

# Alternative fuels and the future of road tunnels and road tunnel design

Gary Clark

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# Introduction



- TUNNEL DESIGN: Chief Engineer Tunnel Ventilation Design
- TUNNEL OPERATION: Safety Officer for TERN Tunnels in England
- INDUSTRY:
  - Member UK Tunnel Design Authority
  - EN Secretary to PIARC Committee
  - Co-lead for PIARC WG4 on Ventilation
  - Member UK Tunnel Operators' Association

# Introduction

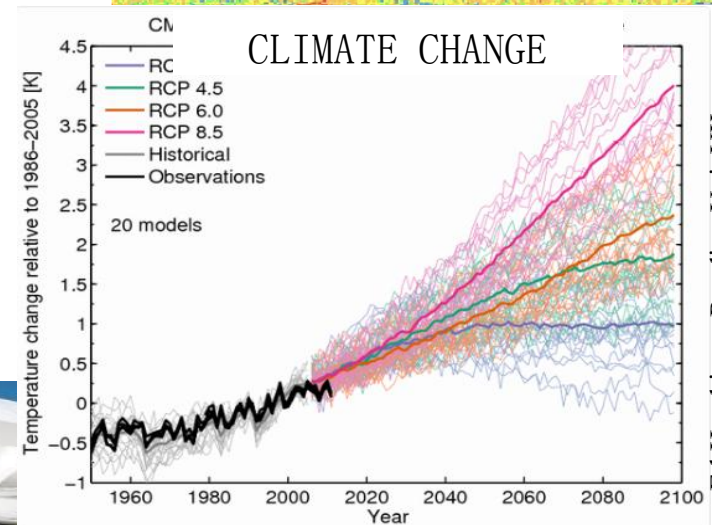
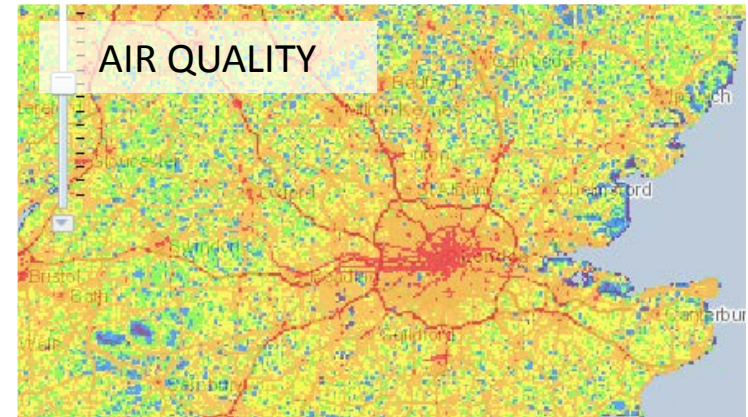
## Collaborators

- Peter Sturm, University of Graz, Austria
- Norris Harvey, Mott MacDonald, USA
- Matt Bilson, WSP, USA

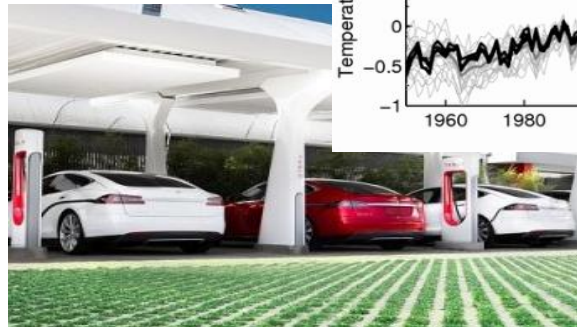
# Introduction

- Why are things changing?
  - Air quality NOx levels / AQM
  - Climate change
  - Technological development

NO2 Production NAEI, UK

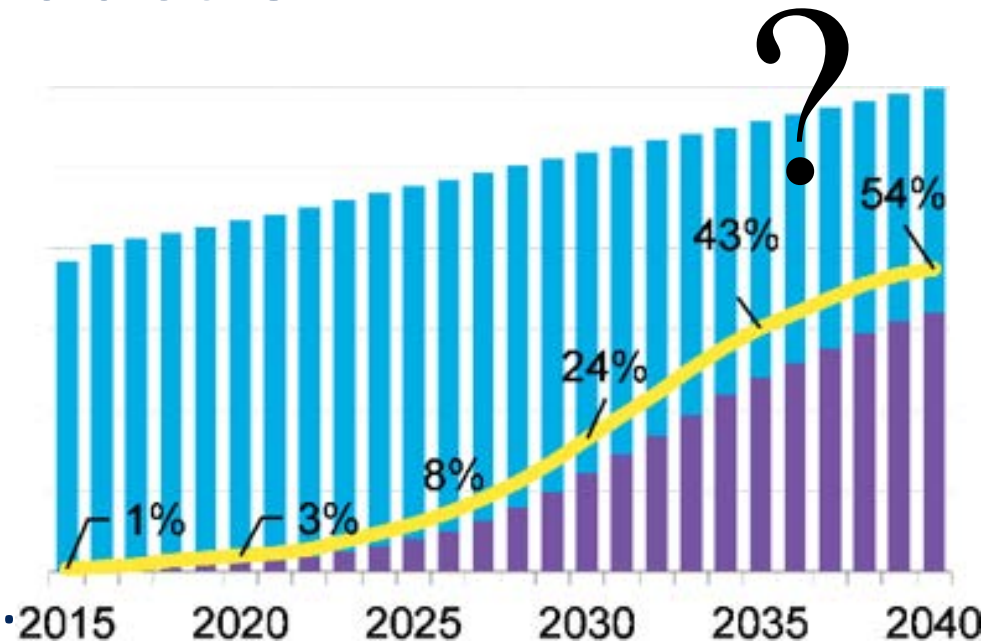


Ed Hawkins - Reading Uni, UK



# Introduction

- What's happening?
- Battery Electrics
  - BEVs in the UK up 51% from 2016 to 2017 (still only 3% incl. hybrid)
  - Private fleets (buses) moving to all-electric?



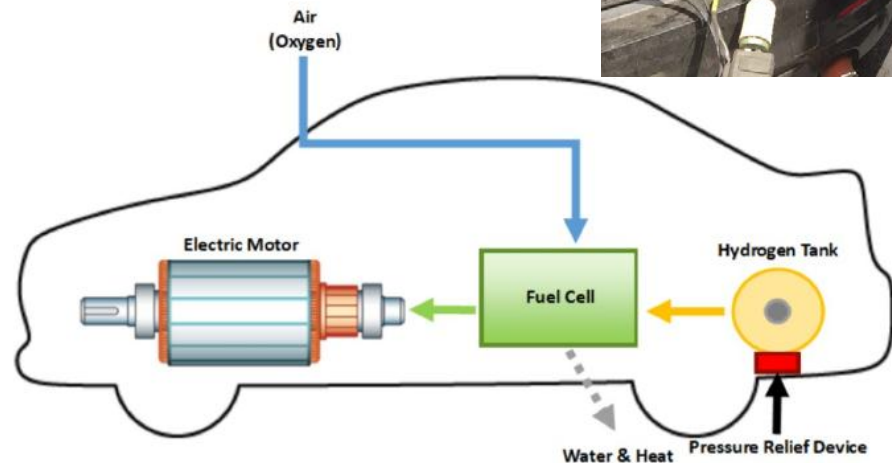
# Introduction

- What's happening?
  - Hydrogen fuel cells
    - High energy density, good for mid to long range
    - Oxidation process with water as only by-product

Hydrogen fuel cell



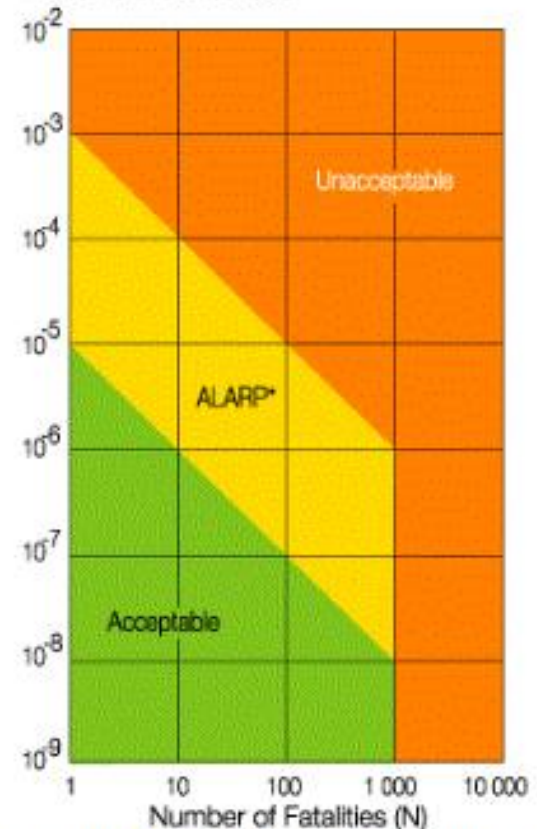
TU Graz



# Introduction

- Impacts on tunnel safety risk
  - Likelihood of incidents
    - Per vehicle km of new-fuel vehicle
    - Consequences of incidents
      - For tunnel users
      - For firefighters
      - For the tunnel

Frequency (F) of Accidents with N or More Fatalities per year



\* Risk within the ALARP should be mitigated to as low as reasonably practicable.



# Battery Electric Vehicles

## (Some basics)

- Electric motor powered by battery pack
- Typically liquid-cooled Li-ion
- Fire could be caused by:
  - Damage from collision
  - Short circuit
  - Thermal problems during loading



# Battery Electric Vehicles

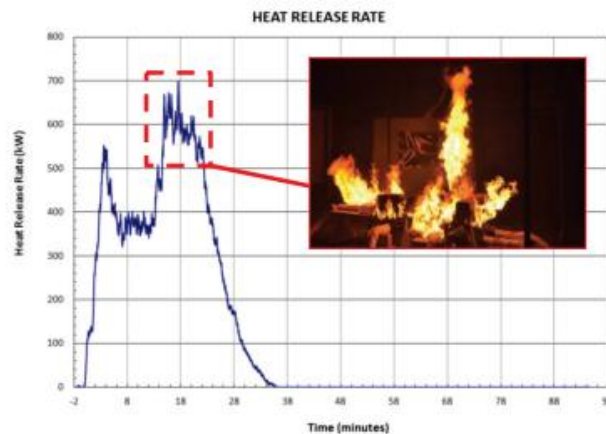
## (Safety Risk)

- Thermal runaway
  - Temp increase and chain reaction one cell after another
  - Oxygen is released within the battery to support combustion
  - Suppression is very difficult
- Toxic gases
  - Breakdown of battery components creates large volume of toxic gases
  - Levels of toxicity may be high – uncertainty still exists

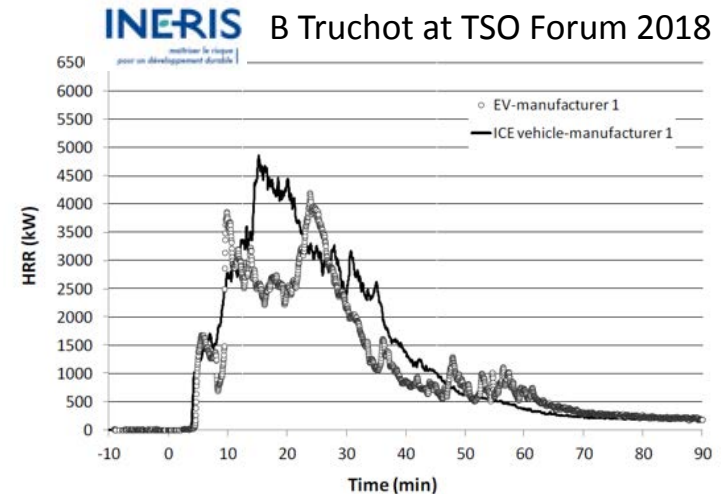
# Battery Electric Vehicles (Safety Risk)

## Heat Release Rate

- Depends on extent of damage
- Peak not significantly different to traditional?



Colella et al ISTSS 2017



# Battery Electric Vehicles

## (Safety Risk)

- Toxics
  - During thermal runaway, flammable and highly toxic gases are released from the battery
  - Acids (eg HF), heavy metals as well as standard combustion products
- Does this change our tenability assessments?
- Are smaller car fires to become more of a concern?

# Battery Electric Vehicles

## (Safety Risk)

### ■ Extinguishing

- BEV fires are not easily extinguished
  - Oxidation process continues without supply of external oxygen
  - Cooling is required - research (eg Colella 2016) reported that up to 10m<sup>3</sup> of water to cool the batteries in a BEV
  - High risk of re-ignition
- 
- Which of these is a BEV?  
or hybrid?



# Fuel-Cell Powered Vehicles

## (Some Basics)

- Fuel cells chemically (oxidation) convert H<sub>2</sub> to electric power without burning
- Water is the only emission
- Higher energy density so potential for long ranges
- Fire could be caused by:
  - Damage from collision
  - Thermal problems during loading
- Hazards
  - Fire
  - Explosion



# Fuel-Cell Powered Vehicles

## (Safety Risk)

- Prevalence
- Vulnerability
  - Hydrogen burns very hot (2000degC)
  - Fuel tank (H<sub>2</sub>) if heated will result in a H<sub>2</sub> release and flame (low energy required for ignition)
  - Rupture of tank unlikely?
  - Battery (bigger than conventional EV)



# Fuel-Cell Powered Vehicles (Safety Risk)

- HRR
  - Depends on extent of damage
  - Depends on success of controlled venting
  - Peak not significantly different to traditional?





# Fuel-Cell Powered Vehicles

## (Safety Risk)

- Toxics – same as BEVs
  - Highly toxic gases are released from the battery
  - Acids (eg HF), heavy metals as well as standard combustion products
- Does this change our tenability assessments?
- Are smaller car fires to become more of a concern?

# Discussion points

What are our obligations as tunnel designers, owners and operators?

- Acceptable safety levels
  - As % of vehicles increase, are our safety levels reducing?
- Ensure self rescue is possible from BEV incident, H2 incident, whatever the likelihood?
- Ensure PRMs kept safe until fire service arrival?



# Discussion points

## We have new Scenarios

- New fire and burning behaviours
- Different toxic gases
- Many uncertainties requiring research
- Should we prohibit these vehicles until we are ready for them?
- Is this even possible?



# Discussion points

## New Emergency Response

- Identification of vehicles
- Evaluation of risk (dynamic)
- Emergency plans & procedures
- Will the fire service respond to fires of unknown risk?



# Concluding comments

## Action is needed

- Priority topic for PIARC TC D5 for the coming cycle
- Subject of interest for ITA-COSUF (workshop planned for 2019)
- Collaboration between PIARC and COSUF agreed
- Research is underway – more is needed



# Some references

## ELECTRIC MOBILITY AND ROAD TUNNEL SAFETY HAZARDS OF ELECTRIC VEHICLE FIRES

9<sup>th</sup> International Conference 'Tunnel Safety and Ventilation' 2018, Graz

<sup>1</sup>L. D. Mellert, <sup>1</sup>U. Welte, <sup>2</sup>M. Hermann, <sup>2</sup>M. Kompatscher, <sup>3</sup>X. Ponticq,

## ROUTES/ROADS

PIARC September 2018, N Harvey  
et al

## Fire and explosion hazards of alternative fuel vehicles in tunnels

Ying Zhen Li



Risks associated with alternative fuels in road tunnels and underground garages

Jonatan Gehandler, Peter Karlsson, Lotta Vylund

Seventh International Symposium on Tunnel Safety and Security, Montréal, Canada, March 16-18, 2016

## Electric Vehicle Fires

Francesco Colella<sup>1</sup>, Hubert Biteau<sup>1</sup>, Nicolas Ponchaut<sup>1</sup>, Kevin Marr<sup>1</sup>, Vijay Somandepalli<sup>1</sup>,  
Quinn Horn<sup>1</sup>, Richard Thomas Long<sup>1</sup>  
<sup>1</sup>Exponent, USA



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Federal Ministry  
of Education  
and Research

Safety of City Underground Structures due to the use of New Energy Carriers



## Challenges of New Energy Vehicles

B. TRUCHOT and G. MARLAIR  
5<sup>th</sup> Tunnel Safety Officer Forum



**Thank you for your attention**