Whilst alternative fuels bring many benefits, are the risks fully appreciated by the events industry and are we doing enough to control them?

Introduction: Sustainability, decarbonisation and climate change policies are at the forefront of the minds of both the public and governments. We are likely to experience a significant shift in personal transport policy from internal combustion engines (ICE) to electrical vehicles (EV). By 2030, the sale of internal combustion engine (ICE) propelled cars will be banned in the United Kingdom, with other countries following suit. More than a quarter of the new car market in the UK is for vehicles with a battery, with sales increasing by 186% in the last year. Clearly EV's are not restricted to cars - the sales of electrically supported cycles and scooters are also rising exponentially. Hydrogen fuel cell (HFC) technology is becoming part of our everyday lives for example in Aberdeen, the UK's oil city, the council's buses and civic car fleet are powered by HFC's. Within the events industry, hybrid generators running on biofuel, which in turn charge an onboard battery are becoming ever more commonplace. But what are the risk associated with alternative fuels – are they inherently more dangerous than ICE powered vehicles and associated technologies? Due to batteries being in your watch, phone, headphones and laptops, the risk has largely been seen as negligible. But is it? In this article we look at the growth of alternative fuel technology in everyday life, its safety implications, and how this could impact event operations and infrastructure.

Fire Risk: In normal operation, EVs might not seem to be more inherently dangerous than their ICE cousins. The world's firefighting services, however, are finding that may not be the case when one of these vehicles catches fire. The component materials of the lithium-ion batteries (LIB) within them means that the fires are very energetic and traditional firefighting techniques do not necessarily work. 'Fires' in EV's is somewhat of a misnomer. Chemically, a 'thermal runaway' is a chain reaction propagating within a battery cell that can be exceedingly difficult to stop once it has started. It occurs when the temperature inside a battery reaches the point that causes a spontaneous chemical reaction to occur. For example, in April last year a crashed Tesla Model S took eight fire fighters seven hours to put out using 28,000 gallons of water – a typical month's usage for that fire department. It begs the question what would an EV fire look like in the loading bay or underground car park of a typical event venue? Risk perception on LIB's is now changing. In December 2021 Transport for London announced a ban on all e-scooters on their services and premises specifically due to the batteries catching fire.

Statistically, the estimated failure rate (and therefore risk of combustion) of an individual battery cell is one in ten million. However, when you consider that an average EV contains approximately 7,000 cells, the risk increases significantly. Data from the London Fire Brigade suggests an incident rate of 0.04% for ICE car fires, but the rate for EVs is more than double that at 0.1%. Although it is not clear whether EVs are more likely than ICE vehicles to catch fire, it is commonly accepted that the consequences are potentially more disastrous and significantly more difficult to control. Either way, it follows that as the proportion of EV's to ICE modes of transport increases exponentially over the next few years, then so the statistical risk of an EV fire will increase exponentially.

Sporting applications for EV's in Formula E, Moto GP, Extreme E and E Touring cars are clearly increasing the speed of development of EV's, but can we compare the use of EV's in sport to the increase in sales of road going EV's? Probably not. EV's in motorsport are managed by teams of highly qualified engineers monitoring the battery cells in real time during races. This clearly does not happen in a standard roadgoing EV's, therefore it is fair to conclude that real world's risks of an EV used on the highway cannot be compared to a sporting application of EV technology. Notwithstanding, just as Formula 1 racing has led to the development of safety technology for road vehicles so Formula E could help to improve safety in EV's.

Studies by the Federation International Automobile (FIA) indicated that maintaining a state of charging of the battery significantly mitigates the risk and EV manufacturers should consider a safe charging mode that ensures the battery is in the safest state possible (30%). It is likely early detection of an increase cell-pack temperature will be key. Manufacturers can assist by developing a way of plugging the vehicles into a monitoring system utilising the batteries' internal sensors. Traditionally we rely on detecting smoke or heat to indicate a fire but with an LIB that may be too late. We therefore need to understand whether battery technology can reduce the probability risk of a thermal runaway to an acceptable level.

So how do you fight an EV fire? There is a fundamental distinction between ICE and EVs when considering the risk of fire. Whilst it can be disconnected, the component that carries the fire risk in an EV cannot be removed; the battery cannot be drained of electrolyte. Nor is there a tank of fuel which can be drained. An EV has chemical components that, in specific circumstances, can initiate and sustain a fire; often a very energetic fire. In addition, 'normal' firefighting techniques are less effective in fighting EV fires. Two common suggestions are either to let the vehicle burn out, which would have profoundly serious implications for an event venue, or submerse it in water, for which there are obvious significant practical difficulties. There is a further complication in that most of the firefighting water used will be contaminated during the firefighting process adding environmental pollution as a real and significant risk.

This raises the question of an event venue's first response in a fire caused by or involving these devices given that it would also result in the rapid release of toxic fumes. A recent IOSH Magazine feature outlined how G4S prepares and trains first response staff to deal with thermal runaway fire in an electric vehicle production facility**.** Whilst not directly related to events, it throws a light on how other industries are tackling the issue. In summary, first response staff are issued with lightweight flame-retardant coveralls. Smoke hoods fitted with P3 filters are issued to cope with the gases that would be released in a thermal runaway. Fire blankets are provided to throw over a battery to suffocate a fire. The third element of the mitigation response plan is training. G4S developed safety briefings and training so all those working in the vicinity know what to do in in the event of a thermal runaway. Can event safety managers learn from this? For an EV, given the risks, an event or venue strategy may be to back off and leave the fire to the professionals, however, these risks letting the fire take hold to a point where even the fire and rescue service may not be able to contain it. There are also e-scooters and e-bikes to consider. Prompt action with these devices might, however, be within the capabilities of an in-house fire safety team and could make a significant difference to the outcome but what does that response look like? How many venues or event fire safety teams have the equipment or training to respond to such a fire?

E-scooters and e-bikes. Any road vehicle must meet stringent safety criteria before it can be sold, and in the UK and most other countries must be regularly serviced and checked for safety, for example the annual MOT in the UK. The same cannot be necessarily said about e-scooters and e-bikes which are quickly becoming part of our everyday lives. At a recent conference for safety managers in the Canary Wharf Estate in London it was pointed out that storing and charging these devices in the basement of a multi-storey office block can be an uninsurable fire risk. Some building insurers are now requiring the construction of a special containment facility designed to withstand the type of fire that can result from a fire caused by an e-scooter or e-bike. These devices are a growing feature of events as they are particularly useful to get around a large venue or outdoor event. Events are especially vulnerable because temporary event structures are not built to comply with the same fire safety standards that would be required under regulations for permanent structures. Granted, in the UK, flammable materials used for temporary event structures must be zero rated 'flame resistant' but they will still burn if exposed to the intense heat of an LIB fire. Unlike an office block where e-scooters and e-bikes would at least, in theory, be confined to a loading bay or basement car park, at events they are brought into the venue itself and possibly left charging overnight.

Hydrogen and hydrogen fuel-cell (HFC) technology: While EV cars sales are growing exponentially and are widely seen as the future of emissions free motoring, hydrogen cars are still somewhat overlooked. While there are hydrogen-powered cars available for sale in the UK, very few people are currently buying or even considering them. One of the biggest reasons for the slow uptake of hydrogen vehicles is the existing infrastructure. According to UK Hydrogen Mobility, there are currently only eleven hydrogen stations open in the UK. Much of this infrastructure which exists is for the sole use of single users such as a fleet of local council buses.

How do hydrogen cars work and what are the fire risks? Whilst it is the tenth most abundant element on the planet, because hydrogen doesn't occur naturally, it has to be extracted, then compressed in fuel tanks. It is then combined with oxygen in a fuel cell stack to create electricity to power the vehicle's motors. Whilst hydrogen is very flammable, ultimately, it is no more or less dangerous than other flammable fuels including natural gas and gasoline. In many ways it is safer. A petrol vehicle displayed at an event, even with an 'empty tank' will still contain a potentially explosive mix of petrol vapour in the tank. Because hydrogen is 14 times lighter than air it disperses very rapidly. If you release the hydrogen nothing remains in the tank. Petrol from a ruptured tank will pool and give off flammable vapor creating a serious fire risk. Hydrogen would simply dissipate. Hydrogen has a low Explosion Level Limit, which means that a small spark can set it off, but it requires a 4-75% fuel air ratio to be flammable. Because it disperses so rapidly it means that it would actually be quite hard to ignite it in uncontrolled conditions like a leak. Consider this. An HFC generator, if it contains no hydrogen, is just a fancy piece of electronics with no inherent fire risk. An LIB whether in use or not still contains the chemical elements for a thermal runaway with the attendant risks of toxic fumes. At a recent meeting for event safety professionals from the Association of Event Organisers, the Manchester Fuel Cell Innovation Centre posited a strong scientific case to show that HFC technology is widely misunderstood and is actually much safer than its LIB equivalent.

Lithium-ion vs. HFC technology. HFC cars still require an LIB to function. Such vehicles are referred to as fuel cell EV's (FCEV's). The technologies are therefore, in this case, interdependent. This is not, therefore, a 'Betamax moment' where one technology becomes dominant over another for largely arbitrary reasons epitomised by Betamax losing the videotape format war to VHS in the late 90's. Batteries are heavy and difficult to scale up for larger vehicles. The future may be that HFC powered transport is mostly confined to industrial fleets of large vehicles. The scientific press has also covered the potential for its use to power commercial ships and aircraft.

What does all this mean for our event infrastructure in fire safety terms? Event venues are built mainly to cope with a Class A fire, of normal combustibles such as wood, paper, and cloth with fire risk assessments used to identify controls needed for potential fire accelerants such as the presence of fuel, compressed gases or flammable glues. Guidance on compressed gases already exists and could easily be expanded to cover the risk from HFC's. Temporary structures in events do not have to comply with Building Regulations and in the UK, we rely on guidance such as the AEV eGuide (for exhibitions and similar events) or the ABTT guide (for theatres) to provide event specific fire safety guidance. The point is that neither the law nor current relevant guidance was written with the kind of fire risks posed by a thermal runaway from an LIB in mind. Do venues even know if their fire detection, zoning, and separation arrangements would cope with the combination of heat intensity and rapid release of toxic fumes that would be created by a fire associated with a lithium-ion battery?

Is there an environmental consideration? Absolutely**.** Lithium mining is damaging to the local environment. A report by Friends of the Earth points to the harm to rural communities where lithium is mined. Emerging technologies, such as graphene batteries may allow a pivot away from lithium but for now are not commercially viable. The point is that the choice of an EV is not necessarily an unequivocally environmentally safe choice not least because the electricity to charge the battery usually comes from the national grid which is predominantly fossil fuel sourced. It should be noted that in the UK, venues and events are liable for prosecution under environmental laws for any pollution that is certain to result directly or indirectly from water run off by fighting the fire even if the fire is accidental.

Emerging new technology. Lithium-ion vs. Solid-State batteries: The key difference is what the ions move through. In a 'traditional' LIB it requires a liquid electrolyte, while a solid-state battery would use a solid material. These are more technically more demanding to make, but they could be more efficient than 'normal' lithium batteries. With an energy capacity at least two times greater than traditional LIB's with flammable liquid electrolytes, solid-state batteries are safer, as well as more efficient. The point is that the race for new, efficient, and safe alternative fuels means that these technologies are evolving pushed along by innovative specialist sectors like Formula E.

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Conclusion: While it is clear that in most developed countries ICE vehicles will be phased out before the end of this decade, the alternative vehicle power sources to replace them are less clear. A combination of ICE, EV's and FCEV's will compete for primacy in the personal transportation market for the foreseeable future. At present market forces appears to be the main driver of development alongside practical realities like the limit on the size of batteries. It is unlikely we will ever see a battery powered passenger airliner, but HFC powered planes are perfectly possible. Outside of elite motor racing the events industry will have very little scope to influence these changes.

It is the interface with the built environment that should most concern the event industry as this brings a potentially serious fire risk that is not well understood outside academia and some key specialists into the same space as crowded events. Industry is responding slowly to this change, especially for firefighting tactics for EVs in the most vulnerable settings (e.g., underground carparks and loading bays). Insurers are also beginning to stipulate new requirements on battery storage within workplaces. Whilst LIBs in a workplace should be treated as any other fuel source, and risk assessed/ managed appropriately the special nature of that risk also needs to be recognised.

However, they develop, alternative fuel technologies will be a significant part of the event landscape in future so it is important in the events industry that we not only understand the nature of the associated risks but also the likely direction and scale of the adoption of these new technologies so that we can safely incorporate them into the future design of events and event venues.

The Author:

Richard Bate *CMIOSH is the Principal Health and Safety Consultant for the FIA Formula E race series, an IOSH Vice President and member of the IOSH Sports Grounds and Events Committee.*

Notes & Research:

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- *Retained Update Nov - Battery Tech / X Venture Global Risk Solutions*
- *AEO/AEV/ESSA cross association health and safety working group*