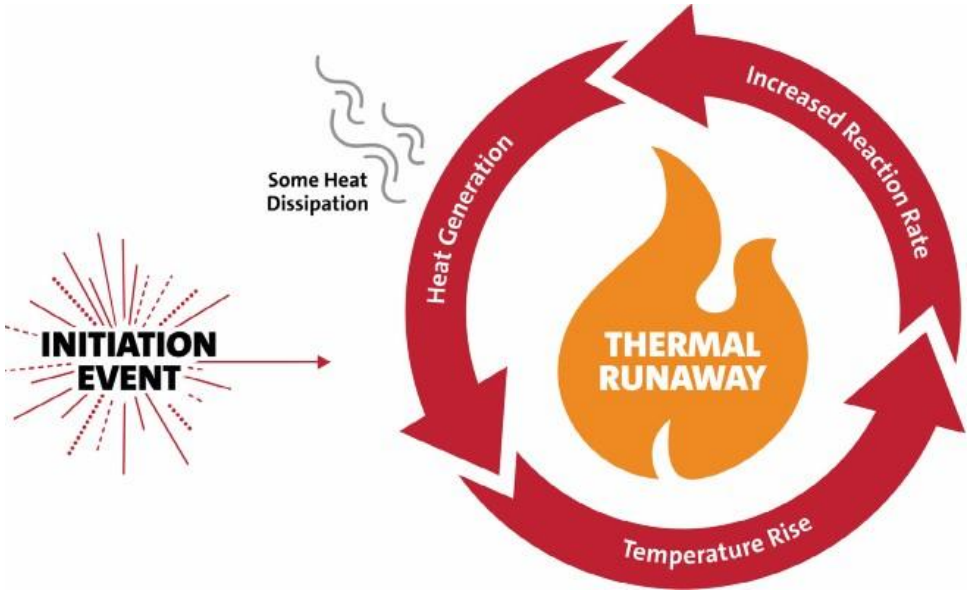
Thermal Runaway

- 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**



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Voltage and Temperature in a Li Battery

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Flood Damage

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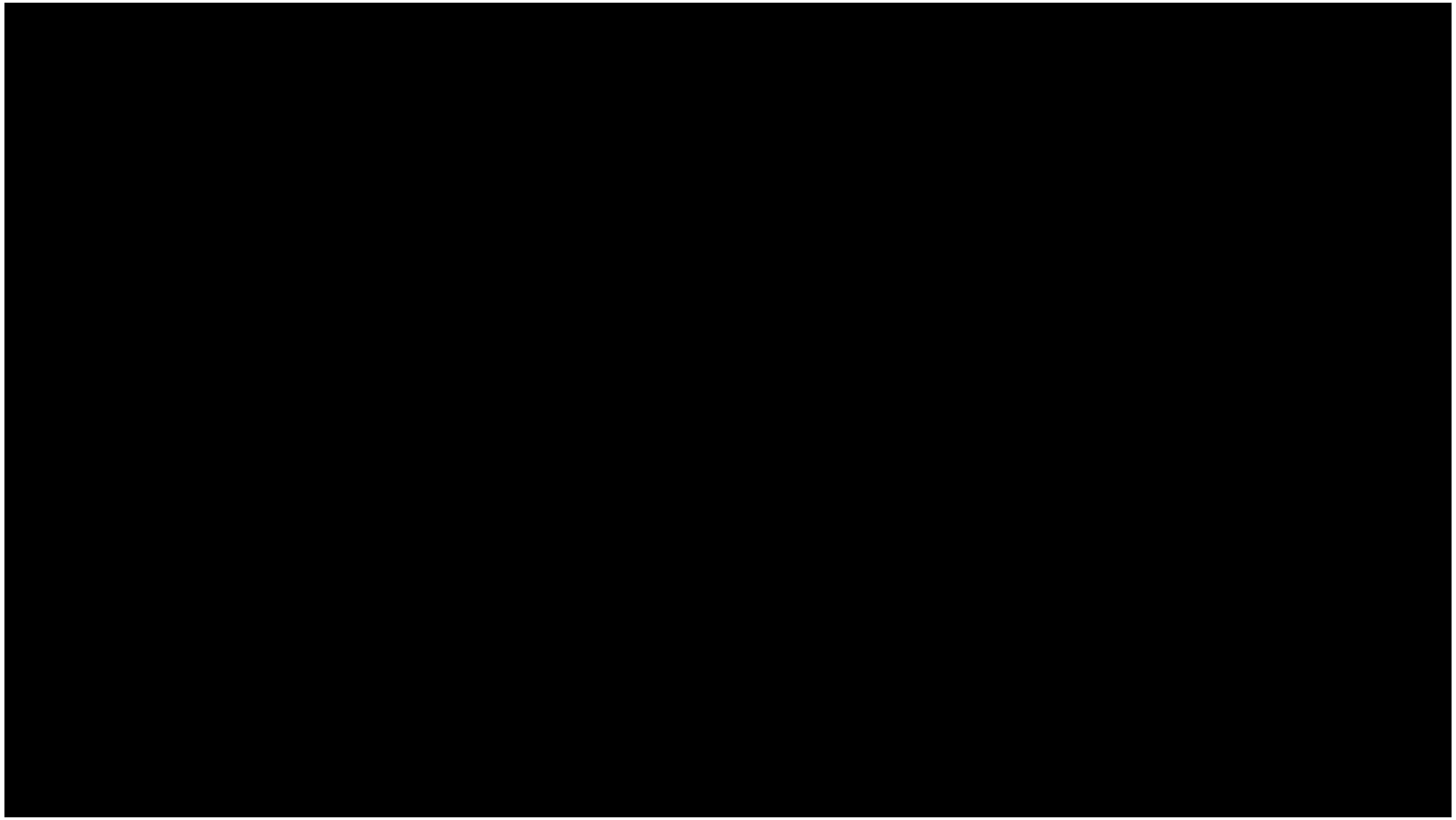
Thermal Runaway Indicators

- 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

Mobility Device Hazards



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

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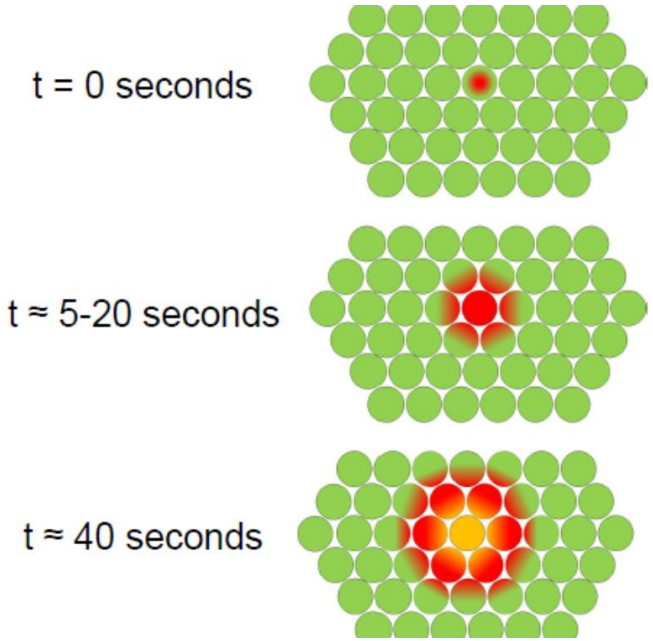
Gases Liberated in Thermal Runaway

- 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.



Electric Vehicle Response Guides

- Energy Security Agency (ESA) Response Guides
- National Fire Protection Agency (NFPA) Vehicle Response Guide
- International Association of Fire Chiefs (IAFC) Response Guidance
- Vehicle Manufacturer Response Guides

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Other Resources

- **National Fire Protection Agency (NFPA)**

Emergency Response Guides

Lithium-Ion Battery Safety (nfpa.org)

- **EV Rescue- Response Guide application**

Apple Store Application: EV Rescue-Electric Vehicles (EVR)

EVR

- **Fire Safety Research Institute (FSRI)**

Take Charge of Battery Safety

- **International Association of Fire Chiefs (IAFC)**

Lithium-Ion and Energy Storage Systems Resources

- **European Environment Agency (EEA)**

Report 13/2018: Electric Vehicles From Life Cycle and Circular Economy Perspectives

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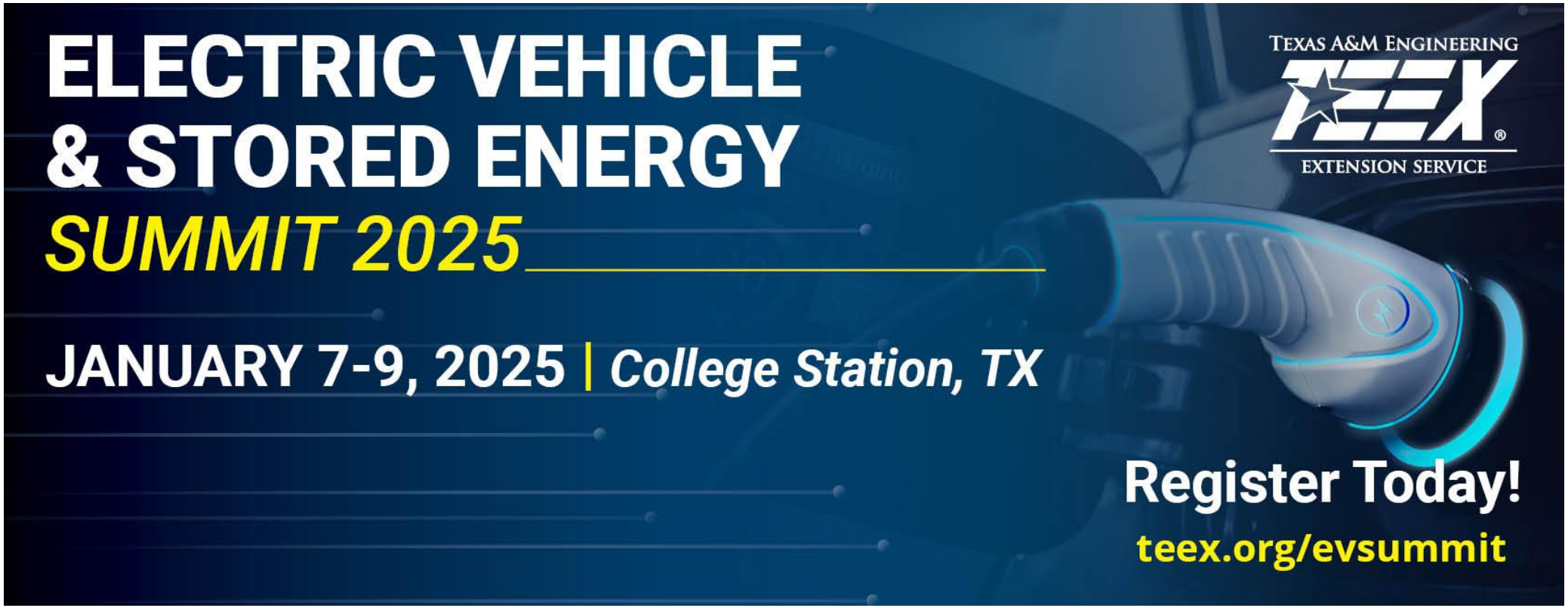
2nd Annual TEEX EV Summit



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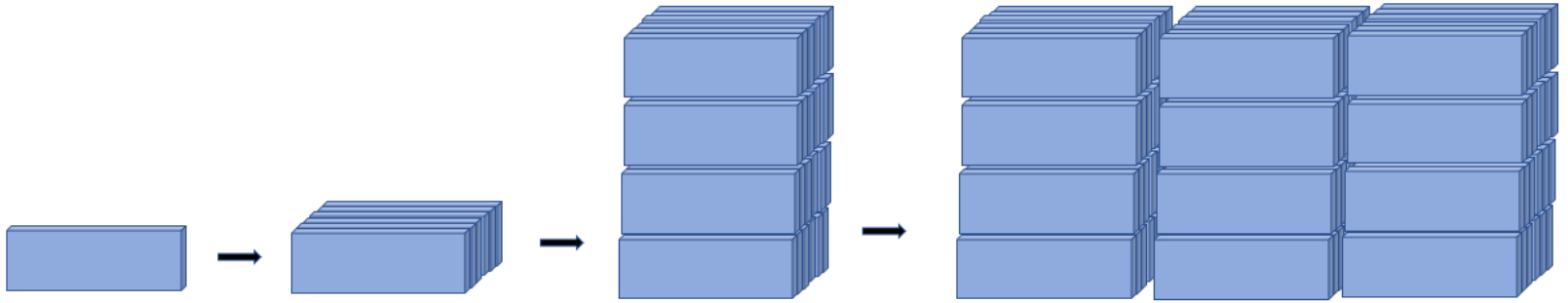
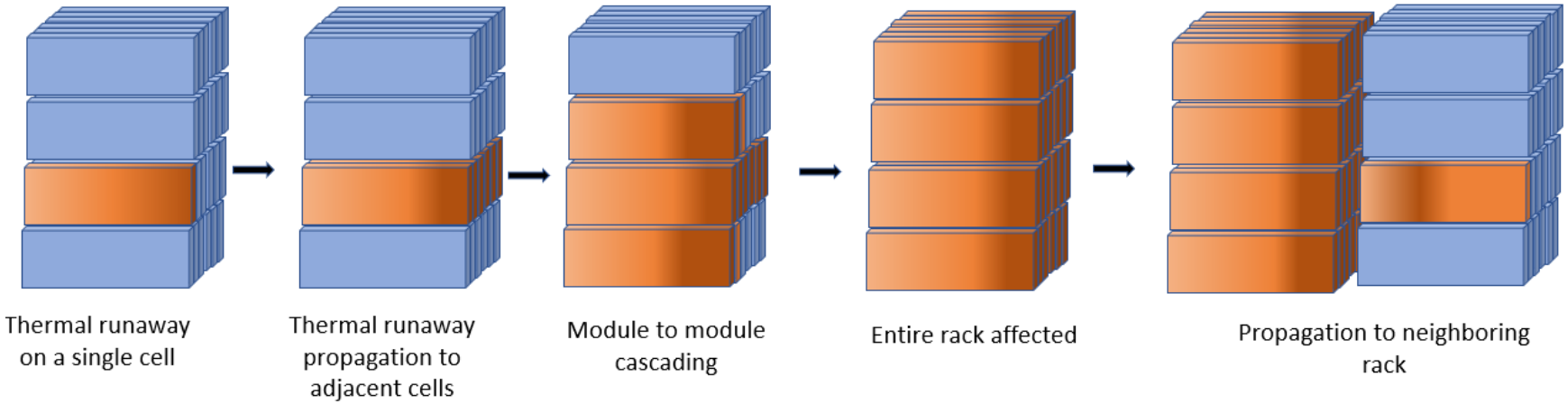
Battery Energy Storage Systems (BESS)

- 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

Battery Energy Storage Systems





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May 15, 2024 Fire at the Otay Mesa BESS Facility

- **Gateway Energy Storage Facility** In San Diego, 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) San Diego County

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January 16, 2025, Fire at the Vistra Energy (Moss Landing facility) Monterey County California

- One of the Worlds largest Battery Energy Storage Facility
- 930 MW of Battery Energy Storage
- Expected to be deemed a “Complete Loss”
- Researchers say they 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

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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!**

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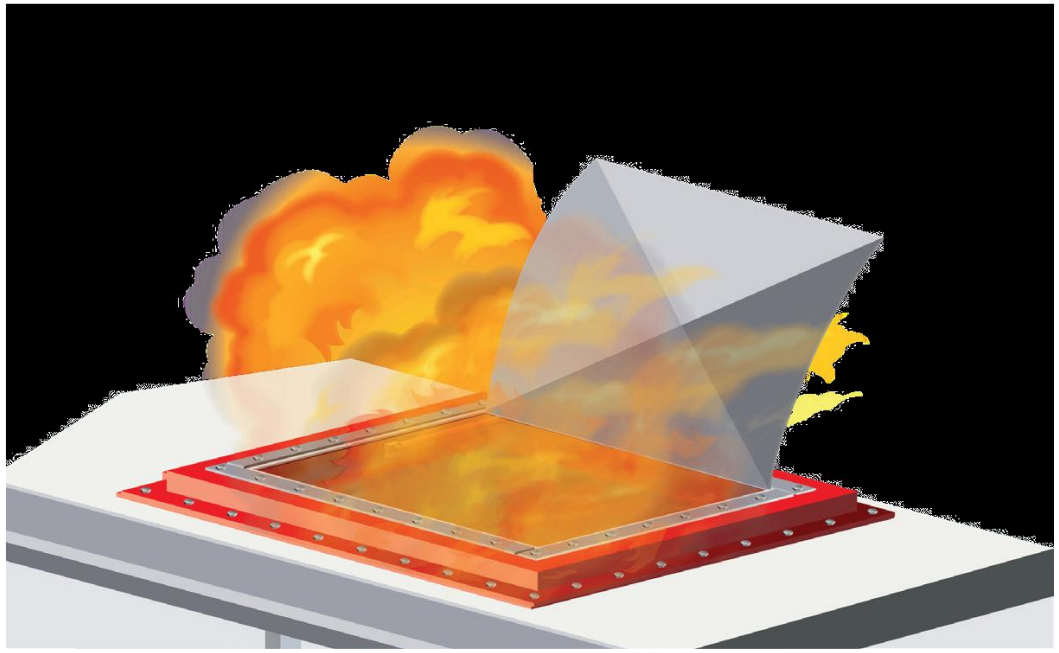
Deflagration Panels & Venting



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

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

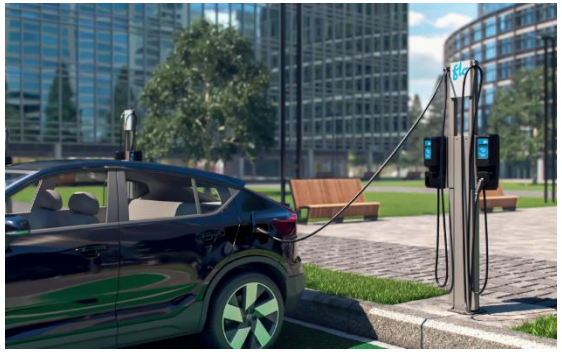
Level 2 Charging

- 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

Level 1, 2 and 3 Recharging Options and E-Stops



NFPA **70**, 30a,
and 855

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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

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Porsche Italia Partners with EmiControls

- 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 Dave Parker (Aldine Fire & Rescue) – EV Tainer

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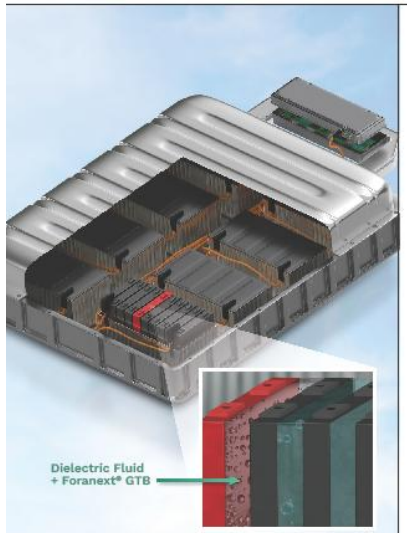
Emerging Technology

FORANEXT®

Foranext® Gaseous Thermal Barrier



IMPROVE THE BATTERY IMMERSION COOLING SAFETY, ONE CELL AT A TIME

The industry is making great strides to improve battery charge time as immersion cooling is more widely adopted. However, these new fluids and systems still run the risk of ignition.

Enter Foranext® GTB, the game-changing material added to immersion cooling fluid to fight thermal runaway propagation. GTB is triggered to engage when thermal runaway temperatures become abnormally high. As it changes phase, the gas partially captures the heat generated and forms a gaseous layer at the edge of the cell.

The heat is then contained and a barrier is formed between neighboring cells. Gas is also vented off during the process, further reducing the chance of ignition.

	IMMERSION COOLING	IMMERSION COOLING + FORANEXT® GTB
BASE FLUID TYPE	Dielectric Fluid	Dielectric Fluid + Foranext®GTB
THERMAL MANAGEMENT PERFORMANCE	★★★	★★★
ELECTRICAL INSULATION PROPERTIES	★★★	★★★
THERMAL RUNAWAY PROPAGATION	★★	★★★
FIRE RESISTANCE	★	★★★

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Emerging Technology

EV Fire Blankets

Multiple Manufactures:

Fire Cloak

Darley Fire Blanket

Bridgehill Fire Blanket

Encapsulator Agents such as F-500

Encapsulator Agents work on a chemical molecular level, changing the composition of plain water

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Emerging Technology

FireXO Extinguishing Agent

Full Circle Lithium FCL – X

Knight Fire Thermal Shield

EV Emergency Plug - blue it’s safe for you

*Does not disable Hummer EV and Chevrolet Blazer EV (as of 2/16/24)

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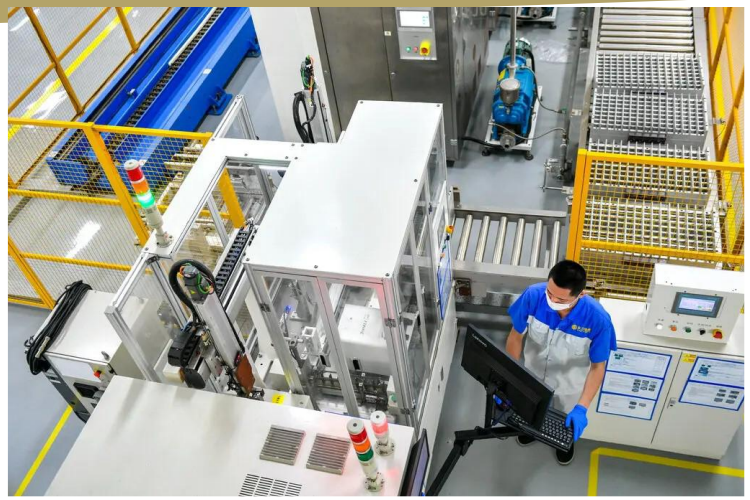
Sodium Batteries

- 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



Damaged, Defective or Recalled (DDR) Li-Ion 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…..Anodes rubbing on Cathodes, with leaking Electrolyte, etc.
- 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

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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 30a, 855)

TEEX and Li-Ion Battery Research

- National Laboratories
- Southwest Research Institute (SwRI)
- Federal Partners
- Other Texas A&M University System Components
- Quantify Exposure to First Responders and the Community
  - Poisonous & Dangerous 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

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Li-Ion Battery Research 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 Barrier)
  - 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

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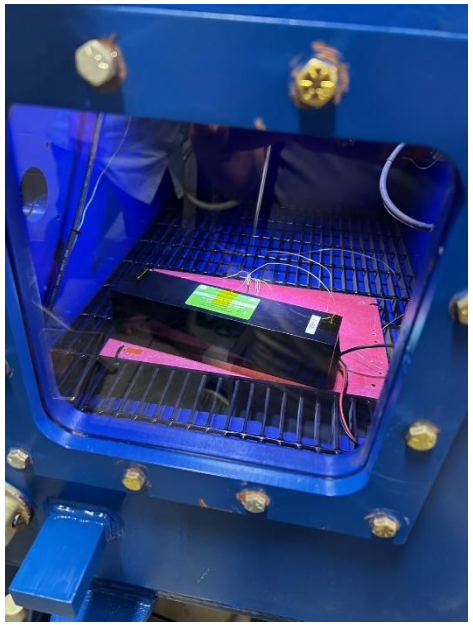
Batteries Tested



- Battery Management System (BMS)
- Current Interrupter Device (CID)

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PPE Test Samples

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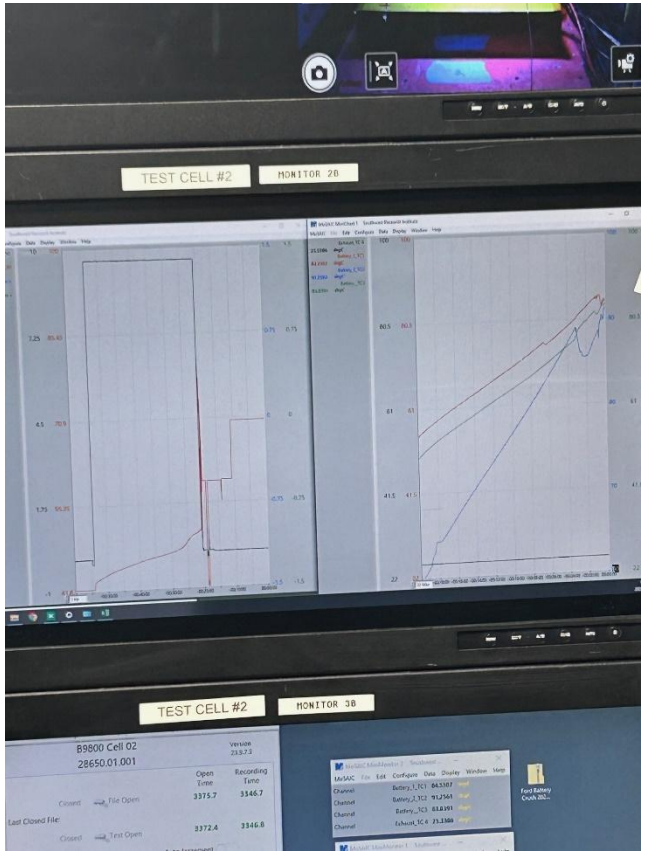
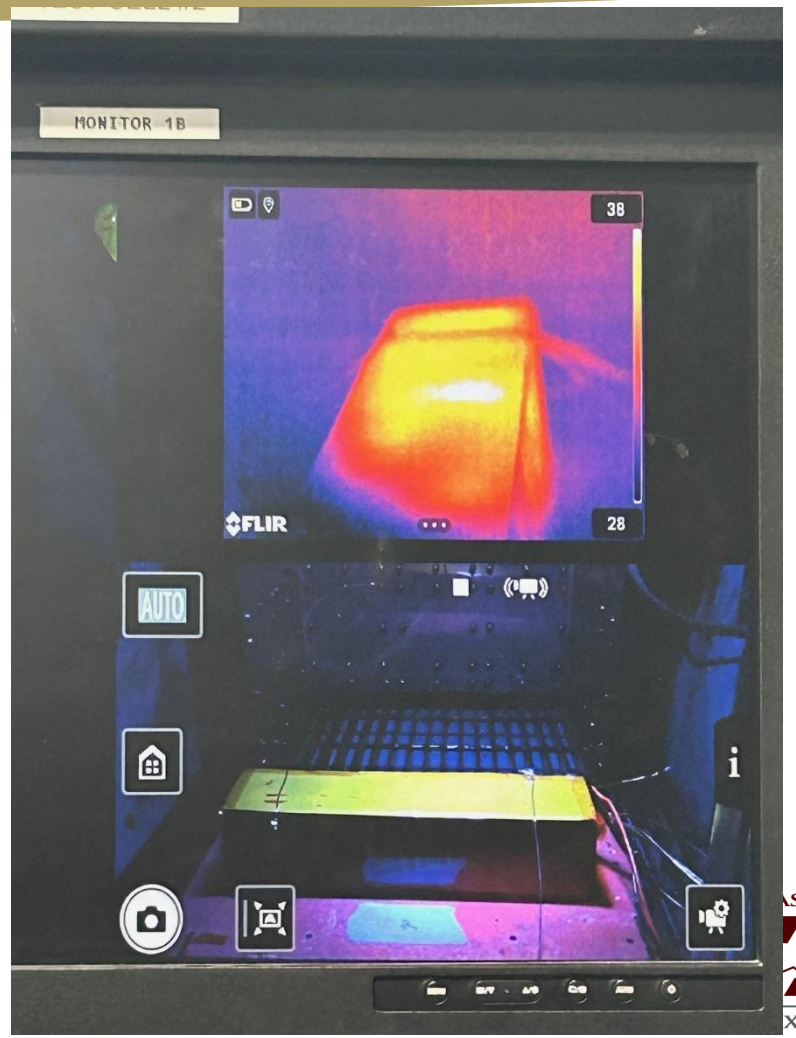
Indicators of Thermal Runaway





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Side-by-Side Thermal Runaway

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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 $\mu g/m^3$. **Emissions were dominated by metallic particles, with the highest being Lithium. Other battery materials were also detected such as nickel, manganese and cobalt. 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.

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Test Results

- In each test, peak temperatures were observed in the 1100° C range **(>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 117-125 deg. C **(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.

- CO2 based cleaning proved to be effective in removing SVOCs that penetrated the outer layer of gear and were deposited in the vapor barrier.

- 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.

- **Iron, Lead and Magnesium proved to be the most difficult to remove from PPE, regardless of the cleaning method.**

- **Even after cleaning, metals such as cobalt, copper, manganese and nickel remain on the bunker gear swatches at levels above the unexposed sample**.

- The PM2.5 collection was dominated by metallic elements with a small fraction of soot. **Dominant elements were Lithium followed by Nickel, Manganese and Cobalt.**

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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 contaminates entrained in the fabric once exposed to a Li battery fire. This is likely due to the smoother service 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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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

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Texas A&M Engineering Extension Service (TEEX)

- **TEEX continues to work with Industry Partners, National Laboratories, Federal Agencies and EV Manufacturers to conduct testing, training and develop practical solutions for lithium-ion battery response issues.**

- **Updated information can be found online at teex.org**

CEF102 - Electric Vehicle (EV) Safety for the First Responder

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