APL
DATA CENTERS EXPERT

MANAGEMENT OF FIRE RISKS RELATED TO LI-ION BATTERIES IN DATA CENTERS

FEEDBACK AND BEST PREVENTION PRACTICES

WHITE PAPER

ACKNOWLEDGMENTS

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GLOSSARY

Abbreviations and parameters	Definition
BaMS	Battery Management System
BESS	Battery Energy Storage System
BMS	Building Management System
CTM	Centralized Technical Management
DGPR	Direction Générale de la Prévention des Risques (French Risk Prevention Agency or DGPR)
DGSCGC	Direction Générale de la Sécurité Civile et de la Gestion des Crises (French Civil Security and Crisis Management Agency)
ECS	Monitoring and Indicating Equipment
EPC	Engineering, Procurement and Construction
ESS	Energy Storage Systems
FM Global	Factory Mutual Insurance Company
FPS	Fire Protection System
FSS	Fire Suppression System
ICPE	Classified Installations for Environmental Protection
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LFL	Lower Flammability Limit
LFP	Lithium Iron Phosphate
NFPA	National Fire Protection Association
NMC	Lithium nickel, manganese, cobalt oxide
PPE	Personal Protective Equipment
TCO	Total Cost of Ownership
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
VLRA	Valve Regulated Lead-Acid

PREFACE

Data centers, which are essential infrastructures for the operation of digital services, must be constantly supplied with electricity to ensure the continuity of these services. Electrical backup systems are essential to meet this challenge of providing a constant power supply. They compensate for any failure of the main distribution network.

Lithium-ion (Li-ion) batteries stand out as one of the most popular solutions thanks to their high energy density and longevity. They have started gradually to overtake traditional lead-acid batteries, especially VRLAs. Although this technology brings undeniable benefits, it is not without risk.

Battery fires have always been a concern for data center operators. But recent incidents in France and elsewhere have highlighted the fact that Li-ion battery fires are much harder to bring under control than lead-acid battery fires. It takes a fast response and specialist expertise to extinguish a Li-ion battery fire, which raises new challenges for data center operators.

In addition, although some standards and decrees (e.g. ICPE 2925-2) have been introduced, as far as we know, no comprehensive guide is available to help data center stakeholders plan for and protect themselves against this type of fire.

This white paper has a twofold objective: share concrete feedback and offer a summary of current best practices. It consists of three parts:

- Understanding and controlling fire risks related to Li-ion batteries;
- Deploying appropriate detection and extinguishing systems;
- Establishing an effective protocol for managing incidents.

It is particularly intended for:

- Design offices specializing in infrastructure design;
- Data center operators, which guarantee service availability;
- Energy solution integrators;
- Technical managers in charge of maintenance and safety.

KEY TAKEAWAYS

- Li-ion batteries are rechargeable batteries that use lithium ions as an active material to store and supply electrical energy.

- The use of Li-ion batteries is growing: 15% of data center batteries were Li-ion models in 2020, compared to nearly 40% today according to forecasts[1].

- Li-ion batteries offer a worthwhile alternative to lead-acid batteries thanks to their advantages in terms of density, reduced weight, and a smaller footprint.

- Under normal operating conditions, Li-ion batteries, just like lead-acid batteries, pose minimal risks. However, **a Li-ion battery fire is much more complex to extinguish and the consequences can be more serious. A fast response, combined with knowledge about the specific nature of these batteries, is therefore essential.**

- Fires involving Li-ion batteries are more often caused by external conditions (impacts, inadequate charging and discharging, temperature and humidity conditions, etc.) than equipment (design faults).

- The main chemical components used in the industry are NMC **(Lithium nickel, manganese, cobalt oxides)** and LFP **(Lithium Iron Phosphate),** and the choice of composition affects the fire detection methods to be used.

- The risk and vulnerability analysis approach should be selected according to chemical composition in order to control the risks and implement the appropriate protective measures.

1 Analysis of Lithium Ion Battery in Data Centers. 2021. Frost & Sullivan.

- Protection and extinguishing measures depend on the type of battery, involve separating and containing them with respect to other installations, implementing suitable detection, monitoring, and prevention systems, and, finally, operating in accordance with manufacturer requirements.

- It is important to plan for emergency and crisis management to provide an appropriate response to the disaster.

CONTENTS

I. WHAT'S IT ALL ABOUT?

Historically, uninterruptible power supply (UPS) systems in data centers were powered by lead-acid valve-regulated (VRLA) batteries. Just like with consumer and industrial equipment, in recent years, Li-ion batteries have been increasingly used in data centers. Thus, 15% of the batteries in use in data centers were Li-ion models in 2020, compared to 40% today according to forecasts. How do Li-ion batteries work?

I.1 Li-ion batteries: operating principles

Li-ion batteries are rechargeable batteries that use lithium to store and supply electrical energy. Li-ion batteries convert chemical energy into electrical energy through the interaction of three main components: the lithium-cobalt cathode ($LiCoO_2$), the graphite anode, and an ion-conducting electrolyte. The electrons produced by oxidation at the anode are absorbed by the cathode via reduction, thus generating an electric current.

I.2 Characteristics

Li-ion batteries have the following[2] key characteristics:

- **High energy density:** the energy density of Li-ion batteries is high, which means that they can store a large amount of energy per unit volume or weight, making them very efficient in terms of energy storage (up to 500 Wh/kg[3][4][5]).

- **Rechargeable:** they are rechargeable, so they can be used for a long time. They also charge five times faster.

2 https://www.securipro.eu/blog/securite/les-risques-incendie-des-batteries-lithium/

3 https://www.developpez.com/actu/343820/CATL-le-plus-grand-fabricant-de-batteries-fait-une-percee-majeure-dans-la-densite-energetique-des-batteries-qui-atteindrait-maintenant-les-500-Wh-kg-CATL-compte-entamer-leur-production-cette-annee/

4 https://blog.enconnex.com/comparing-lithium-ion-batteries-to-lead-acid

5 https://lohum.com/media/blog/evolution-of-batteries-lithium-ion-vs-lead-acid/

- **Long life:** if well maintained, their service life can last several years (up to 20 years[6]).

1.3 One technology, with several chemical compositions!

Although several different chemical compositions are used, two are prevalent in data centers:

1. **LFP:** excellent in terms of safety and service life, at a reasonable cost. However, LFP models offer lower specific energy and performance, which can limit use in applications requiring a high energy density.

2. **NMC:** well balanced over all criteria with good performance, effective specific energy, and reasonable safety levels at a moderate cost, with an acceptable service life and specific power.

Although NMC is still the most widely used chemical composition for data center energy storage at present, LPF technology is rapidly gaining ground. This applies to the market for battery energy storage systems (BESS, energy storage for later use during a critical period and to offer grid flexibility), which also uses this composition, mainly for its high thermal stability and the fact that it is cobalt-free.

6 https://www.mitsubishicritical.com/uninterruptible-power-supplies/battery-and-dc-technologies/lithium-ion-vs-vrla/

Practical case based on a project requiring a computing power (IT) of 1330 kW for an operating life of 5 minutes at end-of-life. Three solutions are evaluated: calcium lead, pure lead, and LFP Li-ion batteries (see section VII.1).

Technology	Levels (cabinets)	Rows	Total weight (metric tons)	Footprint (m^2)	Floor loading (kg/m^2)	Battery type
Lead-calcium	7	4	15.010	5.16	2908	105 Ah
Pure lead	6	4	13.200	5.16	2557	92 Ah
Lithium-ion LFP	4.5	-	5.15	2.55	2019	-

There was a 65% increase in weight compared with calcium lead.
And what about fire hazards?

II. WHAT CAN CAUSE A LI-ION BATTERY TO CATCH FIRE?

II.1 Foreword

While lead-acid battery fires are easier to manage, although attention must be paid to acid splashes and explosive gases, Li-ion battery fires are much more complex to extinguish and require a fast response.

The energy levels of Li-ion batteries are much higher due to their density, which leads to a faster increase in temperature in the event of a malfunction. Once heating or **thermal runaway** has started, the chain reaction in the cells can lead from localized overheating to the rapid spread of heat affecting several cells.

This spread of heat degrades the materials and produces gases which then ignite in turn under the effect of the accumulated energy, thus increasing the risk of fire affecting data center accumulators.

Thus the occurrence of a fire in data centers depends on several factors: **a cause attributable to a malfunction that will lead to thermal runaway, which, if not contained, will in turn cause a fire to start and possibly spread.**

II.2 What can cause a battery cabinet to catch fire[7][8]?

II.2.1 Design and production checks

Standards such as **UL 1741**[9] and **UL 9540**[10] ensure that, under certain conditions, heating one cell does not cause heat to spread to neighboring cells. The tests are carried out at cell, module, and pack levels. These tests are conducted on a representative sample of the products as validating all battery packs and cells is not feasible. Thus, applying the standards is therefore a good starting point, but risks are not 100% under control.

In addition, cell structure defects and contamination by impurities, which are rare events, can significantly decrease a battery's capacity and service life.

The BaMS is designed to monitor battery temperature in real time and prevent critical situations from occurring. These mechanical failures, if they occur, may go unnoticed and not be reported by the BaMS. This exposes the battery to an increased risk of overheating or fire.

II.2.2 Inappropriate operation and storage

Several (non-exhaustive) conditions can cause the batteries to malfunction:

- **Improper wiring of connections:** these can increase contact resistance, which is equivalent to increasing the internal resistance of the battery and consequently increasing its temperature. This phenomenon can therefore lead to external and internal short circuits and put the battery at risk of thermal runaway.

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7 https://www.badina-incendie.fr/blog/batteries-au-lithium-risques-dincendie-securite-prevention-dangers/

8 https://www.securipro.eu/blog/securite/les-risques-incendie-des-batteries-lithium/

9 https://www.shopulstandards.com/ProductDetail.aspx?productId=UL1741_3_S_20210928

10 https://www.ul.com/services/ul-9540a-test-method

The **UL 9540** standard establishes safety requirements for energy storage systems (ESS) and their components, focusing on construction and testing to ensure safe operation under normal and fault conditions. This is critical to allow data centers to maintain reliable energy storage solutions in compliance with strict safety standards.

The UL 9540A (2019) standard provides a test method for assessing fire spread and thermal runaway in ESS, which helps data centers assess and mitigate fire risks caused by battery systems.

- **Vibrations:** they can also lead to the loss of connections to the battery cells and sensors, resulting in abnormalities in the reading of battery status data.
  Vibrations also lead to a temperature increase, which triggers external short circuits.

- **Incorrect storage:** storing batteries in a confined environment, near or below spaces with a risk of water leakage, such as water tanks, water towers, and water sources, where heat dissipation is limited, can accelerate the chemical reactions inside the battery. These reactions increase internal pressure and the risk of thermal runaway or explosion.

- **Charge management:** during charging, the lithium ions move between the cathode and anode, causing energy to be released. The higher the battery charge, the more likely it is to react and the greater the effects produced. An overload can lead to combustion due to the increase in temperature, and therefore a fire.

- **Discharge management:** in the event of a deep discharge, the chemical reactions inside the Li-ion battery may be unbalanced, leading to internal short circuits. These short circuits increase the temperature of the cells, triggering heating or thermal runaway.

- **Total energy stored:** the more energy is stored, the greater the potential effects in the event of a fire/explosion.

- **Exposure to extreme heat sources:** exposure to direct sunlight or heat sources can increase battery temperature and heat the electrolyte, which can trigger thermal runaway.

- **Air conditioning system failures:** faulty air conditioning systems can create harsh conditions such as temperature variations and high humidity levels, leading to the formation of condensation and short circuits in batteries. These conditions degrade the electrical insulation inside the modules, and may lead to fires.

- **Normal aging:** batteries lose their capacity and efficiency over time. Aging can result in excessive heat build-up during normal operation or charging, increasing the risk of fire.
  Proper management of charging and discharging can mitigate these effects, but many challenges still remain.

II.2.3 Unknown causes

In some cases, the conditions triggering thermal runaway are not known. In addition, thermal runaway can occur spontaneously, even in the absence of misuse or inappropriate environmental conditions.

Now that we understand how Li-ion batteries operate, and how fire spreads, how can we avoid fire outbreaks or control the consequences of such an outbreak?

III. AVOIDING THE OUTBREAK OF A FIRE

III.1 Li-ion battery regulations

III.1.1 The standards in force in France

The **ICPE 2925** decree[11], applied in France since the 2000s, concerns electric batteries, under the category of electric accumulators that do not produce hydrogen.

However, with the more widespread use of Li-ion batteries, which do not release hydrogen, but present other risks, this regulation does not fully cover the specific nature of these batteries.

Moreover, it is interesting to note that due to the renewed rise in incidents and fires, and how difficult it is for emergency services to identify the type of battery involved in an incident, the authorities have begun to take on board the risk related to Li-ion batteries. In Réunion and in the department of Charente-Maritime, ministerial decrees have been established in response to these incidents **(ICPE 2925-2[12])** and apply to premises that store Li-ion batteries **outdoors**. This recent regulation remains a reference text for amendments to laws worldwide.

In addition, **IEC 62485-5** provides guidance on safety requirements for stationary battery systems, including aspects related to ventilation. This standard helps to ensure that battery systems are designed and installed in a safe manner, minimizing the risks of fire and explosion.

Specific legislation is required for Li-ion risks. A draft general decree is currently being drawn up by the DGPR[13] and could be implemented in the next year or two.

11 https://aida.ineris.fr/reglementation/2925-ateliers-charge-daccumulateurs-electriques

12 https://www.charente-maritime.gouv.fr/contenu/telechargement/69624/499231/file/AP%20prescriptions%20-%20rubriques%202925-2.pdf

13 https://www.ecologie.gouv.fr/direction-generale-prevention-risques-dgpr

In addition, other standards exist to ensure the safety and efficiency of data centers incorporating energy storage systems (ESS). These standards have not yet been recognized in France, but could allow for the implementation of complementary best practices which do not conflict with current best practices in France.

III.1.2 Non-mandatory standards

NFPA 855[14], for example, provides guidelines for the safe installation of energy storage systems including Li-ion battery-based systems. This standard covers aspects such as design, installation, maintenance and fire protection. These guidelines help reduce the risks of fire and explosion.

FM Global 5-32 and 5-33[15] include specific guidelines for data centers and electrical energy storage systems. They address loss prevention and risk management, and include recommendations for fire protection, physical safety, and the operational resilience of data centers.

Although not mandatory, these standards are sometimes recommended by insurers or included in the specifications of operators.

All these standards are summarized in Table 1 and Table 2.

III.2 Best practices when designing, building and laying out data centers

III.2.1 Construction materials

IEC 62485-5 sets out strict construction guidelines to ensure the safety of energy storage systems. These guidelines include the requirement that batteries be placed in fireproof enclosures to minimize the risk of fire.

In addition, the floors and walls of installations must be fire-resistant, which helps to contain any outbreak of fire and limit its spread. These measures are essential to ensure the optimal protection of data centers and energy storage systems.

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14 https://www.nfpa.org/codes-and-standards/nfpa-855-standard-development/855

15 https://fireprotectionsupport.nl/wp-content/uploads/2022/08/FMDS0532-2022-07-Data-Centers-and-Related-Facilities.pdf

Moreover, ICPE 2925 requires that the premises housing the installation have the following minimum reaction and fire resistance characteristics:

- High fire walls and floors with a two-hour rating,
- Non-combustible roofing,
- Indoor fire doors with a half-hour rating, equipped with a mechanical or automated door closer,
- Fire door leading to the outside with a half-hour rating,
- For other materials: class M0 (non-combustible).

NFPA 855 recommends at least a one-hour fire resistance rating for the building materials used for battery rooms, with a sprinkler protection system with an operating life of at least 60 minutes and a water flow density of 8 mm/minute.

Feedback No. 1:
Reinforce walls with steel bars

Using reinforced concrete walls to prevent explosive conditions and contain flames is a good practice to implement. However, we have found in several similar incidents that while solid concrete blocks resist explosions, they can be deformed by the force of an explosion.

We therefore recommend using aggregate concrete walls reinforced with steel bars so that walls will not collapse in the event of an explosion. The structural strength of such walls is superior and they are more able to contain flames, making the facilities safer.

III.2.2 Battery location

Li-ion batteries must be installed away from direct sunlight or heat sources. This helps to maintain a stable temperature, which is crucial to prevent thermal runaway.

In addition, if the batteries are mounted in separate cabinets in the building, they must be easily accessible for the purpose of inspecting the components and wiring. This simplifies maintenance and allows for the rapid detection of any signs of damage or failure.

IEC 62485-5 sets minimum distances to limit the spread of fire and ensure the safety of facilities.

- **Between battery racks:**
  - ≥ 1.5 m if the batteries are not protected by a firewall.
  - ≥ 0.6 m if class A2-s1, d0 (fire-retardant material) fire protection is installed between racks.

- **Between batteries and adjacent walls or structures:**
  - ≥ 0.8 m to allow for heat dissipation and maintenance.
  - ≥ 1 m if the wall is combustible.

- **Between batteries and heat sources (generators, transformers, etc.):**
  - ≥ 2.5 m to avoid an accidental rise in temperature.
  - ≥ 5 m if the equipment generates temperatures above 200°C.

- **Fire escape routes and access routes for the emergency services:**
  - ≥ 1.2 m of clear space in front of the batteries to allow for emergency responses.
  - ≥ 2 m between batteries and emergency exits.

These distances may vary according to local regulations and the specific recommendations of the battery manufacturer. It is essential to check the specific instructions for the models used. In addition, NFPA 855 recommends that battery capacity should be limited to 50 kWh and ESS limited to 600 kWh per pack, and the minimum distance between battery packs and walls should be 0.914 m.

Feedback No. 2:
Separate battery rooms

If the batteries are not stored outside the building, the swing doors in the corridors, designed to create compartments in the event of a fire, are effective. They can open during the explosion to allow air and smoke to pass through, and close immediately afterwards to reconstitute the volumes.

It is nevertheless essential to control access to these doors with locks that can release when a fire is detected in order to satisfy safety requirements. In addition, it would be wise to build an explosion-proof wall in front of this type of door, designed to withstand and dissipate the explosion.

Based on our experience, we recommend separating the battery rooms from the rest of the building whenever possible, especially outside the building, for example in containers.

III.2.3 Fire detection and suppression system

III.2.3.1 Smoke/gas/particle detection: the importance of the chemical composition of the battery

The key difference between the two types of chemical composition used for the batteries lies in their reaction to thermal runaway. For example, with the LFP composition, thermal runaway occurs at higher temperatures, which can lead to greater offgassing before the onset of flames. On the other hand, with the NMC composition, thermal runaway is triggered at lower temperatures, which may cause a faster reaction, with limited offgassing and more immediate combustion (Table 1).

Table 1: Fire risks and chemical composition

	NMC composition	LFP composition
Fire	More immediate	Less immediate
Explosion	Slightly less likely	More likely

The detection method must be suitable for the battery composition.

The NMC composition primarily requires smoke detection systems, based on temperature, heat, flames and smoke as well as the **immediate application of water** due to its rapid thermal reaction. Some NMC manufacturers incorporate heat absorption systems or extinguishing devices to limit the increase in temperature.

LFP batteries primarily require a gas detection system and adequate ventilation to avoid the formation of an explosive atmosphere, since this composition reacts at higher temperatures without immediate ignition. This means that smoke and gas detectors are preferable for LFP batteries. The use of a hydrogen gas detector or an explosimeter is recommended, even if hydrogen is not present, to detect the presence of gases that may create an explosive atmosphere. Ventilation systems able to release gases are also needed to prevent mechanical explosions due to overpressure.

III.2.3.2 Other monitoring and detection systems

Modern fire detection and suppression systems may additionally include the following key components:

Optical smoke detectors: if smoke particles enter the dark chamber of the detector, the light emitted by a light source is diffused (Tyndall effect). A receiver picks up the scattered light and transmits the alarm signal. These detectors may also incorporate a temperature sensor; in which case they are referred to as multi-sensor detectors.

Remote visual monitoring: cameras or other monitoring systems are used to observe the space remotely, allowing for a fast response in the event of a problem. Two-spectrum systems currently exist: video imaging and thermography.

Infrared visible flame detector: this device can identify the specific characteristics of flames, such as their infrared emission spectrum.

Monitoring and indicating equipment (ECS of the FPS): the heart of the fire safety system, which receives data from the detectors and transmits it to the WSIS, which then activates the alarms, smoke extraction, and suppression systems accordingly or any other safety equipment linked to the fire detection system.

III.2.3.3 Automatic fire extinguisher systems

The battery rooms must comply with local standards and be equipped with fire suppression systems to automatically extinguish fires. Two types of such systems exist: water and gas.

The most effective agent is high-pressure water for all types of chemical composition. Although this solution has advantages and disadvantages, it remains the most recommended approach because it cools the system. **Water mist**[16] is particularly effective at absorbing heat by turning into vapor.

Water mist includes a range of droplet sizes below 1000 m, much smaller than sprinkler droplets. The finer droplets have a larger surface-to-volume ratio, which means that more heat is absorbed from the hot air by the same volume of water.

Sprinkler systems are most effective at managing energy storage fires when used in combination with efficient ventilation. The NFPA 855 standard recommends using sprinkler systems with a density of **12.2 mm/min**, which is stricter than recommendations for conventional systems.

Finally, some recent designs incorporate **localized water extinguisher systems**. This system is activated when heat is detected (by a fuse) and can be used to specifically spray the module(s) affected. This system acts directly on the affected module, thus avoiding the need to spray all the modules/racks, which could risk short-circuiting other cells/modules or causing collateral damage to the rest of the system, considered as sufficiently protected.

However, caution should be exercised with water, because it can also trigger thermal reactions. For example, if batteries in good condition are exposed to sprinkler spray or water mist, they can react adversely.

16 https://www.ineris.fr/sites/ineris.fr/files/contribution/Documents/207085-VERSION%20PUBLIC%20Op%20B2%20IDE-10%20moyens%20de%20ma%C3%AEtrise%20des%20risques%20des%20batteries.pdf

If other types of fire protection are considered, gases such as nitrogen or nitrogen/argon (argonite) mixtures can also be used to reduce the oxygen concentration and stop combustion. Halocarbon-based extinguishing gases such as **Novec 1230** and **FM-200** absorb heat and interrupt the combustion chain reaction without reducing the oxygen.

In general, these gases act for about 10 minutes, after which point the flame reaction can resume, and some of the agent will be deposited on the combustible materials in the battery. These gases may be more effective on the immediate part of the battery, but they are only effective for a short period. On the other hand, for a more durable installation, it would be preferable to opt for a system that could continue extinguishing fire for an hour.

Finally, recommended fire extinguishing agents include perfluorohexanone, heptafluoropropane, and solid aerosols. Solid aerosols inhibit chemical reactions, interrupting chain reactions at the molecular level. Potassium salt agents can be used, by being quickly released via boxes on the ceiling of the container. However, their effectiveness may be significantly reduced if the fire detection system fails to simultaneously shut off the internal ventilation system.

Table 2 presents a classification of the different extinguishing agents by effectiveness at suppressing Li-ion battery related fires.

Table 2: Classification of extinguishing agents by effectiveness

	Extinguishing system
Highly effective	Sprinkler with ventilation system
	Water mist
	Localized water extinguisher system
Effective	Sprinkler
	Inert gases
	Extinguishing gases
Moderately effective	Extinguishing agents
	Solid aerosols

These instructions are general. **High-performance extinguishing agents and automatic extinguishing systems are recommended.** It is obviously necessary to take into account the specific features of data centers and therefore consider the extinguishing systems for Li--ion batteries as part of the system chosen for the entire building. The importance of smoke extraction must also be taken into account.

Feedback No. 3:
Extinguisher systems in battery rooms

The water mist system can effectively protect equipment in rooms adjacent to the battery room where a fire broke out, and contain the fire within the battery room. This system can operate continuously for up to 13 hours.

However, we recommend checking the operating life and replenishment strategy of this system regularly. A direct connection to the tank from outside of the dry pipes, allowing firefighters to connect their truck to ensure continuous filling of the tank during their operations is essential.

In addition, water leakage protection should be used above the batteries. It must be possible to deactivate this system in the event of a fire to allow the water spray nozzles to operate.

Finally, while the water mist system works well, if the site is compatible, sprinkler systems are preferable as they can completely flood the room and cool the batteries more quickly.

III.2.4 The ventilation system

IEC 62485-5 recommends a forced ventilation system with an air flow controlled according to the installed energy output. This ventilation system must be independent of the main building to prevent the spread of harmful gases.

However, there is no mandatory prescription in this standard. In this case, article 554-2 of standard NF C 15-100 must apply to the room as well as any enclosure containing the accumulator batteries. NFPA 855 recommends that the ventilation system installed in battery rooms keep flammable gases below 25% of the **Lower Flammability Limit** (LFL) to reduce the risk of explosion.

If air conditioners and ventilation ducts are shared, fire dampers must be installed. The ventilation system must renew air at a rate of at least 1.7 m^3/h per m^2 to dilute and remove flammable gases. Ventilation can be continuous or activated by a gas detector to balance safety and energy consumption. The following ventilation systems are required on this basis:

- **Mechanical extract ventilation:** installed in the accumulator rooms to effectively evacuate heat and dangerous gases in the event of battery failure. This system must be supervised by a fire alarm system to ensure a prompt response and immediately alert personnel in case of danger. Alerts should also be forwarded to a control room for a quick and coordinated response. If fans are installed in the room, the type of equipment must be classified as ATEX.

- **Natural extractor hood:** a natural extractor hood must be installed in addition to the forced ventilation system, to help maintain a stable temperature and prevent thermal runaway.

- **Main building ventilation systems:** the ventilation system in rooms where batteries are installed must be mounted separately from the main building ventilation ducts. This layout will prevent harmful gases from spreading to other parts of the building.

- **Fire dampers for air intakes:** the Halton fire damper system for data centers includes storm-proof external grilles combined with internal dampers to control the volume of the enclosure. Dampers can be made of high-strength stainless steel with thermally insulated blades that withstand corrosion and improve thermal performance.

III.2.5 Explosion vents

An explosion vent is a device installed on enclosures where gas or dust explosions may occur. These vents can quickly release combustion gases in order to reduce explosion pressure, which is particularly useful for Li-ion battery systems installed in a container or a room.

These vents, located on the side walls or roof, direct gases, smoke and flames upwards. They must be sized to contain explosions caused by a cloud of flammable gas emitted by the batteries. Recent designs include explosion hatches and gas dilution systems able to prevent explosive atmospheres in the event of an accident.

III.2.6 Cooling

Li-ion battery performance is highly dependent on battery temperature and a uniform distribution within the battery, therefore it is essential to regulate temperature. The temperature difference between the outside and inside (T delta) of the battery must currently be kept below 5°C[17]. Several Li-ion battery temperature control systems are offered by battery suppliers. A data center operator should ensure that these cooling systems integrated into the batteries comply with the applicable standards and are sufficient to maintain the expected temperature.

Feedback No. 4:
Decompression systems

Based on our experience, pressure relief systems are essential for several reasons, in addition to the other mechanisms mentioned. In case of an incident, such as an explosion or a fire, the pressure inside the room where the batteries are installed can rise quickly. A pressure relief system can release this pressure in a controlled manner, avoiding any serious structural damage to the building.

In addition, by allowing the pressure to escape, pressure relief systems reduce the force of the explosion, potential damage to nearby walls or equipment, and potential injury to people nearby. They therefore help to contain the incident and limit the damage.

Pressure relief systems can also improve the effectiveness of fire protection systems by allowing gases and smoke to escape, making it easier for firefighters to respond and extinguish the fire.

17 T. Deng, Y. Ran, Y.L. Yin, P. Liu. Multi-objective optimization design of thermal management system for Li-ion battery pack based on Non-dominated Sorting Genetic Algorithm II, Appl. Therm. Eng. 164 (2020), 114394, https://doi.org/10.1016/j.applthermaleng.2019.114394

In summary, the following best practices should be adopted for Li-ion battery rooms:

- Choose batteries that comply with UL standards.
- Use an insulated battery room with fire resistance of at least two hours.
- Provide an automatic fire detection and suppression device with a water mist or sprinkler extinguishing system.
- Avoid placing batteries in a room where explosive gases may exist or be released.
- Equip the battery room with an overpressure protection system for use in the event of an explosion.
- Avoid placing batteries near or under spaces with risks of water leakage, such as water tanks, water towers, and water sources.
- Do not store combustible materials in the battery room. Keep this type of material at least 3 meters from the battery room.
- The facility must be located at a distance of at least 5 meters from the property boundaries.
- Separate battery rooms outside buildings from the following locations by at least 10 m: restricted areas; storage warehouse for combustible materials; hazardous materials; energy infrastructure; public roads.
- Ensure that the capacity of a battery room does not exceed 1000 kWh, particularly if NFPA 855 is waived.
- Ensure that the fire resistance and thermal insulation properties of these materials are the same as for the battery room.
- Carry out a risk analysis before starting any installation process on roofs or in basements.
- Equip the room with CO, smoke, H_2 (hydrogen) temperature, and flame sensors.

- Deploy independent ventilation systems, separate from other rooms.
- Stay below 25% of the LFL threshold for flammable gas concentrations.
- Install water systems (sprinklers or sprayers) capable of operating for as long as possible to limit re-ignition risks.
- Collect wastewater in a designated area or direct to a specific treatment system.
- Disconnect the electrical system automatically in case of fire.

III.3 Best operating and maintenance practices for data centers

In parallel, some best practices should be applied during the design and operating phases. These practices apply at several levels:

III.3.1 Vulnerability analysis and safety management

The vulnerability analysis is used to identify weak points, assess functions and sources of risk, and suggest appropriate preventive measures. For this purpose, the vulnerability analysis method must be based on eight essential steps[18], ranging from the identification of risks to the creation of a handling and monitoring plan.

If no regulations apply, companies may be tempted to reduce costs at the expense of safety. However, adequate prevention costs less in the long run than the consequences of an incident. On this basis, instead of waiting for the adoption of binding regulations, operators should take proactive measures to control risks.

18 https://cybel.cnpp.com/livre-referentiel-cnpp-6011-analyse-de-risque-et-de-vulnerabilite-2018.html

III.3.2 Fire risk management

Risk management begins with collecting information, identifying risks, assessing their likelihood and severity, and then integrates existing means of control. The risks differ according to battery compositions and uses. A customized approach is recommended for each specific case.

Risk management is based on both technical studies and their practical application. Risk management requires clear objectives to be defined, transparent communication, careful planning, and rigorous monitoring.

Safety management thus includes evacuation plans, alert drills, training and regular inspections, aimed at preventing, detecting and managing fires and capitalizing on lessons learnt to ensure continuous improvements.

III.3.3 Training and awareness-raising

An emergency response plan must be drawn up to manage events at a facility, in accordance with IEC TC120 standards[19]. The effectiveness of such a plan depends on the provision of training for experts and first responders, knowledge of the power system, and coordination with firefighters. Many accidents have occurred due to a lack of adequate contingency plans.

First responders, often site personnel or technicians, detect and report incidents, and play a key role in providing information to fire services. This plan should include clear instructions, alarm management, and critical threshold information. Ensuring that responders are familiar with the plan will improve the initial response.

III.3.4 Alert monitoring

Thermal runaway is often sudden. However, several parameters may be abnormal for a period of varying length before runaway occurs. Monitoring these parameters can provide long-term, medium-term and short-term alerts.

19 https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID:9463

III.3.4.1 Short-term alerts

The installation of temperature sensors and monitoring systems provides real-time data on battery temperature and helps to ensure the early detection of any temperature increase.

III.3.4.2 Medium- and long-term alerts

These alerts relate to cooling system anomalies or severe overloads or discharges that can accumulate to gradually expose the battery to a risk of runaway.

III.3.4.3 Long-term alerts

These alerts are triggered for minor anomalies when the battery is relatively "unhealthy" but not faulty. Detecting such anomalies helps to avoid future failures.

III.3.5 Appropriate operation

Several best practices are recommended:

- **Avoid over-charging or under-charging the battery:** over-charging or under-charging a battery can lead to the uncontrolled release of energy and combustion. It is therefore important to monitor the battery charge and disconnect once it is fully charged.

- **Check the operating environment:** this includes measuring ambient temperature. An appropriate operating environment is crucial for proper battery operation.

- **Test the internal impedance of the components:** these tests evaluate battery aging. A large (two- to three-fold) and rapid (a few weeks) increase in internal impedance may indicate battery deterioration.

- **Run an infrared inspection:** this technique can be used to detect overheating. This helps to identify batteries that are at risk of thermal runaway.

- **Service the batteries regularly:** it is essential to establish direct and reliable communication between the BaMS system and the charger, unless integrated in the battery. Charging parameters can be synchronized and management optimized thanks to this communication, especially for fast charging.

- **Promote communication between the BaMS and the charger:** direct and reliable communication must be established between the BaMS and the charger, unless integrated in the battery. Charging parameters can be synchronized and management optimized thanks to this communication, especially for fast charging.

- **Systematic battery-inverter coupling:** strict coupling between the battery and the inverter is mandatory, especially for fast charging applications, to prevent any malfunctions.

- **Integrate Li-ion battery data:** the inverters alone will not retrieve all this information, making direct BaMS-BMS/CTM communication essential. It would therefore be necessary to report the BaMS data from the Li-ion batteries to the CTM or BMS (building management system), or even the FPS.

- **Check the batteries:**
  - Regularly inspect electrical connections;
  - Test safety devices every six months;
  - Maintain a stable temperature in the battery rooms (25 ± 2°C);
  - Regulate the humidity level between 5% and 95%, avoiding excessive humidity levels of 80%;
  - Protect batteries from direct light and avoid placing them behind glass walls;
  - Never place UPS units in battery rooms and vice-versa;
  - Organize the premises to allow the emergency response teams to take action easily, and plan appropriate measures if the batteries are installed in a basement.

- **Integrate the batteries into the FPS** to improve the detection and management of incidents related to fire risk.

- **Separate areas:** battery installation areas must not be mixed with areas containing other sensitive systems, such as IT rooms.

- **Add an emergency stop device** accessible from outside the battery room which can disconnect the battery cabinets from the UPS.

Feedback No. 5:
Need for the BaMS-CTM/BMS connection

Li-ion batteries are equipped with battery management systems (BaMS), therefore it is important that these systems are connected to the building management system (BMS/CTM) and integrated into the FPS. This is currently unusual as VRLA lead-acid batteries lacked embedded intelligence (or optional BaMS).

Connecting the battery BaMS to the BMS/CTM ensures smooth communication, facilitating the early detection of anomalies and the implementation of rapid corrective actions to prevent incidents.

Integrating Li-ion battery BaMS data into the FPS allows for the real-time monitoring of battery conditions, ensuring a rapid response if the battery fails or a risk of thermal runaway arises.

III.4 The risks with Li-Ion batteries and insurance

Insurers struggle to assess the risks associated with Li-ion batteries due to a lack of expertise and rapid technological developments. Insurance premiums do not always reflect the actual level of risk, making it difficult to negotiate insurance policies.

Some insurance companies refuse to cover risks related to Li-ion batteries, while others set specific conditions, such as **installation outside buildings** or compliance with preventive measures.

Admissibility studies and risk analyses must be completed in order to convince insurers that risks are under control and obtain adequate cover. These processes can:

- Identify the specific risks attributable to Li-ion batteries;
- Evaluate storage and handling practices to limit the occurrence of incidents;
- Install suitable extinguishing systems to limit any damage.

IV. ACTIONS TO TAKE IN CASE OF FIRE

All fires are subject to the fire triangle, which consists of three fundamental elements: fuel, oxidizer, and activation energy.

Fuel. The material likely to burn if an ignition source is present. In the context of a room containing Li-ion batteries, fuel includes pack and rack materials, as well as the electrolyte in the cells, which is converted into a flammable gas by thermal runaway.

The oxidizer. The crucial ingredient that drives combustion. Oxygen is the most common oxidizer. The more oxygen is available, the more intense the fire will be. The oxidizer in the room and generated by the gaseous decomposition of the cell materials will drive combustion.

The activation energy. This component can be considered the initial trigger of a fire. Any element capable of producing a spark, flame, heat source or electrical short circuit can trigger a fire. In the event of thermal runaway, the battery will generate its own activation energy.

For a fire to break out, all three conditions must be met; the absence of one will prevent the outbreak of fire. On this basis, the following actions can be taken in order to stop the fire and stem its spread.

IV.1 Cooling

Reducing the temperature of the fuel to below the ignition point and blocking the continuous supply of heat will stop thermal runaway. This method must be applied very close to the reaction.

Recommendations for fire services (DGSCGC[20]): once the battery has entered thermal runaway and the fire has started spreading, depending on environmental issues (spreading, isolation, etc.), it is advisable to refrain from any attempt to extinguish the fire, which could only have adverse effects:

20 https://www.interieur.gouv.fr/Le-ministere/Securite-civile

- Increased combustion time;
- Increased smoke and vapor production;
- Significant projection of molten metal particles;
- Pollution risks for extinguishing water.

According to recommendations, protecting the environment is the only action which should be taken. If the fire is triggered by a factor that is external to the battery (e.g. a fire in its immediate environment), it is important to limit the temperature increase of the battery using a suitable screen (water, fireproof cover).

Feedback No. 6:
Energy released from Li-ion batteries

Li-ion batteries can release up to 2.5 MJ/kg (equivalent to 694 Wh/kg). To put this figure in perspective, that is 54% of the energy that TNT can release, i.e. 4.61 MJ/kg (or 1280 Wh/kg). However, the kinetics involved in the release of this energy are essential when assessing the inherent hazard. Thermal runaway can occur extremely rapidly. For this reason, known fire development models and related protection applications are obsolete.

The difficulty facing emergency services is therefore to absorb the power generated by the fire using the hydraulic means available. Li-ion batteries can generate very large amounts of power, therefore enormous quantities of water are required. In addition, a massive water attack brings another problem: how to treat the water used to extinguish the fire...

This underscores the benefits of carrying out a prior vulnerability and prevention study.

IV.2 Smothering and isolation

Extinguishing agents (water with foam additive, CO2, and powders) isolate components (separation of fuel and oxidizer) or lower the oxygen level to stop combustion, however their effectiveness is limited. They can be used to extinguish the main fire and stop spreading, but do not avoid the risk of the fire restarting. Foam actively contributes to cooling and isolation, but brings no additional benefits.

Flame-retardant tarpaulins can limit the projection of material, but are only effective for a relatively short time. In addition, they promote the emission and spread of flammable white fumes, helping the fire to spread if they ignite.

Inert materials such as sand or cement smother the fire, provided that enough such materials are available. This action leads to the generation of cold and flammable white fumes (risk of a crater forming, allowing flammable gases, or even flames or projected material, to escape).

IV.3 Separation

Isolating or separating the burning combustible substance from other combustible substances and interrupting the supply of combustible substances to stop the combustion could be an effective solution, but which is difficult to achieve.

Moving a damaged battery can lead to internal or external short circuits resulting in:

- Violent arc flashes with the projection of molten metal;
- New immediate thermal runaway;
- New delayed thermal runaway (a few hours to several days later);
- Latent electrical risks.

If a damaged battery must be moved, suitable PPE must be used, as well as an available water source, and thermal monitoring equipment. The battery must only be moved if justified by a residual risk threatening people, property, or the environment. A secure battery quarantine site must be identified.

However, no specific protocols apply due to the differing battery compositions. In the event of large-scale thermal runaway, the recommendation is to prevent spreading and allow the fire to burn.

IV.4 Inhibition

Interrupting the chain reaction between the free radicals produced during combustion in order to stop combustion will eliminate the flames. This approach involves gas agents and powders. This method can be effective for a fire that is just starting, but will not have an effect on thermal runaway, which can only be stopped by cooling. Moreover, once the gas concentration has been diluted, this approach is no longer effective.

Drowning/immersing batteries is often mentioned and is considered as a solution by some parties. However, feedback on battery immersion indicates other problems:

- Combustible gas;
- Water electrolysis;
- Pollution of immersion water and future treatment.

IV.5 Smoke management

It is essential to evacuate smoke from a confined environment because of its flammability and toxicity, even for cold smoke or fumes emitted without a flame. Such fumes or smoke can condense on cold surfaces, depositing a flammable electrolyte, and remain flammable if they are not condensed. In an inert or oxygen-poor atmosphere, thermal runaway can potentially induce explosive pressure waves.

According to ICPE 2925, the upper areas of battery rooms must be equipped with devices able to evacuate the smoke, fumes, and combustion gases released in the event of fire (skylights, lateral openings or any other equivalent device). The manual opening controls are placed near access points. The smoke extraction system must be appropriate to the specific risks of the installation.

IV.6 Post-fire actions

The risk of thermal runaway resuming within timescales that are often well beyond the timescales observed for other types of fire (from a few hours to several days) cannot be ruled out.

Thus, after a fire linked to a Li-ion battery, the risk of the fire restarting persists due to the batteries, which remain hot and the toxic gases emitted. It is important to be aware of this point. Management methods depend on battery size. This phase is of paramount importance and requires the Emergency Operations Commander to pay close attention, because residual risks (electrical, thermal, chemical, etc.) remain significant.

One of the difficulties lies in assessing whether or not all the cells have completely burned. Once this point has been clarified, it should be possible to apply the appropriate protective measures. It is not recommended to handle a partially damaged battery without taking special precautions, due to the risk of re-ignition.

Waste must be treated specifically and transported as hazardous materials.

Feedback No. 7: Water management

When water is used for fire protection purposes, it is essential to consider a stricter strategy to drain the polluted water from the water mist system from the building.

Water drainage should be considered for each room and corridor to facilitate the drainage of water to another location where it will be stored until remediation can be carried out.

This extinguishing water must be retained, treated or recovered by a specialist company. Under no circumstances should it be discharged directly into wastewater systems. After fires, ICPE inspection offices may request information on how this water was managed. It is important to plan ahead for these points.

Finally, we can recommend removable water retaining walls in every room where a water mist or fire protection system is installed. Such retaining walls have proven to be very effective during incidents.

V. CONCLUSIONS

Li-ion batteries offer significant advantages in terms of efficiency, durability and compactness, compared to lead-acid batteries.

They not only offer a modern and efficient solution for data centers and critical infrastructures, but they are also one of the fundamental pillars of the energy transition.

However, these batteries also bring new requirements with respect to safety and heat management.

We have therefore highlighted the various potential causes of fire, ranging from battery and data center design to operating and maintenance policies.

Best practices to avoid such fires have been proposed. With adequate measures such as the development and implementation of strict safety protocols, state-of-the-art fire detection systems, the outdoor installation of batteries, compliance with installation conditions (including the use of water mist), effective cooling strategies to protect not only the health of the batteries but also the operating environment, and strict heat management, fire risks can be significantly reduced.

Regarding the necessary actions in the event of a fire, fire suppression procedures were discussed, highlighting the importance of a quick and effective response to limit potential damage.

A well-developed emergency response plan and adequate training of first responders is crucial for a safe response. Normative and regulatory changes are underway to improve the safety of stationary storage systems and protect facilities and people.

Such a proactive approach can not only address the problem of reluctant insurers, but also help ensure more competitive premiums. Working closely with insurers, demonstrating that all safety aspects are covered, can increase trust and thus mitigate concerns about fire risks.

VI. SOURCES

1. **INERIS report 204864 2705199-V3**

2. **DNV-GL, Technical Reference for Li-ion Battery Explosion Risk and Fire Suppression, 2019**

3. **https://liiontamer.com/wp-content/uploads/Nexceris-2021-Test-Summary-Report.pdf**

4. **CEA stationary storage working group – DGSCGC & SDIS**

5. **Euralarm guide dated 15/02/2022**

Founded in 1983, APL specializes in consulting, engineering, construction, and operation services for data centers. Thanks to its "Organic Design" mission, APL is committed to creating data centers that blend seamlessly into their environment, ensuring that the proliferation of digital infrastructures is compatible with sustainable regional development. APL's services are based around four activities: data center consulting and engineering, IT consulting and engineering, maintenance and operations, and sustainable IT.

APL holds Tier Designer and Operations Specialist certification from the Uptime Institute, and received the silver medal in the Ecovadis CSR ranking. APL has carried out thousands of assignments for companies such as Air France, BNP Paribas, Crédit Agricole, Data4, Dataxion, Econocom, Equinix, Groupama, Casino Group, Digital Realty (formerly Interxion), Macif, Orange, Sigma, SNCF, Telehouse, Vinci and many public sector organizations.

With offices in Paris (head office), Lyon, Marseille, Bordeaux, Rennes, Toulouse and Lausanne, and Milan, APL is expected to achieve a turnover of €60 million in 2024, with more than 230 employees, and is developing its activities in Europe and Africa.

Georges Ouffoué
Lab-by-APL Manager

Georges is an engineer and holds a doctorate in computer science from the University of Paris-Saclay. He is aware of the impact of digital technology on the environment, and joined APL Datacenter as Manager of the Lab-by-APL. He manages customer assignments and innovation projects in collaboration with academic and industrial partners in this capacity. Thanks to his technical expertise, he has also contributed to the creation of several reference standards, including the baseline for the environmental labeling of data centers and cloud services. Finally, Georges is the author and co-author of several articles and white papers, including the white paper titled "Datacenter, maîtriser et optimiser son impact environnemental" (Controlling and optimizing the environmental impact of data centers).

In a world where safety is a top priority, the use of fire vulnerability studies guarantees the protection of your property and your employees. The aim is to prevent risks, limit the impact on the various issues, set up robust emergency plans, and give you peace of mind.

BCFI is a consultancy firm specializing in fire safety management. When the safety of your employees and property is at stake, fire prevention is crucial. BCFI is your trusted partner for fire prevention. We carry out assignments for companies and institutions of all sizes and in all business sectors looking to better control the risks in their field. We conduct in-depth fire vulnerability studies, specific to your environment, to identify risks and offer tailored solutions.

Our team is based on a network of multidisciplinary experts, including engineers and specialists with fire-related professional experience and skills. Our expertise extends well beyond emergency and protection measures, encompassing areas ranging from building design to the implementation of a fire safety management system, the ultimate means of risk control to date.

With our expertise, we can help you prepare for any eventuality. Working with BCFI means averting rather than fighting risks.

Benjamin Cherdrong
Founding partner
Fire-Explosion Risk Management
Engineer

I am passionate about fire risk prevention, and my goal is to use my operational experience, acquired over more than 20 years as a firefighter, and my fire risk management skills, to the benefit of companies. In 2019, I created the BCFI brand and a consultancy firm with the aim of offering a comprehensive fire safety improvement support service based on prevention. For you, it means transforming the fear of a major fire and its consequences into the assurance of having done everything possible to reduce the risk.

HUAWEI

Huawei Digital Power is one of the world's leading providers of digital energy products and solutions. We are committed to integrating digital and power electronics technologies, developing clean energy, and enabling the digitization of energy to drive the energy revolution for a better, greener future. Our diverse skill set allows us to operate in several sectors: for the production of clean energy, we contribute to creating new electricity systems that rely mainly on renewable energies.

For the electrical infrastructures of green ICT (information and communication technologies), we help to build green, low-carbon and intelligent data centers and communication networks.

For green transportation, we are redefining driving experiences and consumer safety in electric vehicles (EVs), accelerating the electrification of transportation. Huawei Digital Power continues to innovate through open collaboration with global partners aiming to promote carbon neutrality. With approximately 10,000 employees, 60% of whom are dedicated to R&D, Huawei Digital Power serves a third of the world's population in more than 170 countries and regions. For more information, please visit Huawei Digital Power online at https://digitalpower.huawei.com/en/

Julien Paynel
Data Center Facility Solutions Expert

With an engineering degree and about fifteen years of professional experience, Julien Paynel is passionate about the field of energy in a technical environment. The world of data center infrastructures therefore struck him as an obvious fit because it encompasses all of these technologies: MV/LV electrical distribution, energy conversion, emergency energy, cooling management, layout of IT rooms, etc.

Exide Technologies' Energy Solutions division is a leader in the development and manufacture of advanced stationary energy storage solutions. These solutions operate as essential backup or energy management systems and integrate renewable energies perfectly.

Exide's innovative battery technologies, based on lead-acid and Li-ion models, are carefully designed to offer tailored solutions for backup and network applications both behind and in front of the meter.

Exide meets the needs of a wide range of industries, including UPS, telecommunications, power generation, data centers, emergency services, railways, medical, and many more.

Their lithium-ion-based energy storage solutions (ESS) cover a multitude of applications, such as renewables, time lag, self-consumption, frequency control, peak smoothing, fast charging and energy trading. They are used for electric vehicle charging, integrating renewable energies and much more. Exide's energy solution products are renowned for their unparalleled performance and reliability. They offer new revenue streams for customers, facilitate the energy transition and improve energy efficiency.

Jean-Claude Sabetta
Product Manager
for UPS Li-Ion batteries EMEA

Jean-Michel Keloumgian
Director of Sales, Lithium UPS segment

VII. APPENDICES

VII.1 Comparing lead-acid to Li-ion batteries

To illustrate the differences between the battery technologies available, let's take a look at a practical case based on a project requiring a computing power (IT) of 1330 kW for an operating life of 5 minutes at end-of-life. Three solutions are evaluated: lead-calcium, pure lead, and LFP lithium-ion batteries:

Lead-calcium
Lead-calcium acid batteries are installed on a construction site spread over seven levels and arranged in four rows. The total weight of the batteries represents 15,010 metric tons, requiring an area of 5.16 m². The floor loading is 2,908 kg/m². The batteries used are 105 Ah, offering a reasonable capacity but resulting in a large footprint. This solution is the heaviest and most demanding in terms of surface area.

Pure lead
Opting for pure lead-acid batteries gives a site arranged over six levels, also with four rows. This technology saves 12% in weight, for a total of 13,200 metric tons. The footprint remains unchanged at 5.16 m², but the floor loading decreases to 2,557 kg/m² thanks to the use of 92 Ah batteries. This option offers a modest reduction in weight and floor loading, while maintaining a footprint similar to lead-calcium.

Lithium-ion LFP
LFP Li-ion batteries stand out. Only 4.5 battery cabinets are needed with this set-up, for a total weight of 5.15 metric tons, representing a dramatic weight saving of 65% compared to lead-calcium models. The footprint is drastically reduced to 2.55 m², with a floor loading of just 2,019 kg/m². This technology offers unparalleled compactness and lightness.

Conclusions
According to this analysis, LFP Li-ion batteries far outperform both lead-acid technologies in terms of weight and footprint. Although pure lead has a moderate advantage over lead-calcium in terms of weight, the operating costs and footprint remain equivalent.

On the other hand, LFP Li-ion batteries are the ideal solution for projects where compactness, energy efficiency and a reduced floor load are essential. On this basis, for complex and demanding projects, opting for LFP Li-ion batteries seems to offer the best compromise between performance, lightness and space optimization. In conclusion, using Li-ion batteries would result in a lower TCO.

VII.2 Applicable norms and standards

Table 3: ICPE 2925.2 Decree

Topic	Specifications
Installation location and layout	At least 10 m from property lines and buildings
	Easy access for emergency services with appropriate signage
	Flood protection
	Sufficient lighting for night operations
	Ventilation to prevent the build-up of hazardous gases
	Hazardous Liquid Retention Devices
	Lightning Protection
	Monitoring system to detect anomalies and intrusions
Safety and operations	Posted emergency plan specifying the action to take in the event of an incident
	Personnel training in safety procedures
	Regular equipment maintenance program
	Waste management as per regulations
	Atmospheric emission and liquid discharge testing
	Recording of incidents and inspections
	Insurance covering operational risks
	Periodic safety audits
	Obligation to inform the authorities in the event of a major incident
	Technical documentation available for inspections

Conformity and standards	Compliance with applicable French and European standards
	Electromagnetic compatibility of equipment
	Protection against explosions in at-risk areas
	Energy management system for optimization purposes
	Grounding of electrical equipment
	Surge protection for sensitive equipment
	Continuous monitoring of critical parameters (temperature, etc.)

Table 4: Main standards and norms applicable to Li-ion batteries

Standard	Title	Description
ICPE 2925.2 Decree	**Electric accumulator charging workshops**	- Scope: applies to stationary energy storage battery charging facilities located outdoors, using lithium technologies. [Article 1] - General requirements: includes fire risk prevention, environmental protection, and personal safety measures. [Articles 2 to 5] - Ventilation: the facilities must be equipped with suitable ventilation systems to avoid the accumulation of flammable gases. [Article 3] - Safety systems: obligation to install appropriate fire detection and fire-fighting devices. [Article 4]
IEC 62485-5	**Lithium secondary batteries for industrial applications**	IEC 62485-5 defines the safety requirements for the installation and operation of lithium batteries. It particularly insists on: -Prevention of thermal risks: temperature management systems and devices to prevent the spread of fire. -Electrical protection: prevention of overvoltages and isolation of circuits. -Safety measures in the event of failure: automatic disconnection systems and temperature alarms. - Maintenance framework: regular checks and replacement of defective cells.

NFPA 855	**Standard for the Installation of Stationary Energy Storage Systems**	– Separation and location: Energy Storage Systems (ESS) must be installed in spaces separated from other areas of the building by two-hour fire barriers. [Section 4.3.6] – Ventilation: ventilation systems must keep the concentrations of gases, such as hydrogen, below 1% to avoid the risk of explosion. [Section 2-3.2.1] – Fire detection and suppression: an ESS must be equipped with appropriate smoke detection and fire suppression systems. [Table 4.4.2]
ISO 9001	**Quality management systems**	– Quality management: data centers must establish processes to ensure the consistent quality of products, including Li-ion batteries, with a focus on continuous improvement and customer satisfaction. [Chapter 8] – Planning: identify risks and opportunities related to product quality and implement actions to address them. [Chapter 6]
ISO 14001	**Environmental management systems**	– Environmental management: organizations must identify and manage the environmental impacts of their activities, including the production, use and disposal of Li-ion batteries. [Chapter 6 & 8]

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MANAGEMENT OF FIRE RISKS RELATED TO LI-ION BATTERIES IN DATA CENTERS

FEEDBACK AND BEST PREVENTION PRACTICES

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