Challenges of Electrifying the Aviation Industry

An issues paper looking at alternative and renewable energy technologies within aerodromes

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Executive Summary

The global aviation industry has entered an era of significant technological innovation, driven by government decarbonisation policies and industry initiatives to reduce carbon emissions, to achieve Net Zero targets by 2050.

This paper examines the potential impacts of alternative and renewable energy technology adoption within the aviation setting; proposing these technologies introduce new hazards, shifting the existing risk profile. It also discusses the contextual challenges that these technologies, such as solar panels, energy storage systems, electric vehicles and hydrogen, present for contemporary emergency management and business continuity practices within the aerodrome environment.

In writing this paper, a comprehensive analysis of government publications, regulations, and industry standards, as well as current commercial initiatives and industry trends was completed. It is demonstrated that significant gaps exist, resulting in limited information or guidance regarding renewable energy technology and their associated risks.

This paper highlights the concept that the unprecedented scale of industrial development and the rate of commercial adoption of renewable energy technologies within the safety sensitive aerodrome environment, has credible potential to impact the safety of the traveling public, airport employees and emergency responders.

This has been demonstrated with recent incidents involving these technologies, exemplifying the identified risks.

It is timely to identify the challenges and issues alternative and renewable energy technologies present and discuss safe and reasonable practices. These include the update of legislation, review of emergency plans, staff awareness and training programs and greater consideration for emerging risks.

EV FireSafe would like to acknowledge Traditional Custodians throughout Australia and their continuing connection to land, sea and community. We acknowledge the Kulin Nation, the Traditional Custodians of the land on which this paper was prepared, and pay our respects to their Elders, past, present and emerging.

Foreword

EV FireSafe is funded by the Australian Department of Defence to research electric vehicle battery fires & emergency response. Since the launch in late 2021 of evfiresafe.com, an online hub of important data-driven information for emergency responders, EV FireSafe's work has been referenced by a global network of EV manufacturers, fire & emergency agencies, battery fire experts & private sector companies.

Our team, the majority of whom are emergency responders, are strong advocates for electrified transport, renewable energy and carbon reduction initiatives across all sectors. However, we also recognise a significant knowledge gap with Alternative and Renewable Energy Technologies (ARET) that requires concerted research and testing efforts, as well as training for those responsible for the implementation and operation of ARET.

These facts are widely acknowledged by the global emergency community responsible for the response and management of incidents involving ARET and their respective hazards. EV FireSafe's work has opened an important conversation for responders, government bodies and organisations;

How can we support the *safe* adoption, operation and charging of emerging technologies?
What do emergency responders need to learn and how quickly can we get them there?

We believe that this issues paper is an opportunity to apply a knowledge based approach and situational expertise to raise awareness and influence future policy, especially within the aviation industry.

EV FireSafe's insights are freely available at evfiresafe.com & data-driven training is now online at evfiresafe.business

Table of Contents

The rapid and mass adoption of

Alternative and Renewable Energy Technologies

has the potential to impact safety and aerodrome operations, as well as challenge contemporary emergency management principles and business continuity practices.

Background

As an Australian-based company, this paper primarily references domestic actions and activities for carbon reduction, however all challenges and issues discussed have global applicability.

Driven by government policies and international aviation initiatives, Australian airports are striving towards the achievement of sustainable environmental goals with ARET. Many of the technologies have existed for some time, however commercial and industrial applications are significantly increasing the scale of the existing renewable energy market.

The industrial application of ARET introduces a range of new technological and chemical hazards with emerging or misunderstood risks. This is especially the case within the safety sensitive aerodrome environment, representing a significant risk to the safety of the travelling public, airport workers and emergency responders. Additionally, consequences of these hazards represent a challenge to contemporary emergency management principles and business continuity practices, impacting aerodrome operations.

The challenges and issues raised within this paper are designed to proactively engage with the aviation industry and regulators, to seek safe and reasonable solutions to existing and emerging hazards. With several recent events involving these technologies within airport environments, this is especially timely and relevant.

Although the challenges discussed are designed to be holistic and applicable to every aerodrome, each issue will highlight a specific example.

As ARET is rapidly evolving, solutions may not be readily available for all hazards, however, recommendations are made to address identified issues, promote further discussion, and inform future decision making, ensuring the continued service delivery, business operations and the safety of the travelling public.

Australia's long term carbon emissions reduction strategy requires the accelerated development and adoption of fossil fuel alternatives. In 2019, the electricity generation and transport industries represented a combined 53% of all national carbon emissions (DCCEEW, 2020). To achieve Net Zero by 2050, the development of Alternative and Renewable Energy Technologies (ARET) for clean energy generation, storage and use is critical (DCCEEW, 2021). These technologies include solar photo voltaic (PV) panels, Battery Energy Storage Systems (BESS), Electric Vehicles (EV) and Hydrogen.

In addition to Australian government policy, the global aviation industry, regulatory bodies, and associations, have also committed to reducing aviation-based carbon emissions.

The use of alternate and renewable methods for energy generation, storage and use is critical to meet net zero targets

International programs such as the Airport Carbon Accreditation program establishes a global standard for aviation carbon management (ACI, 2023).

It encourages airports to embrace renewable energy technology and implement best practices for meaningful emissions reductions.

As high energy users, clean sources of energy provides significant environmental and economic benefits for airports as well as increasing their social capital.

However, increasing pressure from government policy, commercial market opportunities and a need to meet public expectations are exposing airport operators to an emerging hazard classification with little consideration for associated risk. During the journey to achieve net zero targets, airports will become more vulnerable.

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In the journey to net zero, airports may become *more* vulnerable.

Challenge 1

Speed and scale of renewable energy technology development

Australia's long term emissions reduction strategy comprises of several publications, each contributing to the accelerated development and adoption of technology to reduce carbon emissions (DCCEEW, 2020). Renewable energy technology, such as photo-voltaic cells (solar panels), that generate electricity from sunlight has been available for decades. However, the rapid increase of commercialisation and industrial scale applications of new technologies is unprecedented.

Large-Scale Solar (LSS) arrays are far more advanced than standard domestic installations, generating significant amounts of energy. Between 2012 and 2018, LSS energy generation grew from 10 Mega Watts (MW) to 3000MW nationally, with an additional 10 Giga Watts (GW) in development (DCCEEW, 2020).

The storage of clean energy with large-scale Lithium-ion Battery Energy Storage Systems (LiBESS) will support the increase of renewable energy generation as well as powering electric vehicles. The National Energy Market intends to increase BESS capacity to 640 Giga Watt hours (GWh) by 2050. Additionally, hydrogen gas has been identified as the next significant national export, potentially contributing an additional $11 billion a year to GDP (COAG Energy Council, 2019).

Although the generation, storage, and use of alternative energy does provide environmental and economic benefit, it may also present a conflict of competing priorities between commercial decisions and emergency management considerations. The evidence suggests that the former is prevailing, with the government acknowledging that their approach is "hard-headed" (DCCEEW, 2020, p7). The transition to renewable energy and the emergence of potentially new hazards will require a paradigm shift in emergency planning and incident response.

Challenge 1 - example

Standards for Large-Scale Solar Installations

The advancement of technology and commercial application has progressed beyond the scope of existing legislation and faster than standardised practices can be created or updated.

This is especially the case for LSS and installations. Existing Australian Standards and the application of current guidelines is ambiguous, relying on individual interpretation, especially regarding LSS.

The advancement of technology and commercial application has progressed beyond the scope of existing legislation and regulation

Although the standard provides installation guidance and safety requirements for PV arrays, it was intended for small scale and rooftop installations, stating that it "does not apply to PV arrays on large-scale" and advises that "in the absence of an Australian Standard, this document should be used as guidance" (Standards Australia, 2021, p1).

Additionally, it has been identified that there is no Australian standard or equivalent for the electrical wiring design or installation of earthing systems for LSS (Bowman, Bale and Luekhamhan, 2018).

The principles within the electrical installation standard (Standards Australia, 2018) do provide relevant information, however, it does not address the specific requirements of large and complex electrical systems with multiple variations of both DC and AC electrical outputs.

This is a significant issue for emergency responders as PV panels have been found to still generate electricity even when damaged. If fire is involved, the use of a firefighting water stream can provide an electrical conduit and electrocution risk from the PV panel to the firefighter.

Fire damaged solar panels are still capable of producing large amounts of electricty and present significant risks to life in the area.

Large-Scale Solar (LSS) such as this represent the industrial scale of solar installations. They currently sit outside of current domestic (Australian) standards and represent real significant risks if they are damaged.

Challenge 2

Unconsidered risks for airport adoption of Large-Scale Solar

The implementation of renewable energy initiatives provide environmental and economic benefits. However, they are also introducing new hazards with risks that are not yet fully understood, adequately assessed, or controlled, especially within the aerodrome context. LSS arrays provide an example of clean energy generation that also have unconsidered risks.

When exposed to light, Photo Voltaic (PV) cells generate a continuous supply of electricity. Even when isolated, the panels and connected systems remain electrified. If the panel is damaged, the electrical flow can "leak" onto the aluminium frame, mounting rail, and other structural components. Damaged panels can also result in high voltage electrical arcing and electrical fire, producing significant amounts of toxic smoke with no current ability to be isolated or de-energised during daylight hours, providing an ever-present electrical hazard and fuel load.

Damage to the PV cell can be caused by natural weather events, such as hail. However, the terrain that LSS arrays are usually located on includes graded earth or grasslands. This introduces further potential causes for panel damage, grass fires and maintenance programs. If the grass is not removed, a grass fire could burn through electrical systems and escalate to the panels themselves. Grass maintenance activities, such as slashing, also have the potential to throw rocks onto the panels.

Not only does this present a risk to life, but a potential disruption of airport operations in the event of a fire. In the last 12 months, there have been over 155 solar panel fires (Taouk, 2023). These fires produce significant amounts of black smoke that can affect aircraft visibility and movements.

Challenge 2 - example

Large Scale-Solar array locations

The Public Safety Area (PSA) located at each end of a runway is designated as a critical area and the most likely location of an aircraft incident. When risk is considered for land use within the PSA, only ground based public safety is considered when determining compatible or non-compatible uses and activities.

With regards to PSA use for LSS, only pilot glare, thermal currents and wildlife management was considered.

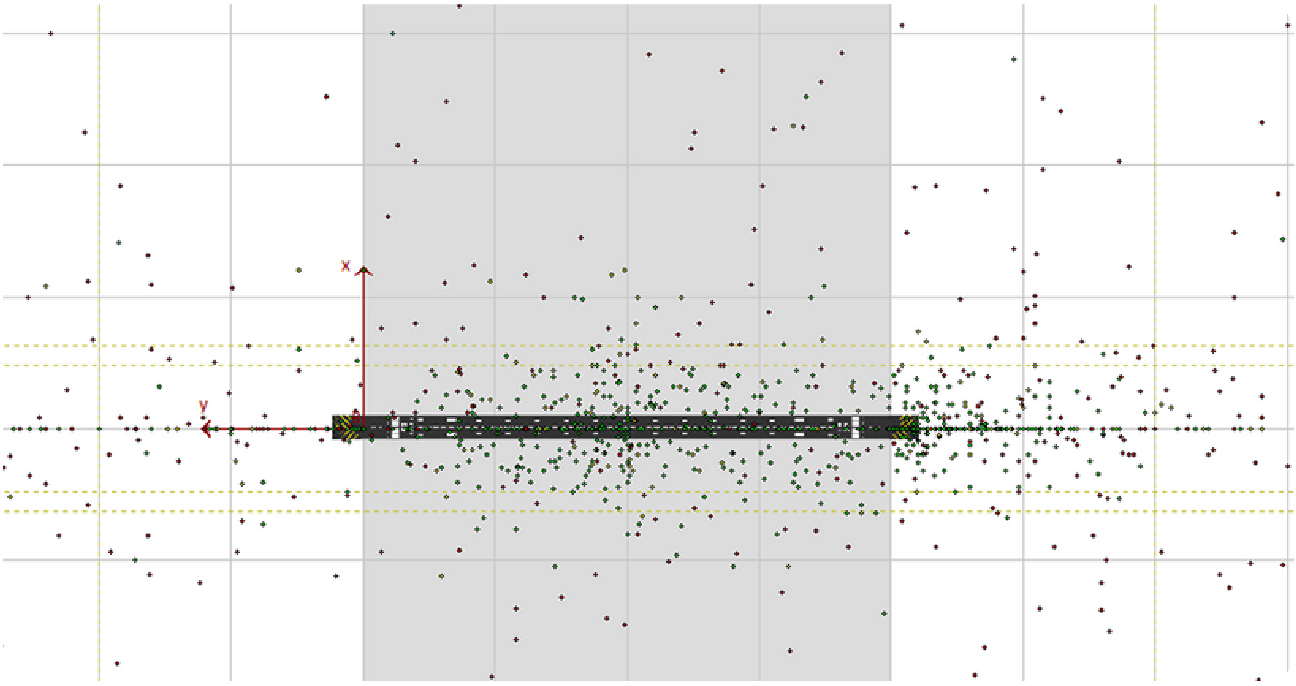
The location of LSS arrays within the PSA represent a significant operational and safety risk for responding emergency services and evacuating passengers in the event of an incident.

As an example, Melbourne Airport has installed a LSS array outside of the airport perimeter but within the PSA. Additionally, they have announced another LSS array to be constructed within the airport boundary, approximately 650m from the runway threshold (Melbourne Airport, 2023).

The location of LSS arrays within the PSA represent a significant operational and safety risk for responding emergency services and evacuating passengers

A study of the Spatial Distribution of Aircraft Crashes (SDAC) found that between 1995 and 2015 there were over 1700 aircraft incidents in the vicinity of the runway.

Over a third of these incidents occurred either before or after the runway, within the PSA's (Pandolfi, 2017). The selection of the geographical location for a LSS arrays need to be carefully considered as the consequences of an aircraft or LSS incident could impact saftey and operations.



The Spatial Distribution of Aircraft Crashes demonstrates the most likely areas for an aircraft incident, before, on and after a runway. The consequences of an incident in these areas are significantly increased if LSS is located within the Public Safety Areas. *Ref: Pandolfi, 2017.*

The 12 MW LSS array located within Public Safety Area to the north of Melbourne airport. Another LSS array will be constructed to the south of this one, just 650m fom the runway. *Ref: Google earth*

Challenge 3

Emerging lithium-ion battery market and commercial propriety

Technological development is rapidly generating new commercial opportunities, consequently driving further development. The commercialisation of these new technologies within an emerging market is introducing issues for commercial propriety. The internal chemistry and mineral composition of a lithium-ion battery (LiB) represent key factors which could provide a competitive advantage within the market.

There are many variations of LiB chemistry, manufacturing processes and technological design that define the specific energy, power, performance, and life span. These factors permit LiB cells to be utilised in many configurations and applications, each have their own advantages, disadvantages and critical factors that contribute to the associated risk profile of the respective LiB.

However, due to commercial propriety and lack of current regulatory requirements, Original Equipment Manufacturers (OEM's) do not disclose battery chemistry or other factors that could provide insight for their behaviour under fire conditions or guide an emergency response.

This is especially the case for the category of LiB used in Light Electric Vehicles (LEV). Currently, there is no regulation for LEV based LiB's to be tested for internal short circuiting or thermal stability, representing a greater fire risk.

Poor battery quality and electrical based faults have been identified as possible causes for over 500 LEV battery fires globally in the first 6 months of 2023, which resulted in at least 137 injuries and 36 fatalities (EV FireSafe, 2023). LEV's are currently utilised in Australian airports, both privately by staff and by operators within terminals and those numbers will increase as they become more cost effective & accessible.

Challenge 3 - example

Predicting battery fire behaviour in thermal runaway

The most significant hazard associated with the LiB is an event called thermal runaway. This phenomenon can occur within a LiB cell regardless of the chemical composition, physical configuration, or functional use.

The typical initiating event is a short circuit within an individual LiB cell as a result of electrical, mechanical, thermal or environmental abuse. The outcome is a self-sustaining, uncontrolled exothermic reaction, during which chemical components within the battery undergo rapid chemical reactions, producing significant amounts of flammable and toxic gaseous vapours; up to 6000 litres of gases for every 1 kWh of battery capacity (Christensen, 2022)

When ignited, the escaping vapor will generate jet-like, directional flames extending several metres in length and can reach temperatures over 1000 degrees Celsius.

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If ignition does not occur, the escaping vapour will fill the surrounding environment and may violently deflagrate (explode) when an ignition source is introduced.

The scale of these events is dependent on the battery size, state of charge and nature of abuse. However, the event is always violent and very difficult to stop, representing a significant risk to life, property, and the environment.

An example of a thermal runaway event with a 1.4kWh lithium-ion battery, 100% state of charge. Flames are 4 metres in length, reaching 1000 degrees celsius. *Ref: Christensen, 2023.*

An example of a thermal runaway event with a 1.4kWh lithium-ion battery, 40% state of charge. Large amounts of toxic, flammable vapour fill the confined space. *Ref: Christensen, 2023.*

Challenge 4

Large-Scale Battery Energy Storage Systems

Aligning with Australia's emissions reduction initiatives, the National Battery Strategy identifies batteries as a critical component to meet the governments net zero emission initiative (Department of Industry, Science and Resources, 2023). Batteries will support the increase in renewable energy generation, facilitating small and grid scale energy storage systems as well as powering electric vehicles. However, Large-Scale Battery Energy Storage Systems (BESS) is an emerging industry, significantly larger than current commercial and residential applications. The government does acknowledge the challenges that BESS projects present, however, are focused on increasing commercial viability and developing market opportunities.

Large-scale BESS are the next critical link for a renewable energy grid, providing stored energy during periods of high demand or contingency power through outages. The Victorian Big Battery is a 300MW grid connected system that is charged via the grid during off peak times and can provide emergency power to one million homes for half an hour (Neoen, 2023). However, new projects such as the Gannawarra Energy Storage System (Edify, 2021) is an example of a Large-scale BESS combined with a Large-scale solar (LSS), providing renewable and clean energy generation and storage.

Although these Large-scale BESS represent advancements in renewable energy technology, they also introduce significant risks. Both the Victorian big battery and Gannawarra project utilise Tesla mega packs, each with the capacity of 3MWh per unit. Tesla advises within its Emergency Response Guide (ERG), that if a fire was to occur, emergency responders should "allow the affected unit to consume itself" (Tesla, 2022, p17). This response advice will impact contemporary methods of minimising disruptions and business continuity practices.

Challenge 4 - example

Co-location of large-scale battery energy storage with large-scale solar

The Gannawarra energy project in Victoria (ARENA, 2023) is an example of how Large-Scale Solar (LSS) and Large-Scale Battery Energy Storage Systems (BESS) technologies could be combined, demonstrating a clean and renewable energy grid. The project is the first of its kind within Australia, integrating a 25MW / 50MWh BESS with a 50MW solar installation.

As high energy users, a project such as this would provide airports with a clean method to reduce energy costs and their carbon footprint.

The Australian Airports Association is rightly advocating for projects such as these, outlining "the storage of renewable energy for use at night or in bad weather is the missing piece of a renewable electricity strategy at airports" (AAA, 2023, p3).

However, the increasing popularity and mass adoption of these technologies is increasing the overall risk profile due to a delay in regulation development and only nascent understanding of emergency consideration.

The increasing popularity and mass adoption of these technologies is increasing the overall risk profile due to a delay in regulation development and lack of emergency consideration

Recent fire incidents involving BESS in Queensland and Victoria demonstrate the challenges of responding to these types of installations. If a BESS was located next to the Melbourne LSS in a similar fashion to that of the Gannawarra project, an fire incident involving the BESS would have a significant impact on airport operations.

The Gannawarra energy project combines a 25MW / 50MWh BESS with a 50MW solar installation. The AAA is advocating for airports to adopt such installations. *Ref: Edify, 2021.*

A fire in one of the Tesla Megapacks at the Victorian Big Battery during construction. The incident required a significant emergency response and burnt for over 3 days. *Ref: Wong. L. 2021*

Challenge 5

Commercial adoption and integration of new technology

Commercial and business incentives to adopt new technology provide significant economic benefits, either in direct financial savings or carbon offset credits to achieve Net Zero (DCCEEW, 2021). Additionally, individual consumer tax rebates and “green” loans (DCCEEW, 2023) are ultimately an effective method to increase community acceptance and mass adoption of renewable technology.

Since its release in 1997, the Toyota Prius hybrid electric vehicle is most recognisable for its use as a taxi. Its ability to remain on the road longer as well as its low operating costs provided significant economic benefits when compared to a standard combustion vehicle.

However, the global popularisation and rapid expansion of electric vehicles (EVs) for personal use is due to the success of Tesla (Hawkins, 2017). Their success, coupled with government incentives in some markets, have driven shift to EVs for environmentally focused consumers, organisations & fleets seeking meaningful ways to reduce their carbon footprint.

The commercial integration of renewable energy technologies demonstrates an organisation’s commitment to an environmental, social, and corporate governance (ESG) philosophy.

However, there are currently only emerging considerations for the new hazards EVs introduce, and the changing risk profile they present, within the airport environment.

Challenge 5 - example

Rental car industry and terminal locations

The integration of electric vehicles (EV) into the fleets of the rental car industry presents new challenges for terminal based companies.

The vehicles are hired and driven by customers who may not fully understand how the EV operates and may be hesitant to report damage or accidents they have been involved in upon returning the EV. In addition, hire companies themselves are unaware of the risks of EV battery fires & how to conduct visual or thermal checks of returning EVs.

While EV battery fires are very rare, EV FireSafe's research has found they can occur hours, days or even months after an incident involving physical abuse of the battery (EV FireSafe, 2023).

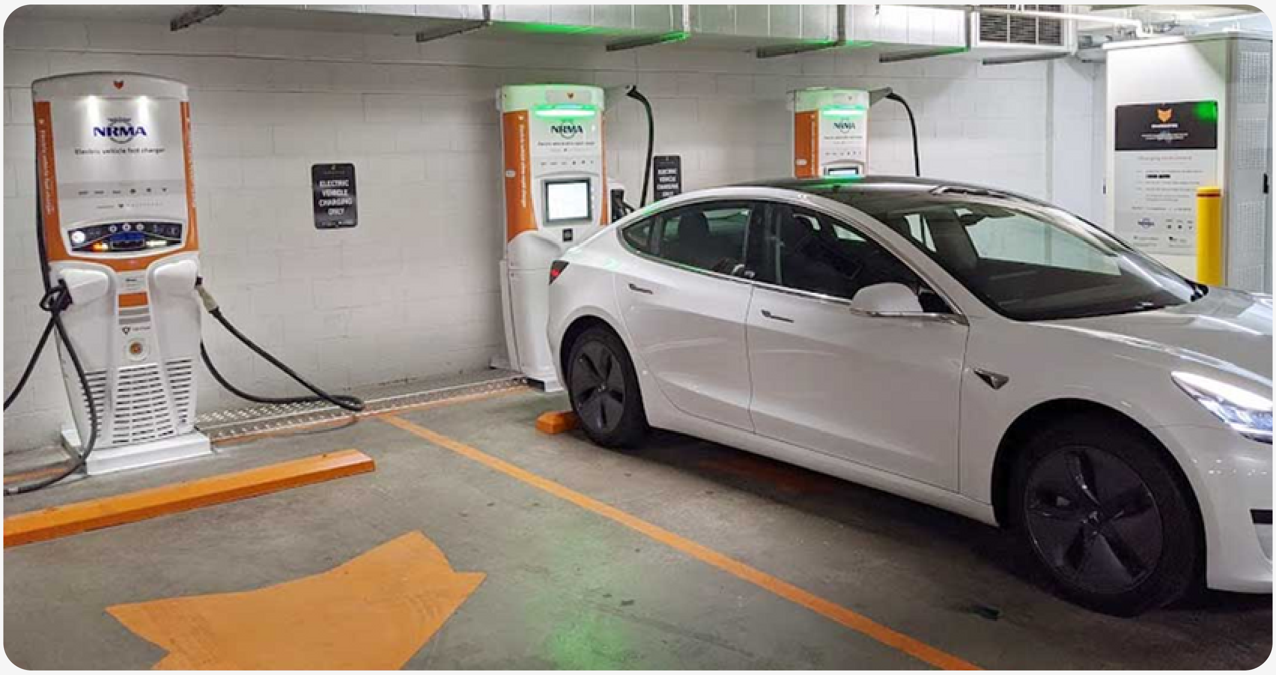
This is exemplified with a recent rental EV incident at Sydney Airport. A damaged EV was stored in a holding lot, with the hire company apparently unaware of fire risks. The battery pack - separated from the vehicle & left on the ground - went into thermal runaway, destroying several vehicles in the lot and impacted surrounding areas with smoke.

Rental cars are often located in carparks, near high pedestrian flow paths enabling quick access from airport terminals.

If the thermal runaway event in the holding lot occurred within a carpark structure, the result could have been worse, risking life and significantly disrupting terminal operations.

Had the Sydney event occurred within a parking structure, particularly while connected to charging, the result could have been worse, risking life and significantly disrupting terminal operations (however, it should be noted this would be the case regardless of vehicle fuel type).

The result of an EV fire in the rental car holding yard, Sydney Airport. The car was returned after being damaged during a rental period. The close proximity of the holding yards to the airport, & the often extended duration of an EV battery fire incident, may increase the consequences of an EV event. *Ref: Taouk, 2023*.



An electric vehicle charging station within a confined parking structure. This is similar to what rental car companies are installing in terminal carparks. Charging is conducted following rental return, however without visual & thermal checks to mitigate risk should the EV battery have been damaged. *Ref: Sykes, 2023*

Challenge 6

Aviation regulatory frameworks

As previously identified, there are substantial gaps in legislation, regulations, and standards with regards to the adoption of ARET.

This extends into the aviation industry, with regulatory shortfalls increasing the magnitude and potential consequence during a period of significant transformation.

Here in Australia, the legislative responsibility of monitoring current and identifying emerging aviation safety issues, hazards, and associated risks falls upon the Civil Aviation Safety Authority (CASA).

Sector safety risk profiling (SSRP) is one of CASA's responsibilities, providing a snapshot of key risks within a specific sector, supporting decision making and addressing potential threats to safe operations (CASA, 2023a). In addition to SSRP, safety inspections of equipment are also required (CASA, 2023b).

However, as the race to decarbonise our airports accelerates, we were unable to find any global regulatory body with published considerations of the new challenges electrified equipment and technology introduces.

Any such considerations should include all operations and equipment for ground-based functions that service aircraft. In short, we believe there is a significant gap in safety standards within a safety critical airside environment.

Challenge 6 - example

Introduction of electric ground service equipment (eGSE)

Ground Service Equipment (GSE) services aircraft and includes catering vehicles, baggage loading, waste disposal, re-fuelling operations and the tugs/ tractors used to push aircraft away from the terminal aerobridge.

Traditionally, these vehicles were powered by combustion engines or standard batteries (Lead acid/ AGM). However, these are now being replaced with new electric ground service equipment (eGSE) powered by lithium-ion batteries.

As these vehicles operate within the airport environment, there is no need to be road registered, removing the requirement to meet existing vehicle safety standards and regulations.

Furthermore, EV FireSafe is concerned a lack of regulation or standards may provide some manufacturers the opportunity to utilise cheaper battery chemistry and components to keep costs down.

The procurement, charging and use of electric ground service equipment in safety sensitive areas without proper consideration of quality, maintenance, awareness and training is a new risk

The procurement, charging and use of eGSE in safety sensitive areas, without proper consideration of quality, maintenance, and staff awareness and training, is a new risk that is yet to be identified, profiled, or addressed by airports. This may lead to eGSE operating with no oversight or assurance of safe use, maintenance, or fault identification.

Ground service equipment (GSE) provide critical services for aircraft. They operate within close proximity to aircraft and are often stored under terminal structures. International and domestic airports and ground operation companies have already started to eGSE that utilise LiB’s.

An example of eGSE storage and re-charging at Heathrow airport, London.
Ref: Smith, 2023

Challenge 7

The localised generation and use of hydrogen

Hydrogen is the most abundant and basic element in the universe. As the world looks for clean and renewable alternative fuel sources, hydrogen will play a key role during the transition to a sustainable energy future.

It can be utilised in traditional combustion method or within a fuel cell stack, each producing energy and zero carbon emissions. The use cases of hydrogen include transport, electricity storage, residential heating and some industrial uses.

As the basic elemental component of many compounds, hydrogen needs to be "created" or separated from these forms. This can be achieved through several methods, resulting in green, blue and grey produced hydrogen.

Green hydrogen is generated through electrolysis, with the renewable sources of electricity such as LSS and BESS. As there are many challenges of transporting large amounts of hydrogen, the most effective and efficient method would be to establish localised hydrogen hubs. These hubs would include a method of generating and storing clean energy to be used for the electrolysis process to produce hydrogen. It would then be stored on site, easily accessible for its relevant use case.

However, hydrogen is a significant hazard, presenting new risks for those who use it and those required to respond to an incident involving it. Hydrogen is odourless, colourless, emits very low radiant heat and burns with an invisible flame, and is extremely explosive. Any future attempts of generating, storing or using hydrogen will require considerable emergency management planning

Challenge 7 - example

Hydrogen fuel cell electric vehicles

Fuel Cell Electric Vehicles (FCEV) utilise hydrogen in a chemical process, combining hydrogen with oxygen from the atmosphere which generates an electrical current. This energy is then stored in an onboard lithium-ion battery. This in turn, powers the electrical motor of the FCEV.

Several aircraft manufacturers, including Airbus, are designing new aircraft with hydrogen propulsion technology (Airbus, 2023). Additionally, existing airframes are being converted with retrofitted electric engines; for example, Australian based Rex Airlines will introduce an electric / hydrogen hybrid aircraft for short regional flights in 2024 (Dowling, 2022).

While hydrogen aircraft are in development, FCEV technology is already being utilised in large vehicles such as mass transport public vehicles.

A collaboration between Toyota and CaetanoBus has produced the first electric hydrogen-powered bus using 37kgs of hydrogen and a 44 KWh battery pack. Vehicles such as this would provide significant benefits for airports that provide airport transfers and car park transport.

However, vehicles such as these combine two significant hazards, hydrogen gas and lithium-ion batteries, representing an operational and safety challenge.

Vehicles such as these combine two significant hazards; hydrogen gas and lithium-ion batteries, and represent an operational and safety challenge.

For example, in the event of a battery fire, there is a small risk that hydrogen tanks are impacted. Conversely, should a hydrogen fire occur, this may impact the LiB. Additionally, hydrogen refuelling requires airport based fuel storage, presenting additional challenges.

Hydrogen (left) burns with a invisible, more intense flame when compared to butane or propane gas (right).

The H2 City Gold bus, built in collaboration by Toyota and CaetanoBus. This vehicles carries 37kg of Hydrogen gas and a lithium-ion battery pack, ranging from 44 - 80kWh. Ref: *Thomson, 2022*

Challenge 8

Contemporary emergency management practices

Within this sensitive and safety critical context, the industrial application of ARET on an aerodrome represents a considerable and potentially unappreciated risk that requires the application of government regulation.

However, as there are significant gaps in current legislation and guidance, airports cannot rely on solely meeting their legislative requirements and call for localised situational analysis and assessment. The concern is that the emerging risk profiles of ARETs are not yet fully known or understood, therefore representing a challenge to contemporary risk assessments and emergency management practices.

Although the likelihood of an incident involving these emerging hazards is very low, the potential consequences are significant. Contemporary emergency management practices would advocate for increasing the airport's resilience to these hazards (AIDR, 2020). However, due to the potential consequences of these emerging risks and limited knowledge to control them, the reduction of the airport's vulnerability is required, rather than an increase in resilience.

This requires a shift from traditional linear based thinking to a systems thinking approach. Systems thinking is able to account for greater complexity and integrate new risk methodologies, such as the extended risk framework.

The extended risk framework focuses on the subject's exposure and vulnerability to an identified risk, rather than the precursor risk factors of likelihood and consequences. This broader perspective provides risk owners greater ability to examine new or emerging hazards and assess their exposure or vulnerability to the associated risk.

For example, due to the rapid adoption of new technologies with limited regulated guidance or little consideration for the risks they introduce, airports are exposed and vulnerable, potentially increasing the consequences and risk profile.

Challenge 8 - example

Updating aerodrome emergency and business continuity plans

It is essential that critical infrastructure owners maintain situational awareness of their risk profile and update emergency management plans as required to be prepared for all emergencies and have capability to recover from them.

However, this may be particularly difficult with ARET, as the rate of rollout, location within safety sensitive areas and difficulty of accurate hazard identification may expose airports, and the travelling public, to unknown risks.

Each airport has a regulatory requirement to document an Aerodrome Emergency Plan (AEP) which details the response to a pre-determined emergency. Ideally, the AEP should be closely linked to the Business Continuity Plan (BCP) as any significant disruption to airport operations will most likely be a result of an incident.

These two documents should identify the potential risk of all hazards within the aerodrome footprint and detail appropriate control strategies.

However, EV FireSafe is aware that this is generally only in very early consideration by many airports, who may be 'leapfrogged' by new technologies.

The rate of ARET rollout, location within safety sensitive areas and difficulty of accurate hazard identification may expose airports, and the travelling public, to unknown risks.

The lack of a fully considered emergency response plan will not only impact airport operations and business continuity but may result in a higher risk to life and property safety, especially for emergency responders themselves.

Key points

1.

The advancement of technology and commercial application has progressed beyond the scope of existing legislation and regulation.

2.

The location of LSS arrays within the PSA represent a significant operational and safety risk for responding emergency services and evacuating passengers.

3.

The rapidly developing lithium-ion battery market and associated commercial propriety could increase the potential risks of thermal runaway and fire behaviour.

4.

The combination of large-scale BESS with solar panels may compound hazards, increasing the risk profile for airports and responders.

5.

The adoption of EV's by the rental car industry and their location within terminal parking structures represet a risk to life and terminal operations.

6.

The use of eGSE in safety sensitive areas is an emerging risk that requires identification, profiling and addressing by airport regulators.

7.

Hydrogen and fuel cell electric vehicles is a developing technology that requires real consideration now due to its risks and requirements for operational use.

8.

Airports should review and update emergency and business continuity plans to ensure they can adequately respond, manage and recover from all hazards, including newly intoduced ARET.

Recommendations

Recommendations made here are designed to guide collaborative efforts across airport, government and emergency agencies, and are based on EV FireSafe's research and discussions with a wide range of international experts, manufacturers and emergency agencies.

In some areas, EV FireSafe has commenced or delivered solutions, either for public use or private clients; these are highlighted in green.

1 **Increase consultation with all stakeholders and SMEs**

Assist in gaining different perspectives of the changing risk profile, enabling the airport to make informed decisions, implement preventative measures and develop corrective actions to reduce the likelihood and consequence of a potential emergency involving ARET.

2 **Greater awareness of ARET in Airports**

Includes guidance for the procurement, location, installation, charging, operation, emergency response, recovery and responsible disposal for:

- LSS and BESS
- EV, eGSE and FCEV operation,
- Storage, refuelling and recharging

Note: EV FireSafe is working with Professor Paul Christensen to write a 'Strategies and Tactics to Mitigate Risk of EVs and LiBs in Airports' report, which is anticipated for launch in late November 2023.

3 **Inspection and maintenance policies for eGSE / EVSE**

When equipment is purchased from a manufacturer, they must provide important safety documentation to ensure safe handling, use, monitoring and maintenance of electric vehicles and associated charging infrastructure.

4 **Development of Emergency Response Guides**

ERGs should be written to ISO 17840 and should identify risks and document emergency procedures for airport workers to follow during an incident. ERGs must also be shared with airport and landside emergency services.

5 **Develop guidance for battery damage checks**

A series of pre-and-post operational checks should be developed and implemented across all sites where electric vehicles and charging equipment is located.

Note: EV FireSafe has developed a Electric Vehicle Assessment of Battery Condition (EV ABC) method for this purpose.

6 **Staff awareness and training programs**

As new equipment is deployed into operations, all staff, including airside firefighters, should participate in an appropriate training and awareness program. This will ensure that operators can take immediate action in the event of an incident and reduce the risk to life.

Note: EV FireSafe has developed dedicated online LMS at evfiresafe.business and will be launching 'Battery Fire Safety Basics for Airports' in late October 2023.

7 **Identify lithium-ion battery fire management products**

A number of products are coming to market for the management of EV and lithium-ion battery fires, however many remain untested and some many actually increase risk to users and responders. Products should only be procured with a risk assessment and SOP for use.

Note: EV FireSafe is conducting a full desktop review of all such products, which will be available early November 2023.

8 **Review/update legislation, regulation and standards**

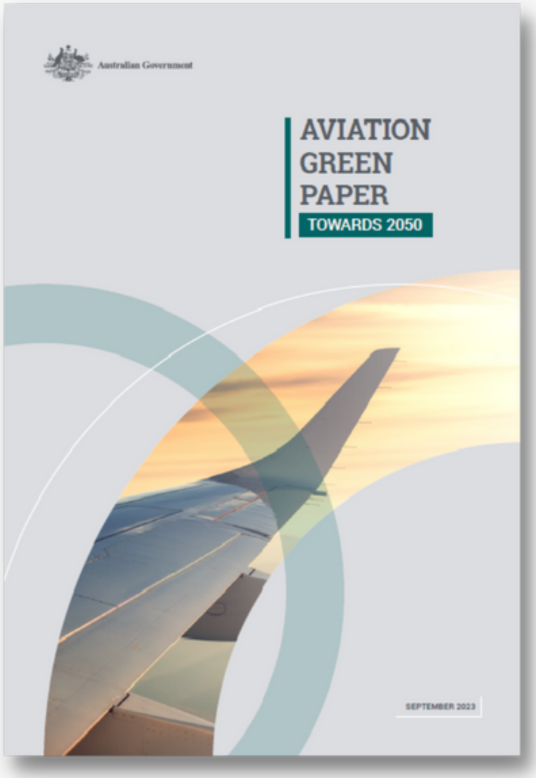
This work must be done as a matter of priority and include a standing item for new renewable energy initatives. They should specifically include hazards, risk and safety considerations that ARET is introducing within the airport enviornment.

9 **Review/update Emergency and Business Continuity Plans**

Aerodrome Emergency Response and Business Continuity Plans must address site specific hazards and risk profile and aim to reduce the likelihood of an incident, but prepare for an emergency, identifying how it would disrupt operations and have a plan to restore normality.

Impacts of the Aviation Green Paper

The recently released Aviation Green Paper by the Australian Government seeks contributions to policy direction for the aviation sector.



The government recognises that the aviation sector needs to remain competitive, efficient, sustainable, and safe during the industry's decarbonisation and transition to net-zero aviation operations.

To achieve this, they identify that emerging technologies will provide the opportunities needed to drive long term sustainable growth.

However, the paper also acknowledges the challenges and potential weaknesses in the regulation of aviation. It is encouraging to read that "*policy and regulatory options will be needed as the technologies mature to give industry certainty and ensure safety outcomes*" (p7). This will especially be the case as airport initiatives, including the generation of renewable electricity and electrification of ground operations are developed and deployed.

Note: This issues paper will be submitted as part of the consultation process and EV FireSafe hopes to positively influence the safe integration of ARET into aerodrome operations.

Results of ACCC report

The publication of the Australian Competition and Consumer Commission (ACCC) report into lithium-ion batteries (LiBs) and consumer product safety will influence future LiB technology.

The report was generated after a 2022 issues paper highlighted concerns with the growing number of fire incidents involving LiBs, many resulting in personal injury.

The ACCC report provides six recommendations to address the present and emerging risk profile that LiB and their applications represent.

Of these recommendations, two stand out:

- The ACCC identify LiB fire incidents are complex and highlight the importance of capturing incident data for further analysis.
- The inconsistent approach to regulatory frameworks and standards, which this paper has also identified.

Note: EV FireSafe has an established a globally recognised database of road-registered EV battery fire incidents, from which we continue to draw open-sourced data-driven learnings for the use of the emergency community and private sector companies. As such, we look forward to contributing to the responder, workplace & public safety efforts of the ACCC in the future.

About EV FireSafe

EV FireSafe is funded by the Australian Department of Defence to research electric vehicle high voltage battery fires & emergency response, particularly where the EV is connected to energised charging.

With this funding EV FireSafe has built a global database of EV battery fire incidents, the first of it’s kind, from which real-world learnings are drawn to begin filling the knowledge gaps of emergency response to electrified transport.

Our world-leading research & SME knowledge is freely available online at evfiresafe.com and is referenced globally, by the Australasian Fire Agencies Council, National Fire Chief's Council (UK), National Fire Protection Association (US) & various EV manufacturers such as Tesla.

In 2023, our data-driven knowledge has been leveraged to build online training, via our dedicated learning management platform, evfiresafe.business, and our growing team of firefighting & battery experts provide consulting advice for international private businesses concerned about battery fire risks.

This paper was written by Nathan Smith, EV FireSafe’s Airports & Emergency Management Specialist, with support from EV FireSafe Director, Emma Sutcliffe, and EV Technical & Fire Safety Specialist, Dan Fish. All team members are also operational firefighters with experience in EV and lithium-ion battery fires.

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Partnerships & collaborations

EV FireSafe works with a wide range of battery experts, fire agencies, EV manufacturers and other SMEs to better understand and communicate the risks and hazards of electric vehicles and lithium-ion batteries.

Our initial research funding was awarded by the Australian Department of Defence.

We are an invited Technical Panel Member for a 2 year testing program "*Assessment of Electric Vehicle Firefighting Techniques, Technologies & the Impact of Stranded Energy*" being conducted by the Fire Protection Research Foundation (at the National Fire Protection Association, US).

We also work closely with our friend and mentor Paul Christensen, Professor of Pure & Applied Electrochemistry, Newcastle university (UK).

Our work is referenced by &/or we collaborate with:

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Thank you for your time and kind attention.