WPI

International Fire Conference & Exhibition Malaysia

SUSTAINABLE FIRE SAFETY TAKING FIRE SAFETY IN CAR PARKS TO A NEW LEVEL

OUTLINE

- Sustainable Design
- Changes Impact & Consequence
- Fire and Life Safety Challenges
- Analysis and Research
- Findings and Solutions
- Conclusions –Road map for innovation

SUSTAINABLE DESIGN

- **What is Sustainable Design**

Definition :

A design method that aims for meeting the objective considering of economic , sociological and ecological factors

CHANGES
IMPACT & CONSEQUENCE

AUTOMOBILE INDUSTRY TREND

Alternative Fuel vs Traditional Fuel

Alternative Fuel :

plug-in hybrid electric vehicles (PHEVs)

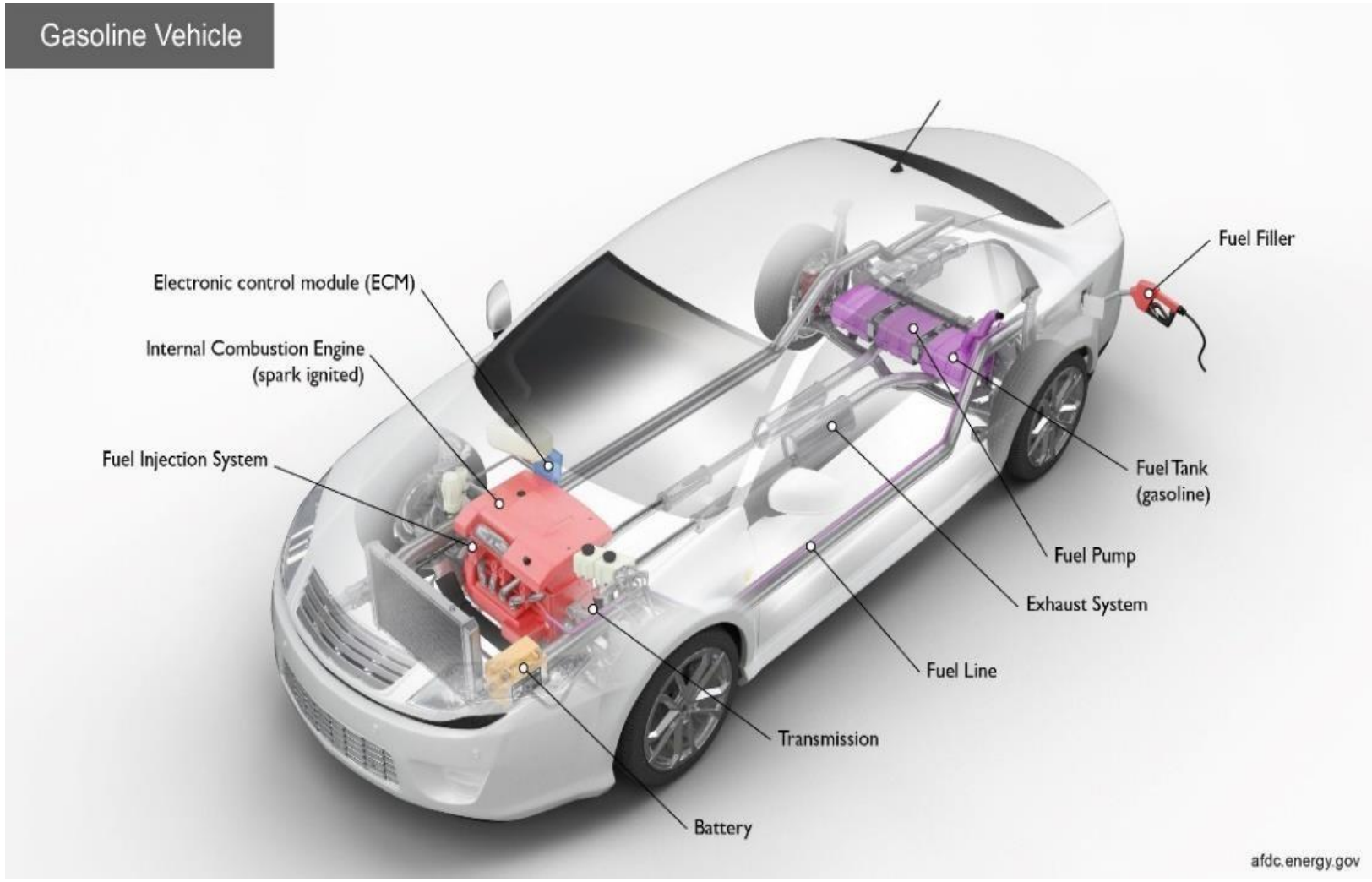
fully electric vehicles (EVs),

hydrogen fuel cell

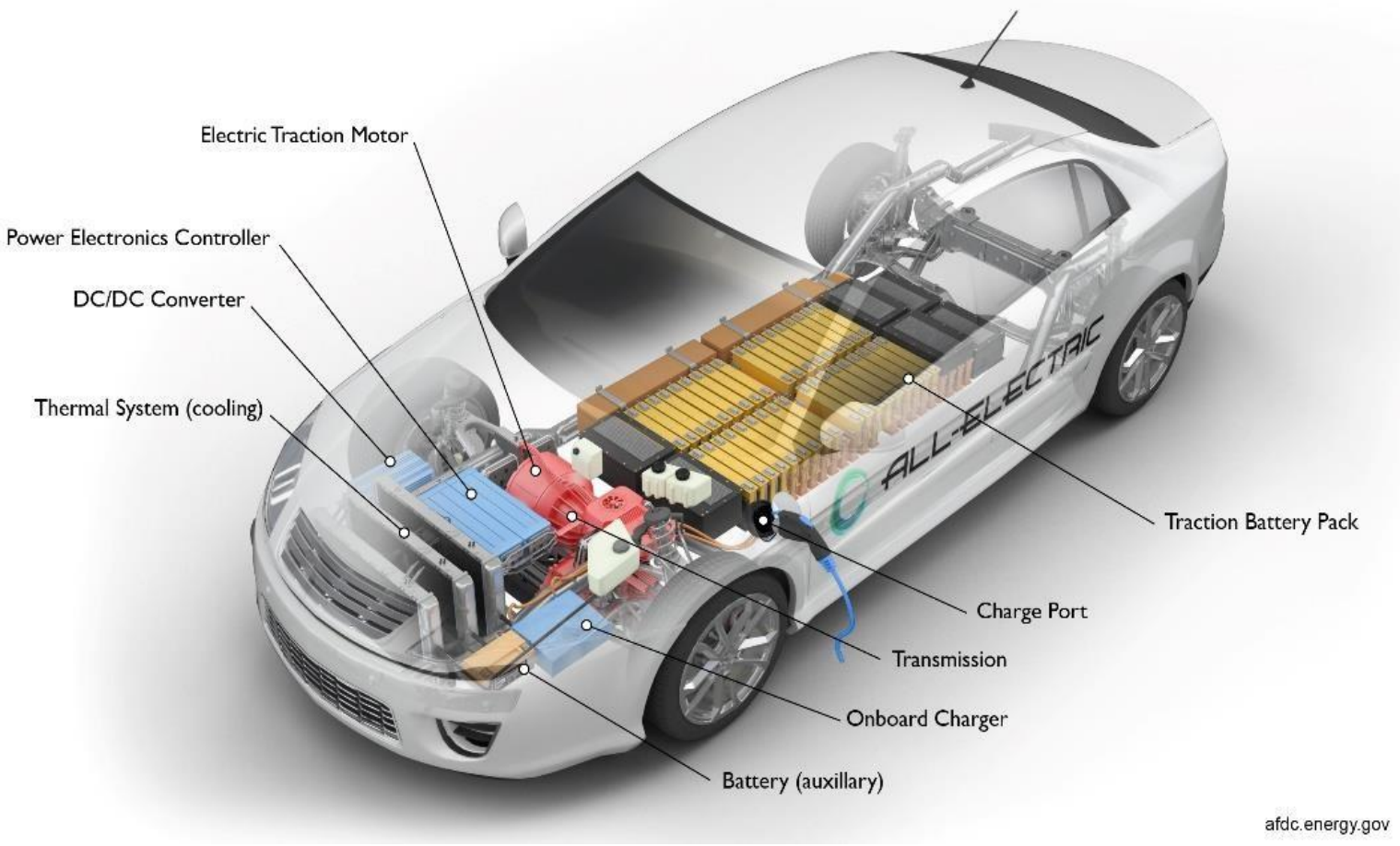
Traditional Fuel -internal combustion engines (ICE)

AUTOMOBILE INDUSTRY CHANGE

Larger vehicles with increased use of polymers and other combustible materials in construction


Gasoline Vehicle
Electronic control module (ECM)
Internal Combustion Engine (spark ignited)
Fuel Injection System
Fuel Filler
Fuel Tank (gasoline)
Fuel Pump
Exhaust System
Fuel Line
Transmission
Battery
afdc.energy.gov

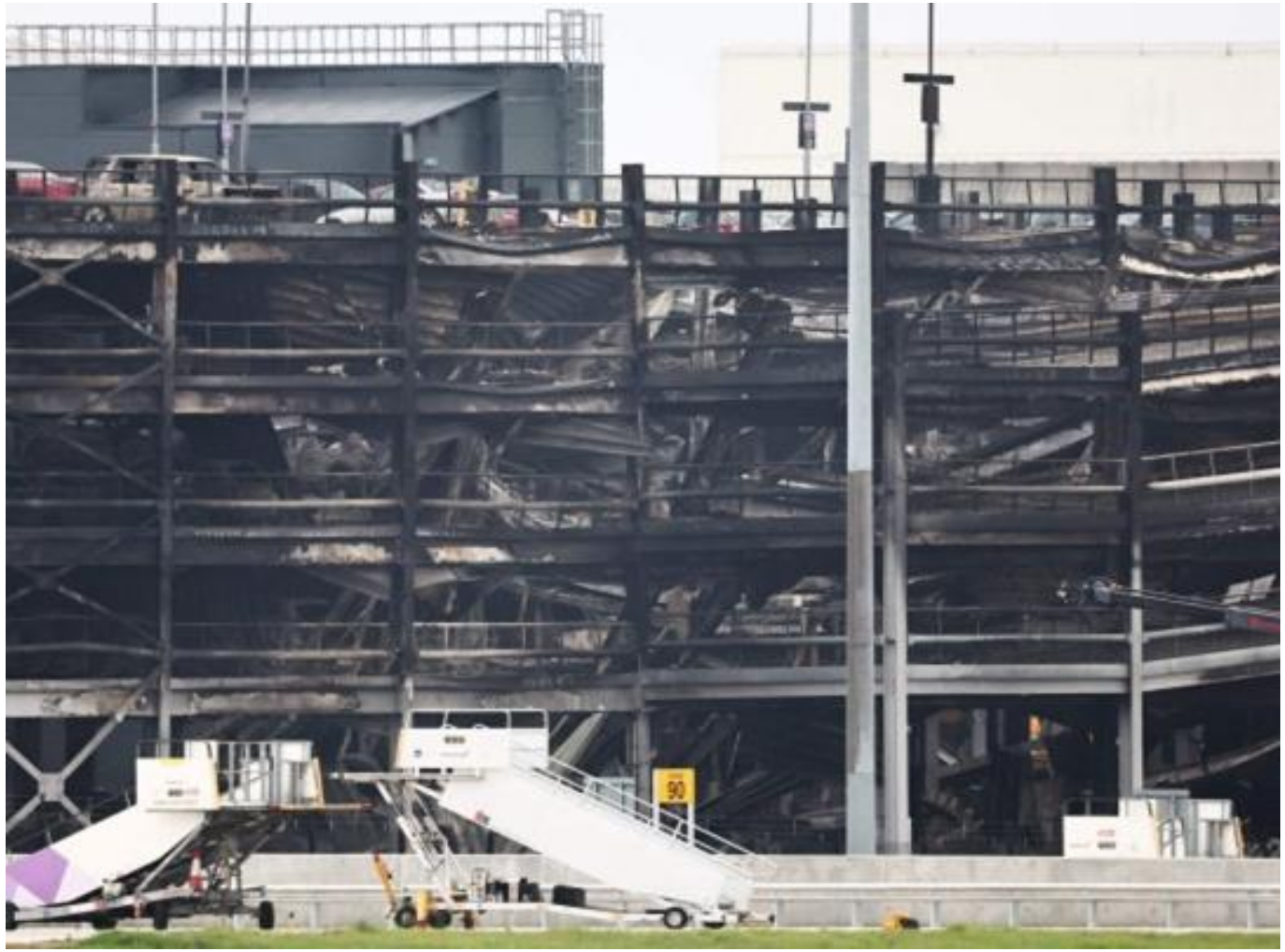
All-Electric Vehicle



FIRE AND LIFE SAFETY CHALLENGE

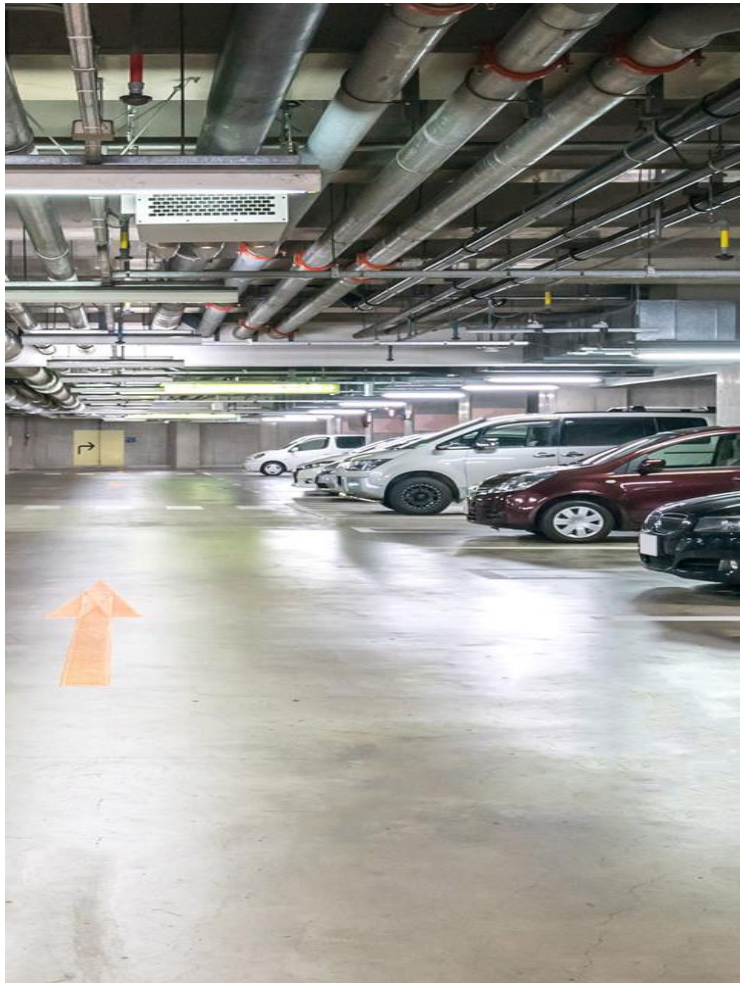
- Materials often ignite easier, contain more chemical energy per volume, and burn more intensely and/or longer than legacy materials

Layout: PhotoCaption



CAR PARKING GARAGE DESIGN

- Stand-alone construction or attached to other occupancies
- Car stacking mechanisms, where hydraulic systems lift two or more cars above each other, effectively inside the footprint of a single car



Relatively large, open spaces, little in the way of internal separations. Generally, the floor-to-ceiling height is less than other building types and can be as low as 7.22 feet (2.2 meters). The structural capacity of the garage must be sufficient to support its own weight plus the weight of the vehicles, etc. The design needs to consider factors such as the movement of vehicles to and from the parking bays, the size of the bays to accommodate the vehicles, plus space to allow passengers with different physical capabilities to exit and enter the vehicles

FIRE RISK

- Materials used in modern vehicles present a significant increase in energy content during a fire, both in intensity and duration, compared to older vehicles

- Placement of multiple vehicles in a vertical configuration is advantageous for rapid fire spread.

ANALYSIS AND RESEARCH

- Case studies analysis
- Code and standard research

CASE STUDY
(LESSONS LEARNED)

- The incident investigation reported that the fire spread rapidly to several vehicles, aided by both strong winds (around 11-12 m/s with 19 m/s gusts) and the leakage of fuel from burning vehicles.

- The carpark consists of three distinct parts, each using different construction methods and opened in 1991, 2001 and 2014 respectively. The fire broke out in a diesel vehicle on the ground floor of the central portion of the building (constructed in 2001), which was a concrete structure using elements with a fire resistance level (FRL) of 60 minutes.

- The newest portion of the carpark was constructed from steel primary structure and a composite (steel and concrete) deck. The fire strategy specified 15 mins of load-bearing capacity for the columns and 10 mins for the beams, citing the BHP Steel research (discussed in Section 4.3) as evidence of suitability. After around two hours, parts of the 2014 building down-wind of the fire origin location collapsed.

- Whilst there were no life safety impacts, there were significant financial and operational / business continuity impacts: several hundred vehicles were damaged, and the airport was shut down for over a day.

- Norway had the most electric vehicles on the road per capita in the world at the time, however the investigation report stated that “electric vehicles did not contribute to the fire development beyond what is expected from conventional vehicles”, despite initial media reports falsely stating the fire originated from an EV

CASE STUDY 2

- The carpark measured approximately 77 m x 64 m (using a floorplan reproduced in the MF&RS's report) [63], and had eight storeys (G+7). It complied with local building regulations for open-sided carparks. On the afternoon of the fire (on New Year's Eve) an event was being held at the arena, therefore many vehicles were present in the carpark. The fire originated on Level 3.

- It is thought that the high patronage contributed to the quick spread of the fire from one vehicle to another. Additionally, it took a relatively long time for the alarm to be raised. The first emergency call was 13 minutes after the first signs of fire. Some of the first occupants to witness the fire did not raise the alarm

- The building had a 15-minute FRL. Remarkably, the concrete structure remained standing after the fire, even though there were clear signs of explosive spalling, floor failure and structural element damage .

- Suggesting that fire safety guidance should be revisited, particularly where there is a carpark beneath a block of flats or offices or a timber-framed building. The MF&RS protection report stated that the fire could have been contained if a sprinkler system had been installed

CASE STUDY 3

- The fire occurred in the underground carpark of a newly constructed residential care home. The construction complied with the Building Regulations; the care home was sprinklered, but the carpark was not. The fire destroyed 22 cars and subsequently spread to the upper residential levels through external windows. One fatality was caused by smoke inhalation and 60 residents had to be evacuated. It is believed that the residential sprinkler system delayed the fire spread into the residential area . Extensive spalling of the carpark concrete was observed.

CASE STUDY 4

- The fire initiated in a garden, ignited by a cigarette butt. Several factors contributed to the fast fire spread in this incident, despite being an external parking area. Contributing factors included elevated ambient temperature, strong winds, a higher-than-normal carpark occupancy due to high patronage of the site, small separation between parked cars, as well as the presence of large quantities of mulch and vegetation in the surroundings, and high bushfire activity in the surrounding area, which limited the fire brigade response capacity. The control of the fire was hindered because of the restriction to not use foam as an extinguishing agent, considering the environmental damage to surrounding wetlands.


huber

Fire investigation revealed there where errors in the structural calculations for the structure and on the construction resulting in an overload of soil and a decreased punching shear capacity, which caused the roof to collapse. 10 firefighters were trapped. Three were rescued, but seven died .Smoke spread to the stairs leading out of the building on top of the carpark. A technical defect in a parked car was thought to have initiated the fire.

Case Study 5

- A fire started within an electric vehicle (EV) when it was charging in an underground carpark. The carpark was relatively new. The fire broke out in the middle of the night and the entire EV became involved, including the batteries [73]. “The position of the e-parking spaces apparently prevented worse things from happening”.
- The carpark was provided with a suppression system; sprinklers designed to Ordinary Hazard 2 (OH2) criteria as per European standards (with an application density of 5 mm/min over an area of operation of 144 m^2). Whilst temperatures above the fire were high enough to cause minor spalling, the suppression system was effective at controlling the fire until the fire brigade arrived.

FIRE INCIDENTS

LOCATION	YEAR	VEHICLES INVOLVED	INJURIES / FATALITIES	TYPE	DESCRIPTION
Oaklands Park (Australia) [75]	2023	5	None	Open air	**Two vehicles destroyed, another three damaged.**
Bankstown (Australia) [76]	2023	6	1 injury (smoke)	Open	**Fire controlled by early intervention of fire and rescue services.**
Ravensburg (Germany) [73]	2021	4	None	Closed	**EV caused the fire. OH2 sprinkler system controlled the fire, before brigade suppressed.**
Märsta (Sweden) [77]	2021	200	None	Closed	**Roof collapsed, building demolished.**
Fremantle (Australia) [78]	2021	4	1 injury (smoke)	Closed	**Fire in the underground carpark of a residential block. Did not cause any structural damage.**
Geraldton (Australia) [79], [80]	2021	7	None	Open	**Caused by an electrical fault. 125,000 AUD damage.**
Warsaw (Poland) [81]	2020	22	None	Closed basement	**150 residents evacuated. Reoccupation delayed hours by high temps. Considerable spalling.**
Epe (Netherlands) [82]	2020	1	None	Closed	**EV fire in shopping centre carpark controlled by sprinkler system.**
Gaithersburg (MD, USA) [54]	**2020**	**4**	**None**	**Open**	Significant damage – up to 150,000 USD in losses.

FIRE INCIDENTS (CONTINUED)

Richmond (VA, USA) [54]	**2019**	**3**	**None**	**Closed basement**	The fire destroyed one vehicle and heavily damaged two others. Heavy smoke spread over several floors of the structure.
Cork (Ireland) [83], [84]	2019	60	None	Open	**Fire spread to 60 cars. Prompt evacuation prevented injuries. Part of the structure unsafe and demolished. 30M EUR in damage.**
Chicago (IL, USA) [54]	2019	4	None	Open	**Fire in a 10-storey carpark.**
Houston (TX, USA) [54]	2019	2	None	Open	**Smoke spread past nearby high-rise buildings.**
Hong Kong [85]	2019	1	None	Closed	**Shopping mall carpark EV fire.**
Shanghai (China) [54]	2019	3	None	Closed	**EV was the ignition vehicle.**
Newark (USA) [54], [86]	2019	17	None	Open air	**Caused by a faulty alternator at roof level.**
Chadstone (Australia) [79], [87]	2018	11	None	Closed	**Fire in a shopping centre carpark. Controlled partial evacuation of the shopping centre.**
Liverpool (UK) [62], [63], [64], [65], [67]	2017	1400	None	Open	**See detailed summary above.**
Jecheon (South Korea) [88]	**2017**	**Unknown**	**29 deaths, 36 injuries**	**Closed**	Fire began above the carpark. Slab failed, and cars below became involved. Fire then spread through eight storeys above (fitness complex).

FIRE INCIDENTS (CONTINUED)

Edinburgh (UK) [89]	**2014**	**21**	**None**	**Open air**	External airport carpark.
Odense (Denmark) [90]	2014	10	None	Open air	**Residents of apartments above evacuated.**
Sydney (Australia) [70]	2013	80	None	Open air	**See detailed summary above.**
Markenhoven (Netherlands) [91]	2013	5	None	Open	**Suppression system and the fire service controlled and extinguished fire.**
Appelaar (Netherlands) [91]	2010	26	None	Closed	**Structural damage led to repairs that took four months.**
Stansted (UK) [92]	2010	24	None	Open air	**High winds caused the flames to spread rapidly.**
Bristol (UK) [68], [69]	2006	22	1 fatality	Open basement	**Fire in a lower ground floor carpark which spread to the care home above.**
Gretzenbach (Switzerland) [71], [72]	2004	100	7 fatalities, 3 injuries	Closed basement	**Parts of the concrete ceiling fell down and buried 10 firefighters during the extinguishing work.**
Schiphol (Netherlands) [93]	**2002**	**90**	**None**	**Open**	Caused by arson. Cars were only 40 cm apart. Some beams collapsed. 5M EUR damage.

CURRENT FIRE PROTECTION DESIGN REQUIREMENTS

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Car Parking Garage Design

Structural protection

Passive Fire Protection

Active Fire Protection

COUNTRY	REGULATION / GUIDANCE COVERED	PUBLICATION YEAR
Australia	NCC BCA Volume One	**2022**
New Zealand	C/AS2	**2020**
England and Wales	Approved Document B – Volume 1 & 2	**2022**
Scotland	Non-Domestic Technical Handbook	**2022**
United Kingdom	BS 9999	**2017**
Ireland	Technical Guidance Document B	**2020**
Germany	Muster einer Verordnung über den Bau und Betrieb von Garagen (Muster-Garagenverordnung M-GarVO) Model Regulation on the Construction and Operation of Garages (Model Garage Regulation M-GarVO	**2020**
Netherlands	**Until 31 Dec 2023: Bouwbesluit 2012, NEN 6098, municipal guidelines;** **From 1 Jan 2024: Besluit Bouwwerken Leefomgeving, NEN 6098**	2023 2024

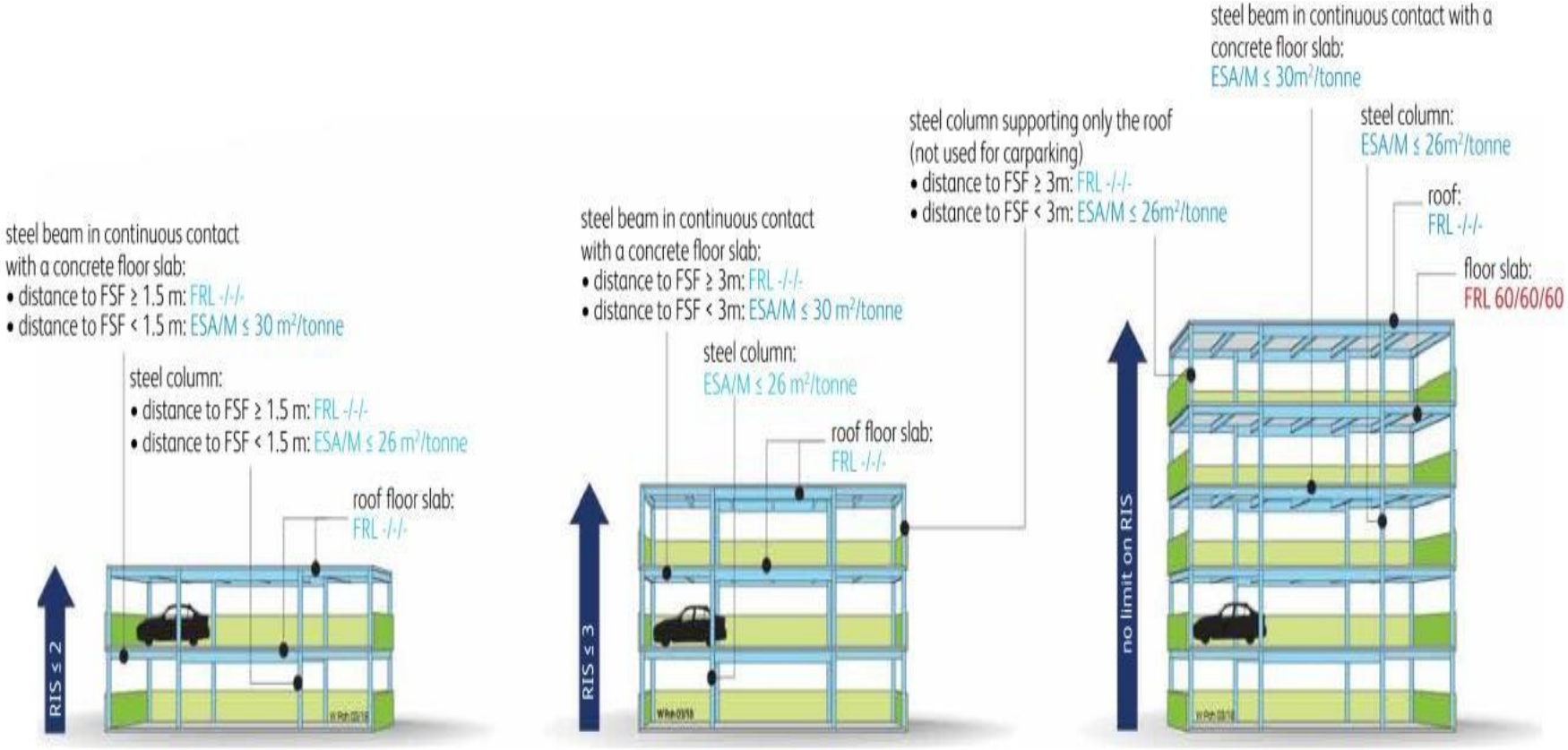
COUNTRY	REGULATION / GUIDANCE COVERED	PUBLICATION YEAR
Denmark	Bilag til BR18's vejledning til kapitel 5 – Brand. Bilag 9 - Præ-accepterede løsninger - Bygningsafsnit med garageanlæg	**2019**
United Arab Emirates	UAE Fire and Life Safety Code	**2018**
Hong Kong	Code of practice for fire safety in buildings 2011 Code of practice for minimum fire service installations (FSI) and equipment AND inspection, testing and maintenance of installations and equipment, September 2022 (FSI code) FSD Circular letter No. 4/2020 Additional fire safety requirements for car parking facilities installed with electric vehicles charging facilities.	**2011** **2022** **2020**
Singapore	Code of Practice for Fire Precautions in Buildings 2023	**2023**
United States	International Building Code (IBC)	**2021**
United States	**NFPA 5000 & NFPA 88A**	2021

- Open and Enclosed Parking Garages Throughout NFPA 88A, a distinction is made between parking structures with an open configuration and those with an enclosed configuration, as defined in section 5.5 (2019 ed). These are defined by the fraction of wall surface that is open directly to the outside. An open parking structure is one with “uniformly distributed openings on two or more sides”, with at least 20% of the total area of the outside perimeter and interior walls being open. The openings also must be distributed over at least 40% of the length of the building perimeter, or on two opposing sides.

STRUCTURE FIRE PROTECTION

- In the United States, the general structural fire resistance guidelines refer to requirements and categories in NFPA 220, Standard on Types of Building Construction [NFPA, 2018]. Fire Resistance and Compartmentation 12 3.7
- Per section 5.1.2 of NFPA 88A, open parking structures shall only be constructed of materials with type I or II fire resistance, meaning only noncombustible or limited combustible materials. Unlimited height and floor areas are allowed if the structure is Type I, II (222), or II (111)

AUSTRALIA NATIONAL CODE



Type C Construction (BCA Spec C1.1, Table 5.2)

Type B Construction (BCA Spec C1.1, Table 4.2)

Type A Construction (BCA Spec C1.1, Table 3.9)

PASSIVE FIRE PROTECTION

- Fire Separation
- Fire Compartmentation
- Egress path

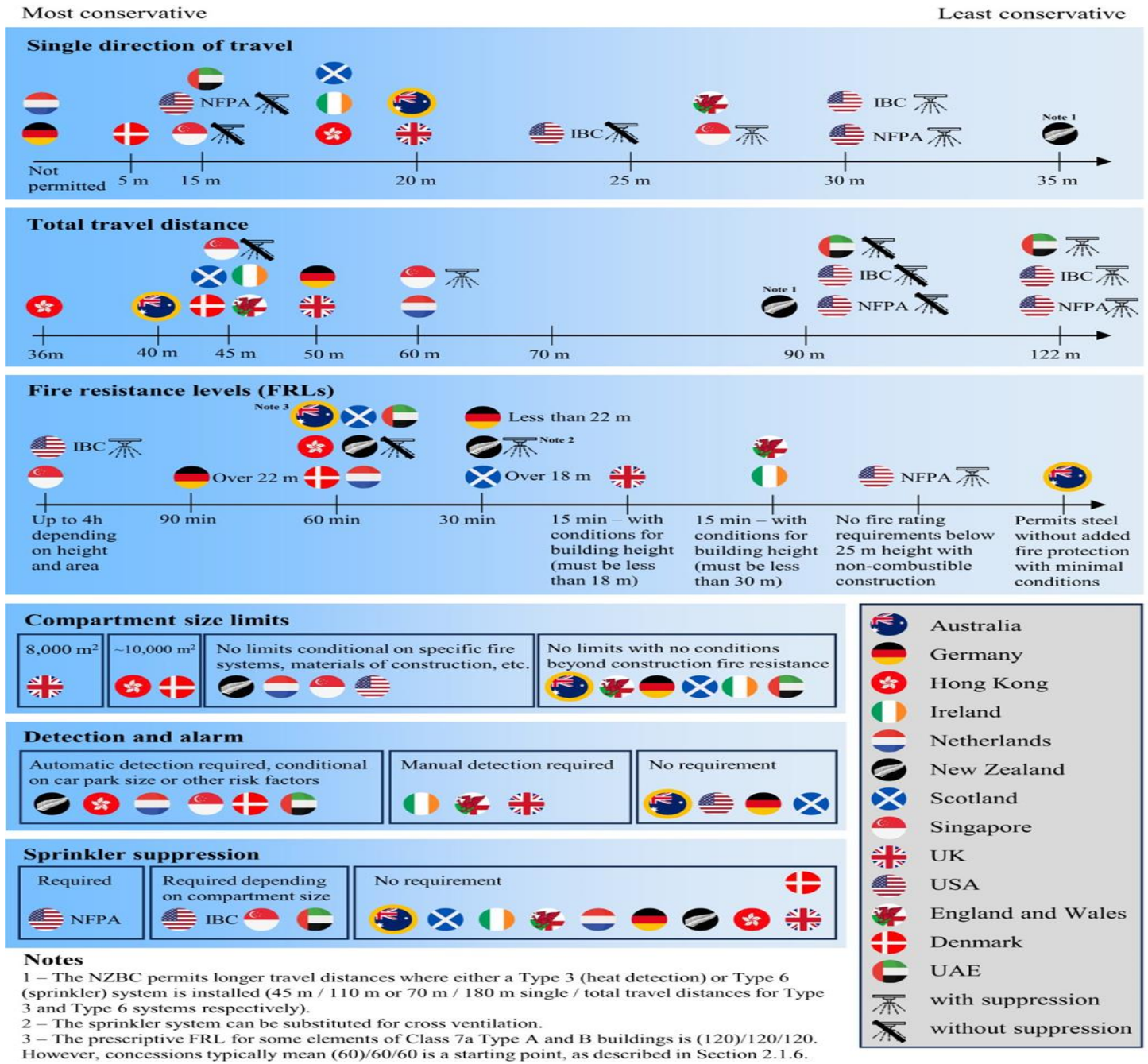
Fire Separation

Current legislation states that car park premises must be provided with a means of ventilating the area, and be separated from other parts of the premises with fire-resisting construction

Fire Compartmentation

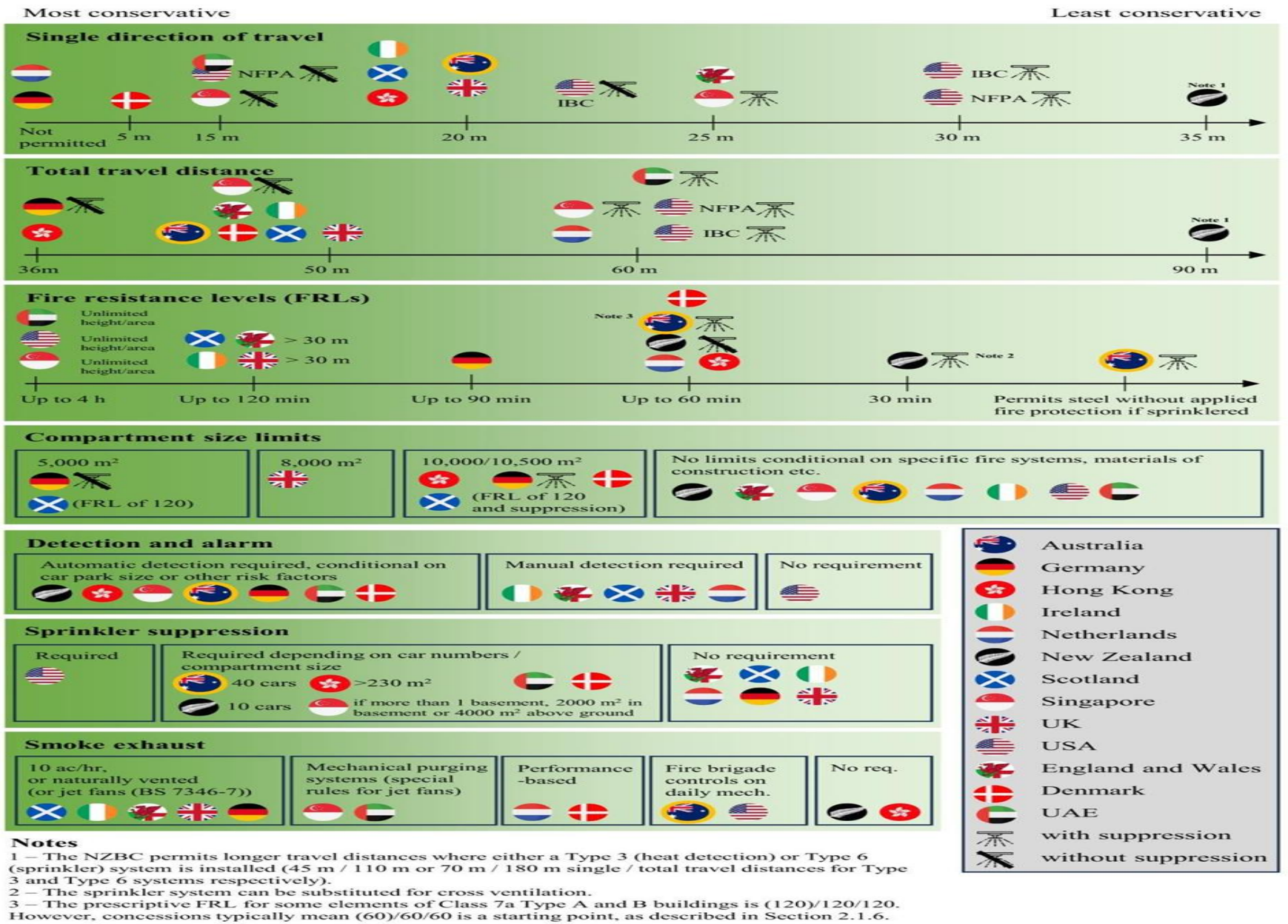
China : 2000-4000 sqm

United States : Based on the Function



Notes

1 – The NZBC permits longer travel distances where either a Type 3 (heat detection) or Type 6 (sprinkler) system is installed (45 m / 110 m or 70 m / 180 m single / total travel distances for Type 3 and Type 6 systems respectively).
2 – The sprinkler system can be substituted for cross ventilation.
3 – The prescriptive FRL for some elements of Class 7a Type A and B buildings is (120)/120/120. However, concessions typically mean (60)/60/60 is a starting point, as described in Section 2.1.6.



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ACTIVE FIRE PROTECTION

- Fire Suppression
- Fire Detection
- Smoke control System

FINDINGS AND OBSERVATIONS

- Plastic material growing
- Ideal space for autonomous innovation
  - Self-park within carparks

    Alternative Fuel
  - EV - Thermal runaway – a phenomenon which can potentially result in sudden, extensive vehicle fires)
  - EV fires are more difficult to extinguish due to the Lithium-ion batteries
  - Many new parking garages include photovoltaic panels and electric charging stations

FINDINGS AND OBSERVATIONS

- Hydrogen fuel cell vehicle's storage tank rupture could lead to a vertical jet flame with potential damage of structural failure (building collapse) invisible for visual detection and threat to fire fighters or other first responders
- EV fire extinguish tactics water supply and containment of the fire
- Stacking car parking and condensed space questioning the sprinkler system effeteness

FINDINGS AND OBSERVATION

- Environmental elements, such as wind conditions at the time of the fire, also can potentially affect fire growth rates and spread. In open parking garages
- Enclosed parking garages, the requirement for sprinkler protection appears adequate to control a vehicle fire until fire-fighting personnel arrive
- The lack of any requirements in fire codes for active protection systems in open parking structures, and trends of larger vehicle widths and tighter parking spaces in garages suggest that large, devastating fires in these structures could become increasingly common

ROAD MAP FOR INNOVATION

- Fire department response is to remain the sole means of fire control and extinguishment in these garages, a method to ensure rapid fire detection and fire department notification should be evaluated and possibly mandated
- Further testing is also necessary to determine the minimum response times required to control a vehicle fire
- Open garages, environmental effects such as cold weather and wind, can cause significant delays on the activation of bulb or fusible link sprinklers and further evaluation of these effects is warranted.

ROAD MAP FOR INNOVATION

- Full-scale testing with a range of configurations should be performed to evaluate the spread dynamics and critical parameters
- Evaluate the current code standards and determining the right level for the fire protection level
- Global cooperation for technology exchange and research sharing

Q & A

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Thank You