Perceived and Actual Fire Safety – Case of Hybrid and Electric Vehicle Fires in Finland 2015–2023

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Abstract: - As an emerging technology, hybrid and electric vehicles draw media attention and so does their fire safety. For this article, Finnish national rescue task database (Pronto) was reviewed for electric and hybrid vehicle fires for years 2015–2023, and the 44 records found were analyzed for the fire behavior and the successfulness of the rescue operation. Hybrid and electric vehicle fires are both absolutely and relatively rare compared to conventional vehicle fires. The incident rate for plug-in vehicles has been 0.2–0.9 per 10000 vehicles per year in the 2020s, which is significantly smaller than the rate for all passenger vehicles (4.6). Small absolute number is due to the small total number of hybrid and electric vehicles. Small relative number of fires may be due to the age of vehicles. Electrified vehicles can catch fire while plugged in, parked or while driving, with no significant differences in the incidence of the state of the vehicle. In road accidents, only one vehicle caught fire after a crash. All electric vehicle fires, even if the lithium-ion traction battery is involved, successfully extinguished with a branch pipe and traditional firefighting gear, as the rescue staff had been trained for handling incidents involving electric vehicles. There exists a media bias in reporting battery electric vehicle fires: of all 5 fires of BEV origin found, 4 have been reported in the media as an electric vehicle fire.

Key-Words: - electric vehicle fire, battery fire, electric vehicle safety, fire rate, incident rate, lithium-ion battery fire.

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1 Introduction

The ignition sources in motor vehicle fires are similar to those associated with structural fires, such as electric arcs, mechanical sparks, overloaded wiring, open flames, and smoking materials. In addition, there are unique sources such as hot surfaces in the exhaust system and brakes, [1]. The variety of car makes and models, manufacturer's reluctance to disclose information about the incidents, and high cost of systematic fire tests result in a lack of comprehensive information on vehicle fires, [2]. Electrical fire is the most common type of fire occurring in automobiles. In some fires, the evidence is consumed to the point where a determination of the cause of the fire cannot be made with any degree of certainty, [3]. If the vehicle is old and therefore of low value and no arson is suspected, it is also cost-inefficient to do a closer (electric) fire investigation.

Battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and conventional (non-rechargeable) hybrid electric vehicles (HEV) with a lithium-ion traction battery pose new challenges to firefighting and rescue personnel, including new toxic gas emissions and the need for excess use of water, [4]. In addition, the battery may re-ignite even days or weeks after the first extinguishment, [5]. Further research and assessment are needed also in extinguishing water treatment, [6]. The most efficient way for extinguishing an electric vehicle is still being discussed. In addition to the traditional branch pipe (the normal nozzle attached to the firefighting hose), there are multiple products in the market for extinguishing and managing electric vehicle fires:

- A variety of extinguishing containers where the car is to be placed for or after the extinguishing.
- A water lance to be hammered inside the battery compartment.
- A tool that penetrates the battery casing underside of the car
- A sprinkler tool that is to be slid under the vehicle
- Fire blanket for the vehicle

In this article, BEVs, PHEVs and HEVs are referenced as electrified vehicles. Most of the hybrid (HEV) vehicles contain a nickel metal hydride (NiMH) battery, which is not prone to thermal runaway like lithium-ion batteries and requires no special attention from firefighting staff from the point of the extinguishing process.

According to the literature, there seems to be no significant difference in the fire risk between conventional and electrified vehicles, but as the majority of self-ignited vehicle fires start in old vehicles and the majority of electrified vehicles are rather new, it is difficult to make a fair comparison, [4], [7], [8]. The small absolute number of vehicles and incomplete statistics on vehicle fires by traction power also obstruct making strong conclusions on fire rate. Recent reports by an insurance company, [9], and a Swedish safety authority, [10], suggest that currently, the probability of a BEV starting a fire is even lower than in vehicles with combustion engines. Collecting data on vehicle fires varies nationally, which makes comparing the incident rates difficult, [11].

When discussing fires of electrified vehicles, a distinction has to be made between a "normal" vehicle fire and a traction battery fire. If the battery is not on fire nor in a thermal runaway state, the fire can be extinguished just like any conventional vehicle fire. The ignition of the battery usually results from internal faults in the battery pack, as the battery is well protected and tested for external sources of ignition. For instance, in the massive fire in Stavanger airport, no electric vehicle battery packs caught fire, [12]. No signs of battery fires were found in the interview of the rescue personnel, nor chemicals associated with damaged batteries (e.g. lithium) were found in the samples of the extinguishing wastewater, [13]. The possible reason is that the battery is located in the underbody of the vehicle and therefore not prone to external heat. The type test for the vehicle traction batteries also demands them to tolerate direct flame from underneath for a few minutes, [14].

In Finland (an industrialized country with a 5.5 million population), over 2000 vehicle fires are recorded annually in the Finnish national rescue task database Pronto. Of these, ca. 1300 are passenger cars, vans, and pickups. Compared to 2.7 million passenger cars, this accounts for 5 fire incidents per 10000 vehicles annually (Table 1).

Table 1. Road Vehicle Fires in Finland 2015–2022 according to the PRONTO DATABASE

Year	Passenger car	Van or pickup	Truck	Bus
2015	1 303	155	197	53
2016	1 320	150	205	57
2017	1 242	146	209	44
2018	1 296	143	247	51
2019	1 275	161	236	48
2020	1 239	148	204	31
2021	1 214	165	248	31
2022	1 174	144	263	40
Fires total	**10 063**	**1212**	**1809**	**355**
Annual average	1258	152	226	44
Vehicles total (2019)	2 720 307	330 671	95 141	12 577
Fires per 10000 vehicles	4.6	4.6	23.8	35.3

As modern electric vehicles are rather new technology on the market, media bias and prejudices among the public do exist, as does bias caused by industry and environmental politics, [15]. A fire incident of an electric car will draw media attention, which may propagate the bias further.

The goal of this paper, extending the work presented in [16], is to analyze the accidents and fires in the Finnish carpool to provide information on fire likelihood as well as fire behavior and extinguishing needs in electrified vehicles and provide comparable information for researchers in different countries. National accident information and statistics are usually available in the national language only and collection and accuracy of statistics varies from country by country, which makes comparison difficult, [17]. Unlike structural choices in buildings and electrical installations, a certain model of a vehicle is the same or modified in the slightest, and therefore information on vehicle fires in one country is globally useful.

As every rescue mission is recorded in the national Pronto register, the data from the register provides an opportunity to get an unbiased value for the incident rate of electric vehicle fires. The knowledge base on lithium-ion battery fire chemistry and physics is researched comprehensively and is expanding fast, but for incident rate and behavior of actual electric vehicle fires have not been researched comprehensively.

2 Methods

In this paper, the national rescue task register Pronto was searched for vehicle fires and traffic accidents involving an electrified passenger or heavy vehicle. Light vehicles such as scooters and e-bikes were omitted. As the power source of a vehicle involved in a fire or accident is not recorded in the database in particular, an extensive keyword search was performed, including words associated with electric and hybrid powertrain (electric, hybrid, battery, high voltage) as well as popular electric and hybrid vehicle model names. From the search results, mismatches were pruned off manually.

Content analysis was applied to the incident records to identify relevant similarities in the chain of events. All the events identified are presented as an appendix of this paper.

3 Results

From the database, 46 incidents involving hybrid or electric vehicles were identified during the years 2015–2023. From the 46 instances, incidents with:

- no clear indication of fire or smoke
- one incident involving a boat with self-installed used electric vehicle batteries as the focus of the study is on-road vehicles

were rejected, resulting in 44 cases. The results are presented in Table 2, Summary of all the incidents analyzed is presented as an attachment to the article.

Table 2. Hybrid and Electric Vehicle Fires in National Accident Register in Finland

Year	Fires total	BEV fires (total)	PHEV	HEV	Other
2015	2	0 (614)	0 (1017)	1 (14055)	1 (a hybrid bus)
2016	3	0 (844)	0 (2437)	2 (19250)	1 (a straddle carrier)
2017	0	0 (1449)	0 (5719)	0 (28519)	
2018	3	1 (2404)	1 (13095)	1 (41696)	
2019	3	1 (4661)	0 (24704)	2 (58632)	
2020	4	0 (9697)	2 (45621)	2 (77357)	
2021	6	1 (22921)	1 (76990)	4 (105465)	
2022	4	0 (44889)	3 (104039)	1 (131174)	
2023	19	6 (83765)	10 (135090)	1 (152338)	2 BEV buses

3.1 Battery Electric Vehicle (BEV) Fires

Of the 9 BEV passenger vehicle fire incidents recorded in 2015–2023, 3 happened when the car was plugged in, 3 while driving and one because of a drive-out accident. In addition, 2 BEV fires were the result of a structural fire, of which one was identified as an arson. Only in one instance in March 2023, the actual fire started during driving, [18]. The other two incidents while driving were identified as a smoke emission from a heat pump failure of a Tesla Model 3.

Of the 9 incidents, 4 of them involved the fire of the high voltage battery.

In the first of the BEV fires recorded (October 2018), the car had stopped working on the road and was towed to the owner's house to wait for a delivery to a repair shop. The vehicle (Think City) was plugged into the mains all the time because the vehicle had a high-temperature battery ("Zebra") and therefore had to be plugged in with no long breaks. A week after this, the car caught fire. The owner woke up from a banging noise in the morning and saw the car on fire and called the emergency number. According to the Pronto record, the car was fully destroyed in the fire and therefore the accurate starting point of the fire was not investigated. As the car was parked next to a residential house, there was also a building fire risk. The fire had burned the painting of the sheet metal covering of wall and melted the wall sockets on it. The incident was noticed shortly in the local newspaper, [19].

The second fire on BEV took place in March 2019. At 5:23 in the morning, a security guard noticed that smoke was coming out from an electric vehicle (Hyundai Kona Electric), which was parked in front of a car dealership and plugged in. The guard called the emergency number and unplugged the car. When the first unit arrived at the scene at 5:28, there was a lot of smoke coming out from under the car. A couple of minutes after the arrival of the rescue unit, the gases burst in flames.

The burning car was winched away from the building and the other cars, and the fire was extinguished with water. The representative of the company arrived, and the last rescue unit left the scene at 6:45. The total amount of used water was recorded to be 1 m^3.

Almost immediately after that (6:50), the company representative noticed the car had re-ignited and called the emergency number. The fire was put out, and the car re-ignited again. The total water consumption on these two re-ignitions was recorded to be 10 m^3.

There does exist a professional magazine report of the case, discussing this particular case and the

extinguishing of electric vehicles in general, [20]. According to the article, one specific problem is the lack of clear and brief ("fitting on a single A4 paper") instructions for fire personnel on how to deal with electric vehicle fires. There have been some training events and courses on the subject in Finland, but no systematic training for all fire personnel, and the situation varies by fire department. The incident was also noticed in local media, [21].

In the following years, there were no BEV fires recorded in Finland, until the first half of the year 2023. In March 2023, seven units of fire engines were dispatched to a vehicle fire in Lohja, [22]. According to the Pronto record, the fire was probably started from the electrical box in the building, not from the car, which suffered only minor damages and was in traffic. Interestingly, in the news the car was not mentioned to be an electric one, making this the only BEV fire incident that was not reported as an *electric vehicle* fire. This is remarkable because normal vehicle fire does not lead to dispatching seven units of fire engines, but usually one or two.

Later in March, a BEV caught fire while driving. The driver heard a boom from the back of the car, then smoke and flames erupted. The fire did not involve the high-voltage battery but was probably started by the inverter of the vehicle. In the media, the fact that the fire did not involve the battery, was reported, [18].

In June 2023, an incident happened in an underground parking facility drew a lot of media attention. A Volkswagen ID. Buzz electric van of a car-sharing company, was reported exploding in the parking hall on Saturday morning, [23]. In the news photographs, the car looked like something had exploded inside the vehicle. No actual fire was observed, and the battery of the car looked undamaged. The car was transported to the fire station to wait for further investigations. After being transported from the fire station to an authorized service shop for further investigations on Tuesday, the traction battery caught fire and burned totally, [24]. Because such an incident is very uncommon, a thorough investigation with eyewitness interviews and analysis of all photographs of the vehicle and its parts was carried out, [25]. According to the investigation, some of the cells of the high-voltage battery have vented flammable gases, which formed a combustible mixture inside the vehicle and deflagrated. The resulting blast triggered the sprinkler in the parking garage. The thermal reactions in the battery did not spread as a full-scale battery fire in the parking hall and from outside, the battery looked intact. However, the damaged battery ignited three days later in the yard of the repair shop. A plausible reason for the incident is an internal fault in a battery cell.

The only accident-related BEV fire happened in July 2023 in Salo: the driver drove out of the road in a bend with a Nissan Leaf BEV. The vehicle fell 5 meters and the rocks on the ground damaged the battery and ignited it. The driver and passenger managed to leave the car before it ignited. The vehicle burned completely. The bottom of the vehicle was immersed in water to prevent re-ignition during transport. The accident was reported in the media, [26], [27], but the fact that the vehicle was electric was not reported.

In addition to the passenger BEVs and ID. Buzz van fire, two battery electric buses had a fire incident in 2023. The first one was a battery fire and the second one was a tire fire resulting from an overheated brake assembly, having possibly no causal relation to the power source of the bus. In passenger vehicles, brake problems caused by not using the mechanical brakes are a recognized issue, but not in the sense of fire safety, [28]. Only the first fire, involving battery modules, was reported in the media, [29].

Of the 5 actual fires of BEV origin, all were reported by the Finnish media. One notable perception is that in the incident where the car drifted off the road, fell 5 meters and the traction battery was ignited, the fact that the car was electric, was not reported. In all four other news, the drivetrain type was mentioned. Commonly, electric vehicle fires to gain attention and attract readers and social media discussion, which in turn attracts more visitors, which may lower the threshold for reporting all fires and accidents involving an electric vehicle, [30], [31]. The accident news is commonly based on eyewitness tips and news announcements of the authorities. As the accident happened in a rural area and the authorities did not disclose that the vehicle was electric, it was reported as an accident and a vehicle fire in the media.

All the battery electric vehicle fires except the bus tire fire, Nissan Leaf drive-out accident, and the building fires which only damaged the BEVs, were reported in the media as EV fires.

3.2 Plug-in Hybrid Electric Vehicle (PHEV) Fires and Hybrid Electric Vehicle (HEV) Fires

Compared to BEVs, PHEVs and HEVs have smaller batteries, and therefore they can be considered more easily extinguishable than BEVs with large

batteries. In addition, most HEVs have a NiMH battery, which is not prone to thermal runaway.

Of the 17 PHEV fire incidents analyzed, 9 of them took place while driving and 3 while plugged. Four caught-fire while parked and one perished in a farm building fire together with three other cars.

Of the 16 incidents of PHEV origin, one was an incident where only smoke under the hood was detected, but the fire personnel found no sign of ignition in the engine compartment. The only hot spot in the IR camera was the exhaust manifold. Therefore, the number of actual PHEV fires totals to 15.

Of the 14 HEV fires, 7 happened while driving and 7 when parked (of which one occurred immediately after driving). In one of the parked fire instances, the fire started from a mains-powered engine pre-heater, and one from misuse: the owner was trying to de-ice the frozen windscreen washer tank with an electric heater left unsupervised. No HEV incident was directly accident-related, but in one instance the vehicle had been driven off the road earlier.

In the first recorded plug-in-hybrid passenger vehicle fire (July 2018), a Volvo S90 T8 hybrid began to emit smoke while being charged at home. The neighbor of the owner noticed the smoke at midnight and called the emergency number and the owner de-energized the charger. The firefighters chose to drill two holes in the traction battery compartment to get the water inside the battery. 3500-4000 liters of water was used. The car was transported to a salvage yard, escorted by a firefighting unit. The charger and charging cable remained intact and neither the RCD nor the circuit breaker was tripped during the incident. The fire was noticed briefly in the local newspaper, [32].

The PHEV incident which drew large media attention was an incident where a Range Rover with a family with children inside caught fire while driving in May 2023 in Mikkeli. The battery ignited spontaneously while driving. According to the driver, the heating of the vehicle was suddenly disabled, then the power output of the vehicle ceased and white smoke started to emit from the location of the traction battery, [33]. The family was able to get out of the car, and the car burned totally, [34].

In a structural fire in May 2023 in Kouvola, a Mercedes-Benz 250E PHEV was being charged in an old cattle shed used as storage room, [35]. According to the fire investigation result inquired from the local police, the probable reason for the fire was either the internal charger of the vehicle, charging station or the wiring, but no doubtless result was obtained in the fire investigation.

3.3 Incident Rate for Fires of Electrified Road Vehicles

The number of fires per 10000 vehicles is presented in Table 3. As the number of these vehicles has increased steeply, the number of fires is compared with the average of the number of vehicles at the beginning of the year and the end of the year.

The total number of electric vehicle-related fire incidents per 10000 vehicles per annum is 0–1.1 for HEVs and PHEVs and 0–5.2 for BEVs. For BEVs, HEVs and PHEVs the incident rate is significantly smaller than the average for all passenger vehicles (Table 1). The young age of electrified vehicles probably biases the comparison, as the aging of the vehicles increases the fire risk, [8]. For years 2018 and 2019 the incident rate is non-comparable, as the small number of BEVs causes the incident rate to jump up with a single incident occurring. In 2020, the incident rate has been under 1/10000 for all electrified powertrains.

It is worth noting that not all incidents logged are actual fires with flames and damage, but for every incident where there has been smoke and the fire brigade has had a mission, the incident is logged in Pronto. As the same applies to all vehicle fires logged in Pronto, the figures are comparable between all vehicles and electrified vehicles.

Table 3. Incidents per 10000 BEVs, PHEVs and HEVs. The Absolute Number of Incidents is Presented in Parentheses

Year	BEV	PHEV	HEV
2015	0	0	0.8 (1)
2016	0	0	0.6 (2)
2017	0	0	0
2018	5.2 (1)	1.1 (1)	0.3 (1)
2019	2.8 (1)	0	0.4 (2)
2020	0	0.6 (2)	0.3 (2)
2021	0.6 (1)	0.2 (1)	0.4 (4)
2022	0	0.3 (3)	0.1 (1)
2023	0.9 (6)	0.8 (10)	0.1 (1)

Arsons are rare in Finland, as are felonies overall, [36]. The most common reason recorded for vehicle fires in Finland is technical fault (Table 4). Of fires caused by human action (Table 5), 70 % are deliberate, totaling in 10 %.

Table 4. Causes of All Vehicle Fires 2015–2022

Cause	
Technical fault	66 %
Human action	15 %
Could not be assessed	14 %
Other reason	4 %
Flammable substance	1 %
Natural phenomenon	2.4 ‰
Animal	0.6 ‰

Table 5. Vehicle Fires, when Recorded Caused by Human Action 2015–2022.

Cause	
Deliberate	68 %
Accidental	12 %
Act of negligence	14 %
Could not be assessed	5 %

None of the fires caused casualties, nor no electrified vehicle catch fire on repair shop and only one vehicle ignited in a crash. However, in one of the incidents where a HEV caught fire while driving, the vehicle had been driven off the road on the previous day.

In almost of all the incidents, the rescue personnel knew how to de-energize the vehicle and extinguish the fire if needed. In one incident in 2016, where the lithium-ion battery of a straddle carrier caught fire, the rescue personnel thought incorrectly that a lithium-based battery fire could not be put out with water and used CO_2 instead.

A persistent misconception is that submerging is the only way to put off an electric vehicle battery fire. All the vehicle fires studied were extinguished with a traditional branch pipe. In three instances, the vehicle was submerged after being extinguished, to prevent re-ignition. The average amount of water needed to put out the studied fires is computed in Table 6. Incidents that have involved a structural fire or multiple vehicles have been omitted. Extinguishing and aftercooling a BEV requires twice fold amount of water compared to PHEVs and HEVs.

Table 6. The Average Amount of Water used by Vehicle Class

Vehicle	
BEV	4.1 m^3
PHEV	1.8 m^3
HEV	1.7 m^3

4 Conclusions

Battery electric vehicles with large lithium-ion batteries require a large amount of water to be put out efficiently: whereas a normal vehicle fire can be suppressed with some hundreds of liters of water or foam, an EV fire, especially the aftercooling of the battery to prevent re-ignition, can require 10000 liters or even more water. Additionally, compared to conventional vehicle fires, there is always a risk for re-ignition.

Electric vehicles with large lithium-ion batteries are relatively new technology and no data is available on how the cars perform when they reach the age of 15–20 years. The average life for a scrapping passenger car in Finland is 22 years, [37] and the average age of the carpool in Finland is 13 years, [38] and both have been gradually increasing. The aging pool of electric and hybrid cars might cause a fire risk to be mitigated.

From the records analyzed in this article, no new threats compared to previous literature are recognized. The probability of a vehicle fire incident is low and ignition of the vehicle in crash accidents is rare.

One limitation of this study is the reliability of the Pronto register. The accuracy and comprehensiveness of the records depend on many factors, for instance, as the annual rescue mission ratio rises, the quality of the reporting process decreases, [39]. There might be instances where an electrified vehicle has caught fire, but the fact that the vehicle is electrified is not recorded in Pronto. However, taking the bias towards new technology into account, it is unlikely that severe fires would not have been recorded. There is no multi-step verification for entries in Pronto database and small errors are possible. For instance, the vehicle model and make are not always recorded or are misrecorded. For instance, a vehicle fire in May 2023 in Helsinki, was described as a “mild hybrid vehicle” and the model was recorded to be Volvo V60. As the Volvo V60 is not a mild hybrid vehicle, a request for information was made to the vehicle register, which revealed the vehicle to be a Volvo S60 PHEV.

One significant finding is the media bias for reporting electric vehicle fires. The bias has been speculated in media and social media but has not been studied quantitatively. The fact that 4 of 5 actual electric vehicle fires have been reported in the media, mentioning that they are electric vehicle fires, gives strong evidence that media bias toward electric vehicle fires does exist. Typically vehicle fires are not reported in the news unless the place or consequences of the fire are significant, as there are about 1300 rescue missions related to vehicle fires yearly.

5 Discussion and Further Research

Bias towards new technology may lead to unnecessary cautiousness, and therefore scholarly research especially comparing traditional and electrified vehicles is needed. For instance, as lithium-ion batteries are known to release toxic gases, [4], the toxicity of fire-extinguishing water has been suspected, and claimed that the water should be collected and treated, [40]. However, when compared in parallel, extinguishing wastewater from a BEV can be even less toxic than water from a vehicle with a combustion engine, [41]. Research-based decision-making should also be encouraged with extinguishing methods and tools: for instance, fire blankets are marketed for EV firefighting, but if the battery is involved in the fire, the blanket does not suppress the battery fire successfully, [42], although they may control the spread of fire in early stages, [43]. Incorrect perceptions of fire risks of electrified vehicles can lead to bad decision-making, [44].

The scholarly knowledge base on electric vehicle fires is at times well-developed and continuously improving further. However, the knowledge and practices should be communicated to the field more efficiently. The rescue and fire staff need clear and brief instructions. A good example of simple instructions is from the United States, in SAE standard J2990:2019 *Hybrid and EV First and Second Responder Recommended Practice* (Figure 1), [45].

Fig. 1: SAE instructions for first and second responders, [45]

The need for excess use of water and the probable re-ignition are the main distinctive factors when compared to regular vehicle fires. The re-ignition possibility is a challenge especially in underground parking garage fires, while the car should be safely transported out before possible re-ignition, to minimize the smoke emissions in closed space. This is a challenge, especially in garages which are too small to be accessed with a flatbed tow truck.

One risk which may arise from the electrification of vehicles is the fire risk from electrical installations of the buildings. Charging electric vehicles causes a novel long-term, repetitive, high-current, and year-round load for domestic electrical installations. In Sweden, at least one building fire has happened due to using a regular wall socket and a timer between the charging cable, [46]. It is possible that even if the charging cable plug was equipped with a temperature sensor, the sensor was unable to react properly to the heat from defective contact inside the timer or the wall plug. In Finland, one fire from the electrical installation of a vehicle charger, [47], and one near-miss incident, [48], have been documented. In the near-miss incident, charging with 16 A single-phase charger resulted in the smell of burning from the main board in a wooden house built in 1962. The screwed connections of the master switch had probably loosened and oxidized during the years, which resulted in overheating. In the fire incident, a faulty connection inside a junction box caused a storage building fire when charging an electric vehicle.

As the carpool ages, further research is needed to assess the fire risk of aging electrified vehicles as well as map possible incidents from the electric vehicle charging infrastructure.

The need and status of training of firefighting personnel in Finland is also an area that needs further research. Almost all incidents have been handled efficiently, except for one misconception for not using water but CO2, and the PHEV incident in which the vehicle re-ignited not due to thermal runaway but the reason that the electrical system had not been deactivated properly. In a survey conducted in the United States, more than 40% of first responders reported that they have never received EV safety training, [49]. The situation could be better in Finland but should be assessed. Especially small rural fire departments and volunteer-based fire brigades may not have received any training on electric vehicles.

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APPENDIX

Summary of all Identified Hybrid And Electric Vehicle Fires

Time and Location	Vehicle	Summary	Extinguishing method	Water used (m^3)	Re-ignition?	Covered in media?
August 2015, Turku	Hybrid bus	Smoke from the air compressor for brakes, no flames / actual fire	N/A	0	N/A	No
November 2015, Äänekoski	Toyota Auris (HEV)	Red triangle warning light on dashboard and smoke under the engine hood. No flames.	N/A	0	N/A	No
April 2016, Tampere	An electric straddle carrier	2-meter-long flames from the lithium-ion battery (500 kg).	CO_2	0	No	No
October 2016, Urjala	Toyota Prius (HEV)	Smoke and exploding sound from NiMH battery while driving.	Powder (no actual fire, extinguisher used just in case)	0	No	No
November 2016, Paimio	A passenger car (HEV)	Owner tried to defreeze the windscreen washer tank with an electric heater without supervision, which started the fire. No battery fire.	Fire blanket and 2 kg powder extinguisher (owner), branch pipe (firefighters).	0.5	No	No
February 2018, Tampere	Toyota Prius (HEV)	A fire in the engine compartment, possibly from an electric engine heater.	Branch pipe	1.5	No	No
July 1018, Ylöjärvi	Volvo S90 T8 (PHEV)	Excess smoke from the traction battery while charging	Drilled holes in the battery and used branch pipe	4	No	[32]
October 2018, Lapua	Think City (BEV with Zebra battery [molten salt])	Caught fire while charging. Had a traction system fault and was waiting for service.	Branch pipe	2	No	[19]
March 2019, Lahti	Hyundai Kona Electric (BEV)	Caught fire while charging: first smoke under the car, then flames. Clear battery fire.	Branch pipe	11	Twice	[21]
September 2019, Vantaa	Toyota Auris (HEV)	While driving, first smell of smoke, then flames from the engine compartment.	Branch pipe	1	No	No
October 2019, Rovaniemi	Toyota Yaris (HEV)	The car was driven off the road one day before. While driving, the car caught fire from the high voltage components	First-aid extinguishing by bystanders with water from a nearby ditch.	0	No	No
June 2020, Ylöjärvi	Volvo V60 (PHEV)	While driving, the diesel engine stopped and started EV mode, simultaneously smoke from the	Branch pipe	1	No	No

Time and Location	Vehicle	Summary	Extinguishing method	Water used (m^3)	Re-ignition?	Covered in media?
		engine compartment				
June 2020, Espoo	Toyota Auris (HEV)	Fire in the engine compartment while parked, with no external reason.	Branch pipe	0.8	No	No
August 2020, Helsinki	BMW X5 (PHEV)	Smoke from the engine compartment when driving. The firefighters found no signs of fire, the only hot spot in the IR camera was the exhaust manifold.	N/A	0	N/A	No
September 2020, Keminmaa	Lexus GS450H (HEV)	Caught fire when parked, probably from a technical fault.	Branch pipe	0.4	No	No
March 2021, Vantaa	Toyota Prius (HEV)	A small fire in the tail light when parked, self-extinguished when the firefighters arrived.	N/A	0	No	No
March 2021, Liminka	Tesla Model 3 (BEV)	Oil leak and smoke from the AC compressor while driving, but no actual fire.	N/A	0	No	No
April 2021, Sysmä	Lexus (HEV)	While driving, smoke under the seat and flames from the back left corner. 12 V battery suspected.	Branch pipe	3	No	[50]
May 2021, Helsinki	Toyota Prius (HEV)	While driving, smoke from the engine compartment, then fire	Branch pipe	5	No	No
June 2021, Utajärvi	Toyota Prius (HEV)	Immediately after driving, the 12 V battery started a fire	First-aid was extinguished by the driver with a small amount of water	0	No	No
December 2021, Vantaa	Mercedes-Benz GLE 500e 4MATIC (PHEV)	While driving, fire in the engine compartment. Not a battery fire, but re-ignited because the HV system was not properly deactivated.	Hand extinguishers and branch pipe	0.5	Once	[51] (A Pronto-based yearly review – not reported in the local news media.)
May 2022, Helsinki	BMW X5 (PHEV)	Caught fire when parked and not plugged in.	Branch pipe and penetrating lance for battery	4	No	No
May 2022, Kemijärvi	BMW X5 (PHEV)	Caught fire while driving.	The fire brigade chose to let the car burn down, in a rural area.	0.2	No	No
May 2022, Siilinjärvi	BMW 320e (PHEV)	Began smoking while charging. Caught fire when being winched farther from the	Branch pipe	2	No	No

Time and Location	Vehicle	Summary	Extinguishing method	Water used (m^3)	Re-ignition?	Covered in media?
		house by the fire brigade				
August 2022, Tampere	Toyota Prius (HEV)	Smoke from the trunk when parked. No fire and no hot surfaces when inspected with an IR camera.	N/A	0	N/A	No
December 2022, Rovaniemi	Unspecified BEV	The fire brigade called but no fire on site. Very deficient report.	N/A	0	N/A	No
January 2023, Lahti	Scania bus (BEV)	HV battery modules started burning during the test drive.	Branch pipe, submerging the removed modules	4	No	[29]
February 2023, Kolari	Mercedes Benz E-Class Hybrid (PHEV)	Flames from the floor when driving	Branch pipe	2	No	No
March 2023, Lohja	Tesla Model Y (BEV)	A BEV was slightly damaged from a building fire (the fire did not start from the car)	Branch pipe	0.1	No	[22]
March 2023, Loppi	Kia EV6 (BEV)	While driving, the driver heard a boom from the back of the car, then smoke and flames. No battery fire, an inverter fault.	Branch pipe	3	No	[18]
May 2023, Helsinki	Volvo S60 (PHEV)	A parked vehicle battery ignited spontaneously.	Branch pipe	1	No	No
May 2023, Mikkeli	Range Rover (PHEV)	The battery ignited spontaneously while driving.	Branch pipe + submerging the extinguished vehicle	2 (extinguisging) + 12 (submerging)	No	[33]
May 2023, Kouvola	Mercedes 250E (PHEV)	A building fire, four cars inside involved, of which one is a PHEV. The electrical wiring, charging station, or the internal charger was suspected.	Branch pipe	189 (total for the structural fire, not comparable)	No	[35]
May 2023, Pälkäne	Range Rover (PHEV)	Fire in the engine compartment while driving	Branch pipe	2.5	No	No
June 2023, Lahti	VW ID.Buzz (BEV)	The van was plugged in and fully charged, and gases vented from the HV battery deflagrated damaging the vehicle and causing a fire alarm. Three days later, the vehicle caught full fire while waiting for investigations.	No actual fire in the first event. The re-ignition was extinguished by branch pipe and by submerging the vehicle after that.	10	Once	[23]
June 2023, Tampere	BMW X5 (PHEV)	A plugged-in PHEV caught fire after charging finished, fire spread to the garage.	Branch pipe	12.5 (total for the structural fire, not comparable)	No	No

Time and Location	Vehicle	Summary	Extinguishing method	Water used (m^3)	Re-ignition?	Covered in media?
June 2023, Tuusula	Yutong E12 (BEV bus)	Brake of a bus was overheated and caused a tire fire.	Branch pipe	1	No	No
July 2023, Iitti	Mercedes-Benz C350 E (PHEV)	A hybrid car started the engine by itself and did not turn off the key. Had been driven 4 hours before the incident. Flames under the hood behind the engine. No battery fire is suspected.	Powder extinguisher	0	No	No
July 2023, Vantaa	Mercedes-Benz GLC Coupe (PHEV)	A PHEV caught fire while plugged in. Fire spread to one another car and three other cars suffered damage from the heat.	Branch pipe	3.3 (including the neighboring car)	No	No
July 2023, Helsinki	Nissan Leaf (BEV)	An arsonist had made a fire next to trash bins and a carport. Four vehicles, including one BEV, caught fire. No battery fire.	Branch pipe	8	No	No
July 2023, Salo	Nissan Leaf (BEV)	The driver drove out of the road in a bend. The vehicle fell 5 meters and the rocks on the ground damaged the battery and ignited it. The driver and passenger managed to leave the car. The bottom of the vehicle was immersed in water to prevent re-ignition.	Branch pipe + immersion to prevent re-ignition during transport	2	No	[26], [27] (No mention of the fact that the vehicle was electric.)
August 2023, Lohja	BMW 330e (PHEV)	While driving, the driver noticed a strong smell of fuel, then smoke and flames from the engine compartment. No battery fire.	Branch pipe + foaming	2	No	No
December 2023, Helsinki	Unknown (HEV)	Front brakes overheated while driving a rental HEV car, and smoke and flames were reported. Extinguished by throwing snow on the wheels and brakes.	First-aid extinguishing with snow	0	No	No
December 2023, Tuusula	Mercedes-Benz C 350 e (PHEV)	A PHEV caught fire while driving, the driver stopped at a parking lot and	Branch pipe + foaming	0.1	No	No

Time and Location	Vehicle	Summary	Extinguishing method	Water used (m^3)	Re-ignition?	Covered in media?
		called the emergency number. Extinguished with water and foam.				
December 2023, Oulu	Tesla Model 3 (BEV)	Pale smoke under the hood near the left front light, no actual fire. The smoke entered the cabin also. The heat pump is suspected.	N/A	0	No	No

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