SWEDISH CLUB WEBINAR

# Fire safety with electric vehicles onboard - Should we be worried?

Franz Evegren, Magnus Arvidson
RISE Research Institutes of Sweden
2023-04-26


RI.
SE
We are Sweden’s
research institute

# Research Institutes of Sweden

- Non-profit, 3 000 employees
- Department of Fire and Safety
- Test facilities in Sweden and Norway

# New facilities for battery testing

## Gothenburg 2023:
## Heavy and light vehicles

Electric powertrain
Full scale vehicles

## Nykvarn 2023:
## Heavy vehicles

Electric powertrain
Hybrid transmission

## Borås 2023:
## Safety tests

Abuse cycling and cycling while Climate, Vibration, Mechanical, and Fire abuse testing




**SEEL**

SEEL Swedish Electric Transport Laboratory, är en del av RISE – Research Institutes of Sweden och Chalmers University of Technology.

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Felicity Ace Fire is Out But Why Do Car Carriers Have So Much Trouble?
There have been eight major incidents since 2002, half of them capsizings.
BY MARK VAUGHN
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START SPORT NÖJE PLUS TV TIPSA KULTUR LEDARE
Schibsted
Tesla
Brand hos Tesla – sju bilar i lågor
Av: Hans Österman
NYHETER
Branden på Teslas parkering började strax efter 01 under natten mot tisdagen.
Sju bilar på en yta av mer än 300 kvadratmeter stod i lågor när räddningstjänsten kom fram.
Polisen undersöker nu om gärningsmännen kan ha fastnat på
SERVICE
NBC NEWS
POLITICS U.S. NEWS WORLD CULTURE AND TRENDS HEALTH BUSINESS TECH NBC NEWS TIPLINE
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Tesla car battery 'spontaneously' catches fire on California freeway, requiring 6,000 gallons of water to put it out
No injuries were reported. Tesla CEO Elon Musk has previously stated only 0.01% of Teslas have ever caught fire.
BURNING EVS
ELECTRIC CARS HAVE ONE PROBLEM: THEY KEEP LIGHTING PEOPLE'S HOUSES ON FIRE
"IF WE HAD LIVED UPSTAIRS IN THIS HOUSE, WE'D BE DEAD."

# 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 presc. drencher on BEV

**Increased knowledge in BEV fire safety**

LASH FIRE

challenges:
accepted

LASH FIRE Coordinator RISE

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

**Lash** [laʃ]

***verb*** strike forcefully against

bind down, secure, control

***noun*** …

www.lashfire.eu

| | |
|---|---|
| **Programme:** H2020-MG-2018-2-2 | **Duration:** Sept 2019 - Aug 2023 |
| **Call topic:** Marine Accident Response, Subtopic C | **Total Budget:** 13.5 M€ |
| **Coordinator:** RISE Research Institutes of Sweden | **Instrument:** Innovation Action (IA) |

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

2023-04-26

# Strategic objective

"To provide a **recognized technical basis** for the revision of international **IMO regulations**, which greatly **enhances fire prevention** and **ensures independent management of fires** on ro-ro ships in current and **future** fire safety challenges."

# 20 challenges addressed

LASH FIRE Coordinator RISE

| WP06 | Effective Manual Operations | Cur | Fut | Reg.i | TRL | Validation |
|---|---|---|---|---|---|---|
| 6-A | Manual screening of cargo fire hazards and effective fire patrols | C | F | R | 6-7 | Onboard/Terminal |
| 6-B | Quick manual fire confirmation and localization | C | F | | 6-7 | Onboard |
| 6-C | Efficient first response | C | | | 6 | Onboard |
| 6-D | Effective and efficient manual firefighting | C | F | | 6 | Onboard/Field |
| **WP07** | **Inherently Safe Design** | **Cur** | **Fut** | **Reg.i** | **TRL** | **Validation** |
| 7-A | Improved fire detection system interface design | C | | R | 5-6 | Onboard/Virtual |
| 7-B | Efficient extinguishing system activation and inherently safe design | C | | R | 6 | Onboard |
| 7-C | Firefighting resource management centre | C | F | | 6 | Onboard/Virtual |
| **WP08** | **Ignition Prevention** | **Cur** | **Fut** | **Reg.i** | **TRL** | **Validation** |
| 8-A | Automatic screening and management of cargo fire hazards | C | F | | 5 | Onboard/Shore |
| 8-B | Guidelines and solutions for safe electrical connections | C | F | R | 6-7 | Onboard |
| 8-C | Fire requirements for new ro-ro space materials | C | F | R | 6-7 | Lab |
| **WP09** | **Detection** | **Cur** | **Fut** | **Reg.i** | **TRL** | **Validation** |
| 9-A | Detection on weather deck | C | | R | 6-7 | Onboard |
| 9-B | Detection in closed and open ro-ro spaces | C | | R | 7 | Onboard |
| 9-C | Technologies for visual fire confirmation and localization | C | | | 6-7 | Onboard |
| **WP10** | **Extinguishment** | **Cur** | **Fut** | **Reg.i** | **TRL** | **Validation** |
| 10-A | Automatic first response fire protection systems | C | F | | 5 | Lab |
| 10-B | Weather deck fixed fire-extinguishing systems | C | | R | 6 | Onboard |
| 10-C | Updated performance of alternative fixed fire-fighting systems | C | | R | 6 | Lab |
| **WP11** | **Containment** | **Cur** | **Fut** | **Reg.i** | **TRL** | **Validation** |
| 11-A | Division of ro-ro spaces | C | | | 5 | Lab/Onboard |
| 11-B | Ensuring safe evacuation | C | | R | 6 | Virtual/Shipyard |
| 11-C | Safe design with ro-ro space openings | C | | R | 6 | Virtual/Lab |
| 11-D | Ro-ro space ventilation and smoke extraction | C | | R | 5-6 | Lab/Onboard |

# LASH FIRE consortium

LASH FIRE Coordinator RI.SE

CIMNE

INTERFERRY Representing the Ferry Industry World-Wide

FLOW SHIP DESIGN

University of Cyprus

UNIFIRE

FIFI4MARINE

SEA Europe Shipyards' & Maritime Equipment Association

VTT

Fike

DFDS

RS2N

Stena

Wallenius Wilhelmsen Ocean

RI.SE

NTNU Knowledge for a better world

AP SENSING advanced photonic

Marioff United Technologies

magellan European Affairs Consultancy

CMT Center of Maritime Technologies gGmbH

BUREAU VERITAS 1828

UNIVERSITÉ DE LORRAINE

SICK Sensor Intelligence.

NTNU Social Research

# What are the greatest BEV fire hazards on ships?

”BEV fires are **more frequent**”

”BEV fires are **more intense**”

”BEV fires **cannot be extinguished**”

”BEV fires are **not controlled by fixed systems**”

”**Jet-flames** will increase the fire spread from BEV”

”You risk **electrocution** when fighting BEV fires”

”BEV pose a higher **re-ignition potential**”

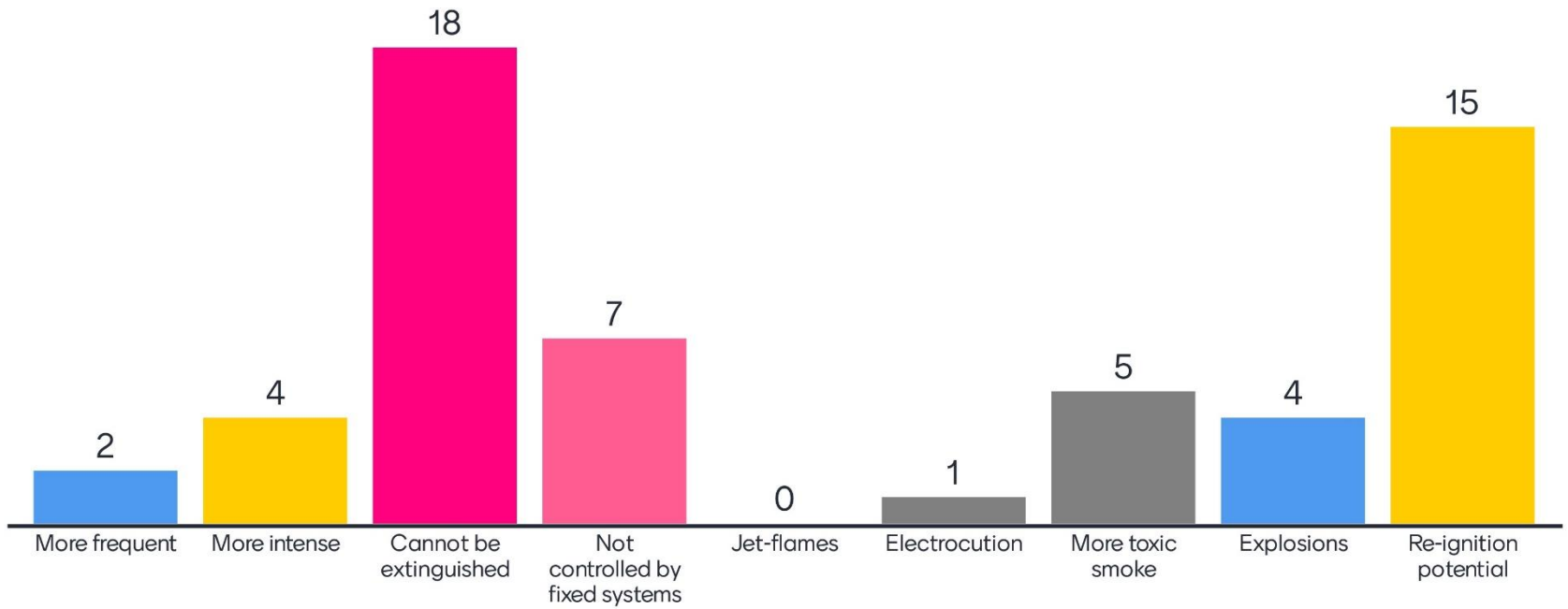
”BEV fires have **more toxic smoke**”

”BEV can cause gas **explosions**”

Go to www.menti.com

Use code: 5283 5398

# What is the greatest BEV fire hazard on ships?



# BEV fire frequency

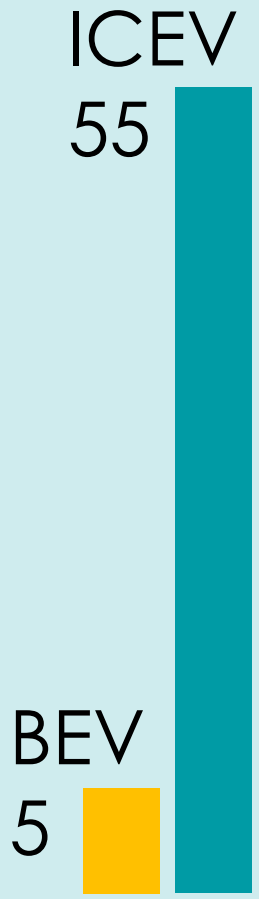
| Type | Total fires | Fires per 100k vehicles |
|---|---|---|
| Petrol/ diesel | 200 000 | 1 500 |
| Battery electric | 50 | 25 |

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 on Electric Vehicle Fire Safey in Enclosed Spaces 2022

- Fire frequency in Norway:
  - BEV population 2020: 17.3%
  - BEV fires (2016-2022): 2.3% (slight trend decline since 2018)
  - A factor 8
- Fire frequency in Sweden: Lower relative frequency of BEV fires by a factor ~10.
- Project report:
  - Electric Vehicle Fire Safe in Enclosed Spaces

30 Ah, NCA, pouch cell

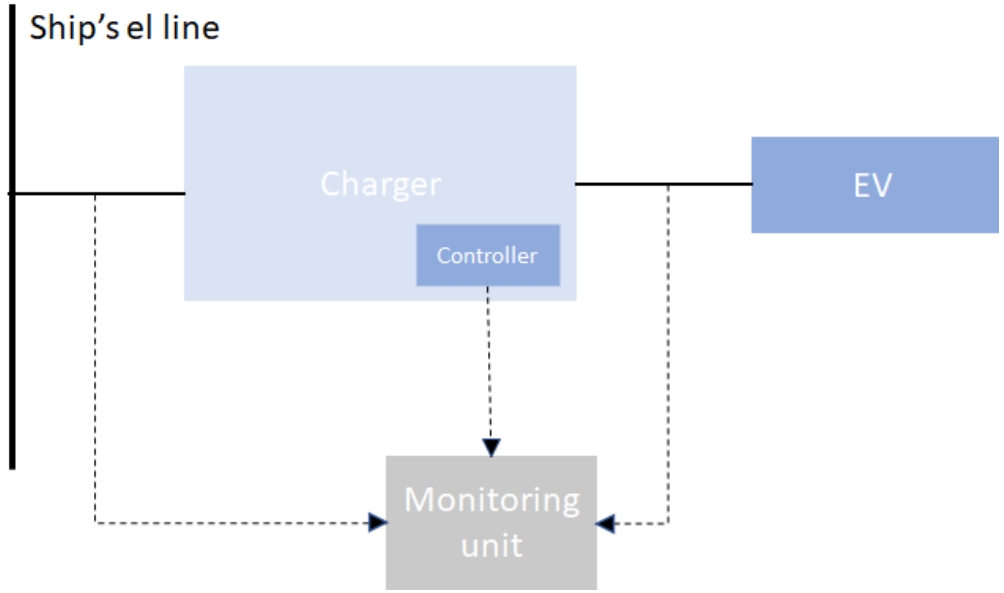
Photo:Mattijs van de Wiel - NOS

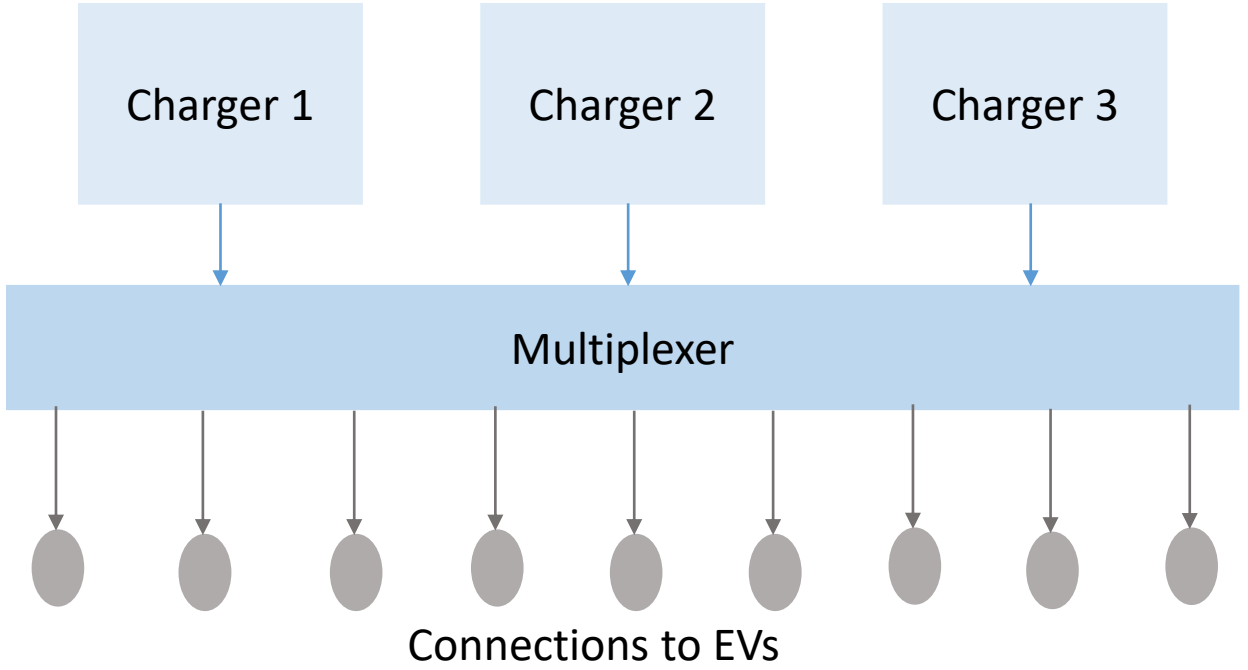
# Will charging of lithium-ion batteries increase the risk of fire?

Thermal runaway causes:

- External shortage of battery pack/cell
- Internal shortage of cell
- Overcharge/Over-discharge
- Mechanical damage
- External heating

# The LASH FIRE solution



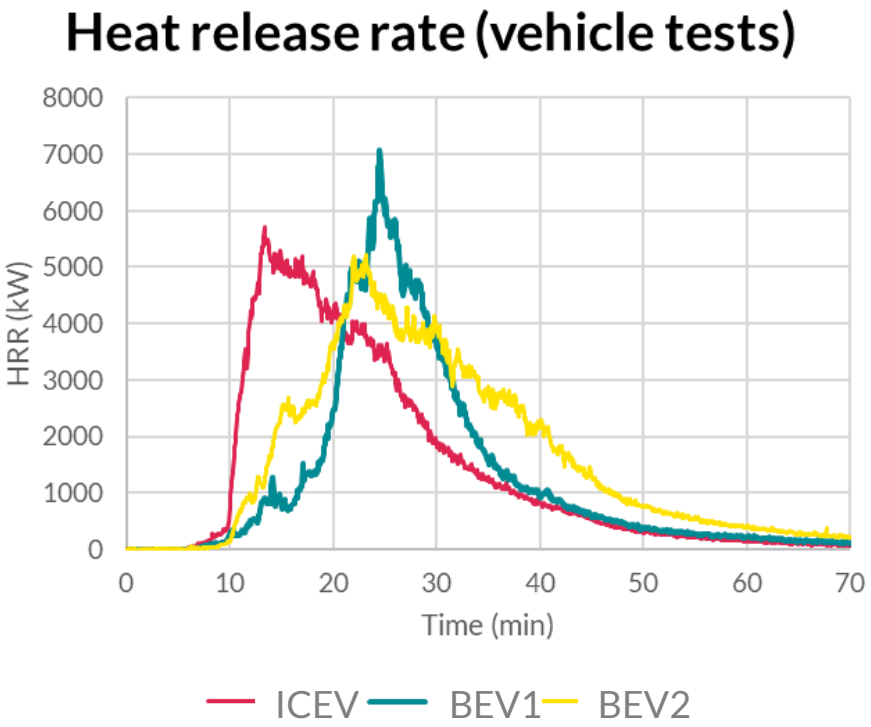




- A monitoring unit captures all measurable electrical parameters between the EV, the charging unit and the ship's main. Additional EV data from charger is a plus (Battery state of charge, charge request, etc)
- During charging, data are monitored in real time.
- Remote disconnection of individual cars is possible if needed.
- Charging solution to be at least a Mode 3 level.

Project report will be available soon at www.lashfire.eu

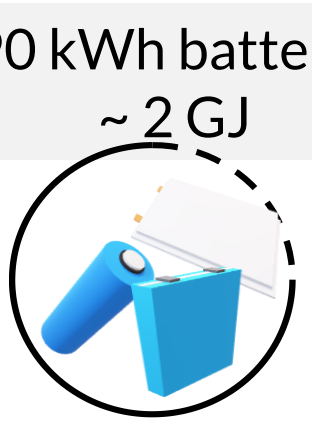
# BEV fire intensity

E-TOX




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

- Fire intensity:
  - Fire growth rate – not faster for BEV
  - Peak heat release rate – not higher for BEV
  - Total energy released – not higher BEV



- 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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# What are the greatest BEV fire hazards on ships?

”BEV fires are **more frequent**”

”BEV fires are **more intense**”

”BEV fires **cannot be extinguished**”

”BEV fires are **not controlled by fixed systems**” -> Magnus!

”**Jet-flames** will increase the fire spread from BEV”

”You risk **electrocution** when extingushing BEV fires”

”BEV fires have **more toxic smoke**”

”BEV can cause gas **explosion**”

”BEV pose a higher **re-ignition potential**”

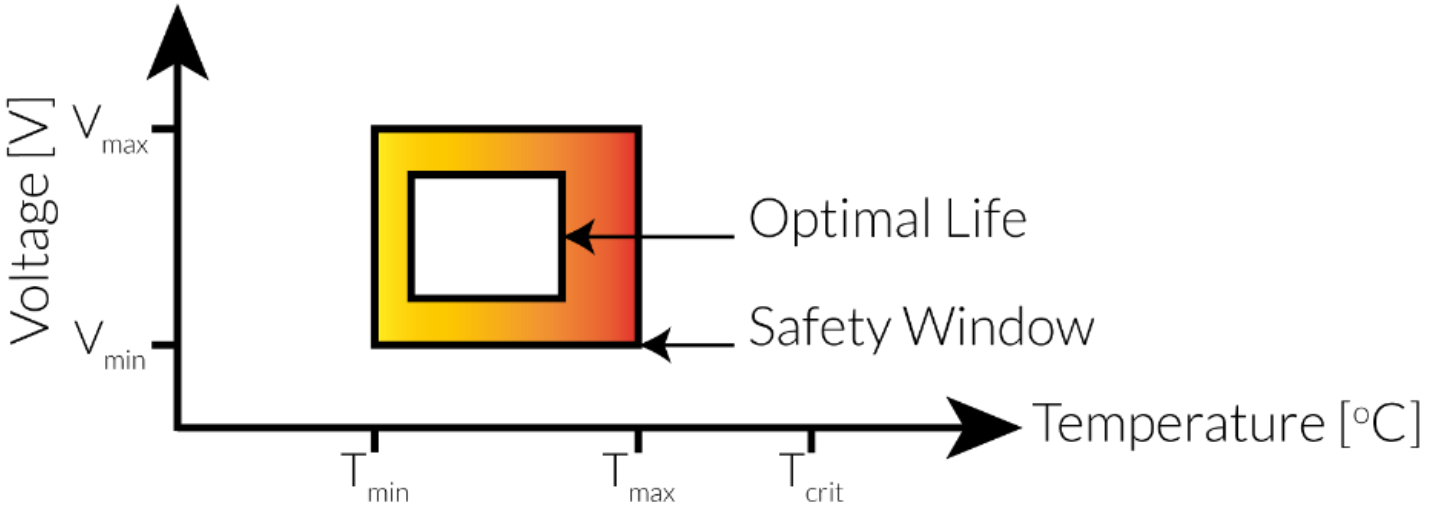
# Can fixed fire-extinguishing systems handle BEV fires?

- Drencher – YES
- High-expanding foam – YES
  - Does not affect the thermal runaway.
  - Controls the fire.
  - Some questions remain, see documentation at www.kashiwa-tech.jp
- Carbon dioxide – UNCLEAR

Photo: Joel Blom, RISE

# BEV fires cannot be extinguished

**”Thermal runaway in a vehicle should be extinguished with a massive amount of water”**




Upon cell failure, heat from chemical reactions in one cell can spred and cause chemical reactions in adjacent cells, causing an escalation referred to as Thermal Runaway. The temperature inside the battery increases rapidly as toxic and flammable gases are generated from chemical reactions in the cells. In many cases, the gases released from the ruptured cells will also ignite, causing fire.

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# BEV fires cannot be extinguished

**”Thermal runaway in a vehicle should be extinguished with a massive amount of water”**

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

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

Fog nails/extinguishing lances are **NOT** recommended for use in the engine compartment or directly in the battery



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SE

# Will jet flames increase the fire spread from BEV?

What determines the fire spread?

- Distance between objects
- Heat radiation
- Petrol vs battery

Gehandler and Lönnermark, RISE Report 2019:120 (2019)


Photo: Joel Blom, RISE

# BREND 2017-2019

**HAZARDS IN ADDITION TO EXPLOSION:**

**Liquified compressed** (LPG, DME) – jet flames will occur.

**Compressed gas** (CNG, H2) – jet flames and TPRD should not be cooled.

**Cryogenic liquid gas** (LNG) – continous venting.

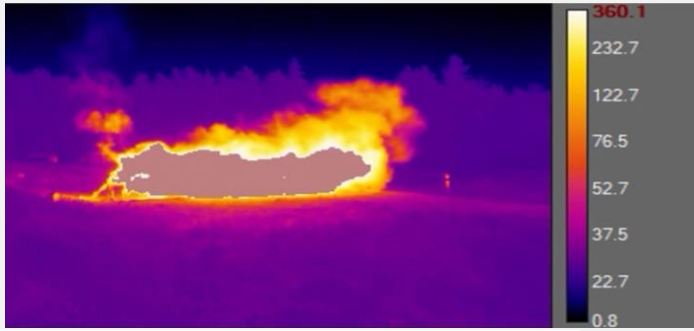
**Batteries** – manual extinguishment impossible and reignition risk.

- Strategy for firefighting of AFV in ro-ro spaces, based on literature study:
  - Activate fixed fire suppression system
  - Do not approach a burning electrical or gas vehicle - focus on cooling and hindering fire spread from a safe place.
  - Do not attempt to extinguish jet flames or other burning leakage of gases
  - Risk for explosion if TPRD of compressed gas tanks is cooled.
- Quick fire suppression and control is even more important with AFV – new tactics, methods and equipment were developed – see guideline in report!
- Project reports:
  - Methods and equipment for firefighting with AFV in ro-ro spaces
  - Firefighting of AFV in ro-ro spaces

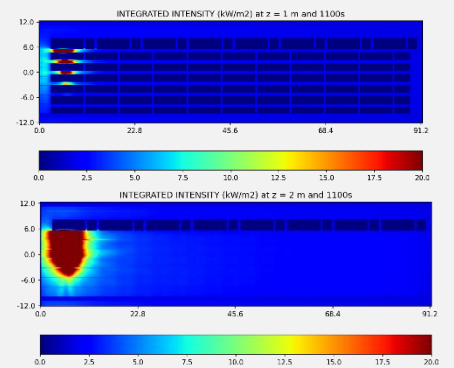
# BREND 2.0

## BREND 2.0 2020-2022

- Fires from thermal runaway generally grow slowly, with low thermal exposure close to the fire for an extended period.
- Tanks with TPRD can be cooled with water from sprinklers or manual firefighting, without great risk for pressure vessel explosion – tests showed that direct cooling rather gave a positive cooling effect and more time until rupture.
- Jet flames are good! They prevent explosion, their duration is relatively short (normally <1 min) and their incident heat flux is relatively low, compared to flames from burning objects.
- Developed tactics: Cool the burning unit and prevent spread, but do not extinguish jet flames or burning gases. Training…
- During a vehicle fire in a ro-ro space, **ventilation** is the greatest single factor determining the toxicity (HF and other gases investigated, incl. FED and FEC dose). Regardless of type of vehicle, simulations showed that toxicity limits are much exceeded in a closed ro-ro space, while values were well below toxicity limits in well ventilated spaces, except close to the ceiling. Values were only slightly lower for ICEV than for BEV. Smoke is toxic.
- Project reports:
  - Fighting fires in new energy carriers on deck 2.0
  - BREND 2.0: Fire simulation technical report





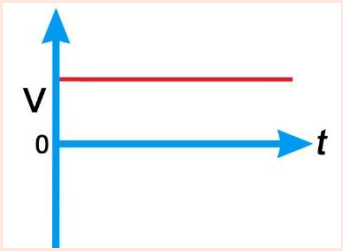
# What firefighting should you do?

- Activate fixed fire-extinguishing system without delay!
- Manual firefighting to:
  - save life,
  - as a proactive measure,
  - to complement fixed system, or
  - post-fire control.
- Most fires do not initially involve the traction battery – generally requires about 30 min of fire exposure.
- The battery is only a minor part of the fire energy – you can still:
  - Extinguish the car fire!
  - Avoid fire spread!
- Water is a good coolant for vehicle fires, also for BEV. Water washes out gases from air, reducing toxicity and risk of explosion.

# No risk of electrocution during BEV firefighting

Long, T. R. et al., *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results*; 2013. NFPA

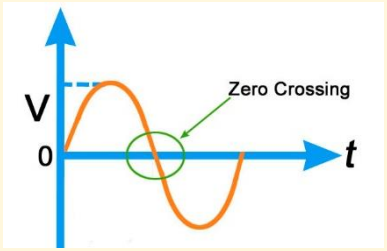

Battery: Direct Current




Current only travels between poles!

≠

Power grid: Alternating current




Current can travel to any earth!

**Cut the power before extinguishing a charging vehicle!**

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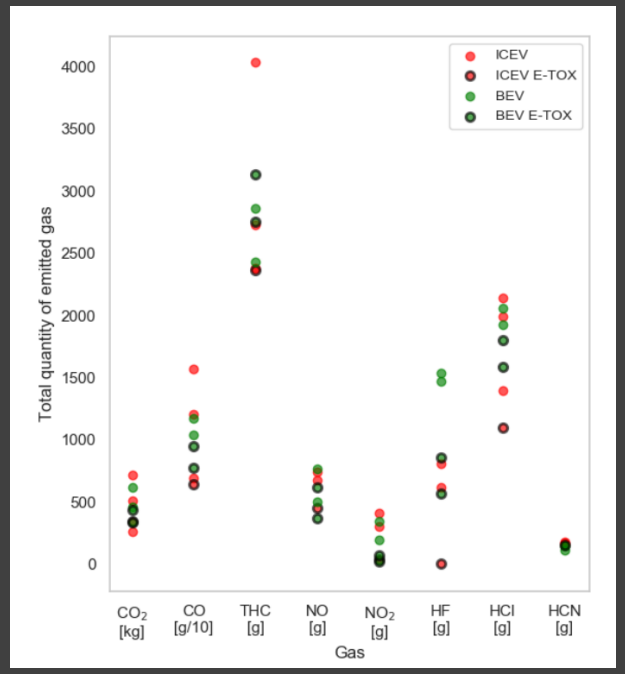
# BEV smoke toxicity




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



# E-TOX

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

- There are several acute toxic gases released from both BEV and ICEV fires: CO, HF, HCl, HCN, SO2, 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.
- Sprinkler 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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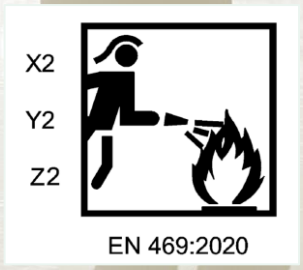
**From crew in user study:**
*”It’s totally incomprehensible to me why the clothing worn by a smoke diver ashore isn’t allowed for a smoke diver at sea. It is an obstacle for us to get hold of good equipment – especially at reasonable prices.”*

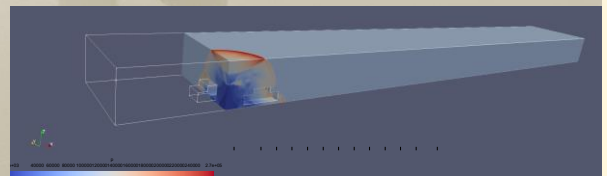
**> Firefighter’s outfit required by SOLAS**

**◀ MED/3.3b & 3.3c: Firefighter’s outfit with reflective surface**
For protection against “intense radiant heat”

**▲ MED/3.3a: ”Regular” firefighter’s outfit.**
Tested according to the same standard as land-based rescue service (EN 469). Comes in two levels, where level 2 is higher.




▲ The level is possible to identify by the pictogram included on the garment
X: Heat protection
Y: Water penetration resistance
Z: Breathability



# Safe and Suitable Firefighting 2020-2022

- State-of-the-art firefighting gear protect well, but SOLAS requirements are outdated! **EN 469:2020 level 2 should be required for firefighting onboard!**
- With EN469:2020 level 2 suits, flash hood, second layer and BA, firefighters are well protected from all vehicle fire gases, including those of Li-ion batteries such as HF.
- Further recommendations: Type 2/3 footwear, lightweight cylinders, communication device for **each** smoke diver…replace axe?
- Maximum total exposure time in a toxic smoke environment is 40 min.
- All equipment that has been used in the fire and smoke should be treated as hazardous.
- Project report:
  - Safe and Suitable Firefighting

# BEV can cause gas explosion

## Ignition vs explosion

95%

Ignition
Jet like, directional flames

5%

Vapour cloud explosion
Violent deflagration

## Vapour cloud explosion

Of total vapour cloud explosion incidents:

70%

Underground / enclosed space

30%

Open air

- Only relevant if there is no ignition, e.g. in case of a slow thermal runaway event.
- Needs further study!

Statistics from www.EVfiresafety.com, EV battery fire overview December 2022

# BEV pose a higher re-ignition potential

- BEV must be monitored after fire suppression
- Do not remove firefighting equipment
- Cooling should continue until a safe return to port
- When in port, vehicle should be moved to safe location ashore

# Summary

- BEV fires are not more common nor more intense than ICEV fires
- The fixed fire-extinguishing system should be started without delay and will suppress a BEV fire - if possible, keep it activated during manual intervention
- A thermal runaway cannot be stopped – firefighting should focus on controlling the fire and preventing fire spread, and potentially on cooling the battery.
- Fire effluents are toxic, both from ICEVs and BEVs, and should be fought with EN 469:2020 level 2 suits
- There is a higher re-ignition potential that must be handled.
- The BEV explosion risk has not been investigated.



**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!

# Check out our training videos!

LASH FIRE videos on YouTube:

https://youtube.com/playlist?list=PLi4tb8wkruNdRwLD525MQnC_zqx73-ZU6


LASH FIRE - EV Firefighting Film06 Post fire

33 visningar • för 7 dagar sedan


LASH FIRE - EV Firefighting Film05 Manual firefighting of gas vehicles

12 visningar • för 7 dagar sedan


LASH FIRE - EV Firefighting Film04 Fire Fighting Methods

23 visningar • för 7 dagar sedan


LASH FIRE - EV Firefighting Film03 First Response

8 visningar • för 7 dagar sedan


LASH FIRE - EV Firefighting Film02 Protection Suits

16 visningar • för 7 dagar sedan


LASH FIRE - EV Firefighting Film01 Introduction

76 visningar • för 7 dagar sedan


LASH FIRE - Webinar 'Fire on ro-ro deck'

293 visningar • för 2 veckor sedan


LASH FIRE - Tests on weather deck fixed fire-extinguishing systems

126 visningar • för 4 månader sedan


LASH FIRE – Interview with Calle Ortner, Safetygroups – Fire Safety Meet - DSM2022

41 visningar • för 7 månader sedan


LASH FIRE - Tests on fighting electric car fires

968 visningar • för 7 månader sedan


LASH FIRE - Tests on fighting electric vehicle fires: first response firefighting

2 506 visningar • för 7 månader sedan


LASH FIRE - Tests on fighting electric car fires: freeburn test 1

312 visningar • för 7 månader sedan

lashfire.eu

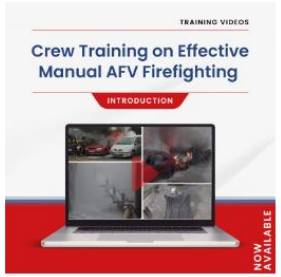
LASH FIRE

News | Project | CFIS 2023 | LASH FIRE results | Videos | For media | Contact


# Thank you for your attention!

Registration | CFIS2023 Agenda | CFIS2023 Attendee Kit

**LASH FIRE is an international research project aiming to significantly reduce the risk of fires on board ro-ro ships. The project is running from September 2019 to August 2023.**




Now available: Crew training videos on Effective Manual AFV Firefighting!

Alternative-fueled vehicles (AFV) represent different types of hazards compared with vehicles with traditional fuel such as gasoline and diesel with internal combustion engines. Do our usual methods, equipment, and training work, or do we need to do something more to be safe? Watch the LASH FIRE movies here.


LASH FIRE Webinar – Fire on a ro-ro deck!

On April 5th 2023, LASH FIRE held a appriciated webinar on "Fire on ro-ro deck". Besides presentations and discussions on prohibiting carriage of BEV and sea-water drenchers we also had the chance to discuss fire-fighting capabilities and see a LIVE demonstration of extinguishment techniques.

Watch the recorded webinar here.


Short introduction to the LASH FIRE project

For a quick overview of the project and its objective, watch our short introduction animation here. (2 minutes)

**Go to lashfire.eu!**

LASH FIRE

Funded by

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