Fires in electric vehicles

European Fire Safety Week 2024
November 21, 2024

4a. Webinar: Overcoming the challenges with the fire safety of BEVs in Covered Car Parks: Guidelines and Best Practices | Online 10h00 - 11h30 (CET)

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RISE Research Institutes of Sweden

*) Presenter

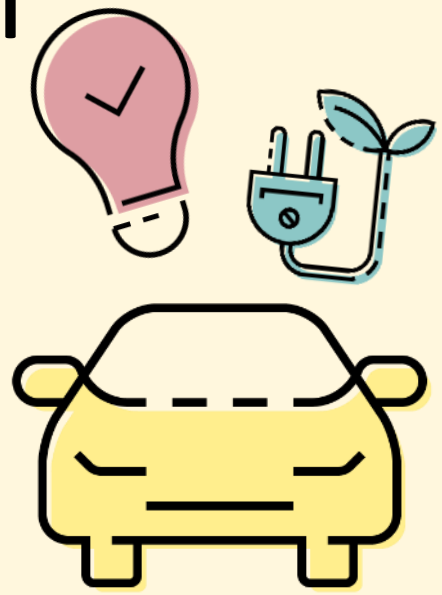
Outline

- Sources (projects) for the information.
- Frequency of fires in electric vehicles (EVs) vs. internal combustion engine vehicles (ICEVs).
- Fire load and its main contributors.
- Fire sprinkler protection of EVs vs. ICEVs.
- Smoke toxicity and environmental consequences.
- Fire protection challenges and measures.

Summary of results from several RISE led projects

- **BREND** (2017-2019)
- **E-TOX** (2019-2020)
- **BREND 2.0** (2020-2022)
- **Safe and Suitable Firefighting** (2020-2022)
- **E-TOX 2** (2021-2022)
- **ACEA: Electric Vehicle Fire Safety in Enclosed Spaces** (2022)

- **LASH FIRE** (2019-2023)
  - Manual firefighting of BEV
  - Screening and management of AFV
  - Safe BEV charging onboard
  - Early detection of BEV fire/hazard
  - Early BEV fire suppression on vehicle carriers
  - Evaluation of prescribed drencher systems on BEV



Increased knowledge on battery and EV fire safety

Frequency of EV fires

Type	Total fires	Fires per 100k vehicles
Petrol/ diesel	200 000	1 500
Battery electric	50	25

Data on car fires from the NTSB (Nov 2022), vehicle sales data from the BTS. https://www.carsmetric.com/electric-car-fire-statistics/

Why vehicle fires?

- Arson
- Engine compartment
- Overheated brakes

Fires per billion miles travelled

ACEA study

Electric Vehicle Fire Safey in Enclosed Spaces

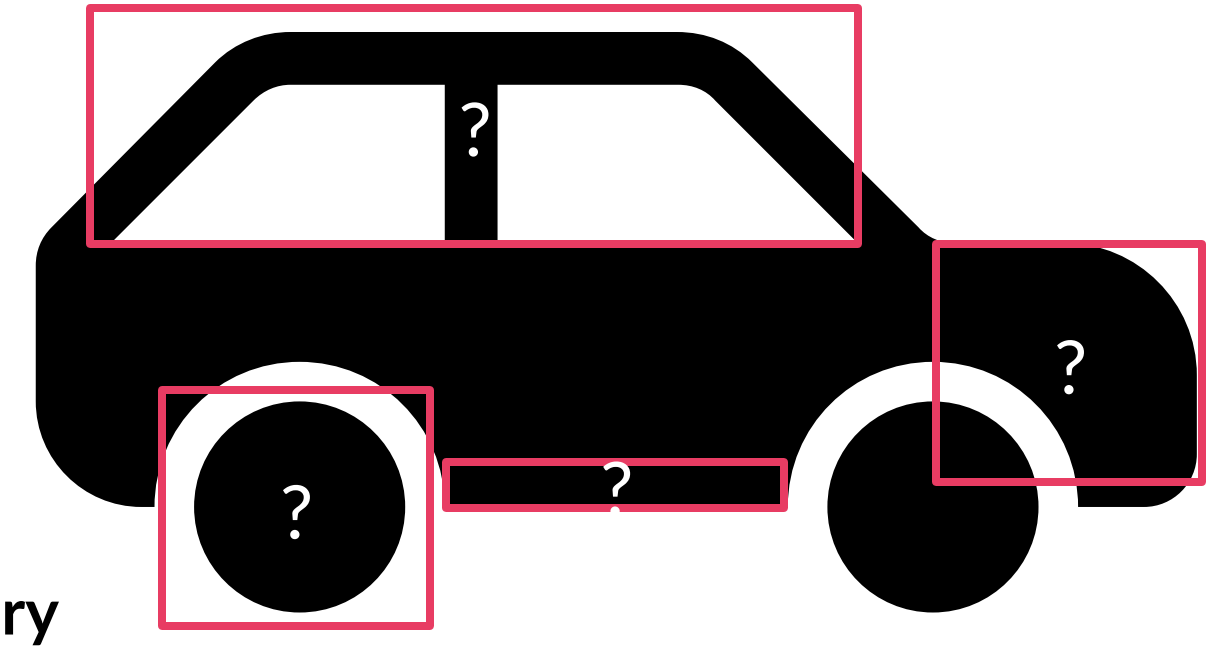
- Fire frequency in Norway:
  - EV population 2022: 17.3%
  - EV fires (2016-2022): 2.3% (slight trend decline since 2018)
  - A factor 8 less common to have a fire in an EV compared to an ICEV
- Fire frequency in Sweden: Lower relative frequency of EV fires by a factor ~10.

Project report: Electric Vehicle Fire Safety in Enclosed Spaces

Fires in Electric Vehicles

Where is the fire?

- Wheel house
- Engine compartment
- Passenger compartment
- Battery



→ **Most fires do not start in the battery**

Fire load vehicle fires

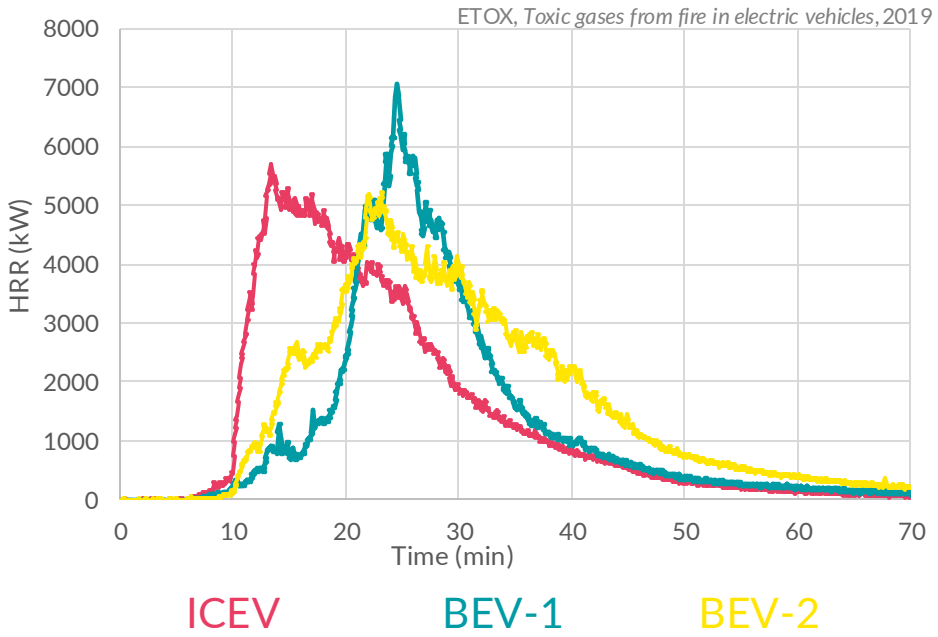
Fire growth rate

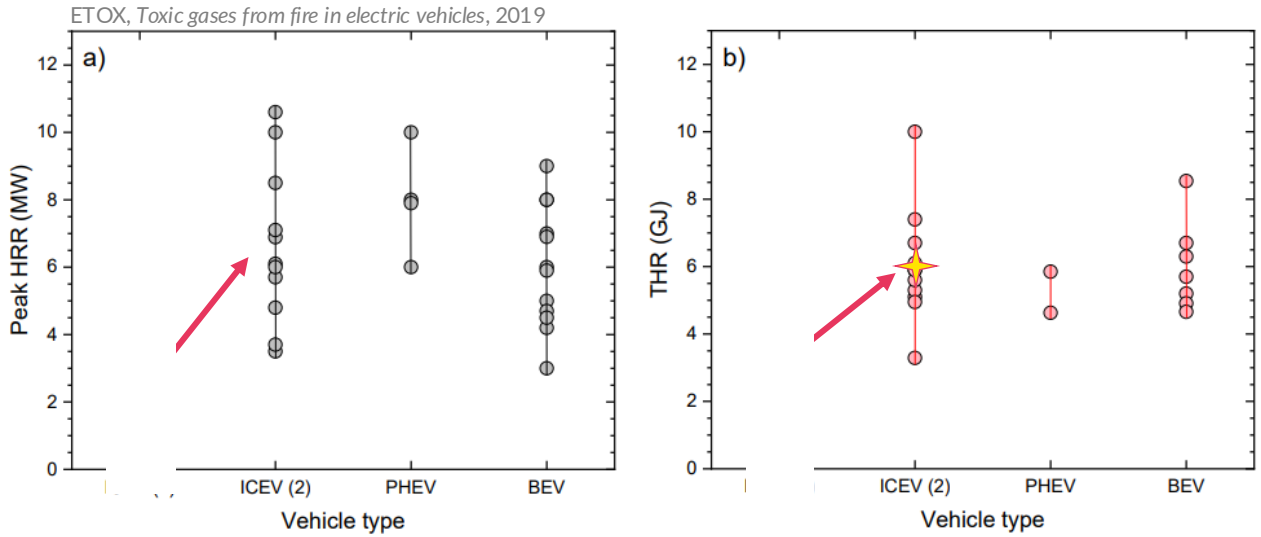
Peak heat release rate

Total energy released

Not faster or higher for battery electric vehicles

Total heat release
ICEV and BEV 3 - 10 GJ





Project report: E-TOX: [Toxic Gases from Fire in Electric Vehicles]

Modern vehicles

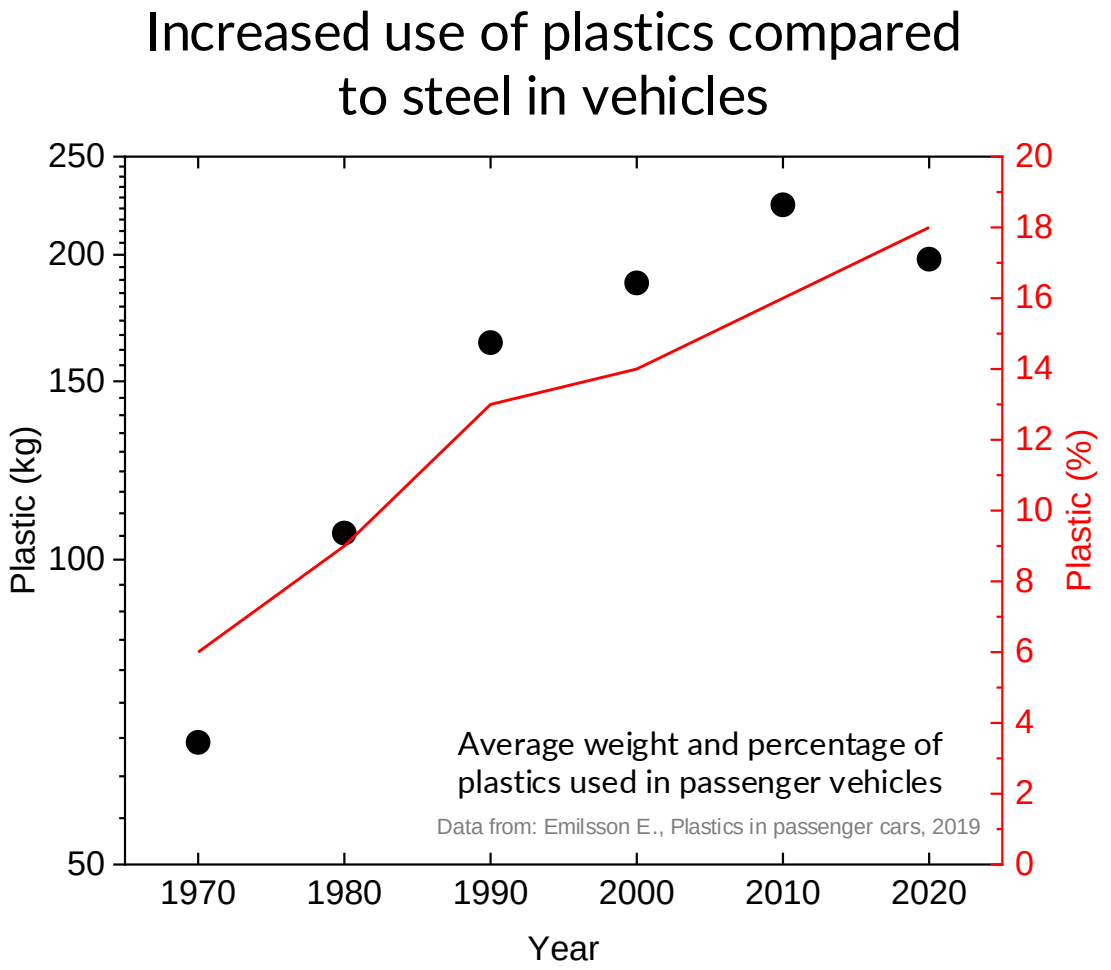
Plastics in cars
~ 3 - 7 GJ

45 kWh battery
~ 1 GJ

30 L petrol
~ 1 GJ

New materials and increased size and width

Photo: C. Meraner (RISE Norway)



Project reports:
E-TOX: Toxic Gases from Fire in Electric Vehicles
E-TOX 2: Investigation of extinguishing water and combustion gases from vehicle fires

Fire spread

Exterior plastic components can be ignited by an irradiance level of 20 kW/m^2 in 7.5 minutes, whereas it takes less than one minute with an irradiance level of 30 kW/m^2 . The ignition of tires takes longer time (18 and 10 min respectively). Wind conditions and distances between cars will influence the time to ignition.

References: Fire spread in car parks, BRE, 2010

Photo: C. Meraner (RISE Norway)

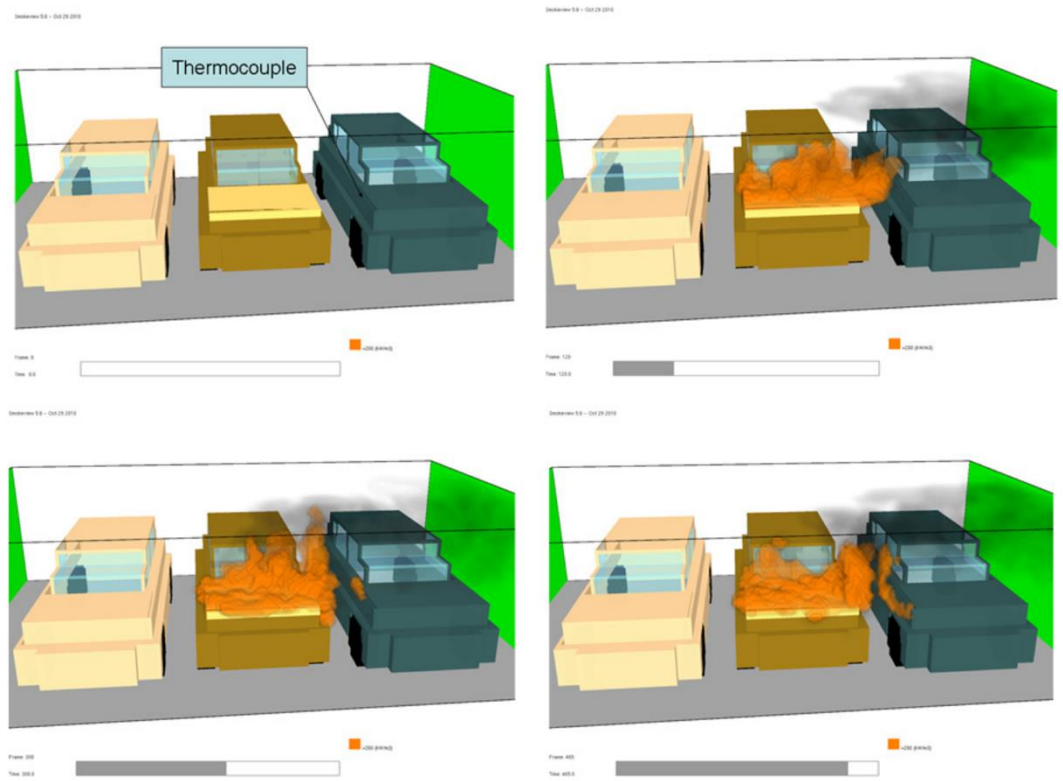


Figure 19. Simulation of near-standing automobile ignition: the case of 45 cm distance between automobiles and 2 m.s^{-1} air flow velocity in the 0th, 120th, 300th and 465th s of fire

	0 m.s^{-1}	0.5 m.s^{-1}	1 m.s^{-1}	2 m.s^{-1}	3 m.s^{-1}
15 cm	304 s	251 s	185 s	137 s	107 s
30 cm	384 s	327 s	254 s	193 s	167 s
45 cm	494 s	441 s	348 s	288 s	268 s
60 cm	-	-	474 s	407 s	389 s
75 cm	-	-	-	575 s	-

Table 1. Time of the third automobile ignition for different distance and air flow velocity values

Halada L. et al., Advances in Modeling of Fluid Dynamics, chapter 9, 2012

Can BEV fires be extinguished?

An initiated thermal runaway **CANNOT** be extinguished from the outside. Stopping the thermal runaway requires cooling - very ineffective from outside the battery.

Propagation to undamaged cells **CAN** be hindered/slowed down, if sufficient cooling is provided – but this is difficult with current vehicle/battery designs.

Important to prevent fire spread between vehicles to reduce the risk of severe consequences.

Fire sprinkler system tests

- Comparison of the fire suppression performance of sprinkler systems in large-scale fire tests with BEVs and ICEVs.
- Four tests: Two + two geometrically similar vehicles of both types.
- Fire started in either fuel spill or in battery pack.

Work by: Magnus Arvidson & Örjan Westlund
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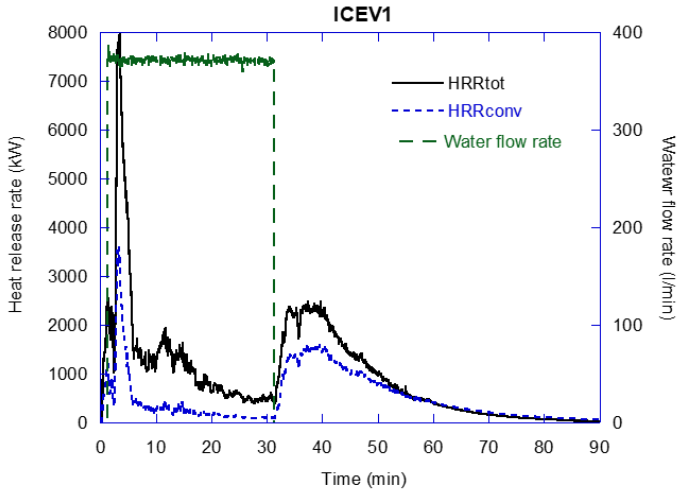
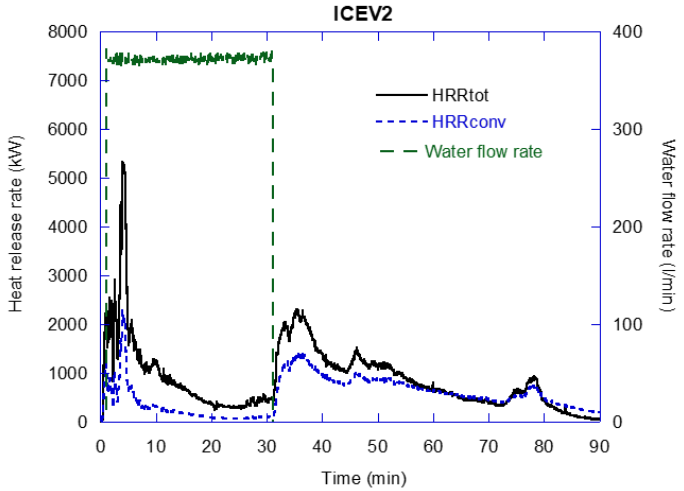
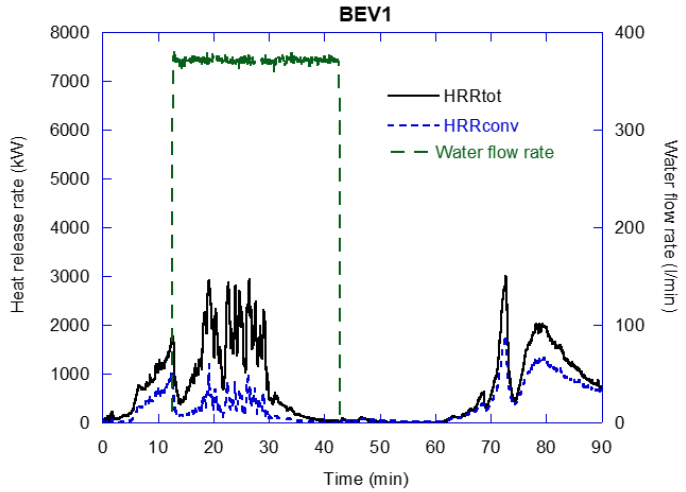
Results

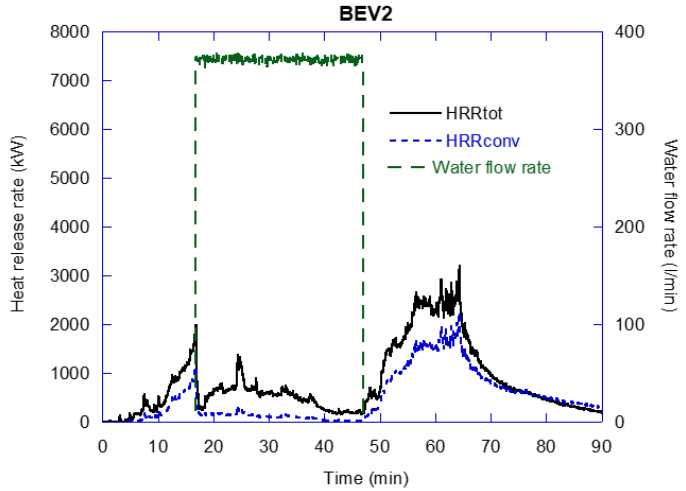
Arvidson, M., Westlund, Ö. *Water Spray Fire Suppression Tests Comparing Gasoline-Fuelled and Battery Electric Vehicles*. Fire Technol 59, 3391–3414 (2023).

ICEV2: The fire size at the most intense stage at about 04:00 min





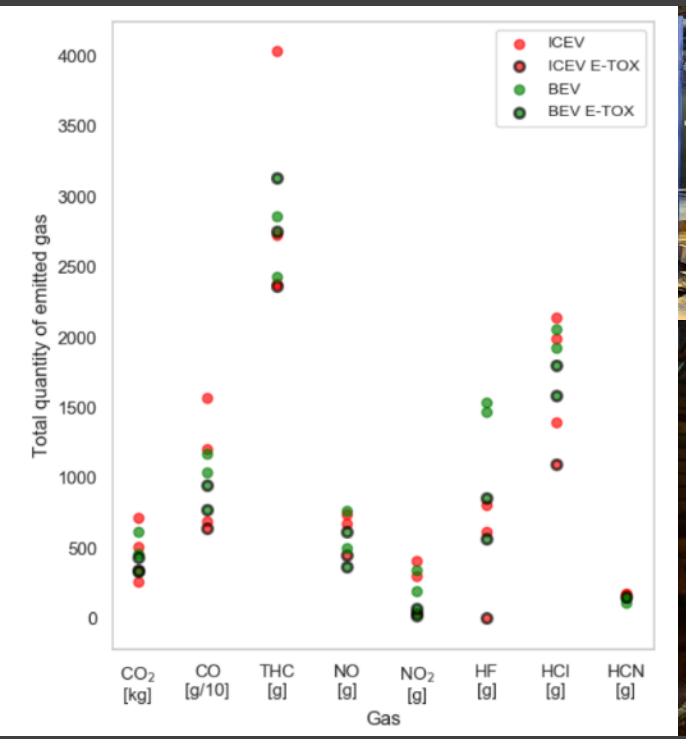




BEV2: The fire size at the most intense stage at about 24:40 (min:s)

Sprinkler setup: Four nozzles, spacing 3.05 m by 3.05 m with a water discharge density of 10 mm/min (total: 372 L/min)

Smoke toxicity



FOI & MSB, *Gasformig HF vid brand i trånga utrymmen – risker för hudupptag vid insatser* 2021

E-TOX 2019-2020
E-TOX 2 2021-2022

- There are several acute toxic gases released from both BEV and ICEV fires: CO, HCN, HCl, HF, SO_2, NOx.
- HF represents the largest difference between EVs and ICEVs and, unlike other irritating gases, HF also has a systemic toxic effect and can be absorbed through the skin.
- Sprinklers had a large effect on HF concentration in smoke – HF “washed out”, but greater mixing of gases.

Project reports: E-TOX: Toxic Gases from Fire in Electric Vehicles
E-TOX 2: Investigation of extinguishing water and combustion gases from vehicle fires

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Environmental consequences

- Combustion gases are toxic.
- Personal Protective Equipment (PPE) should be worn when dealing with battery fires: EN 469:2020 level 2 and breathing apparatus.
- Water run-off should be collected, especially if in a sensitive area. This is valid irrespective of the type of vehicle.

Photo: Göteborgs Posten, Läsarbild (Fire in a container with batteries, Sisjön Gothenburg)

Summary

- BEV fires are not more common nor more intense than ICEV fires. Fire duration is in the order of 60 – 90 minutes.
- Increased use of plastics in modern vehicles contributes to higher fire loads.
- Modern vehicles are larger and wider which increase fire load and probability for fire spread.
- Complete fire extinguishment of a battery pack fire may be difficult. Potential for fire re-ignition.
- A fire in a BEV is no more challenging for a sprinkler system than a fire in an ICEV.
- All fire effluents are toxic and environmental concerns independent of the type of vehicle.

Traditional fuels are potentially dangerous
- we have learned to handle them safely

Li-ion batteries are relatively new
Imply other hazards – we are still learning!

Fire protection challenges

General issues

- Large interconnected multi-floor (often) spaces, above- or underground.
- Typically, low ceiling heights.
- Vehicles closely parked – overall high fire load and high probability for fast fire spread.
- Accessibility problems for fire fighters.

Issues specifically related with BEV

- Final fire extinguishment may take longer time (if battery pack involved in fire).
- Fire re-ignition may occur after several hours or even days.

Fire protection measures

All common measures are valid

- Passive fire protection (to limit the spread and consequences of fire).
- Fire detection systems (to provide an early alarm).
- Smoke and heat ventilation (to help accessing the fire).
- Fire sprinkler systems (to control a fire and prevent it from spreading).
- Means for manual fire fighting (as standpipe systems to provide reliable water for the manual suppression of fire).

Measures to address new issues

- Wider parking lots (to delay fire spread).
- Personal Protective Equipment that withstands HF.
- Emergency fire fighting equipment to fight fires inside battery packs.
- Collection of water run-off to reduce the environmental impact.

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Thank you for your attention!

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