

Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

For more information please contact,

IFE Firefighter Safety Database Project Lead Adam Course BSc(Hons) MIFireE

adam.course@avonfire.gov.uk



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Covering today.....
- Disclaimer
- Thanks and acknowledgements
- Is there a problem with electric vehicle fires and what is the problem?
- What do firefighters do with regards to these types of fires before they happen and when they happen?
- What I don't have time to cover in this presentation?
- Review and thanks



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Disclaimer
- Things (risks/hazards) change, further knowledge is gained, additional risks & hazards emerge, new research is conducted, if you ask again in a week, month, year some of the tactical 'advice/guidance' may have changed.....
- Some peer reviewed references and sources of information here but some are not.....
- Keep up to date with your risks and your formal fire and rescue service guidance whether you are writing it or using it!!!
- Cannot answer all the questions.....this research, like any research, poses more questions than it answers.....
- More research on the fire risks of electric vehicle, alternative fuelled vehicles & any energy storage systems is required.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Thanks and acknowledgements
- There are a lot of colleagues and organisations to thank for their part in my journey to this point – I may not get everyone by name.....apologies
- Assistance with this presentation – Lotta Vylund (RI.SE), Kurt Vollmacher (Belgium) & Grant Smith (UKRO).
- The Institution of Fire Engineers (IFE) and Avon Fire and Rescue Service (AFRS) has enabled some significant personal learning and development of a sharing mechanism to be created – the IFE Firefighter Safety Database (FFSDB)

<https://www.ife.org.uk/Firefighter-Safety-Incidents>



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Thanks and acknowledgements continued.....
- The National Fire Chiefs Council (NFCC) & previous Chief Fire Officers Association (CFOA)
- Contributing fire & rescue services, principle officers, officers & staff and decision makers who said yes and assisted getting the FFSDB project this far
- Russ Timpson & the Tall Buildings Fire Safety Network
- Support of IFE IGA (19 UK & 23 International branches), the Board of directors and the IFE staff.....
- The FBU



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Thanks and acknowledgements continued.....
- Fire Emergency New Zealand (FENZ) (Trent Fearnley, Graham, Trevor *et al.*)
- Metropolitan Fire Brigade (MFB) (Melbourne)..... Now Fire Rescue Victoria (FRV) (Adam Dalrymple)
- South Australia Metropolitan Fire Service (Grant Lupton & Dave Launder),
- National Institute for Occupational Safety and Health (NIOSH)
- The Instituut Fysieke Veiligheid (IFV, Institute for Safety) & Ricardo Weewer,
- Deputy Chief Jason Krusen – Charleston Fire Department



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Thanks and acknowledgements continued.....
- The European Union (EU) exchange of experts programme
- International Fire Instructors Workshop and Conferences (IFIW).....and all those involved in that forum.....
- UL & UL FRSI (Sean DeCrane & Steve Kerber in particular)
- LFB Dep(ret) Roy Bishop, D&SFRS Dep(ret) Neil Gibbins, Martin Shipp.....
- ACFO Rob Davis, CFO Mick Crennell, ACFO Simon Shilton, DCFO Jon Day (ret) and CFO Kevin Pearson (RIP).



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Is there a problem?
- With electric vehicles?
- With covered car park fires that are e.g. underground or under buildings?
- With high rise buildings & fire? What's the number of these & with carparks?
- With any vehicle catching fire?
- With FRS (national or international) knowledge and understanding about contemporary, emerging or future risks?



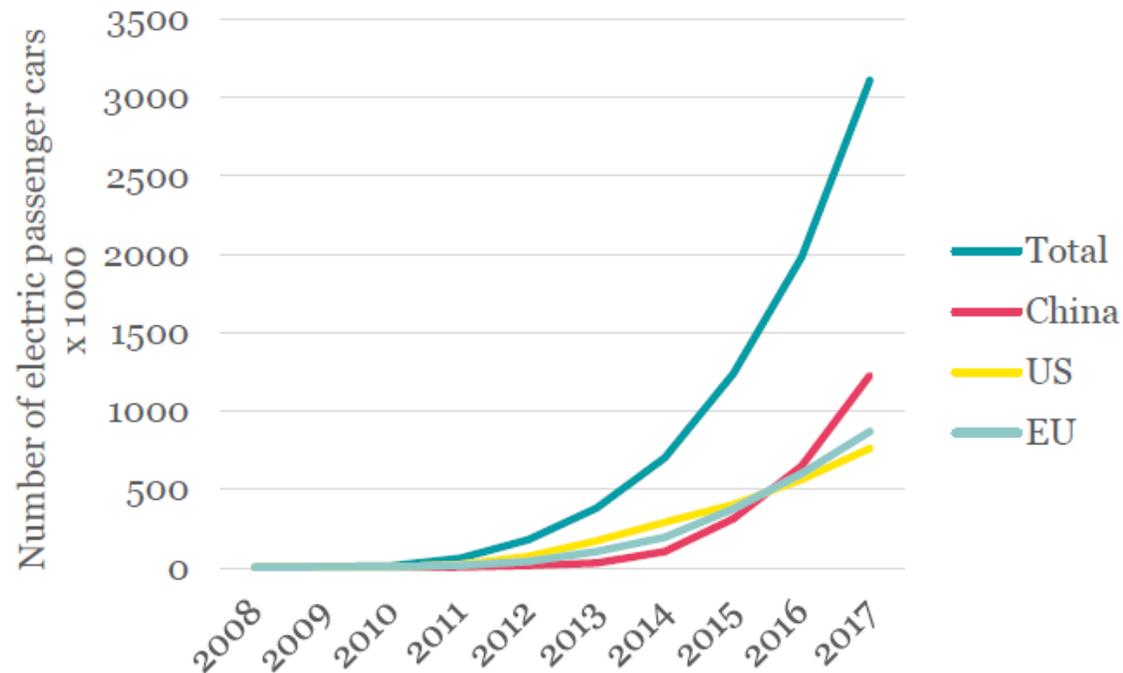
Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Is there a problem?
- With research into fire risks nationally or internationally?
- With data on certain risks including alternatively fuelled vehicle fires and the built environment?
- With sharing knowledge and information?
- With thinking holistically about risk & solution across industry, emergency response, governance & regulation, academia etc etc?



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What is the problem? Electric vehicles?
- Bisschop *et al.* (2019) <http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1317419&dsid=5310> RI.SE. gave number of electric vehicles driving around in 2017 Globally, as 40% of all EV passenger cars in China followed by EU (870,000) and then USA (760,000) for same year.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What is the problem? Electric vehicles?
- From Vehicle Licensing Statistics the number of UK alternative fuel vehicles is given as an annual change increase of 26% in 2019 compared to 2018
- https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882196/vehicle-licensing-statistics-2019.pdf
- Ultra Low Emission Vehicles (ULEV) 36% increase in 2019 compared to 2018

Figure 2: Cars registered for the first time by fuel type, Great Britain, 2001 to 2019 ^[VEH0253]

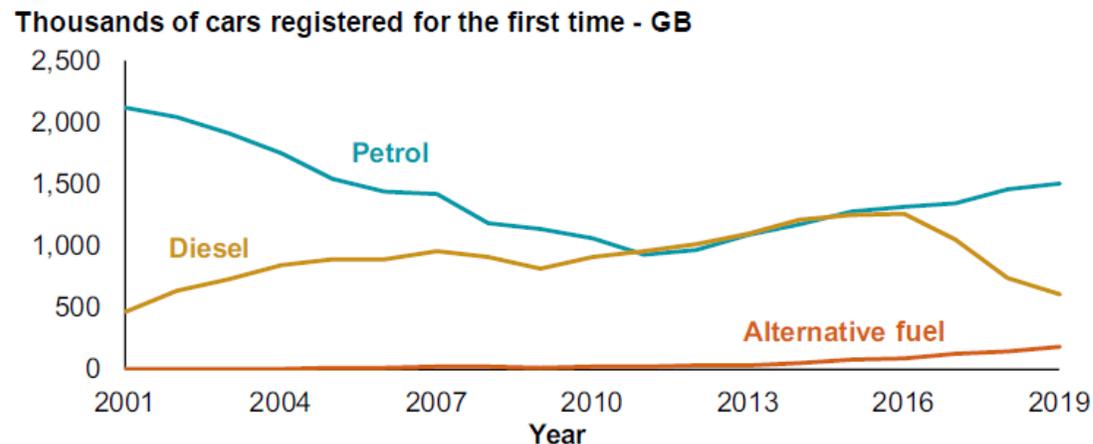
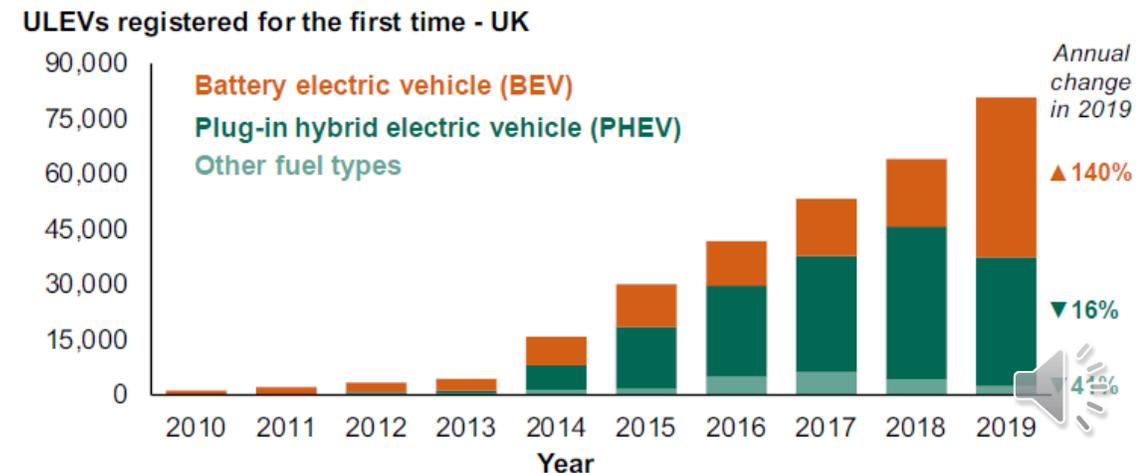


Figure 3: ULEVs registered for the first time by fuel type, United Kingdom, 2010 to 2019 ^[VEH0171]



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What is the problem? Electric vehicles?
- From Vehicle Licensing Statistics the number of UK alternative fuel vehicles is given as an annual change increase of 26% in 2019 compared to 2018
- https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882196/vehicle-licensing-statistics-2019.pdf
- Ultra Low Emission Vehicles (ULEV) 36% increase in 2019 compared to 2018

Figure 5: Licensed ULEVs by fuel type, UK, 2019 [VEH0133]

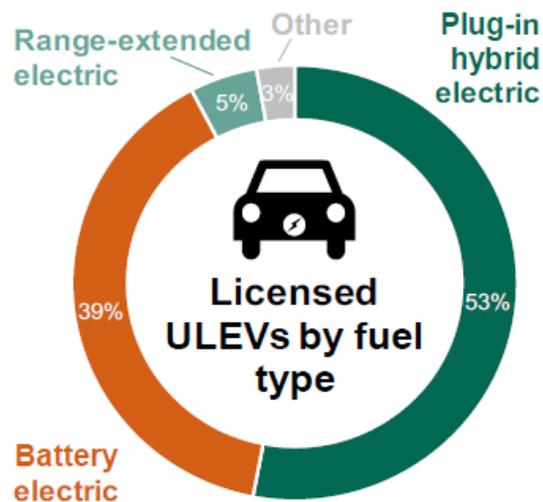
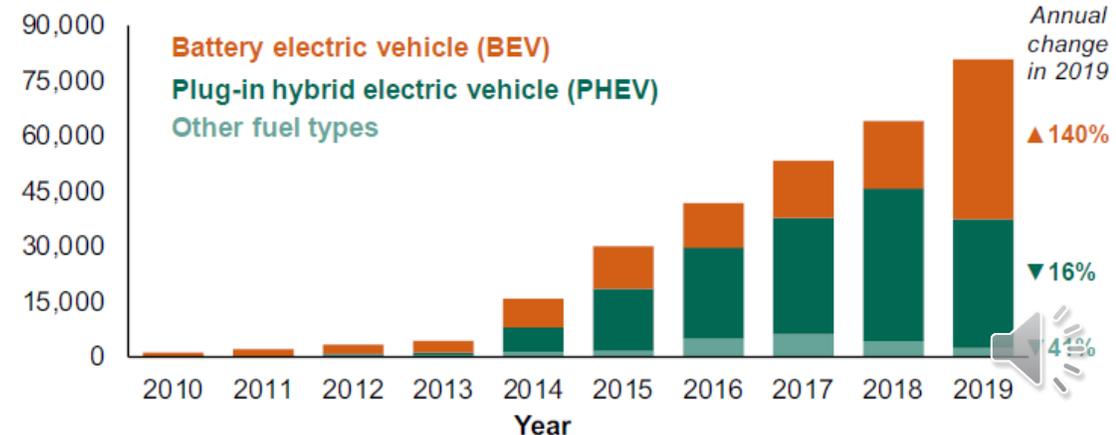


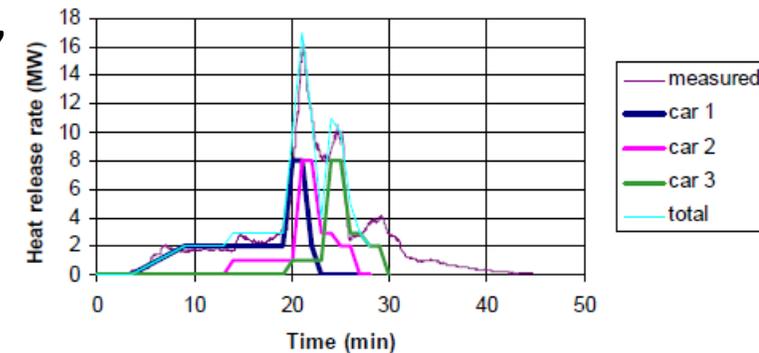
Figure 3: ULEVs registered for the first time by fuel type, United Kingdom, 2010 to 2019 [VEH0171]

ULEVs registered for the first time - UK



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What is the problem? Electric vehicles?
- Part of the biggest problem is not understanding the risks of any vehicle fire within certain covered car parks, never mind alternative fuelled vehicles or within high rise buildings.....
- Peak heat release rate of a car fire has increased and will continue too no doubt.....
- Shipp, *et al.* for BRE (2008) reported during live fire tests in underground car park testing the in test 1, the 1st vehicle (2002 Renault Laguna) burning peaked at about 2 MW for 20 minutes, then when the neighbouring vehicle (1998 Renault Clio) ignited there was a peak heat release (HRR) rate of 16 MW
- No alternative fuels involved in tests.....
- Bearing in mind the date of the tests (2008), peak HRR were shown to be between 1.5 up to 10 MW for various vehicles.....likely to be a significantly higher average now!!



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Part of the biggest problem is not understanding the risks of any vehicle fire within certain car parks, never mind alternative fuelled vehicles
- Heat release rates (HRR) for firefighters?
- Average training container burn, around 1 to 1.5 MW for knowing what 1.5ish MW feels like and how much water is needed to put it out.....
- Multiply energy by 10 and then 100 or even 200++??
- Consider the effect on the building and its potential occupants.....firefighters or building users.....
- Should firefighters understand elementary fire science & fire engineering principles, including heat release rates, heat flux, fire behaviour/phenomena and adequate flow rates and all that affects that.....?
- Should they and others understand the built environment & its reaction or potential reaction to fire more?



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Firefighting flow rates and how firefighters know and understand this.....
- No flow meters? You will only have part understanding of flow because you are only working in pressure rather than flow and pressure.....
- Will be needing more flow in certain fire circumstances including Alt energy vehicles



THE INSTITUTION OF FIRE ENGINEERS

FOUNDED 1918 • INCORPORATED 1924

Firefighter Safety Special Interest Group (FFSSIG)



Gretzenbach, Underground Car Park Fire & Structural Collapse

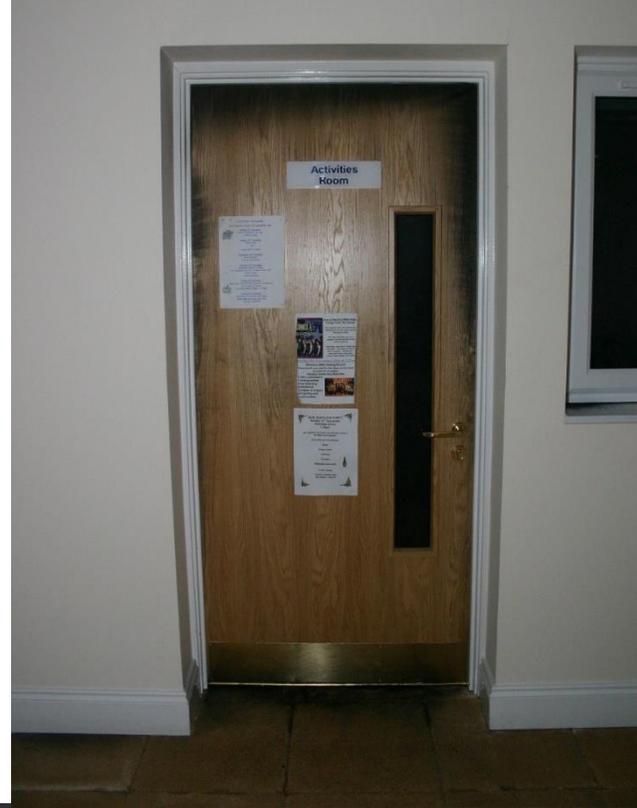
November 2004



7 Firefighter fatalities – Vehicle origin, collapse approximately 90 minutes after fire occurred



Monica Wills House, Bristol 20th December 2006



1 fatality – Vehicle origin, car park fire spread and smoke spread to areas of sprinklered building except car park which was not sprinklered..... <https://www.ife.org.uk/Firefighter-Safety-Incidents/2006-monica-wills-house/41922>



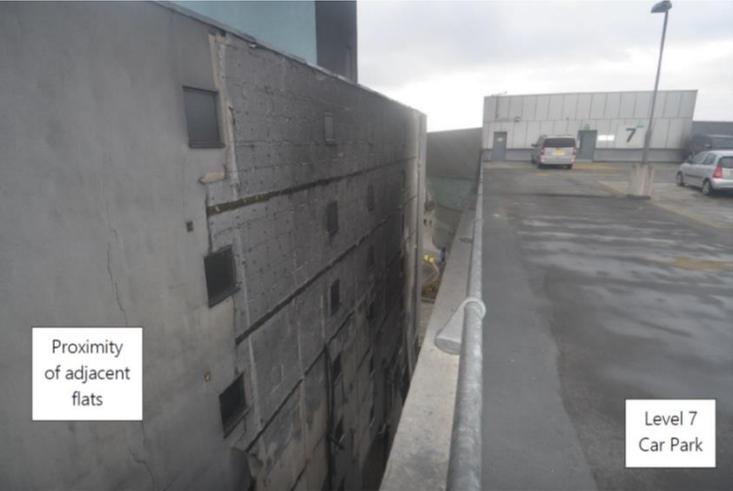
Duson Sporium Sport Centre, Jechon, South Korea 21st December 2017



29 fatalities – Electrical in origin, car park fire spread to rest of building



Kings Dock Car Park Fire, Liverpool 31st December 2017



0 fatalities – Vehicle origin, car park fire spread



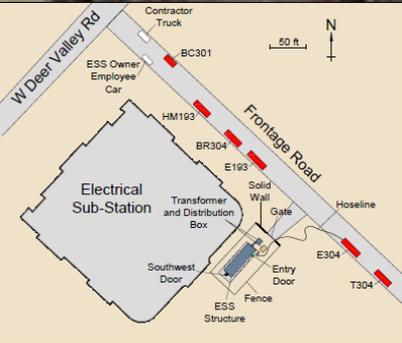
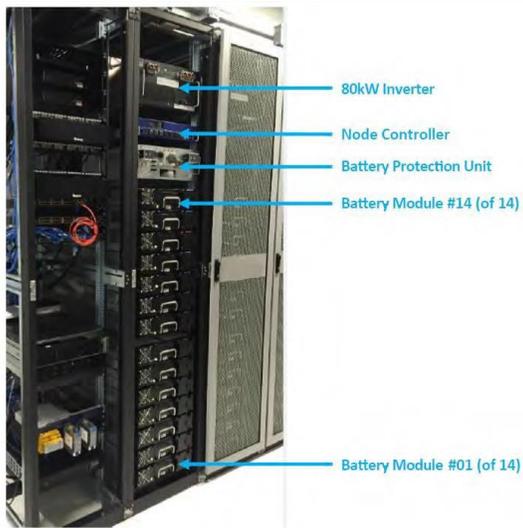
Blodgett Street Fire, Houston, USA 8th November 2016



0 fatalities – Vehicle origin, car park fire spread



4 Ffs Injured, Lithium-ion Energy Storage System Explosion, Arizona USA - 19th April 2019



4 injuries – Lithium-ion battery, thermal runaway origin.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Moore *et al.* for Merseyside Fire and Rescue Service reported in the Kings Dock Car Park Fire Protection Report (2018) numerous previous car park fire related incidents of interest..... Several more since this list was created....
- **Fleming Way, Wiltshire, 29/01/18** - Multi-storey car park, attached to local shopping centre, three crews dispatched to tackle a vehicle fire on the third floor, suspected to have been deliberately ignited.
- **Topp Way, Bolton, 20/01/18** - Multi-storey car park, single vehicle fire within the multi-storey car park. Firefighters using one main jet on scene for 1 hour, recorded as an accidental fire.
- **Paris, France, 10/01/18** - Fire in underground car park, 1 Firefighter fatality (heart attack), 120 Firefighters attended.
- **Jecheon, South Korea, 20/12/17** - Fire in a ground floor car park spread to the floors above in an eight storey building. 29 people were killed.
- **Boomtown Festival Fire, Hampshire, 12/8/16** - Open car park on a straw stubble field. 92 vehicles involved in fire.
- **Southwater, Telford, Shropshire, 20/6/16** - Multi-storey car park, fire involving several vehicles causing damage to wiring, electrical fittings and surrounding structures on the third floor. 3 appliances dispatched, using BA and one main jet brought the fire under control within 2 hours.
- **Cheltenham Rd, Harrogate, 4/12/15** - Multi-storey car park, vehicle fire on 5th floor, 4 appliances dispatched and one aerial ladder platform due to the position of the fire. Crews used 1 dry powder and 1 carbon dioxide extinguisher to resolve the incident.
- **Isle of Wight, Newport town centre, 17/7/15** - Multi-storey car park, one car involved, crews hauled up a hose reel to extinguish the vehicle, fire investigation concluded as accidental ignition.
- **Willow Place Shopping Centre, Corby, Teeside, 30/12/14** - Multi-storey car park building, several vehicles involved, damage to the car park structure and several retail outlets. 6 appliances attended, 30 firefighters worked for four hours to extinguish the fire. 4 youths aged between 14 and 20 charged with arson in connection with the incident.
- **Place Vendome, Paris, 2012** - Underground car park, 40 high performance and luxury vehicles lost in fire, declared as accidental ignition due to electrical fault.
- **Ivry-sur-Seine, France, 2009** - Multi-storey car park, 200 vehicles involved in fire, fifteen appliances engaged, use of aerial appliances as water towers.
- **Foregate Shopping Centre, Kilmarnock 26/12/08** - Multi-storey car park, fire on the third level with heat and smoke travel up to the fourth and fifth levels. 2 BA teams deployed, a total of 11 vehicles damaged, fire investigators found the cause to be accidental.
- **Monica Wills House, Bristol, England, 2006** - Multi-storey car park, fire involving 22 vehicles, one fatality due to smoke inhalation from occupancy above the parking facility.
- **Gretchenbach, Switzerland, 2004** - Underground multi-storey car park, fire involving up to one hundred vehicles, 7 firefighters killed during firefighting operations.



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What type of vehicle/s is/are burning here?



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What type of vehicle/s is/are/were burning here?



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What type of vehicle is burning here?
- Sharjah covered car park fire <https://www.emirates247.com/news/emirates/two-vehicles-catch-fire-in-sharjah-residential-tower-car-park-2015-05-26-1.591915>



THE INSTITUTION OF FIRE ENGINEERS

FOUNDED 1918 • INCORPORATED 1924

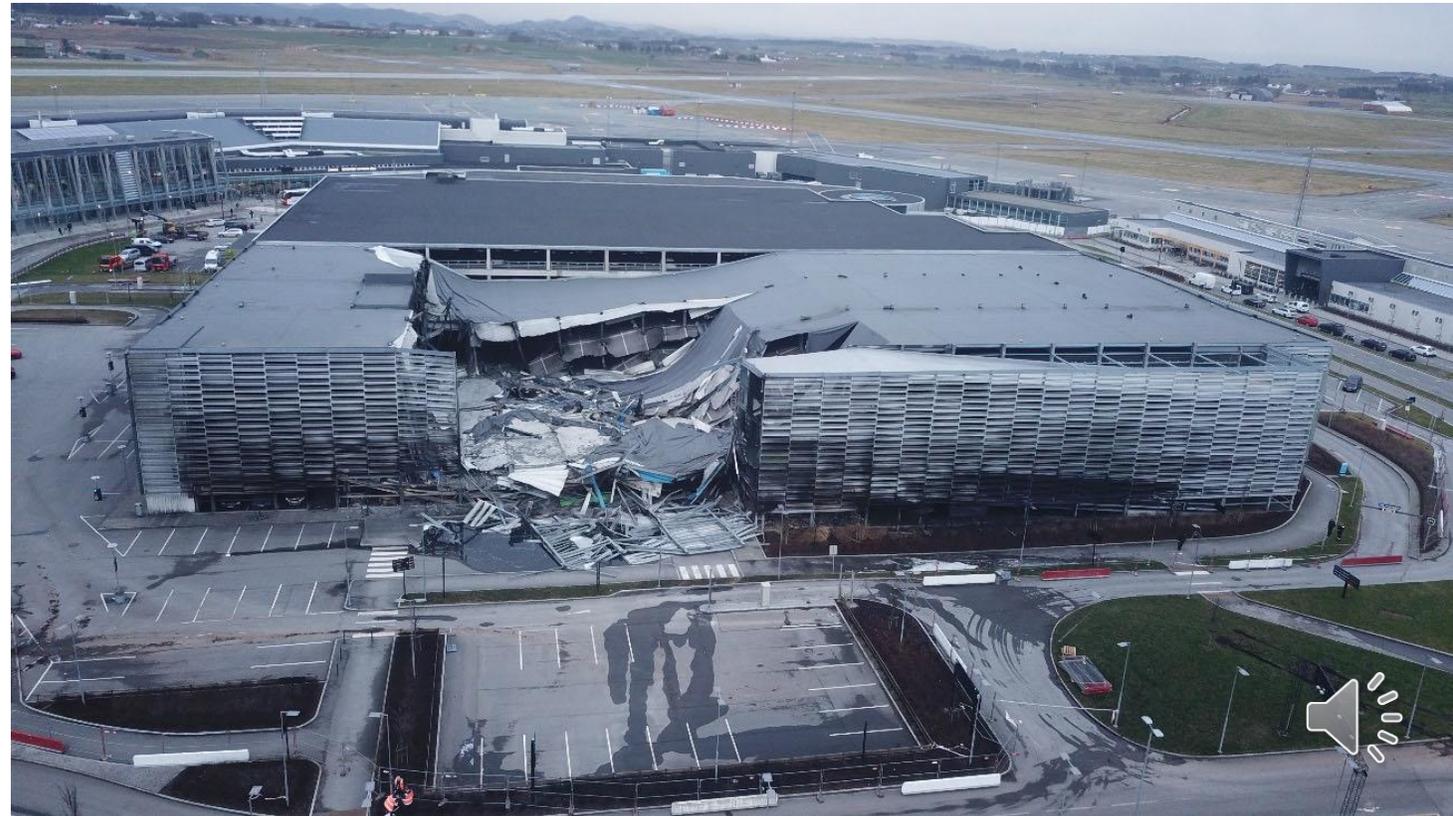
Firefighter Safety Special Interest Group (FFSSIG)



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What type of vehicle is burning here?
- Stavanger covered car park fire 7th January 2020

• Storesund, K., Sesseng, C., Mikalsen, R. F., Anders Holmvaag, O., & Steen-Hansen, A. (2020). Investigation of fire in multi-storey car park at Stavanger airport Sola 7th January 2020. [pdf & online]. Available at: <https://risefr.com/media/publikasjoner/upload/2020/rise-rapport-2020-43-evalueringbrannparkeringshusstavangerlufthavnsola.pdf> [Accessed 5th October 2020]. RI.SE



Is covered car park spread to external
façade an issue?.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do with regards to these types of fires before they happen?
- Learn and understand about the risks & issues as holistically as possible
- Any vehicle fire presents risks – have we (FRS's) got these weighed off correctly tactically & preventively e.g. risk info/risk reduction/technical fire safety etc....?
- How many covered car parks in your FRS area have sprinklers fitted?
- Immediate risks to firefighters? Risks to other highway/road/building users?
 - Explosions, toxins and contaminates..... Traditional vehicular environment was really bad (whether we like that or not), now its going up a level of bad toxin & contaminant wise.....
- Risk to the environment understood? Where is the firefighting run off going, City, Town, road? Check out some of the research Amon *et al.* 2019 via Brandforsk have been doing in relation to this.....consider surface, ground water and soil pollution not to mention the atmospheric plume considerations.....
- See Amon *et al.* (2019). Measuring impact of fire on the environment – Fire impact tool, version 1. [pdf]. Available here; <https://www.brandforsk.se/en/research-projects/2019/measuring-the-impact-of-fire-on-the-environment/> Brandforsk.
- Are 'we' making it worse or better when 'we' turn up to firefight.....??



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do tactically with regards to these types of fires when they happen?
- Suitable & effective information gathering... MDT 'CRASH' systems – registration capable??
- Effective resource make up, large volumes of water and significant monitoring & cooling likely – How many BA wearers likely to be used??.....
- Scene safety, suitable cordon, evacuation considerations?
- Use suitable PPE – always always Breathing Apparatus (BA) including when firefighting at a distance..... Consider smoke plume travel (in building or outside) – laden with additional toxins to 'normal' smoke
- Suitable built environment firefighting tactics/guidance combined with vehicle fire tactics, high rise, medium rise, basement, marine, tunnel?? Etc etc – do we need new tactics for covered open spaces e.g. car parks or other open plan areas e.g. offices?
- Isolate building services (electrics/gas etc), including charging points if relevant?

Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do tactically with regards to these types of fires when they happen?
- Is electrocution a risk when dealing with batteries involved in fire?
- Electric vehicles involved in fire presents a limited electrocution risk for firefighters (Smith, 2020., Vollmacher, 2020., & Vylund 2020).
- Battery cells are usually constructed '*inside stiffened and reinforced compartments or areas less prone to be affected in crash conditions*' (Bisschop, et al. 2019) with often '*watertight compartments*' (Unknown authors, 2020).
- High voltages from these batteries, why is it acceptable to use copious amounts of water then?? Why less voltage transfer??
- Tests show 'relative' safety from electrocution from this source while firefighting – PPE!!
- DO NOT CUT or any form of mechanical intervention into a battery pack – RTC or fire. This is asking for increased electrocution risk! Varying voltages.....more than enough to kill. Careful not to try and rip out for example.....
- Don't put straight stream directly or close up to battery units.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do tactically with regards to these types of fires when they happen?
- Assess water supplies.....attack with suitable flow rates
- Peers suggest at least 150 litres per minute (lpm) x 2 if possible starting from a distance
- Peers (e.g. Vollmacher, Vylund & Smith) and Unknown author 2020 suggest a distance of 25m &/or jet length at first, from an angle/at corners, moving in when deemed safer.....fire/explosion risks reduced..... Batteries not currently commonly observed to explode, LPG, CNG, LNG & Hydrogen does, as do struts, tyres some SRS etc.....
- Consider vehicle rolling as with any vehicle when involved in fire.....
- Why the distance??





Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks





Bestel uw gratis
SIM op lebara.nl

 **Lebara**



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do tactically with regards to these types of fires when they happen?
- Need too understand firefighting may be extended and require significant amounts of water. Battery units may require extensive cooling and monitoring – watertight structural battery compartments!!
- Ask where is the fire water going?? Volumes of water and potential toxin considerations – basements, lower floors, lift shafts, environment?
- Consider re-ignition of battery units – appears a relatively common issue
- Let it burn itself out tactics not really possible (or palatable) inside buildings or most car parks unless considerable cooling of surrounding area/structure of building near to fire.....
- May require mind set changes in some firefighting tactics.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do tactically with regards to these types of fires when they happen?
- Post fire considerations.....
- Decontamination – PPE, equipment, area affected by fire, suitable procedures??
- Debrief (hot), record, report and feedback into learning and development nationally or internationally, e.g. NOL/FFSDB or other mechanisms etc



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What do firefighters do tactically with regards to these types of fires when they happen?
- Why risk firefighters with entry to covered car park area or even some vehicles?
- Robotic firefighting?? Project GHOST no longer, is there a need? Alternatives?



THE INSTITUTION OF FIRE
ENGINEERS
FOUNDED 1918 • INCORPORATED
Firefighter Safety Special Interest Group

履带式机器人平台
防爆消防灭火侦察机器人



中信重工开诚智能装备有限公司
CITIC HIC KAICHENG INTELLIGENCE EQUIPMENT CO., LTD.



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What I didn't have time to cover in the presentation?
- More in depth look at alternative fuelled vehicles, (not just passenger cars) including more electric vehicle statistics and further current research
- The environmental agendas primarily based around Carbon reduction that is in turn driving the change in transportation or the changes to the built environment as a result of the same agendas
- No time to discuss the consequences of not thinking holistically about design, planning, construction, guidance, regulation and use of our built or transport environment and the environmental agendas that mean using modern methods of construction and/or propulsion even more in the future than now....
- No time to discuss the consequences of the lack of holistic or joined up thinking that has played out in various incidents that have killed people or nearly killed people, destroyed or damaged buildings or caused destruction and/or damage to the environment.....
- No time to discuss the widely varied physics & chemistry of lithium ion batteries, including flammable components (e.g. electrolytes such as propylene carbonate) or dissolved salts such as Lithium hexafluorophosphate) or the work of Bisschop et al. (2019) and Vylund et al. (2019) as a good sources of information on this..... <http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1317419&dswid=5310> and <http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1392421&dswid=-3539> respectively.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What I didn't have time to cover in the presentation?
- Not enough time to discuss various toxic and/or flammable gases (in addition to any 'normal vehicle fire smoke' emitted from Lithium batteries on fire such as Hydrogen Fluoride (HF), Phosphoryl Fluoride (POF3), Phosphor Pent Fluoride (PF5), Hydrogen (H2) etc. (Vylund, *et al.* 2019 & Larsson *et al.* 2018)
- No time to discuss other alternative fuelled vehicle risks and hazards LPG, CNG or Hydrogen fuel cell vehicles.....
- No time to discuss composite materials, such as Carbon fibre used in modern vehicle construction and the hazards these create when involved in fire for firefighters, members of the public or the environment
- No time to discuss the importance of having sprinklers in any building but especially in any covered car parks, not just in high rise scenarios.....(legislations/guidance changes?)
- No time to discuss the importance of technical fire safety and how this fits in with firefighting as well as helping to prevent fires happening in the first place through good building design, fire engineering, planning, construction, guidance, management and regulation.
- Didn't have time to discuss the failures of compartmentation, fire resistance, other passive or active fire protection measures, smoke spread through buildings, failures in fire resistance due to construction defects or post build fire related defects & faults being created



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- What I didn't have time to cover in the presentation?
- No time to discuss other firefighting tactics for electric vehicle fires such as dry powder (e.g. Strike spikes, piercing nozzles), large fire blankets, picking up burning vehicle/s and placing in tank of water and move to safer location, robotic firefighting or let it burn out strategies.....
- Other vehicle hazards such as exploding pistons/gas struts, tyres, contents of vehicles,
- Didn't have time to discuss the vast increase in other types of lithium ion batteries now being seen in use for other forms of transport (scooters, ships, aircraft, LGV/HGV, public transport) and energy storage systems around the World on an industrial scale and the future progression of smaller units to be installed into peoples homes in the future
- No time to discuss the differences in learning lessons across 'developed' nations to 'developing' nations and how fires affect countries prevention and response differently.....
- Didn't have time to discuss the importance of firefighters having a good understanding of principles of fire science and fire engineering such as heat release rates (HRR), heat flux, adequate flow rates, air flow/s and how important an understanding of the contemporary and modern built environment is in relation to materials used and behaviour in a fire.....
- Wish I had had more time to talk about the importance of the importance of organisations such as the IFE and its international sphere of influence, the NFCC, UL, UL FRSI, IFV, RI.SE, IFIW, Tall Buildings Fire Safety Network etc etc etc.
- Vehicle fires in other 'covered' settings, e.g. tunnels or ships or incidents such as the MV SI Salam Boccaccio 98 – 2006 Red Sea (1031 deaths) onboard a RoRo ferry that experienced a fire on the vehicle deck or various vehicle related tunnel fires.....



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- Review..... What we covered today.....
- Disclaimer
- Thanks and acknowledgements for my personal learning journey & colleagues such as Lotta Vylund (RI.SE), Kurt Vollmacher (Belgium) & Grant Smith (UKRO) who assisted....
- Is there a problem with electric vehicle fires and what is the problem?
- What do firefighters do with regards to these types of fires before they happen and when they happen?
- What I don't have time to cover in this presentation?
- References in following slides at end.....



Thankyou, any questions?

For more information please contact,
Project Lead Adam Course BSc(Hons) MIFireE
adam.course@avonfire.gov.uk

100
historic
years >



Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- References and sources of information
- Smith, G. (2015). Incidents involving electric vehicles – fire services college national challenge 2015. [pdf]. Also available at; <https://www.ukro.org/userfiles/files/nat2015/UKRO%20FSC%202015%20Handout%20EV.pdf> United Kingdom Rescue Organisation (UKRO).
- Vylund, L., Gehandler, J., Karlsson, P., Peraic, K., Huang, C., & Evegren, F. (2019). Fire-fighting of alternative fuel vehicles in ro-ro spaces. [pdf]. Also available at; <http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1392421&dswid=-3539> RI.SE.
- Bisschop, R., Willstrand, O., Amon, F., & Rosegren, M. (2019). Fire safety of Lithium-ion batteries in road vehicles. [pdf]. Also available at; <http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1317419&dswid=5310> RI.SE.
- Vollmacher, K. (2020). Personal communication based on Kurts research on subject of alternative energy vehicles and firefighting tactics in dealing with fires involving them. [PowerPoint]. Personal research.
- Moore, B., & Blythe, A. (2018). Kings Dock Car Park – 31st December 2017. [Prezi]. Merseyside Fire & Rescue Service (MFRS).
- Brandweeracademie. (2018). Liverpool carpark fire - Liverpool carpark fire Nick McCormack and Andrew Blythe. [online]. Available at; <https://www.youtube.com/watch?v=1iiimcAfKio> [Accessed 13th May 2019]. YouTube.
- Avon Fire & Rescue Service. (2019). 2006 – Monica Wills House. [Online]. Available at; <https://www.ife.org.uk/Firefighter-Safety-Incidents/2006-monica-wills-house/41922> [Accessed 22nd September 2019]. Institution of Fire Engineers – Firefighter Safety Database.
- Unknown author. (2018). Kings dock car park fire protection report April 2018. [pdf]. Merseyside Fire and Rescue Service (MFRS).
- Multiple contributors & authors. (unknown date). Project: Fires in enclosed car parks. [online]. Available at; <https://www.bre.co.uk/page.jsp?id=1524> [Accessed 20th May 2019]. BRE.

Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- References and sources of information
- Multiple contributors & authors. (unknown date). Project: Review and findings: A Review of Part B of the Building Regulations. [online]. Available at; <https://www.bre.co.uk/page.jsp?id=402> [Accessed 20th May 2019]. BRE.
- Multiple contributors & authors. 2010. Fire spread in car parks BD2552. [online]. Available at; <http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795610.pdf> [Accessed 20th May 2019]. BRE & Department of Communities and Local Government (DCLG).
- McKinnon, M., DeCrane, S., & Kerber, S. (2020). Four firefighters injured in Lithium-ion battery energy storage system explosion – Arizona. [pdf & online]. Available at; <https://ulfirefightersafety.org/posts/four-firefighters-injured-in-lithium-ion-battery-energy-storage-system-explosion.html> [Accessed 20 September 2020]. Underwriters Laboratory (UL) & UL FRFSI.
- Multiple contributors. (2014 to 2018). The Hampstead - 1508 Blodgett Street. [online]. Available at; <https://www.houstonarchitecture.com/haif/topic/30489-the-hampstead-1508-blodgett/> [Accessed 18th May 2019]. Houstonarchitecture.com.
- Unknown author. (2017). South Korea fire at public gym and sauna kills 29. [online]. Available at; <https://www.bbc.co.uk/news/world-asia-42442715> [Accessed 19th May 2019]. The BBC.
- Nam_miso. (2017). Untitled video. [online]. Available at; https://www.instagram.com/p/Bc9Wj0bl0RJ/?utm_source=ig_embed&utm_campaign=embed_video_watch_again [Accessed 19th May 2019]. Instagram.
- Unknown author. (2004). Seven Swiss Firefighters Die in Collapsed Parking Garage. [online]. Available at; <https://www.firehouse.com/lodds/news/10514192/seven-swiss-firefighters-die-in-collapsed-parking-garage> [Accessed 19th May 2019]. SWI Swissinfo.ch.

Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- References and sources of information
- Unknown author. (2005). No charges to be brought in firefighter tragedy. [online]. Available at; <https://www.swissinfo.ch/eng/no-charges-to-be-brought-in-firefighter-tragedy/4847960> [Accessed 19th May 2019]. SWI Swissinfo.ch.
- Unknown author. (2004). Seven firefighters killed. [online]. Available at; <https://www.swissinfo.ch/eng/seven-firefighters-killed/4222382> [Accessed 19th May 2019]. SWI Swissinfo.ch.
- Yonhap. (2017). State crime lab confirms Jecheon fire started from ceiling. [online]. Available at; <http://www.koreaherald.com/view.php?ud=20171223000049> [Accessed 20th January 2020]. The Korea Herald.
- Amon *et al.* (2019). Measuring impact of fire on the environment – Fire impact tool, version 1. [pdf]. Available here; <https://www.brandforsk.se/en/research-projects/2019/measuring-the-impact-of-fire-on-the-environment/> Brandforsk.
- Unknown authors. (2020). Instructions for lithium-ion battery firefighting in vehicle fires. [pdf & online]. Available at; <https://publikationen.dguv.de/regelwerk/publikationen-nach-fachbereich/feuerwehren-hilfeleistungen-brandschutz/feuerwehren-und-hilfeleistungsorganisationen/3926/fbfhb-024-instructions-for-lithium-ion-battery-firefighting-in-vehicle-fires?c=155> [Accessed 5th October 2020]. DGUV Fachbereich Feuerwehren Hilfeleistungen Brandschutz & Komm mit mensch.
- Sesseng., C. (2020). Major fire destroyed parking garage in Stavanger. [online]. Available at; <https://www.ri.se/en/our-stories/major-fire-destroyed-parking-garage-stavanger> [Accessed 5th October 2020]. RI.SE
- Storesund, K., Sesseng, C., Mikalsen, R, F., Anders Holmvaag, O., & Steen-Hansen, A. (2020). Investigation of fire in multi-storey car park at Stavanger airport Sola 7th January 2020. [pdf & online]. Available at; <https://risefr.com/media/publikasjoner/upload/2020/rise-rapport-2020-43-evalueringbrannparkeringshusstavangerlufthavnsola.pdf> [Accessed 5th October 2020]. RI.SE

Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- References and sources of information
- Philly FireFeed. (2018). 10-19-18, Harrah's Casino Parking Garage Car Fire. [online]. Available at; <https://www.youtube.com/watch?v=Sc1ipNOxHSM> [Accessed 13th May 2019]. YouTube.
- Drew, J. (2018). Houston Fire Department 1508 Blodgett Street, Apartment Fire. [online]. Available at; https://www.youtube.com/watch?v=_yNznPAY5zk [Accessed 18th May 2019]. ABC 13.
- Unknown author. (2016). 45 apartments damaged in museum district fire. [online]. Available at; <https://abc13.com/news/45-apartments-damaged-3-injured-in-museum-district-fire/1596523/> [Accessed 18th May 2019]. ABC 13.
- Hindustan Times. (2019). Aero India Show: Massive fire near venue, almost 300 cars burned. [online]. Available at; <https://www.youtube.com/watch?v=w8t7sJsBKrY> [Accessed 13th May 2019]. YouTube.
- McKirdy, E. (2017). South Korea fire: 29 killed as flames rip through Jecheon building. [online]. Available at; <https://edition.cnn.com/2017/12/21/asia/south-korea-building-fire/index.html> [Accessed 19th May 2019]. CNN.
- What you haven't seen. (2017). NATURAL GAS BUS ON FIRE VENTS SIXTY-FOOT HORIZONTAL FLAMES. [online]. Available at; <https://www.youtube.com/watch?v=vHf2o9oVY24> [Accessed 10th September 2020]. YouTube. Originally from the Dutch Safety Board.
- RT. (2018). USA: 21 injured as fire engulfs multi-storey car park in New York City. [online]. Available at; <https://www.youtube.com/watch?v=OWCGNjoSW8g> [Accessed 21st September 2019]. YouTube.
- CBS New York. (2018). Kings Plaza Garage Fire May Have Been Intentional. [online]. Available at; <https://www.youtube.com/watch?v=bOJXrtT5iEM> [Accessed 16th October 2019]. YouTube.
- CBS New York. (2018). 7-Alarm Fire Burns Parking Garage In Brooklyn. [online]. Available at; <https://www.youtube.com/watch?v=gzMpg2UzkdY> [Accessed 16th October 2019]. YouTube.
- CBS New York. (2018). Raw Video: Kings Plaza Parking Garage Cars On Fire. [online]. Available at; <https://www.youtube.com/watch?v=73nYEcc-7nM> [Accessed 16th October 2019]. YouTube.
- YTN News. (2017). Large fire in Jecheon sports center kills at least 29 / YTN. [online]. Available at; <https://www.youtube.com/watch?v=HJD7tk0Bz30> [Accessed 19th May 2019]. YouTube.

Tactics for Dealing With Electric Car Fires in High Rise and/or Covered Car Parks

- References and sources of information
- Black Helmet Films. (2018). WEAR YOUR PPE!! Fireman caught in explosion. [online]. Available at; <https://www.youtube.com/watch?v=IK1uUSqq7rk> [Accessed 19th May 2020]. YouTube.
- ViralHog. (2018). Toyota RAV4 Bursts into Flames || ViralHog. [online]. Available at; <https://www.youtube.com/watch?v=QPToAvwo4W0> [Accessed 19th May 2020]. YouTube.
- Per Andre Naustvik. (2015). Firefighters extinguishing a car fire goes wrong. [online]. Available at; <https://www.youtube.com/watch?v=NsYOTERciOU> [Accessed 13th May 2020]. YouTube.
- The Good Smiley. (2016). Engine 53 Arriving on scene to Car Fire Fully involved 5/9/16. [online]. Available at; <https://www.youtube.com/watch?v=VLgKgC1LtvA> [Accessed 20th September 2020]. YouTube.
- GTFD8215. (2016). Firefighter Close Call - Catastrophic Gas Strut Failure in Car Fire. [online]. Available at; <https://www.youtube.com/watch?v=N9ugWixB15s> [Accessed 20th September 2020]. YouTube.
- Jason Thomas. (2010). Evansville Indiana Close Call Magnesium Explosion Car Fire. [online]. Available at; <https://www.youtube.com/watch?v=IxRJIOJqP3I> [Accessed 20th September 2020]. YouTube.
- Australia Wei's Technology Pty Ltd. (2017). Explosion-Proof Fire Fighting Robot Field Test- September 2016. [online]. Available at; <https://www.youtube.com/watch?v=gH4rPVHxfhA> [Accessed 15th September 2020]. YouTube.
- Mashable. (2019). This Robot Helped Firefighters Extinguish the Notre-Dame Fire. [online]. Available at; <https://www.youtube.com/watch?v=109lZVuI5Dc> [Accessed 25th September 2020]. YouTube.