Full scale fire tests of Battery Electric Vehicles

First results of project BRAFA

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Quelle: TU Graz / Lunghammer

Overview

- **Duration**
  - June 2019 – May 2021
- **Funding**
  - Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology
  - ASFINAG
  - Austrian Research Promotion Agency (FFG)

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

ASFINAG

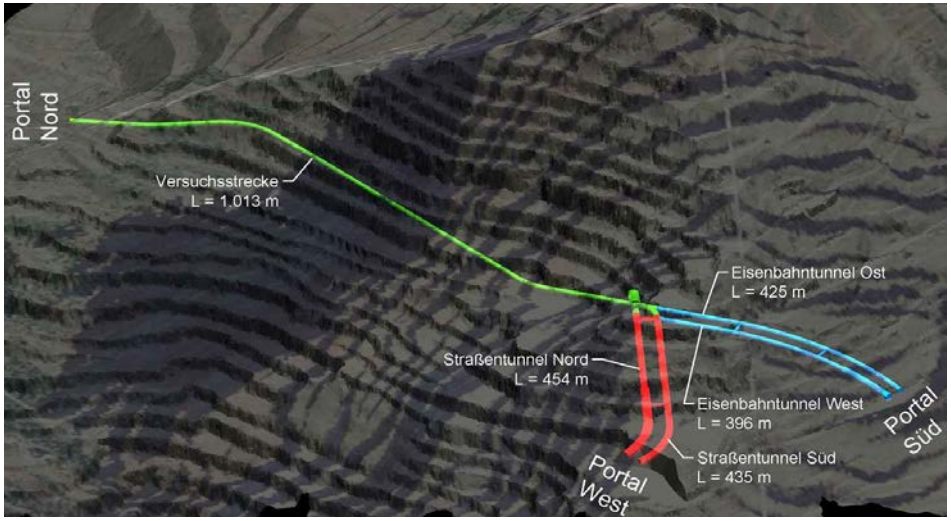
FFG
Promoting Innovation.

Objectives & Partnership

- **TU Graz | Institute of Internal Combustion Engines and Thermodynamics**
  - ➔ Lead, numerical simulations
- **TU Graz | Vehicle Safety Institute**
  - ➔ safety aspects of electric driven vehicles
- **ILF Consulting Engineers Austria GmbH**
  - ➔ risk assessment for road tunnels
- **Austrian Firebrigade Association**
  - ➔ testing of extinguishing techniques
- **MU Leoben | Chair of Subsurface Engineering**
  - ➔ provides infrastructure for experiments

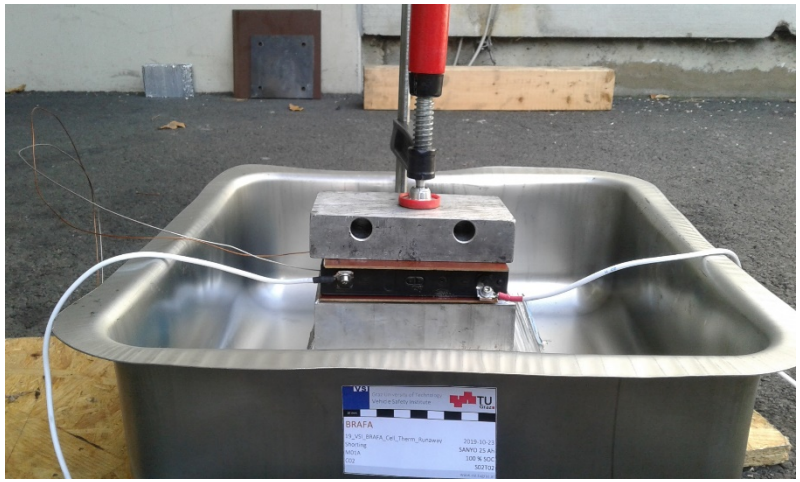
Test site „Zentrum am Berg“

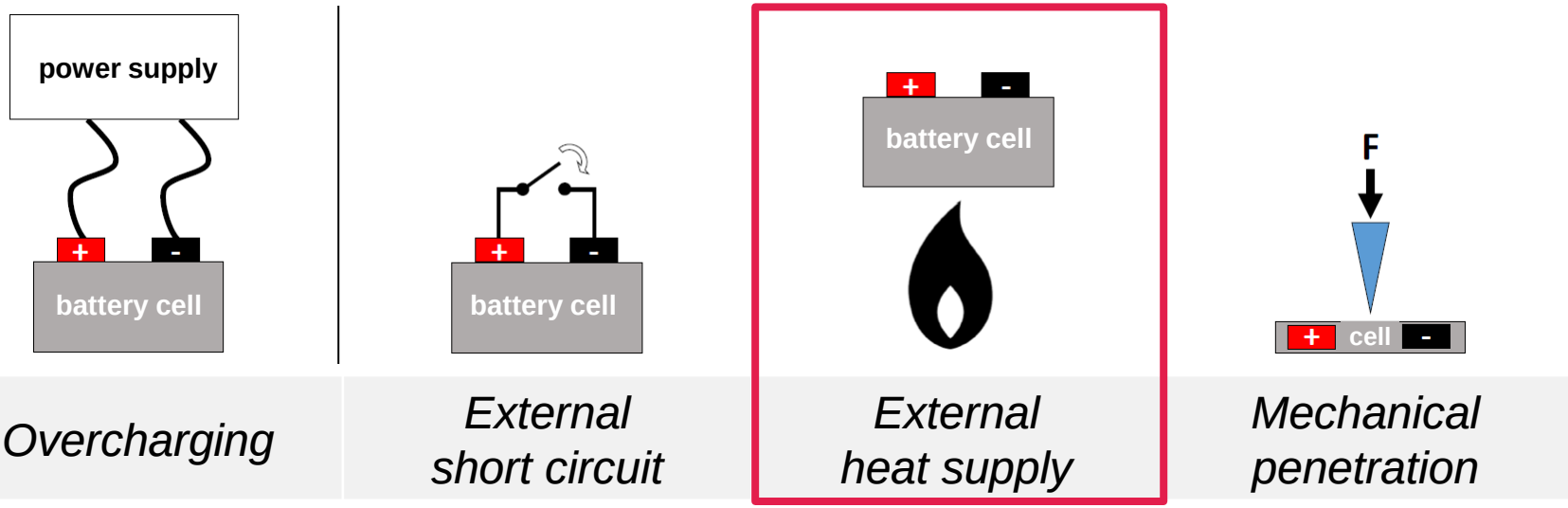
- Research facility at Erzberg (Styria, AT)
- 2 road tunnels, 2 railway tunnels
- Underground testing areas (4km)
- Managed by MU Leoben (AT)



1. Pre-study tests

- **Single battery cells**
- 4 possibilities to cause a Thermal Runaway





Overcharging	*External short circuit*	*External heat supply*	*Mechanical penetration*

2. Module tests - Setup

- **Location:** Test-tunnel
- **Air flow:** ca. 1.5 – 2.0m/s
- **Measurements:**
  - **Voltage:** cells / module
  - **Temperature:** module / environment
  - **Air:** velocity / humidity / pressure
  - **Weight loss** of modules
- **Gas emissions:**
  - **Dräger short-term tubes** => HF, HCl, HCN
  - **Filter stacks (QAT, Teflon)** => HF, HCl, H_3PO_4
  - **Gas solution absorbers** => HF, HCl, H_3PO_4
  - **Horiba Gas Analyzer** => CO, CO_2, O_2, NO_x

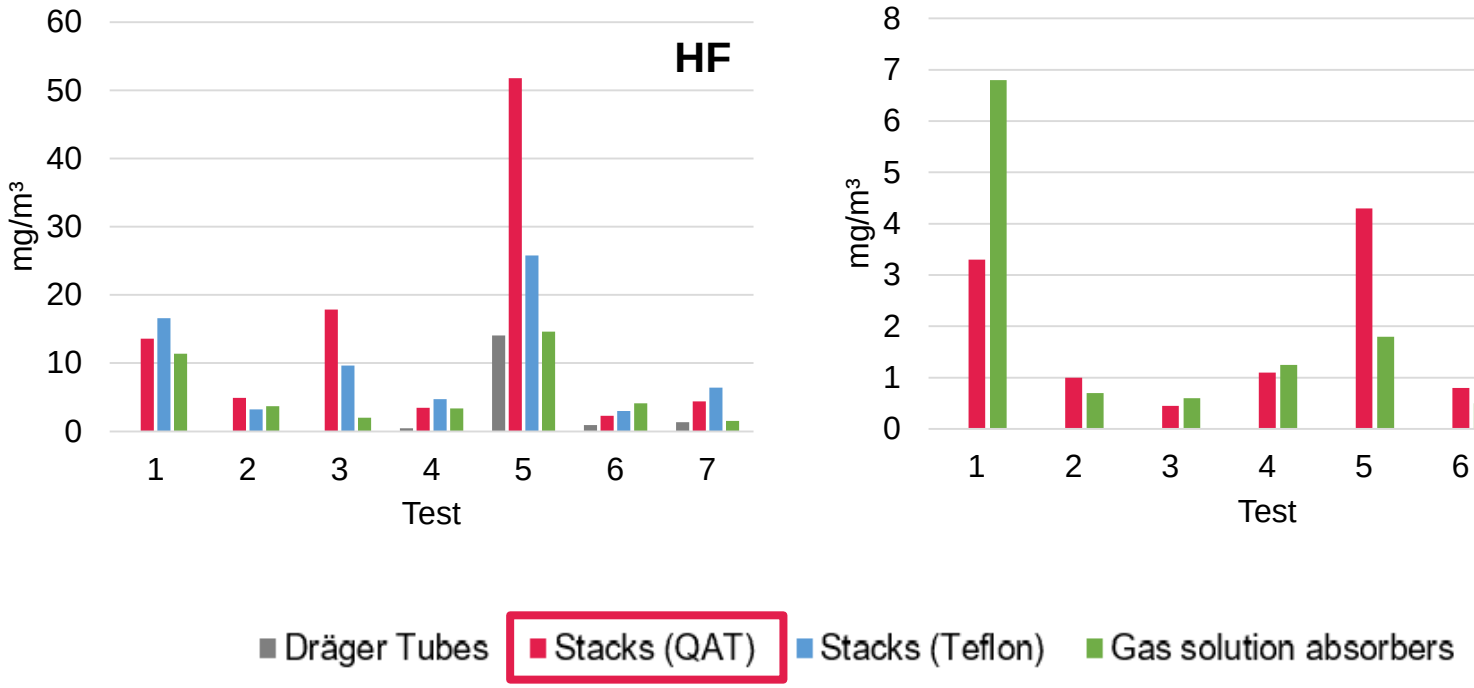
2. Module tests - Experiments

- Series of **7 module tests**
- **Li-Ion** battery types:
  - NMC = Nickel, Manganese, Cobalt
  - LFP = Lithium Iron Phosphate
- **State of Charge (SOC):** 100%

Test	Battery type (car manufacturer)	Number of modules
#1	NMC (A)	1
#2	NMC (A)	1
#3	NMC (A)	2
#4	NMC (A)	2
#5	LFP (C)	1
#6	NMC (B)	1
#7	NMC (B)	7

2. Module tests - Results

- Standardized concentration (on 1 module)
- Compared **by method**



3. Battery-pack tests - Setup

- **Location:** Full-scale tunnel
- **Air flow:** ca. 1.5 – 2.0m/s
- **Measurements:** as module tests
- **Gas emissions:**
  - Filter stacks QAT
  - Horiba Gas Analyzer
- Series of **2 battery-pack tests**

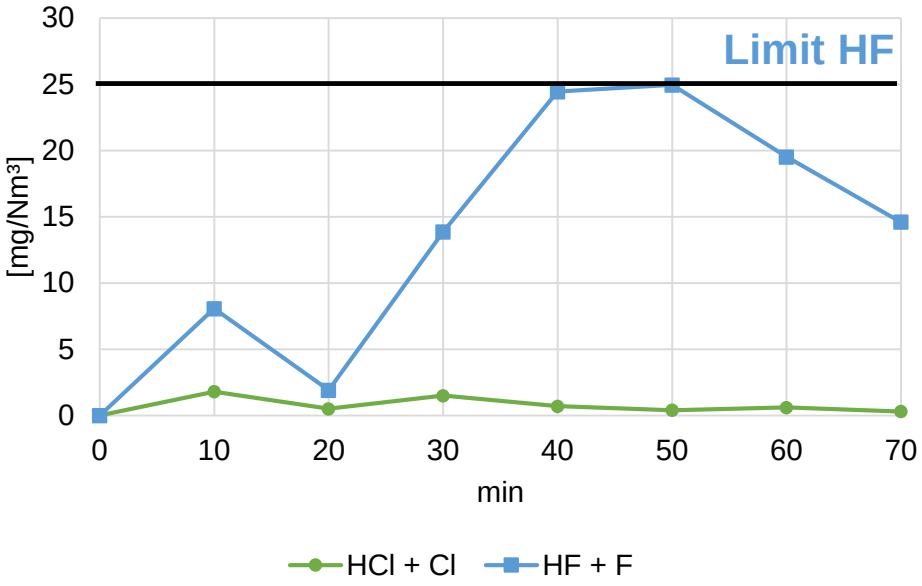
Test	Battery Type (Car manufacturer)	Number of modules	SOC
#1	LFP (C)	18	Undef.
#2	NMC (B)	27	100%

3. Battery-pack tests - Results

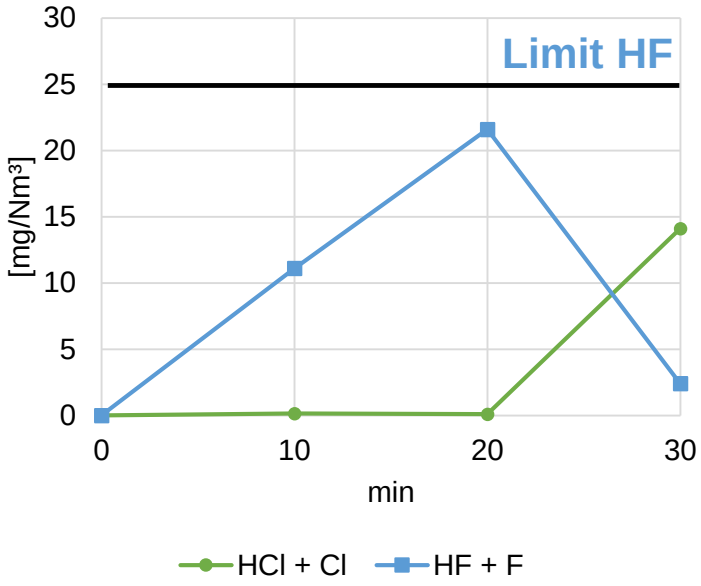
- **Acids gases**
- **Limit:** IDLH-Value

Substance	IDLH [ppm]	IDLH [mg/Nm³]
HCl	50	75
HF	30	25

#1

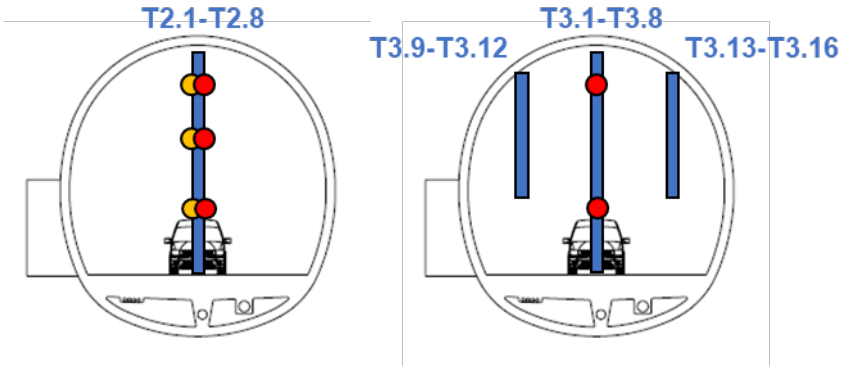


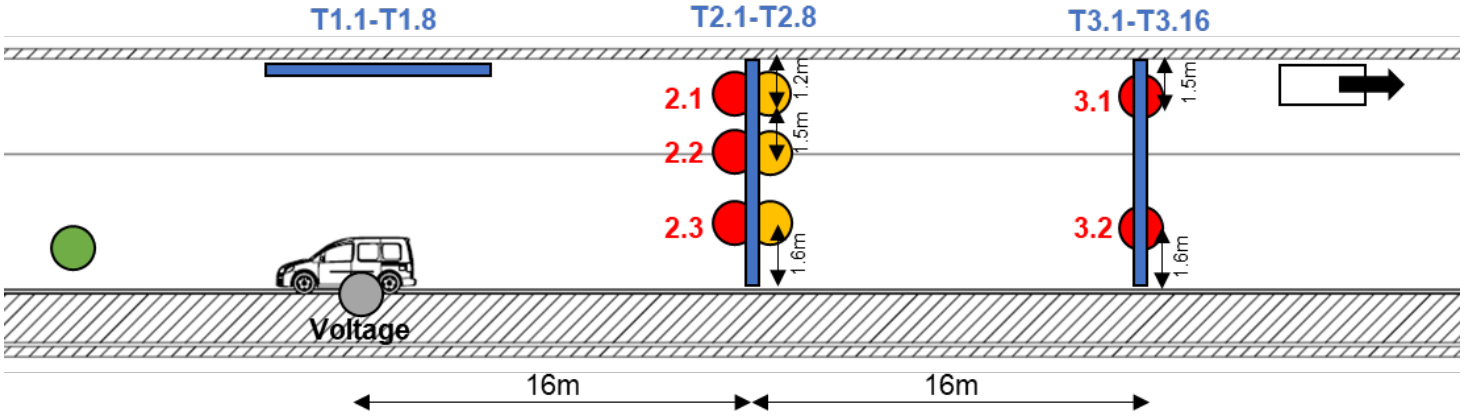
#2



4. Vehicle tests - Setup

- **Location:** Full-scale tunnel
- **Air flow:** ca. 2.0m/s
- **Measurement setup:**
  - CO measurement points
  - positions of filter stacks
  - air velocity measurement
  - set of temperature sensors





4. Vehicle tests - Experiments

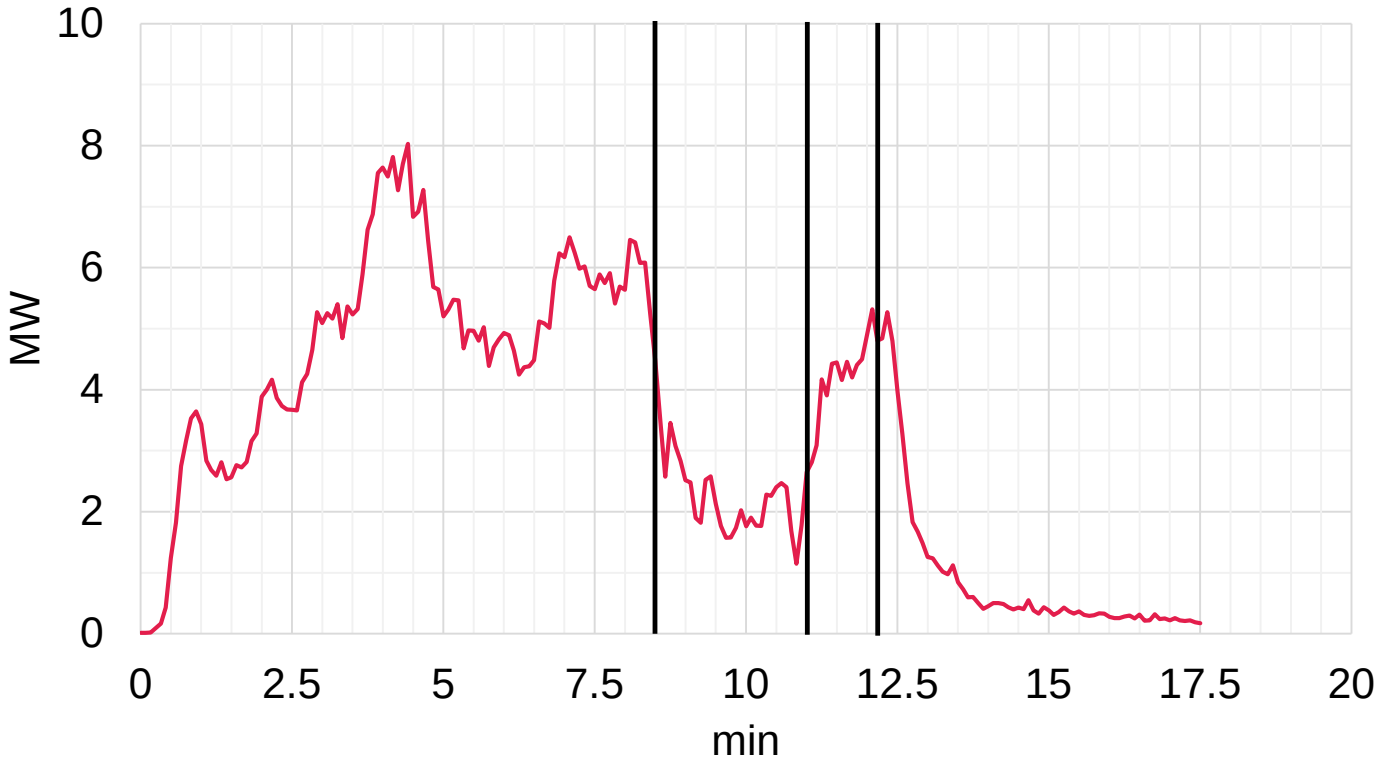
- Series of **5 vehicle tests**
- **Comparison** of
  - BEV = Battery Electric Vehicle
  - ICEV = Internal Combustion Engine Vehicle
- **Tank / SOC:** Full / 100%

Test	Car type
#1	BEV compact car
#2	BEV utility vehicle
#3	ICEV utility vehicle
#4	ICEV SUV
#5	BEV SUV

4. Vehicle tests - Results

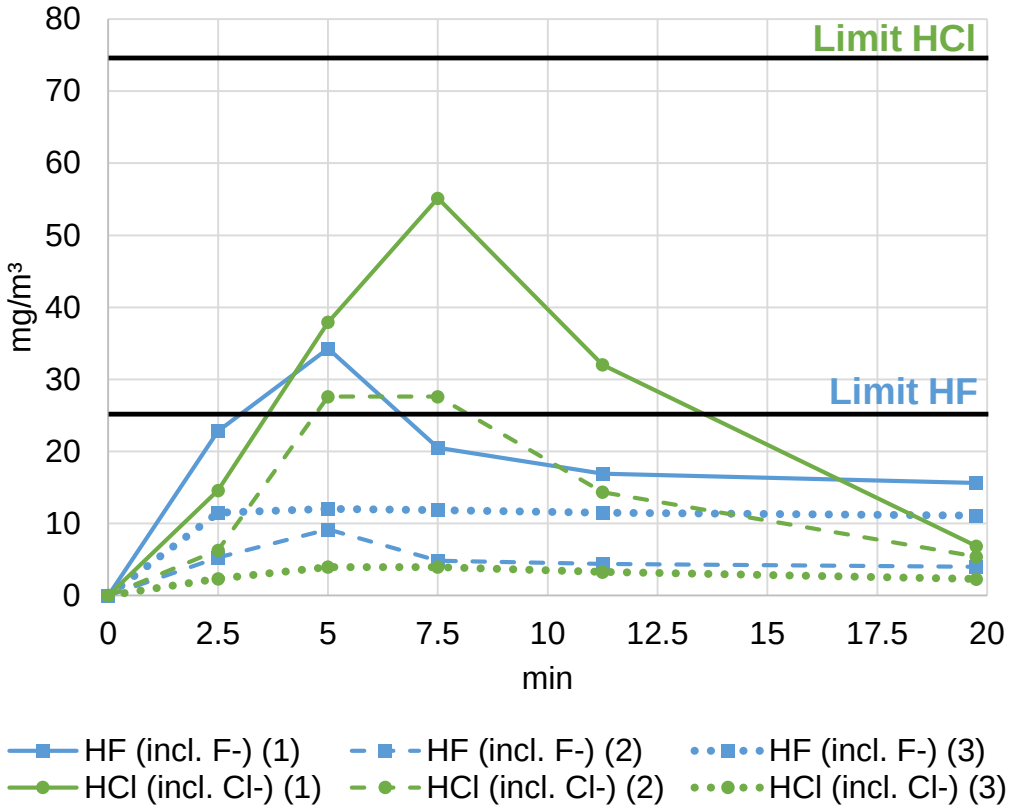
Test #1: Heat Release Rate (HRR)

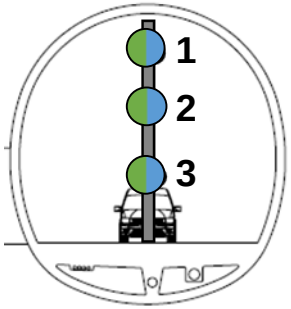
Start of interventions by fire brigade after 08:30



4. Vehicle tests - Results

Test #1: Acid gases





Total amount

	EV1 [1]	EV2 [1]	Car4 [2]	BRAFA #1
HCl [g]	2060	1930	2213	**1511**
HF [g]	1540	1470	1697	**1405**

[1] Comparison of the fire consequences of an electric vehicle and an internal combustion engine vehicle; Lecocq A.; Bertana M.; Truchot B.; Marlair G.; Proceedings from 2nd International Conference FIVE 2012
[2] An experimental evaluation of toxic gas emissions from vehicle fires; Truchot B.; Fouillen F.; Collet S.; Fire Safety Journal 2018

Extinguish Techniques

- **Extinguishing nozzle**
- **Fire blanket**

Conclusions

- Tests performed for
  - Battery packs
  - Vehicles (3 BEV, 2 ICEV)
- Comparison of BEV:
  - **HRR:** average HRR as ICEV, peak HRR higher
  - **Acid gases**: absolute values of HCl, HF similar to literature
- Detailed data processing still ongoing

Next steps

- **Evaluation of all measurement data**
- **Consequences, Risk Assessment**
- **Numerical simulations:**
  - 3D-CFD Software CONVERGE
  - Upscaling: 100kWh => 400kWh

Quelle: https://ecomento.de

Quelle: https://www.formtrends.com

Quelle: https://cleantechnica.com

Acknowledgements

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Thank you for your attention

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