Regent
FIRE CONSULTANTS

FIRE SAFETY ASSESSMENT & ADVICE REPORT

Tirawley BESS Facility, Co. Mayo

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Fire Safety Assessment & Advice Report

Client	Regnum Renewables Developments Limited
Project	Fire Safety Assessment and Advice Report for a proposed Battery Energy Storage System (BESS) facility in Tirawley, Co. Mayo
Our Ref:	2511224IE-FS-DM
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01	09/04/2025	DM	Technical peer review of Report
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DM Damian Mullarkey

JG James Gall

SH Siobhan Hynes

External Control

Issue	Date	Reviewed/ Revised By	Details
02	24/04/2026	DM	Updated to reflect revisions to site layout and development description.

DM Damian Mullarkey

JG James Gall

SH Siobhan Hynes

Executive Summary

Regent Fire Consultants (Ireland) Limited have been instructed by Jennings O'Donovan and Partners Limited on behalf Constant Energy Limited to carry out a desktop assessment for the proposed construction of a battery energy storage system (BESS) facility at Tirawley Wind Farm in Co. Mayo. The purpose of this assessment is to support the planning application for the project which involves the construction of the afore mentioned BESS facility, a windfarm, a sub-station and (at a future date) expansion to include solar photovoltaic (PV) panels at an existing greenfield site. The scope of this assessment is associated to the proposed BESS facility only and will specifically address the fire and explosion hazards which have been identified at design stage. This assessment will also provide advice in relation to mitigation measures which should be implemented to address the specific hazards identified.

The proposed development is within a total site area of .61 hectare and will involve the construction of all relevant equipment and infrastructure for the provision of a 150MW battery energy storage system (BESS) facility. The site/works/equipment will consist of the installation of electrical inverters, electrical transformers, containerised battery storage modules, access roads, associated electrical infrastructure, security gates and site fencing and all associated ancillary infrastructure.

Regent Fire Consultants have carried out a desktop Fire Safety Assessment of the proposed BESS facility at Tirawley, Co. Mayo. As part of this desktop review, a Hazard Mitigation Analysis was carried out. The findings of this HMA are presented in detail in Section 6.0 and summarised in Section 7.0 of this Report. It is put forward that, if the mitigation measures which are proposed in this Report are implemented, the fire and explosion hazards which are considered relevant to this proposed facility are adequately controlled and mitigated.

The content of this Report is relevant only to the design and planning phase of this project. This Fire Safety Assessment and Advice Report should be not be used to inform the construction phase and any Building Control requirements for this project. It will be the responsibility of the client and/or person/body corporate responsible for the BESS facility to ensure that this Report is fully reviewed prior to commencement of construction to ensure that all relevant changes to legislation, guidance, design standards, industry knowledge and product technologies have been addressed, accounted for and updated accordingly.

List of Abbreviations/Nomenclature

BESS	Battery Energy Storage System
ESS	Energy Storage System
MW	Megawatt
MWh	Megawatt Hour
kW	Kilowatt
kWh	Kilowatt Hour
MJ	Megajoule
kV	Kilovolt
Wh/kg	Watt Hours per Kilogram – Energy Density
W/kg	Watts per Kilogram – Power Density
EPRI	Electric Power Research Institute
VBB	Victorian Big Battery
FRS	Fire and Rescue Service
BMS	Battery Management System
HMA	Hazard Mitigation Analysis
FMEA	Failure Mode Effects Analysis
HVAC	Heating, Ventilation and Air Conditioning
H_2	Hydrogen
CO	Carbon Monoxide
IP	Ingress Protection
LCO	Lithium Cobalt Oxide
LFP	Lithium Iron Phosphate
LMO	Lithium-ion manganese oxide
NMC	Lithium nickel manganese cobalt oxide
PV	Photovoltaic

Table of Contents

1.0 Introduction

1.1 Background

Regent Fire Consultants (Ireland) Limited ("Regent Fire Consultants") have been instructed by Jennings O'Donovan and Partners Limited ("Jennings O'Donovan") on behalf Constant Energy Limited ("Constant") to carry out a desktop assessment for the proposed construction of a battery energy storage system (BESS) facility at Tirawley Wind Farm in Co. Mayo ("Tirawley BESS Project", "BESS Facility" or "the site"). The purpose of this assessment is to support the planning application for the project which involves the construction of the afore mentioned BESS facility, a windfarm, a sub-station and (at a future date) expansion to include solar photovoltaic (PV) panels at an existing greenfield site. The scope of this assessment is associated to the proposed BESS facility only and will specifically address the fire and explosion hazards which have been identified at design stage. This assessment will also provide advice in relation to mitigation measures which should be implemented to address the specific hazards identified.

At the time of writing, the Irish Government has not prepared any definitive guidance on minimum requirements with regard to the design, installation/construction and operation of energy storage facilities/systems. In fact, public consultation was carried out by the Irish Government on developing an electricity storage policy framework for Ireland which closed in January 2023 [1]. What the outcome of this framework will be is, at the time of writing, unclear. Furthermore, as this is an ever changing and advancing industry, the content of this Report may, in all likelihood, be outdated by the time of construction.

As such, this Fire Safety Assessment and Advice Report has been prepared to address the general hazards associated with BESS facilities, with particular focus on the Tirawley BESS project. Advice and recommendations (rather than minimum provisions/requirements) will be provided in consideration of the hazards, given that this is a design/planning phase assessment of hazards. This is considered the most appropriate approach on the following basis:

i. Guidance may be forthcoming from the Irish Government at a future date which sets out minimum provisions for energy storage facilities which may be more (or less) onerous than the advice and recommendations of this Report;
ii. Further incidents may have occurred at BESS facilities by the time construction phase is reached which highlights the need for additional protection measures;
iii. Existing design standards (e.g. UL 9540A, NFPA 855 etc.) may have been reviewed and updated by the time construction phase is reached;
iv. Manufacturers of BESS plant may have advanced technology beyond what is considered 'industry standard' at the time of writing this Report.

[1] Irish Government (2023). *Consultation on developing an Electricity Storage Policy Framework for Ireland*. Available from: https://www.gov.ie/en/consultation/c65b6-consultation-on-developing-an-electricity-storage-policy-framework-for-ireland/ [accessed 16/06/2023].

On the basis of the above, the content of this Fire Safety Assessment and Advice Report **MUST BE** the subject of a full review prior to commencement of construction and the associated Report submitted to the approving authority for review/approval prior to commencement of construction.

1.2 Project Description

The location of the site is highlighted below in Figure 1. The site is located in a rural location in the townlands of Barrow and Carrickanass, Co. Mayo. The approximate location of the site is circa 9km Northwest of Killala. The location of the site on Google Maps is as follows:

https://www.google.com/maps/search/54.245615,+-9.291193?entry=tts&g_ep=EgoyMDI1MDMwOC4wIPu8ASoASAFQAw%3D%3D

Figure 1 – Site location [2]

The proposed development is within a total site area of .61 hectare and will involve the construction of all relevant equipment and infrastructure for the provision of an 150MW battery energy storage system (BESS) facility. The site/works/equipment will consist of the installation of electrical inverters, electrical transformers, containerised battery storage modules, access roads, associated electrical infrastructure, security gates and site fencing and all associated ancillary infrastructure. Figure 2 below illustrates the proposed site layout plan for the facility.

[2] Image sourced from Google Aerial View on 13/03/2025

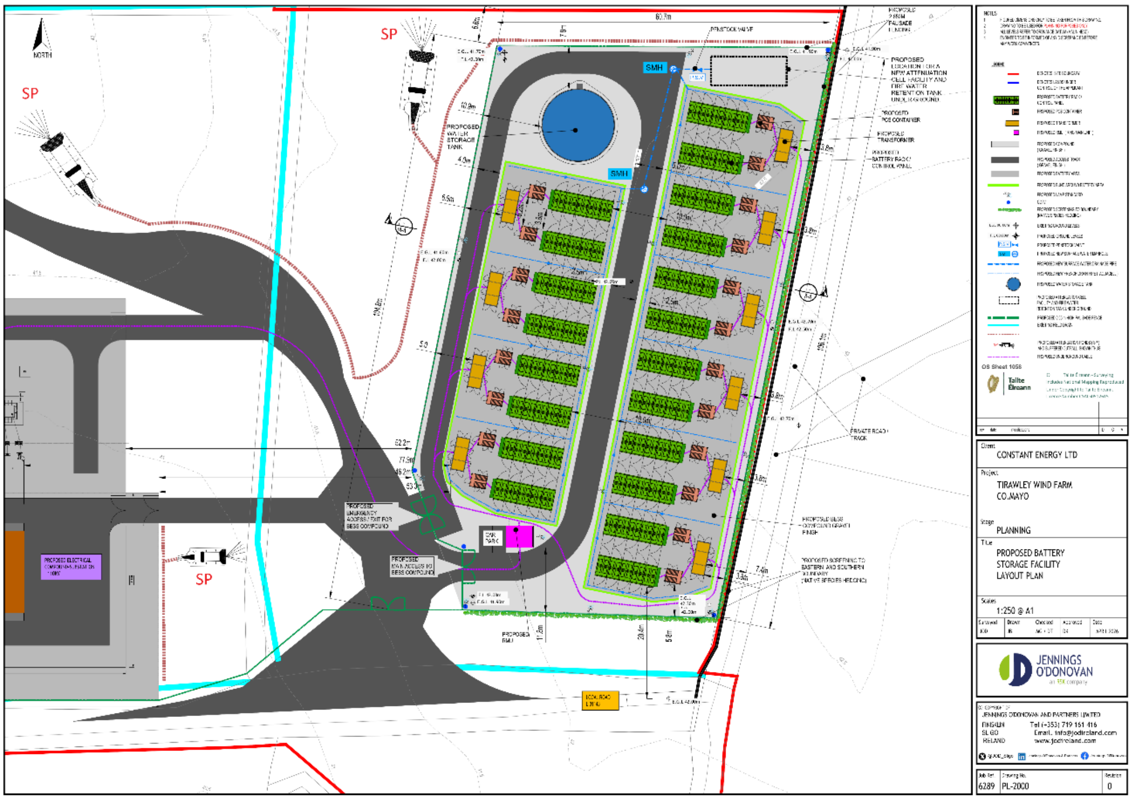

Figure 2 – Site layout plan [3]

On completion of the project, the BESS facility will work in tandem with the proposed windfarm (and potential future expansion to include solar PV), providing a total of 150MW of storage for a 6-hour period. The purpose of the site is to provide additional storage/grid balancing to the existing national electrical grid. That is, the BESS facility will not be directly connected to/powered by a dedicated solar or wind power generation source.

In terms of personnel/occupancy of the site, the facility will be managed/manned 24/7 during normal operation. Personnel will be in attendance at the site for the purposes of undertaking general/reactive maintenance, regular inspections, general management of the site etc.

At the time of writing, no particular product data or specifications have been provided for any of the proposed equipment to be installed at this site. As such, a make/model of BESS unit is not known and cannot be referred to. Therefore, recommendations shall be made within this Report based on the knowledge which this consultancy has of other similar BESS installations. These recommendations shall relate to specific fire safety provisions, features and performance requirements which it is expected the chosen product should achieve as a minimum.

[3] Provided by Mabel Consulting Engineers

2.0 Basis of Assessment

2.1 Applicable Legislation and Guidance

As discussed in Section 1.1, at the time of writing this Report, the Irish Government has completed a public consultation period with a view to publishing a national framework for energy storage. It is not yet clear when this framework will be completed and implemented. Nor is it clear if the outcome of this national framework will include for the provision of design standards which would set out minimum provisions for BESS facilities.

Energy Storage Ireland [4] has produced an information paper which has considered some of the safety issues associated with BESS. While the information contained within this paper is useful and has been consulted in the preparation of this Report, it does not provide any clear design guidance for BESS facilities nor does it recommend/compel designers to adopt a particular guidance standard.

As such, this Report has been prepared to take into consideration current industry standards, guidance and best practices as gleaned from various sources across the world. The documentation (including relevant standards/guidance) which has informed the content of this Report is summarised in Table 1, Section 2.2 below and referenced accordingly throughout this Report. The following sub-sections provide an overview of current fire safety legislation in Ireland and discusses the applicability of said legislation to the proposed BESS facility.

2.1.1 NFPA 855 – Standard for the Installation of Stationary Energy Storage Systems

The National Fire Protection Association (NFPA) is a global organisation that provides advice and produces standards in relation to fire safety, explosion risks/safety and other industrial hazards. The codes and standards produced by the NFPA are widely used across the world and are often applied where a gap in legislation and guidance exists in a particular country for a particular hazard/technology.

NFPA 855 was drafted to address the design, construction, installation, commissioning, operation, maintenance, and decommissioning of stationary energy storage systems (ESS), including mobile and portable ESS installed in a stationary situation and the storage of lithium metal or lithium-ion batteries. It is the intention of NFPA 855 to provide minimum requirements for mitigating the hazards associated with ESS and the storage of lithium metal or lithium-ion batteries.

As such, it is considered that NFPA 855 is the most applicable design guidance for BESS facilities (pending the publication of local guidance).

2.1.2 UL 9540A Test Method

The underwriter's laboratory (UL) has developed a test standard in response to safety concerns identified in the United States in relation to BESS and ESS in general. UL9540A is a recognised test procedure which has been adopted by BESS manufacturers to examine and test for fire spread from a

[4] ESI (2021). Safety of Grid-Scale Battery Energy Storage Systems – Information Paper. [created 06 August 2020, updated July 2021]

battery cell failure and allows manufacturers of BESS units to evaluate thermal runaway fire propagation. While the content of UL9540A does not provide all encompassing design guidance for BESS facilities, BESS containers/systems which have been tested and certified to UL9540A demonstrates that the potential impact of a cell failure/thermal runaway event has been tested for.

As such, the chosen make/model of containerised battery storage unit should have appropriate test certification to UL9540A. This is discussed further in the relevant sections of this Report.

2.1.3 Building Control Act and Building Regulations

The design and construction of buildings are regulated by Building Control bodies under the Building Control Acts 1990 to 2014 (updated to 2023 as appropriate). However, the Building Regulations provide guidance in relation to "buildings". Part B of the Second Schedule to the Building Regulations requires a building to achieve a minimum standard with regard to fire safety and sets out 5 functional requirements. The functional requirements are:

i. B1 – Means of warning and escape
ii. B2 – Internal fire spread (linings)
iii. B3 – Internal fire spread (structure)
iv. B4 – External fire spread
v. B5 – Access and facilities for the Fire and Rescue Service.

The design and construction of BESS facilities such as the proposed facility in Tirawley, Co. Mayo does not adhere or conform to the typical examples which are outlined in Technical Guidance Document B: 2024 Fire Safety Volume 1 – ("TGD-B"). This is due to the fact that the associated plant and infrastructure will be in an outdoor/external setting and will not be contained within a building. Furthermore, following consultation with Jennings O'Donovan, Regent Fire Consultants understand that BESS facilities are outside the scope of the Fire Safety Certificate regime, implying that current Building Regulation guidance for Part B – Fire Safety may not be entirely suitable for such outdoor facilities.

It remains to be seen if any legislative changes occur in the coming months/years which would provide both designers and approving authorities with clear guidance on outdoor ESS facilities and any compliance requirements with Building Control legislation. This should be investigated as part of the review of this Fire Safety Assessment and Advice Report prior to commencement of construction phase.

In consideration of the above, there is certainly ambiguity around application of the Building Control Act/Building Regulations to BESS facilities which are in an outdoor setting. Regent Fire Consultants advise that consultation be carried out between the client and Building Control as part of this process in order to confirm that the above interpretation as to Building Control/Building Regulation requirements is correct. While Regent Fire Consultants have undertaken a high-level review of Access and Facilities for the Fire and Rescue Service as part of this Safety Assessment from a planning perspective, this should not be interpreted as a demonstration of compliance with Part B5 of the Building Regulations.

2.1.4 Fire Services Act (1981 & 2003)

The Fire Services Act (1981 and 2003) places a legal obligation on the person/organisation having control over a premises *'to take all reasonable measures to guard against the outbreak of fire on such premises, and to ensure as far as is reasonably practicable the safety of persons on the premises in the event of an outbreak of fire'*.

However, there is no clear definition of "premises" given in the interpretation of the Fire Services Act. It is noted that a definition of building is given ***as "a building, structure or erection (whether permanent or temporary) of any kind or of any materials"***. But there is a lack of clarity as to whether "premises" retains the same definition as "building". Furthermore, Section 18 of the act sets out general obligations with regard to fire safety. The following text was extracted from the act and is reproduced below for clarity:

This section applies to premises or any part thereof put to any of the following uses—

- *(a) use as, or for any purpose involving the provision of, sleeping accommodation, excluding premises consisting of a dwelling house occupied as a single dwelling;*
- *(b) use as, or as part of, an institution providing treatment or care;*
- *(c) use for purposes of entertainment, recreation or instruction or for the purpose of any club, society or association;*
- *(d) use for purposes of teaching, training or research;*
- *(e) use for any purpose involving access to the premises by members of the public, whether on payment or otherwise; and*
- *(f) use for any other prescribed purpose, but excluding—*
  - *a. premises used as a factory within the meaning of the Safety in Industry Acts, 1955 and 1980;*
  - *b. premises used as a store and subject to licensing under regulations made under the Dangerous Substances Act, 1972;*
  - *c. a magazine, store or registered premises within the meaning of the Explosives Act, 1875; and*
  - *d. an oil jetty within the meaning of regulations under the Dangerous Substances Act, 1972.*

It is unclear if the scope of the Fire Services Act 1981 and 2003 extends to facilities such as the proposed BESS facility. It will be a matter for the approving authority/local Fire and Rescue Service to advise accordingly if BESS facilities fall within the scope of the Fire Services Act and, therefore, are expected to comply with the relevant sections of the act.

2.1.5 Safety, Health and Welfare at Work Act 2005 and the General Application Regulations 2007 (as amended)

The Safety, Health and Welfare at Work Act 2005 states that employers must 'ensure, so far as is reasonably practicable, the safety health and welfare at work of his or her employees'. Section 11 of the Act states that employers are required to prepare and revise adequate emergency plans and procedures and provide the necessary measures for firefighting and the evacuation of the workplace. Section 12 of the Act clarifies that consideration must also be given to the safety of persons other than employees within the workplace (e.g. visiting members of the public). It is a requirement under Section 19 of the Act that employers carry out risk assessments, which should include a Fire Risk Assessment. All information pertaining to the above should be maintained and recorded in a Safety Statement.

Sections 8, 9 and 10 of this Act require that sufficient information, training and supervision is provided to ensure the safety of employees, and also that such instruction, training etc. must take account of any employees with specific needs, to ensure their protection against dangers that may affect them.

Part 3 of the General Application Regulations addresses Electricity and its application extends to ***"persons who design, install, maintain, use, or are in control to any extent of… an electrical network, including the generation, transformation, conversion, switching, controlling, regulating, rectification, storage, transmission, distribution, provision, measurement or use of electrical energy at a place of work"***.

While the BESS facility will be, for the most part, unmanned, it is the interpretation of this consultancy that the provisions of both the Safety, Health and Welfare at Work Act 2005 and the General Application Regulations 2007 apply to this facility. The individual/employer/body corporate in control of this facility (i.e. the body corporate and person who is responsible for the BESS facility) should be aware of their statutory duties as set out in the Safety, Health and Welfare at Work Act 2005 and General Application Regulations 2007 and take measures to comply with this legislation where relevant.

2.2 Supporting Documentation/Information

The following list of standards, drawings and documentation were reviewed and/or applied in the preparation of this Report.

Reference	Source of Information	Date
6289-PL-2000	Proposed Battery Storage Facility – Option 2: Prepared by Jennings O'Donovan	02/2025
6289-PL-2000	Proposed Battery Storage Facility – Option 3: Prepared by Jennings O'Donovan	02/2025
ESRI	BESS Failure Incident Database – Published by the EPRI [available from: https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database]	25/03/2025
ESI	Energy Storage Ireland: Safety of Grid-Scale Battery Energy Storage Systems – Information Paper	July 2021
NFPA 855	NFPA 855 – Standard for the Installation of Stationary Energy Storage Systems	2023
UL9540A	UL9540A – Test Method	2023
DNVGL-RP-0043	Safety, operation and performance of grid connected energy storage systems – recommended practice	2017
FIA	Fire Industry Association – Guidance on Li Ion Battery Fires	December 2020
NFPA Fact Sheet	NFPA: Energy Storage Systems Safety Fact Sheet	June 2020
Allianz	Allianz Risk Consulting (ARC) – Tech Talk Vol. 26: Battery Energy Storage Systems (BESS) Using Li-Ion Batteries	NA

GOV	Government of Ireland - Consultation on Developing an Electricity Storage Policy Framework for Ireland	November 2022
CS1	DNV-GL: McMicken Battery Energy Storage System Event Technical Analysis and Recommendations	18 July 2020
CS2	Victorian Big Battery Fire: Report of Technical Findings	30 July 2021
CS3	EPRI: Carnegie Road Energy Storage System Failure – Response, Recovery and Rebuild Lessons Learned	April 2023
NA	Verbal discussions and email correspondence between Damian Mullarkey (Regent Fire Consultants) and Michael Garvey (JOD)	Various

Table 1 – Supporting information and documentation

3.0 Scope, Limitations and Assumptions

This Fire Safety Assessment and Advice Report takes into account the particular instructions and requirements of our client Jennings O'Donovan and it is for their use only. It is not intended for use by and should not be relied upon by any third party and no responsibility is undertaken to any third party. Regent Fire Consultants (Ireland) Limited shall not be liable for the reliance on or use of the Report by any third party. Neither the whole nor any part of the Report, nor any reference thereto may be shared in any way without prior written approval from Regent Fire Consultants (Ireland) Limited. The scope of this Fire Safety Assessment and Advice Report extends to the areas identified in Section 1.0 only.

The following assumptions underpin the content of this Fire Safety Assessment and Advice Report:

i. The BESS facility will be constructed on a greenfield site comprised of externally positioned containerised battery units and associated plant/equipment;
ii. This Fire Safety Assessment and Advice Report has been prepared in support of the planning application for the proposed BESS facility. The content of this Report is only valid in support of planning and should be fully reviewed/amended prior to commencement of construction to reflect and changes in legislation, BESS guidance and/or battery related technology;
iii. Consultation should be undertaken with both the Fire and Rescue Service and Building Control authorities to ensure that a clear position is obtained prior to commencement of construction on what the statutory requirements are regarding compliance with fire safety and Building Control/Building Regulation legislation where relevant;
iv. Recommendations on mitigation measures are given in Section 6.0 of this Report. These recommendations are made in consideration of industry knowledge and best practice combined with the knowledge and experience of this practice current and relevant at the time of writing this Report. As there is no clear/defined guidance recommended or required by the Irish Government for ESS facilities at the time of writing, there is no legal obligation to adopt any of the recommendations contained herein. Alternative safety measures, design solutions etc. may be acceptable provided an adequate equivalent level of safety can be achieved to satisfy life safety requirements.

Drawings and other information were provided by Jennings O'Donovan to assist in the preparation of this Report. Regent Fire Consultants have taken the information provided to us at face value and do not accept any responsibility for inaccuracies in the information provided or the plan drawings supplied. Should the drawings be subject to any revisions prior, during the development of or following submission of this Report, the content of this Report may no longer be valid and Regent Fire Consultants should be notified immediately.

The BESS will form part of an overall development which will incorporate a windfarm, a sub-station and (at a future date) expansion to include solar photovoltaic (PV) panels. The scope of this assessment is associated to the proposed BESS facility only.

The purpose of this Fire Safety Assessment and Advice Report is to ensure an appropriate standard of life safety for relevant persons within and around the facility in the event of fire, as well as for the Fire and Rescue Service attending a fire incident. This Report will make recommendations which should be implemented to ensure that the facility will meet an acceptable standard in consideration of the hazards identified. It will be the responsibility of the person/body corporate in control of the facility to ensure that the recommendations set out in this Fire Safety Assessment and Advice Report are implemented.

The objective of the fire safety measures set out in this Report is to satisfy the obligation of the regulations regarding life safety requirements, (i.e. health, safety and welfare of persons in and about a building) and not, as such, to protect against the risk to property and consequential loss. The client may wish to consult their insurers regarding the proposals of this Report. This is to ensure that no additional provisions above those set out in this Report (i.e. for property protection purposes) are required.

4.0 Case Studies

4.1 Introduction

Regent Fire Consultants are acutely aware of the hazards associated with battery energy storage systems and, in particular, BESS facilities which utilise lithium-ion batteries. There have been several high-profile incidents involving BESS facilities. The Electric Power Research Institute (EPRI) has recorded a database of failure events in stationary energy storage facilities which date back to 2018 [5]. In total, 94 events are recorded (updated to March 2025) with regard to stationary storage facilities. The locations of these failures are represented graphically below in Figure 3.

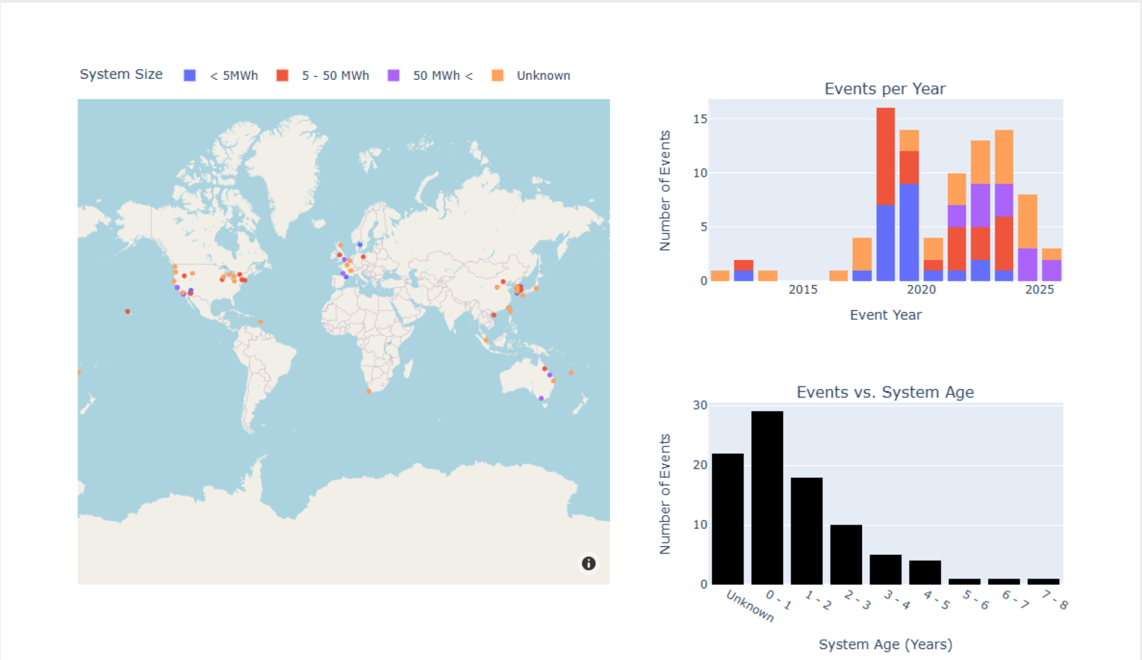

Figure 3 – BESS failure locations [5]

In order to better understand the hazards associated with BESS facilities and make appropriate recommendations, it is first necessary to review historic incidents which have resulted in changes to the industry.

This section of the Report will present an overview of three high profile incidents involving lithium-ion BESS failure events as well as the key lessons which were learned and (where applicable) recommendations which were made following the incident. A summary of other similar incidents is also presented in this section for informative purposes. This is not intended to be an exhaustive review of BESS failure incidents but rather an informative overview of BESS failure events.

[5] EPRI (2023). BESS Failure Event Database. Available from: https://storagewiki.epri.com/index.php/BESS_Failure_Event_Database. [accessed 25 March 2025]

4.2 McMicken BESS Thermal Runaway and Explosion

4.2.1 Background [6]

A BESS facility was installed, commissioned and integrated by the AES Corporation on behalf of Arizona Public Services (APS) who were operators of the McMicken BESS facility. The system was comprised of lithium-ion battery technology with a capacity of 2MW/2MW-hours whose primary function was to integrate solar/renewable energy resources on the electrical grid. Essentially, the BESS was charged during the day via solar energy with the stored energy discharged into the grid in the evening/night.

At circa 1700 hours on 19 April 2019, smoke was reported to be issuing from a building which housed the energy storage system at the McMicken facility. First responders arrived to investigate at circa 1748 hours. At approximately 2004 hours, responders attempted to enter the unit by opening the door. This resulted in a deflagration (explosion) event which seriously injured 4 of the first responders who attempted to enter. An image of the incident container is included below in Figure 4.

Figure 4 – BESS contained post deflagration event [7]

4.2.2 Investigation

Investigations were carried out by 3 separate parties who were:

i. DNV-GL;

[6] DNV-GL (2020). *Technical Report for APS Related to McMicken Thermal Runaway and Explosion: McMicken Battery Energy Storage System Event Technical Analysis and Recommendations* [18 July 2020].

[7] DNV-GL (2020). *Technical Report for APS Related to McMicken Thermal Runaway and Explosion – Figure 9*

ii. Exponent Inc;
iii. Underwriters Laboratories.

Following in-depth investigations into the incident, it was established that the cause of the incident was a single lithium-ion battery cell failure which transitioned into a cascading thermal runaway event, spreading to other cells in the module. From there, the thermal runaway event continued cascading to involve all modules on rack 15 in the container. The incident was first detected when a voltage drop occurred at circa 1654 hours on 19 April in a battery cell in module 2 of rack 15. Cell 7 module 2 entered thermal runaway phase shortly thereafter. As a result, the cell experienced off-gassing which generated smoke, activating the smoke detection and discharge of the suppression agent (Novec 1230). While the suppression agent operated as it was supposed to, it did not prevent cascading thermal runaway to the adjoining cells and adjoining modules. The continued off-gassing of lithium-ion battery cells created a flammable atmosphere within the BESS container. When first responders opted to enter the BESS container circa 3 hours after the first alarm, the flammable atmosphere was still present. Ignition occurred within 2 to 3 minutes of the door into the container being opened, agitating the flammable gas/air mixture. The specific ignition source was not known, but a deflagration occurred which caused BESS container doors and other internal materials/components to be violently discharged from the container, thus causing the injuries sustained by the 4 first responders.

4.2.3 Outcome/Lessons Learned

The incident highlighted the potential short comings in suppression systems in that a suppression system would not successfully prevent a cascading thermal runaway event. Suppression systems are effective at extinguishing fires; however, the phenomenon of cascading thermal runaway requires more preventative measures than just a suppression system. Recommendations which were made by DNV-GL are summarised below. Please note these are the opinions of DNV-GL and should not be interpreted as the opinions/recommendations of Regent Fire Consultants:

i. *Address vulnerabilities to thermal runaway cascading, ventilation and suppression in existing and operational systems;*
ii. *Update standards and codes to directly address cascading thermal runaway in future energy storage systems. Merely acknowledging cascading thermal runaway in the annex or appendix of the standard is insufficient to warn the industry of the hazard and falls short of requiring prevention;*
iii. *Implement ventilation and extinguishing or cooling systems to manage thermal runaway in future energy storage facilities;*
iv. *Implement battery and battery storage system designs that aim to slow or halt cascading or propagation of battery cells and modules during thermal runaway;*
v. *Implement education, training and emergency response procedures that account for the risks and hazards of cascading thermal runaway – including flammable gases – and how to enter systems after failure.*

4.3 Victoria Big Battery Fire

4.3.1 Background [8]

The Victorian Big Battery facility is a 300 MW / 450 MWh BESS facility located in Geelong, Australia. It is regarded as one of the largest BESS facilities in the world, capable of powering over one million homes in Victoria for circa 30 minutes during peak load situations. The system consists of 212 Tesla Megapacks which are charged by renewable sources during peak generation times. The Tesla megapack consists of the following components:

i. Lithium-ion battery energy storage system (BESS) in the form of cells/modules;
ii. Thermal management system;
iii. Overall BESS container circa 7.2m x 1.6m deep x 2.5m in height;
iv. No suppression system was incorporated into the Tesla megapack, instead relying on passive fire protection (i.e. fire resistance of the enclosing cabinet).

A fire occurred on 30 July 2021 in a single Megapack which spread to a neighbouring Megapack. This fire occurred during initial installation and commissioning of the Megapacks. While the fire was contained to the 2 Megapacks and no injuries occurred to site personnel, the fire took circa 6 hours to burn out. No deflagration occurred during the fire as a consequence of off-gassing.

4.3.2 Investigation

An investigation was carried out which aimed to answer how the fire started within the first Megapack and how it was able to spread to the adjoining Megapack. The root cause (on the balance of probability) was most likely a leak in the internal liquid cooling system which instigated an arc tracking fault on the battery modules. It is thought that this arcing event triggered a thermal runaway event which resulted in the fire.

Spread of the fire between Megapacks was also investigated. Tesla Megapacks rely on passive fire protection to inhibit fire spread (i.e. the fire resistance of the enclosures). This passive fire protection is provided through insulated panels which have been tested by Tesla. Test results permit the Tesla Megapacks to be installed as close as 150mm to each other at the sides and back with a 2.4m clearance to the front of the BESS container. The investigation determined that the fire spread from the Megapack of origin to the adjoining Megapack as a result of the following sequence of events:

i. Flames exited from the top (‘roof’) of the Megapack of origin;
ii. Wind conditions were strong on the day of the incident, with wind pushing the flames towards the adjoining Megapack;
iii. All Megapacks were fitted with plastic overpressure (explosion) vents. The flames from the Megapack of origin ignited the plastic overpressure vent in the adjoining Megapack, allowing the fire to spread directly into the battery bay.

[8] Fisher Engineering Inc (2022). *Victorian Big Battery Fire: July 30, 2021 – Report of Technical Findings* [25/01/2022]

4.3.3 Outcome/Lessons Learned

Contributory factors were identified following the investigation. These included faults with the commissioning process for the Megapacks and issues with some of the failsafe features including the keylock switch and Tesla 'pyro disconnect' safety device fitted in each battery module.

As a result of the incident, Tesla modified their Megapacks to include the following mitigations:

i. Improved inspection regime for coolant leaks during assembly;
ii. Reduce the period of time that Megapacks are 'offline' during the commissioning phase (the incident Megapack's were offline for 24 hours during commissioning; this has been reduced to 1 hour);
iii. Do not operate the keylock switch unless undergoing maintenance. Operation of the keylock switch shuts down key telemetry, fault monitoring and electrical fault detection/safety devices;
iv. Add alarms into the coolant system to detect leaks;
v. All electrical safety protection devices are to be active at all times irrespective of keylock switch position;
vi. Continually monitor the pyro disconnect safety device such that the device will actuate in the event of a power failure to the Megapack;
vii. Thermally insulated steel vent shields to be installed in the roof of all Megapacks to protect the plastic overpressure vents from direct flame impingement.

The general conclusion of the investigation was as follows:

In summary, the VBB fire event proceeded in accordance with its fire protection design and pre-incident planning. It presented no unusual, unexpected, or surprising characteristics (i.e., explosions) or resulted in any injuries to site personnel, the general public or emergency responders. It was isolated to the units directly involved, had minimal environmental impact, did not adversely impact the electrical grid, and had appreciably short mission interruption.

4.4 Carnegie Road Energy Storage System Failure

4.4.1 Background [9]

The BESS facility at Carnegie Road is located in Liverpool England and was first energised in December 2018. The facility was fully commissioned in May 2019 and is interconnected to the Scottish Power Energy Network at 33kV. At the time of the incident, the facility consisted of 3 containerised BESS enclosures capable of charging/discharging up to 20MW of stored power for up to 30 minutes. The BESS enclosures housed a total of 2142 lithium-ion modules over 126 racks. An image of the facility is included below in Figure 5 for reference.

[9] EPRI (2023). *EPRI White Paper – Carnegie Road Energy Storage System Failure: Response, Recovery and Rebuild Lessons Learned* [dated April 2023]

Figure 5 – Carnegie Road BESS facility [10]

At approximately 1249 hours on 15 September 2020, the local Fire and Rescue Service were alerted to a fire at the facility. 5 appliances attended and found Container 1 of the 3 containers well alight. Post incident photographs taken by Merseyside FRS are shown below in Figure 6 and Figure 7. The extent of damage sustained by the container was consistent with that of a fire and explosion (deflagration).

Figure 6 – Post incident photographs [11]

[10] EPRI (2023). *EPRI White Paper – Carnegie Road Energy Storage System Failure: Response, Recovery and Rebuild Lessons Learned – Figure 1, pp 3*

[11] EPRI (2023). *EPRI White Paper – Carnegie Road Energy Storage System Failure: Response, Recovery and Rebuild Lessons Learned – Figure 3, pp 5*

Figure 7 – Post incident photographs [12]

4.4.2 Investigation

The investigation was significantly hampered by the extent of damage sustained to Container 1. The overarching theory on cause was considered to be an internal failure of a lithium-ion battery cell. However, the investigation was hampered by several factors including the COVID-19 pandemic and lack of understanding/knowledge as to the potential for stranded energy to still exist in a container post incident.

4.4.3 Outcome/Lessons Learned

The Carnegie Road facility was commissioned in 2018-2019 and it is acknowledged in the Report that industry knowledge had advanced significantly between the time of installation/commissioning and preparation of the Report by the EPRI. Examples of the failures which contributed to this incident are as follows:

i. The first call was received by Merseyside FRS at 0049 hours. The first system alarm activated at 0029 hours. A fire warning occurred at 0031 hours with an explosion recorded by CCTV footage at 0039 hours. This quick transition from fault to deflagration resulted in a loss of communication with the battery management system (BMS) which disabled telemetry/alarms for the other modules;
ii. Merseyside FRS were advised that they were attending a “large refrigeration unit” fire. They were unaware what the Carnegie BESS facility was, despite having being involved in an emergency response plan at the site months before the incident where training was carried

[12] EPRI (2023). *EPRI White Paper – Carnegie Road Energy Storage System Failure: Response, Recovery and Rebuild Lessons Learned – Figure 4, pp 6*

out for an emergency. However, this information was not disseminated to local crews prior to the incident;

iii. The Carnegie Road containers were missing safety components which would be expected to be in place in modern day containers such as explosion ventilation, suppression etc. Furthermore, the construction and configuration of the containers/battery modules has advanced considerably in the time since commissioning.

One of the key aspects of this incident was highlighting the importance of having adequate procedures, protocols and preparedness in place to deal with a BESS failure incident. While no injuries were sustained as a result of the incident, it highlights the importance of cooperation and communication between operators of a BESS site and the local FRS.

4.5 Summary of Other Notable Incidents

For completeness, a review of other notable incidents has been carried out for the past 2 years, given that there has been a significant increase in the number of BESS facilities worldwide in recent years. The information summarised in Table 2 was sourced from the BESS Failure Incident Database published by the EPRI [5]. This is intended to give a summary overview of fire/explosion incidents in other energy storage facilities, demonstrating the range of potential causes which can result in a failure. In many instances, detailed incident reports could not be sourced or were not made publicly available to permit a more in-depth analysis to be carried out.

Location	Date	Capacity (MWh)	Incident Description
England, Essex, Tilbury	19/02/2025	600	A fire occurred in a single BESS container and was extinguished 1 day later. The Thurrock site was still under construction at the time. Firefighters relied on thermal imaging cameras and drones to monitor temperatures and manage the fire, and a water curtain was used to prevent propagation.
US, CA, Moss Landing	16/01/2025	1200	A fire broke out in Vistra's 300 MW / 1200 MWh Phase I BESS plant. Firefighters are using a ""monitor and contain"" approach and allowing the fire to burn itself out. The police issued evacuation orders and closed two nearby roads and a highway, and the local school district closed all schools for one day. The US EPA, the Monterey Bay Air Resources District, and Vistra monitored air quality in and around the fire perimeter and across Monterey County, and found that levels of Hydrogen Fluoride (HF) remained below acute Reference Exposure Level thresholds. Moss Landing Marine Laboratories found elevated levels of nickel, cobalt, and manganese in soil samples at concentrations roughly 100 to 1,000 times higher than normal. The Moss Landing site is home to two separately owned BESS systems: PG&E's Elkhorn system, and Vistra's Moss Landing systems (Phase I, II, and III). The Phase I Vistra system experienced an incident in 2021 and came back online in 2022.
US, CA, Escondido	05/09/2024	120	One of 24 containers caught fire. Businesses adjacent to the substation or within approximately 0.25 mi were evacuated. A shelter-in-place order was issued for locations farther east. Classes were cancelled at some nearby schools. The fire started at noon on September 5, and was extinguished by 1 AM on September 6. Air quality and water runoff reports were made publicly available after

			the incident, and found that all readings taken were well below acceptable exposure limits and considered expected readings during a routine structure fire.
USA, CA, San Diego	15/05/2024	250	The Gateway Energy Storage Facility was involved in a fire, and water was pumped into the building's fire suppression system to extinguish it. A 600-foot safety barrier was maintained for over 22 hours due to air monitors showing high levels of hydrogen. A drone and unmanned robot were been used to monitor the fire, measure air quality and take temperature readings, and firefighters opened the building once heat was no longer detected. A shelter in place order and an evacuation warning were sent out as a precaution. The fire was declared extinguished the next day, but reignited several times until the fire department left the scene nearly 17 days later.
Australia, Queensland, Bouldercombe	26/09/2023	100	Fire at a Tesla battery storage facility in Queensland involving one of 40 lithium Megapack 2.0 units supplied by Tesla on a site privately owned by renewable energy and storage developer Genex. No specific cause is stated.
US, CA, Valley Center	18/09/2023	560	Fire in one of the containers. This is the 2nd event that this system has experienced
France, Saucats, Barban	22/08/2023	98	Fire broke out at an outdoor storage facility. A water curtain was used to prevent propagation. No injuries were reported. Local residents raised concerns about smoke affected nearby cropland and forests.
US, NY, Chaumont	27/07/2023	15	Fire was reported in an outdoor storage facility co-located with solar PV. A shelter-in-place order was issued for the surrounding community within 1 mile of the facility.
US, NY, Warwick	27/06/2023	17.9	This event is one half of a larger simultaneous failure across 2 discrete sites in Warwick, NY. Both sites deployed the new "Centipede" model from Powin and both failures seemed to have occuredwithin 24 hours of each other. The failure appeared to occur during a large storm that affected both sites in Warwick.
US, NY, Warwick	26/06/2023	36	This event is one half of a larger simultaneous failure across 2 discrete sites in Warwick, NY. Both sites deployed the new "Centipede" model from Powin and both failures seemed to have occuredwithin 24 hours of each other. The failure appeared to occur during a large storm that affected both sites in Warwick
US, NY, East Hampton	31/05/2023	40	A 'smoldering battery' was reported, closing down roads and stopping train service for about an hour until the fire was contained. NextEra reported that an internal sprinkler system contained the fire.

Table 2 – Summary of other notable incidents

5.0 BESS and Lithium-Ion Battery Systems

This section provides a brief and basic overview of energy storage systems with specific reference to lithium-ion battery energy storage systems. This is not intended to be a comprehensive review of the technology but rather to give an overview of BESS so that the associated hazards can be identified and addressed through adequate mitigation measures.

5.1 General BESS Design

Electrical energy storage systems are designed to convert and store electrical energy such that the energy can then be re-introduced to the electrical grid when demand requires. Figure 8 below illustrates a proposed scheme in Germany whereby BESS units will be used to store both power surplus from the national grid while also storing energy which is generated from a hydropower source. The BESS units will also provide a grid balancing function.

Figure 9 below provides a high-level overview of an on-site BESS facility. The system is comprised of several components but the key component is the method of energy storage (in this case, lithium-ion BESS). Energy is delivered to the BESS site where it is converted and stored within the lithium-ion battery cells/modules. Electrical energy from a battery source is output in direct current (DC) format. Inverters convert that electrical energy to alternating current (AC). Transformers are used to alter the rated current before power is returned to the grid.

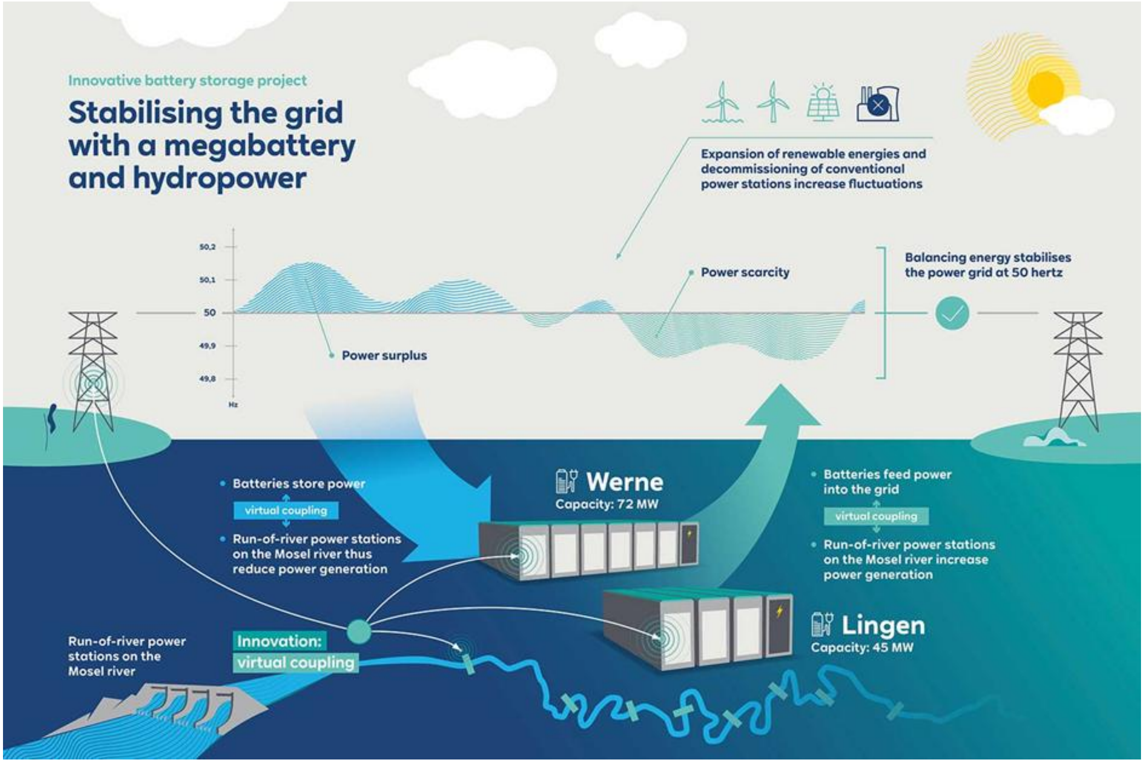

Figure 8 – BESS diagram for a scheme which combines grid stabilisation with hydropower generation [13]

[13] RWE AG (2023). *Innovative and intelligent: RWE builds one of the largest battery storage facilities in Germany.* Available from: https://www.rwe.com/en/press/rwe-ag/2021-07-22-rwe-builds-one-of-the-largest-battery-storage-facilities-in-germany/. [accessed 14/06/2023].

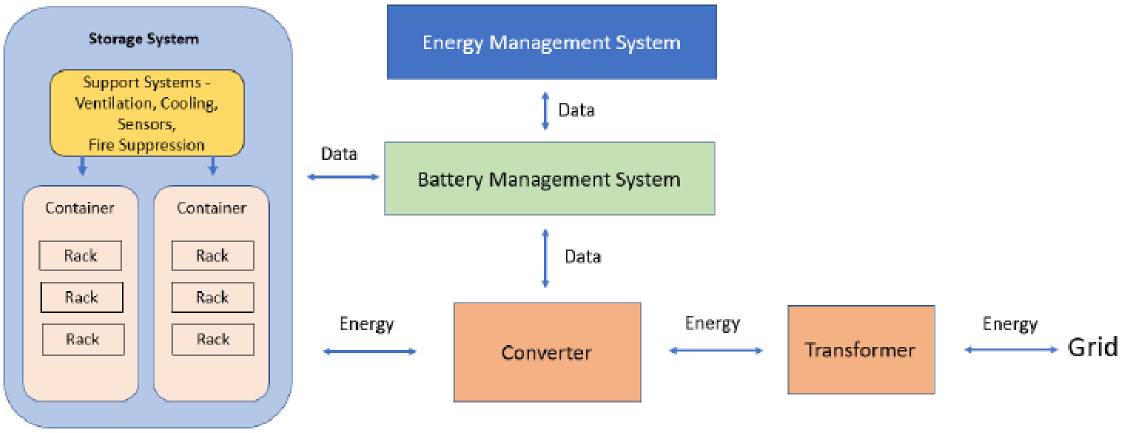

Figure 9 – Basic schematic of a site level BESS [14]

5.2 Lithium Ion Based BESS Systems

Lithium-ion energy storage systems are comprised of lithium-ion battery cells which are configured into modules and racks for the purposes of large-scale energy storage. These basic components are illustrated below in Figure 10.

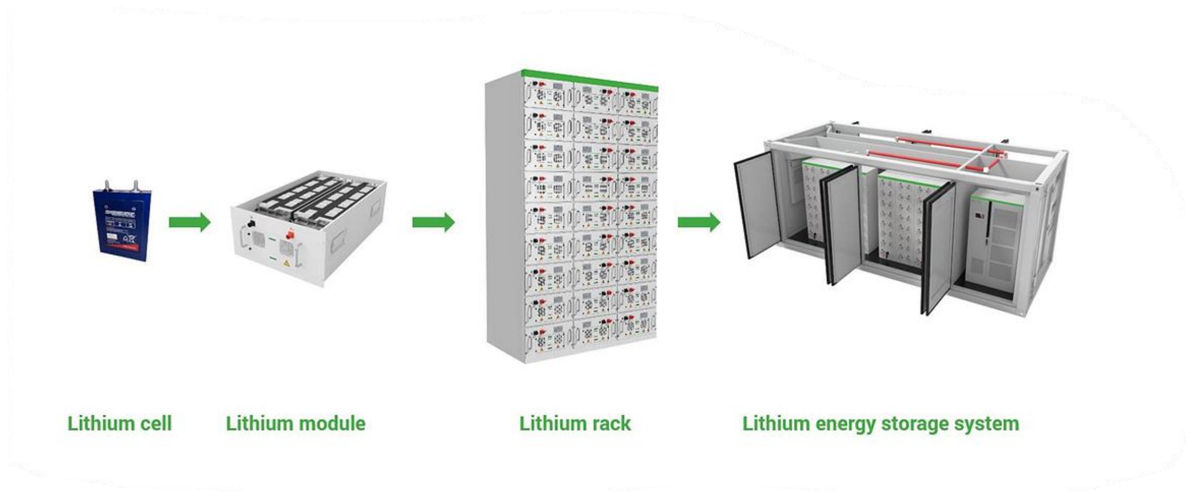

Figure 10 – Lithium-ion cell, module, rack and ESS configuration [15]

At their core, lithium-ion battery cells are comprised of an anode, cathode, separator, electrolyte and 2 current collectors (designated positive and negative as with any battery). Lithium is stored in the anode and cathode while the electrolyte carries positively charged lithium ions between the anode and cathode through the separator. This movement creates free electrons in the anode, charging the positive current collector. Electrical current then flows through the object which is to be powered (e.g. a mobile phone) back to the negative collector. These components are illustrated in Figure 11 below for reference.

[14] ESI (2021). *Safety of Grid-Scale Battery Energy Storage Systems Information Paper – pp9*
[15] EVESCO (2023). *Battery Energy Storage System Components.* Available from: https://www.power-sonic.com/blog/battery-energy-storage-system-components/. [accessed 14/06/2023]

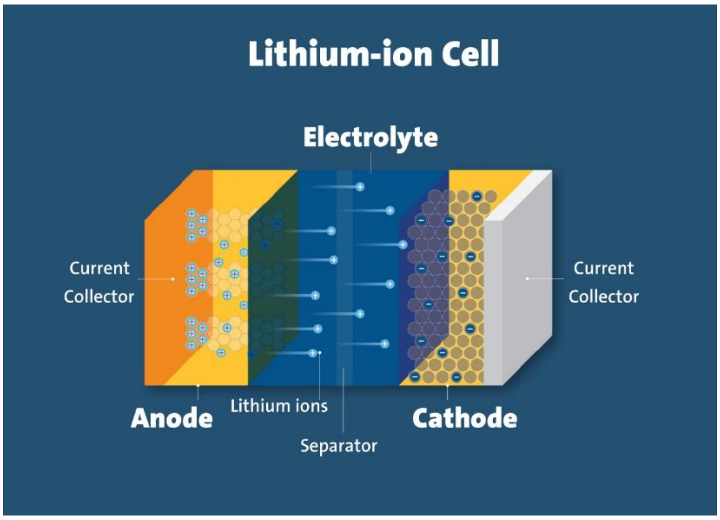

Figure 11 – Lithium-ion cell components [16]

It is by this process that energy can be stored in the batteries (i.e. charging – lithium ions moving from the cathode to the anode) and also taken from the batteries (i.e. discharging – lithium ions moving from the anode to the cathode) in an energy storage system. This is a somewhat simplified overview of the process focusing on a single cell. Efficacy of the lithium-ion cells is dependent upon the energy density (i.e. amount of energy the battery can store – in Wh/kg) and power density (i.e. amount of power than can be generated by the battery as a function of battery mass – measured in W/kg). As the number of cells are increased, so too does the energy density and power density values. It is possible for the lithium ion cells to be configured in series or in parallel to meet the design requirements for storage purposes.

At a very high level, there are several mechanisms by which failure can occur with regard to lithium-ion battery cells. These are discussed in the next section of this Report as part of the Hazard Mitigation Analysis. Furthermore, there are various types of lithium-ion batteries which include:

i. Lithium cobalt oxide ($LiCoO_2$ or LCO);
ii. Lithium iron phosphate ($LiFePO_4$ or LFP);
iii. Lithium-ion manganese oxide ($LiMn2O_4$, $Li2MnO_3$ or LMO);
iv. Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC).

LFP, LMO and NMC type batteries are widely used in stationary storage applications such as BESS due to their longer battery life and given that they are widely regarded as having a reduced propensity for thermal runaway failure.

[16] EVESCO (2023). *Battery Energy Storage System Components.* Available from: https://www.power-sonic.com/blog/battery-energy-storage-system-components/. [accessed 14/06/2023]

6.0 Hazard Mitigation Analysis

This section of the Report has been prepared in consideration of the advice/guidance given in NFPA 855. Criteria has been set out in section 4.4.1 of NFPA 855 whereby a Hazard Mitigation Analysis (HMA) should be carried out and provided to the approving authorities as part of the planning and design stage. Generally speaking, HMA's are only required by NFPA in the following circumstances:

(1) Technologies not specifically addressed in Table 1.3 of NFPA are provided;
(2) More than one ESS technology is provided in a single fire area where adverse interaction between the technologies is possible;
(3) Where allowed as a basis for increasing maximum stored energy as specified in 9.4.1.1 and 9.4.1.2 of NFPA 855;
(4) Where required by the Approving Authority to address a potential hazard with an ESS installation that is not addressed by existing requirements;
(5) Where required for existing lithium-ion ESS systems that are not UL 9540 listed in accordance with 9.2.2.1 of NFPA 855;
(6) Where required for outdoor lithium-ion battery ESS systems in accordance with 9.5.2.1 of NFPA 855 (i.e. where the outdoor installation exceeds 600 kWh or 2160 MJ).

At the time of writing, it is understood that none of the above conditions are present. Nevertheless, a Hazard Mitigation Analysis has been carried out for the proposed Tirawly BESS Facility. The structure of this section of the Report is as follows:

Section 6.1 – Hazards Identified;

Section 6.2 – Recommended Mitigation Measures;

Section 7.0 – Summary of Hazard Mitigation Analysis and Recommendations.

PLEASE NOTE: This is a high-level assessment of hazards based on information which is available at design/planning stage. This Fire Safety Assessment and Advice Report should be reviewed prior to commencement of construction and amended accordingly.

6.1 Hazards Identified

6.1.1 Lithium Battery Cell Failure – Electrical

There are a variety of methods and mechanisms by which a lithium-ion battery cell can fail. These can be somewhat generalised into electrical, mechanical and thermal failure modes albeit it can be argued that the mechanisms of failure are often complex and difficult to categorise. For example, electrical mode of failure can occur as a consequence of a mechanical fault. Generally speaking, all faults can result in fire/explosion risks which can be classified as thermal events/failure modes. Nevertheless, for the purposes of clarity and understanding, this Report will consider cell failure hazards under these headings. Some of the most common methods/failure mechanisms are discussed in the sub-sections below.

6.1.1.1 Overvoltage or Overcharge

This fault mechanism can occur where the charging voltage exceeds design limits and results in excessive current flow into the battery and lithium-ion cells. This results in overheating or excessive heating of the battery cell leading to battery failure.

6.1.1.2 Undervoltage or Over-Discharge

When voltage is drained from the battery below manufacturer designed limits or if a battery is stored for a prolonged period such that voltage drops below that limit, a breakdown in the anode/cathodes can occur. This breakdown can cause the anode to dissolve into the electrolyte solution which can lead to an internal short circuit event.

6.1.1.3 Internal Short Circuit

Following on from the above fault mechanisms, internal short circuits can occur for a variety of reasons which include mechanical damage, manufacturing defects, overheating or the electrical fault mechanisms discussed above. It can be difficult to diagnose internal short circuit causes due to the rapid failure and resulting damage to the cell. Nevertheless, internal short circuits can be considered an electrical fault mechanism which can lead to cell failure, fire and/or explosion hazards.

6.1.1.4 External Short Circuit

External short circuits can happen when external influences result in short circuit events which are outside the lithium-ion cell. Examples include wet or dry arc tracking faults which are instigated by foreign contaminants coming into contact with the cells (such as conductive dusts, leaks of conductive liquids/coolants etc.) which can create pathways for current to flow from positive to negative poles. These current pathways can result in ignition of combustible materials in the vicinity, resulting in a fire.

6.1.2 Lithium Battery Cell Failure – Mechanical

Faults which are categorised as mechanical can be sub-categorised beyond what is discussed in this section of the Report. The content of this section is intended to provide an overview of common mechanical failure modes which could lead to a lithium-ion cell failure, rather than presenting a detailed root cause analysis of mechanical defects e.g. impact to the external casing of a cell may result in damage to or create a hole within the separator. The root cause in that incident could be assigned to a mechanical failure of the separator instigated by mechanical damage to the overall cell.

6.1.2.1 Manufacturing Defects

The efficacy of operation of a lithium-ion cell is highly dependent upon the manufacturing process. Lithium-ion cells contain several components which are assembled through a variety of methods such as soldering, spot welding, moulding etc. Any weakness in the cell which is inherent from the time of manufacture could manifest in failure once the cell is put into service.

6.1.2.2 Transportation

It is highly likely that the type of battery/BESS which will be installed at the Tirawley BESS facility will be imported to Ireland having been manufactured and assembled in another country (or possibly several other countries). This could give rise to the possibility of battery cells/modules sustaining mechanical/physical damage during transportation.

6.1.2.3 Vibration

Modern day BESS units are comprised of multiple components including coolant circulation systems and HVAC systems. Earthquake considerations are not considered relevant for the proposed site. Malfunctioning ancillary equipment (such as circulation pumps or motors) could create vibrations which may have an adverse impact on the battery cells, depending on proximity of the equipment to the battery cells/modules.

6.1.2.4 Impact

BESS containers and, therefore, the cells could be subjected to mechanical damage once the unit is in service. This could be introduced during routine maintenance (e.g. tool damage) of the battery cells/modules/racks, servicing or it could occur as a result of a physical impact/collision between a vehicle and a BESS unit given that the site will be provided with vehicular access.

6.1.3 Lithium Battery Cell Failure – Thermal

Thermal effects which result in battery failure are discussed below in a general manner. As discussed above, the relationship between failure mechanisms can be complex with one failure mechanism leading to another.

6.1.3.1 Excessive Operational Temperatures

If a lithium-ion cell operates at a temperature which is below manufacturer designed limits, this can cause a reduction in current carrying capacity during both charging and discharging. It can also result in lithium plating and dendrite growth on the anode surface which can lead to an internal short circuit in certain circumstances.

Similarly, operation of a lithium-ion cell in high temperatures above manufacturer designed limits can lead to a chemical decomposition of the internal solvent which, in turn, can lead to thermal runaway.

6.1.3.2 Fire Effects

Lithium-ion battery cells may be subjected to thermal stress and failure if exposed to fire effects from an external source. As modern-day BESS units are largely self-contained units, they come with several other components as part of the assembly such as HVAC systems, cooling systems, fault protection devices and disconnection equipment which are electrical in nature. In the event of a fault in an ancillary item of plant, this could lead to thermal damage to the lithium ion cells which in turn may result in thermal runaway and a fire/explosion hazard.

6.1.4 Thermal Runaway

Thermal runaway has been discussed under its own heading, given its prominence as a generalised fault mechanism for lithium-ion battery failures. Thermal runaway may be the outcome where a battery has developed a fault of the type discussed in the preceding sub-sections. Thermal runaway is often labelled as a phenomenon as it is not required to have all components of the fire triangle (i.e. heat source, air and fuel) present as is the case with a conventional fire. Thermal runaway occurs as a result of an exothermic reaction which can generate heat in the absence of oxygen/air. As such, removing oxygen (e.g. through use of gas suppression) does not have the desired effect, instead either the source of heat needs to be dissipated or the fuel source limited/removed.

Thermal runaway can be readily present in a standard domestic setting as a potential cause of fire. Textiles which have been soiled with oils (such as cooking oil, wood oils etc.) rarely have all oils removed during a wash cycle. Should the textiles be dried in a 'traditional' heating element tumble dryer, this can cause the residual oils in the textiles to heat up. If the tumble dryer is stopped early before the cooling cycle is complete and the textiles are removed and stored in a pile/folded, the heated oils are unable to dissipate the heat. This results in an exothermic reaction, leading to thermal runaway and eventually auto-ignition. This is a very common cause of fire in laundrettes and in tumble dryers in general.

The mechanism described above is similar to that experienced with lithium-ion battery cells. Should the battery sustain damage or have a fault (as discussed previously), this can instigate a voltage or temperature instability within the cell. This can lead to a breakdown of the electrolyte solution within the cell. As the internal cell materials fail, voltage drops to zero and an internal short circuit occurs resulting in significant internal temperature spikes. This process is exothermic in nature and continues to produce heat which eventually needs to dissipate. Lithium cells which are in open air can often progress to flaming ignition at this stage, with the excessive heat resulting in ignition of combustible materials.

However, where cells are configured within modules, this can very much be dependent upon the cell configuration as the heat can be retained within the module for a prolonged period. In this instance, the materials which form the cell can continue to be consumed by the thermal runaway event (referred to in the industry as cascading thermal runaway). Gases are produced as a result of this which are both toxic and flammable, which have the potential to create a flammable atmosphere. This is commonly referred to as de-gassing or off-gassing. If left undetected and untreated, it is possible for the thermal event in one cell to spread to adjoining cells and even onto adjoining modules. This can result in several cells entering thermal runaway and producing further quantities of flammable gas. It is as a result of this process that lithium-ion battery cells present both a fire and explosion hazard.

6.1.5 Installation and Commissioning

The fire which occurred at the VBB facility involving the Tesla Megapacks occurred during commissioning of the Megapacks. The commissioning process involved disconnecting certain monitoring functions which meant that the onset of failure went undetected.

6.1.6 *Liquid/Coolant Leaks*

The fire which occurred at the VBB facility in the Tesla Megapack was determined to be as a result of a liquid coolant leak onto the battery modules, which most likely instigated a tracking fault. Following the incident, Tesla modified the Megapacks to include telemetry to identify and respond to a possible coolant leak.

The GridSolv Quantum module contains a glycol/liquid circulation cooling system at each rack level to keep the batteries operating within nominal temperature ranges. Glycol/liquid mixtures are widely used in heat exchanger assemblies due to the excellent heat transfer properties of the glycol liquid. There are, however, risks associated with glycol use. Glycol is corrosive in nature and has a propensity to corrode/deteriorate connections over time, particularly as the glycol ages and deteriorates due to repeated heating and cooling. Corrosion inhibitors can reduce the propensity for corrosion to occur but routine maintenance/replacement of the glycol is required to ensure effective system operation. In consideration of a glycol-based cooling system, the following hazards are considered credible:

i. A glycol coolant leak onto the batteries or other energised electrical component resulting in a tracking fault/ignition;
ii. Failure of a circulation pump resulting in temperature increases in the battery modules;
iii. Incendive electrical failure of a circulation pump;
iv. It is a relatively unreported phenomenon that glycol has the ability to self-heat and spontaneously combust in the right circumstances. Those circumstances usually involve leaks of glycol onto fibrous insulation material which is then heated. This can lead to a thermal runaway situation until such time as the glycol/insulation combination auto-ignites. This is a cause of fire in thermal solar panel installations where glycol/water mixture is used in the circulation system. The propensity for this to occur in a monitored BESS is considered low but is acknowledged as a potential hazard.

6.1.7 *Failure of Management System*

BESS configurations should be fitted with a battery management system as well as more high-level monitoring for other equipment within the container. In the event of a failure or disconnection of the BMS or other monitoring systems, this could transition to a fault which goes undetected eventually leading to failure and a fire/explosion hazard.

6.1.8 *Failure of Protection Systems*

Modern day BESS products (including the GridSolv Quantum product which has informed the content of this Report) are fitted with various protection systems including, but not limited to;

i. Fire detection and alarm systems;
ii. Hydraulic cooling circuit;
iii. HVAC;
iv. Monitoring systems at cell, module and rack level;
v. Suppression systems;
vi. Explosion vents;

vii. Fire rated enclosures/partitions;
viii. Methods of electrical disconnection/isolation.

These protection systems are what mitigate the hazards associated with failure at a lithium-ion cell level. Should one or more systems fail/go offline, this could create the required circumstances for a fire and/or explosion event.

6.1.9 Fire Hazards / Fire Originating in Other Equipment on Site

The preceding sections have discussed, in some detail, mechanisms by which lithium-ion battery faults can progress to result in fires.

Other equipment shall be located on site which is necessary to the operation of the BESS facility which poses a fire risk which includes:

i. Transformers;
ii. Inverters;

The site will be comprised of other equipment including transformers and inverters. It is understood that no substation shall be included at this site. The type of transformer is not known at the time of writing this Report. Oil filled transformers pose a credible fire and explosion hazard in the event of a failure. Inverters are used to convert DC current to AC and are comprised of a variety of electrical components for this purpose. As with any electrical equipment/appliance, incendive electrical faults are possible.

6.1.10 Creation of an Explosive Atmosphere

As discussed above in Section 6.1.4, a thermal runaway event in a lithium-ion cell can spread to involve other cells to produce quantities of flammable gases which are byproducts of the combustion process. This has the potential to create an explosive atmosphere as a result of off-gassing.

6.1.11 Maintenance/Actions of Contractors

BESS facilities and the associated plant/infrastructure will require routine maintenance. There will also be reactive maintenance required as and when required. Such works are not limited to the BESS containers and may involve repairs/maintenance to other site plant, fences, excavation works etc. Potential hazards associated with such works include:

i. Grinding, welding or hot working in general;
ii. Damage instigated by excavations e.g. impact to a BESS container, displacement as a result of excavation works;
iii. Inadvertent disconnection of power to BESS containers.

6.1.12 Arson/Actions of Unauthorised Persons on Site

The site is located in a rural setting in Co. Mayo. While it is understood there will be security fencing surrounding the site as well as 24 hour monitored CCTV, arson remains a risk where unauthorised persons force access to the site. It is also possible that such unauthorised persons could inadvertently cause damage to a BESS unit through their actions i.e. the actions of intruders are not solely attributable to fires started using ignitable liquids.

6.1.13 Human Agency

In consideration of the proposed site, human agency hazards can be generally classified as follows:

i. Unauthorised smoking at the site and/or careless discarding of smokers materials;
ii. Hot working actions such as grinding, welding, soldering etc.;
iii. Mechanical damage as a result of vehicular operation;
iv. Unintentional disconnection of vital power sources/connections for safe operation and monitoring of the BESS.

6.1.14 Lightning

Met Eireann has produced a database of cloud to ground lightning strikes which is produced with the support of the UK Met Office. This information can be obtained and viewed at the following location:

https://www.met.ie/climate/what-we-measure/lightning

By way of an example, approximately 1,286 cloud to ground lightning strikes were recorded on 12 June 2023 (see Figure 12 below for representative image of lightning strikes).

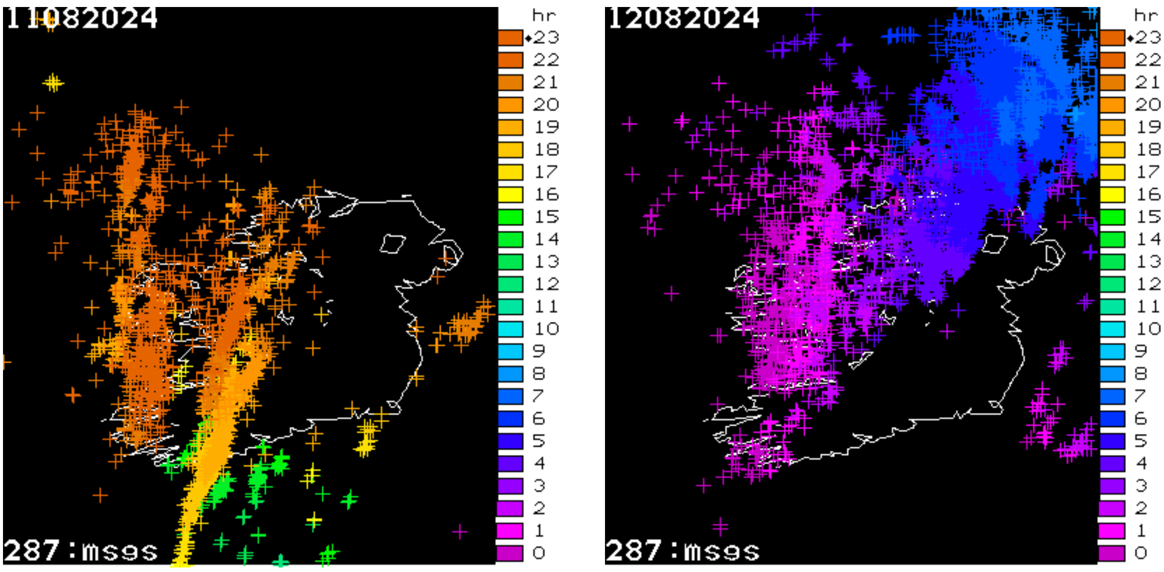

Figure 12 – Cloud to ground lightning strikes on 11 and 12 August 2024 [17]

As such, faults which are introduced or fires which occur as a result of a lightning strike are a credible hazard to the operation of the BESS facility.

[17] Met Eireann (2023). *Lightning Archive – Archived Reports of Lightning Strikes Over Ireland 11 and 12 August 2024.* Available from: https://www.met.ie/climate/what-we-measure/lightning/lightning-archive/ [accessed 09/04/2025]

6.1.15 Livestock

The site is located in a rural setting and is surrounded by land which appears predominantly used for the purposes of agriculture. Were livestock (such as bovine livestock) to inadvertently enter the site, these animals could cause physical/mechanical damage to the BESS containers and/or associated plant and equipment.

6.1.16 Health & Safety of Site Personnel

The site at Tirawley will be primarily unmanned, with the exception of when site personnel will be in attendance to carry out routine/planned or reactive maintenance and/or site inspections. Should a fault condition arise while personnel are on site which transitions to a fire and/or explosion incident, site personnel should be equipped with the necessary knowledge of health and safety procedures, appropriate training and have adequate knowledge as to safe means of escape from the site (should that be required).

6.1.17 Inadequate Facilities/Training/Preparedness for Fire and Rescue Service

The proposed BESS site is located in a rural setting in Co. Mayo. Existing facilities for the Fire and Rescue Service (e.g. provision of public fire hydrants) are yet to be confirmed albeit there does appear to be a public watermain in the adjoining road (see Figure 13 below of SV marker post on adjoining road). It is noted that modern BESS containers are fitted with a combination of continuous monitoring and passive/active fire protection measures such that the design intent is to intercept faults before they transition to a fire/explosion hazard or, where a fire occurs, contain the fire to the incident container. Nevertheless, as this is an unmanned site, it is possible that the presence of the local Fire and Rescue Service may be requested in reaction to an incident.

Figure 13 – Sluice valve marker post on road adjoining site [18]

[18] Image sourced from Google Streetview on 09 April 2025

6.1.18 Fire Spread Beyond Site

Consideration has been given to the potential for the fire to spread beyond the site and potentially impact on neighbouring properties in the local area. The location of the site is rural with the nearest habitable dwelling noted to be circa 200m from the proposed site. The current view of the site is noted below in Figure 14. The site and overall area are relatively open and exposed, with natural hedgerows forming the site boundary. These will be removed as part of the works and replaced with security fencing and new hedgerows for screening.

Where BESS sites are located rurally and sited within close proximity to or bordering forestry, there is a credible risk that a fire in the facility (irrespective of whether the fire originates in a BESS unit or transformer) could spread beyond the site to the forestry/vegetation, resulting in a forest fire. This risk would be extremely high were prolonged periods of dry or hot weather to occur, presenting ideal conditions for fire spread.

Figure 14 – View of site and adjoining lands from public road [19]

6.2 Mitigation Measures

This section outlines a general overview of proposed mitigation measures in consideration of the hazards identified in Section 6.1. These mitigation measures should be interpreted as recommendations rather than a legal obligation/requirement given the absence of clear and robust legislation/guidance within the Republic of Ireland at the time of writing. A particular make/model of BESS unit has not been specified at the time of writing. As such, recommendations have been made regarding the minimum fire safety provisions which the chosen BESS unit should achieve. This is not intended to be a particular system specification but rather a summary of general fire/explosion safety provisions which it is recommended should be incorporated into the chosen BESS unit based on the knowledge/experience of this consultancy.

[19] Image sourced from Google Streetview on 26 March 2025

The content of this Report should be the subject of a full review prior to commencement of the construction phase.

6.2.1 Review Prior to Construction

As discussed above, the content of this Fire Safety Advice and Assessment Report should be the subject of a full review prior to commencement of the construction phase. This is considered a mitigation measure on the basis that such a review should seek to undertake the following:

i. Ensure that any domestic legislation, guidance or other requirements which are introduced between planning and construction phase are adhered to in the construction phase Fire Safety Assessment Report;
ii. Ensure that any update to international legislative/guidance changes (in the absence of domestic legislation/guidance) is adhered to;
iii. Ensure that the products which have informed the content of this Report remain current. Any change of product should equate to or exceed the minimum specifications of the products which have informed this Report;
iv. Subject to selection of the final BESS container/product, it may be required to fully review the HMA or to produce a failure mode effects analysis (FMEA) if deemed necessary by the relevant approving authority;
v. Ensure any other relevant changes to the design, site layout etc. are addressed in the updated Report.

6.2.2 Lithium-Ion Battery Cell Failure

The following mitigation measures should be implemented as a minimum package in any BESS to address the potential hazards associated with a battery cell failure:

6.2.2.1 Construction and Siting

The enclosure to the BESS should have a fire rating of not less than 1 hour and should be sited/spaced from neighbouring plant/equipment in accordance with manufacturers installation instructions. Should there be no clear guidance from manufacturers, BESS containers should be spaced in accordance with NFPA recommendations which specify spacings as a function of BESS capacity and sprinkler protection. The enclosure should be rated to a minimum of IP55 provided site conditions do not merit an increase in ingress protection to IP66. It should not be possible to enter the enclosure; all systems should be accessed from outside which would negate any requirement to enter the enclosure.

6.2.2.2 Battery Cell/Module Design

In consideration of the recommendations made by DNV-GL following their investigation of the McMicken battery fire, consideration should be given to methods of preventing cascading thermal runaway. Methods considered included cooling of the cells and separation of the cells using larger air gaps and/or non-combustible/metal plates. This should be specifically addressed as part of the final product specification. All battery cells/modules should have obtained appropriate test certification in accordance with UL 9540A (or similar approved test standard). LFP, LMO and NMC type batteries are the preferred battery type in stationary storage applications due to their longer battery life and given that they are widely regarded as having a reduced propensity for thermal runaway failure when compared with lithium cobalt oxide batteries. As such, where lithium-ion batteries are to be installed, all BESS units should be fitted with LFP, LMO or NMC type batteries. Vanadium redox batteries would also be considered acceptable subject to a product data review. If vanadium redox batteries are proposed prior to construction phase, this should be addressed as part of the review to this Fire Safety Assessment prior to construction. In any event, the chosen battery type should be appropriately tested and certified in accordance with UL 9540A.

6.2.2.3 Protection Against Overheating

BESS modules can be susceptible to overheating from the charging/discharging process and as a consequence of environmental effects. All BESS modules should be fitted with adequate means of cooling the battery racks and the overall BESS module/enclosure (e.g. a glycol/water-based cooling system installed within each battery rack level).

6.2.2.4 Gas Detection

All BESS units should be fitted with suitable gas detection. The type of gas detector should be selected as a function of the type of battery cell to ensure that it is adequately equipped to detect the gaseous by-products of combustion. The type of gas detector should be selected in consideration of the guidance of Annex G of NFPA 855. It is recommended that as a minimum both a hydrogen (H_2) and carbon monoxide (CO) detector are incorporated into each BESS unit.

6.2.2.5 Automatic Fire Detection

All BESS units should be fitted with a suitable means of automatic fire detection (i.e. smoke and/or heat detection). IS 3218:2024 is the design standard for fire detection and alarm systems in the Republic of Ireland. However, this design standard was not prepared to specifically address installation of fire detection and alarm systems within BESS units. Therefore, the design, selection and installation of equipment should be in accordance with manufacturer specification and/or NFPA 855.

6.2.2.6 Automatic Fire Suppression System

All BESS units should be fitted with a suitably designed and installed fire suppression system. Actuation and operation of this system should be in line with the manufacturers design recommendations and specification. It is proposed to use a gas-based suppression system within all BESS units at this site, subject to discussion and agreement with the approving authorities under review of this Fire Safety Assessment and Advice Report.

6.2.2.7 Battery Management System (BMS)

All BESS units should be fitted with a BMS compliant with the guidance of NFPA 855. This BMS should provide continuous monitoring at cell, module and rack level. Minimum safety functions should include (but are not limited to):

i. High cell temperature trip;
ii. Thermal runaway trip;
iii. Rack switch fail to trip;
iv. Inverter/charger fail to trip.

6.2.2.8 BESS Condition Monitoring

All BESS containers should have monitoring of the overall enclosure temperature. Additional monitoring at cell or module level should include:

i. Charging and discharging voltage and current;
ii. Temperature;
iii. Internal ohmic (resistance);
iv. Capacity;
v. State of charge (SOC);
vi. State of health (SOH);
vii. Alarm or fault log.

The online condition monitoring system should include the following features:

i. The ability to transmit data to a constantly attended location or specific operations personnel;
ii. The ability to generate alarms when unusual conditions are detected;
iii. The ability to analyse monitored parameters and generate a summary of the condition of the battery;
iv. Security to prevent unauthorized changes of critical parameter limits, such as voltage, temperature, and current, which are essential to maintain reliable LIB operation;
v. Self-diagnostic capability.

6.2.2.9 Means of Electrical Disconnection

Means of electrical disconnection should be provided within each BESS as follows:

i. A disconnect device for maintenance needs or abnormal events should be provided for each rack.
ii. A method of manual, remote, and local disconnect for the ESS should be provided. A remote disconnect should be in an accessible area that is monitored 24/7. A local disconnect should be provided adjacent to the ESS space.
iii. Temperature monitoring with high alarm for the BESS enclosure should be provided. Alarms should be routed to a continuously attended location or specific operations personnel.

The manufacturer of the chosen BESS unit should be consulted prior to construction to ensure the additional provisions as outlined above are also included in the enclosure.

6.2.2.10 Explosion Ventilation

In consideration of the explosion hazard, all BESS enclosures should be designed and fitted with explosion vents capable of venting a deflagration event.

6.2.3 Installation and Commissioning

Installation and commissioning of the BESS and overall facility plant and equipment should be carried out by competent contractors who are familiar with such facilities and the installation of equipment. All plant and equipment should be installed in accordance with manufacturers recommendations. Moreover, the selection of equipment should be such that it is suitable for the required use e.g. the type of inverter and transformer should be suitable for use with a BESS unit. Where interaction is required between contractors e.g. ESB Networks and appointed contractors/sub-contractors, there should be adequate controls in place from the outset to ensure cooperation between all construction related personnel.

6.2.4 Liquid/Coolant Leaks

All BESS modules should be fitted with a suitable system for cooling the battery racks/modules and the overall BESS enclosure. Where the system is a liquid/glycol-based circulation cooling system, all BESS modules should be fitted with adequate means of access to facilitate inspection and maintenance of the circulation system. This should include access to all pipework/connections, circulation pumps etc. The glycol should be removed and replaced at the intervals which are recommended by the BESS manufacturer. Consideration should also be given to the use of telemetry/monitoring to ensure that any liquid coolant leaks are detected at as early an opportunity as possible.

6.2.5 Failure of Management and/or Protection Systems

The BESS shall, as a minimum, be fitted with the safety provisions which are detailed in Section 6.2.2. Given the extent of protection, it is envisaged that a failure of one or even more than one safety provision would be unlikely to result in a fire and/or explosion event. However, as with the safety of any installation, building etc., efficacy of the safety provisions are reliant on a robust and diligent management system for the site. Were a safety provision to go offline for a prolonged period of time, this could introduce factors which may result in a fire or explosion incident. It is vital that complacency does not become a characteristic of management of the facility, particularly given that it will largely be monitored remotely.

6.2.6 Fire Hazards / Fire Originating in Equipment other than BESS

Other equipment present on site will include transformers and inverters. The type of transformers to be used on site was not known at the time of writing this Report. Typically, transformers are of the dry or wet (oil filled) type. Oil filled transformers pose a credible fire/explosion hazard. The following recommendations should be implemented:

i. Only transformers/inverters which are suitable for use with BESS units should be used on site;
ii. The transformer/inverter should be confirmed as suitable for use with the chosen make/model of BESS by manufacturers of all 3 components;
iii. Transformers should be adequately separated from neighbouring fire sources (including the inverter and BESS modules). This separation distance should be in accordance with one of the following sources:

a. As specified by ESB Networks;
b. As specified by manufacturers of the transformer or BESS module;
c. In accordance with the guidance of NFPA 850 or other suitable guidance. NFPA 850 advises that physical separation should be between 1.5m and 15m depending on the quantity of oil contained within the transformer.

6.2.7 Maintenance/Actions of Contractors

Only approved contractors should be permitted access to the site. Management should ensure that safe systems of work/permit to work systems are in place which ensure that all contractors approved to work on site are fully familiar with health and safety protocol including what to do in the event of fault detection within a BESS module.

Where possible, hot working should be avoided. Where there are no alternatives to hot working, a permit system should be in use with relevant control measures including a fire watch both during and after the works are complete.

Where specialist sub-contractors are present to carry out work, they should be supervised at all times and for the duration of any works by a BESS facility representative who is familiar with the operational procedures of the facility.

Excavations should only be carried out if deemed absolutely necessary. The method of excavation should be given careful consideration. It is recommended that excavators are not used in or around the BESS units.

6.2.8 Arson/Actions of Unauthorised Persons on Site

The site should be fitted with a monitored CCTV system. It is understood that the BESS facility will be enclosed with palisade fencing around the perimeter with access restricted via gates which will be secured when the facility is not manned. This is deemed adequate protection for the site.

6.2.9 Human Agency

It will be the responsibility of management to ensure that site personnel and contractors are fully trained and aware of the protocols with regard to operation of BESS plant and equipment, smoking, hot working, vehicle operation etc. at the site. A robust and comprehensive management plan should be implemented with all site personnel/contractors having received training prior to entering the site making them aware of the dangers and procedures in the event of an emergency.

6.2.10 Lightning

A suitable lightning protection system should be installed at the site to mitigate against any risk of failure induced as a consequence of a lightning strike. The chosen BESS unit should be fitted with surge protective devices which connect between the feeder and the ground to protect the equipment in the event of a voltage spike.

6.2.11 Livestock

The site is separated from the adjoining land by a combination of hedgerows/embankments and it is proposed to install palisade fencing as part of the works to separate the site from the adjoining lands. This is considered to be adequate.

6.2.12 Health & Safety of Site Personnel

Responsibility for the health and safety of site personnel will rest with management of the BESS facility. Regent Fire Consultants consider that this proposed BESS site falls within the scope of the Safety, Health and Welfare at Work Act 2005 and the General Application Regulations 2007 (as amended). As such, the site operator/employer (i.e. person or body corporate responsible for fire safety at the site) should ensure that safe systems of work are in place prior to commissioning and occupation of the facility. This includes, but is not limited to, undertaking a full risk assessment (which should include a full fire and explosion risk assessment) on completion of construction but prior to occupation/operation of the facility.

As discussed at the beginning of this Report, it would appear that this facility falls, for the most part, outside the scope of the Building Regulations and Building Control Act. It is the understanding of Regent Fire Consultants that a facility such as this which is located in an outdoor setting would not require Fire Safety Certification. Furthermore, standards/guidance documents have not yet been produced by the Irish Government, CRS etc. to address fire safety in such a facility as standard Building Regulation Technical Guidance Documents are primarily concerned with fire safety in buildings.

It is the view of Regent Fire Consultants that a design carried out in accordance with current standards and best practice guides such as NFPA 855 will achieve an acceptable standard of fire safety regarding BESS facilities. However, it is also recommended that consultation be carried out with the relevant local authority building control body and Fire and Rescue Service to ascertain any additional design requirements from a local authority perspective.

6.2.13 Access and Facilities for Fire and Rescue Service

At the time of writing, there are no domestic guidance documents available with regard to the design of access and facilities for the Fire and Rescue Service to BESS facilities. As such, this section has considered the guidance of both TGD-B and NFPA 855 with regard to access and facilities for Fire and Rescue Service Use and included mitigation recommendations as a result.

6.2.13.1 Technical Guidance Document B

Section B5 sets out the minimum requirements for access and facilities for the Fire and Rescue to buildings. It is considered that this facility falls outside the scope of fire safety certification. Nevertheless, consultation will be required with the local authority building control body and Fire and Rescue Service to confirm this. If a fire safety certificate application is required, a summary of design requirements to satisfy the requirements of Part B5 of the Building Regulations include (but are not limited to) the following:

i. ***Source of firefighting water*** – Appliances will typically carry water to site. It may be necessary to have a secondary source of water (e.g. a public fire hydrant outside the site, static storage tank). This will be subject to consultation as to the minimum requirements of the Fire and Rescue Service;

ii. ***Vehicle Access*** – There should be sufficient vehicle access to the site and to the building. The following are minimum requirements as set out in Table 5.2 of TGD-B:
   a. Minimum width of road between kerbs – 3.7m
   b. Minimum gateway width – 3.1m
   c. Minimum carrying capacity of roadway – 12.5 tonnes
   d. Maximum dead end access route length – 20m [20]

6.2.13.2 NFPA 855

Annex C of NFPA sets out guidance with regard to firefighting operational considerations at BESS facilities. It should be acknowledged that the BESS modules represent the most significant hazard on site and these modules will be fitted with both active and passive fire protection measures. Nevertheless, other equipment remains on site which also poses a credible hazard on site (such as the transformers and inverters). The following recommendations are made in consideration of NFPA 855 guidance:

i. The local Fire and Rescue Service should develop a pre-incident plan for responding to fires, explosions, and other emergency conditions associated with the BESS facility, and the pre-incident plan should include the following elements:
   a. Understanding the procedures included in the facility operation and emergency response plan described;
   b. Identifying the types of ESS technologies present, the potential hazards associated with the systems, and methods for responding to fires and incidents associated with the particular ESS;
   c. Identifying the location of all electrical disconnects in the building and understanding that electrical energy stored in ESS equipment cannot always be removed or isolated;
   d. Understanding the procedures for shutting down and de-energizing or isolating equipment to reduce the risk of fire, electric shock, and personal injury hazards;
   e. Understanding the procedures for dealing with damaged ESS equipment in a post-fire incident, including the following:
      i. Recognizing that stranded electrical energy in fire-damaged storage batteries and other ESS has the potential for reignition long after initial extinguishment;
      ii. Contacting personnel qualified to safely remove damaged ESS equipment from the facility (this contact information is included in the facility operation and emergency response plan).

[20] Subject to discussion with the Fire and Rescue Service. This maximum figure of 20m was historically established before the arrival of modern-day appliances. The attending FRS may be comfortable with reversing a longer distance than 20m.

ii. Handover procedures for potentially damaged systems should be developed for fire departments to ensure the timely response of qualified technical representatives to manage safety issues. These procedures would also cover issues such as the removal or recycling of damaged equipment. Another procedural component is the realization that damaged ESS system components could include significant stored or stranded energy with no known method for safe dissipation. Stored or stranded energy could be defined as energy that remains in a battery after the system has been shut down;
iii. There should be close cooperation between management of the site and the Fire and Rescue Service to ensure that any design, layout, equipment or operational changes are transmitted to the local Fire and Rescue Service to afford them an opportunity to update their emergency response plan.

The following requirements from NFPA 855 for water supplies are included for informative purposes. It will be at the discretion of the local fire authority as to the requirement for water and hydrant provision at the site:

4.9.4.1 Where required elsewhere in this standard, sites where nonmechanical ESS are installed shall be provided with a permanent source of water for fire protection, unless modified in Chapters 9 through 13.

4.9.4.2 Where no permanent adequate and reliable water supply exists for firefighting purposes, the requirements of NFPA 1142 shall apply.

4.9.4.3 Accessible fire hydrants shall be provided for site ESS installations where a public or private water supply is available.

4.9.4.4 Fire hydrants installed on private fire service mains shall be installed in accordance with NFPA 24 or equivalent local requirement where NFPA 24 is not adopted.

6.2.13.3 Summary of Recommendations

The following is a summary of recommendations with regard to access and facilities for the Fire and Rescue Service:

i. Consultation should be held with the local fire authority to establish their requirements with regard to provision of firefighting water sources and vehicle and firefighting personnel access to the site during the planning and design phases of the project. It should be taken into consideration that the BESS modules will be fitted with a suppression system;
ii. On completion of construction and prior to the site becoming operational, the local fire authority should be consulted and furnished with relevant information as to the type of plant and equipment at the site. The FRS should also be afforded an opportunity to attend site to carry out an operational risk visit including inspection of the facility, undertaking any drills considered necessary and to assist in preparation of an emergency response plan;
iii. In the event of a developing fault within a BESS container, consideration should also be given to how the attending FRS will be made aware of which BESS container has registered a fault. For example, in the event that a cell has failed and has entered thermal runaway, it may not

be readily evident to the attending FRS which BESS unit poses a fire/explosion hazard. Measures to overcome this issue may include (but are not limited to):

a. Having a central control panel which is remote from the BESS containers which will indicate which BESS units has registered a fault;
b. Provision of an external warning/visual beacon on each BESS (subject to discussions with the manufacturer).

6.2.14 Management

Safe and effective operation of the BESS facility will be reliant upon a robust and diligent management system for the site. The following is a non-exhaustive list of recommendations which should be implemented once the site is operational:

i. An emergency response plan should be developed which is specific to the site prior to commissioning of the facility. That ERP should be prepared in conjunction with any ERP prepared by the local FRS;
ii. A Fire Risk Assessment should be carried out at the site prior to commissioning. This FRA should be updated as and when changes occur at the site but at least annually;
iii. All site personnel should be fully trained, familiar and deemed competent before they are permitted access to the site. Site personnel should be familiar with minimum standards for health and safety on the site and should be familiar with procedures in the event of a fire emergency. Only staff who are suitably qualified should be allowed access to the BESS plant and equipment whether that be for inspection or maintenance purposes;
iv. The site should be subjected to routine inspections irrespective of whether or not fault conditions are logged on the BMS. Such inspections should be carried out at least weekly and involve a full, methodical inspection of all BESS plant and equipment. Inspection logs should be kept which document such inspections and any observations;
v. All systems in the site should be subjected to 24/7 monitoring. There should be a clear and defined management plan in place to deal with any issues which arise including, but not limited to:
    a. Fault logged on BMS;
    b. Activation of a gas or smoke detector;
    c. Issue detected on CCTV system;

    The management plan should include how incidents are to be responded to, protocols which warrant alerting the FRS, minimum response times for staff to investigate etc.
vi. All equipment (i.e. BESS modules, transformers etc.) should be inspected for any evidence of fault/developing fault at regular intervals. These intervals should be not less than manufacturer specified intervals. In the absence of any such specification by manufacturers, inspections should be carried out at least weekly;
vii. All electrical components on site should be the subject of periodic electrical inspection and testing in accordance with the manufacturer’s requirements or the requirements of I.S. 10101:2020+AC1:2020 - National Rules for Electrical Installations;
viii. All fire protection devices (i.e. gas detectors, sprinklers etc) should be subjected to regular inspection, testing and maintenance in accordance with manufacturers recommendations;

ix. The site should demonstrate good 'housekeeping' practices. There should be no combustible materials stored at the site other than combustibles which are present within the necessary plant and equipment;
x. Where new equipment is installed, that equipment should be verified as suitable for use in the intended location and with the existing products/installations. Product substitution (particularly where technology becomes outdated) can have adverse impacts on existing installations if it is designed/installed to a different standard.

6.2.15 Fire Spread Beyond Site

At present, the proposed BESS site is located rurally and in a largely open location such that the perceived risk of fire spread is low. However, were the adjoining lands to be repurposed for forestry use, that risk could increase significantly.

It is not possible to control or dictate the use of lands which are outside the ownership of the BESS site. However, draft guidance has been published by the Department of Agriculture, Food and the Marine [21] in relation to forestry and sets out guidance for land owners who are beneficiaries of the afforestation scheme grants. Section 12.2 of this guidance sets out certain requirements for forestry in relation to fire risk and states "*The potential risk that fire poses to forests may vary and its should be assessed and methods to reduce these risks should be prescribed and implemented. Where appropriate, protection against fires is a requirement for grant approval*". Furthermore, it is required that a Fire Plan be prepared in accordance with the Forestry Division's Forest Protection Guidelines which should include a risk assessment identifying potential sources of fire ingress to the forest.

Therefore, and in consideration of the above, the following recommendations are made:

i. Any adjoining lands which are under the ownership of the BESS facility should not be used for the purposes of planting forestry unless otherwise agreed with the planning authority;
ii. Where lands outside the control of the BESS facility are to be used for afforestation, it is not possible to impose controls on these lands, given that they are privately owned. However, it is noted that the following processes are in place for afforestation land which should ensure that there is adequate consideration given to the proximity of the BESS facility to any proposed forest:
    a. Under the Forestry Act 2014, an afforestation Licence is required for all afforestation projects where the area involved is greater than 0.10 hectares (approximately 0.25 acres). All afforestation projects must obtain prior written Technical Approval from the Department of Agriculture, Food and the Marine before they can commence;
    b. If the planned forest is on 50 hectares of land or more, it is required to submit an Environmental Impact Statement (EIS) with the application for technical approval. The EIS should outline any environmental impact that might be caused by the proposed planting and the steps to be taken to minimise these.

[21] DAFM (2023). Forestry Standards Manual – Working document v.08Nov23. Department of Agriculture, food and the Marine (DRAFT)

c. In addition, a Fire Plan must be submitted as part of the afforestation grant application which would afford an opportunity for fire risks such as a BESS facility to be identified and ensure that mitigation measures are implemented which would be within the control of the associated landowner.

In consideration of the above, while the use of lands for afforestation is outside the control of the BESS facility and site, it is deemed that there is adequate oversight in place to ensure that any adjoining lands used for afforestation are subject to their own risk assessment procedure.

7.0 Summary of Hazard Mitigation Analysis and Recommendations

The following is a summary of the hazard mitigation analysis carried out in Section 6.0 of this Report. Please refer to the relevant sections for further detail:

<table>
<tr><th>Section No.</th><th>Sub-Section No.</th><th>Hazard</th><th>Mitigation Measure</th></tr>
<tr><td>6.1.1</td><td>6.1.1.1</td><td>Overvoltage or Overcharge</td><td rowspan="11">In general, all BESS modules should contain the following safety provisions as a minimum standard:
• Have an enclosure which has been tested to achieve a minimum performance of 1 hour fire resistance;
• Have a minimum IP rating of IP55;
• Is sited/spaced in accordance with manufacturer’s instructions;
• Be fitted with LFP, LMO, NMC or vanadium redox flow type batteries;
• Should have adequate means of protecting against overheating of the batteries/enclosure which should be via a liquid-based circulation cooling system, HVAC or combination of both;
• The enclosure should be fitted with temperature sensors fitted at battery cell/module/rack level and in the overall enclosure;
• Gas detection to detect both H_2 and CO;
• Automatic fire detection by way of photoelectric (or similar approved) smoke detection;
• Automatic fire suppression;
• A continuously monitored BMS;
• Continuous monitoring of the enclosure environment (i.e. temperature, humidity etc.);
• Means of transmitting faults to the monitoring station;
• Means of electrical disconnection;
• Explosion ventilation by way of deflagration vent panels.</td></tr>
<tr><td></td><td>6.1.1.2</td><td>Undervoltage or Over-Discharge</td></tr>
<tr><td></td><td>6.1.1.3</td><td>Internal Short Circuit</td></tr>
<tr><td></td><td>6.1.1.4</td><td>External Short Circuit</td></tr>
<tr><td>6.1.2</td><td>6.1.2.1</td><td>Manufacturing Defects</td></tr>
<tr><td></td><td>6.1.2.2</td><td>Transportation</td></tr>
<tr><td></td><td>6.1.2.3</td><td>Vibration</td></tr>
<tr><td></td><td>6.1.2.4</td><td>Impact</td></tr>
<tr><td>6.1.3</td><td>6.1.3.1</td><td>Excessive Operational Temperatures</td></tr>
<tr><td></td><td>6.1.3.2</td><td>Fire Effects</td></tr>
<tr><td>6.1.4</td><td>-</td><td>Thermal Runaway</td></tr>
<tr><td>6.1.5</td><td>-</td><td>Installation and Commissioning</td><td>• Installation and commissioning should be carried out in accordance with manufacturers recommendations for all products (i.e. BESS, inverters, transformers etc.)</td></tr>
</table>

Section No.	Sub-Section No.	Hazard	Mitigation Measure
			• Only experienced competent contractors should be appointed who are familiar with BESS facility installations.
6.1.6		Liquid/Coolant Leaks	• All BESS modules should be fitted with a suitable system for cooling the battery racks/modules and the overall BESS enclosure; • Where the system is a liquid/glycol-based circulation cooling system, all BESS modules should be fitted with adequate means of access to facilitate inspection and maintenance of the circulation system; • The glycol should be removed and replaced at the intervals which are recommended by the BESS manufacturer; • Consideration should also be given to the use of telemetry/monitoring to ensure that any liquid coolant leaks are detected at as early an opportunity as possible.
6.1.7	-	Failure of Management System	• Given the extent of protection which is proposed to the BESS modules, it is envisaged that a failure of one or even more than one safety provision would be unlikely to result in a fire and/or explosion event. • Efficacy of all safety provisions are reliant on a robust and diligent management system for the site.
6.1.8	-	Failure of Protection Systems	
6.1.9	-	Fire Hazards	Transformers pose a credible risk of fire and explosion, particularly oil filled transformers. Inverters also pose a risk of fire. The following recommendations apply: • Only transformers/inverters which are suitable for use with BESS units should be used on site; • Transformers should be adequately separated from neighbouring fire sources (including the inverter and BESS modules). Separation distance to be specified by ESB, the manufacturer and/or as a function of the oil capacity of the transformer.

Section No.	Sub-Section No.	Hazard	Mitigation Measure
6.1.10	-	Creation of an Explosive Atmosphere	Mitigation measures are discussed above in relation to the BESS modules to prevent the creation of an explosive atmosphere.
6.1.11	-	Maintenance/Actions of Contractors	• Only approved contractors should be permitted access to the site; • Management should ensure that safe systems of work/permit to work systems are in place which ensure that all contractors approved to work on site are fully familiar with health and safety protocol including what to do in the event of fault detection within a BESS module; • Where possible, hot working should be avoided. Where there are no alternatives to hot working, a permit system should be in use with appropriate control measures implemented; • Where specialist sub-contractors are present to carry out work, they should be supervised at all times and for the duration of any works by a BESS facility representative; • Excavations should only be carried out if deemed absolutely necessary.
6.1.12	-	Arson/Actions of Unauthorised Persons on Site	The site should be fitted with a monitored CCTV system. It is understood that the BESS facility will be enclosed with palisade fencing around the perimeter with access restricted via gates which will be secured when the facility is not manned. This is deemed adequate protection for the site.
6.1.13	-	Human Agency	• It will be the responsibility of management to ensure that site personnel and contractors are fully trained and aware of the protocols with regard to smoking, hot working, vehicle operation and operation of BESS plant and equipment at the site; • Management should prepare an implement a robust and comprehensive management plan prior to commissioning and occupation of the facility.

Section No.	Sub-Section No.	Hazard	Mitigation Measure
6.1.14	-	Lightning	• Lightning protection to be installed at the site with surge protection/lighting protection to be incorporated into each BESS unit; • All electrical equipment should be earthed by adequate means and in accordance with the requirements of the manufacturer of the equipment.
6.1.15	-	Livestock	The site is separated from the adjoining land by a combination of hedgerows/embankments and it is proposed to install palisade fencing as part of the works to separate the site from the adjoining lands. This is considered to be adequate.
6.1.16	-	Health & Safety of Site Personnel	• Regent Fire Consultants consider that this proposed BESS site falls within the scope of the Safety, Health and Welfare at Work Act 2005 and the General Application Regulations 2007 (as amended); • The employer (i.e. person or body corporate responsible for fire safety at the site) should ensure that safe systems of work are in place prior to commissioning and occupation of the facility; • A full risk assessment (which should include a full fire and explosion risk assessment) should be carried out on completion of construction but prior to occupation/operation of the facility; • It is the view of Regent Fire Consultants that a design carried out in accordance with current standards and best practice guides such as NFPA 855 will achieve an acceptable standard of fire safety regarding BESS facilities. However, it is also recommended that consultation be carried out with the relevant local authority building control body and Fire and Rescue Service to ascertain any additional design requirements from a local authority perspective.
6.1.17	-	Inadequate Facilities/Training/Preparedness for Fire and Rescue Service	At the time of writing, there are no domestic guidance documents available with regard to the design of access and facilities for the Fire and Rescue

<table>
<tr><th>Section No.</th><th>Sub-Section No.</th><th>Hazard</th><th>Mitigation Measure</th></tr>
<tr><td></td><td></td><td></td><td>Service to BESS facilities. The following recommendations are made with regard to access and facilities for the FRS:
Consultation during the planning and design phases of the project should be held with the local fire authority to establish their requirements with regard to provision of firefighting water sources and vehicle access to the site. It should be taken into consideration that the BESS modules will be fitted with a suppression system;
On completion of construction and prior to the site becoming operational, the local fire authority should be consulted and furnished with relevant information as to the type of plant and equipment at the site. The FRS should also be afforded an opportunity to attend site to carry out an operational risk visit including inspecting the facility, undertake any drills considered necessary and to assist in preparation of an emergency response plan;
In the event of a developing fault within a BESS container, consideration should also be given to how the attending FRS will be made aware of which BESS container has registered a fault. For example, in the event that a cell has failed and has entered thermal runaway, it may not be readily evident to the attending FRS which BESS unit poses a fire/explosion hazard. Measures to overcome this issue may include (but are not limited to):
Having a central control panel which is remote from the BESS containers which will indicate which BESS units has registered a fault;
Provision of an external warning/visual beacon on each BESS (subject to discussions with the manufacturer).</td></tr>
<tr><td>6.1.18</td><td></td><td>Fire Spread Beyond the Site</td><td>It is not possible to control or dictate the use of lands which are outside the ownership of the BESS site. However, draft guidance has been published by the Department of Agriculture, Food and the Marine in relation to forestry and sets out guidance for land owners who are beneficiaries of the</td></tr>
</table>

Section No.	Sub-Section No.	Hazard	Mitigation Measure
			afforestation scheme grants. In light of this the following recommendations are made: • Any adjoining lands which are under the ownership of the BESS facility should not be used for the purposes of planting forestry unless otherwise agreed with the planning authority; • Where lands outside the control of the BESS facility are to be used for afforestation, it is not possible to impose controls on these lands, given that they are privately owned. However, it is noted that the following processes are in place for afforestation land which should ensure that there is adequate consideration given to the proximity of the BESS facility to any proposed forest: o Under the Forestry Act 2014, an Afforestation Licence is required for all afforestation projects where the area involved is greater than 0.10 hectares (approximately 0.25 acres). All afforestation projects must obtain prior written Technical Approval from the Department of Agriculture, Food and the Marine before they can commence; o If the planned forest is on 50 hectares of land or more, it is required to submit an Environmental Impact Statement (EIS) with the application for technical approval. The EIS should outline any environmental impact that might be caused by the proposed planting and the steps to be taken to minimise these. o In addition, a Fire Plan must be submitted as part of the afforestation grant application which would afford an opportunity for fire risks such as a BESS facility to be identified and ensure that mitigation measures are implemented which would be within the control of the associated landowner.

8.0 Conclusions

Regent Fire Consultants have carried out a desktop Fire Safety Assessment of the proposed BESS facility at Tirawley Wind Farm, Co. Mayo. As part of this desktop review, a Hazard Mitigation Analysis was carried out. The findings of this HMA are presented in detail in Section 6.0 and summarised in Section 7.0 of this Report. It is put forward that, if the mitigation measures which are proposed in this Report are implemented, the fire and explosion hazards which are considered relevant to this proposed facility are adequately controlled and mitigated.

The content of this Report is relevant only to the design and planning phase of this project. This Fire Safety Assessment and Advice Report should not be used to inform the construction phase and any Building Control requirements for this project. It will be the responsibility of the client and/or person/body corporate responsible for the BESS facility to ensure that this Report is fully reviewed prior to commencement of construction to ensure that all relevant changes to legislation, guidance, design standards, industry knowledge and product technologies have been addressed, accounted for and updated accordingly.

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