NEW ENERGY CARRIERS IN ROAD TUNNELS

2021 WEBINAR – ITA-COSUF, PIARC, KPT

CONSEQUENCES OF BATTERY ELECTRIC VEHICLE FIRES IN TUNNELS – A QUANTITATIVE ASSESSMENT

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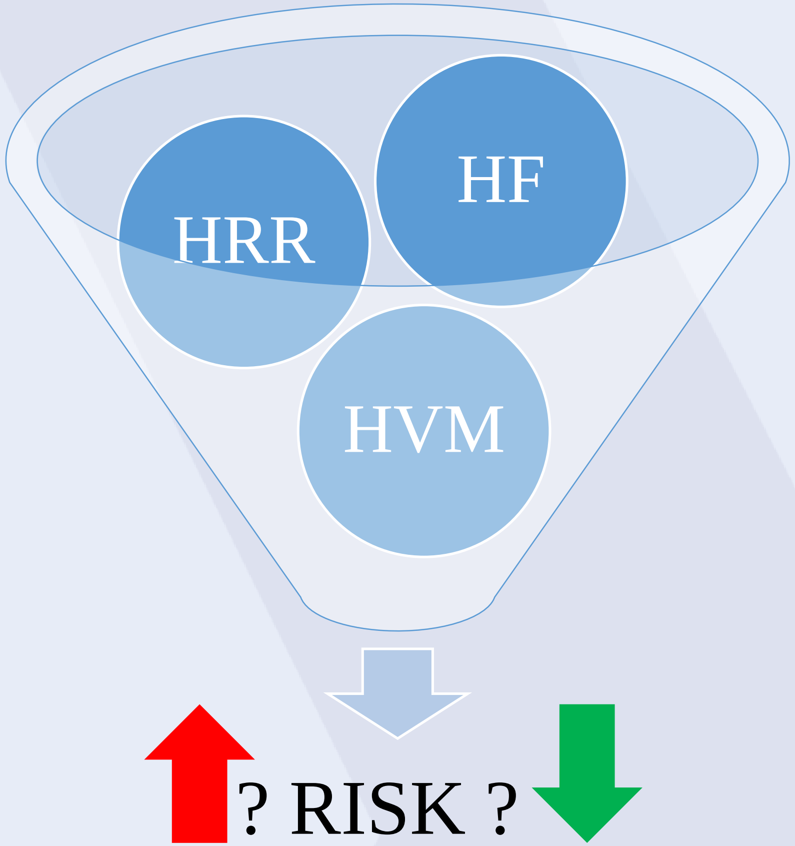
WHAT HAVE WE LEARNED FROM THE BEV FIRE TESTS

RESULTS FROM BATTERY- AND BEV FIRE TESTS



“We know, after almost a decade of testing, BEV fires can lead to increased heat release rates and increased emission of toxic products, but the increase over all is rather limited.”

BRAFA PROJECT

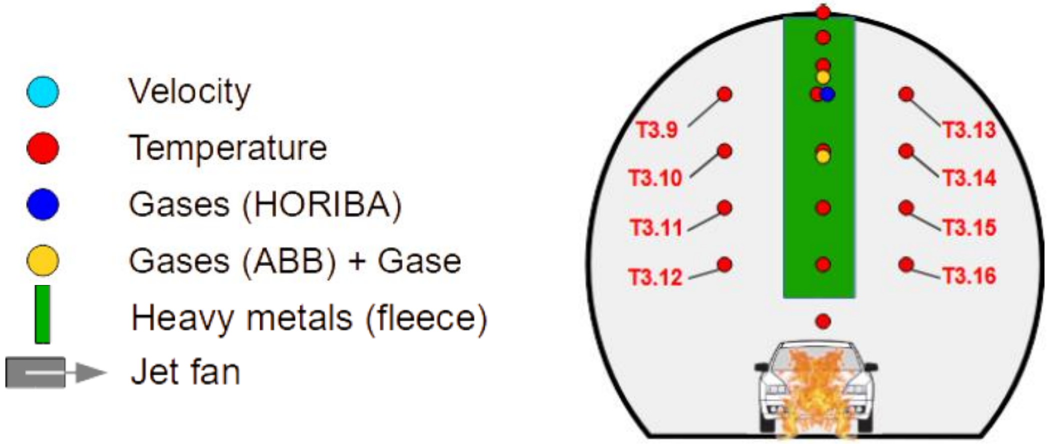
Quantitatively assess the consequences of BEV fires on tunnel users by implementing recorded hazards in TuRisMo.

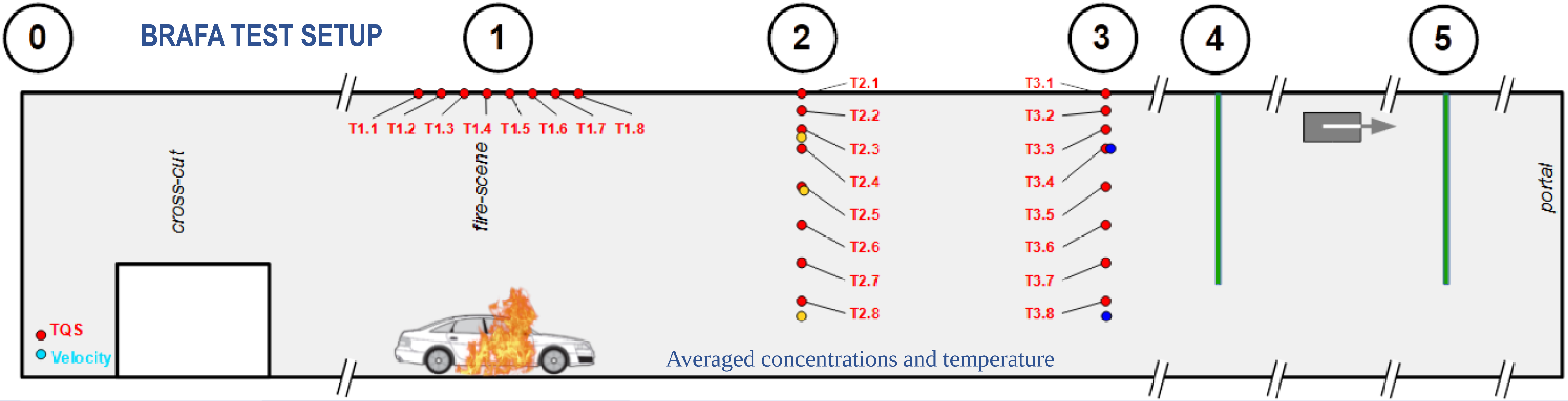
HAZARDS OF TUNNEL FIRES

HAZARDS AFFECTING EGRESS CAPABILITY[1]

- **Hazard of high temperatures**
- **Hazard of toxic substances**
- Hazard of reduced visibility

Stec, A.A., Hull, T.R., Introduction to fire toxicity, 2010





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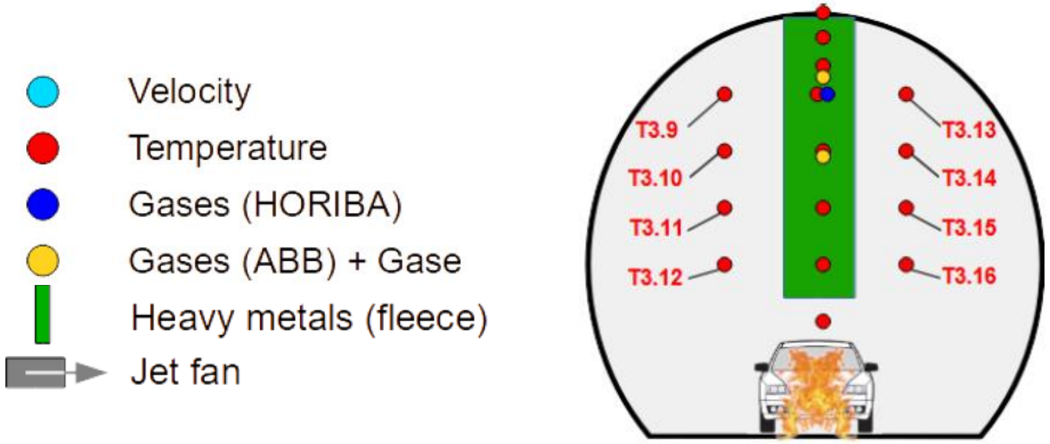
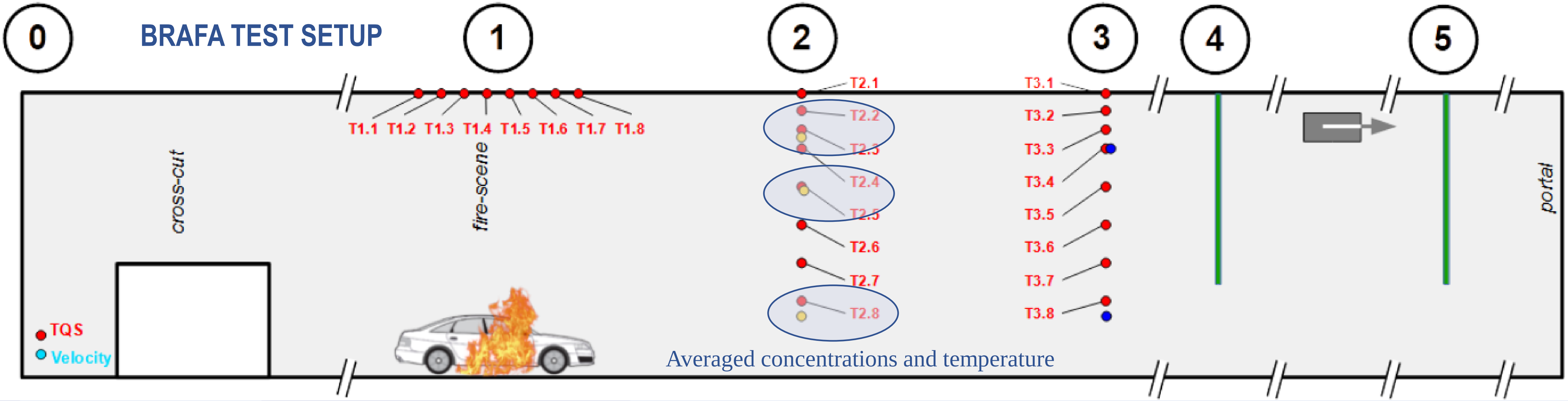
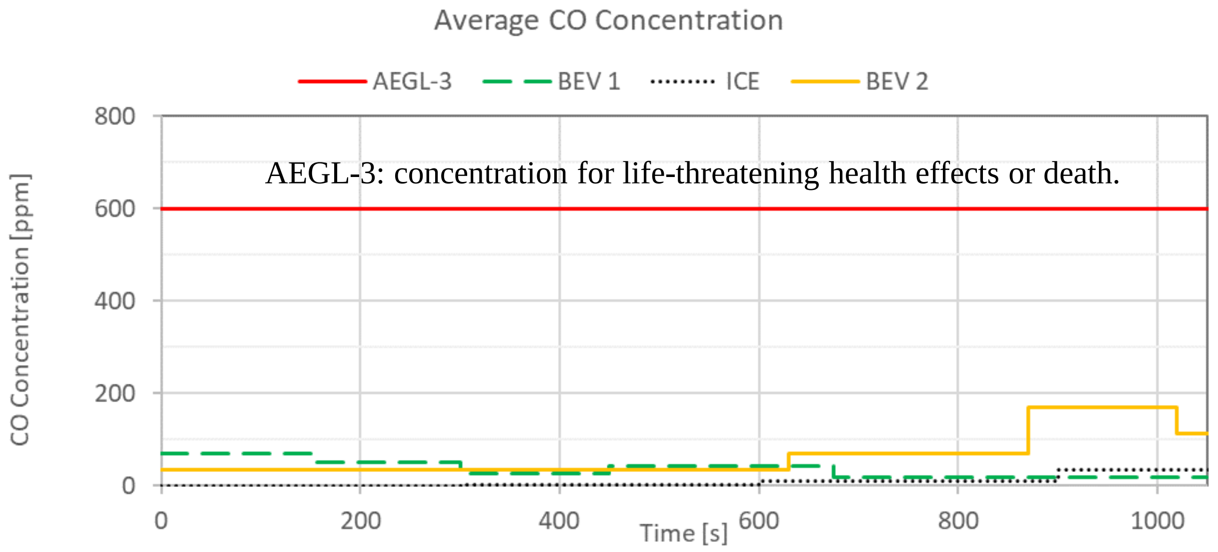
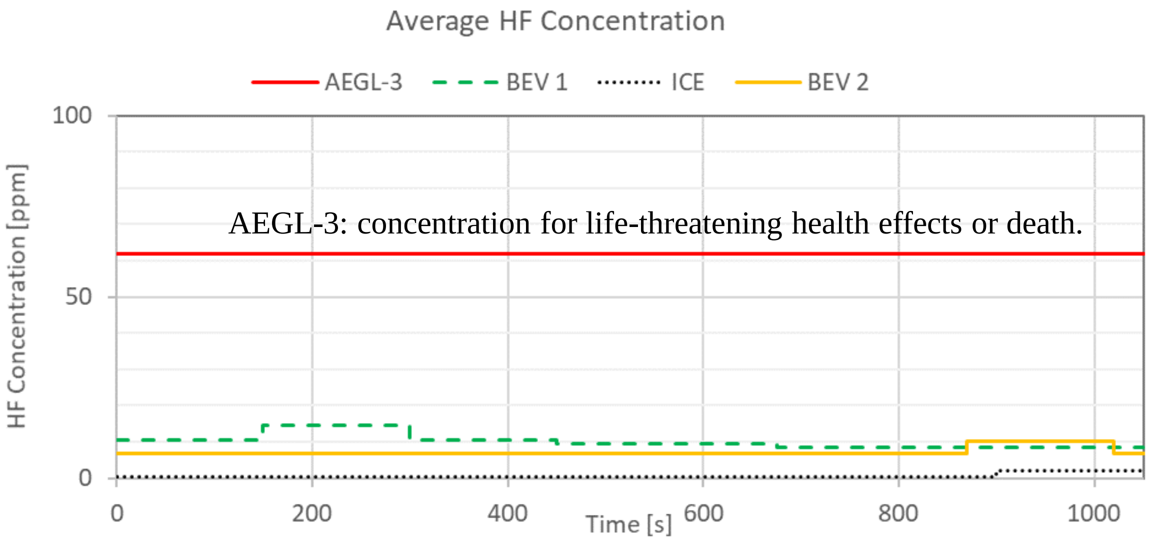
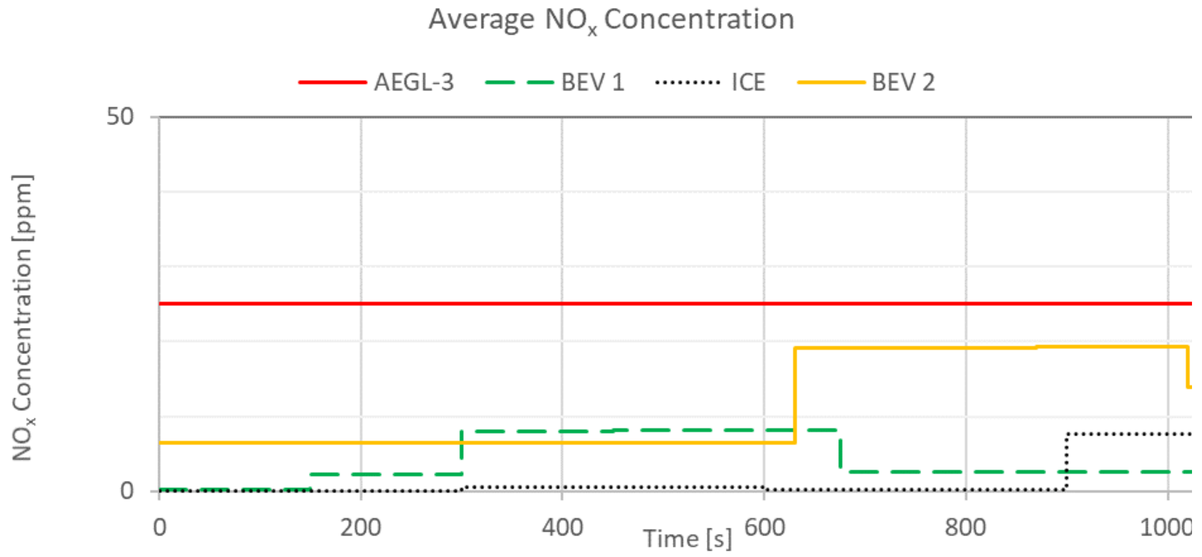


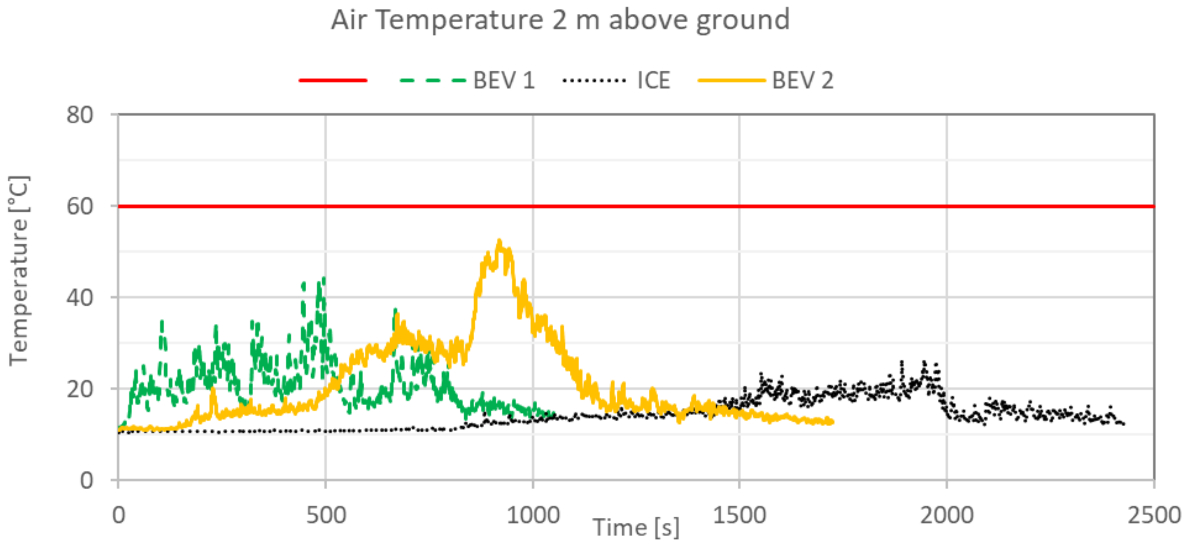


BRAFA HAZARD MEASUREMENTS









GENERALIZATION OF THE FINDINGS

FINDINGS FROM THIS COMPARISON

- Temperatures and concentrations are higher for BEV tests
- Temperatures and concentrations at face level and as cross-sectional average are still tenable
- What happens in a different tunnel environment and what about interaction effects?

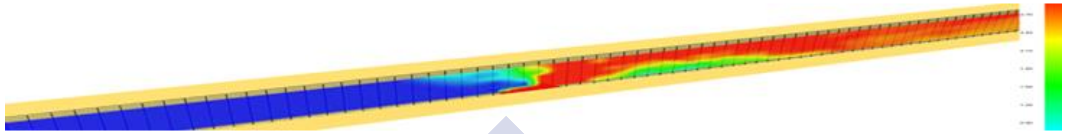
FOR A GENERALIZED ANSWER WE NEED A UNIVERSALLY APPLICABLE MODEL

➡ **DETERMINE HRR AND TOXIC GAS EMISSION RATES FOR BEV**

DETERMINE TOXIN EMISSION RATES AND HRR

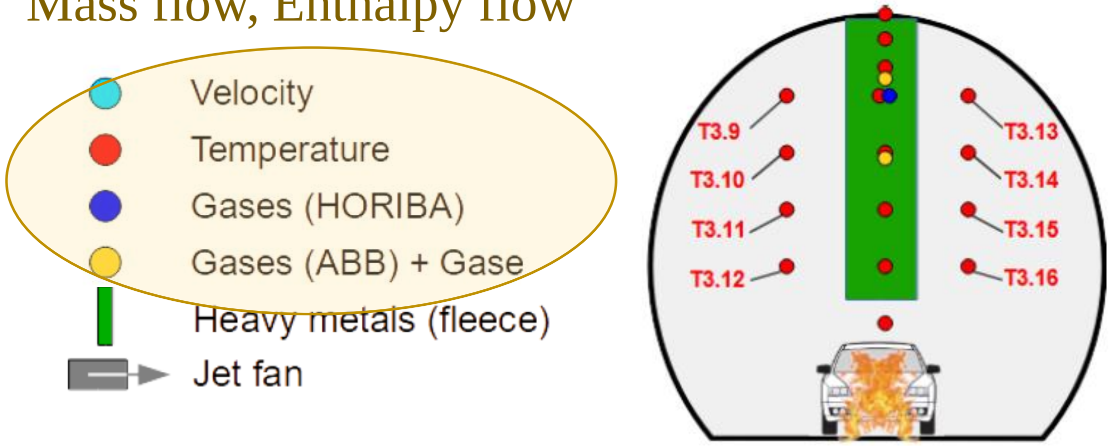
INPUT PARAMETERS FOR CONSEQUENCE MODEL

- HRR(t) from enthalpy flow
- Emission rates from mass flow and concentrations

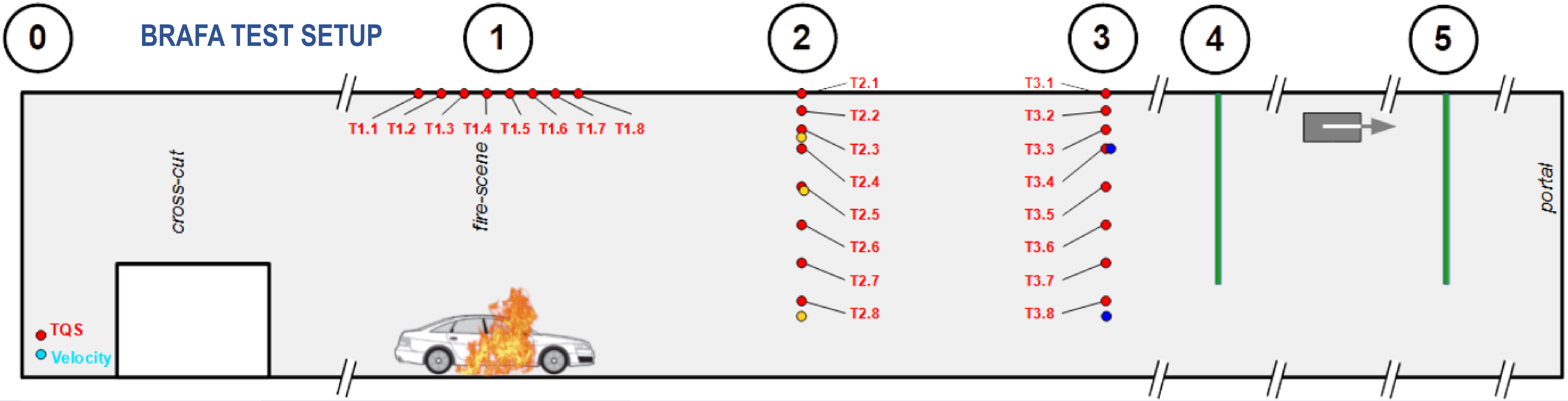


Input: $\dot{M}_i(t), \dot{Q}(t)$

Mass flow, Enthalpy flow

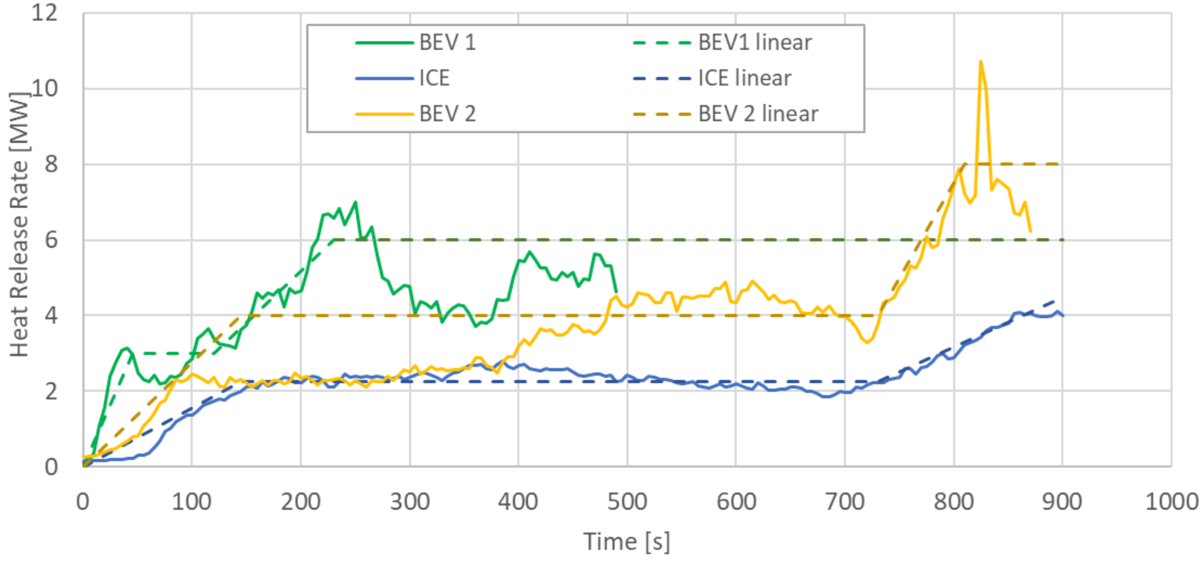


BRAFA TEST SETUP

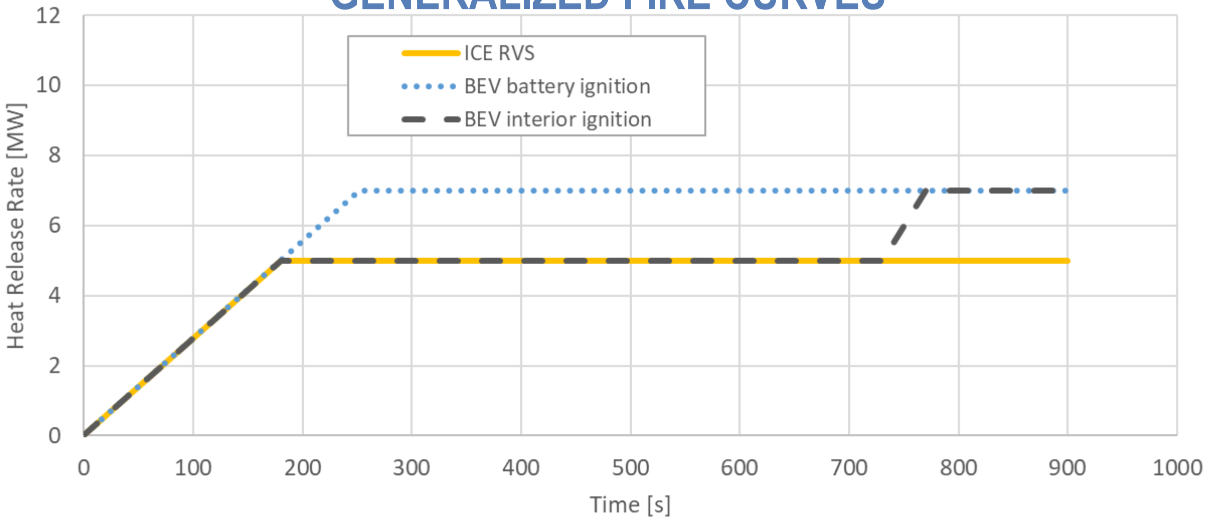


DETERMINE TOXIN EMISSION RATES AND HRR

MEASURED FIRE CURVES



GENERALIZED FIRE CURVES



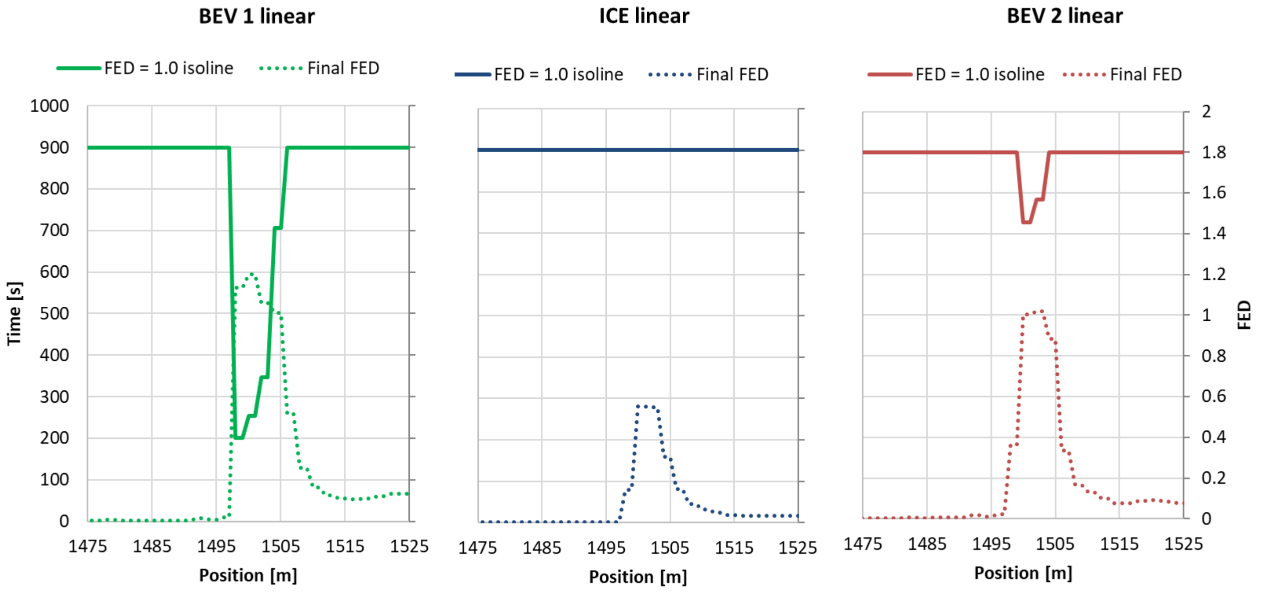
"The developed approach is not limited to a specific risk model but can be applied in any risk model which allows to define toxic emission rates and is based on a physiological intoxication- and irritancy model (i.e. Purser Model) ."

EMISSION RATES

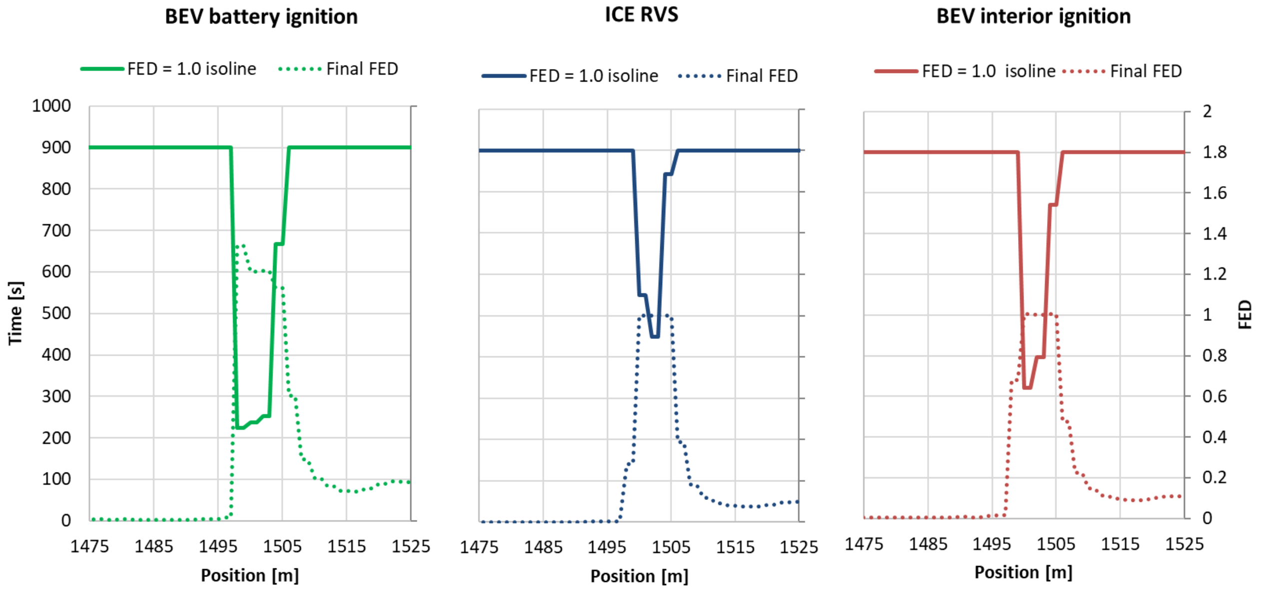
Toxic product	**BEV 1** [kg/MJ]	**ICE** [kg/MJ]	**BEV 2** [kg/MJ]	**ICE RVS** [kg/MJ]
CO	0.002	0.0013	0.0019	0.0036
CO_2	0.094	0.124	0.101	0.092
NO_x	0.00025	0.00035	0.00034	-
HCl	0.00052	0.00039	0.00034	-
SO_2	0.00012	0.000044	0.000045	-
H_3PO_4	0.000034	0.000004	-	-
HF	0.00049	0.00005	0.00021	-
HCN	-	-	-	0.0009
Soot	-	-	-	0.0025

BEV-FIRE SCENARIO ANALYSIS

MEASURED FIRE CURVES



GENERALIZED FIRE CURVES



D.A. PURER FED/FIC MODEL

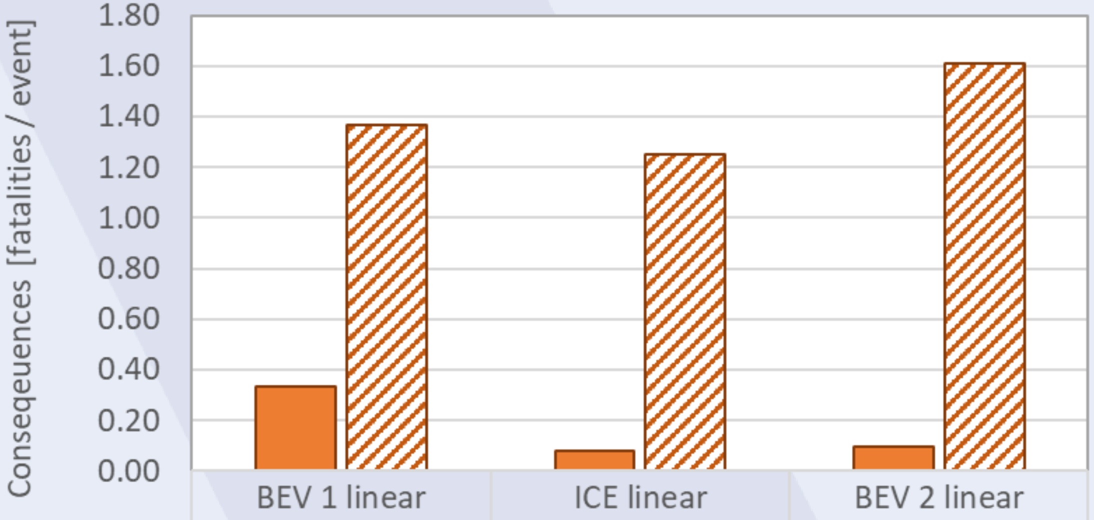
SFPE Handbook of Fire Protection & ISO 13571: Life threatening Components of Fire

$$\boldsymbol{FED_{Asphyxiation}(t)} = \sum_{\tilde{t}=0}^{t} \left(FI_{CO}(\tilde{t}) + FI_{CN}(\tilde{t}) + \boldsymbol{FLD_{irr}(\tilde{t})}\right) \times V_E \times V_{CO_2}(\tilde{t}) + FI_{LO}(\tilde{t})$$

$$\boldsymbol{Irritants}: \ \boldsymbol{HCL, HF, SO2, NO2}$$

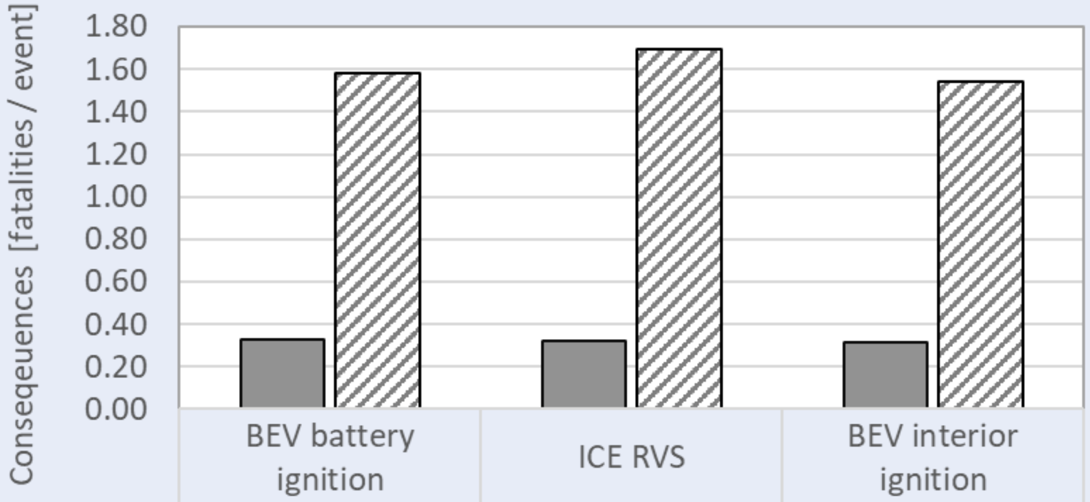
BEV-FIRE CONSEQUENCE ANALYSIS

MEASURED FIRE CURVES



	BEV 1 linear	ICE linear	BEV 2 linear
Flowing traffic	0.332	0.077	0.098
Congested traffic	1.367	1.250	1.608

GENERALIZED FIRE CURVES



	BEV battery ignition	ICE RVS	BEV interior ignition
Flowing traffic	0.325	0.324	0.314
Congested traffic	1.579	1.691	1.541

BEV RISK ANALYSIS

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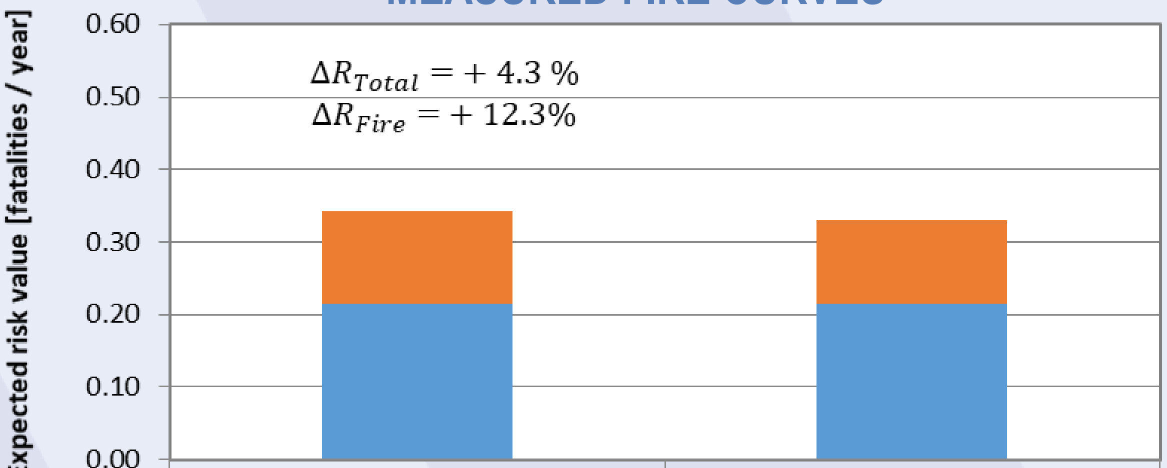
MODEL TUNNEL PARAMETERS

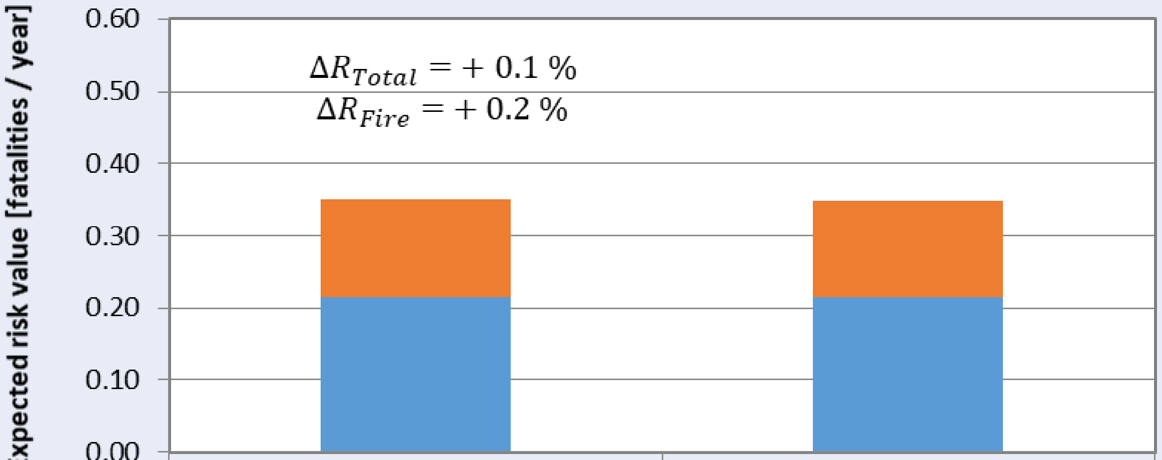
- 3 km tunnel with 1.5 % inclination
- unidirectional traffic – longitudinal ventilation
- Horseshoe cross-section 57 m²
- 300 m cross-passage distance
- 30’000 veh./day in each direction
- 14.5% hgv, 0.5% BUS
- 0.3% congestion

MEASURED FIRE CURVES



	100% BEV	100% ICE
Fire	0.128	0.114
Collision	0.215	0.215

GENERALIZED FIRE CURVES



	100% BEV	100% ICE
Fire	0.134	0.134
Collision	0.215	0.215

CONCLUSIONS

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GENERAL RESULTS

- Generic consequence model for BEV fires was developed and BEV specific input data was deduced
- Increased fire size and emission rates of specific toxins lead to a increased fire risk
- Overall risk for BEV is comparable to risk associated with conventional vehicles

LIMITATIONS OF THE RESULTS

- General conclusions based on a small number of fire tests must be interpreted with care
- Risk of a single BEV fire can be increased due to specific circumstances
- Localized hazards in the direct vicinity of the BEV where not investigated
- Results should be validated based on a larger dataset

THANK YOU FOR YOUR ATTENTION!

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