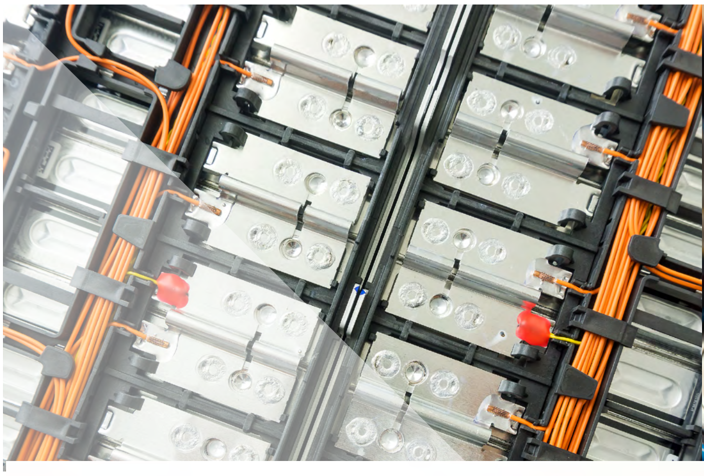


# WHITE PAPER

## Battery Power Storage: Protecting People and Plant

Energy storage systems are essential to bolster global efforts to pursue alternative energy sources such as solar and wind to reduce our reliance on fossil fuels. Storage technologies include batteries, thermal storage, hydropower, mechanical storage, and other technologies. These systems are found in several applications, including utilities and energy companies, commercial facilities, transportation, banking, hospitals, and industrial operations.

This paper focuses on battery storage facilities and the potential for leaked gas, which poses fire and explosion hazards.

Detecting Gas Saving Lives

# Battery Technology

The battery was first invented over 200 years ago, but it has only been during the past century that the product has been commercially applicable. Batteries use chemical potential to accept, store and release electricity. Different battery technologies are available with chemical, materials, and construction variations, but commercial batteries still utilise similar procedures to store electricity. Battery types include rechargeable (secondary), non-rechargeable (primary), and application batteries (biobattery, button cell, flow, inverter, wet cell, etc.,) which include several technologies including chemical, electrochemical, electrical, and mechanical.

From remote control devices to cell phones to cars to solar panels, batteries are necessary for functioning in society today. The worldwide focus on green energy has stimulated the development of wind turbine and solar panel installations, with batteries needed to store the power generated. Renewable energies such as solar and wind require local energy storage facilities to act as a buffer when these facilities are not operational or at total capacity at night or on days when the sun doesn't shine and is not windy. Energy may be released later – when the grid requires more power or when there is less sun or wind. These battery storage facilities are essential in reducing minor power outages since they can also store excess traditional grid energy for up to twelve hours. These storage facilities are imperative during a power failure and critical at facilities where continued operation is crucial, including hospitals, military facilities, and data centres. The need for uninterruptable energy has these facilities spreading everywhere, from garage units to power plants.

These energy storage facilities allow flexibility during high demand and help the power grid avoid the need to build additional (and expensive) power plants. This results in fewer new power plants, and this aids the power industry with other environmental issues. These facilities should also translate to lower consumer costs, especially as energy costs increase.

Chemical and electrochemical battery technologies are powered by potentially dangerous chemical compositions, including ammonia, hydrogen, methanol, synthetic fuel, lead-acid, lithium-ion, sodium-cadmium, and sodium-ion. The technology in electrical and mechanical batteries includes compressed air, gravity, pumped hydro, supercapacitors, and superconductive magnetic storage.

Lead-acid batteries are large-capacity and rechargeable technology that has been popular for over 100 years and is commonly used in boats, automobiles, and uninterruptable power supplies (UPS). The wet-cell deep cycle batteries have also been used in solar arrays for several decades. Lead-acid batteries include wet-cell, gel-cell, and AGM (absorbed glass mat). These batteries should be refilled with water regularly to prevent the electrolytes from evaporating when charging.

Hydrogen fuel cell electric vehicles (FCEVs) vary from typical electric vehicles. While batteries are more efficient than fuel cells, hydrogen fuel cells are smaller, lighter, and can store far more energy than standard lithium-ion batteries. With superior energy density, the hydrogen FCEV has a significant advantage for travelling distance and provides the extra power required for short bursts of acceleration. The hydrogen fuel stack is a construction of individual membrane electrodes that require hydrogen and oxygen to produce electricity. While a typical battery is used to start the vehicle and operate accessories like most automobiles, the high-voltage battery pack stores energy generated from regenerative braking. It also provides supplemental power to the electric traction motor that propels the vehicle.

Lithium-ion batteries are replacing lead-acid technology for fork trucks and solar and wind farms. It is today's most popular battery technology due to its high energy density and longer life. These batteries have a much greater depth of discharge (DoD) which allows a much more significant percentage of use of the battery's power and are lighter than conventional lead-acid batteries.

## Gathering insights across all sites will help organisations operating on a larger scale to ensure ongoing visibility, compliance,

## New Battery Technologies under Research

Solar farms are expanding everywhere with the eventual intent to power almost everything in our lives; there is tremendous research into superior battery performance to produce safer batteries that last longer, lighter weight, and store more power. Some of the new battery technologies include:

**Solid State Batteries** - This technology replaces the electrolyte gel used in lithium-ion batteries with a solid material such as ceramic or glass. This makes these batteries non-flammable when heated; they utilise high-voltage, high-capacity materials and are lighter in weight. And since these batteries have high energy storage and lighter weight, they are an option for replacing electric vehicle batteries.

**Sodium or saltwater batteries** – The batteries use salt for power storage. Their chemistry differentiates this battery significantly from lead-acid and lithium-ion batteries. This battery technology is gaining popularity in the solar industry as they produce non-toxic power for a long duration. Saltwater batteries hold an impressive 5,000 cycles; since the product is not susceptible to explosions, you can use it beyond the indicated cycles. Saltwater batteries allow full discharge without harming the battery. Also, fully discharging the battery does not affect the life cycle of the storage system. Additionally, the battery can stay for weeks or days without charge. For this reason, battery maintenance systems to control the charge are unnecessary. These batteries are fully recyclable compared to lithium-ion and lead-acid batteries. The current drawback to saltwater technology is the higher price.

**Organosilicon electrolyte batteries** – Similar to solid-state batteries, this is a carbonate-based solvent system in Li-ion batteries. These electrolytes can be engineered at the molecular level for various battery markets.

**Zinc-manganese oxide batteries** – Researchers are hopeful this technology can increase energy density in conventional batteries without increasing cost. Both elements are readily available.

**NanoBolt lithium tungsten batteries** - Tungsten and carbon multi-layered nanotubes are bonded to a copper anode substrate and build a web-like nanostructure that forms a vast surface. This allows more ions to attach during recharge and discharge cycles making the battery charge faster and store more energy.

**TankTwo String Cell™ batteries** - The modular String Cell™ battery contains a collection of small independent self-organising cells. Each string cell consists of a plastic enclosure covered with a conductive material that allows easy contact with other cells. An internal processing unit controls the connections in the electrochemical cell. To facilitate quick charging of an EV, the little balls in the battery are sucked out and swapped for recharged cells at the service station. Later at the station, the cells can be recharged at off-peak hours.

**LiS/B4C Hemp** – This technology uses industrial hemp as one of the core materials due to its durability, porosity, and low costs. Less dangerous chemical catalysts are used to power the cells, and, unlike many rare earth elements, sulphur is abundant and boron almost as much. It is also relatively available, and the batteries would be safer and easily recyclable. With longer life, these batteries would be possible for heavy-duty trucks and electric aeroplanes.

**Lithium Iron Phosphate (LiFePo4)** – Quickly replacing larger batteries, LeFePo4 batteries require no maintenance, are safe, efficient, lightweight, and contain no rare earth metals. There is no propensity for thermal runaway. These batteries do require special handling, do not perform well in the cold and have a low density making them ill-suited for small devices such as cellular.

## Most all batteries will produce gas if overcharged, overheated, damaged, or left drained of charge for an extended period.

Most all batteries will produce gas if overcharged, overheated, damaged, or left drained of charge for an extended period. The liquid chemical components in the battery can vaporise and produce gas under these conditions. These situations can lead to a thermal runaway where the internal battery temperature reaches a critical point where flammable gasses are released and present the risk of fire or explosion. Since batteries operate in a relatively small temperature range, thermal runaway is a complex process to stop. Electric vehicle batteries have interconnected cells, so if one cell fails, it can swell and heat up quickly. As gasses begin to vent and temperature increases, the problem worsens and spreads to the other cells with potentially devastating results.

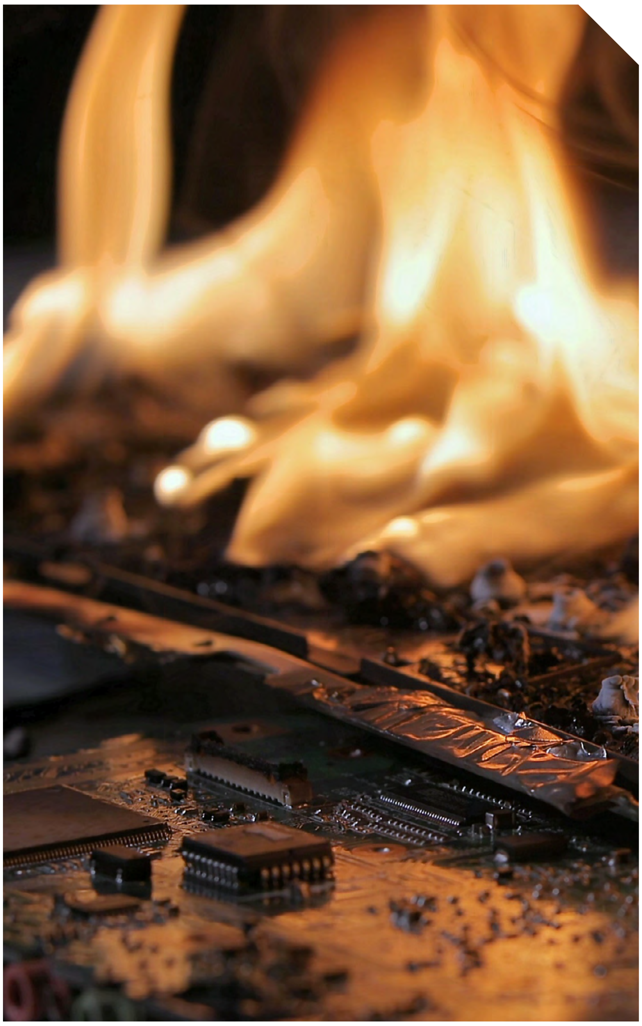
Lithium-ion is today's most abundantly used battery technology due to its high energy density and longer life. It also gets the majority of bad press with cell phones and portable devices, causing fires and exploding laptops. The lithium-ion battery has a potentially flammable electrolyte which may become a dangerous gas vented from the battery cell if overheated, damaged, or exposed to external heat sources (e.g., above 54°C / 130°F). They may also vent in temperatures below freezing during charging or if damaged or the manufacturer's instructions are not followed. Recent developments by Tesla have helped lithium-ion products become more affordable, dependable, and the battery of choice for solar and wind farm energy storage. And as a result, the new technology in almost all of our new devices.

The reality is that all battery types are prone to this infrequent but potentially deadly problem. Continual battery charging may also lead to a gas leak and thermal runaway. That is why trickle chargers are advised to help prevent batteries from overcharging. Even so, damaged battery cells and ground faults in power may also lead to thermal runaway.

During battery discharge, the risk is low as little or no gas is vented from lead-acid batteries during this process. The primary concern is the mixtures of oxygen and hydrogen produced during battery charging. Hydrogen is a highly flammable, lighter than air, odourless, and colourless gas that is dangerous, especially in poorly ventilated areas. The danger increases with vented Oxygen, which amplifies the fire or explosion.

There have been several accidents across the globe where the failure of a single Lithium-ion battery was the catalyst to major fires and explosions with thermal runaway events that spread to the adjacent cells. In most cases, combustible gasses built up within the containment facility and exploded. Some of the more notable examples include South Korea experiencing twenty-three lithium-ion battery fires in 2018, drawing even more attention to the potential risks. Most consumers recall when Dell recalled four million laptops in 2006 due to overheating batteries and Samsung recalled the Galaxy Note 7 smartphone due to battery fires. In 2001, a UPS data centre in California suffered a hydrogen gas explosion where batteries were charging.

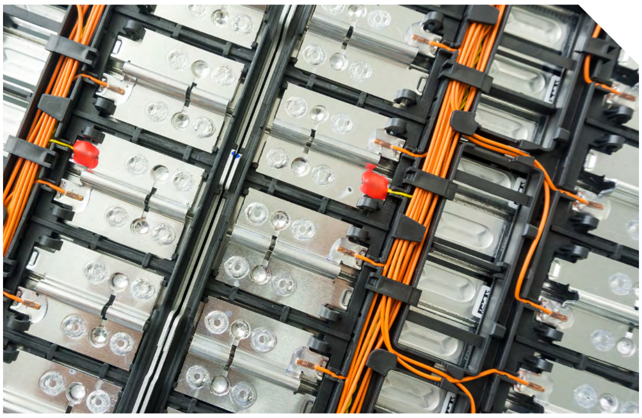
The bottom line is that the risks of gas leaks and chemical explosions are severe concerns for employee safety. The impact on the storage facility can have repercussions on the entire business and customer base with facility repairs, accident investigations, and employee morale. Gas leakage is an issue that must be monitored to prevent thermal build-up and potential catastrophe.



**Hydrogen gas is explosive at only 4% by volume in air, and most battery storage and charging facilities are enclosed areas.**

## Importance of Detection Technology

Given the potential for gas emissions and potential fire and explosion from improperly charged or maintained batteries, the importance of detecting these gases before thermal expansion is paramount. Safety systems quickly alert personnel to potential dangers of gas leakage, including toxic gas poisoning, asphyxiation, fire, or explosion. For example, Hydrogen gas is explosive at only 4% by volume in air, and most battery storage and charging facilities are enclosed areas. A poorly ventilated battery storage area can quickly lead to a dangerous situation when these minor hydrogen levels are attained. Properly implemented gas detection technology will increase safety and meet and exceed safety expectations in these areas.



## Other Detection Methods


Aside from the essential focus on sampling air quality for dangerous gasses, here are several other suggestions to ensure a safe battery storage environment.

**Preventive Maintenance** - Be sure to include batteries and the storage and charging areas in preventive maintenance plans. A good battery maintenance program will help optimise battery life, prevent failures, and reduce premature replacement and associated costs: the battery room's cleanliness, safety, and environmental aspects. The ventilation equipment should operate as per the manufacturer's specifications. Other maintenance checks may include regular battery load testing, corrosion and damage checks, battery cables cleaning and maintenance, checking grounds, connections, wire insulation, and electrical safety, and the calibration of inspection and monitoring tools and equipment.

**Fire Suppression System** – While a reactive rather than proactive safety measure, engineered fire suppression systems are designed for specific applications. Several fire suppression systems include water mist, foam, dry chemicals, CO2, and inert gas. This illustrates why the correct system should be designed for most battery storage applications.

**Battery Management System (BMS)** – This electronic system monitors the battery state while managing the temperature, voltage, current, and internal short circuits. These systems help extend battery life and reduce the likelihood of battery fires and explosions.

Gathering insights across all sites will help organisations operating on a larger scale to ensure ongoing visibility, compliance,

## Increased understanding

When it comes to multi-site organisations, the need for reliable data and a solid tool for the foundation of governance is even more crucial. Gathering insights across all sites will help organisations operating on a larger scale to ensure ongoing visibility, compliance, asset management and the smooth running of the day to day.

Utilising data solutions that can offer you a way in which to accurately record your data, to analyse the insights it offers and from there to act in ways that achieve the central objectives and goals of your team is the focus of this white paper.

We will explore the ways in which data solutions, such as Crowcon Connect, can reduce your costs, improve plant and personal safety, deliver compliance and boost your operations productivity and overall efficiency.

# Regulations and Standards

## EU Regulations and Standards

Following are several fundamental regulations and standards regarding battery storage facilities, testing, and maintenance. In addition, most battery manufacturers publish testing requirements to ensure warranty compliance. The EU recently discussed several proposals for the new regulatory framework for batteries and existing standards.

**Directive 2006/66/EC** of the European Parliament and of the Council of 6 have updated regulations regarding batteries and accumulators and waste batteries and accumulators.

**IEC62133 Safety Requirements for Rechargeable Cells and Batteries used in Portable Devices.** This is the de facto standard for international compliance. Volume 1 is for nickel batteries; volume 2 is for lithium-ion batteries.

## The United States and International Regulations and Standards

Below are the primary Standards & Model Codes for Energy Storage in the United States.

**National Fire Prevention Association 1:** Fire Code 2021 – NFPA 1 is the U.S. national code addressing fires and life safety issues for the public and first responders and the standard for energy storage systems. Pertinent chapters include chapter 52: Energy Storage Systems, chapter 70: Oxidizer Solids, and Liquids

**National Fire Prevention Association 855:** Standard for the Installation of Stationary Energy Storage Systems - An installation code that addresses the dangers of toxic and flammable gases, stranded energy, and increased fire intensity that can result from a defect or operational failure in an energy storage system.

**National Fire Prevention Association 70:** National Electrical Code - The benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards.

**UL 9540A, Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems** - UL 9540A is a standard that details the testing methodology to assess the fire characteristics of an ESS that undergoes thermal runaway. Data from the testing is then used to determine the fire and explosion protection requirements applicable to that ESS, consistent with the requirements outlined in NFPA 1 and NFPA 70.

**UL 9540 Standard for Energy Storage Systems (ESS) and Equipment** - UL 9540 is the recognised certification standard for all types of ESS, including electrochemical, chemical, mechanical, and thermal energy. The standard evaluates the safety and compatibility of various elements and components when integrated into an ESS, whether intended to be used in standalone mode or as part of an electrical power system or electric utility grid.

**IEC 62933, Electrical Energy Storage (ESS) Systems–** The IEC 62933 series of standards explicitly addresses various aspects of ESS, including testing methods, safety requirements for grid-integrated ESS, safety considerations for grid-integrated ESS, planning and performance assessment of ESS, and guidance on environmental issues.

**IEC 62109-1, Safety of Power Converters for Use in Photovoltaic Power Systems Part 1: General Requirements -** IEC 62109-1 applies to power conversion equipment used in photovoltaic systems. The standard defines minimum requirements for the design and manufacture of such equipment for protection against electric shock, energy, fire, mechanical, or other hazards to help ensure a consistent technical level of safety in the equipment.

Note: The inter-agency Federal Consortium on Advanced Batteries (FCAB) seeks to eliminate the need for both cobalt

# Gas Detection Products

Gas detection is an invaluable safety technology often equipped in battery charging rooms. Ventilation is also advised, and while helpful, it is not fool proof as fan motors can fail and should not be relied upon as the sole safety measure for battery charging areas. Fans mask the problem while gas detection notifies personnel to act before problems escalate. Gas detection systems are crucial in informing personnel of increasing gas leaks before becoming dangerous. Gas detection units comply with local building codes and NFPA 111, the National Fire Protection Association standard on stored electrical energy emergency and standby power systems. They include maintenance, operation, installation, and testing provisions regarding the system's performance. In addition to permanent gas detection systems, handheld units are available. The benchmark products are provided by Crowcon and are listed below.

**Portable Gas Detectors** - Crowcon's portable gas detectors (Gasman, Gas-Pro, T4x, Tetra 3 and T4) protect against a wide range of industrial gas hazards, with both single gas and multi-gas monitors available. With a wide range of sizes and complexities, you can find the right portable gas detection solution to meet the number and type of gas sensors you need and your display and certification requirements.

**Fixed Gas Detectors** - Crowcon gas detection fixed systems offer a flexible range of solutions that can measure flammable, toxic, and oxygen gases, report their presence, and activate alarms or associated equipment. Crowcon fixed gas monitoring systems (Xgard, Xgard Bright and XgardIQ) are designed to be interfaced with manual call points, fire and gas detectors, and distributed control systems (DCS).

**Control Panels** - Crowcon gas detection control panels offer a flexible range of solutions that can measure flammable, toxic, and oxygen gases, report their presence, and activate alarms or associated equipment. Crowcon fixed gas (Vortex, GM Addressable Controllers, Gasmaster) monitoring systems are designed to be interfaced with manual call points, fire and gas detectors and distributed control systems (DCS). In addition, each system can be engineered to drive remote annunciators and mimic panels. Crowcon has a gas detection product to suit your application regardless of your operation.

**Temperature Measurement** – Crowcon has extensive experience with temperature measurement. There are several models of temperature measurement, from pocket thermometers to industrial kits ranging from -99.9 to 299.9°C with probes and clamps. They are enhancing their fixed detection capabilities by adding high-temperature electrochemical sulphur dioxide detection for battery manufacturing and charging stations. This is critical during the first charge of a battery, as a fault is most likely at that time. Their fast-acting systems detect the precursors to thermal runaway and quickly terminate power to the batteries to avoid damage.


## Summary

The reality is that all commercial battery types are prone to this infrequent but potentially deadly thermal runaway problem. While new technologies may be on the horizon, the cost will likely take years to be competitive with existing technology. Ventilation fans cannot alert personnel to a gas leak and may only mask the problem until a fan motor fails and compounds the issue. Gas detection technology is critical in helping keep workers and worksites safe from flammable and toxic gases. Combined with regular maintenance and compliance with battery storage regulations, these gas detection systems should lead to increased uptime, greater productivity, improved employee health, and a more profitable operation.

For more information about the Crowcon gas detector and other products or to ask further questions about gas detection for battery power storage, contact your area Crowcon facility.