Presentation Title: A Holistic Approach for Performance-based Design of Data Centres containing Lithium-Ion Energy Storage Systems (ESS) in Australia

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1.0 EXTENDED ABSTRACT

1.1 INTRODUCTION

Businesses are always looking for ways to safeguard their property and assets. For many companies these assets are not always physical and can be in the form of electronic data and information technology. Combining this with the recent workforce trends to be able to work from home and the increasing adoption of Artificial Intelligence (AI) applications (e.g. ChatGPT, Copilot, DeepSeek), there has been a significant shift from physical storage on hard drives to online services that provide access from 24-7-365 day access from anywhere and promises of data security. This has fuelled the rapid growth of large data centres which house equipment capable of storing all this data so that it can be accessed at any time. 'Zero downtime' and 'Maximum uptime' are common data centre design objectives. This implies the need for data centres to be extremely reliable and robust to current demand.

The constant requirement for power supply in data centres necessitates backup power in the form of batteries and generators to maintain power when the electricity grid cannot meet the demand. This is where Lithium-ion batteries (LiBs) provide short-term power supply to the data centre while Diesel generators are brought online to take over long-term energy supply, when the electricity grid cannot meet the demand or is down.

LiBs are an emerging fire hazard and could be prone to thermal runaway leading to the production of flammable gases and toxic gases which present a unique risk to occupants and fire brigade personnel. These types of fires are often very difficult to extinguish as the decomposition reaction provides the heat and fuel required to sustain the fire. Additionally, the cabinets that store the LiBs shield the batteries from suppression making it hard to cool the seat of the fire and reduce the heat [1].

Limited full scale fire testing has been undertaken on Battery Energy Storage Systems with research programs currently being developed to gain further understanding into how best to combat and contain these fires when they do occur. One such example is the FRNSW SARET Program [2]. Large-scale testing by FM Global has reported that a single battery failure would lead to involvement of the entire rack or cabinet and would likely spread to the adjacent cabinet if the fire was left to burn freely [1].

A holistic performance-based fire strategy has now become essential for modern datacentre design beyond the traditional fire engineering addressing only variations from the NCC BCA Deemed-to-Satisfy Provisions from the Building Code of Australia (BCA). Furthermore, there are a number of other considerations beyond traditional

‘Alternative Solution’ based Fire Engineering. Some the key considerations for a Datacentre fire strategy include the following:

1. Fire Safety Study - Adequacy of the fire safety systems to deal with the emerging hazard posed by Lithium-ion Battery fires as assessed in the Fire Safety Study and any outcomes arising.
2. Dangerous Goods Compliance - Storage of other dangerous goods in the form of large volumes of Diesel fuel.
3. Security Considerations - Site security where a building may be tenanted out to multiple companies and access through the building is required to be carefully managed, even in a fire event.
4. Occupant and Fire Brigade life safety - Compartment conditions during the initial growth phase for occupant evacuation and fully developed phase when fire brigade personnel arrive on site.
5. Planning / Environmental Protection Authority Provisions - Potential environmental impact to the surrounding areas contaminated fire water discharge and toxic plume release.
6. Best practice guidance – FM Global, NFPA 855, AFAC, FRNSW, CFA Renewables Guidelines, NSW Firewater Guide to mention a few.
7. Building Code Compliance – Consideration of how the various deviations from the National Construction Code will be addressed while still satisfying the other requirements of the building based on the building use.

The presentation will elaborate on the above via learnings from previous projects to illustrate development of a holistic fire strategy.

1.2 FIRE SAFETY STUDY

The Fire Safety Study (FSS) forms one of the most crucial assessments for a data centre as it addresses the adequacy of the fire safety systems within the building to manage a mitigate a fire event, as well as modelling of the credible fire scenarios to determine the consequences. Fire suppression, fire detection, smoke management and explosion hazard require consideration in the context of a new emerging fire hazard The FSS is based on the NSW HIPAP 2 (Planning NSW) Guidelines [3] which is a planning document that is specifically developed for NSW. However, a number of other states including Victoria have adopted this same methodology for assessing developments that contain Lithium-ion Batteries and other hazards.

It is important that the Fire Engineer and the Risk Engineer coordinate with the design team to develop a coherent strategy for the building. The FSS not only needs to consider the building design but also the proposed Performance Solutions and how they could impact on the consequence modelling presented within the FSS. This assessment makes use of not just compliance with Australian Standards but includes best practice Australian Guidelines like the CFA Renewables Guideline [4] and Best Practice Guidelines for Contaminated Water and Treatment Systems [5]. In addition, international standards like NFPA 855 [6] and testing conducted on the LiBs including UL 9540A [7] testing and full-scale burn tests are utilised to support the assessment.

1.3 DANGEROUS GOODS

Data centres typically contain the following materials that need to be considered:

1. Diesel in the form of bulk storage tanks and belly tanks within the generators.
2. Lithium-ion Batteries (LiB) in the form of racks that operate as the initial backup power supply; and
3. Cooling oil housed within the transformers located on the site.

Typically, the Australian Dangerous Goods Codes has limited requirements on these materials, particularly LiB which fall under Class 9. Hence, the fire risks from Dangerous Goods and Hazardous Substances need further consideration as part of the fire safety strategy for the site.

1.4 SECURITY

A data centre is typically tenanted out to multiple parties based on the number of data halls they require as part of their operations. As the equipment within the data halls typically contains sensitive client data which is the responsibility of the tenanted party only. Entry into the data rooms requires access control. Thus, careful consideration of occupant evacuation is required through the use of building compartmentation and systems that allow occupants to evacuate from a secure space without compromising the secure access.

1.5 OCCUPANT LIFE SAFETY AND FIRE BRIGADE INTERVENTION

Toxic and flammable gases are the one of the emerging considerations for fire brigade personnel attending to LiBs in data centres. The toxic gases present an inhalation risk to occupants which in turn can put fire brigade personnel at risk when undertaking search and rescue efforts. Additionally, the flammable gases produced as part of thermal runaway can create a potential explosion risk for fire brigade personnel when attempting to enter a data hall or room containing LiBs.

1.6 PUBLIC AUTHORITY REQUIREMENTS

One of the main considerations for other Public Authorities (e.g. Environmental Protection Authority) is the treatment the contaminated firefighting water from a sprinkler or hydrant system post incident. This requires special consideration such that the containment of the water does not pose an added risk to occupants or fire brigade personnel.

The first consideration is to simply contain all of the water within the building or data hall where the discharge occurred and remove the water post incident. However, this presents a risk to fire brigade personnel as the batteries within the data halls and electrical areas are utilised to store electrical energy. This means that even if the power to the site is isolated the risk of electrocution is still present, similar to the risks associated with solar panels. To address fire brigade and occupant life safety, a balanced approach considering other risks including environmental risks is required.

Appropriate measures in the form of drainage and external water containment need to be considered such that they are appropriate for both the life safety risk and environmental risk.

As an example, a recent data centre project incorporated dedicated tanks exceeding 700,000 L solely for the purpose of fire water containment post a fire event. These tanks are extremely large taking up significant onsite space as well as requiring ongoing maintenance requirements. Hence, alternative options were explored including a review of the other water management systems for the site which included a 2,000,000 L on-site stormwater detention (OSD) basin. The detention basin was fitted with automated knife valves that are designed to close on fire trip containing all water on-site. This made use of the capacity required by other water management systems thereby optimising dedicated water containment tank capacity.

1.7 BUILDING CODE AND STANDARD COMPLIANCE

Due to the increased reliance on these data centres, they are continuing to expand in size. As land size comes at a premium, these buildings are looking to expand vertically such that they can accommodate the maximum amount equipment on the limited land available. However, that provides additional complexities as the National Construction Code (NCC) was never designed to deal with such large buildings with the additional risks that Lithium-ion Batteries present. The NCC defers these types of buildings to Fire Engineers to address through Clauses E1D17 and E2D21 provisions for special hazards. Therefore, a holistic strategy site wide fire safety strategy is required considering the data-centre day to day operations.

Additionally, recent amendments to AS 2419.1 in 2021 for fire compartments in excess of 108,000 m^3 are now considered beyond the scope of the standard and require special consideration for firefighting as per Appendix C. However, one challenge is that Appendix C was based on single storey warehouse which is a large-isolated building rather than a multiple storey building that is potentially above 25 m. As a result, the considerations in Appendix C need to be appropriately managed such that the intent of the clauses and operational requirements of the Fire Brigades are met.

In summary, the fire safety strategy for the building would typically extend beyond the NCC and Australian Standards and look to International Standards or Best Practice Guides that provide greater levels of protection for areas with LiBs. These would typically include NFPA 855, UL 9540A cell, module and unit level testing and the consideration of sprinkler flow rates proposed by FM Global in Data Sheet 5-32 if racks are less than 20 kWh or Datasheet 5-33 if they exceed 20 kWh.

1.8 PERFORMANCE BASED DESIGN

Recent experience with data centres including one (1) with an effective height greater than 25 m highlighted a number of key considerations that are required to be addressed through Fire Engineering and Performance Solutions. Some of these are discussed below:

1. Occupant evacuation – Large floor areas in the range of 150,000 – 200,000 m^2 necessitate extended travel extended distances up to 90 m and 170 m between exits, while navigating secure doors along the path of egress due to security requirements. The Performance Solution typical relies on internal compartmentation with 2 hr and 4 hr construction, early notification using advanced smoke detection and dynamic exit signage to assist with directing occupants away from the location of the fire.

2. Fire brigade intervention – Relatively large floor areas in the range of 150,000 – 200,000 m^2, locating the seat of the fire and safely accessing firefighting equipment becomes challenging for fire brigade personnel. If the size of the building resulted in travel distances up to 90 m, then fire hydrants within the fire isolated stairs alone would not be capable of servicing the entire building. Therefore, two (2) internal hydrants will be required on the floor plate utilising two (2) lengths of hose to achieve full coverage of the building. The location of the hydrants requires strategic placement adjacent to the 4-hr fire wall separating compartments to provide a horizontal exit for fire brigade personnel.

3. Limitations of design standards – Many of the Australian Standards for fire services - hydrants, sprinklers, EWIS and other fire life safety systems have limitations on the floor area and floor volume that they serve. For instance, the latest amendment of the hydrant standard AS 2419.1:2021 under Section 1.1 Scope, notes that the standard is for Class 7b and 8 buildings not exceeding 108,000 m^3, whereas a contemporary datacentre may have a total volume closer to 1,000,000 m^3. Furthermore, the fire engineering design requires consideration of Appendix C, which was intended to be utilised for single storey warehouses as large-isolated buildings under BCA C3D5, as opposed to a building with an effective height above 25 m. Considerations around external hydrant placement, limiting travel distances to a maximum of 90 m based on the limitations of fire brigade self-contained breathing apparatus (SCBA) and consultation with fire brigades on their standard operating procedures for datacentres were critical to the fire strategy.

1.9 CONCLUSION

In summary, the design of a contemporary data centre requires substantial performance-based Fire Engineering input on a holistic basis beyond the traditional 'Alternative Solution' based fire engineering approach to bring all parts of the datacentre design and operation leading to the development of a coherent fire strategy. This paper outlines a framework for addressing the fire hazards associated with data centres containing LiBs based on a holistic site wide approach with the aid of learnings from recent project experience. This includes a rigorous fire hazard identification process, consideration of dangerous goods and hazardous substances, development of a Fire Safety Study as NSW HIPAP 2 (Planning NSW) Guidelines [3] consultative design consultation process led by the Fire Safety Engineer using the ISO 31000 Risk Management Framework with relevant input by various project stakeholders including the Site Operator, Fire Protection Designer, Building Certifier, Building Insurer, Fire Brigades and other regulatory authorities such as the Environmental Protection Agency.

2.0 REFERENCES

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[7] Underwriters Laboratories (UL), *UL 9540A - Test Method for Battery Energy Storage Systems (BESS)*, UL 9540A, Dec. 03, 2025.