Hybrid and Electric Vehicle Fires in Finland 2015–2019

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ABSTRACT

As an emerging technology, hybrid and electric vehicles draw media attention and so does their fire safety. For this paper, Finnish national rescue task database PRONTO was reviewed for electric and hybrid vehicle fires and road accidents, and similarities were identified using thematic content analysis. Hybrid and electric vehicle fires are both absolutely and relatively rare compared to conventional vehicle fires. 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. Conventional hybrid electric vehicles caught fire usually while driving, whereas battery electric and plug-in hybrid vehicles ignited while being charged. In road accidents, neither a hybrid nor an electric vehicle caught fire in the data studied.

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, p. 292] 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, p. 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, p. xi] If the vehicle is old 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 need for excess use of water. [4] In addition, the battery may re-ignite even days after the first extinguishment. [5] Further research and assessment is needed also in extinguishing water treatment. [6, p. 59] In this paper, BEV:s, PHEV:s and HEV:s are referenced as electrified vehicles.

According to 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 is 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 obstructs making strong conclusions on fire rate.

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 thermal runaway state, the fire can be extinguished just like any conventional vehicle fire. The ignition of the battery usually results from internal fault 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. [9]

In Finland, 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 to 5 fire incidents per 10000 vehicles annually (Table 1).

Table 1: Road vehicle fires in Finland 2015-2019 according to PRONTO.

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
Fires total	**6436**	**755**	**1094**	**253**
Annual average	1287	151	219	51
Vehicles total (2019)	2 720 307	330 671	95 141	12 577
Fires per 10000 vehicles	4.7	4.6	23.0	40.2

As modern electric vehicles being rather new technology on the market, media bias and prejudices among public do exist. A fire incident of an electric car will draw media attention, which propagates the bias further.

The goal of this paper is to analyze the accidents and fires in the Finnish car pool to provide information on fire likelihood in electrified vehicles and provide comparable information for researchers in different countries. National accident information and statistics is usually available in national language only and collection and accuracy of statistics varies country by country, which makes comparison difficult. [10] Unlike structural choices in buildings and electrical installations, a certain model of a vehicle is the same or modified in slightest, and therefore information in vehicle fires in one country is globally useful.

METHODS

In this paper, the national rescue task register PRONTO was searched for vehicle fires and traffic accidents. 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.

Thematic content analysis was applied to the incident records to identify relevant similarities in the chain of events.

RESULTS

From the database, 11 fire incidents and 19 crash incidents involving hybrid or electric vehicles were identified during the years 2015–2019. The results are presented in Table 2.

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 (14 055)	1 (a hybrid bus)
2016	3	0 (844)	0 (2437)	2 (19 250)	1 (a straddle carrier)
2017	0	0 (1449)	0 (5719)	0 (28 519)	
2018	3	1 (2404)	1 (13095)	1 (41 696)	
2019	3	1 (4661)	0 (24704)	2 (58 632)	

All the BEV fires and the PHEV fire started when the car was connected to a charger. All the HEV vehicle fires started while driving, except for two incidents, of which one fire started from a mains powered engine pre-heater, and the other fire started from misuse: the owner was trying to de-ice the frozen windscreen washer tank with an electric heater left unsupervised.

In the majority of 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-battery of a straddle carrier caught fire, the rescue personnel thought incorrectly that a lithium battery fire cannot be put out with water and used CO_2 instead. In one roadside accident, the rescue personnel were unsure how to de-energize the hybrid vehicle involved.

In one of the BEV fires (October 2018), the car had stopped working on the road and towed to the owner's house to wait for a delivery to a repair shop. The vehicle (Think City) was plugged to 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 totally 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. [11]

The other fire on BEV took place in March 2019. At 5:23 in the morning a security guard noticed that smoke is 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 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 bursted 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 has 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 electric vehicles in general. [12] 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. [13]

In the only 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 to 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. [14]

Of the 19 identified hybrid and electric vehicle crashes, none of them caught fire on site nor at the repair shop. However, in one of the incidents where a HEV caught fire while driving, the vehicle was driven off the road on the previous day.

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 high voltage system related fires per 10000 vehicles per annum is 0–1.1 for HEV:s and PHEV:s and 0–5.2 for BEV:s. For HEV:s and PHEV:s the number is significantly smaller than the average for all passenger vehicles (Table 1). For BEV:s, the number is in the same order of magnitude. The young age of hybrid and electric vehicles probably biases the comparison, as the aging of the vehicles increases the fire risk [8].

Table 3: Fires per 10000 BEV:s, PHEV:s and HEV:s. The absolute number of fires is presented in parenthesis.

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)

The most common reason recorded for vehicle fires in Finland is technical fault (Table 4). From fires caused by human action (Table 5), 70 % are deliberate, totaling in 11 %.

Table 4: Causes of vehicle fires 2015–2019.

Cause	
Technical fault	64 %
Human action	16 %
Could not be assessed	15 %
Other reason	4 %
Flammable substance	1 %
Natural phenomenon	2 ‰
Animal	0.8 ‰

Table 5: Vehicle fires, when recorded caused by human action 2015–2019.

Cause	
Deliberate	70 %
Accidental	13 %
Act of negligence	12 %
Could not be assessed	5 %

The data analysed for this paper was for the years 2015–2019. For the year 2020, four hybrid vehicle rescue tasks have been recorded and no BEV tasks are recorded in PRONTO till 13th December 2020. Two of them were HEV:s which both caught fire when parked. The other two were PHEV:s which emitted smoke under the hood when driving, but when the fire personnel arrived on scene, no fire nor signs of fire were observed.

CONCLUSIONS AND DISCUSSION

Battery electric vehicles with large lithium-ion batteries require a large amount of water to be put out efficiently. 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 20 years and the average age of the car pool in Finland is 12 years. The aging pool of electric and hybrid cars might cause a fire risk to be mitigated.

From the current fire and accident data about vehicle fires in Finland 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 in this study is the reliability of the PRONTO register. The accuracy and comprehensiveness of the records depends on many factors, for instance, as the annual rescue mission ratio rises, the quality of the reporting process decreases. [15] 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 media bias into account, it is unlikely that severe fires would not have been recorded.

The scholarly knowledge base on electric vehicle fires is at time fairly adequate 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) [16, p. 57].

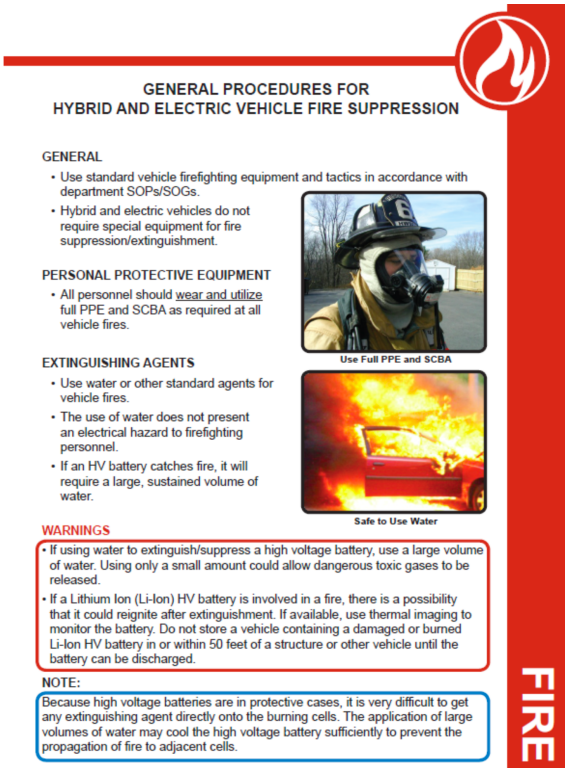

Figure 1: SAE instructions for first and second responders (SAE J2990:2019 p. 57).

The need for excess use of water and the probable re-ignition are the main distinctive factors when comparing 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 rise from 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 regular wall socket and a timer between the charging cable. [17] 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, no electrical installation fires due to electric vehicle charging have been documented, but one near-miss incident can be found from Finnish electric vehicle enthusiasts' public Facebook group. [18] In the incident, charging with 16 A single-phase charger resulted in 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.

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