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What Fire Safety Managers Need to Know About Energy Storage Systems (ESS) – Provision, Operation & Maintenance

Critical insights for safe ESS management and compliance

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FSM Seminar 2025 - Anticipating Tomorrow's Risks

29 July 2025

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Introduction to ESS Fire Challenges

- Lithium-ion batteries have become the backbone of modern renewable energy systems due to their high efficiency, compact size, and adaptability.

- Fire and Explosion Risk
  - Sensitive to overheating,
  - Overcharging,
  - Or physical damage.

- Risk of thermal runaway, which can lead to fires or explosions.

Battery Fires and Explosion

Report: Four Firefighters Injured In Lithium-Ion Battery Energy Storage System Explosion - Arizona

July 29, 2020

FSRI releases new report investigating near-miss lithium-ion battery energy storage system explosion.

- April 19. 2019
- 2.16MWh lithium-ion battery energy storage system (ESS)
- The smoke detector in the ESS signaled an alarm condition at approximately 16:55 hours and discharged a total flooding clean agent suppressant (Novec 1230).
- The team opened the door to the ESS at approximately 20:01 hours.
- A deflagration event was observed by the fire fighters outside the hot zone at approximately 20:04 hours.
- All HAZMAT team members received serious injuries in the deflagration and were quickly transported to nearby hospitals.

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Fire Involving Li-Ion Batteries

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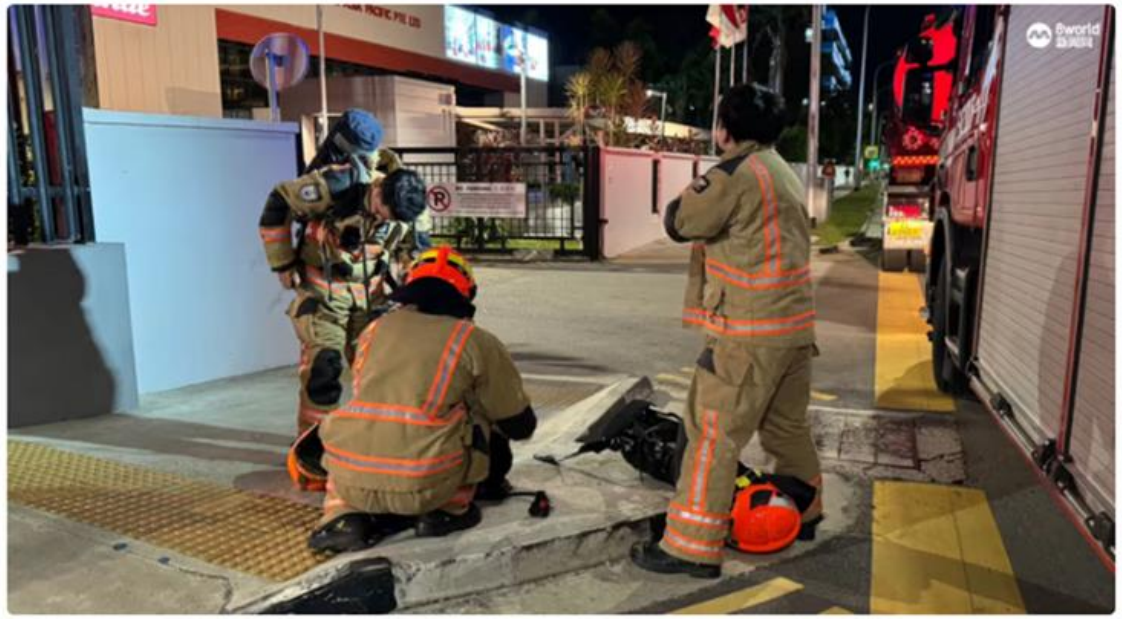
Fire at Loyang data centre, SCDF operations still ongoing after a day



Singapore Civil Defence Force (SCDF) personnel prepare to conduct firefighting operations at 3 Loyang Way on Sep 10, 2024. (Photo: 8world News)

10 Sep 2024 11:47PM
(Updated: 11 Sep 2024 05:20PM)

"The fire involved lithium-ion batteries housed in battery rooms on the third floor of a four-storey building," said SCDF.

"SCDF deployed four water jets to contain the fire. The sprinkler system was also activated."

It added that about 20 people had evacuated from the building before firefighters arrived.

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Loyang Data Center Fire (11 Sept 24

Early SCDF investigations suggest that the fire was likely caused by an electrical issue in one of the battery rooms. PHOTO: LIANHE ZAOBAO

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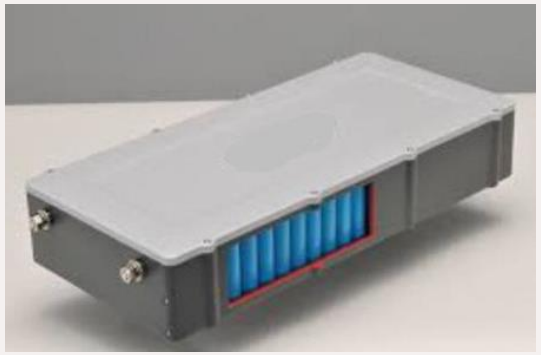
Understanding the Terminology

1. Cell
2. Module
3. Rack/Unit

Cell



Module

Rack

Distributed Power vs. Energy Storage Systems (ESS)

Distributed Power

- Modules interspersed in server racks
- Limited common controls

Energy Storage System (ESS)

- Multiple modules or racks
- Connected to a common control system
- Includes UPS (Uninterruptible Power Supply)

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Lithium-Ion Battery Energy Storage Systems

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Energy Storage Systems in the Fire Code Clause 10.3

SCDF Circular-2 September 2024 (2nd Batch of Amendment)

- Compartment Requirements for Battery Rooms
- Aboveground ESS Requirements-
- Threshold Storage Energy and Maximum Stored Energy (Aboveground)
- Ventilation Requirements – Provision of H_2 Sensors
- Ventilation Requirements – Display Panels & Supervisory Systems
- Underground BESS Storage – Category 1 (<500 kWh)
- Underground BESS Storage – Category 2 (<1200 kWh)

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Compartment Requirements for Battery Rooms – Structural Fire Precautions

TABLE 6.4A COMPARTMENTATION REQUIREMENTS FOR SPECIAL PURPOSE ROOMS IN BUILDINGS					
Usage (1)	Non-sprinkler protected building		Sprinkler-protected building		
	Compartmentation (2a)	Door rating (2b)	Compartmentation (3a)	Door rating (3b)	Sprinkler (3c)
Battery room[6]	2 hr	2 hr	2 hr	2 hr	S[5]

(5) = Water mist system can be considered in lieu of conventional automatic fire sprinkler system.

(6) = This requirements of compartmentation shall apply to any room that is designated as a battery room or of Threshold Stored Energy exceeded the limits stated in *Cl.10.3.1e.*. This does not apply to battery used in consumer products such as laptop, phone, etc.

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Threshold Stored Energy and Maximum Stored Energy (Aboveground)

TABLE 10.3.1: STORED ENERGY CAPACITY OF ENERGY STORAGE SYSTEM		
Type	**Threshold Stored Energy** [a] (kWh)	**Maximum Stored Energy** [a] (kWh)
Lead-acid batteries, all types	70	600
Nickel batteries [b]	70	600
Lithium-ion batteries, all types	20	600
Sodium nickel chloride batteries	20	600
Flow batteries [c]	20	600
Other batteries technologies	10	200

Notes:

[a] It shall refer to an aggregated stored energy capacity per compartment. For battery rating in Amp-Hours, kWh is equal to maximum rated voltage multiplied by amp-hr rating divided by 1000.

[b] Nickel battery technologies include nickel cadmium (Ni-Cad), nickel metal hydride (Ni-MH), and nickel zinc (Ni-Zn).

[c] Includes vanadium, zinc-bromine, polysulfide-bromide, and other flowing electrolyte-type technologies.

Aboveground Energy Storage System (ESS) Requirements

Clause 10.3.1 – Aboveground ESS

- These fire safety requirements are **not applicable** to Energy Storage System installations where the **total stored energy is below the Threshold Stored Energy** specified in Table 10.3.1.
- ESS installation shall be **located at ground level**, i.e., on the same storey as the fire engine accessway or access road.
- The **maximum allowable stored energy** per compartment for various battery technologies **to comply with Table 10.3.1** of the Fire Code.

Ventilation Requirements – Control and Exhaust of Smoke and Toxic Fumes

Clause 7.1.15 – Ventilation System for Rooms Housing Batteries

Rooms housing batteries shall comply with the following requirements:

a. The batteries shall be of either **vented or sealed type**.

b. The room ventilation system shall be designed to l**imit the maximum concentration of Hydrogen (H_2) gas to 1%** of the total volume of the room during the worst case event of simultaneous “boost” charging of the batteries. The inlets and outlets of the ventilation system shall be properly located so that there is no stagnant area in the room.

Ventilation Requirements – Provision of H_2 Sensors and Display Panels

Clause 7.1.15 – Ventilation System for Rooms Housing Batteries *(cont)*

Rooms housing batteries shall comply with the following requirements:

c. Adequate **hydrogen gas detectors shall be provided** inside the room to monitor the hydrogen concentration and to activate the fan, if necessary, to ensure that the hydrogen concentration level at any part of the room does not exceed 1% of the total volume of the room. Display panels showing the readings of the detectors shall be located at the entrance to the room. At the same time, an **alarm signal shall be sent to** a manned station such as **security control room, guard house or FCC**.

d. The design of the **battery room ventilation** shall be in accordance with **BS EN IEC 62485-2 & BS EN IEC 62485-3.**

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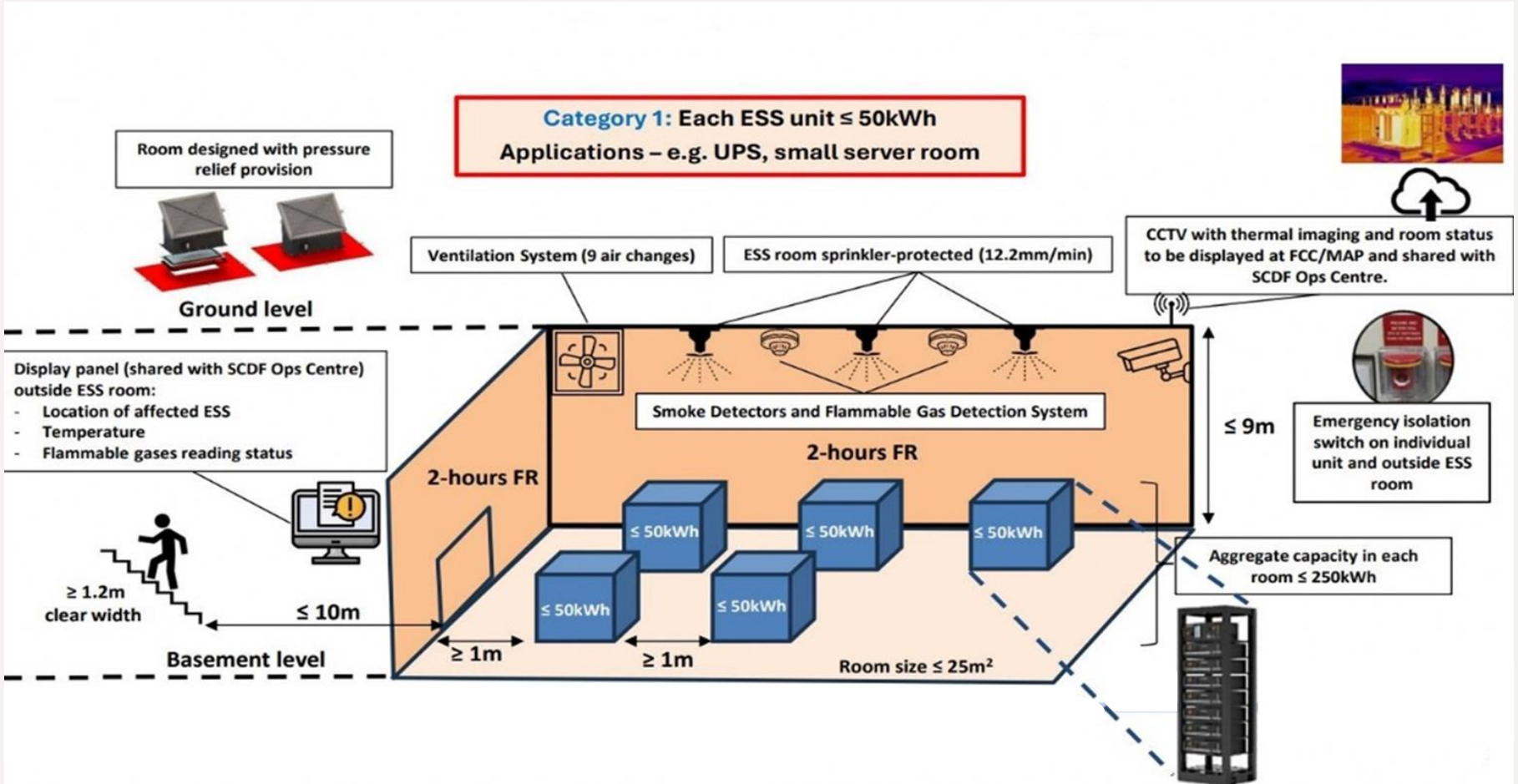
Underground BESS – Storage Category 1 (<500 kWh)

Detection • Protection • Means of Escape • Operation • Rescue



Clause 10.3.3 – BESS Installation Requirements for Category 1 and 2

1. ESS units is permitted to be located in basement not exceeding a depth of 9m below the fire engine accessway/ fire engine access road level.
2. Limit the room size based on fire load: Each compartmented ESS room shall not exceed 25m².
3. ESS unit limit: 50 kWh per unit, up to a total of 250 kWh.
4. Minimum spacing around each ESS unit: 1 m all round.
5. Maximum allowable stored energy with multiple compartments: 500 kWh.
6. Fire Protection System:
    1. Sprinkler protection (high hazard occupancy).
    2. ESS housed in open rack.
    3. Ventilation and smoke purging system.
7. Flammable gas detection system based on LEL (lower explosion limit).
8. Display panel to indicate location, temperature, and flammable gas readings.
9. CCTV cameras equipped with thermal imaging capabilities.

Clause 10.3.3 – BESS Installation Requirements for Category 1 and 2

10. Pressure Relief Provisions:
    1. Explosion prevention systems designed, installed, operated, maintained, and tested in accordance with NFPA 69.
    2. Deflagration venting installed and maintained in accordance with NFPA 68.
11. Battery Management System (BMS) installed.
12. Emergency main isolation switch provided to cut off power supply.
13. Firefighting access:
    1. Provision for deployment of unmanned firefighting equipment (e.g., UFM).
    2. Exit staircase with a minimum clear width of 1.2 m.
    3. Maximum distance of 10 m from ESS room door to exit staircase door.
    4. Directional signage provided.

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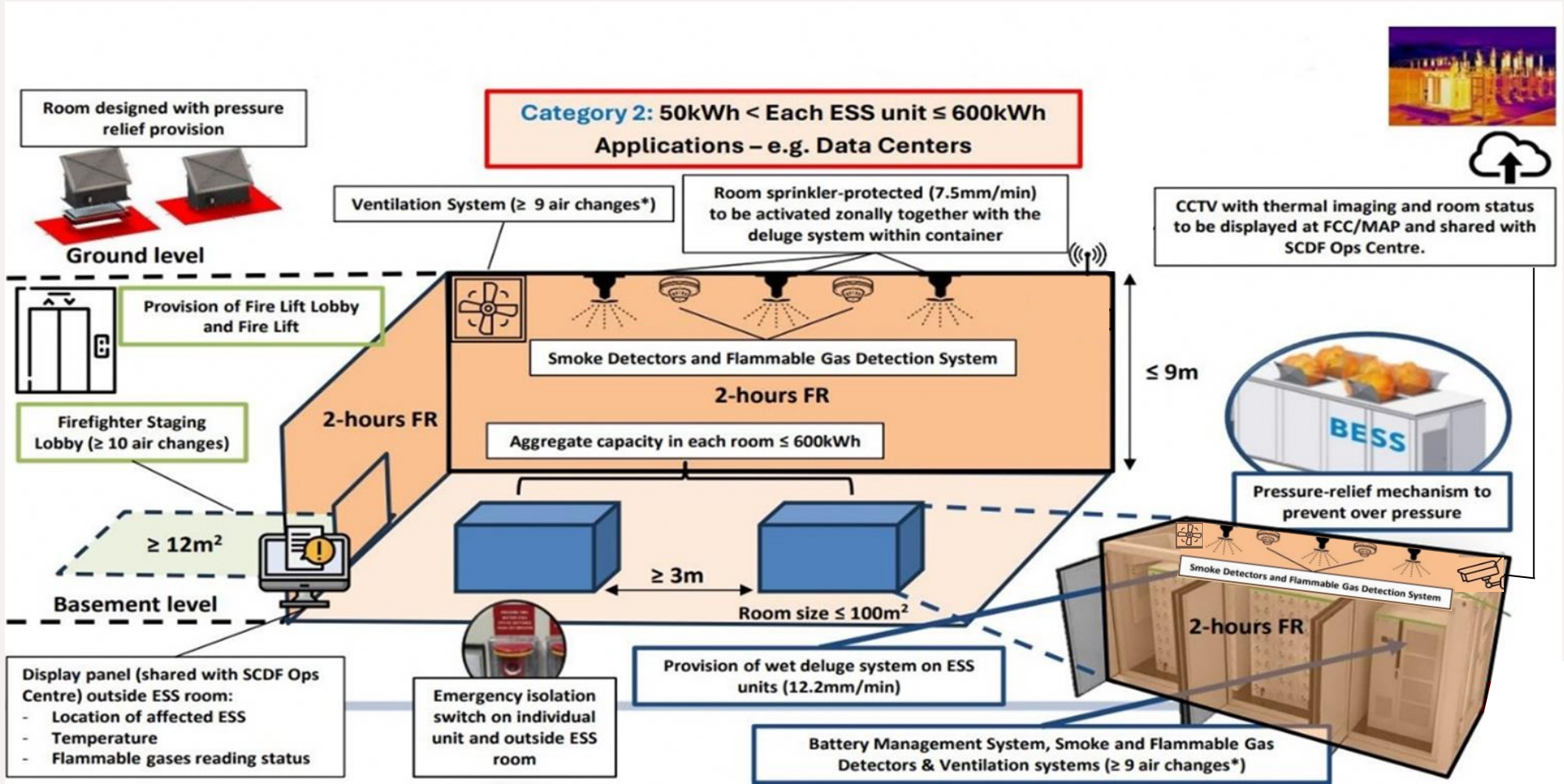
Underground BESS – Storage Category 2 (<1200 kWh)

Detection • Protection • Means of Escape • Operation • Rescue



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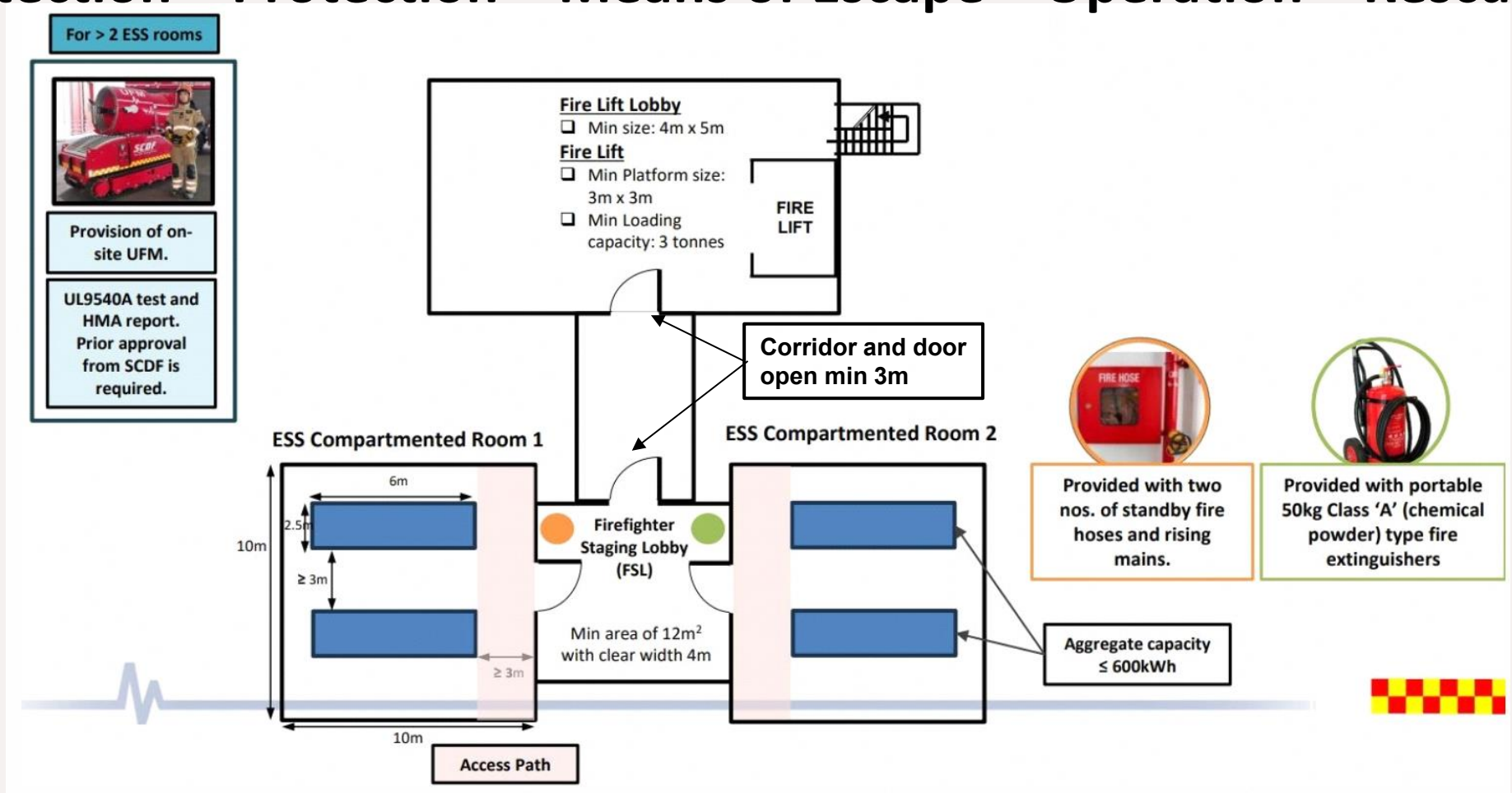
Underground BESS – Storage Category 2 (<1200 kWh) (Access)

Detection • Protection • Means of Escape • Operation • Rescue



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Clause 10.3.3 – BESS Installation Requirements for Category 2

1. No public accommodation shall be located above ESS premises.
2. ESS unit > 50 kWh must be housed within a 2-hr fire-rated containerized compartment.
3. Each compartmented ESS room shall not exceed 100 m^2.
4. Only two compartments are allowed, with a maximum of 600 kWh each (600 kWh × 2).
5. Fire protection system: containerized ESS units shall be protected by a wet deluge system and breeching inlet.
6. Flammable gas detection system is required for each containerized ESS unit.
7. Smoke purging system must be installed for the compartmented ESS room and each containerized unit.
8. Display panels must indicate the location, temperature, and flammable gas readings, and be connected to the SCDF Operations Centre.

Clause 10.3.3 – BESS Installation Requirements for Category 2

9. Fire lift lobby minimum area: 12 m^2.
10. Corridors and door openings serving compartmented ESS rooms must have a minimum width of 3 m.
11. Maximum distance from the lobby door to the most remote ESS unit door shall not exceed 8 m.
12. Firefighter staging lobby shall serve no more than two compartmented ESS rooms.
13. Firefighter staging lobby minimum area: 12 m^2, with a minimum width of 4 m.
14. Provision of rising mains, two standby fire hoses, and portable 50 kg AB-type fire extinguishers.

Relevance of ESS to Fire Safety Managers (FSMs)

Agenda Overview

- **Provision Phase:** Design and Setup of ESS Fire Safety Measures
- **Operation Phase:** Ensuring Daily Readiness and ERP Implementation
- **Maintenance Phase:** Sustaining Fire Safety System Reliability
- **Preventive Measures For ESS Premises**
- **Emergency Response Protocols For ESS Incidents**
- **Obligations for Training, Documentation, and Compliance**

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Relevance of ESS to Fire Safety Managers (FSMs)

- **Understanding ESS Fire Hazards**
  FSMs must recognize the potential fire risks associated with energy storage systems to effectively prevent incidents.
- **Implementing Preventive Measures**
  Proper preventive actions by FSMs help reduce fire risks in ESS, enhancing overall facility safety.
- **Emergency Response Preparedness**
  FSMs should be equipped with tailored emergency response strategies for ESS fire incidents to ensure swift and effective action.
- **Regulatory Compliance**
  Ensuring compliance with fire safety regulations for ESS is critical for FSMs to maintain legal and operational standards.
- **CERT and Fire Drills**
  Establish a CERT team and conduct fire drills in coordination with SCDF to ensure preparedness.

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Provision Phase:

Design and Setup of ESS Fire Safety Measures

FSM’s Role in Approving ESS Fire Safety Design

Provision Phase: Design and Setup of ESS Fire Safety Measures

- **Review of Fire Safety Designs**

  Fire Safety Managers (FSMs) thoroughly review fire safety designs to ensure they comply with all regulatory and safety standards.

- **Compliance Verification**

  Approval involves verifying adherence to statutory requirements and industry best practices for ESS fire safety.

- **Risk Mitigation Focus**

  The primary focus is on mitigating ESS fire risks through careful design and strict adherence to safety protocols.

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Operation Phase:

Ensuring Daily Readiness and ERP Implementation

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Daily Readiness Checks and Regular Drills

- **Routine Inspections**

  Daily checks verify that all emergency systems and equipment are functioning properly and ready for use.

- **Scheduled Drills**

  Regular drills verify personnel are trained to respond quickly and effectively during emergencies.

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Updating ERP to Reflect Operational Changes

- **Importance of ERP Updates**

  Regular ERP updates verify that the system adapts to changing operational conditions and ESS configurations.
- **Maintaining System Relevance**

  Updating ERP systems keeps them relevant and effective for evolving business processes and operational needs.

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Ensuring ERP Addresses ESS-Specific Scenarios

- **Thermal Runway Response**

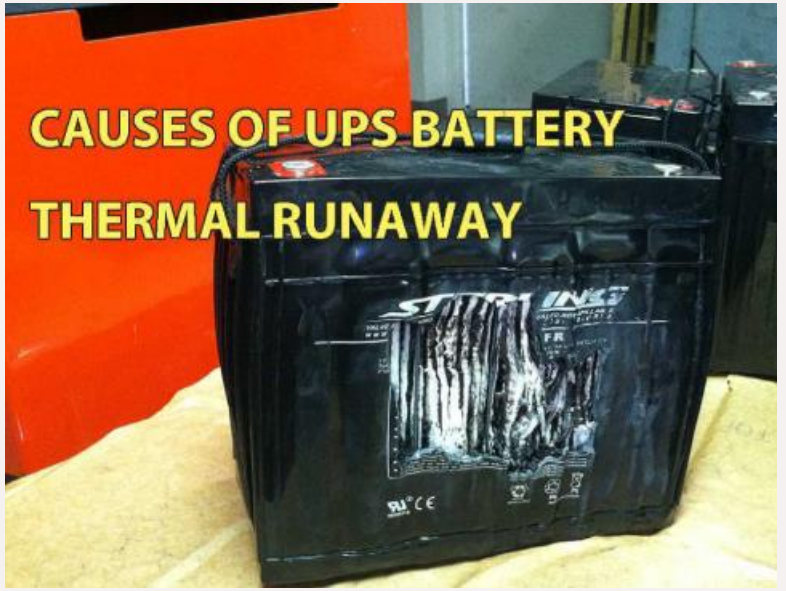
  Protocols must address thermal runway to prevent escalation and protect personnel effectively.

- **Toxic Gas Release Protocols**

  Emergency plans should cover toxic gas detection and evacuation procedures to ensure safety.

- **Personnel and Property Protection**

  ERP must safeguard both personnel and property through tailored emergency responses.



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Maintenance Phase:

Sustaining Fire Safety System Reliability

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Routine Testing of Fire Safety Systems for ESS

- **Suppression System Testing**

  Regular tests ensure fire suppression systems can effectively control fires in ESS installations.

- **Detection System Verification**

  Scheduled checks confirm fire detection systems detect smoke or heat promptly within ESS areas.

- **Ventilation System Evaluation**

  Testing ventilation systems ensures proper airflow to prevent smoke buildup during a fire event.

Maintaining As-Built Records and Documentation

Accurate As-Built Drawings

Precise as-built drawings provide a detailed record of the completed system for future reference and updates.

Support for Maintenance

Accurate documentation enables efficient system maintenance and reduces downtime by aiding troubleshooting efforts.

Regulatory Compliance

Well-maintained records ensure systems comply with regulations and standards, avoiding penalties and ensuring safety

Compensatory Actions in the Event of System Failure

System Failure Impact

Fire safety system malfunctions require immediate attention to avoid safety risks and hazards.

Temporary Compensatory Measures

FSMs must implement temporary safety measures to maintain safety until repairs are completed.

Role of FSMs

FSMs coordinate safety protocols and compensatory actions during system failures.

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Preventive Measures for ESS Premises

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Housekeeping and Routine Inspections

Importance of Cleanliness

Regular housekeeping reduces combustible buildup and minimises fire risk in ESS areas.

Routine Inspection

Conducting inspections helps detect equipment degradation and prevent hazards early.

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Physical Security Against Arson and Sabotage

Deterring Unauthorized Access

Strong physical barriers and access control systems prevent unauthorized entry to sensitive ESS facilities.

Preventing Fire Hazards

Robust security measures reduce risks of arson and potential fire outbreaks in ESS environments.

Protecting Against Sabotage

Surveillance and monitoring systems detect and deter sabotage attempts targeting critical infrastructure.

Illustrative Flowchart for Preventive Measures

Visual Summary of Steps

The flowchart provides a clear visual summary of key steps in fire safety management, improving understanding.

ESS Preventive Fire Safety

The chart outlines the ESS preventive measures to ensure fire risks are minimised and managed effectively.

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Emergency Response Protocols for ESS Incidents

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Recognising and Responding to Battery Fires and Thermal Runway

Thermal Runway Identification

Thermal runway causes rapid battery temperature increase leading to fire hazards if not detected early.

Rapid Fire Escalation

Battery fires can intensify quickly, requiring urgent attention to prevent severe damages.

Specialised Response Protocols

Effective mitigation relies on specialised response protocols and appropriate firefighting equipment.

Managing Toxic Gas Releases and Evacuation Procedures

Hazardous Gas Emissions

ESS fires can release toxic gases posing serious health risks to occupants and responders.

Coordinated Evacuation

Effective evacuation plans to ensure safe and orderly removal of people from affected areas.

Ventilation Measures

Proper ventilation reduces concentration of hazardous gases, protecting health during emergencies.

Coordination with SCDF during Emergencies

Professional Emergency Support

Collaboration with SCDF provides expert assistance and essential resources during fire emergencies.

Effective Communication

Maintaining clear communication channels ensures efficient coordination during emergency situations.

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Obligations for Training, Documentation and Compliance

Training Requirements for CERT and Premises' Personnel

Importance of Continuous Training

Regular training keeps CERT and premises staff skilled and ready for emergency situations.

Emergency Procedures Competency

Training focuses on mastering ESS emergency procedures to ensure quick and effective response.

Safety Measures Awareness

Staff learn critical safety measures to protect themselves and others during emergencies.

FSMs' Obligations for Documentation and Record-Keeping

Compliance Audits

Proper documentation ensures smooth compliance audits and verifies adherence to fire safety regulations.

Emergency Preparedness

Accurate records help prepare for emergencies by providing quick access to vital fire safety information.

Continuous Improvement

Regular record-keeping supports ongoing evaluation and improvement of fire safety practices.

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Ensuring System Compliance with Statutory and Regulatory Requirements

Monitoring Fire Safety Compliance

FSMs continuously monitor fire safety systems to ensure they meet statutory and regulatory standards for protection.

Enforcing Safety Regulations

Enforcement of fire safety laws by FSMs helps safeguard people and property from potential hazards.

Adherence to Relevant Guidelines

FSMs ensure all systems follow specific ESS guidelines and standards critical to fire safety compliance.

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Conclusion

Role of Fire Safety Managers

Fire Safety Managers oversee provision, operation, and maintenance to manage ESS fire risks effectively.

Understanding Statutory Roles

Knowing legal responsibilities ensures compliance and supports effective fire safety in ESS premises.

Emergency Planning and Safety Protocols

Effective emergency plans and protocols are essential for managing fire safety and minimizing risks.

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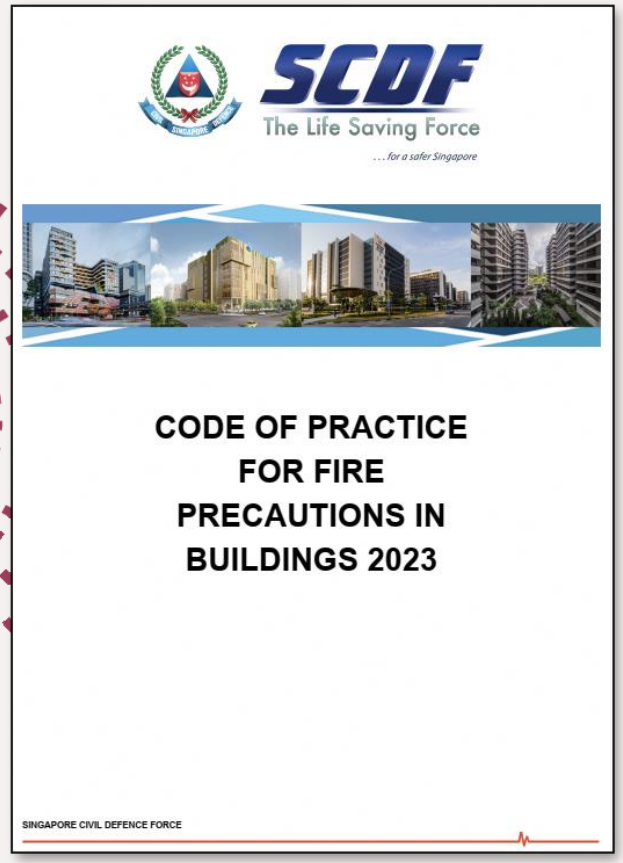

Get Support From Fire Code

Appendix 01- Fire Safety Report

- Summing up of the outline concepts and systems that have been designed for the project.
- Location plans of steel structural members coated with intumescent paint.
- Location plans of fire risk areas.
- Shop drawing of various services involved in the building

Appendix 02 - Fire Safety Instruction Manual

- The maintenance details.
- Include maintenance regimes, evacuation procedures.

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