BATTERY BOX FIRE SAFETY

Fire Safety Explainer

AMP CLEAN ENERGY LTD

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EXECUTIVE SUMMARY

This report has been commissioned by AMP Clean Energy Limited (AMP) in relation to their 200 kW / 800 kWh battery storage solution 'Battery Box'. Starting in 2024, AMP are seeking planning consent for over one-thousand (>1,000) 'Battery Box' locations around the UK, supporting frequency response services, arbitrage and other balancing services on the UK grid.

As part of 'Battery Box' development DNV have taken on the role of fire safety advisor to AMP, supporting risk management processes in line with relevant standards, regulations, and industry best practice. This report containers Fire Safety Explainer prepared by DNV for 'Battery Box', providing a concise summary of the good engineering practices and controls included by design which effectively prevent, control and mitigate risk of fire and explosion.

It is intended the contents of this Fire Safety Explainer will be utilised in planning processes for 'Battery Box', forming part of application submittal to the local planning authority and consultees. DNV have presented the Fire Safety Explainer in standard DNV report format.

GLOSSARY OF TERMS

Term	Description
BESS	Battery Energy Storage System
BMS	Battery Management System
CO	Carbon Monoxide
ERP	Emergency Response Plan
FAQ	Frequently Asked Questions
FRS	Fire and Rescue Service
GW	Gigawatt
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
IEC	International Electrochemical Commission
kW	Kilowatt
LFP	Lithium Iron Phosphate
MW	Megawatt
NFPA	National Fire Protection Agency
SoC	State of Charge
SoH	State of Health
TMS	Thermal Management System
UL	Underwriters Laboratories

1 INTRODUCTION

AMP Clean Energy (AMP) is a full-service Independent Power Producer (IPP) responsible for over two-hundred (200) assets across the UK, hosting a range of biomass, flexible generation and battery storage facilities. In 2023 AMP announced 'Battery Box' a mid-capacity Battery Energy Storage System (BESS) solution intended to bring grid flexibility and balancing services to local electricity distribution networks. 'Battery Box' offers 200 kW / 800 kWh capacity across 25 m^2, making use of Low Voltage (LV) grid connections.

Prior to roll-out of the technology, AMP are undertaking a significant Health & Safety exercise to demonstrate fire safety provisions of 'Battery Box'. This Fire Safety Explainer highlights the good engineering practices and controls included in 'Battery Box' which effectively prevent, control and mitigate risk of fire and explosion. By harnessing relevant legislation, standards and current industry best practices, key safety features are defined, and Frequently Asked Questions (FAQs) for BESS highlighted.

1.1 Why 'Battery Box'

As a Distributed Energy Resource (DER),'Battery Box' offers several benefits to consumers and system operators:

- Grid Support: The grid must observe constant balance in supply and demand to avoid widespread blackouts. 'Battery Box' can provide high-speed import export control enabling effective management of grid conditions.
- Energy Reserve: Renewable energy sources such as solar and wind suffer from intermittent generation capacity. 'Battery Box' acts as an energy reserve, ensuring supply is available when needed

By bringing energy storage closer to consumers, 'Battery Box' supports grid transition and a Net Zero future. A separate report, also authored by DNV on the carbon life cycle of a version of 'Battery Box' shows that each installation will save around 160 tonnes of carbon a year, around 5,000 tonnes over the project life (Ref. /1/).

1.2 Battery Fire Safety

Battery storage has received considerable scrutiny in recent years, particularly relating to safety concerns surrounding lithium-ion batteries. Incidents reported in the press however often relate to low quality poorly manufactured, un-regulated and poorly maintained batteries within products such as e-bikes and e-scooters. Meanwhile reputable manufacturers claim hundreds of thousands and even millions of hours of operation with no significant failures.

Thermal runaway is a topic of frequent discussion, a failure phenomenon unique to BESS characterised by highly exothermic self-sustaining reactions which can result in cell fire, and, in a worst case, explosion.

- The UK has suffered only one major instance of a BESS fire: Carnegie Road Liverpool, 2020 (Ref. /2/).
- Following Carnegie Road, the sector has significantly matured. Standards bodies including IEC, UL, and NFPA have established new requirements for BESS supporting proper safety provisions at new developments.

The requirements for proper fire safety measures in BESS are well recognised. Developers are recommended to adopt a hierarchical approach to risk management, based on elimination, prevention, control, detection and mitigation of risk factors relating to thermal runaway fire and explosion.

2 FIRE SAFETY IN 'BATTERY BOX'

2.1 Safe Cell Technology

'Battery Box' employs Lithium Iron Phosphate (LFP) battery cells. LFP batteries are considered to be the safer and preferred choice for stationary lithium-ion BESS applications due to their exceptional thermal stability, safety characteristics and durability in contrast to other chemistries.

LFP battery cells are connected to form larger units (modules, packs, racks), protected from the external environment by a suitable enclosure.

2.2 Battery Management System

The Battery Management System (BMS) is the in-built monitoring and control system ensuring safe operation of 'Battery Box'. The BMS ensures the battery cells are maintained within their Safe-Operating-Envelope, including control of an integrated cooling system which prevents battery temperature rise towards thermal runaway.

Live BMS status signals will be relayed to AMP's remote monitoring facility 24/7. In case of any serious faults, including thermal runaway, priority alerts will be raised to operators, and emergency procedures engaged.

2.3 Fire Detection and Propagation Control

Several detection methods can be used to provide early warning of thermal runaway. 'Battery Box' adopts a multi-disciplinary approach integrating heat, smoke and off-gas detection linked to protection controls and the remote monitoring facility.

In the very unlikely event battery fire is realised, 'Battery Box' is designed to limit propagation. The system will be tested at the unit level per standard UL9540A. This standard is globally recognised as an essential requirement in BESS fire safety and used to demonstrate effective design to limit fire propagation between cells, modules and enclosures.

2.4 Firefighting Strategy

Firefighting strategy for BESS assets has been a topic of increasing scrutiny in recent years. Lithium-ion battery fires are distinct by the threat of reignition, whereby self-oxidizing degradation reactions can reinitiate fire, even after flames are first extinguished.

There is an increasing consensus in the BESS community to adopt a 'controlled burn' approach in battery firefighting - aiming not to tackle any battery fire directly. A controlled burn is favored to allow battery fire to diminish naturally, consuming faulted cells and further avoiding any environmental damage from firewater runoff contaminated with toxic metals or electrolytes. As an added precaution, limited volumes of firewater can be applied for 'boundary cooling' to ensure fire is localized and unable to propagate to further areas.

In line with recognized industry practice, AMP will recommend the local fire rescue service observe controlled burn for any firefighting requirement at 'Battery Box'.

3 FREQUENTLY ASKED QUESTIONS (FAQ)

3.1 Are people safe around BESS?

Yes, lithium-ion batteries are remarkably safe when designed and managed properly. BESS technology has undergone extensive research and present-day systems are no riskier than an electrical substation. The inherent hazards from the lithium chemistries are counteracted by state-of-the-art engineering controls. In the UK, good engineering practices and safety requirements are strictly followed and adherence to international safety standards is embedded into every step of BESS design, build and operation.

A pivotal aspect of BESS safety involves crafting a thorough Emergency Response Plan (ERP). Such a plan mitigates risks to public and personnel and also enhances preparedness for first responders in the rare event of a major fire.

3.2 Why do we need BESS?

Battery storage systems have emerged as essential infrastructure, required to enable the global renewable energy transition. The principal role of BESS is to ensure the constant balance of electricity supply and demand. Unlike traditional energy sources (coal, gas, nuclear) the generation profile of renewable technology (solar, wind etc) is sporadic. At any given instant the generation capacity on the grid can peak or drop resulting in disparity between energy availability and end user demand. Although the grid can tolerate some variation in supply and demand, excessive or prolonged drift can lead to major equipment damage.

BESS are rapid acting, high-power systems able to instantaneously draw from or inject power into the grid to maintain the balance of supply and demand. As the proportion of renewable generation increases on our energy networks, the need for batteries becomes paramount.

BESS play a critical role in decarbonisation and improving stability of the national grid. These sites play an important part in preventing large scale blackouts and ensure that our critical national infrastructure and important operations such as NHS hospitals and railways are never without power.

3.3 What is thermal runaway?

Thermal runaway is a battery failure phenomenon characterised by rapid, uncontrolled heating of faulted cells, promoting self-accelerating exothermic reactions and degradation. The possible causes of thermal runaway can be categorised across electrical (e.g. short circuits, power surge), environmental (e.g. extreme weather) and physical (e.g. impact) causes.

Thermal runaway is a self-sustaining process which can escalate over a matter of seconds leading to a rapid rise in battery temperature, cell degradation and the venting of flammable gases. If this gas ignites, the resulting fire will be sustained until materials within the battery are consumed. In a worst-case (rapid multi-cell / module / container event) thermal runaway can also create a localised explosion hazard, alongside release of toxic and corrosive gases to the local environment.

3.4 How can we prevent thermal runaway?

Use of a well-engineered Battery Management System (BMS) reduces the risk of thermal runaway during operation. The BMS is a combined control and safety system based on programmable electronics, deployed widely across hazardous industries and other major machinery. An effective BMS continuously monitors several parameters which are critical to the health of a battery. The monitoring is done at individual cell level as well as overall pack level, using a variety of sensors embedded in the battery system. These parameters include temperature, voltage, current, State of Charge (SoC), and State of Health (SoH).

The BMS promptly responds to any abnormal conditions before thermal runaway can occur. To work alongside the BMS, a Thermal Management System (TMS) is also deployed to actively regulate battery temperature and prevent the formation of hot spots.

For events where the BMS is not able to respond in its full capacity (such as sudden impact or BMS failure), BESS enclosures can be fitted with strategically placed fire detection and suppression systems, which may include smoke and gas detectors alongside fire suppression such as water and aerosol generators. Enclosures can also be fitted with deflagration panels or active ventilation measures to reduce explosion risk.

3.5 How do you tackle a BESS fire?

Lithium-ion batteries present distinct challenges for firefighting. As the industry has developed, several firefighting strategies have been adopted and substantial research undertaken to determine the optimal approach. The three most common firefighting techniques are described as follows (Ref /3/):

- Aerosol Based Suppression - Early BESS solutions integrated propelled aerosol systems to tackle fire through oxygen exclusion. Although effective in the first instance, thermal runaway reactions are self-oxidising, meaning they evolve additional oxygen as the reaction proceeds. Aerosol protected battery systems are thus subject to reignition after suppression reserves are spent.
- Water Based Suppression - Water based suppression systems (e.g. sprinkler or dry pipe solutions) manage BESS fire through cooling of the battery units. This quenches existing flames, whilst also reducing risk of reignition by removing heat from the system. Direct BESS firefighting can be effective, however produces significant quantities of contaminated water run-off which requires safe disposal.
- Controlled Burn - For commercial and utility scale battery units, it is preferable to manage fire through a ‘controlled burn’ applying boundary cooling (indirect water application) to prevent any propagation, and letting the fire diminish naturally in size and intensity until it is able to self-extinguish. It is expected that a BESS fire will burn out within 20 – 30 minutes before reducing to smolder. To prevent reignition, fire blankets or water may be used at this stage. This minimises risk from firewater runoff.

3.6 Will BESS fire cause environmental damage/or contamination?

Lithium-ion battery thermal runaway can, in some cases, result in evolution of environmental pollutants. Contamination risk can be effectively managed by adopting a ‘controlled burn’ for BESS firefighting. By not tackling BESS fires directly, contaminants can be maintained in the battery container, without being washed away or released to the local surroundings.

3.7 Is there risk to the public from electrocution?

No, under normal operation BESS are protected and contained in suitable enclosures. There are no exposed (live) electrical components or otherwise, which may be accessible to members of the public. From the perspective of electrical safety, BESS can be considered no more risky than a typical electrical substation or transformer.

3.8 Could a BESS explode?

In the worst case scenario, poorly designed, maintained and operated BESS could suffer an explosion as a result of thermal runaway. But this is very rare in BESS such as’ Battery Box’. A battery explosion occurs where flammable off-gases from thermal runaway accumulate and ignite, producing a high temperature pressure wave as the gas expands.

The latest BESS technology manage explosion risk through both active and passive explosion protection systems. In the first instance, explosion is avoided by preventing gas accumulation; this can be done by using automated exhaust fans which expel gases from the container. In case this fails, and in the unlikely case explosion does occur, engineered blast vents can control directionality of the explosion ensuring any debris or pressure waves are not directed towards persons or structures nearby.

It is important to stress, whilst not impossible, BESS explosions are considered incredibly rare.

3.9 If a battery is on fire, are the fumes toxic?

In the case of fire, combustion of battery electrode, electrolyte and/or casing materials can result in evolution of gases hazardous to health (HCl, HF, HCN, CO). The specific volume and concentration of gas is determined by several factors including the scale of fire, underlying battery chemistry and local environmental conditions which can assist in dissipation. In practice, DNV have found battery fires can be viewed comparable to typical plastics fires, albeit with some exceptions (Ref. /4/). On average, the emission rate of gases from a burning battery is lower per kilogram of material compared to a plastics fire. However, during thermal runaway (the most intense phase), the peak emissions rate is higher.

3.10 How frequently do BESS have fires?

In the UK, there are currently 105 battery sites in operation with a total capacity of 2,014 MW; of these, 56 are stand-alone BESS sites, 43 are co-located with renewable energies and 6 are co-located with fossil fuel plants (Ref. /5/). Since 2006, there has only been one major incident in the UK that has required assistance from the FRS: Carnegie Road, Liverpool, 2020.

Following Carnegie Road, the sector has made strides in BESS safety, a number of standards have been released, supporting proper design, installation testing, and operation. These include:

- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems
- UL9540 (and test method UL9540A) Energy Storage Systems and Equipment
- IEC 62933-5-2 Safety requirements for grid integrated EES systems electrochemical based systems

In adopting standards, developers and OEMs continue to de-risk BESS projects. In 2023 the failure rate per GW BESS deployed was the lowest figure on record and continues on a downward trend (Ref. /6/). Since 2020, there have been no significant BESS fires in the UK.

4 REFERENCES

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/6/ The Electric Power Research Institute ‘Insights from EPRI’s Battery Energy Storage Systems (BESS) Failure Incident Database’, May 2024.

About DNV

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