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WEBINAR ON NEW ENERGY CARRIERS IN ROAD TUNNELS-

ADDITIONAL RISKS FOR USERS - CONSOLIDATED RESULTS

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KPT
KENNISPLATFORM TUNNELVEILIGHEID

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Risks taken into account

Classic risks: Fire, accident ;
New and specific ones:

Hydrogen (FCV)

Jet Fire
Vapor cloud explosion
Tank rupture

Compressed Natural Gas (CNG)

Electrical cars (HEV, PHEV, EV, FCV) **Li-Ion only**

Thermal runaway

Main question

Coming from CETU preliminary work:

What are the additional risks for users induced by NEC in tunnels?

Two situations :

- A phenomenon could occur directly on a NEC vehicle (primary risk)
- A phenomenon could be triggered on a NEC vehicle by a distant fire (secondary risk)

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Background

CETU-INERIS joint project research

Main source

Other research projects

- With direct CETU involvement: Suveren, Electro-Mobility
- Or without: Rise work, etc.

Strongly fed

Consolidated results

- Good enough for risk analysis and safety management with French references
- But will benefit from additional researches (to come)

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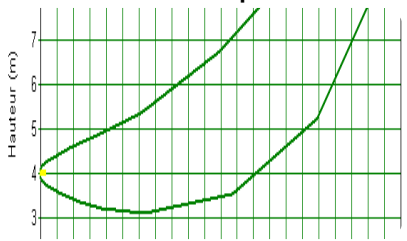
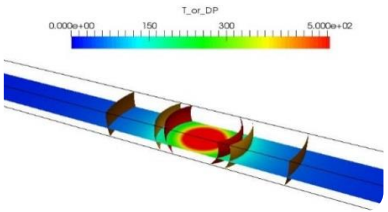
Backbone of CETU-INERIS project

- Presented in detail during previous PIARC-ITAC-COSUF workshop
- In a nutshell :
  - Phenomenon sequences highlighted by using bow-tie approach
  - When no representative feedback (new phenomena): formula used to calculate occurrence rate
  - Different modelling methods adapted to each phenomenon (eg: dispersion model coupled with multi-energy for pressure consequences)





Preliminary remarks

- Occurrence rates :
  - Meant to put severity in perspective,
  - When based on formula, bring uncertainties

To be used cautiously within risk analysis

- Severity :
  - Based on French regulation : e.g 200mbar is the threshold for significant lethal effect (conservative approach)
  - A user subjected to lethal effect is likely to be dead but not certainly dead (175 mbar lung damage threshold + indirect effects)

To be interpreted cautiously

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Primary risk – CNG fire

CNG FIRE ≅ **CLASSIC FIRE**

Frequency
Heat release rate
Toxic release

Bus - right lane – TPRDS horizontally oriented

Fire ➡ **Jet Fire** ➡

0 to all passengers (50) subjected to sign lethal effect (depending on evacuation conditions)

Fire is not an additional risk except when bus is on the right lane (near the wall) with horizontally oriented TPRDS .

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Primary risk – CNG jet fire resulting from collision or malfunction during filling

Only an issue for buses on right lane with horizontally oriented TPRDs.

Bus rate	CNG penetration rate	Frequency by comparison with classic vehicle fire
0,02%	2%	~ $3*10^6$ times lower
1,8%	100%	~ 680 times lower

Severity (number of users subjected to significant lethal effect)

0 to all bus passengers (50) depending on evacuation conditions

Primary risk – CNG Vapour Cloud Explosion (VCE)

Frequency by comparison with classic vehicle fire		
CNG penetration rate	**LV**	**HGV (5%)**
2%	~ 140 times lower	~ 2700 times lower
100%	~ 3 times lower	~ 55 times lower

Severity (number of users subjected to significant lethal effects)		
area	**LV or HGV (2 lanes tunnel)**	**congestion**
25 m centered on the NEC vehicle	4	NO
	8	YES

Buses: ~ $3*10^7$ times to 250 times lower than classic vehicles fire (depending on penetration rate and bus rate), 4 to 58 users subjected to significant lethal effects

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Primary risk – CNG Tank rupture

Frequency by comparison with classic vehicle fire		
CNG penetration rate	**LV**	**HGV (5%)**
2%	~ 26 *10^3 times lower	~ 330*10^3 times lower
100%	~ 530 times lower	~ 6700 times lower

Severity (number of users subjected to significant lethal effects)		
area	**LV or HGV (2 lanes tunnel)**	**congestion**
50 m centered on the NEC vehicle	8	NO
	16	YES

Buses: ~ 19*10^3 to 83*10^6 times lower than classic vehicles fire (depending on penetration rate and bus rate), 8 to 66 users subjected to significant lethal effects

Time to tank rupture is between 8 and 20 min if NEC vehicle is on fire

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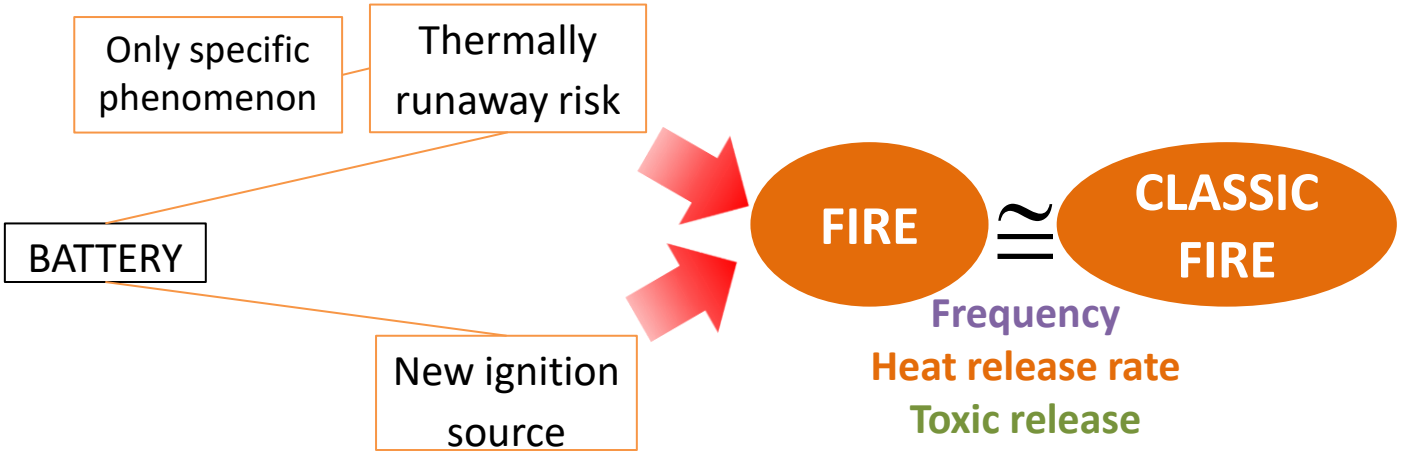
Other results in a nutshell

- CNG
  - Secondary risk (distant fire) : only VCE-bus: up to $5*10^4$ times lower than classic fire, up to 58 users subjected to significant lethal effect
- HYDROGEN
  - Primary risk :
    - Jet fire – bus_700 bars _ right lane _ “horizontal” TPRD, 0 to 50 users subjected to lethal effect, frequencies ten times higher than CNG jet fire
    - VCE – [LV, HGV]: 15 to 30 users subjected to significant lethal effect, frequency around five times lower than CNG VCE
    - Tank rupture - [LV, HGV]: 15 to 30 users subjected to significant lethal effect; same frequency than CNG
  - Secondary risk : VCE-bus: same frequencies and bit higher severity than hydrogen
- LNG : primary risk: tank rupture of HGV : area of significant lethal effect : 750 meters, 48 to 225 users subjected to these significant lethal effects

Other results in a nutshell

ELECTRICITY (Li-ion)



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Other results in a nutshell

ELECTRICITY (Li-ion)

EXPLOSION not taken into account for Li-ion

- Possible in theory
- But highly improbable in practice for Li-ion
  - ✓ In case of Li-ion, explosion can only be the one of a cloud following the quick vaporisation of the whole electrolyte because of a fire
  - ✓ In practice, due to the battery technology (cells and packs), there will rather be successive vaporisation and inflammation of small amounts of electrolyte

Conclusion and perspective

- **Electricity (Li-ion):** no significant additional risk
- Gas:
  - **Jet fire** only a concern for certain buses with TPRD horizontally orientated solution TPRD vertically orientated
  - **Tank rupture**: there is time to put users in safe zone (more tricky with LNG-HG)
  - **VCE**: no immediate solution to manage the risk

Conclusion and perspective

- Results are feeding a document written within a group of stakeholders to present a state of play (risk, operational and regulatory constraints on operation and intervention, safety management, etc.)

- Next researches at CETU:
  - Deepen and precise the results (e.g. determine the pressure at any distance of the source)
  - Seek mitigations measures (e.g. reduction of TPRD diameter to prevent VCE?)
  - Integrate NEC to French risk analysis and safety management (e.g. new evacuation procedures)