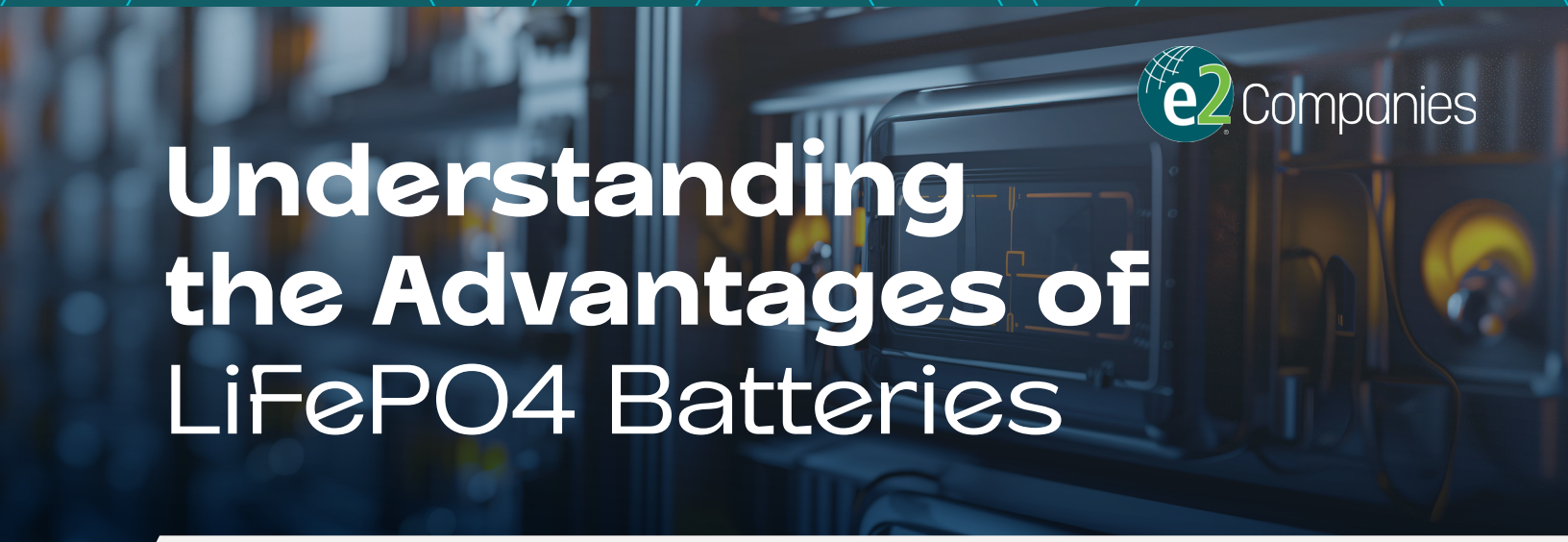


e2 Companies

Understanding the Advantages of LiFePO4 Batteries

As companies strive to meet the demand for high-performance products and services while maintaining their footing on the path to zero, the LiFePO4 battery is becoming an important component of many innovations due to its long lifecycle, safety, and low environmental impact.

When deciding which battery would help power our R3Di® system, **we chose the only battery that made sense: The Lithium Iron Phosphate (LiFePO4).** In this paper, we'll explore the five major benefits of the LiFePO4 over other battery types.

What Are LiFePO4 Batteries?

From a chemistry perspective, lithium iron phosphate (LiFePO4) or "LFP" batteries are a type of lithium battery using lithium iron phosphate as the cathode material and a graphitic carbon electrode with a metallic backing as the anode.

LiFePO4 was introduced in 1996 when a group of researchers at the University of Texas-Austin first used phosphate as cathode material for rechargeable lithium batteries. Lithium Iron Phosphate has may benefits: **in particular, thermal stability, which increases the safety of the battery.**

LiFePO4 batteries are a well-known choice for energy-dense power applications due to the absence of the more-volatile and less sustainable elements such as cobalt, which is found in other lithium battery chemistries. With appropriate application and design, LFP batteries can assist in providing a reliable, available, and cost-effective power source for small and large loads.

Batteries in the Lithium Category

Complete Name	Chemical Symbols	Acronym
Lithium Nickel Manganese Cobalt Oxide	LiNiMnCo02	NMC
Lithium Cobalt Oxide	LiCo02	LCO
Lithium Manganese Oxide	LiMn204	LMO
Lithium Iron Phosphate	LiFePO4	LFP
Lithium Nickel Cobalt Aluminum Oxide	LiNiCoAl02	NCA
Lithium Titanate	Li2Ti03	LTO

LiFePO4 Batteries Offer Superior Performance

Due to their unique battery chemistry, LiFePO4 batteries have an excellent reputation when it comes to performance and efficiency, making this technology a popular choice for energy storage and powering electric vehicles (EVs).

Some of the performance benefits include:

- ✓ Ability to reach full charge in **two hours or less**
- ✓ A self-discharge rate of only **two percent per month**, compared to the 30% rate of lead acid batteries
- ✓ **Significantly higher runtime** compared to other lithium-ion and lead acid batteries
- ✓ **Consistent power**, even when battery life is below 50%
- ✓ **Zero** maintenance

LiFePO4 batteries are also known for their long lifespan, with the ability to charge and discharge between 2,500 and 5,000 cycles before losing 20% of their original capacity.[1] LiFePO4 also offers a slower rate of capacity loss compared to other formulations. After a year, a LiFePO4 cell typically has approximately the same energy density as a LiCo02 lithium-ion cell. Battery charging time is also considerably reduced, adding yet another convenient performance perk.

Additionally, LiFePO4 batteries operate in a wider temperature range than lithium-ion batteries, which makes them a better fit for applications that will exhaust the batteries or run in extreme weather conditions. Hospitals, grocery stores, and plastics manufacturers are among the many businesses that can't afford to shut down, even for a moment, regardless of weather conditions.

As with most batteries, a Battery Management System (BMS) is required to prevent over-voltage and degradation of the cathode material.

LiFePO4 Batteries Enable Faster Charging

LiFePO4 batteries charge much more quickly compared to other battery types.[2] While actual charging time depends on several factors, including battery capacity, current, and charging method, they typically charge within 1-2 hours using AC power and 3-6 hours using solar panels.

This makes them a great fit for applications used in electric vehicle (EV) fast charging, such as the R3Di® System.

While this system can power a facility, it can also provide a reliable and effective power source for EV charging with Level III DC fast chargers, enabling customers to charge multiple vehicles at a time and achieve a full charge in only 10-30 minutes. The system integrates with current EV and fleet chargers and with no impact to the provider facility as the system only uses excess capacity for charging. LiFePO4 can help society meet the increasing EV charging demand, which is expected to surge from 11 billion kWh to 230 billion kWh by 2030.[3]

1. https://www.super-b.com/en/lithium-iron-phosphate-batteries/benefits-lithium-batteries
2. "Thermally modulated lithium iron phosphate batteries for mass-market electric vehicles," Nature Energy 6, 176-185 (2021)
3. "Building the electric-vehicle charging infrastructure America needs," McKinsey & Company

The LiFePO4 Is a Safer Battery Choice

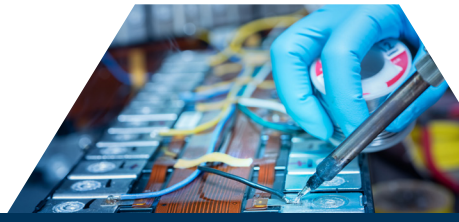
LiFePO4 batteries are renowned for their safety features among battery experts and the industries that use them. The Fire Industry Association's Guidance on Li Ion Battery Fires shows the LiFePO4 has with the lowest thermal spike during abuse testing. In fact, the high-profile battery fire incidents are Li Ion chemistries using Cobalt in the cathode, not LiFePO4 chemistries.[4]

All batteries store and release electrical energy through electrochemical reactions. When a battery purposely discharges electrical energy, ions move from one electrode to the other through a liquid medium called electrolyte. If that battery undergoes some stress during this process, such as an internal short or abnormal heat, the cobalt in the cathode can release fire-sustaining oxygen.

This can result in "thermal runaway," which is a heat generating reaction that is greater than the ability of a battery cell to release.

In lithium cobalt oxide batteries, thermal runaway can result from the omission of the cobalt with its negative temperature coefficient. The LFP battery does not use cobalt, greatly reducing the risk of fire ignition or propagation. Overall, LFP is thermally and chemically stable, making it less prone to explosions or fires due to misuse or structural damage.

LFP is reported to emit one sixth of the heat of nickel-rich NMC. The Co-O bond is also stronger in LFP batteries, so if short-circuited or overheated, oxygen atoms are released more slowly. What's more, no lithium remains in fully charged cells, making them highly resistant during oxygen loss compared to exothermic reactions typical of other lithium cells.



LiFePO4 Is the Winner in Thermal Runway Study Battery Comparison

In one study, the severity of thermal runaway hazards were greatest for cobalt-based Li-ion while the LiFePO4 was the least severe.[5] The thermal runaway risk for LiFePO4 cathode material is higher but the resulting hazard score of LiFePO4 less than 0.35 (compared to >1 otherwise). There were no explosions during LiFePO4 testing, only low-level gas release. In other words, the possibility of thermal runaway exists in all Li-ion chemistries, with the LiFePO4 type of Li-ion cell showing a safer outcome after a thermal event.

The protection system slows or even stops the propagation of increased temperatures. In the case of LiFePO4 chemistries, thermal propagation is recommended to be maintained below the ignition temperature of the cell (270°C).

Finally, a protection system should also provide a method of safely releasing off-gassing from extreme thermal events. Thermal runaway temperature must also be avoided (270°C). An internally initiated thermal runaway event was tested for UL9540A certification. The **UL9540A testing** shows measurable gas concentrations:

- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Hydrogen (H_2)
- Unburned Hydro-Carbons (UHCs)

During the test, thermal runaway did not induce a chain reaction from cell to cell or to other modules. The temperature observed was not greater than 450°C. No explosion or flame events were observed.

4. Guidance on Li Ion Battery Fires, Fire Association Industry, page 5 graph

5. "Overcharge-to-thermal-runaway behavior and safety assessment of commercial lithium-ion cells with different cathode materials: A comparison study," (Journal of Energy Chemistry), Zhenpo Wang et al

LiFePO4 Batteries Are Cost-Effective Long Term

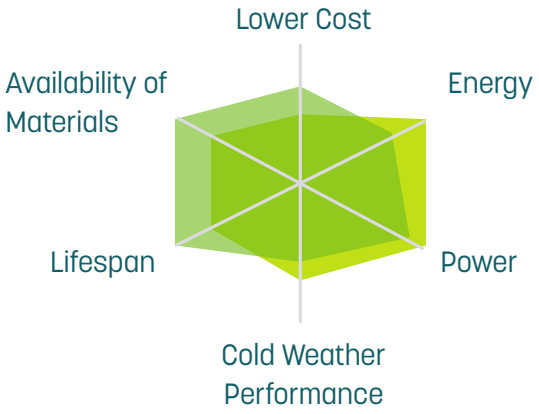
Although the initial investment may be higher, LiFePO4 batteries' extended lifespan and reduced maintenance costs make them a smart choice for long-term savings.

Additionally, LiFePO4 batteries weigh almost 50% less than lithium manganese oxide batteries and 70% less than lead acid batteries, making them less costly to ship while adding less weight to equipment. While LFP batteries have higher up-front costs than other battery systems, they last much longer and perform better than lead-acid, saving you or your business money overall.

Battery Benefits

NCM **Nickel cobalt managanese**

LFP **Lithium iron phosphate**



LFP Battery Cost Breakdown

While the most crucial factor in calculating how much money you can save by switching to lithium batteries is likely the number of cycles the battery will run until the end of its life, other elements to consider include:

Retail cost of the battery.	This is the largest cost of initial installation.
The cost of the labor needed to install the battery.	This should be performed by a professional who, in some cases, must be scheduled and dispatched to the customer's site. The labor cost for installing any battery type should be about the same; with lead-acid batteries, the process must be repeated multiple times, compared to one single installation for the entire life cycle of a LiFePO4 battery.
The cost to maintain the battery.	Lead-acid batteries require maintenance that includes checking and topping off water levels, cleaning acid residue off the battery and terminals, as well as cleaning or replacing nuts, bolts, and cables that have become corroded over time. LFP batteries require no maintenance over the entire life of the battery, making them a more cost-effective solution.
The cost of replacing batteries.	Lead-acid batteries will need to be replaced multiple times before a lithium battery will need to be replaced.
Cost of battery charging.	This is the nominal cost of electricity for charging the battery, including the need to overcharge lead-acid batteries to avoid stratification (the accumulation of lead sulfate on the battery's plates). In our calculations, we assumed a DOD (depth-of-discharge) of 80% on all batteries before recharging was necessary.

LiFePO4 Can Increase Your Societal Return on Investment

The disposal or recycling of batteries remains a key environmental concern. Lead is one of the most recycled metals, with six million tons of it being gathered annually, often for batteries. While recycling is usually a good thing, it's complicated, especially when lead is involved.

"...the unsafe recycling of lead batteries, mostly from automobiles, is a lethal and growing scar on the planet."[6]

There are significant environmental advantages to using lithium iron phosphate batteries over lead-acid batteries. With electrodes made of non-toxic materials, LiFePO4 batteries pose far less risk to the environment than lead-acid batteries. They can also be recycled to recover the materials used in their electrodes, wiring, and casings to be used in new lithium batteries.

It's also worth considering how LiFePO4 batteries stack up against other types of lithium batteries in terms of their impact on the environment.

Lithium itself is not toxic and it does not bioaccumulate like lead or other heavy metals. But most lithium battery chemistries use oxides of nickel, cobalt, or manganese in their electrodes. **Estimates suggest it takes 50% more energy to produce these materials compared to the electrodes in lithium iron phosphate batteries.[7]**

The absence of cobalt in LiFePO4 means they can be much more ethically sourced than traditional lithium-ion batteries, which must be manufactured using nickel and cobalt.

Over 70% of the world's cobalt comes from mines in the Democratic Republic of the Congo, where unethical labor conditions persist.[8]

A 2013 report by the EPA[9] as well as a recent climate blog[10] revealed the harmful effects of lithium-based batteries using nickel or cobalt. They have the highest environmental impact, including resource depletion, ecological toxicity, and human health impacts. This is almost entirely due to the production and processing of nickel and cobalt.

6. https://e360.yale.edu/features/getting-the-lead-out-why-battery-recycling-is-a-global-health-hazard
7. https://www.relionbattery.com/blog/lifepo4-and-the-environment#:~:text=Lithium%20itself%20is%20not%20toxic,the%20electrodes%20in%20LiFePO4%20batteries.
8. https://investingnews.com/where-is-cobalt-mined/
9. Environmental Protection Agency https://archive.epa.gov/epa/sites/production/files/2014-01/documents/lithium_batteries_lca.pdf
10. https://greenly.earth/en-us/blog/ecology-news/the-harmful-effects-of-our-lithium-batteries

LiFePO4 batteries, by contrast, have big advantages over other lithium chemistries:

- They use no rare earths or toxic metals and employ commonly available materials including copper, iron, and graphite.
- Less energy is consumed in mining and processing of materials.
- Phosphate salts are also less soluble than metal oxides, so they are less likely to leach into the environment if the battery is improperly discarded.
- LiFePO4 batteries are chemically stable against combustion and rupture under nearly all operating and storage conditions.

Compared to other lithium battery technologies, LiFePO4 batteries use more abundant and non-toxic materials that can be produced with less energy.

The performance and safety of LiFePO4 batteries also make them a superior choice for electricity storage like the R3Di® and zero-emission renewable electricity, wind, and solar power systems.

LiFePO4 Battery Specification

VLFP 51.2V100Ah

Requirements:

ESS application with max 100A charge current/ 400A discharge current used for high voltage system

Item	General Parameter	Details
Model	VLFP-51.2V100Ah	
Casing material	Steel case	**Black**
Assembly	16S2P	Single cell capacity 50Ah
Rated voltage	51.2V	Working voltage
Standard capacity (0.2C5A)	100Ah	
Standard Charging voltage	56V	
Cut-off voltage	45V	3.5V/cell
Maximum discharge current	400A	
Maximum charge current	100A	<50A recommended
Operating temperature around module	Charging temp. range: -5 ~ 55°C Discharging temp. range: -30 ~ 55°C	**Recommended**
Standard charging (0°C~60°C)	CC-CV Charge: 56V/0.2 C5A Charging end current: 0.01C5A	Charging time: About 5.5hours
Recommended Floating charge	Charging volt. 55.2-56V	3.45-3.5/cell
Battery module dimension (Length*Width* Height)	See drawing	±2mm
Recommended charge type	CC-CV-floating charge	CC: 0.2C to 56V CV:57V Floating: 55.2V
Battery Weight (Approx. including case)	61Kg	
Storage temperature range	Less than 9 months at -20 ~ 25°C Less than 6 months at 25 ~ 35°C Less than 3 months at 35 ~ 55°C	
FAN	DC24V	

LifePO4: The Battery of a Sustainable and Productive Future

As innovators, we are charged with satisfying the demand for high-performing products while contributing to a positive SROI. Our extensive review of independent research has concluded that the benefits of incorporating LiFePO4 batteries into our technology, particularly the R3Di® system, far outweigh the costs.

Because this self-contained, modular and mobile unit consists of a prime-rated, rich-burn natural gas generator and a **lithium-iron phosphate battery energy storage system**, it can provide up to 1 MW of power 24 hours a day, 7 days a week, 365 days a year.

As you consider this technology for your company, think about what service you can offer to offset the larger upfront cost. For example, at e2, we offer a 24/7/365 assets monitoring platform, **Grove365**.

Our experts monitor the customers' R3Di® system and other assets to determine the cost-effectiveness of using the public utility versus another energy source. In addition to saving money long-term with LiFePO4 batteries, e2Companies further increases these savings with our dedicated monitoring service.

About e2Companies

e2Companies is the creator of the world's first Virtual Utility® and offers integrated solutions for power generation and distribution. With a commitment to delivering energy resiliency, reliability and regulatory compliance, our customers can unlock savings along with opportunities for revenue.

Our patented R3Di® system is an example of this commitment. With Grove365's asset monitoring and Palm Energy's market expertise, our customers can achieve a positive ROI for both their company and society.

Learn More

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