FIRE SAFETY FOR THE ELECTRIFICATION OF BUILDINGS (BATTERIES)

SAFE INTEGRATION OF BESS FROM DWELLINGS TO HOSPITALS

OCTOBER 3RD 2025

Efectis

WHY NOW? ELECTRIFICATION + SMART GRIDS → BESS EVERYWHERE

- Drivers of growth
  - Solar PV self-consumption & tariff optimization
  - EV smart-charging and vehicle-to-building (V2B)
  - Grid support: frequency, reserves, black start
  - Resilience against outages

- From utility scale to buildings
  - Residential dwellings with wall-mounted BESS
  - Commercial/multi-unit buildings with shared storage
  - Hospitals & critical facilities (future diesel replacement)

- The challenge
  - No harmonized EU rules for BESS installation
  - Fragmented requirements across building codes, product standards, and local approvals
  - Creates uncertainty for designers, insurers, and AHJs

BATTERY TECHNOLOGIES IN BUILDINGS

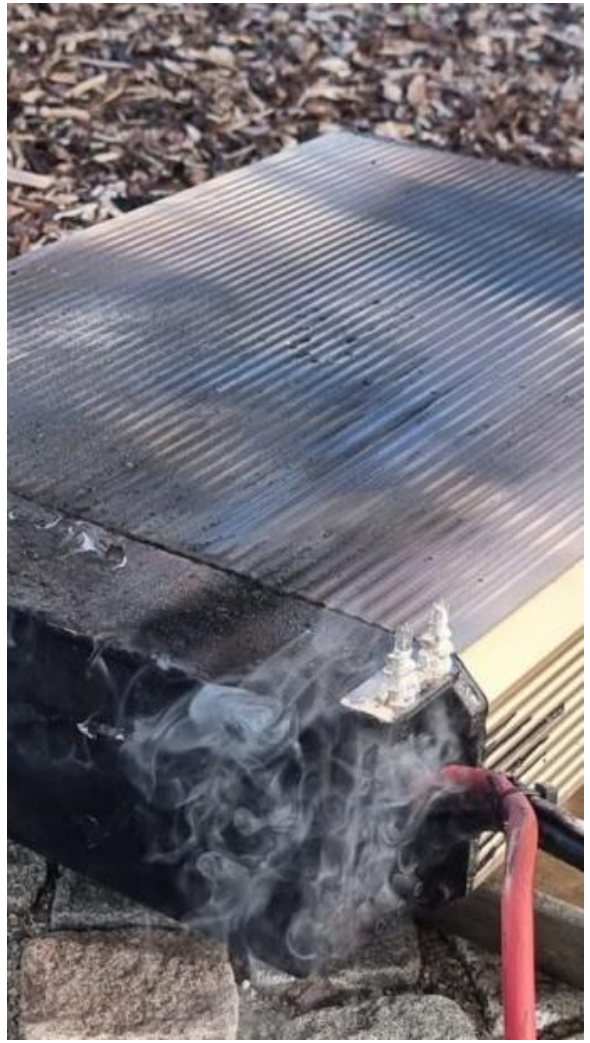
- Chemistries
  - Lithium-ion (LFP, NMC) → dominant in residential & commercial
  - Sodium-ion → emerging, safer thermal profile, but limited capacity today
  - Legacy lead-acid (VRLA) → still present in UPS & small installations

- Formats
  - Residential wall-mounted packs (5–20 kWh)
  - Racks & cabinets in technical rooms (100–500 kWh)
  - Containerized systems for larger buildings or campuses (MWh scale)
  - Second-life EV packs (increasingly reused in dwellings & small buildings)

- Key subsystems – compliance with future battery passeport (EU regulation 2023/1542)
  - Battery modules
  - BMS/EMS: monitoring, balancing, fault management
  - PCS / inverters: interface with grid & building loads
  - Disconnects & protection: DC isolators, fuses, breakers
  - Connections, cables and penetrations

Efectis

MAIN HAZARD MECHANISMS



- **Thermal runaway (TR):** defect, abuse, or external fire → jet flames & intense heat; potential module/rack propagation.
- **Combustible gases accumulation** → explosion risk: off-gases (H_2, CO, hydrocarbons) can accumulate in confined rooms.
- **Overpressure & blast effects:** deflagration risk in rooms without adequate venting.
- **Toxic & corrosive gases/smoke:** HF and others → tenability loss, equipment corrosion.
- **Electrical hazards**: high-voltage DC, arc flash, isolation/earthing faults.
- **Re-ignition potential**: persistent hotspots → delayed fires; requires extended monitoring & cooling.

LESSONS LEARNED FROM INCIDENTS

- Early warning signs often missed– Off-gas odor, abnormal BMS signals, module overheating
- Propagation is fast if spacing/compartmentation is insufficient
- Combustible gas accumulation → deflagration/explosion risk in closed rooms
- Firefighting challenges: difficult access, encapsulated modules, re-ignition risk
- Operational impact: long downtime, environmental contamination, insurance consequences

Battery explosion in dwelling, Schönberg, Germany, Feb. 2025

REGULATORY & STANDARDS LANDSCAPE (EU-CENTRIC)

- Battery/ESS: IEC 62933 (ESS safety), IEC 62619 (industrial Li-ion), IEC 62133 (portable), EN 62485 (stationary batteries), product marking.

- System & testing: UL 9540/9540A widely referenced for fire tests; NFPA 855 as a design benchmark (to be adapted to EU specifics).

- EU Battery Regulation 2023/1542:
  - Introduces battery passport, and conformity assessment.
  - Mentions the missing standards and need for CEN/CENELEC mandate (external fire test, system tests, gases evolved)

FIRE SAFETY EVENTS TO CONSIDER (EU BATTERY REGULATION ANNEX V)

1. Thermal propagation within the battery system (cell → module → pack)
2. Gas release: nature (toxic/flammable), volume, and release rate
3. Smoke emission: opacity, corrosivity, and quantity
4. Fire spread inside the system and to adjacent materials
5. Explosion or sudden pressure release due to accumulated combustible gases
6. Ejection of projectiles or fragments during cell rupture
7. Electrolyte leakage and associated chemical hazards
8. Re-ignition potential after suppression or cooldown
9. External fire vulnerability: system behaviour when exposed to fire from outside the BESS compartment

RESIDENTIAL & SMALL BUILDINGS (DWELLINGS)

Design goals: prevent TR initiation, limit propagation, maintain tenability & egress.

Location	Separation	Penetrations	Detection	Shutdowns	Ventilation
prefer detached utility rooms/garages	fire-rated enclosure or cabinet	fire-stopped conduits/cables and penetrations	early off-gas detection + smoke	automatic DC isolators	normal + emergency purge strategy
avoid escape routes and sleeping rooms	spacing to other combustibles & EVSE	Maintain EI ratings.	local alarm & remote alert	inverter trip	avoid gas pockets
outdoor cabinets where possible	protection from vehicle impact in garages		BMS alarms exposed to occupants/installer	contactors at string level	

10 kW wall-mounted battery for dwelling

MULTI-UNIT RESIDENTIAL & MIXED-USE

- Centralized BESS rooms vs. unit-level packs.
- Compartmentation:
  - dedicated EI-rated rooms;
  - self-closing fire doors with appropriate classification (S class?);
  - protected escape routes.
- Ventilation & smoke control:
  - mechanical extract sized for emergency purge;
  - smoke detection linked to AHU shutdown/dampers.
- System management:
  - monitored BMS/EMS to a building control room;
  - fault logging and maintenance regime.
  - Coordination with sprinklers where present.

HOSPITALS AND CRITICAL FACILITIES

- Operational concept: UPS + BESS for essential services; potential islanded microgrid.
- Objectives of business continuity & patient safety
- Reliability:
  - redundancy, segregation of strings/rooms, fault tolerance.
  - No-break power: seamless transfer with static switches.
- Rooms:
  - fire-rated compartments;
  - dedicated ventilation/exhaust to safe discharge point.

- Detection & controls: multi-criteria detectors, gas detection thresholds, automatic de-energization sequences.
- Firefighting access: protected approach, pre-plans, clear isolation points.

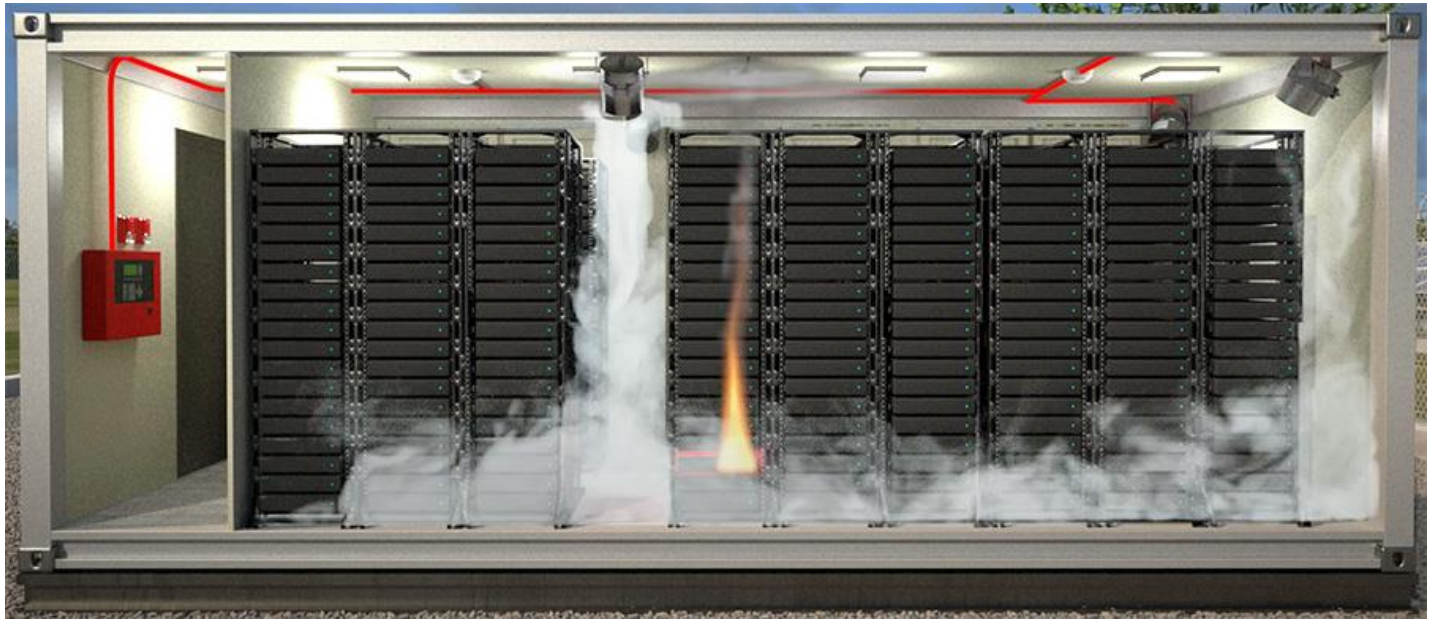
Efectis

SUPPRESSION & FIREFIGHTING STRATEGY

- Fixed systems:
  - sprinklers/water mist may control surroundings;
  - clean agents less effective for deep-seated cells.

- Manual tactics:
  - copious water cooling;
  - access panels/ports;
  - thermal imaging for overhaul;
  - containment & run-off management.

- Re-ignition management:
  - extended monitoring;
  - isolation area.



INSTALLATION QUALITY & MAINTENANCE

- Qualified installers;
  - as-built documentation;
  - labeling & zone diagrams.

- Commissioning tests
  - functional trip, ventilation, alarm paths
  - periodic inspection per manufacturer & code.

- Change management:
  - firmware,
  - EMS strategies,
  - capacity augmentation.

CYBERSECURITY & GRID INTERACTION

- Cybersecurity risks
  - Remote monitoring & firmware updates = attack surface
  - Segregate BMS/EMS networks from corporate IT & internet
  - Fail-safe defaults if communication lost (safe shutdown, not unsafe operation)

- Grid interaction
  - BESS must comply with grid codes for islanding, voltage/frequency support
  - Protection against unintended backfeed into grid faults
  - Coordinated with PV, EV chargers, diesel gensets (during transition phase)

- Why it matters for safety
  - Cyberattack or misconfiguration could disable ventilation/detection
  - Grid disturbances can push BESS outside safe SOC/SOH ranges
  - Functional safety must extend beyond hardware → control integrity

OPEN POINTS AND MISSING RULES

- No harmonized EU rules for BESS installation today
- Need of standards aims to link battery passport data with building safety measures
- Need of test standards for BESS (external fire test, system tests, gases released)
- Still open:
  - Ventilation & purge rate criteria
  - Explosion relief sizing & acceptance criteria
  - Gas detection thresholds (LFL setpoints)
  - Minimum separation distances in dwellings & mixed-use
  - Firefighting water management (containment, run-off treatment)
- Interfaces with PV systems, EV chargers, and microgrids remain unclear

CONCLUSIONS AND CALL TO ACTION

- BESS are essential for electrification, renewables, and resilience
- Safety by design = compartmentation, detection, ventilation, controls
- Today: no harmonized EU rules for testing, and for installation → uncertainty & uneven practices
- Need for guides & harmonized standards
- Next steps: EU guidance and standards needed, insurer & AHJ alignment