Horizon 2020

Project acronym: **LASH FIRE**

Project full title: **Legislative Assessment for Safety Hazard of Fire and Innovations in Ro-ro ship Environment**

Grant Agreement No: **814975**

Coordinator: **RISE Research Institutes of Sweden**

Myths and Facts about Fires in Battery Electric Vehicles

August 2022

Dissemination level: Public

Call identifier: H2020-MG-2018-Two-Stages Starting date: 2019-09-01 Duration: 48 months
MG-2.2-2018: Marine Accident Response, Subtopic C

Abstract

As new energy carriers make their way into the market, some misconceptions will naturally also make their way to the public. The objective of this report is to respond to some of the most common misconceptions and myths regarding battery electric vehicle fires, while highlighting the latest research and available data. Eleven common misconceptions about battery electric vehicle fires are presented and answered. Fires in battery electric vehicles are not more dangerous than fires in conventional vehicles and are currently not more frequent. We have learnt dealing with fires in conventional vehicles and we are currently learning how to deal with fires in battery electric vehicles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814975

Document data

Document Title:	Myths and facts about fires in battery electric vehicles
Work Package:	WP06 – Effective Manual Operations
Related Task(s):	T06.11
Dissemination level:	Public
Lead beneficiary:	1 – RISE
Responsible author:	Jonna Hynynen
Co-authors:	Magnus Arvidson, Ola Willstrand, Franz Evegren, Maria Hjolman
Date of delivery:	
References:	N.A
Approved by	CMT2 on 2022-08-16 / STL on 2022-05-16 / RISE on 2022-07-07

Involved partners

No.	Short name	Full name of Partner	Name and contact info of persons involved
1	RISE	RESEARCH INSTITUTES OFSWEDEN AB	Jonna Hynynen, jonna.hynynen@ri.se
28	CMT2	Centre of Maritime Technology	Grit Ladage, ladage@cmt-net.org
10	STL	Stena Rederi AB	Martin Carlsson, martin.carlsson@stena.com

Document history

Version	Date	Prepared by	Description
01	2022-04-20	Jonna Hynynen	Draft of structure, circulated to reviewers
02	2022-04-29	Jonna Hynynen	Draft
03	2022-05-10	Jonna Hynynen	Draft in correct template, Circulated to reviewers
05	2022-07-01	Jonna Hynynen	Final report, circulated to reviewers
06	2022-08-19	Jonna Hynynen	Final report

Contents

1 Introduction

The vehicle fleet is going through a major change regarding the traction energy. Petrol and diesel used for propulsion in internal combustion engine vehicles (ICEVs) are replaced by alternative fuels, not least batteries. A rapid growth in the number of electric vehicles is seen in major markets such as China and Europe (Dennis, 2021). In 2020, 4 % of new passenger vehicles sold globally were electric, but sales are thought to increase exponentially and could meet benchmark values of >80 % in 2030 (Dennis, 2021).

As new energy carriers make their way into the market, some misconceptions will naturally also make their way to the public. The objective of this report is to respond to some of the most common misconceptions and myths regarding battery electric vehicle (BEV) fires, while highlighting the latest research and available data as of April 2022. Each misconception or myth is presented as a simplified statement and is presented in the **headline**, followed by an answer that describes the topic in more detail. The **short communication** can be found in the **Appendix** and is also published on lashfire.eu.

2 Myths and facts about fires in battery electric vehicles

2.1 "BEVs burn more often than ICEVs"

Short answer: Current statistics from Sweden indicate that the probability of a BEV fire is lower than of fire in an internal combustion engine vehicle (ICEV) (relative to the total number of vehicles) (Bergholm, 2021). The likelihood that the fire would start in the battery is low and has only been validated for one case in Sweden between 2018 and 2020, which was a homebuilt electric vehicle (Bergholm, 2021). Some of the most frequent causes of fire in vehicles are arson, overheated brakes or the combination of flammable liquids and hot surfaces or electrical faults in the engine compartment (Ahrens, 2020; Brzezinska et al., 2020; National Fire Data Centre, 2018). The probability of fire for the former two will most likely not be affected by the change in energy storage.

Long answer: The Swedish civil contingencies agency (MSB) released a *promemoria* (PM) in 2021 that summarised the fires in electric vehicles and electric applications, such as bicycles and hoverboards etc. (Bergholm, 2021). Fires starting in the traction battery are very rare and was only validated for one case, which involved a homebuilt electric vehicle (Bergholm, 2021). Between 2018 and 2021, a total of 57 fires were reported in electric/hybrid vehicles in Sweden. The number of fires in ICEVs during the same period were 505* involving the 12 V battery/charger or electric wiring. The total number of passenger vehicles on fire each year in Sweden is around 4000 and the total number of electric/hybrid vehicles in Sweden was 452 413 in 2021, compared to 4 534 337 vehicles with other traction energy. **Note that the total number of fires is larger. Reported values for ICEV only refer to the fires where the battery, charger or electrical wires were involved in the fire.*

In a report by RISE (Brandt & Glansberg, 2020), current available fire statistics for vehicle fires in car parks and garages in Norway was summarised. A total of 998 fires were recorded in BRIS (DSB reporting system) during 2016 and 2018. Of these, 109 fires were recorded with the cause “electrical equipment” and 65 started in vehicles, of which two were in electric cars. Some international statistics estimate that there are currently around five fires for each 1.6 billion kilometres driven for electric cars, compared to 55 fires for conventional vehicles in the same mileage (Ferrell, 2019; Isidore, 2018).

2.2 “BEV fires are more intense than ICEV fires”

Short answer: All modern vehicles carry a large amount of chemical energy in terms of materials used in for example seating, other cabin interior and tyres. Most of the chemical energy in an average sized passenger car does not come from the energy storage. The total heat release for modern BEVs and ICEVs ranges between 3.3 and 10 GJ and is independent of the traction energy (Willstrand et al., 2020).

Long answer: All modern vehicles carry a large amount of chemical energy, including the power system, plastic/rubber components and of course the energy storage (petrol/diesel, battery etc.). Petrol and plastic have very similar heath of combustion: roughly 47 MJ kg^{-1} for petrol (Sun et al., 2020) and 45 MJ kg^{-1} for plastics (here polypropylene) (U.S. Department of Transportation, 1998).

In work by Emilsson et al. (Emilsson et al., 2019), the plastic use and weight trends for vehicles were analysed. The amount of plastic has steadily increased from the middle of the 1900s to 2000. In the 1970s an average car contained 6% plastics, whereas in 2020 the average vehicle contained 18% plastics. The average weight of the cars in the 1970s and 2020 were the same (1 100 kg), which amounts to a total weight of 66 vs 198 kg of plastic (Emilsson et al., 2019).

The reason for this change in material is the favourable properties of polymers (plastics) compared to metals. Polymers are easy to work with, lightweight, they will not rust and can reduce manufacturing costs compared to metals.

The increased use of plastics in passenger cars has increased the energy available for combustion. In work by Emilsson et al. (Emilsson et al., 2019) it was found that polypropylene (heat of combustion, ~45 MJ kg^{-1} (U.S. Department of Transportation, 1998) is used in majority in the car manufacturing (the rubber from tyres was not included in the analysis). For comparison, polyurethane (heat of combustion, ~24 MJ kg^{-1} (Vanspeybroeck et al., 1993) is used to represent polymers of low heat of combustion. As an example, the increase in plastics from 66 to 198 kg results in an increase in energy content from ~ 2.3 GJ (66 kg x 34.2 MJ kg^{-1}) to ~ 6.8 GJ (198 kg x 34.2 MJ kg^{-1}).

In a review by Sun (Sun et al., 2020), a comparison of a vehicle that could travel 400 km on either petrol or battery power, resulted in 30 l of petrol or a 90 kWh battery (standard electric vehicle 2020, 20 – 50 kWh). Using these estimations, a total heat release of 1 and 2.3 GJ was obtained for the different drivelines respectively (Sun et al., 2020). This indicates that the heat of combustion resulting from the polymeric parts is substantially larger compared to 30 l of petrol or a 90 kWh battery.

In work by Willstrand et al., heat release rates (HRR) from full-scale fire tests performed in recent years with modern vehicles, including both ICEVs and BEVs was summarised. The compiled data showed a minor difference in the total energy released during the fire (total heat release) between ICEVs and BEVs. The total heat release for ICEVs range between 3.3 to 10 GJ and for BEV between 4.7 to 8.5 GJ. No difference in peak heat release rate or effective heat of combustion could be seen for the compared vehicles (Willstrand et al., 2020).

2.3 "BEV fires will spread much faster to cars nearby than ICEV fires, due to long jet flames"

Short answer: Different fuel types have different modes of fire spread. For example, liquid fuel such as diesel may spread the fire by means of leakage and pool fires, and gas pressure vessels and lithium-ion batteries may be prone to jet flames that could spread the fire. If exposed to external heat, such as a fire, a plastic fuel tank will catch fire much faster than a lithium-ion battery.

Long answer: Regarding the potential speed of fire spread, a fully fuelled ICEV contains a large amount of liquid fuel. A leaking fuel tank can enable a running pool fire, which can spread fast for longer distances (several meters). One recent example is the Kings dock car park fire in the UK on New Year's Eve 2017, where "*Running fuel fires were witnessed by BA crews and this undoubtedly led to fire spread through the drainage system, down ramps and along the rib slab floor*." (Merseyside fire and rescue service, 2018).

The combustion of petrol compared to batteries will also differ. A 30 l petrol pool fire has a burning time of roughly 5 – 10 min (pool fire diameter of 0.56 to 1.89 m) depending on the pool size. The larger the pool, the quicker fuel consumption (Marková et al., 2020). Battery fires (thermal runaway) propagate cell to cell, leading to a longer burning time. As an example, in recent testing performed by RISE in Borås a 50 kWh battery pack had a burn time of ~ 25 min (ETOX 2, report available later in 2022).

In work by Gehandler et al., the heat radiance from jet flames resulting from burning compressed natural gas and hydrogen gas tanks were measured. The incident heat flux measured ranged between 2 – 8 kW m^{-2}, which is below the critical irradiance of most materials. Additionally, the time duration of jet flames from gas tanks were short, about 1 min (Gehandler et al., 2022). However, full-scale BEV fire tests that evaluate the effects on fire spread due to jet flames are currently missing.

The ignition point (i.e. where the vehicle is ignited) appears to affect the time to peak HRR (i.e. how fast the fire reaches its maximum intensity) and also the mass loss of the vehicle (i.e. how much of the vehicle that will combust). The collected data in ETOX indicate that if a vehicle, independent of the driveline, is ignited from below, the time to the peak heat release rate is the shortest (amongst the compared scenarios) and the mass loss the greatest. The time to peak heat release rate was 5 to 10 min for vehicles ignited underneath the vehicle, in contrast to 20 to 40 min for an ignition point in the passenger compartment or behind the rear wheel (Willstrand et al., 2020).

2.4 "BEV fires burn very hot and can melt the deck below the fire"

Short answer: The temperature of a fire will vary and depends on several factors such as fuel source, atmospheric pressure, adjacent temperature, oxygen content etc. There is no data which suggests that BEV fires are hotter than ICEV fires.

Long answer: Arvidson performed a large-scale Ro-Ro/vehicle space fire test simulating a fire in a freight truck trailer (Arvidson, 1997). The test was set-up to simulate a large but realistic fire on deck. The simulated fire scenario included both a flowing petrol fire as well as fire in the cargo of a freight truck with a height of 4.5 m. The height of the ceiling was 4.8 m and the calculated total available energy for the tested freight was 12.6 GJ. Ceiling temperatures reached peak values of ~ 1 200 °C (Arvidson, 1997).

Additionally, in full scale vehicle tests performed at RISE Research Institutes of Sweden with burning cars manufactured in the late 1990s and automatic ceiling sprinklers, the gas temperature was found to reach 150 °C and the average surface temperatures of adjacent cars peaked around 100 °C (i.e. boiling point of water) (Arvidson, 2022).

In work performed by BRE (UK), ICEVs and liquefied petroleum gas vehicles were tested with and without sprinklers. Without sprinklers, a peak HRR of 16 MW (2 cars burning), ceiling temperature 1 100 °C, and heat flux exceeding 25 kW/m^2 (excess of critical irradiance of most combustible materials) was found. Whereas with sprinklers, the peak HRR was reduced to 7 MW. In the test performed with sprinklers the fire did not spread to adjacent vehicles. Work showed that sprinklers were very effective in hindering fire spread to adjacent vehicles (BRE, 2010).

The heat generation of a vehicle fires can be very high. High temperatures can result in molten aluminium and ignition of magnesium. As an example, aluminium alloys have a melting point of 570 to 1 500°C (depending on the alloy) and magnesium can ignite around 630°C (Blandin et al., 2004). Burning magnesium can reach peak temperatures of 3 000°C due to the exothermic nature of the process (Czerwinski, 2014; Dreizin et al., 2000). The material used in vehicles will not differ to a larger extent in relation to the traction energy and the traction energy will not be the sole constituent to the heat flux (temperature).

2.5 "Battery fires can't be extinguished, and the drencher system cannot control a BEV fire"

Short answer: A thermal runaway event is difficult to extinguish unless water/fire-fighting agent is injected into the battery to enable efficient cooling of the battery cells. However, the fire will most likely not start in the traction battery. Therefore, activities that support early/fast fire suppression (manual or automatic) are highly encouraged, to hinder the fire to spread to the battery and to adjacent vehicles (Gehandler et al., 2022).

Vehicle fires from other sources, e.g. starting in the brakes, engine, or interior, can be extinguished with the use of handheld extinguishers. A compilation of existing data on ship fires made by Arvidson, shows that early activation of the deluge system also hinders fire spread as it will suppress the fire and cool the deck and nearby vehicles (Arvidson, 2022).

Long answer: In UK during 1994 and 2005, 3 096 fires in cars were reported. In 162 of these fires, an automatic sprinkler system was present, in 0.6% of these cases the sprinkler system was activated but did not manage to contain/control the fire (Arvidson, 2022).

In the Netherlands, a BEV fire was started deliberately on September 1, 2020. The sprinkler system controlled the fire, and the fire did not spread to the battery pack (Arvidson, 2022).

In November, 2021, there was a fire in the underground car park Marienplatzgarage in Ravensburg, Germany. According to initial information, an electric vehicle parked on the first parking level and connected to a charging station was likely the cause of the fire. "*The sprinkler systems and other fire protection devices worked extremely well*", according to the press spokesperson for the Ravensburg fire brigade (Arvidson, 2022).

In work by Arvidson reports from DNV GL that analysed fires within ro-ro spaces on ro-pax vessels, vehicle carriers and general ro-ro cargo vessels were summarised. The two reports identified 53 fires between 1993 and 2016. Between 2005 and 2016 eighteen incidents occurred on ro-pax vessels, nine fires on pure car and pure car and truck carriers and eight fires occurred on ro-ro cargo vessels. In three cases, no water from the deluge system was applied to the area on fire. All three cases were in open ro-ro spaces and all fires resulted in total ship losses (Arvidson, 2022).

The DNV GL report highlights the importance of early activation of the deluge system; three minutes for water deluge systems and 15 minutes for Carbon Dioxide systems is suggested. Additionally, comprehensive crew training and well-defined procedures for responding to fire incidents are necessary to ensure that the crew can operate the fixed fire-extinguishing system as swiftly as possible.

In work by BRE, UK (BRE, 2010) fire tests with multiple cars in car parks were performed, from which the following conclusions were made:

- *"The sprinkler system was effective at controlling a developing fire.*
- *The sprinkler system was equally as effective at controlling a fully developed fire.*
- *Without sprinklers fire is likely to spread from car to car.*
- *With sprinklers spread of fire is unlikely.*
- *Without sprinklers, dangerous levels of smoke are likely for long periods.*
- *With sprinklers, dangerous levels of smoke are likely for long periods."*

2.6 "You can get electrocuted whilst extinguishing a BEV fire with water"

Short Answer: Electric cars have extensive safety systems that will automatically break the power and isolate the battery pack when a collision or a short circuit is detected.

If the car would be submerged in water or if water by other means would get into the battery pack or electrical system and cause a short circuit, then you would need to be physically in between the positive and negative pole or in contact with both conductors at the same time to experience an electric shock, which is very unlikely.

Long answer: All passenger vehicles, both ICEV and BEVs, have an electrical system. For ICEV it operates at much lower voltages, but the principle is the same. Even if you would get water on the battery terminals of the 12 V battery, it would generally cause corrosion and not electrocution or electric shock. However, if the battery has been damaged (in a fire or crash) some safety features (such as electrical insulation) may have become damaged. Therefore, there could be a risk for stranded energy in the battery pack (National Transportation Safety Board, 2020).

The Fire Protection Research Foundation (NFPA) conducted tests where they measured the voltage and current for the chassis as well as for the nozzle of a fire hose during suppression of BEVs. The test results showed that the chassis and nozzle currents were negligible. The voltage levels at the chassis reached approximately 0.3 to 0.4 V. Additionally, voltage levels at the nozzle were negligible. The conclusions drawn were that no adverse electrical conditions were noted for the performed tests (Long et al., 2013).

2.7 "Hydrogen fluoride produced from BEV fires is highly toxic and lethal"

Short answer: It is true that hydrogen fluoride (HF) has been detected in higher quantities in BEV fires than in ICEV fires and it is also true that HF is very toxic.

However, combustion gases from all types of vehicle fires are toxic and can cause incapacitation. Carbon monoxide (CO) and hydrogen cyanide (HCN) are common causes of death when smoke has been inhaled in a fire accident (Eckstein & Maniscalco, 2006; Jonsson et al., 2016; Lawson-Smith et al., 2011). Staying out of the smoke plume and wearing adequate personal protective equipment (see section 2.8) when dealing with burning or burnt vehicles is of great importance for all fires independent of the energy carrier of the vehicle.

2.8 "The fire crew is not protected from BEV fires by the standard fire suits"

Short answer: Regarding the protection by firefighting protective clothing against hydrogen floride (HF), the Swedish Defence Research Agency (FOI) studied the health risks of HF when smoke diving. Firefighters that were fully dressed (*underwear trousers/sweater, thick socks, fire suit trousers, fire suit jacket, boots, balaclava/flash hood, helmet and gloves*) and equipped with breathing apparatus performed different exercises in an HF contaminated enclosure and the penetration of HF through their clothes was measured. According to the authors, a person only wearing breathing apparatus (i.e., a naked person wearing only breathing apparatus) would need to smoke dive for 14 h in 100 ppm of HF to achieve a lethal dose of HF via skin uptake (Wingfors et al., 2021).

Long answer: An increased concentration of hydrogen fluoride (HF) gas has been reported for BEV fires in comparison to ICEV fires (roughly twice as high). In work by Willstrand et al. a compilation of HF concentrations for full scale fire test was made. The reported concentrations of HF detected upon combustion of BEV/batteries vary to a large extent, ranging from 15 to 4800 ppm (reference volume 1000 m^3) (Willstrand et al., 2020). The reason for the varying HF concentration may have an origin in the reactivity of HF, measurement technique and experimental set-up as well as due to different methods to extrapolate the data.

In a study by Dennerlein et al. it was found that only a small amount of HF (1%) in solution was able to penetrate skin at HF concentrations of 5 to 30 wt.%, in 24 h. Increasing the HF concentration to 50 wt.% lead to a skin penetration of 8% (Dennerlein et al., 2016). Such high concentrations are not seen for BEV fires and the measured HF for BEV fires is in the gaseous form.

In work by Wingfors et al. the protection factors of fire suites towards gaseous HF, as well as the risk of dermal exposure to gaseous HF were investigated. The skin uptake of gaseous HF ranged between 7 to 118 mg per 18 000 cm^2 of skin area (which is the average area of a naked adult human). The protection factor of the tested fire suits had an average protection factor of 120. This means that the concentration of HF on average was 120 times lower on the inside of the fabric compared to the outside. The study concluded that the risk for skin uptake of gaseous HF is low, and that adverse health effects are unlikely caused by skin exposure during firefighting (Wingfors et al., 2021).

Using data from Dennerlein et al. and Wingfors et al., the Ambulance care in Greater Stockholm Ltd (AISAB) published an information video on YouTube (21 Dec 2021) where they estimated different lethal doses of HF depending on route of exposure (AISAB, 2021). For highly concentrated HF solutions (50 wt.%) an exposure of 1% of the body area (roughly the size of your palm) would be required for a deadly dose. For a more diluted HF solution of 5 wt.% an exposure of 160% of the body area would be required for a deadly dose. Additionally, a deadly dose of 5 – 30 mg kg^{-1} through inhalation, would require an exposure of 100 ppm of HF for ~ 2 to 12 h (considered heavy breathing, 2400 L h^{-1}) (AISAB, 2021). Additionally, HF in gaseous form, of a concentration of >30 ppm is considered highly irritating for eyes and nose and the highest concentration tolerable for > 1min was found to be 122 ppm (EPA, 2004). This indicates that if a person would be subjected to high concentrations (100 ppm) of HF, the required time of at least 2 h would be unbearable to withstand.

2.9 “Overcharging a lithium-ion battery can cause thermal runaway”

Short answer: This is true on a cell and module level if no safety systems are applied. A lithium-ion battery pack in a car has a battery management system that will prevent the cells from overcharging. When charging, the car communicates with the charging system to ensure that charging process is terminated within an acceptable state of charge.

There has been reports of fires starting in a BEV "while charging". It is important to keep in mind that fires in such situations may have multiple reasons, such as electric malfunction in the charging infrastructure, the cable or other general car fire causes.

For safe charging of an electric vehicle Electrical safety first, UK has listed the following points which can be found on their web page (Drew & Davies, 2019):

- *"Never use a domestic multi socket extension lead when charging your electric vehicle. If you do need to use an extension lead only ever use one that is suitable for outdoor use such as a reel cable."*
- *"Never 'daisy-chain' extension leads. The method of plugging more than one extension lead into another in order to reach a greater distance increases the risk of an electrical fire as well as electric shock."*
- *"Always buy your charging cable from a reputable retailer or directly from the manufacturer who will put such products through rigorous tests to ensure they meet UK safety standards."*
- *"Ensure you frequently check your charging cable for wear and tear and replace it if any damage is evident."*
- *"If you are charging from a 13A mains socket in your home, ensure the wiring in your property has been checked prior to doing so. Old wiring may not be able to cope with the demand from charging your vehicle overnight and risk a fire in your property."*
- *"The safest and most convenient way to charge your vehicle at home is through a dedicated wall box charging point. Ensure this is installed by a qualified, registered, and competent electrician only*."

2.10 "Electric vehicles must be stowed away from other vehicles to increase safety"

Short answer: As the BEV fleet is steadily increasing, it will soon not be feasible to stow away all BEVs in a specific area of the vessel. Additionally, storing fully functioning BEVs in a certain area for fire safety reasons would be unnecessary.

However, if a BEV has experienced mechanical damage (such as in a crash) or has been involved in a fire, it is important to monitor the vehicle (battery) as the battery and its safety systems may have become damaged, which could potentially lead to thermal runaway in the battery.

2.11 "Ageing of batteries in BEVs will increase the fire risk"

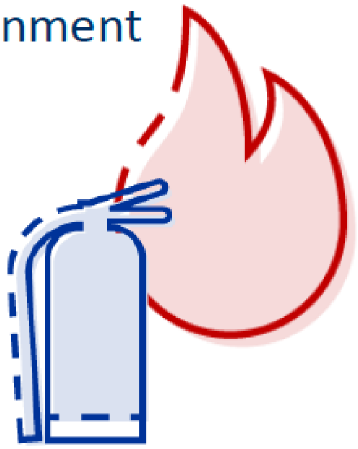
There are still limited statistics on aged lithium-ion batteries and no data on the potential impact of battery aging on fire accidents.

Ageing of battery materials may result in both capacity fade and impedance increase (Xiong et al., 2020). The aging mechanisms of lithium-ion batteries are diverse and complex. Additionally, aging mechanisms are linked to interactive factors, such as battery type as well as operating conditions, which makes general predictions of the ageing characteristics complicated.

Appendix

LASH FIRE

Legislative Assessment for Safety Hazards of Fire and Innovations in Ro-ro Ship Environment



Facts and Myths About Fires in Battery Electric Vehicles

The passenger car vehicle fleet is going through a major change in terms of the energy used for propulsion. Petrol and diesel are exchanged for alternative fuels, not least batteries.

A rapid growth is seen in the sales of electric vehicles in major markets such as China and Europe. In 2020, 4% of new passenger vehicles sold globally were electric vehicles. Sales are predicted to increase exponentially and could meet sales benchmark values of >80% in 2030.

Lithium-ion (Li-ion) batteries

Li-ion batteries can be found in a variety of formats and chemistries which enable them to be used in a variety of different applications, from mobile phones to battery electric vehicles (BEVs).

Fire hazards

New technologies naturally raise a large interest in the public and as new energy carriers make their way into the market, some misconceptions will naturally also make their way to the public.

BEVs are not more hazardous than internal combustion engine vehicles (ICEVs), but the risks of Li-ion batteries differ to those of conventional fuels.

Facts and myths

The objective of this short communication is to respond to some of the common misconceptions regarding BEV fires.

A **detailed answer** to each statement and a **complete reference list** can be found in the report (https//lashfire.eu). Below each statement, a reference to the relevant section in the report is found.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 814975

More information: https://lashfire.eu/

Version: 01 (Published 2022)

FACTS & MYTHS ABOUT FIRES IN BEVs

1. "BEVs burn more often than ICEVs"

The number of BEV fires is currently lower than that of ICEV fires (relative to the total number of vehicles). Common causes of passenger car fires are arson, hot brakes, and flammable liquid + hot surfaces or electrical faults in the engine compartment . The probability of fire for the former two will be independent of the fuel used. (Report Section 2.1)

2. "BEV fires are more intense than ICEV fires"

All modern vehicles carry a large amount of chemical energy in terms of materials used in for example seating, other cabin interior and tyres. Most of the chemical energy in an average sized passenger car does not come from the energy storage. The total heat release for modern BEVs and ICEVs ranges between 3.3 and 10 GJ and is independent of the traction energy. (Report Section 2.2)

3. "Jet flames from BEV fires will spread fire faster than ICEV fires"

Different fuel types have different modes of fire spread. For example, liquid fuel such as diesel may spread the fire by means of leakage and pool fires, and gas pressure vessels and lithium-ion batteries may be prone to jet flames that could spread the fire.

If exposed to external heat, such as a fire, a plastic fuel tank will catch fire much faster than a Li-ion battery. (Report Section 2.3)

4. "Battery fires can't be extinguished & the drencher cannot control BEV fires"

A thermal runaway event is difficult to extinguish unless water/fire-fighting agent is injected into the battery. However, the fire will most likely not start in the battery. Activities that support fast/early fire suppression are highly encouraged, since this will hinder fire spread.

Data indicate that early activation of the deluge system will hinder fire spread by suppressing the fire and cooling ship surface and nearby vehicles. (Report Section 2.5)

5. "BEV fires burn very hot and can melt the deck below the fire"

The temperature of a fire will vary and depend on several factors such as fuel source, atmospheric pressure, adjacent temperatures, oxygen content etc. There is no data which suggests that BEV fires would be hotter than ICEV fires. (Report Section 2.4)

6. "You can get electrocuted whilst extinguishing a BEV with water"

Electric cars have extensive safety systems that will automatically break the power and isolate the battery pack when a collision or a short circuit is detected.

If the car would be submerged in water or if water by other means would get into the battery pack or electrical system and cause a short circuit, then you would need to be physically in between the positive and negative pole or in contact with both conductors at the same time to experience an electric shock, which is very unlikely. (Report Section 2.6)

7. "Hydrogen fluoride produced from BEV fires is highly toxic"

It is true that hydrogen fluoride (HF) is very toxic and that it has been detected in higher quantities in BEV fires than in ICEV fires. However, combustion gases and effluents from all types of vehicle fires are toxic.

Staying out of the smoke plume and wearing adequate personal protective equipment when dealing with burning or burnt vehicles are of great importance, independent of the energy carrier of the vehicle. (Report Section 2.7)

8. "The fire crew is not protected from BEV fires by the standard fire suits"

The health risks of HF when smoke diving was studied by the Swedish Defence Research Agency (FOI). Firefighters that were fully dressed* and equipped with breathing apparatus (BA) performed different exercises in a HF contaminated enclosure. Exposure values observed for a normal firefighting mission were within acceptable limits. (Report Section 2.8)

*Underwear trousers/sweater, thick socks, fire suit trousers, fire suit jacket, boots, balaclava/flash hood, helmet and gloves

9. "Overcharging a Li-ion battery can cause thermal runaway"

This is true on a cell and module level if no safety systems are applied. A Li-ion battery pack in a car has a Battery Management System that will prevent the cells from overcharging.

There have been reports of fires starting in a BEV "while charging". It is important to keep in mind that a fires in such situations may have multiple reasons, such as electric malfunction in the charging infrastructure, the cable or other general car fire causes. (Report Section 2.9)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 814975

More information: https://lashfire.eu/

Version: 01 (Published 2022)

LASH FIRE

References

Ahrens, M. (2020, March). *Vehicle Fires*. NFPA Research. https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osvehiclefires.pdf

AISAB. (2021, December 21). *Prehospital förmåga vid insatser med bränder i litiumjonbatterier*. https://www.youtube.com/watch?v=vaspu8f_X_w

Arvidson, M. (1997). *Large scale Ro-Ro vehicle deck fire test*. http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-4390

Arvidson, M. (2022). *Description of the development of automatic first response fire protection systems for ro-ro spaces on vehicle carriers*. https://lashfire.eu/media/2022/06/LASH-FIRE_D10.1_Description-of-the-development-of-local_application-system-solutions.pdf

Bergholm, U. (2021, May 24). *Sammanställning av bränder i elfordon och eltransportmedel år 2018-2020*. PM 2020-02136. https://www.msb.se/sv/publikationer/sammanstallning-av-brander-i-eltransportmedel-2018-2019/

Blandin, J. J., Grosjean, E., Suéry, M., Kumar, N. V. R., & Mebarki, N. (2004). Ignition resistance of various magnesium alloys. *Magnesium Technology 2004*, 235–240. https://www.scopus.com/inward/record.uri?eid=2-s2.0-2642574459&partnerID=40&md5=8fc051bb65c201437a161f51e284ff7d

Brandt, A. W., & Glansberg, K. (2020). *Charging of electric cars in parking garages*. https://risefr.no/media/publikasjoner/upload/2020/report-2020-30-charging-of-electric-cars-in-parking-garages.pdf

BRE. (2010). *Fire spread in car parks BD2552*. https://webarchive.nationalarchives.gov.uk/ukgwa/20120919204054/http:/www.communities.gov.uk/documents/planningandbuilding/pdf/1795610.pdf

Brzezinska, D., Ollesz, R., & Bryant, P. (2020). Design car fire size based on fire statistics and experimental data. *Fire and Materials*, *44*(8), 1099–1107. https://doi.org/https://doi.org/10.1002/fam.2913

Czerwinski, F. (2014). Controlling the ignition and flammability of magnesium for aerospace applications. *Corrosion Science*, *86*, 1–16. https://doi.org/https://doi.org/10.1016/j.corsci.2014.04.047

Dennerlein, K., Kiesewetter, F., Kilo, S., Jäger, T., Göen, T., Korinth, G., & Drexler, H. (2016). Dermal absorption and skin damage following hydrofluoric acid exposure in an ex vivo human skin model. *Toxicology Letters*, *248*, 25–33. https://doi.org/10.1016/j.toxlet.2016.02.015

Dennis, M. (2021, September 16). *Are We on the Brink of an Electric Vehicle Boom? Only with More Action*. World Resource Institute. https://www.wri.org/insights/what-projected-growth-electric-vehicles-adoption

Dreizin, E. L., Berman, C. H., & Vicenzi, E. P. (2000). Condensed-phase modifications in magnesium particle combustion in air. *Combustion and Flame*, *122*(1–2), 30–42. https://doi.org/10.1016/S0010-2180(00)00101-2

Drew, J., & Davies, T. (2019). *Driven To Danger: Electric Vehicle Drivers Charging Dangerously Due To Lack Of Public Infrastructure*. https://www.electricalsafetyfirst.org.uk/media-centre/press-releases/2019/05/driven-to-danger-electric-vehicle-drivers-charging-dangerously-due-to-lack-of-public-infrastructure/

Eckstein, M., & Maniscalco, P. M. (2006). Focus on Smoke Inhalation—The Most Common Cause of Acute Cyanide Poisoning. *Prehospital and Disaster Medicine*, *21*(S2), s49–s55. https://doi.org/10.1017/S1049023X00015909

Emilsson, E., Dahllöf, L., & Ljunggren Söderman, M. (2019). *Plastics in passenger cars*. https://www.ivl.se/download/18.14d7b12e16e3c5c36271082/1574935157259/C454.pdf

EPA. (2004). *Acute exposure guideline levels for selected airborn chemicals*. https://www.epa.gov/sites/default/files/2014-11/documents/tsd53.pdf

Ferrell, M. (2019, January 1). *Common EV Myths*. Undecided with Matt Ferrell. https://undecidedmf.com/episodes/2019/1/1/electric-cars-myths-vs-facts

Gehandler, J., Olofsson, A., Hynynen, J., & Temple, A. (2022). *BREND 2.0 - Fighting fires in new energy carriers on deck 2.0*. http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-59162

Isidore, C. (2018, May 17). *Are electric cars more likely to catch fire?* CNN Business. https://money.cnn.com/2018/05/17/news/companies/electric-car-fire-risk/index.html

Jonsson, A., Runefors, M., Särdqvist, S., & Nilson, F. (2016). Fire-Related Mortality in Sweden: Temporal Trends 1952 to 2013. *Fire Technology*, *52*(6), 1697–1707. https://doi.org/10.1007/s10694-015-0551-5

Lawson-Smith, P., Jansen, E. C., & Hyldegaard, O. (2011). Cyanide intoxication as part of smoke inhalation - a review on diagnosis and treatment from the emergency perspective. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *19*(1), 14. https://doi.org/10.1186/1757-7241-19-14

Long, T. R., Blum, A. F., Bress, T. J., & Cotts, B. R. T. (2013). *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results*. https://www.energy.gov/sites/prod/files/2014/02/f8/final_report_nfpa.pdf

Marková, I., Lauko, J., Makovická Osvaldová, L., Mózer, V., Svetlík, J., Monoši, M., & Orinčák, M. (2020). Fire Size of Gasoline Pool Fires. *International Journal of Environmental Research and Public Health*, *17*(2). https://doi.org/10.3390/ijerph17020411

Merseyside fire and rescue service. (2018, April). *Kings dock car park fire - protection report*. https://www.bafsa.org.uk/wp-content/uploads/bsk-pdf-manager/2018/12/Merseyside-FRS-Car-Park-Report.pdf

National Fire Data Centre. (2018). *Highway Vehicle Fires (2014-2016)*. https://www.usfa.fema.gov/downloads/pdf/statistics/v19i2.pdf

National Transportation Safety Board. (2020). *Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles*. https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf

Sun, P., Bisschop, R., Niu, H., & Huang, X. (2020). A Review of Battery Fires in Electric Vehicles. *Fire Technology*, *56*(4), 1361–1410. https://doi.org/10.1007/s10694-019-00944-3

U.S. Department of Transportation. (1998). *Heats of Combustion of High-Temperature Polymers*. https://www.fire.tc.faa.gov/pdf/tn97-8.pdf

Vanspeybroeck, R., van Hees, P., & Vandevelde, P. (1993). Combustion behaviour of fabric and polyurethane flexible foam mock-up combinations under Cone Calorimetry test conditions. *Fire and Materials*, *17*(4), 167–172. https://doi.org/https://doi.org/10.1002/fam.810170404

Willstrand, O., Bisschop, R., Temple, A., & Anderson, J. (2020). *Toxic Gases from Fire in Electric Vehicles*. http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-52000

Wingfors, H., Magnusson, R., Thors, L., & Thunell, M. (2021). *Gasformig HF vid brand i trånga utrymmen-risker för hudupptag vid insatser*. https://rib.msb.se/filer/pdf/29507.pdf

Xiong, R., Pan, Y., Shen, W., Li, H., & Sun, F. (2020). Lithium-ion battery aging mechanisms and diagnosis method for automotive applications: Recent advances and perspectives. *Renewable and Sustainable Energy Reviews*, *131*, 110048. https://doi.org/https://doi.org/10.1016/j.rser.2020.110048