NIST Technical Note 2365
NIST TN 2365

Understanding the Risk of Lithium-Ion Battery Fires

multi-source data analysis

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This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2365

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

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March 2026

U.S. Department of Commerce
Howard Lutnick, Secretary of Commerce

National Institute of Standards and Technology
Craig Burkhardt, Acting Under Secretary of Commerce for Standards and Technology and Acting NIST Directory

NIST TN 2365
March 2026

Publication History
Approved by the NIST Editorial Review Board on 2026-02-26

How to Cite this NIST Technical Series Publication
Gilbert SW, Fang H, Butry DT, Tam WC, Donnelly M, Fung JF (2026) Understanding the Risk of Lithium-Ion Battery Fires - multi-source data analysis. (National Institute of Standards and Technology, Gaithersburg, MD), NIST Technical Note (TN) NIST TN 2365. https://doi.org/10.6028/NIST.TN.2365

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Abstract

Lithium ion battery (LIB) fires are a growing problem that extends across the supply chain, including mining, production, warehousing, shipping, and waste disposal, as well as the consumer side. But data on such fires is fragmented and mostly incomplete. Many are secondary data sources, and for the National Fire Incident Reporting System (NFIRS) and the Consumer Product Safety Commission data sets identification of LIB fires is difficult. Some information about LIB fires was estimated from the data sets including typical time of day, time of year, room of house, relative severity, and time trend. Multiple independent data sources make it possible to estimate numbers on some types of fires by identifying the number of such fires that appear in both data sets using the Capture-Recapture method. There have been an estimated 5718 (95 %CI: 2866 – 10 846) electric vehicle and plugin hybrid fires, and an estimated 198 000 (95 %CI: 84 000 – 465 000) LIB fires in structures since 2011. Plugin electric vehicle fires are still a small percentage of the total number of car fires, but are growing at the rate of about 45 % (± 11.3 %) per year, which likely parallels the increase in the number of plugin electric vehicles on the road. Consumer LIB fires appear to be growing at a rate of 10 % (CI: 7.1 – 13.0) per year. The findings indicate a substantial underestimation in current reporting.

Keywords

Lithium Ion Batteries; Fire; NFIRS; AI Analysis; Battery Electric Vehicles; Plugin Hybrid Electric Vehicles.

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1. Introduction

Lithium ion battery fires have become a prominent and widely discussed problem [1], and such fires are often especially difficult for firefighters to extinguish [2]. However, there is no current sense of the scale or scope of the problem. The purpose of this study is to evaluate what is currently known about the fire risks and the limitations of the data available to evaluate those risks. In particular, the study examines the literature on the subject, determining what data is available regarding lithium ion battery problems, and evaluates what that data can tell us about the scope and scale of the problem. As a result, the study identifies gaps in the data and estimates the order of magnitude scale of the actual problem relative to what is reported.

The risk of fire from lithium ion batteries (LIB) is present in residences, transportation networks and roadways, and more generally, in industries and economic supply chains. In a 2018 report [1], the Consumer Product Safety Commission (CPSC) reported that it "conducted a search of the Consumer Product Safety Risk Management System (CPSRMS) for incidents from January 1, 2012 to July 24, 2017 … [and found] … more than 25 000 incidents of overheating or fire hazards with more than 400 types of consumer products."

In a study comparing electric vehicle (EV) fires in Australia and globally, Hassan et al. [3] found that while EV fires occur at a per vehicle rate much lower than for internal combustion engine vehicles (e.g., in the U.S., EV fires represent 0.03 % of all vehicle fires), their overall rate is expected to increase as the sales of EVs continue to comprise a larger proportion of the vehicles on the road. However, the context in which they occur varies. Focusing on reported fire incidents, Sun et al. [4] observed that EV fires occurred while in operation, parked, during charging, and after a vehicle crash. The context and circumstances (e.g., time of day, proximity to people, other vehicles, or structures) may influence the time until fire detection and fire suppression response time.

In addition to consumer goods (e.g., mobility devices, electronics, e-cigarettes and vapes) and personal electric vehicles, supply chains include the potential of fire risks associated with economic activities from the extraction of raw materials to end-of-use waste streams and during the movement of goods or people. Such examples include mining (e.g., [5]), warehouses and factories (e.g., [6]), utility scale energy storage (e.g., [7]), and recycling and waste [8] – non-LIB-specific battery fire risk in waste streams are also noted (e.g, [9–11]). In addition to EVs, transportation examples include the use of or transport of LIB in aircraft (e.g., [12–14]), passenger buses (e.g., [15]), and maritime (e.g., [16]). Roadway tunnel hazards have also been noted (e.g., [17]). Counterfeit LIBs also pose a risk (e.g., [18–20]) within these pathways, although it is not clear what proportion of fires they constitute. While the literature suggests LIB fire risks exist across supply chains, their frequency, severity, and overall trend are not well defined at a broad scale in the United States.

This study evaluates the data currently available regarding the prevalence of lithium ion battery fires (of all types), identifies gaps, and provides a preliminary estimate of the magnitude of the problem based on the data available.

2. Data Sources

Data for this analysis came from eight different sources, including news reports, the Underwriter's Laboratories Lithium-Ion Battery Incident Reporting webpage, the National Fire Incident Reporting System (NFIRS), Tesla Fires, the Consumer Product Safety Commission's SaferProduct database, the National Fire Protection Association (NFPA), the Federal Aviation Administration's Battery Air Incidents database, and the Electrical Power Research Institute's Battery Energy Storage System Failure Incident database. Each of these is described below.

2.1. News Reports

To identify the widespread lithium ion battery fire risks and pinpoint the major fire events and types of fire cases, news reports of battery fires were analyzed. To achieve these objectives, relevant news reports from Google News[1] (https://news.google.com/) spanning from 2015 to 2024 were collected. The query keyword "lithium-ion battery fire incidents" was selected following an exploratory search process in which multiple keyword combinations (e.g., "battery fire", "lithium ion battery fire") were tested. The final query was chosen to provide comprehensive coverage of LIB fire incidents while minimizing irrelevant results unrelated to fire events.

Table 1: Number of news reports collected for each year (Google News).

Year	Count
2015	15
2016	30
2017	28
2018	44
2019	46
2020	40
2021	47
2022	68
2023	173
2024	245
Sum	736

Using this search string, a total of 736 news reports were collected. Table 1 presents the number of news reports collected each year. News reports of LIB fire incidents have been increasing year by year. However, it is important to note that platforms like Google News often limit search results based on recency, relevance, and popularity. Consequently, some older content may have been removed or is no longer indexed by search engines, resulting in an

[1] Certain commercial products or company names are identified here to describe our study adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the products or names identified are necessarily the best available for the purpose

incomplete collection of news reports on LIB fire incidents. Thus these numbers represent lower bounds on the number of news reports. Nevertheless, the collected data can still be used to reveal patterns in LIB fires and help identify typical incident cases.

2.2. Underwriters' Laboratories

Underwriter's Laboratories Lithium-ion Battery Incident Reporting webpage [28] collects and summarizes information on LIB incidents worldwide, including information on class of equipment (consumer products, electric vehicles, micro-mobility devices, and battery energy storage systems), nature of the failure (fire, explosion, heat, swelling, venting), and the number of injuries and fatalities. The data is collected from a wide variety of primary sources, with the majority of data collected from news media reports.

2.3. NFIRS

The NFIRS is a nationwide system for reporting incidents to which fire departments respond. These include fires, hazardous material releases, emergency medical incidents, and others. Detailed information is collected for each incident. Participation in the system is voluntary, and so some fires reported to the fire department are not reported as part of NFIRS.

Incident reports are completed by fire departments, and, for fires, typically include information about the type of fire (e.g., vehicle, structure or brush), property use (e.g., home, apartment, commercial, industrial, etc.), extent of fire spread, ignition source, and other information.

It is important to note that fires fall into three categories under the system: fires that are reported in NFIRS; fires that are reported to the fire department but not reported to NFIRS; and fires that are not even reported to the fire department. The great majority of fires are not reported to the fire department [21]. NFPA estimates that in 2023, 1.39 million fires were reported to the fire department, of which about 644 000 were reported to NFIRS. Most fires that are not reported to the fire department either self-extinguish or are put out by people on the scene [21], so it is expected that such fires are on average smaller than those reported to the fire department. Furthermore, in evaluating data in NFIRS it is important to note that data records in NFIRS are often incomplete (missing information) and at times inaccurate [22].

NFIRS was designed before LIBs were in common use, and so it does not contain fields that would serve to identify such fires or provide useful information about them. The US Fire Administration, which manages NFIRS, has recommended a consistent approach to identifying LIBs involved fires [23]. However, based on the analysis below in Sec. 4.3.2, the approach is not consistently used, so identification of which fires involve LIBs is far from complete.

One approach to dealing with the limitations of NFIRS with regard to LIBs fires is the Lithium-Ion Battery Fire Investigation Checklist (a link to which can be found on this web page https://www.mass.gov/info-details/lithium-ion-battery-safety) used by the State of

Massachusetts. This checklist, in addition to the information collected in NFIRS, also asks for information about the type and size of battery involved, and the type and brand of the equipment it was used in. Aside from the additional information collected, reporting LIB fires uses the same coding approach as NFIRS nationwide.

In the discussion below, "reporting" refers to whether a LIB fire is reported to NFIRS, and "identification" refers to whether a reported LIB fire is identified as being such in NFIRS.

For this paper, the additional data collected by the State of Massachusetts was not analyzed.

2.3.1. NERIS

The National Emergency Response Information System (NERIS) (https://neris.fsri.org/) is the replacement to NFIRS. It is in the process of being rolled out in 2025, so some fire departments will be reporting using NERIS and some will be reporting using NFIRS through 2026. After 2025, reporting to NFIRS is supposed to cease.

NERIS is designed (among other things) to better address and track emerging issues for the fire service like LIB fires and is designed to provide accurate identification of LIB fires and collect detailed information about them. However, there is not sufficient data in the system yet for meaningful analysis.

2.4. NFPA Fire Estimate

The NFPA annually estimates the number of fires in several different categories nationwide. That estimate is based on the data in NFIRS, as well as a survey of fire departments performed annually by the NFPA.

2.5. Tesla Fires

An independent group has compiled a set of Tesla (EV and other Tesla products only) fires based on news reports. The list is maintained relatively frequently and is posted on the website: https://www.tesla-fire.com/. It is not clear who is responsible for maintaining the data set, and it is certainly possible that the compiler(s) have a pecuniary interest in developing the list. However, the data is well-attributed with references to news reports for each incident listed, so it is likely sufficiently reliable to be used in this analysis.

2.6. CPSC Safer Products Database

The Consumer Product Safety Commission (CPSC) hosts the SaferProducts database (www.saferproducts.gov), which is a site where "the public can file and read safety-related complaints about consumer products within the agency's jurisdiction [24]." Reports consist of voluntary consumer reporting of incidents involving potentially defective products. The database is searchable and includes text descriptions from the consumer of what happened and also includes extensive details regarding the potentially defective product.

2.7. Lithium Battery Air Incidents

The Federal Aviation Administration maintains a Lithium Batter Air Incidents database (https://www.faa.gov/hazmat/resources/lithium_batteries/incidents) of LIB incidents involving air travel [25]. Most of these are thermal failures of some form. The incidents include both passenger and cargo flights and include incidents that occur on the ground as well as those that occur in the air.

2.8. BESS Failure Incidents Database

The Battery Energy Storage System (BESS) Failure Incident Database [26] was initiated in 2021 by the Electrical Power Research Institute (EPRI) [27]. It was part of a research program into how to improve the safety of battery energy storage systems, and was prompted by lithium ion BESS incidents in South Korea and Surprise, AZ. The system tracks information on incidents and the systems in which they occur. Information includes age, manufacturer, chemistry, and application. It is primarily focused on incidents in lithium-ion storage systems but includes failure incidents from other battery technologies as well.

The database is built by gathering data "from media reports and other public documents, such as released root cause analyses (RCA) or corporate press releases" [27] as well as using academic publications and collaborating with other organizations tracking such failures. Therefore, the completeness of the database is dependent on the extent to which such incidents are reported by the underlying data sources. EPRI adds that it "engages in every effort to ensure that the information in the database is complete and accurate."

3. Methods

Assuming two samples of the same population are independent of each other, then the number of events that occur in both samples can be used to estimate the total number of events. In this case, we are interested in the population of lithium ion battery fires. The approach, which is often called the capture-recapture method, was pioneered by Petersen [29], and is commonly used in population studies.
Let N be the size of a population, p_1 the probability that any event is identified in survey 1, and p_2 the probability that any event is identified in survey 2. Then the expected number of events identified in Survey 1 is $\mathrm{E}(n_1) = Np_1$, the number of events expected to be in Survey 2 is $\mathrm{E}(n_2) = Np_2$, and the number of events expected to be found in both surveys is $\mathrm{E}(n_{12}) = Np_1p_2$. Then, an estimate of the size of the population is given by:

$$N^* = \frac{n_1 n_2}{n_{12}}$$

And the estimated probabilities associated with each sample are

$$p_1^* = \frac{n_1}{N^*} = \frac{n_{12}}{n_2}; p_2^* = \frac{n_2}{N^*} = \frac{n_{12}}{n_1}$$

The approach described above was modified and coded into Stan [30]. This approach was used to get confidence intervals around the size estimates. Stan works by using a Markov Chain Monte Carlo approach to maximizing a log-likelihood function. In this case, the log-likelihood function being maximized (L) is:

$$\begin{aligned} L = & log\left[\frac{(N)}{\Gamma(n_1)\Gamma(N-n_1)} p_1^{n_1}(1-p_1)^{N-n_1}\right] \\ & + log\left[\frac{(N)}{\Gamma(n_2)\Gamma(n_2)} p_2^{n_2}(1-p_2)^{N-n_2}\right] \\ & + log\left[\frac{(n_1)}{\Gamma(n_{12})\Gamma(n_1-n_{12})} p_2^{n_{12}}(p_2)^{n_1-n_{12}}\right] \end{aligned}$$

where Γ is the gamma function.

4. Data Analysis

In this section, the data is evaluated to identify what information can be gleaned regarding fires involving LIBs. Actual code used for the analysis below is posted to GitHub at https://github.com/usnistgov/li-ion-batteries.

4.1. Underwriter's Laboratories

The Underwriter's Laboratories (UL) Database provides some insight into the proportions of different types of fires. For 2024, 28 % of incidents in the UL database were consumer products, 65 % were mobility devices, 6 % were electric vehicles, and less than 1 % (for 33 incidents) were energy storage systems.

For fires, the UL database reports 550 incidents ever for the United States, which is well below the estimates made in Sec 4.3.2. This serves as a reminder that this is a sample rather than a census of incidents, something that the UL database itself acknowledges.

The publicly available data contains counts of incidents broken down by country, data source, incident type (fire, explosion, heat, swelling, venting) and year. It also breaks down the incidents by category (consumer device, vehicle, battery energy storage system, micro-mobility device), and provides counts of fatalities. Since no other information is publicly available, no additional analysis is possible here.

4.2. Google News Content Analysis

To reveal trends in LIB fires and identify critical cases from news reports, a bibliometric content co-occurrence analysis was conducted using VOSviewer[1] (https://www.vosviewer.com/). Content co-occurrence analysis is a widely used and rigorous method for exploring and analyzing large volumes of unstructured data (e.g., text). By identifying frequently occurring terms within a text corpus, the method estimates relationships based on their co-occurrence. It maps these terms into clusters or topic streams based on their relatedness [31]. In this study, content co-occurrence analysis is employed to develop a comprehensive understanding of the topics related to LIB fires reported in the news and to identify trends and relationships among major fire events in these incidents.

Figure 1 demonstrates the informatics mapping of LIB fire incident news reports from 2016. It is observed that a large portion of the news content focuses on Samsung phone explosions (indicated in red). In 2016, Samsung's Galaxy Note 7 smartphones experienced a widespread issue in which batteries overheated and caught fire, resulting in a global recall [32]. That same year, the Federal Aviation Administration (FAA) banned all Samsung Galaxy Note 7 devices from air transportation in the United States [33] (indicated in green). Furthermore, some of the news content highlights fire risks associated with hoverboards (indicated in yellow). According to a 2016 disclosure by the U.S. Consumer Product Safety Commission [34], a significant number of self-balancing scooters, or hoverboards, were recalled due to safety concerns. The LIB packs in these devices are prone to overheating, posing risks of smoking, catching fire, and even exploding. Additionally, LIB fires in vehicles have begun to draw attention (indicated in blue). The same year, Tesla launched its first mass-market electric vehicle (EV), the Model 3 [35]. As EVs become more widespread, associated fire safety issues and concerns are also emerging.

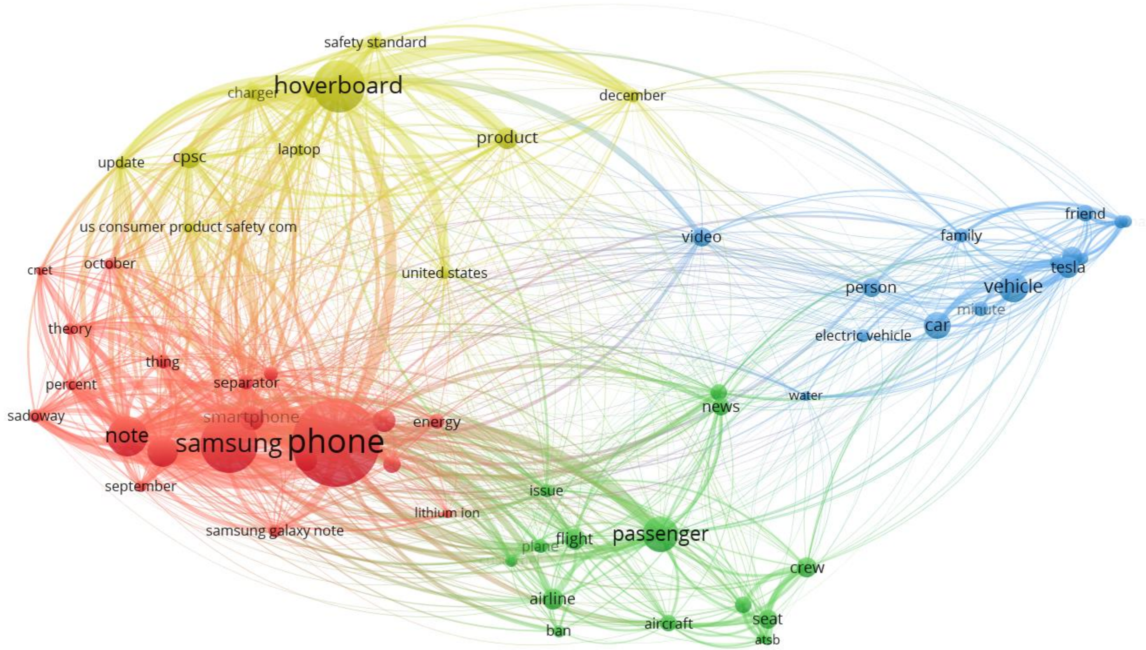

Figure 1: Informatics mapping of LIB fire incident news reports from 2016.

Figure 2 demonstrates the news analysis results for the year 2019. During this year, incidents of LIB fires involving EVs became more prominent (indicated in red). As EV sales surged in 2019 [36], news reports of LIB fires in these vehicles also increased. Among all types of LIB fires, those involving EVs are a major safety concern due to their high energy density and the difficulty of extinguishing them. Furthermore, the results indicated that LIB fires in Battery Energy Storage Systems (BESS) also attracted significant attention this year (indicated in green). This is because of a major explosion and fire that occurred at the McMicken BESS facility in Arizona in April 2019, which resulted in injuries to several firefighters [37]. Since then, there has been increasing attention on the risks associated with LIB fires in BESS. The blue areas on the map also indicate that incidents involving e-bikes and incidents involving small electrical devices during flights continue to occur. These persistent risks raise serious concerns about passenger safety.

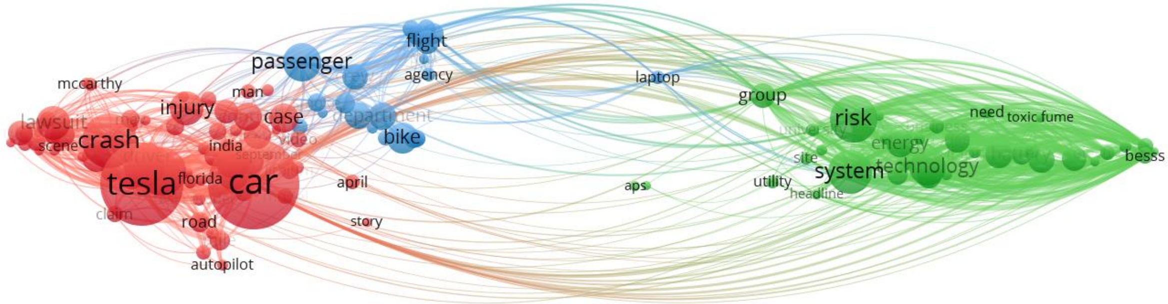

Figure 2: Informatics mapping of LIB fire incident news reports from 2019.

The news analysis results for the year 2024 are depicted in Figure 3. It is observed that e-bike and scooter fires continue to represent a significant portion of the reported incidents in the news (indicated in yellow and blue). This sort of fire is among the leading causes of home-related LIB fires, especially in urban areas [38]. In addition, a large portion of the news reported incidents of LIB fires on freeways (indicated in red and purple). During the year 2024, there were several incidents involving trucks carrying LIBs that overturned and caught fire, causing significant traffic disruptions and road closures [39, 40]. One incident occurred on the 47 Freeway near the Port of Los Angeles, where a truck carrying a large load of LIBs overturned and ignited, leading to the shutdown of the freeway and several port terminals for 24 to 48 hours [40]. These types of accidents cause significant economic losses and have a considerable social impact. Additionally, keywords in green indicate that smoke alarms can assist in alerting occupants before a LIB fire escalates.

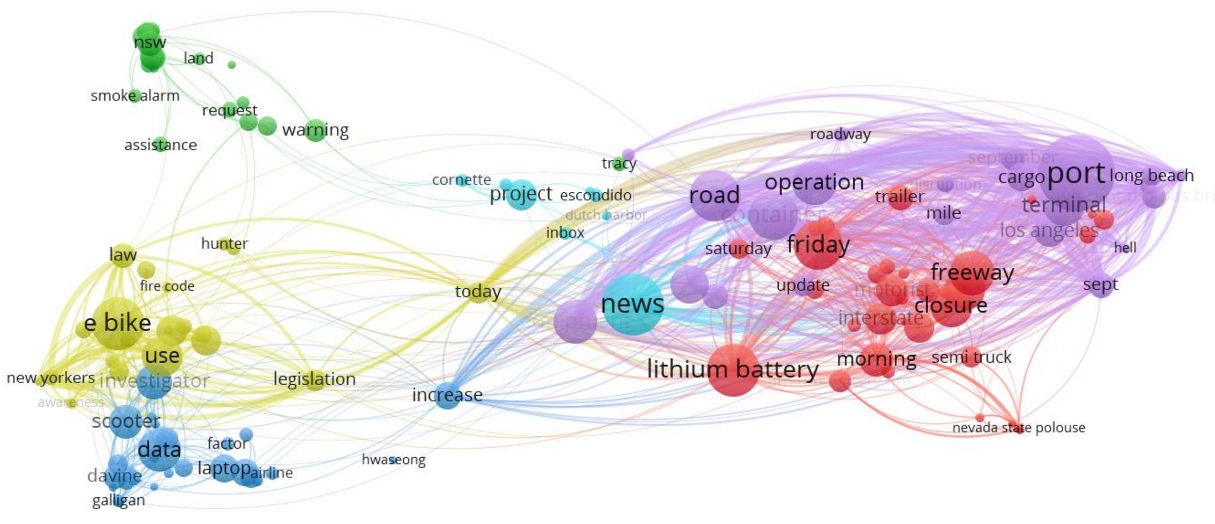

Figure 3: Informatics mapping of LIB fire incident news reports from 2024.

Based on the data analyzed, it can be summarized that the primary categories of current LIB fire incidents include micromobility devices (E-scooter, e-bike), EVs, BESS, and other small electrical devices (laptop, phone, e-cigarette). Based on news reports, fires involving micromobility devices appear to pose significant risks to residents, as these devices are often stored indoors or in garages where they may be left unattended. EV fires, due to their high energy density and the challenges associated with extinguishing them, have emerged as another major concern. Such incidents on major roadways can cause traffic disruptions, underscoring the importance of effective post-incident response to minimize economic losses and social impacts. BESS fires appear to be the most severe type of LIB fire incidents due to the high energy density involved. As they produce intense heat, toxic gases, and heavy smoke, extinguishing these fires is particularly challenging for firefighters. Similarly, the recent rise in LIB fire incidents at battery recycling facilities [41] also highlights the significant risk associated with industrial LIB processing. Fires caused by small electronic devices might seem less dangerous because of their smaller size, but since these devices are allowed on airplanes and in other sensitive places, they still raise serious safety concerns.

4.3. NFIRS

This analysis looks at two different types of fires: vehicle fires and structural fires. As discussed above, NFIRS does not have a specific provision for recording LIB fires, but procedures have been developed by the US Fire Administration for the identification of such fires. Table 2 lists the number of identified battery fires (which encompass more than just LIB fires) in NFIRS for the five years from 2019 to 2023 broken down by location and incident type. Our focus here will be on structural and vehicle fires.

Table 2: Number of battery fires for the years 2019 - 2023 broken down by location and incident type.

	Structure	Vehicle	Portable Building	Outside	Other
Public Facilities	74	9	2	8	26
Industrial/Commercial	122	35	5	28	41
Residential	973	44	28	86	156
Parking	57	67	4	26	9
Roadway	11	151	8	53	38
Storage	77	12	1	16	9
Outside	11	30	9	45	9
Unknown	10	11	0	5	6
Total	1139	315	50	231	227

4.3.1. Vehicle Fires

There are numerous vehicle fires recorded in NFIRS that have a battery as source of ignition. However, the majority of those are likely lead-acid batteries since there are a significant number of reported battery fires as far back as 2005 when the current NFIRS data set begins. The most effective way to identify LIB vehicle fires in the data was to make an identification based on Vehicle Identification Number (VIN)[42]. Roughly half of all vehicle fires recorded in NFIRS have a VIN number associated with them.

Two versions are estimated, one with and one without Florida. The data from Florida appears to be unrepresentative of the rest of the country and likely significantly biases the results of the analysis (discussed later). The number of fires recorded in the Tesla Fires and NFIRS vehicle fires data sets, both including and excluding Florida, is listed in Table 3. The “Both” column represents the number of fires that can be found in both data sets.

Since there are two data sets listing battery fire incidents, it is possible to combine the two to come up with a better estimate of the number of battery fire incidents in the country. Both represent samples of battery fires in the United States.

Table 3: Counts of vehicle fires by type. The ‘TF’ counts are from TeslaFires.com. The ‘Both’ columns are fires that occur in both the TeslaFires.com dataset and in NFIRS. ‘Tesla’ represents the counts of fires involving Tesla vehicles as identified by VIN in NFIRS, ‘BEV’ represents the counts of fires involving battery electric vehicles in NFIRS, and ‘Plugin’ represents the counts of fires involving both battery and hybrid electric vehicles in NFIRS.

	Total					Excluding Florida				
		NFIRS					NFIRS			
Year	TF[2]	Tesla	BEV	Plugin	Both	TF[2]	Tesla	BEV	Plugin	Both
2011		0	1	1	0		0	1	1	0
2012		0	1	1	0		0	1	1	0
2013	4	1	1	2	0	4	1	1	2	0
2014	1	0	0	5	0	1	0	0	4	0
2015	1	2	4	10	0	1	2	4	10	0
2016	1	5	6	16	0	1	5	6	16	0
2017	3	5	9	22	0	3	5	8	17	0
2018	10	6	8	23	0	9	5	7	21	0
2019	13	11	14	31	3	11	7	10	27	1
2020	9	9	17	31	1	9	8	15	28	1
2021	18	16	25	44	0	17	14	22	41	0
2022	40	25	33	59	5	34	16	21	46	2
2023	33	35	62	119	5	31	31	56	109	3
Total	133	115	187	371	14	121	94	158	330	7

[2] *TeslaFires.com*

Assuming that the Tesla Fires data set and NFIRS are independent of each other, then the number of fires that occur in both samples can be used to estimate the total population of battery fires using the Capture-Recapture method described in Sec. 3.

In this case, the two data sets are collected using very different methods and so can be treated as independent. Candidate overlapping incidents were identified based on state and date of the incident. If two incidents occur in the same state within 7 days of each other they are considered a candidate overlap. Candidates were then reviewed by hand to determine actual overlapping incidents. The number of overlapping incidents by year is listed above in Table 3.

Resulting estimates for the number of fires are listed in Table 4. These estimates implicitly assume that all EVs and Plugin vehicle fires are reported and identified at the same rate as Teslas. In 2023, there were an estimated 418 car fires for Battery EVs (95 % CI: 195 – 863), and an estimated 800 car fires for Plugin vehicles (95 % CI: 362 – 1732) including both EVs and hybrids. Across the whole study period there have been an estimated 1761 car fires for EVs (95 % CI: 1047 – 2849), and an estimated 3535 car fires for Plugins (95 % CI: 2187 – 5751).

When excluding Florida, those estimates were 596 car fires for Battery EVs (95 % CI: 216 – 1530), and an estimated 1311 car fires for Plugin vehicles (95 % CI: 439 – 4053) in 2023. Across the whole study period there have been an estimated 2746 car fires for EVs (95 % CI: 1337 – 5324), and an estimated 5718 car fires for Plugins (95 % CI: 2866 – 10 846).

Table 4: Estimated number of BEV and Plugin Hybrid vehicle fires by year.

		USA			USA Except Florida		
Type	**Year**	**Fires**	**LCL[3]**	**UCL[4]**	**Fires**	**LCL**	**UCL**
BEV	2019	63	24	162	156	21.3	435
	2020	157	34.7	603	152	29.5	613
	2021						
	2022	271	119	626	340	94.5	1076
	2023	418	195	863	596	216	1530
	Total	1761	1047	2849	2746	1337	5324
Plugin	2019	145	58	400	309	65.7	1116
	2020	287	67.3	1085	283	59.1	1115
	2021						
	2022	500	218	1128	765	243	2245
	2023	800	362	1732	1311	439	4053
	Total	3535	2187	5751	5718	2866	10 846

[3] *95 % Lower Confidence Limit*

[4] *95 % Upper Confidence Limit*

The data suggest that fires in EVs are growing at a rate of about 46 % (± 14.4 %) per year, and in Plugin vehicles at a rate of about 45 % (± 11.3 %) per year. This is likely driven by the increase in the number of EVs and Plugin vehicles on the road.

As mentioned above, VIN numbers for car fires in NFIRS are reported about half the time. When combined with the non-reporting rate in NFIRS, about one car fire in three has an identified VIN in NFIRS, based on the total number of car fires as estimated by the NFPA. However, for EVs and Hybrids, the results above imply that only about one car fire in 10 is identified in NFIRS by VIN. Florida has a much higher identification rate, near 1 in 3, while the country excluding Florida has an identification rate of about 1 in 17. This dramatic difference in apparent identification rate is driven by the very high rate of overlapping incidents for Florida. It seems likely that the overlap rate for Florida is unrepresentative of the rest of the country and is biasing the estimates down. Thus, it seems likely that the estimates excluding Florida are more reliable.

It is not clear why the vehicle identification rates are so much lower than for other vehicles. One possible explanation is that the intensity and severity of EV and Plugin car fires makes it impossible or unsafe to collect such data in a significant number of such incidents.

4.3.2. Structure Fires

Summary information on the number of structure fires and the number of battery fires in structures is listed in Table 5. The ratios were estimated by using Stan [30] to fit the data to a model using Bayesian Markov Chain Monte Carlo techniques.

Table 5: Summary of LIB fires and injuries in structures.

	Structure	Battery	Percent
Fires	2 664 259	2063	0.08 %
Casualties	118 110	169	0.14 %
Ratio	4.43	8.24	1.85

Out of some 2.66 million reported structure fires from 2011 to 2023, NFIRS identified 2063 battery fires. Approximately 0.078 % (95% CI: 0.074 – 0.081 %) of all structure fires in the time period were identified as battery fires. About 4.43 % (95 % CI: 4.41 – 4.46 %) of structure fires had casualties in some form (including deaths and injuries for both firefighters and civilians),while about 8.24 % (95 % CI: 7.08 – 9.48 %) of the identified battery fires were associated with casualties. That implies that casualties are associated with identified battery fires at a rate that is 1.85 (95 % CI: 1.60 – 2.14) times that of structure fires in general, which is statistically significant.

The results for battery fires are probably not as robust as the confidence intervals above suggest. The analysis implicitly assumes that identification of battery fires is independent of casualties, and that is unlikely. Differences in reporting accuracy may exist between fire incidents with and without casualties [43]. If that is the case, then the rate of battery fire casualties will be overstated relative to structure fires in general.

In this analysis, deaths and injuries are grouped together. The reason is the small number of deaths makes it difficult to produce any statistically reliable results.

To better understand reporting variation across fire departments, preliminary to doing a more detailed analysis, 23 large departments were selected for analysis, and the years of 2019 to 2023 were analyzed. For each department, the number of identified battery fires per total structure fire incidents was computed. The ratio of structure fire incidents per identified battery fire incident ranged from 120 for West Metro Fire and Rescue (Denver) to more than 6000 for Chicago Fire Department. In particular, the largest departments in the convenience sample (Chicago, Los Angeles City and County, and FDNY) have the lowest rate of reported battery fires per structure fire. The very wide range in the ratio of battery fires to structure fires suggests strongly that there are vast differences in the identification of battery fires between departments rather than reflecting differences in the actual number of battery fires between departments.

To understand when and where LIB fires occur and how severe they are, all reported battery structure fires in NFIRS between 2011 and 2023 were selected. This data was evaluated to determine the time of day, season, and (for home fires) room in the home where battery fires occur. In addition, severity of battery fires was evaluated. Since many battery fires are not captured in this data set, these results assume that the battery fires reported are representative of all battery fires that occur. As discussed above, that is a questionable assumption, but it is sufficient for making these first-pass estimates.

Regarding the time of day when battery fires occur, separate analyses were conducted for home structure fires and all structure fires. Results are shown in Figure 4. Structure battery fires tend to occur during the day, when people are around and awake. Battery fires in homes peak at around 6 p.m., when people tend to get home. There are suggestions of a smaller peak on both home and non-home battery fires in the early morning, but that is not statistically significant.

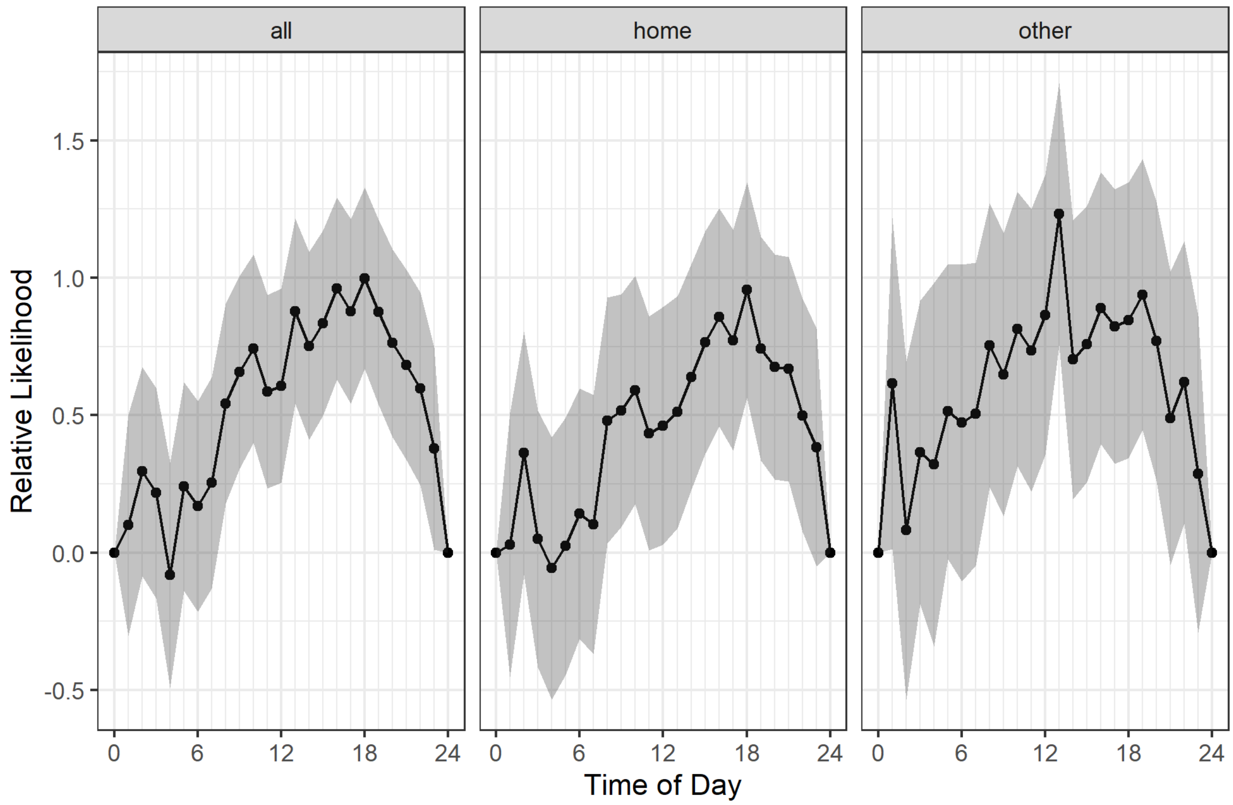

Figure 4: Relative rate of LIB fires by time of day and type of structure. The grey shading is the 95 % confidence interval.

Results per month of the year are shown in Figure 5. The estimates in the chart represent the likelihood of a battery fire by month, along with the confidence intervals, while the shaded band shows the likelihood by season. Results indicate that reported battery fires are most common in summer and least common in winter.

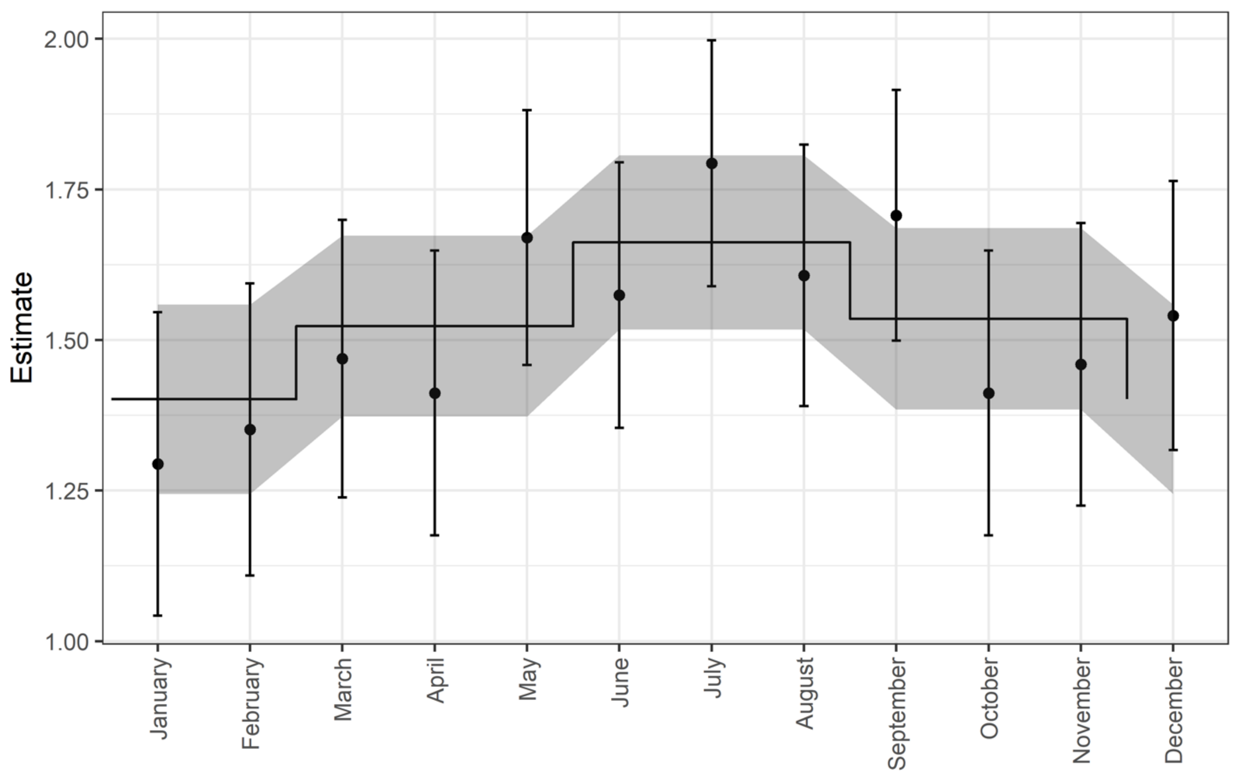

Figure 5: Relative rate of LIB fires by month . The point values are risks by month while the line is the risk by season. Grey shading is the 95 % confidence interval on the seasonal estimate.

Information on fire severity for battery structure fires is shown in Figure 6. Home fires are separated from non-home structure fires. Severity information for structure fires in general is also included. In the figure below, each category represents the probability that a fire got that large or larger. For example, for home fires, more than 80 % of fires extended into the room of origin or beyond (that is, went beyond the object of origin).

As a comparison, battery fires are compared to a baseline consisting of all structure fires (including battery fires). Structure fires generally are less likely to extend into the room of origin than battery fires but are also more likely to extend beyond the room of origin than battery fires. Home battery fires were more likely than non-home fires to extend into the room of fire origin but were less likely to extend beyond it. Essentially, home battery fires are more likely than home structure fires in general to fall within a relatively narrow size range.

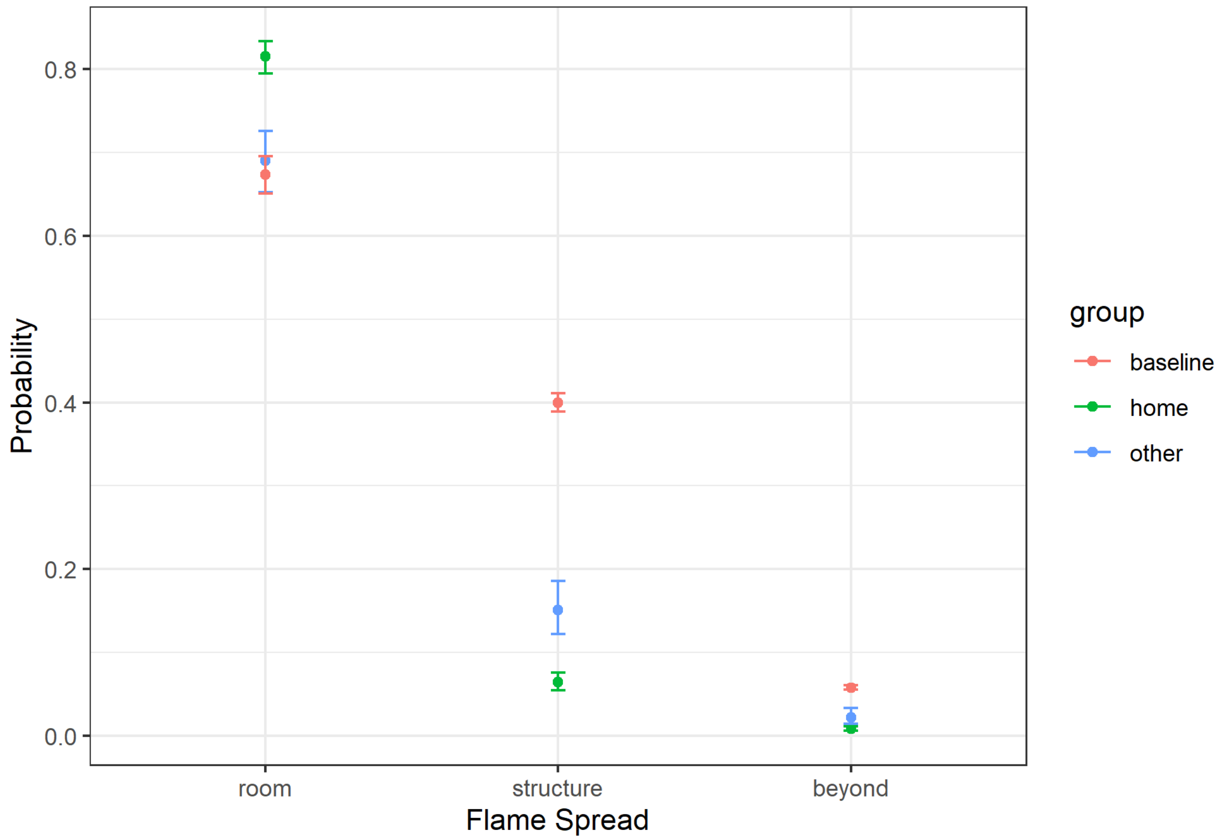

Figure 6: Probability of fire size by structure type. For each location, the probability represents the probability that a fire is that size or larger. "Baseline" is the probability for structure fires in general regardless of heat source. "Home" is the probability for battery fires in homes. "Other" is the probability for battery fires in structures that are not homes.

For home fires specifically, the location of fire origin was also estimated (Figure 7). The garage was the most frequent source of reported battery fires in the home, with the bedroom and common areas (living room, den, etc.) as the next most common locations, and then kitchen . Bedroom and common areas are more likely to have people and their devices, while the garage hosts larger batteries associated with cars and other mobility devices. Garage fires may include ones involving lead-acid batteries as well, which would reduce the relevance of the garage results for this analysis.

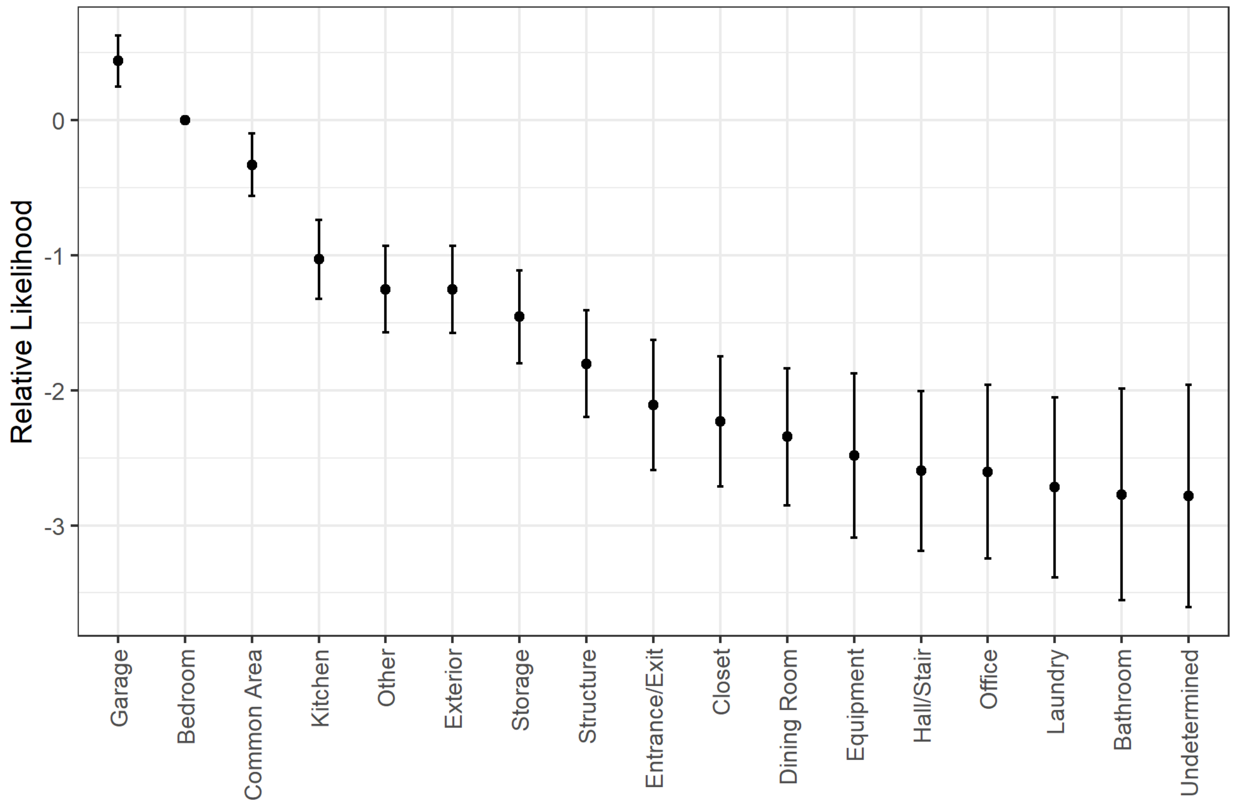

Figure 7: Relative likelihood of a LIB fire in a home starting in the specified room, with 95 % confidence intervals.

4.4. CPSC Safer Products Database

The SaferProducts database was queried for 'batteries' and 'lithium' separately. The two queries were then merged, dropping duplicate records, resulting in a 3800-record data set. The incidents fall roughly between 2011 and 2025. A cursory review of the records indicates that there are many different types of complaints and products included in this data set.

A Large Language Model (LLM) was used to identify incidents in the CPSC data involving LIBs and incidents involving fire. Table 6 provides details of the method used in the analysis.

Because LLMs are inherently stochastic, each question was repeated ten times for each incident. Table 7 summarizes the results. The 'Yes' (resp. 'No') column represents the number of incidents in which all replicates agreed that the answer to the question was 'Yes' (resp. 'No'). The 'Unknown' column represents incidents where the replicates did not agree on an answer or where some replicates did not give a 'yes' or 'no' answer. An example of the latter is an incident where the LLM gives the following response:

> *To answer your question: The text does not explicitly state that the incident involves a lithium-ion battery. It only mentions "the battery." Therefore, based on the information provided, we cannot confirm whether the incident involves a lithium-ion battery or not.*

Table 6: Model parameters used in the LLM model to determine whether incidents involve LIBs or a fire.

Element		Description
AI Model		Llama-4-Maverick-17B-128E-Instruct-FP8[1]
Replicates		10
System Prompt		The text is a description of an incident involving a defective or potentially defective product. The text was submitted by a consumer to the Consumer Product Safety Commission as part of their consumer product monitoring program. For the text please briefly answer the following question. <<Replace with relevant question from below>>
Question	LIB	Does this incident involve a lithium ion battery?
	Fire	Did a fire occur?

Subsequent analysis treats the “Unknown” data as if they were not relevant incidents. Based on the data, the number of LIB fires is increasing at a rate of 10 % per year (CI: 7.1 – 13.0) (Figure 8).

Table 7: Results of LLM analysis of CPSC incident descriptions.

data	No	Unknown	Yes
Lithium	1534	561	1705
Fire	2790	84	926
Combined	3020	223	557

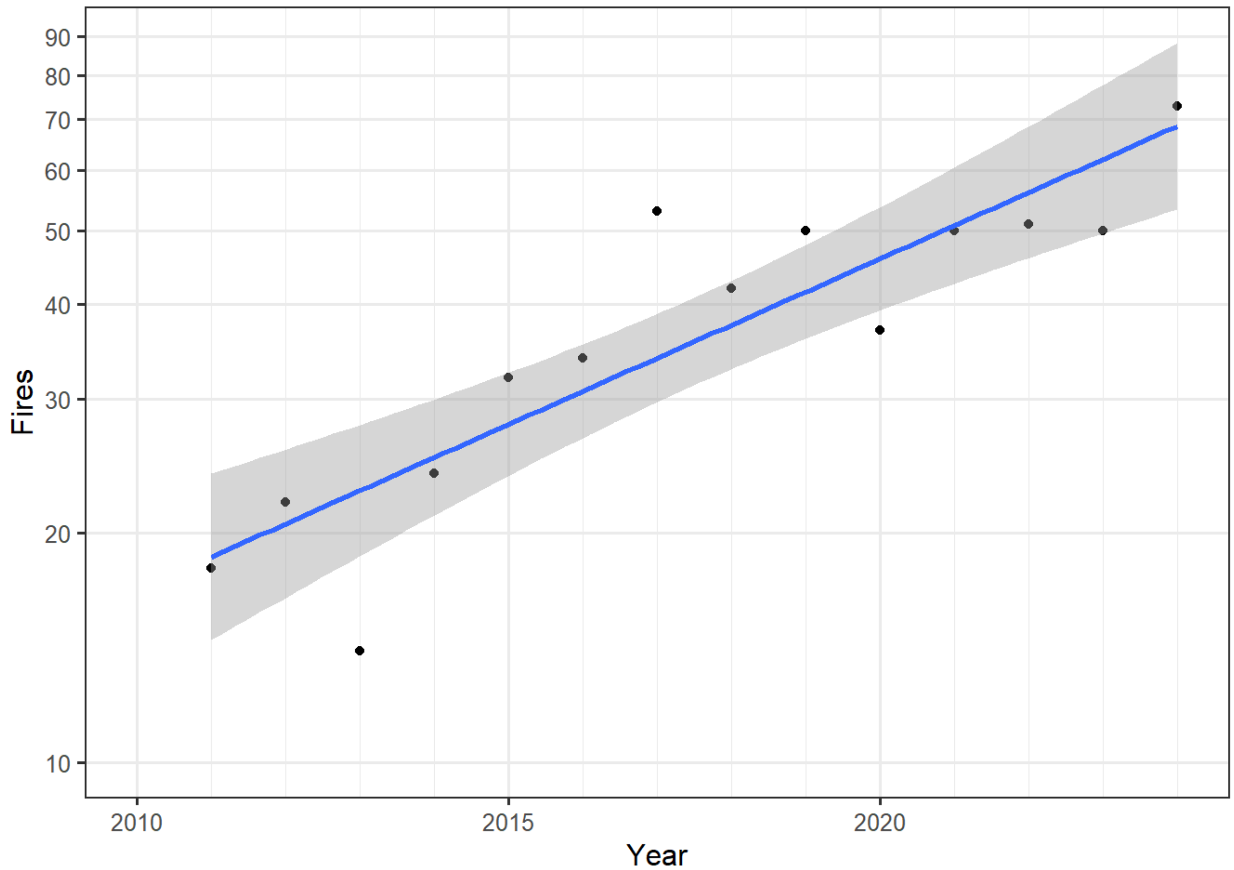

Figure 8: Number of LIB fires identified in the CPSC data by year, along with estimated slope versus time. Grey band is 95 % confidence interval on the slope.

4.5. SaferProducts and NFIRS Combined

Since there are two data sets listing structure battery fire incidents, the Capture-Recapture method described in section 4.3.1 can be applied to combine the two to come up with a more accurate estimate of the number of battery fire incidents in structures in the country. Both represent samples of battery fires in the United States. Since the two data sets are collected using very different procedures, they are considered independent.

Candidate overlapping records were identified if the city and state were the same and the dates were such that the CPSC complaint was made not more than 90 days after the NFIRS report and not more than 7 days before the NFIRS report. The time window was chosen because it was expected that NFIRS reports would be entered relatively quickly after an incident, while a consumer CPSC compliant might take more time to be entered. Candidate matches were then reviewed by hand. “Reviewed Matches” represent the number of incidents that are confirmed to be in both data sets after being reviewed by hand. A summary is listed in Table 8.

Table 8: Number of identified fires and matches.

	Number
NFIRS Fires	2063
CPSC Fires	557
Candidate Matches	16
Reviewed Matches	5

The analysis was performed for the entire aggregate period. These numbers imply a total population of LIB battery fires of approximately 198 000 (95 % confidence interval: 84 000 – 465 000) for the period from 2011 to 2023.

4.6. Lithium Battery Air Incidents

The data in the air-incidents database includes incident date, type of device, whether the carrier was a passenger or cargo carrier, and a text description.

A logistic trend was fitted to the annual number of incidents. Results are shown in Figure 9. The number of incidents is increasing over the time period of the analysis, but the trend has left the exponential growth phase and entered the (approximately) linear growth phase, with the number of incidents growing at the rate of 9 (95 % CI: 3.6 – 13.4) incidents per year.

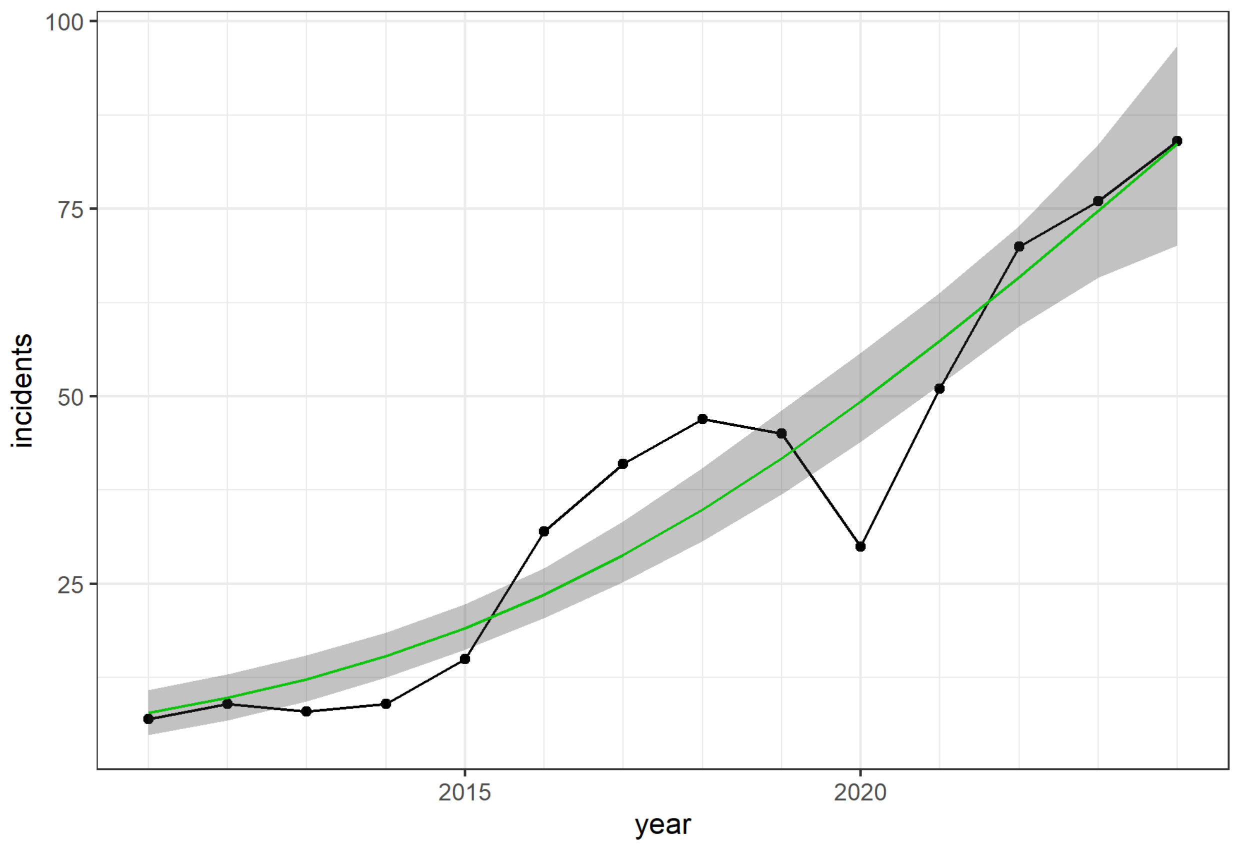

Figure 9: LIB incidents by year in the FAA Data. Smooth line is the estimated logistic trend, and the grey band is 95 % confidence interval on the trend.

4.7. BESS Failure Incidents Database

Figure 10 shows the number of incidents per calendar quarter from 2018 to 2024. There is an average of 2.93 ± 0.63 incidents per calendar quarter, and there is no statistically significant trend.

The reliability of this conclusion is dependent on the reliability of the underlying data set. Trends–or the lack thereof–could be an artifact of changes over time in how such incidents are reported in the media. However, at this point, there is no evidence that changes are occurring.

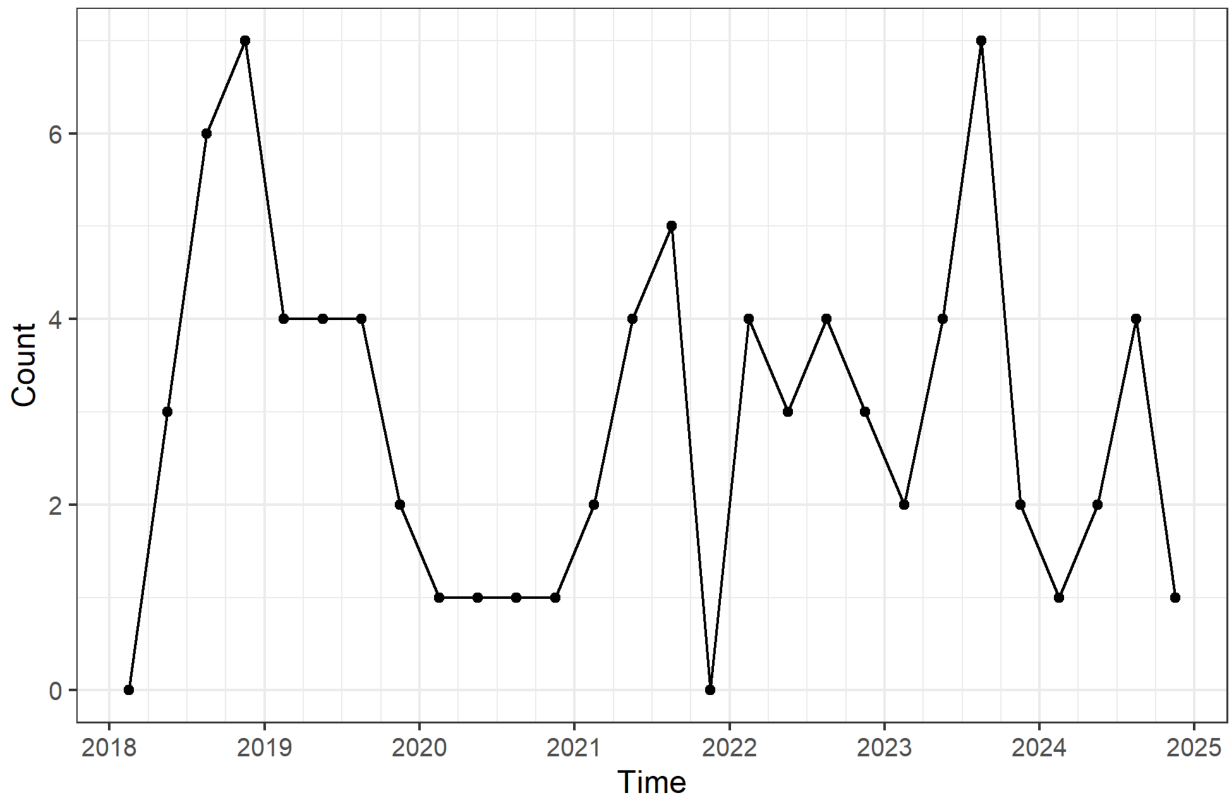

Figure 10: Number of BESS incidents in the EPRI data set by calendar quarter.

5. Data Limitations

Table 9: Summary characteristics of identified data sources. Completeness refers to the likelihood that a covered incident would be included. Breadth refers to the classes of LIB incidents that are covered by a specific data source. For single-class data sets, the class of incidents included is stated.

Data Source	Primary / Secondary	Completeness	Breadth
GoogleNews	Secondary	Unknown	v. Broad
NFIRS	Primary	Med. Low	Broad
TeslaFires.com	Secondary	Medium	Tesla Vehicles
CPSC SaferProducts	Primary	Low	Consumer Products
FAA Air Incidents	Primary	High	Air Incidents
EPRI: BESS	Secondary	Unknown	BESS Incidents
UL	Secondary	Unknown	v. Broad

Data used to characterize the number of LIB fires is fragmented, and each data source used in this paper has significant limitations. Table 9 summarizes the results of this section.

Most of the data sets are designed for a particular purpose, aimed at a specific subcategory of LIB incidents. The UL data set and GoogleNews are the only exceptions. Many of the data sources are dependent on news reports as a major source. Considering that news coverage is a function of interest and attention at least as much as frequency of the underlying event, and that interest and attention can and does change over time, then likelihood that a particular incident gets reported (and thus included in these data sets) likely varies with time. Data sets that do not depend on news reports are NFIRS, the FAA Air Incidents database, and the CPSC SaferProducts database.

The secondary data sources (BESS, UL, Google News, TeslaFires.com) tend to depend on many of the same underlying primary sources and likely correlate in ways that are independent of the actual frequency of incidents.

Examining each data set individually: NFIRS is a special-purpose data set. It is incomplete and its degree of completeness varies over time. It records a much larger class of incidents, and identifying lithium ion incidents is difficult. The CPSC SaferProducts database looks at a broader range of lithium ion incidents than does NFIRS, but like NFIRS it is incomplete, and similar to NFIRS, identifying lithium ion incidents is problematic. Unlike NFIRS, the degree of completeness is probably consistent over time.

The FAA Air incidents database is a primary data source (like NFIRS and the CPSC database) but focuses on a very narrow subset of incidents. However, reporting within that subset is likely complete.

The BESS database and the TeslaFires.com dataset are secondary data sources in that they build their list of incidents from other data sources, primarily (but not necessarily exclusively) news reports. Similarly, the UL database is a secondary data source built up by compiling information from news reports and other primary data sources. It is also not a public data set.

6. Conclusion

LIB fires are a growing problem that extends across the supply chain. In addition to fires on the consumer side, the literature review makes it clear that there are fires in mining, production, warehousing, shipping, and waste disposal. Problems of special note include in-air fires and fires at battery-energy storage facilities.

Data sources for LIB fires are fragmented and mostly incomplete. Many are secondary data sources in that they are often compiled from news reports and other primary sources. Nearly all (except the FAA dataset) are effectively very sparse samples of LIB fires. For the biggest primary sources (NFIRS and the CPSC dataset), identification of LIB fires is difficult. As a result, relatively few conclusions can be drawn from these data independently.

However, because there are multiple data sources (some of which are independent), it is possible to generalize and estimate numbers on some types of fires using the capture-recapture statistical method. Based on this method, there have been an estimated 5718 (95 %CI: 2866 – 10 846) electric vehicle and plugin hybrid fires, and an estimated 198 000 (95 %CI: 84 000 – 465 000) LIB fires in structures since 2011. Plugin electric vehicle fires are estimated to be growing at the rate of about 45 % (± 11.3 %) per year, a number that likely parallels the increase in the number of such vehicles on the road.

Assuming the limited data is representative, some additional observations can be made. Consumer LIB fires in the CPSC data are growing at an estimated rate of 10 % (CI: 7.1 – 13.0) per year. Fires in structures tend to occur when people are around, with home fires peaking at about 6 p.m. Fires are more common in the summer.

Airplane incidents are probably the best documented and are growing at an estimated rate of 9 (95 % CI: 3.6 – 13.4) incidents per year. However, fires at battery-energy storage systems (based on EPRI data) do not appear to be increasing.

To fully understand the extent of the LIB fire problem requires better data. Better identification of LIB fires by fire departments in NFIRS (now NERIS) would improve understanding of the issues presented by LIB fires in structures. Similarly, tools that enable the safe and accurate collection of VIN data from vehicles involved in fires would improve understanding of the issues presented by EV fires. The estimates on the number of such fires assume that EVs and plugin hybrids occur at the same rate, which may not be true.

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