

# Introduction

Lithium-ion batteries power a wide range of devices, from smartphones and laptops to power tools, electric vehicles, and energy storage systems.

Despite their popularity and energy efficiency, lithium-ion batteries pose significant safety risks across the supply chain. These must be carefully managed by product designers, manufacturers, distributors, retailers, end users, recyclers, and waste management companies.

Since the beginning of 2025, the U.S. Consumer Product Safety Commission (CPSC) has issued 46 recalls and safety warnings related to consumer products powered by lithium-ion batteries. Some of these incidents have led to injuries and property damage.

## One such recall highlighted three key hazards:



#### 1. Fire and burn injuries

Defective batteries can ignite, causing burns and other fire-related injuries. In this recall, 32 fire incidents were reported, including one injury.



#### 2. Property damage

Fires caused by faulty batteries can result in significant property damage; five such cases were reported in the same recall.



#### 3. Risk of serious injury or death

In extreme cases, defective batteries can cause severe injury or death due to fire or explosion.

The compact design, high power density, and rapid charging characteristics of lithiumion batteries all increase the risk of fire.

Unlike other rechargeable battery chemistries—such as lead-acid, nickel-cadmium, and nickel-metal hydride—lithiumion batteries use a flammable electrolyte instead of a water-based one. While smaller batteries allow for more convenient devices, they also concentrate energy in confined

spaces. This combination creates conditions for additional fire hazards, including runaway triggered by overheating.

Thermal runaway occurs when a battery's internal temperature rises uncontrollably, potentially resulting in fire or explosion. Overcharging, physical damage, and manufacturing defects can all trigger this dangerous reaction.



# Safety hazards of lithium-ion batteries

While lithium-ion batteries offer numerous advantages—including high energy density, long lifespan, and rapid recharging capabilities—they present inherent safety hazards that require careful management.

A clear understanding of these risks is essential for manufacturers, end users, and safety professionals to minimize associated risks.



#### Counterfeit and aftermarket batteries

While Original Equipment Manufacturer (OEM) batteries typically include built-in safeguards, aftermarket and counterfeit batteries often lack these essential safety features. Consumers looking for less expensive replacement batteries may unknowingly purchase batteries lacking internal safeguards, increasing the risk of fire or explosion.



#### Risk of fire and explosion

Lithium-ion batteries pose a significant fire and explosion risk due to their use of a flammable electrolyte, which can ignite if the battery is damaged, improperly charged, or exposed to extreme environmental conditions.

One of the most critical hazards is thermal runaway—a chain reaction that causes internal temperatures to rise uncontrollably, intensifying heat generation and potentially resulting in fire or explosion.

This process may be triggered by overcharging, which can lead to excessive heat build-up, or by internal or external short circuits that can cause rapid discharge and high thermal stress.



#### Design and manufacturing defects

During manufacturing, the introduction of impurities can compromise the battery's internal structure, puncture the protective film separator, and lead to internal short circuits. In addition, poor design choices or substandard production practices can result in batteries that are inherently more prone to failure, increasing the likelihood of hazardous incidents such as overheating, fire, or explosion.



#### Physical damage

Dropping or crushing a battery can damage its internal structure, increasing the risk of short circuits or electrolyte leakage. Puncturing the casing may compromise internal components and trigger either immediate ignition or delayed fire hazards.



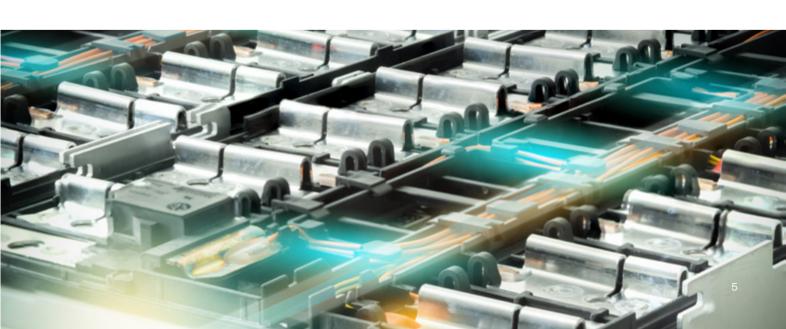
#### Improper charging and discharging

Using chargers that are not compatible with the battery can result in overcharging, excessive heat generation, and potential failure. Deep discharging may damage the battery's internal structure, compromising both safety and performance.



#### **Exposure to extreme conditions**

Exposure to high temperatures can accelerate battery degradation and heighten the risk of thermal runaway. Low temperatures can impair battery performance and reduce operational safety. Contact with water can cause short circuits and compromise the battery's structural integrity.



# Environmental hazards



#### Storage and fire risks

Battery fires release highly toxic gases, including hydrofluoric acid (HF), perand polyfluoroalkyl substances (PFAS), and other hazardous compounds. PFAS, or "forever chemicals," persist in water, soil and living organisms and are increasingly linked to harmful impacts on health and nature. Firefighting water used to suppress battery fires can become contaminated with heavy metals and toxins, creating a risk of soil and groundwater pollution if it is not properly contained.



#### Risks from improper disposal

Batteries are often incorrectly disposed of in household waste, increasing the risk of fire and the release of toxic substances in waste management facilities. Damaged or leaking batteries in landfills may release toxic electrolytes and heavy metals, contaminating surrounding soil and groundwater.



#### Safety protocols and guidelines

Lithium-ion battery manufacturers, academic institutions, Underwriters Laboratories (UL), and the Federal Aviation Administration (FAA) are engaged in research to establish safety protocols, testing standards, and guidelines.

Lithium-ion batteries provide exceptional energy density, extended lifespan, lightweight design, and zero-emission energy storage capabilities. However, safety concerns remain –particularly the risk of thermal runaway.



#### Advantages of LiFePO<sub>4</sub> batteries

Where feasible, consider the use of lithium iron phosphate (LiFePO<sub>4</sub>) batteries. This type of lithium-ion battery uses lithium iron phosphate as the cathode material and is known for its safety, long lifecycle, and thermal stability.

LiFePO<sub>4</sub> batteries offer excellent thermal stability, making them more resistant to overheating and fire and less susceptible to thermal runaway. They are generally lower in cost than other lithium chemistries and have a lower environmental impact due to the absence of cobalt and nickel. These characteristics make LiFePO<sub>4</sub> batteries well-suited for a wide range of applications.

## Key safety features:

Lithium-ion batteries are designed with several safety features to prevent overheating, fire and explosion. The following safeguards are crucial for ensuring the safety and reliability of batteries in various applications:

1

#### Thin film separator

A thin film separator is placed between the electrodes, preventing direct contact between the anode and cathode, which could cause a short circuit. As the internal temperature increases, the membrane pores in the separator close, preventing overheating and further thermal runaway.

2

#### Pressure release vent

Batteries are equipped with a vent to release excess pressure in the event of overcharging or other malfunctions. This helps prevent the battery from bursting or exploding when placed under high pressure.

3

#### Thermal interrupt

Larger battery cells often include a thermal interrupt device. This acts as a switch that disconnects the battery when the internal temperature reaches a certain threshold, thereby preventing further heating and potential thermal runaway.

4

#### Fuse-like device

Many batteries contain fuse-like devices that break the circuit if the current flow exceeds safe levels, helping to prevent overheating and potential fire hazards.

5

#### **Battery Management System**

Advanced lithium-ion batteries are equipped with a Battery Management System (BMS), which monitors and manages the battery's state of charge, temperature, and overall health. A BMS ensures that the battery operates within safe parameters and can disconnect the battery in case of anomalies.

Overcharge protection

Overcharge protection circuitry prevents the battery from charging beyond its safe voltage limit, as overcharging can lead to excessive heat generation and thermal runaway.

This feature prevents the battery from discharging rapidly in the event of a short circuit, reducing the risk of excessive heat and fire.

Temperature sensors

Temperature sensors monitor the battery's internal temperature and can trigger protective measures if the temperature exceeds safe limits. These sensors are often integrated with the BMS.

Cell balancing

Cell balancing ensures that all the cells in a multi-cell battery pack are charged and discharged evenly. This prevents individual cells from becoming overcharged or deeply discharged, which could compromise battery safety.

Flame-retardant electrolyte

Some lithium-ion batteries use flame-retardant additives in the electrolyte to reduce the risk of fire during thermal events.



## General safety tips:

Use only Original Equipment Manufacturer (OEM) rechargeable batteries, as counterfeit or aftermarket versions may lack essential safety features. Batteries should be inspected regularly for signs of damage or wear, and any compromised units should be replaced immediately.

To maintain safe performance, avoid exposing batteries to extreme temperatures, which can degrade internal components and increase safety risks.

For end-of-life management, follow local regulations for proper disposal, and never dispose of lithium-ion batteries in household waste. Wherever possible, recycle through certified waste and recycling providers, take batteries to a designated recycling location, or consult your local authority for specific disposal guidance, as recommended in the

BCMRC 2025 session preview ("How to safely handle batteries"). Discarded batteries should not be stored in piles, as this increases the risk of short circuits and fire.

In preparation for potential battery fires, provide extinguishing agents specifically designed for lithium fires, and avoid the use of standard water-based extinguishers. Establish and regularly rehearse emergency plans for fires and evacuations. Implement temperature monitoring, thermal imaging, and fire detection systems in battery storage and disposal areas.

Ensure employees receive training in lithiumion battery-specific fire response protocols and install containment or retention basins to manage contaminated firefighting water runoff.



# Safety considerations for portable and handheld devices

## Safe handling

Always follow the manufacturer's instructions for your specific battery, tool, and device, and use only original batteries, components, and chargers to ensure compatibility and safety. Avoid physically damaging batteries—do not drop, crush, or puncture them, and never use a battery as a tool, as this can cause internal damage. When handling batteries, wear appropriate personal protective equipment (PPE) such as safety goggles and gloves. Provide employees with training on battery

safety and ensure emergency procedures are clearly posted in relevant areas. Learn to recognize warning signs and stop using any battery that emits an unusual odor, shows color changes, becomes excessively hot, changes shape, leaks, or makes unusual noises. If it is safe to do so, move the device away from combustible materials ("Lithiumlon Battery Safety – UCSC") and call your local emergency services.

### Safe storage

Store batteries in fire-rated cabinets kept in cool, dry places away from direct sunlight and heat sources. Avoid storing batteries on chargers and never leave them in

vehicles that may be exposed to extreme temperatures. When selecting storage cabinets for lithium-ion batteries, look for the following recommended features:



#### Fire-resistant construction

Cabinets should be constructed from non-combustible materials, such as steel, and rated for fire resistance—typically 90 or 120 minutes. They should also comply with relevant safety standards, including UL 94, FM 6050, or EN 14470-1.



#### Ventilation

Passive or forced ventilation is essential to prevent heat build-up and allow hazardous gases to dissipate. OSHA recommends using local exhaust ventilation (LEV) or enclosures to reduce the risk of fire.



#### **Temperature control**

Store batteries in a cool, dry environment, ideally between 15°C and 25°C (59°F to 77°F), and avoid placing them in direct sunlight or near heat sources. Explosion relief or pressure venting cabinets should be equipped with pressure relief panels or explosion vents to release pressure safely in the event of thermal runaway.



#### Spill containment

Leak-proof trays or containment basins should be installed to manage potential electrolyte leaks effectively.



#### Lockable and clearly labeled

Cabinets should be lockable to prevent unauthorized access and clearly labeled with hazard signage, such as "Lithium-Ion Battery Storage – Fire Risk."

## Safe charging

Always charge batteries according to the manufacturer's instructions and only use chargers designed for the specific battery type. Batteries should never be left unattended while charging, and both batteries and chargers should be checked regularly for signs of overheating ("Prevent LiPo Battery Explosions: Key Safety Tips & Risks"). Once fully charged, batteries should be removed from chargers to prevent overcharging ("Why Lithium Batteries Get Hot and How to Stay Safe"). When not in use, disconnect chargers and remove batteries.

# Conclusion

Lithium-ion batteries are integral to modern technology due to their high energy density, long lifespan, and efficiency. However, they also present significant safety challenges.

The risks of thermal runaway, fire, and explosion require stringent safety measures and continuous research to enhance safety protocols. Manufacturers, users, and regulatory bodies must work collaboratively throughout the product lifecycle to ensure safe and effective

battery use, mitigating potential hazards through robust design, correct usage, and adherence to safety guidelines.

Recognizing and addressing these risks is crucial for the continued advancement and safe deployment of lithium-ion battery technology.



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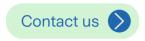
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