COMMITTEE ON SCIENCE, SPACE, and TECHNOLOGY
Subcommittee on Investigations and Oversight

HEARING CHARTER

Examining the Risk: The Dangers of EV Fires for First Responders

February *29, 2024*
10:30 a.m.
2318 Rayburn House Office Building

Purpose:
On Thursday, February 29, 2024, the Investigations and Oversight Subcommittee will hold a hearing to examine emerging electric vehicle (EV) fire concerns. The hearing will discuss the differences between EV fires and internal combustion engine vehicle (ICE) fires, focusing on the novel difficulties the former poses in multiple categories including burdens on local fire departments and the training of first responders, environmental impacts of the fires themselves, and current methodologies to extinguish the fires. The hearing will also discuss the current research at agencies such as the Department of Energy and the National Science Foundation to better understand electric vehicle lithium-ion batteries and recommendations for how to better extinguish these fires moving forward.

Witnesses:
- **Mr. Dan Munsey,** Fire Chief, San Bernardino County Fire Department, San Bernardino California
- **Dr. Judy Jeevarajan**, Vice President and Executive Director, Electrochemical Safety Research Institute at UL Research Institutes, Houston, Texas

Overarching Questions:
- How are ICE vehicle fires different from EV fires?
- How do the differences between ICE and EV fires affect the approach of firefighters to extinguish the fires?
- How are firefighters sharing the information they are learning to address these issues?
- What safety concerns stem from EV fires?
- What environmental concerns stem from EV fires?

BACKGROUND:
The emergence of electric vehicles into the economy presents new takes on old issues. Vehicle fires are not novel, but firefighters are now focusing on methods and best practices to address electric vehicle (EV) fires.[1] EV fires are distinct from traditional internal combustion engine (ICE) vehicle fires and pose new challenges to first responders when they occur.[2] The prevalence of EV fires is uncertain given the gaps in reporting structures, but with the increase of EVs in the consumer market, these fires will likely only become more prominent. The National Fire Protection Association (NFPA) estimates that worldwide, there are about "3.1 million EVs in operation today" and they project that 130 million will be in operation by 2030.[3] They further predict that global lithium battery production will "grow by 800 percent in the next four years."[4] The hearing is an opportunity to better understand these types of vehicle fires, as well as progress towards developing guidelines, training protocols, and effective technologies to address the complexities that chemical fires from lithium-ion batteries present for the protection of Americans and first responders.

EV vs. ICE Vehicles
For over 100 years, highways have been full of internal combustion engine vehicles that burn gasoline and diesel.[5] However, within the last two decades the roads have become more populated with alternative fuel sourced vehicles, most commonly electric.[6] From the early 2000s, these alternative fuel sourced vehicles have varied from plug-in hybrid electric vehicles (PHEVs) which are a combination of an internal combustion engine with an electric motor, to fully electric vehicles that operate on a series of lithium-ion battery cells that are rechargeable.[7] These are referred to as battery electric vehicles (BEVs or EVs for our purposes).

While ICE vehicles and EVs share some similarities, their operating systems have distinct differences. An ICE vehicle ignites and combusts the fuel within an internal combustion engine, which partially converts energy from the combustion into work pushing gases through a fixed cylinder and a moving piston.[8] This process turns the crankshaft and through a system of gears in the powertrain, drives the vehicles wheels.[9] EVs, on the other hand, are powered by the electricity from a rechargeable lithium-ion battery.[10] The motor has two parts, a rotor that turns and a stator

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[1] Willie Jones, Extinguishing the EV Battery Fire Hype, The Numbers Don't Support Persistent Fears of Lithium-Ion Conflagrations, IEEE Spectrum, Dec. 4, 2023, https://spectrum.ieee.org/lithium-ion-battery-fires.
[2] Extinguishing the EV Battery Fire Hype - IEEE Spectrum
[3] Jesse Roman, Stranded Energy, NFPA Journal, Jan. 1, 2020, https://www.nfpa.org/news-blogs-and-articles/nfpa-journal/2020/01/01/ev-stranded-energy?l=61.
[4] Robert Rielage, Resource Round-up: Electric Vehicles and Energy Storage Systems, FireRescue1, Feb. 6, 2020, https://www.firerescue1.com/electric-fire/articles/resource-roundup-electric-vehicles-and-energy-storage-systems-IU53wDvYdysZidgA/.
[5] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[6] *Id.*
[7] *Id.*
[8] U.S. Dep't Energy, Off. Energy Efficiency and Renewable Energy, Internal Combustion Engine Basics, Vehicle Techn. Off., Nov. 22, 2013, https://www.energy.gov/eere/vehicles/articles/internal-combustion-engine-basics#:~:text=The%20engine%20consists%20of%20a,motion%20drives%20the%20vehicle%27s%20wheels.
[9] *Id.*
[10] Steve Melito, ICE Vehicles vs. Electric Vehicles, ElastoProxy, Mar. 12, 2022, https://www.elastoproxy.com/ice-vehicles-vs-electricvehicles/#:~:text=ICE%20vehicles%20ignite%20and%20combust,share%20many%20components%20in%20common%3F.

that does not.[11] Within an EV a chemical reaction in the battery module, which is made up of hundreds of battery cells, generates a direct current.[12] This current produces a magnetic field and spins the rotor.[13] The rotor and the stator in the EV do not touch and the chemical reaction in the battery the battery generates the direct current, and an inverter subsequently converts that direct current into an alternating current. The alternating current then also creates a magnetic field that causes the rotor to spin and transfers the rotation into movement. The batteries in EVs also weigh significantly more than the engine system in ICE vehicles.[14]

Lithium-ion Batteries

Like most batteries, the lithium-ion batteries consist of cells that produce an electric current that is then converted to mechanical energy.[15] These batteries are composed of an anode (negative) and a cathode (positive) separated by an electrolyte to conduct the electricity by transferring the charged ions between the electrodes.[16] The anode is generally made up of carbon (graphite) and the cathode generally consists of layers of lithium and metal oxide.[17] The electrolyte is a lithium salt dissolved in an organic solvent, usually carbonates, which are quite flammable.[18]

These batteries come in various shapes and sizes and are tightly packed together in battery packs to produce the required voltage, power, and energy to operate EVs.[19] The battery packs are then assembled into modules and equipped with a battery management system.[20] The module helps protect the battery packs from external forces and crashes, while the battery management system reports and maintains the functionality of the battery packs.[21] The battery management system monitors the voltage, temperature data, and the state of charge of the battery to help prevent overcharging.[22] The thermal management system helps to regulate the temperature of the modules and works to prevent overpressure by operating venting systems or liquid cooling systems depending on the design of the vehicle.[23]

ISSUES:

Safety Risks:

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[11] *Id*.
[12] *Id*.
[13] *Id*.
[14] *Id*.
[15] Heekyong Yang, Explainer: Are Lithium-Ion Batteries in EVs a Fire Hazard? Rueters (Aug. 23, 2021), https://www.reuters.com/business/autos-transportation/are-lithium-ion-batteries-evs-fire-hazard-2021-08-23/; Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[16] *Id*.
[17] *Id*.ك
[18] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[19] Peter Valdes-Dapena, Electric Car Batteries are Catching Fire and That Could be a Big Turnoff to Buyers, CNN Business, Nov. 10. 2020, https://www.cnn.com/2020/11/10/success/electric-car-vehicle-battery-fires/index.html.
[20] *Id*.
[21] Early Detection of Electric Battery Failures, SAE Government, NHTSA (2023), https://www.nhtsa.gov/sites/nhtsa.gov/files/2023-03/15874-INL_SAE%20Govt%20Industry%20Meeting_032223-tag.pdf.
[22] Sravan Kumar Keerthi, Battery Management System in Electric Vehicles, Cyient, Mar. 29, 2022, https://www.cyient.com/blog/battery-management-system-in-electric-vehicles#:~:text=A%20Battery%20Management%20System%20(BMS,within%20its%20safe%20operating%20parameters; Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[23] *Id*.

Fires in EVs are escalated by the stranded energy that remains in damaged high-voltage lithium-ion batteries. While EV battery fires pose dangerous threats on multiple fronts, they pose significant threats to the first responders attempting to quench the flames and rescue vehicle occupants. First, EV battery fires present a high risk of electric shock from exposure to the high-voltage components of damaged batteries.[24] Second, these fires risk the initiation of a process known as "thermal runaway."[25] During "thermal runaway" the battery will experience uncontrolled increases in temperature and pressure, which can lead to venting and combustion of toxic gases, cell rupture and release of projectiles, and battery reignition/fire.[26] The presence of particular chemical components within the battery cells ignites a fire that occurs at a much faster rate and at temperatures much hotter than anticipated.[27] The energy that remains in the damaged battery known as "stranded energy" feeds the fire, and can cause reignition and electric shock.[28]

Electric Shock

Human bodies are natural electrical conductors. Therefore, if a person contacts an energized source of electricity, the current will flow through the body, but the body's resistance or its ability to reduce an electric current varies from person to person.[29] The maximum voltage considered safe for humans is 50 or 60 volts of direct current.[30] EVs operate well above those thresholds - usually around 300 to 400 volts or more.[31] For comparison, a standard ICE vehicle has a 12.6 volt battery. When a crash occurs that damages an EV battery, or a manufacturing malfunction leads to battery failure, many times the protective covers and circuit fuses are no longer effective.[32] If a person were to touch the vehicle or an exposed connector, they could become a part of the high-voltage circuit and suffer serious injury or death.[33]

Firefighters often need to remove occupants from a vehicle after an accident occurs. This can require the use of the "jaws of life" – a tool that cuts vehicles open and can remove structural components of the vehicle to evacuate the occupant. In EVs, cutting into a vehicle when there may be a high voltage inside of the vehicle's structure poses a significant safety risk for firefighters.

Thermal Runaway

"Thermal Runaway" typically occurs when the battery has been damaged during a crash or a manufacturing error. If the process of thermal runaway occurs it can create a "domino effect" spreading the chemical process of exothermic reaction from one battery cell to another.[34] Generally, the process is started through a short-circuiting inside the battery cell, increasing the

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[24] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[25] *Id*.
[26] *Id*.
[27] Andrew Evers & Lora Kolodny, Electric Vehicle Fires are Rare, but Hard to Fight- Here's Why, CNBC, Jan. 29, 2022, https://www.cnbc.com/2022/01/29/electric-vehicle-fires-are-rare-but-hard-to-fight-heres-why.html.
[28] Jasper Jolly, Do Electric Cars Pose a Greater Fire Risk than Petrol or Diesel Vehicles, The Guardian, Nov. 20, 2023, https://www.theguardian.com/business/2023/nov/20/do-electric-cars-pose-a-greater-fire-risk-than-petrol-or-diesel-vehicles.
[29] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[30] *Id*.
[31] *Id*.
[32] *Id*.
[33] *Id*.
[34] *Id*.

cell's internal temperature.[35] Fires from thermal runaway can lead to explosions and create electrostatic sparks.[36] This can result in popping noises resulting from the venting of heat and other gases.[37] There are four major hazards that are associated with thermal runaway: (1) venting of toxic and flammable vapors from holes in the battery casing; (2) combustion of vapors ejected from the electrolyte solvent; (3) localized overpressure; and (4) release of projectiles due to rupture of the cell casing or fail of the pressure release system.[38] There are various other hazards that are also associated with thermal runaway such as asphyxiation from toxic gases, burn, damaged vehicle components, potential for wildfires, etc.[39]

<u>*Stranded Energy*</u>

These concerns are starkly different from fires in ICE vehicles. Generally, in ICE vehicles electrical faults may trigger sparks, or the engine can overheat because of cooling issues and potentially ignite the fuel.[40] However, given the familiarity of these vehicles, first responders and firefighters are well versed in managing ICE vehicle fires.[41] There are various technologies that help first responders and firefighters to extinguish ICE vehicle fires quickly and efficiently without fear of reignition. However, with EVs, the available stranded energy remaining in the vehicle battery cells is what facilitates the risk associated with lithium-ion batteries. When a battery is damaged, the energy that remains in the cells within the battery pack are what lead to the reignition of fires, electric shock, or the long-term burn that these vehicle fires induce.[42] First responders have no way of knowing how much energy is left within a battery pack or which packs are damaged, and no way of draining the left-over energy.[43] The issue is that usually when the temperature rises above a certain threshold or pressure builds beyond a certain point the battery management system shuts down making it impossible to know how much energy is left in the cells and which ones are damaged.[44]

<u>*NTSB Safety Report*</u>

On November 13, 2020, the National Transportation Safety Board (NTSB) released a Safety Report titled, "Safety Risks to Emergency Responders from Lithium-ion Battery Fires in Electric Vehicles." This report highlights three EV crashes resulting in post-crash fires and one non-crash fire. All of these accidents illustrate the risks to emergency responders posed by the vehicles' high-voltage lithium-ion batteries.[45] The NTSB consulted international and national standards for safety for electric vehicles and reviewed the guidance documents from manufacturers to first and second

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[35] *Id*.
[36] *Id*.
[37] *Id*.
[38] *Id*.
[39] *Id*.
[40] Jasper Jolly, Do Electric Cars Pose a Greater Fire Risk than Petrol or Diesel Vehicles, The Guardian, Nov. 20, 2023, https://www.theguardian.com/business/2023/nov/20/do-electric-cars-pose-a-greater-fire-risk-than-petrol-or-diesel-vehicles.
[41] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.
[42] Andrew Evers & Lora Kolodny, Electric Vehicle Fires are Rare, but Hard to Fight- Here's Why, CNBC, Jan. 29, 2022, https://www.cnbc.com/2022/01/29/electric-vehicle-fires-are-rare-but-hard-to-fight-heres-why.html.
[43] *Id*.
[44] *Id*.
[45] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020), https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.

responders who deal with EV crashes and battery fires.[46] The NTSB provided several findings but the most significant were:

- instructions from most manufacturers' emergency response guides for fighting high-voltage lithium-ion battery fires lack necessary, vehicle-specific details on suppressing the fires;
- thermal runaway and multiple battery reignitions after initial fire suppression are safety risks;
- the energy remaining in a damaged lithium-ion battery (stranded energy) poses a risk of electric shock and creates the potential for thermal runaway;
- the National Highway Traffic Safety Administration (NHSTA) should update the U.S. New Car Assessment Program to incentivize manufacturers to provide better safety guidance for EVs; and
- federal crash standards do not address high-speed, high-severity crashes resulting in damage to high-voltage lithium-ion batteries and stranded energy.[47]

One incident that the report highlighted was the crash on March 23, 2018, in Mountain View, California that truly exemplifies the challenges and dangers associated with these vehicle fires.[48] A violent crash occurred when a Tesla Model X SUV, traveling at 70 mph down a flat straight stretch of the 101 freeway, drifted left and slammed into a concrete median that divided the freeway from an offramp.[49] The front end of the vehicle was torn off, exposing the 1,200-pound, 400-volt lithium-ion battery and scattering energized cells across the road.[50] Once the first responders and Mountain View Fire Department arrived on the scene the car was already engulfed in flames.[51] This was an area of the country near Silicon Valley that is home to the some of the largest technology companies in the country.[52] Nearly ten percent of passenger vehicles in Silicon Valley are either hybrid or fully electric.[53] They, more than anyone else, should have been equipped to handle a crash such as this.[54] This crash was put out with water initially, but still contained a charged battery.[55] After two hours of work, the fire department called Tesla, who sent technicians to come and remove parts of the damaged battery cell by cell.[56] It took six hours before the vehicle chassis was safe to move.[57] Once it was brough to the salvage yard the vehicle reignited twice within 24 hours and then again six days later.[58] Tesla eventually finished removing the remaining

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[46] *Id*.
[47] *Id*. at ix
[48] NTSB: Man Killed in Mountain view Tesla Crash Complained about Autopilot, CBS News San Francisco (Feb. 11, 2020), https://www.cbsnews.com/sanfrancisco/news/tesla-fatal-crash-mountain-view-autopilot-complaint-walter-huang-ntsb/.
[49] Kevin Forestieri, NTSB: Tesla's Autopilot Steered Model X into Highway Median, Causing Fatal Mountain View Crash, Mountain View Voice, Jan. 22, 2020, https://www.mv-voice.com/news/2020/02/25/ntsb-teslas-autopilot-steered-model-x-into-highway-median-causing-fatal-mountain-view-crash/.
[50] Catherine Thorbecke, Tesla on Autopilot had Steered Driver Towards Same Barrier Before Fatal Crash, NTSB says, ABC News, Feb. 12, 2020, https://abcnews.go.com/Business/tesla-autopilot-steered-driver-barrier-fatal-crash-ntsb/story?id=68936725.
[51] Collision Between a Sport Utility Vehicle Operating with Partial Driving Automation and a Crash Attenuator, NTSB Invetigations (2018), https://www.ntsb.gov/investigations/Pages/HWY18FH011.aspx.
[52] *Id*.
[53] *Id*.
[54] *Id*.
[55] *Id*.
[56] *Id*.
[57] *Id*.
[58] *Id*.

battery cells then submerged the remains in a vat of salt water.[59] This was a prime example of the dangers associated with large amounts of stranded energy still within a vehicle and showcases the vast number of resources necessary to handle these fires.[60]

First Responder Impacts and Training Protocols

EV fires have posed significant challenges to the firefighter and first responder communities. These fires behave very differently from regular vehicle fires and require more resources that may not be readily available to all areas of the country.[61] Firefighters have consistently reported the difficulty in actually extinguishing these fires regardless of how much water they use.[62] Last year an EV crashed on I-95 around midnight in Wakefield, MA,.[63] After a guardrail was forced into the bottom of the car it burst into flames.[64] More than two hours and 20,000 gallons of water later, the blaze finally ceased.[65] This is just one example of what it takes to extinguish these fires. In 2022, the Sacramento Metropolitan Fire District firefighters were forced to submerge a Tesla in a makeshift pond because the vehicle kept reigniting.[66] In Florida post Hurricane Ian, numerous EVs caught fire after sitting in saltwater.[67]

According to the NFPA, there is very little information available on how to handle these fires and only about half of the 1.1 million firefighters in the U.S. are actually trained to combat EV fires.[68] **There are currently no unified guidance or national training procedures for how to handle EV fires**.[69] Auto manufacturers have released safety guidance that details how to maintain battery safety and how to disconnect the battery from the rest of the vehicle.[70] However, these are not guidance documents for how to handle EV fires. The guidance that NFPA released focuses on extrication, containment, and extinguishment. First, extricate any individuals from the vehicle(s) and get them to safety. Second, contain the scene as much as possible. Close down roadways, direct traffic, remove all bystanders, ensure that all first responders are equipped with personal protective equipment (PPE). Third, begin extinguishing the fire. These are the main approaches that are communicated to first responders and on the scene firefighters.[71]

Risks of Battery Fire Emissions.

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[59] *Id.*

[60] *Id.*

[61] Andrew Evers & Lora Kolodny, Electric Vehicle Fires are Rare, but Hard to Fight- Here's Why, CNBC, Jan. 29, 2022, https://www.cnbc.com/2022/01/29/electric-vehicle-fires-are-rare-but-hard-to-fight-heres-why.html.

[62] Gabrielle Gurley, Firefighter Hell: When an Electric Car Bursts into Flames, The American Prospect, Jan. 26, 2023, https://prospect.org/environment/2023-01-26-firefighter-hell-electric-car-battery-fire/.

[63] *Id.*

[64] *Id.*

[65] *Id.*

[66] *Id.*

[67] Gabrielle Gurley, Firefighter Hell: When an Electric Car Bursts into Flames, The American Prospect, Jan. 26, 2023, https://prospect.org/environment/2023-01-26-firefighter-hell-electric-car-battery-fire/; Travis Okulski, Fisker Lost $30 Million Worth of Cars in Hurricane Sandy, Jalopnik, Nov. 7, 2012, https://jalopnik.com/fisker-lost-30-million-worth-of-cars-in-hurricane-sand-5958523; Christopher Flavelle, U.S. Hit by Record Number of High-Cost Disasters in 2023, The New York Times, Jan. 10, 2024, https://www.nytimes.com/2024/01/10/climate/billion-dollar-disasters-climate.html.

[68] Jesse Roman, Stranded Energy, NFPA Journal, Jan. 1, 2020, https://www.nfpa.org/news-blogs-and-articles/nfpa-journal/2020/01/01/ev-stranded-energy?l=61.

[69] *Id.*

[70] Electrical Vehicle Charging Safety Tips, FEMA, https://www.usfa.fema.gov/downloads/pdf/publications/electric-vehicle-safety-handout.pdf.

[71] Safety Risk to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles, Safety Report, National Transportation Safety Board (2020) at 44, https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.

While much of the focus regarding EV fires is paid to the actual fires themselves, the risks related to the amount and type of smoke and gases released during these fires are also a significant threat. During the thermal runaway process, reignition of the fire can be attributed to the toxic gases released. The lithium-ion batteries emit various toxic substances such as hydrogen fluoride, phosphorous pentafluoride, and phosphoryl fluoride.[72] These chemicals are highly dangerous and in confined areas with extreme heat, can be flammable and may ignite creating a risk of explosion. Hydrogen fluoride (HF) specifically is an extremely toxic chemical and may penetrate the PPE suits of firefighters and first responders. It remains unclear whether suits tainted with HF can still be used, which adds further hurdles to the resources issue many fire departments already face. While there have not been definitive studies on the effects the release of these toxic chemicals has on the environment, there have been studies that show the excessive exposure to HF can lead to serious health conditions for individuals.[73] HF can be absorbed through the body and ingested through inhalation or through eye or skin contact. The severity of the symptoms depends on the concentration and duration of exposure. These reactions can range from mild skin and eye irritation to severe damage to skin, eyes, other issues, respiratory system, or even death.[74] There are various suggestions from the Occupational Safety and Health Administration (OSHA) and state health departments that discuss how to manage these chemicals despite the research gap in how they affect the broader environment.[75]

SAE standards/ Unified Guidance

The Society of Automotive Engineers International (SAE) is developing fire prevention and suppression solutions for EV battery fires. While not yet final, the document will review various safety solutions employed in battery packs for preventing or suppressing potential fire during a thermal runaway event. These distinctive methods include the use of hydrogel agents, aerosol fire suppressants, and new design safety features. Ultimately, SAE plans to provide a multi-layered approach to battery safety including both active and passive measures.[76]

Fire Grants

The Federal Emergency Management Agency (FEMA), in conjunction with the United States Fire Administration (USFA), issues specific firefighter assistance grants programs. These grants help to fund fire safety through critically needed resources to equip and train emergency personnel, enhance efficiencies, and support community resilience. There are two major grant programs available to firefighters and fire departments to address resources and training.[77] On June 21, 2023, the Committee marked up and favorably reported H.R.4090, the *Fire Grants and Safety Act of 2023*, to reauthorize these programs through fiscal year 2028.

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[72] Fredrik Larsson, Petra Andersson, Per Blomqvist & Bengt-Erik Mellander, Toxic Fluoride Gas Emissions from Lithium-ion Battery Fires, Scientific Reports, Aug. 30, 2017, https://www.nature.com/articles/s41598-017-09784-z#:~:text=While%20the%20fire%20itself%20and%20the%20heat%20it,home%20equipped%20with%20a%20battery%20energy%20storage%20system.

[73] *Id*.

[74] Protecting Workers Exposed to Hydrogen Fluoride (HF), California OSHA Fact Sheet (2022), https://www.dir.ca.gov/dosh/dosh_publications/Hydrogen-Flouride-fs.pdf.

[75] *Id.*ك

[76] A Review on Fire Prevention and Suppression Solutions for EV Battery Packs, SAE International (Jan. 16, 2024), https://www.sae.org/publications/technical-papers/content/2024-26-0012/.

[77] Assistance to Firefighters Grants Program, Preparedness Grants, FEMA, https://www.fema.gov/grants/preparedness/firefighters.

- *Assistance to Firefighters Grant (AFG)* – These grants are meant to meet firefighting and emergency response needs of fire departments and other emergency medical service organizations. These grants have been in existence since 2001 and help firefighters and other first responders obtain equipment, protective gear, emergency vehicles, training, and other resources necessary for protecting public and emergency personnel. The most recent notice of funding opportunity and application period is open until March 8, 2024, at 5pm.[78]

- *Staffing For Adequate Fire and Emergency Response (SAFER)* – These grants were created to provide funding directly to fire departments and volunteer firefighter interest organizations to help sustain and bolster the number of trained firefighters in the community. Specifically, these grants are meant to help with staffing issues and operational standards established by the National Fire Protection Association. These grants are currently up for reauthorization and Congress is currently meeting with stakeholders to negotiate funding for these programs.[79]

Research and Current Technologies

Researchers continue to explore what the best method is for extinguishing these fires. We have certain resources such as foams and traditional fire extinguishers.[80] There have also been experiments with using nitrogen to smother fires or applying blankets.[81] However, these methods are still too new to evaluate their overall efficacy. The general issues with the use of hand-held extinguishers and the foam applicators are the capacity concerns. The canisters only include so much, and the fires burn for much longer and at much higher temperatures than regular vehicle fires.[82]

As noted in examples provided above as well as numerous others, one of the methodologies that has been implemented is submerging the vehicle or using massive amounts of water to cool the battery.[83] The gases produced by the fire themselves are also combustible so containing the fire to reduce the availability of oxygen and then using water to cool the battery has been the most common method to date.[84] Experimentation with blankets to smother the fires has recently begun but there is no conclusive data on the effectiveness of these blankets nor the potential cost for local fire departments.[85]

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[78] *Id*.
[79] Staffing for Adequate Fire and Emergency Response (SAFER), Assistance to Firefighter Grants Program, FEMA, https://www.fema.gov/grants/preparedness/firefighters/safer.
[80] Susan Campbell, Why Electric Vehicle Fires are a Real Pain Point for Arizona Fireighters, Arizona's Family, Oct. 19, 2023, https://www.azfamily.com/2023/10/19/why-electric-vehicle-fires-are-real-pain-point-arizona-firefighters/.
[81] *Id*.
[82] Ewelina Szmytke, Dorota Brzezinska, Waldemar Machnowsky, & Szymon Kokot, Firefighters' Clothing Contamination in Fires of Electric Vehicle Batteries and Photovoltaic Modules, National Library of Medicine, PubMed Central, Oct. 19, 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9566750/.
[83] EV Firefighting Submersion Pool, Garrison Flood Control, https://www.garrisonflood.com/ev-fire-fighting-water-submersion-pool; Up to 150,000 Liters of Water Needed to Put Out a Fire in an Electric Car, CTIF (Sept. 18, 2022), https://ctif.org/news/150-000-liters-water-needed-put-out-fire-electric-car.
[84] Asha C, Gilbert, California Firefighters use 4,500 Gallons of Water to Extinguish Tesla Fire that Kept Reigniting, USA Today, June 23, 2022, https://www.usatoday.com/story/money/cars/2022/06/23/tesla-fire-california-reignites/7709296001/.
[85] Jesse Roman, Stranded Energy, NFPA Journal, Jan. 1, 2020, https://www.nfpa.org/news-blogs-and-articles/nfpa-journal/2020/01/01/ev-stranded-energy?l=61.

Automotive manufacturers have released safety materials detailing how to cut the overall power source to minimize electric shock. Cut loops have become more common in EVs.[86] These are low-voltage wire loops that first responders can safely cut to disconnect the high-voltage system from the rest of the vehicle.[87] While these do not remove the energy from the high-voltage battery, cutting the loops isolates the high-voltage power inside the battery, allowing for vehicle occupants to be evacuated.[88] Manufacturers have also developed technology to drain the energy from the high-voltage batteries, but these tools have to be operated by a specialist because they are specific to the vehicle and work only on an intact battery.[89] The specialist also helps in the removal of the battery from the vehicle as many first responders do not have the expertise to remove them.[90]

Limited research, lack of technology, and no uniform guidance for combating EV fires are not the only issues. Data systems and tracking mechanisms for these fires are virtually nonexistent. Several organizations including the USFA and NFPA, have voiced concerns with the lack of reporting and are working to develop a tracking system for fire departments across the country.[91] Unified data reporting systems could provide information on the frequency and intensity of these fires, insight into successful suppression methodologies, and the development of best practices to be shared across cities, counties, and states.

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[86] *Id*.
[87] *Id*.
[88] *Id*.
[89] *Id*.
[90] *Id*.
[91] Ellie Burgess, Using Crowdsourcing to Address Electric Vehicle Fires, NFPA, Jul. 1, 2014, https://www.nfpa.org/education-and-research/research/fire-protection-research-foundation/projects-and-reports/using-crowdsourcing-to-address-electric-vehicle-fires.