



ZERO

BATTERY WASTE

THE GUIDE TO HOW ZERO WASTE AFFECTS OUR ENVIRONMENT – AND YOU

CREATED BY THE CROWN BATTERY MANUFACTURING COMPANY FOR ENVIRONMENTALLY CONSCIOUS
STAKEHOLDERS AND ADVOCATES FOR A CLEANER WORLD.

HOW TO GET TO ZERO BATTERY WASTE

Landfilled: The Awful Truth About Battery Waste

Nobody wants to buy a battery that'll end up in a landfill – or leach into their drinking water.

But did you know that's exactly what's happening with lithium-ion (Li-ion) batteries today?

According to *Chemical & Engineering News*, 95% of today's lithium-ion batteries end up in a landfill.

Source: "It's time to get serious about recycling lithium-ion batteries"
<https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28>

And the environmental consequences of battery waste are dire:

- ▶ **Higher carbon emissions** because batteries are manufactured using mined materials. That exacerbates climate change.
- ▶ **Less recycling means more virgin mining from conflict zones** – which are less politically stable, support autocracies and child labor, and lack environmental and worker safety regulations.



- ▶ **Without full battery recycling, scientists predict we'll run out of critical materials:** According to a report by the Union of Concerned Scientists, humans only have a 50-year supply of cobalt, nickel, and manganese with current extraction methods and demand. **But demand is predicted to triple.**

And whether you're an installer, distributor, operations manager, or EV or home battery owner...

...YOU'LL PAY A FINANCIAL PRICE FOR BATTERY WASTE, TOO:

- ▶ Li-ion battery buyers may have to pay disposal costs at end of life.
- ▶ Virgin mining makes supply chains longer and more fragile.
- ▶ Wasted materials and inefficient manufacturing are an expense – and guess who ends up footing the bill?

BATTERY FACT:

Crown batteries are manufactured with 100% renewable energy and more recycled than an aluminum can — a world-first.

Source for recycling data: U.S. EPA "Advancing Sustainable Materials Management: 2018 Fact Sheet"

Universal battery recycling is critical to protect these resources, our environment, and your operations.

Barring strong policies, infrastructure investments, and technological breakthroughs, we could use up critical metals and other materials within our lifetimes. We risk millions of tons of hazardous waste entering our landfills. And Li-ion supply chains will remain vulnerable because raw materials come from a small handful of sites – rather than from regional recyclers.



“We can’t build a sustainable economy with single-lifespan batteries – and more landfills.”

– John Connell
Vice President of SLI Products Group
Crown Battery Manufacturing Co.

In this report, you’ll discover how we’re getting to Zero Battery Waste – and how it affects you:

- ▶ What is Zero Waste, and why does it matter now?
- ▶ Why are some batteries 99% recycled – but others are 95% landfilled?
- ▶ Proven strategies to reduce batteries’ environmental footprint and get more from less
- ▶ Is battery repurposing viable yet?
- ▶ Easy steps that strengthen supply chains
- ▶ “The greenest battery is one you don’t buy”
- ▶ Why much of a battery’s waste footprint is upstream in mining and manufacturing
- ▶ Which battery chemistries and manufacturing steps eliminate common waste
- ▶ Battery selection strategies that lower your costs and environmental impact
- ▶ And how can we do better – and bring waste toward zero?

FORTUNATELY, THERE’S HOPE:

The absorbent glass mat (AGM)/lead-acid battery industry has already achieved near-100% recycling rates. And much of that knowledge is transferable.

Yes, we need green energy storage and electric vehicles (personal, corporate, and public) to fight climate change. And Crown Battery has been powering electric vehicles and homes for nearly 100 years.

We need to continue electrifying and ending our reliance on fossil fuels. Crown is the first and only US battery manufacturer to source 100% renewable energy for manufacturing.

And we need to modernize recycling/reuse infrastructure, technology, and legislation for Li-ion batteries – to ensure that people, our environment, our economy, and the climate thrive as we electrify.



WHAT IS ZERO WASTE – AND WHY NOW?

“ZERO WASTE:

The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health.”

– Zero Waste International Alliance (ZWIA)

In other words, our goal is to keep waste out of landfills, incinerators, and bodies of water.

But zero waste isn't just about the end of life (EOL). It aims to eliminate waste across the supply chain and lifecycle – from mining and manufacturing to shipping, use, and recycling.

WHY WE NEED NEAR-ZERO-WASTE BATTERIES NOW:

- ▶ **Batteries are in countless products today.** They power small electronics, appliances, homes and businesses, mining and railroads, power grids, and EVs – ranging from warehouse trucks and short-transit vehicles to full-size cars and trucks.
- ▶ **Energy storage demand is predicted to triple** in the next few years – and we need closed-loop recycling systems for every battery.
- ▶ **More raw materials recycled = fewer mines** and more resilient supply chains and ecosystems.
- ▶ **For the future:** We must ensure we have enough raw materials for future generations.
- ▶ **Climate change is real...**and energy storage (+ renewables) is critical to reversing its potentially disastrous effects.
- ▶ **Renewable energy is intermittent** – batteries store this energy for later.
- ▶ **Less waste saves money:** Efficient energy storage protects us against rising raw material costs... and lowers energy costs by enabling peak shaving, renewable storage, and more.
- ▶ **Avoid massive landfilling and pollution** – both from new battery construction and aging batteries as they reach the end of life.

WHAT ARE THE KEY PRINCIPLES OF ZERO WASTE?

Zero waste products start with environmentally friendly manufacturing. They *restart* with fully recyclable products made from previously recycled materials.



ENGINEER BETTER:

- ▶ Build batteries for longer life and easier recycling (elegant, simpler designs + proper labeling)
- ▶ Shorten the R&D cycle using 3D printing, field-testing, and common sense
- ▶ Collaborate with government laboratories, manufacturing supervisors, and equipment operators to improve quality and eliminate waste



MANUFACTURE & RE-MANUFACTURE:

- ▶ Source previously recycled materials
- ▶ Build near responsible recycling centers where possible
- ▶ Minimize physical waste and energy use during manufacturing
- ▶ Reduce pollution with better technology and smart programs
- ▶ Support local economies



FIELD-TEST:

- ▶ Test batteries to ensure they're performing as planned
- ▶ Study the most brutal applications and environments, not the easiest ones
- ▶ Disassemble and measure test batteries to learn how to improve performance and longevity



EXTEND LIFESPAN:

- ▶ Teach best practices for maintenance, selection, and installation
- ▶ Provide no-cost, advanced technical training programs to installers and distributors
- ▶ Continue improving using buyer feedback + 3rd-party testing + R&D



ALWAYS RECYCLE:

- ▶ Work with the community to raise standards
- ▶ Ensure all batteries are collected
- ▶ Recover more raw materials

WHAT IS “CRADLE TO CRADLE”?

Cradle-to-cradle processes minimize waste and use resources indefinitely –

REDUCE, REUSE, AND RECYCLE.



COMPARING RECYCLING OPTIONS

And Ensuring No Battery is Left Behind



99%

CROWN'S LEAD-ACID
BATTERIES ARE
RECYCLED



95%

LITHIUM-ION
BATTERIES ARE
LANDFILLED

LITHIUM-ION (LI) AND LITHIUM-IRON PHOSPHATE (LFP) REPURPOSING:

Great in theory, unproven at scale

Repurposing promises to breathe new life into aging lithium-ion batteries. But it's still being studied in laboratories – not proven in the field.

What's standing in the way of LI and LFP repurposing?

- ▶ **No national collection system:** Unlike lead-acid batteries, lithium-ion has no standardized collection system for spent batteries. And fire hazards during transit and storage pose additional safety and insurance risks.
(Source: "Lithium-Ion Batteries – A New Fire Risk?" (Property, September 2017))
- ▶ **Wide range of battery designs:** Lithium-based batteries feature a variety of electrode chemistries, formats, and manufacturing decisions. That adds cost, complexity, and uncertainty to repurposing.
- ▶ **Operating conditions and wear/discharge vary:** Virtually no two batteries are the same.
- ▶ **No repurposing standards or regulations:** Determining batteries' State of Health (SoH) and remaining capacity is difficult, making second-life riskier for resellers and end users.
- ▶ **Mixing-and-matching used battery banks is complicated:** Each battery is likely to last and perform differently. That complicates rehabilitation, testing, and warranting for complete systems.
- ▶ **Usable capacity is limited:** To enhance safety and system life, companies decrease usable capacity.

Lots of intelligent people are working hard on lithium-ion repurposing, but we're a long way off.

Research labs, non-governmental organizations (NGOs), and private companies are trying various technical methods and business models to crack the code. And if critical components for EVs continue to increase in price, market economics could make repurposing more attractive.

Still, repurposing would require collection systems, battery standardization, new technologies and business approaches, and regulations.

Recycling reduces waste *now* – and preserves resources for later

"There are more than five times as many humans on Earth as 150 years ago, and we consume far more resources per person. Modern recycling mitigates social and environmental costs, and CO₂ emissions. And recycling ensures we have enough raw materials to continue living abundantly."

– Mark J. Kelley
Vice President of Industrial Products Group
Crown Battery Manufacturing Co.

RECYCLED OR LANDFILLED:

Where do batteries go when they die?

	AGM & LEAD-ACID BATTERIES	LITHIUM-ION & LFP BATTERIES
% COLLECTED TO BE RECYCLED	99% RECYCLED (Source: US Environmental Protection Agency's (EPA) "Advancing Sustainable Materials Management")	5% RECYCLED
% RECYCLABLE	99.3% (Source: Battery Council International)	0%-60% RECOVERY In Most Applications, Often Downcycled (one newer recycler claims 98% recovery rates for some specific materials in li-ion batteries)
MADE USING MOSTLY RECYCLED MATERIALS?	YES For instance, Crown Battery Uses 80% Recycled Lead in Our New Batteries	NO Today's Li-ion Batteries Use Almost Entirely Virgin-mined Materials

Why is there a Battery Recycling Gap?

	AGM & LEAD-ACID BATTERIES	LITHIUM-ION & LFP BATTERIES
DIFFICULTY OF RECYCLING PROCESS	SIMPLE Automated	DIFFICULT Manual Disassembly Requires Trained Technicians
PROFITABLE?	YES Very Profitable	TYPICALLY NOT (e.g. virgin lithium is 6x cheaper than recycled)
RAW MATERIAL VALUE	HIGH Easy To Extract	LOW Except for Limited Materials
EASILY SORTED AND RECYCLED?	YES Consistent Chemistry and Limited Ingredients Simplify Recycling	NO A Wide Variety of Chemistries and Components Makes Separation, Recycling, and Resale Difficult
ARE RECYCLED MATERIALS USED TO BUILD NEW BATTERIES?	YES	DEPENDS Typically Not
COLLECTION INFRASTRUCTURE	YES National and Extensive	NO Lacking National Infrastructure
LEGISLATION FOR RECYCLING	YES Including Strong Regulations	NO Unregulated (For Now)

"[C]urrently a vast recycling supply chain collects, stores, transports, recycles, and re-introduces more than 99% of lead back into the lead-acid battery supply chain."

Source: US Department of Energy
<https://americanmadechallenges.org/challenges/batteryrecycling/>

"... because researchers have made only modest progress improving recyclability, relatively few Li-ion batteries end up being recycled."

Source: Chemical & Engineering News – "It's time to get serious about recycling lithium-ion batteries"
<https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/128>

HOW DO WE ENSURE LOW-WASTE, ETHICAL BATTERY RECYCLING AND MINING?

MEASURE IT.



Regardless of chemistry, all batteries on the market contain or use hazardous substances – and create waste.

But their environmental impacts vary widely... and the ISO 14040 and 14044 Environmental Management Lifecycle Assessment (LCA) standards let us measure them.



“LCA studies the environmental aspects and potential impacts throughout a product’s life cycle (i.e., cradle-to-grave) from raw materials acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences.”

– Life Cycle Assessment (LCA): A Guide to Best Practice
by Walter Klopffer and Birgit Grahl (2014) page 1

FIRST-EVER INDEPENDENT STUDY “Comparative LCA of Lead and LFP Batteries for Automotive Applications”



On September 20, 2023, Sphera Solutions published a brand-new study comparing the cradle-to-grave impact of lead-based and Lithium-iron phosphate (LFP) batteries.

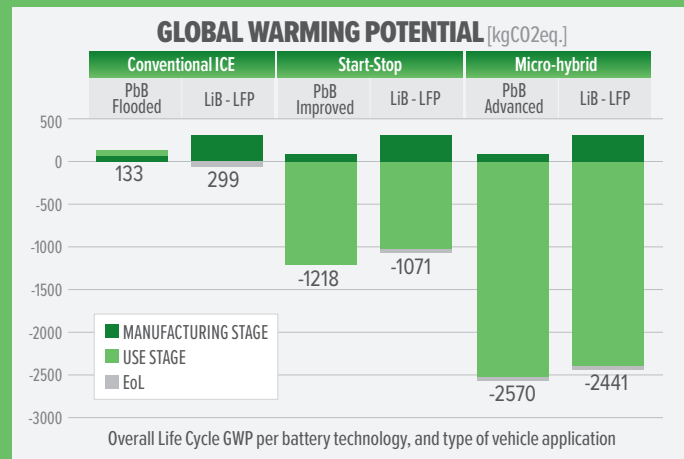
Following ISO 14040/44 standards, this independent report was commissioned by the Battery Council International (BCI) and the International Lead Association (ILA).

Sphera Solutions’s lifecycle assessment evaluated raw material extraction and processing, transportation to production sites, materials manufacturing, battery assembly, lifetime usage, and end-of-life.

After analyzing 12V lead-based and LFP batteries for automotive applications, Sphera's team found that:

- ▶ Lead-acid and AGM batteries have a lower global warming potential (GWP) than Lithium-Iron Phosphate models
- ▶ Recyclable lead-acid and AGM batteries are four times better for our environment
- ▶ Manufacturing burdens are 39%-90% lower for lead-based batteries

You can read the entire report here: <https://batteryCouncil.org/resource/comparative-lca-lead-lfp-automotive-applications>



SAFE, MODERN BATTERY RECYCLING VS. INFORMAL, UNREGULATED RECYCLING

In countries like the USA, lead-acid battery recycling occurs in heavily regulated facilities with stringent safety training, personal protective equipment (PPE) and machinery requirements, and EPA-approved air- and water filtration. These standards protect workers and the environment – and the 99.3% collection rate drastically reduces virgin mining.

These best practices work.

With proper regulation, lead-acid and AGM batteries form a safe, closed-loop – and lead only leaves its protective housing during the recycling process.

Meanwhile, in developing countries, “approximately 1% of the urban poor survives by salvaging recyclables from waste.”

There, battery recycling is often unregulated – sometimes in open pits – and lacks proper safety and environmental oversight, equipment, monitoring, incentives, and protocols. The results are dangerous working environments, pollution, and community harm.

By contrast, Lithium-ion batteries have a different problem: they're 95% landfilled. And they're commonly hand-mined in dangerous conditions – often by children.



“The U.S. Department of Labor estimates that at least 25,000 children are working in cobalt mines in the DRC.”

– Forbes, “To Meet Global Cobalt Demand, Companies Must Reform Mining Practices In The Congo”

<https://www.forbes.com/sites/michaelposner/2023/02/09/as-demand-soars-for-cobalt-used-in-electric-car-batteries-heres-what-companies-need-to-do-in-the-democratic-republic-of-congo/>

“ARTISANAL” AND SMALL SCALE MINING (ASM):

Unregulated cobalt mining for lithium-based batteries

ASM is largely unmechanized. Workers typically dig, crush, wash, and transport materials with their bare hands or shovels.

“Hundreds of thousands of destitute ASM miners collect scraps of cobalt from the ground daily,” says Michael Posner at Forbes. “Using shovels and their bare hands, they dig makeshift tunnels, into which they climb to gather rocks containing cobalt ore.”

“A 2020 report by the Organisation for Economic Co-operation and Development estimated that between 18% and 30% of the cobalt produced by the Democratic Republic of the Congo is mined through artisanal mining.”

ABC News, “Artisanal cobalt mining swallowing city in Democratic Republic of the Congo” <https://abcnews.go.com/International/cobalt-mining-transforms-city-democratic-republic-congo-satellite/story?id=96795773>



THE BATTERY INDUSTRY MUST END ALL INFORMAL/UNREGULATED, UNSAFE ASM MINING AND RECYCLING

These practices are dangerous, irresponsible, and unethical. But with 195 countries (and governments) and different regulations – fixing these problems takes concerted effort.



And whether batteries contain recyclable lead or other heavy metals like cobalt, we have to address the root causes:

- ▶ Regulate, monitor, and enforce mining and recycling to ensure best practices for site permitting, facility design, equipment selection and maintenance, operation, pollution mitigation, and employee safety and health procedures.
- ▶ Adjust market factors to keep used batteries in a formal supply chain – for instance, taxes, subsidies, and battery deposit systems.
- ▶ Educate communities, governments, and workers in emerging economies about best practices for safe and sustainable lead battery recycling.
- ▶ Allow the informal sector to continue collecting and sorting used batteries – but require breaking and smelting to be done formally with proper safety regulations and equipment.
- ▶ Mechanize mining or switch to open pits, minimizing human harm.

Responsible manufacturers support and collaborate with industry groups, NGOs, and governments to demand an end to these unsafe practices... provide modern equipment and safety measures across the supply chain... and ensure no children ever work in recycling plants or mines.

And you can help when you select fully recyclable, sustainably recycled, and responsibly mined batteries.



HERE'S HOW CROWN BATTERY ENSURES ETHICAL AND SUSTAINABLE PRACTICES IN BATTERY RECYCLING AND MINING:



**ETHICALLY SOURCE
RAW MATERIALS**



**REGULATED
FACILITIES**



**80% RECYCLED
MATERIALS**



**SAFE WORK
ENVIRONMENT**



**ONSITE MEDICAL
PROFESSIONAL**



**ENVIRONMENTAL
STANDARDS**

OUR COMMITMENT TO WORKER AND ENVIRONMENTAL SAFETY

We invest heavily to keep our employees, community, environment, and end-users safe:

- ▶ Ethically source raw materials (primarily from domestic suppliers) and ensure our domestic batteries are responsibly recycled
- ▶ Minimize mining for raw materials by sourcing 80% recycled materials
- ▶ Manufacture products in heavily regulated facilities with extensive safety training – not in outsourced plants with lax laws or forced labor
- ▶ Provide good pay, benefits, and a safe work environment to our employees
- ▶ Require personal protective equipment like P-100 negative respirators in manufacturing operations
- ▶ Employ a full-time, onsite registered nurse (RN) who monitors employees' health and safety
- ▶ Work closely with governmental agencies – and safety and environmental experts – to meet or exceed all EPA, OSHA, and other federal, state, and local standards for safety equipment, environmental protection, and air/water filtration

And although our domestic batteries are already 99.3% recycled, we're working hard to close the Battery Recycling Gap – to ensure all battery chemistries are recycled. (Keep reading to see how.)

HOW DO WE GET TOWARD ZERO?

Designing Waste Out of the Loop



It's easy to see battery waste in a landfill. **But a lot of battery waste is hidden upstream — in the manufacturing plant.** These strategies help you avoid it.

Start with recycled materials wherever possible

Crown Battery uses 80% previously recycled lead, along with recycled plastics, acid, and steel. This slashes the waste and carbon footprints of our batteries, compared to battery types that require new mining.

We aren't alone in building with recycled materials. The entire U.S. recycled lead battery industry sources most of its raw materials from recyclers. Our additional steps include maximizing recycled material from domestic sources.

On-site recycling slashes production waste — so we conserve and recover almost **all** resources

Crown batteries are already made using materials like 99.3% recyclable lead. On-site recycling during R&D and manufacturing further reduces our waste.

HERE ARE JUST SOME OF THE RESOURCES WE SAVED IN 2021 BY RECYCLING MANUFACTURING “WASTE”:

- ▶ 411,940 pounds (186,852 kg) of on-site materials recycled
- ▶ 1,441,790 gallons (5,457,768 liters) of wastewater reused through our 19-step filtration process
- ▶ 3,501 trees' worth of fiber avoided
- ▶ 865,074 Kilowatt hours of electricity — enough to power 943 U.S. homes for a month (based on 11,000 kWh yearly usage per household)
Source: U.S. Energy Information Administration's 2015 Residential Energy Consumption Survey
- ▶ 700 cubic yards (535.18 cubic meters) of landfill averted — enough to cover an entire U.S. football field in 3 inches (7.62 cm) of recycled material
**For the rest of the world, that's enough to cover Arsenal's soccer field (105mx68m) in 7.5 cm of recycled material*
- ▶ 84,448 gallons (383,908 liters) of fuel saved

We couldn't do this without our employees, who take the time to sort and load the material, then make sure it's sent to our recyclers.



CROWN BATTERIES ARE MADE WITH 100% RENEWABLE ENERGY A WORLD-FIRST

Building batteries requires a lot of energy. And traditionally, that means burning a lot of fossil fuels (waste) to generate electricity. In the late 2000s, Crown Battery installed on-site solar panels, wind turbines, and high-efficiency robotic assembly. Today, we source 100% renewable electricity for manufacturing — to minimize our waste and embodied carbon.

Our 100% renewable energy comes from AEP Energy's Integrated Renewable Energy (IRE) solution. (AEP Energy is a subsidiary of American Electric Power.) The program lasts for more than 12 years beginning in January 2023.

Because we use renewables, Crown became the first battery company accepted into the EPA Green Power Partnership (GPP), in 2021. (Other GPP members include Apple, General Mills, IKEA, Microsoft, and Toyota North America.)



Field testing improves lifespan + reliability in tough conditions

Extreme temperatures and heavy power demands test batteries' real-world performance – and reveal failure modes. That's why our engineers monitor batteries in mining and motive power applications; if batteries survive there, they'll thrive anywhere.

ZERO WASTE IN THE FIELD:

“Crown Battery has thousands of field research batteries and data collection units strategically placed across North America. We've gathered hundreds of thousands of data points about performance, charging, and operating environments – so much information, we hired employees to monitor it. Our engineering team analyzes this data. And they tear down and test field research batteries to improve our designs, materials, manufacturing methods...and battery life.”

– Mike Fraley

Battery Engineer & Vice President of Manufacturing
Crown Battery

Support recycling and waste reduction programs

We're working closely with our local waste management department to support recycling initiatives in our community. And we've advocated for and invested in nationwide battery recycling programs, to ensure every spent battery is turned into a new one. All responsible battery manufacturers do the same.



Enterprise Resource Planning (ERP) software helps reduce waste

ERP manages and tracks all sales, inventory, and customer information; simplifies daily operations; and helps Maintenance track projects, log equipment repairs and upgrades, and order parts.

Energy-Sipping Shipping

Shipping waste is hidden upstream in fossil fuels extracted, processed, and burned to operate delivery vehicles. But it still increases emissions – and the price you pay for the finished product. That's why we use electric vehicles in manufacturing and warehouses. But these vehicles comprise a fraction of the total distance traveled from raw materials to distribution.

WE ALSO REDUCE SHIPPING WASTE AND COSTS BY:

- ▶ **Sourcing materials from nearby recyclers**, which reduces travel
- ▶ **Optimizing supply shipments** with advanced order/inventory management software
- ▶ **Filling shipping trucks completely.** More batteries per truck mean fewer trucks – and lower shipping costs and waste. We pass on these freight savings to customers
- ▶ **Improving delivery truck routing** by integrating fleet logging with navigation software – more efficient routes reduce shipping costs, wait times, and carbon emissions

And we're looking to fully offset our shipping carbon footprint.

PART 6: LESS BATTERY WASTE

THE LONGER YOUR BATTERIES LAST...

The Fewer Replacement Batteries You'll Need



LONGER BATTERY LIFE IS GOOD FOR OUR ENVIRONMENT AND FOR YOUR WALLET.

But it's hard to tell what actually makes batteries last longer — because most battery information comes from engineers, scientists, and marketers.



ENGINEERS & SCIENTISTS

Engineers and scientist are heavy on technical details but light on simple explanations for the rest of us. You'll need an in-depth understanding of electricity, energy storage, battery chemistries, construction methods, and recycling and waste management.

Then you'll still need to find accurate resources, study them, and determine what's important.

Let's be honest – who has that much time?

MARKETERS

Marketers often ignore technical facts... and “dress up” industry-standard practices and materials with proprietary names.

You'll hear countless claims like, “Our batteries last the longest!” But specifics are rare.

EASY-TO-UNDERSTAND, ACCURATE EXPLANATIONS ARE RARER STILL

Some companies don't want to share the facts or encourage apples-to-apples comparisons. Others don't go to the extra trouble. They'd need to hire a technical writer to meet with engineers, fill in the gaps with independent research, compress hour-long conversations down to a few sentences, and give you a simple overview of what matters.

That's why we invested more than 1,000 hours to distill the keys to longer battery life and less waste down to a few pages. We researched and combed through technical articles from engineers and scientists. We interviewed engineers, field salespeople, installers, and battery users. Finally, we condensed the most important strategies into an objective, easy-to-read primer.

You can choose longer-lasting, near-zero-waste batteries now. Keep reading to learn how...



BUILT TO LAST LONGER

Before They're Recycled

HERE'S WHAT TO LOOK FOR WHEN YOU COMPARISON SHOP:

When batteries last longer, there's a sustainability ripple effect

Less production means less embodied energy, less raw material mining, less wastewater and trash, and a lower carbon footprint. In other words: **less waste**.

That's a key reason why we research, design, and robotically manufacture our batteries in the USA.

Of course, every energy storage company claims longer life. To cut through the marketing hype and greenwashing, you need to know why different battery features matter (the quick and easy-to-understand version, not the 50-page research paper).



Exclusive CAD modeling, NASA-tested measurement systems, and 3D printing

These help Crown Battery engineers solve battery problems creatively... and turn promising designs into test-ready prototypes overnight.

In short, these tools allow us to design, simulate, and refine designs faster and more accurately before building test batteries.

Compare our proprietary R&D process to industry-standard product development

Standard analog and other older R&D tools hamper engineers' ability to create and test unconventional designs. And many R&D labs order prototype parts from machine shops – so it can take weeks before they're able to start testing. Conventional prototyping bottlenecks how many designs are considered for testing – and how much they're improved before release.

CROWN BATTERIES LAST LONGER BECAUSE THERE'S MORE ENERGY-STORING "ACTIVE MATERIAL"

More active material + more surface area

=> **More chemical reactions**

=> **Less maintenance + extended lifespan**

=> **Reduced waste + more money in your pocket**

Since active material stores energy, we invest in the most active material per Ampere-hour (Ah) of rated capacity in the industry.

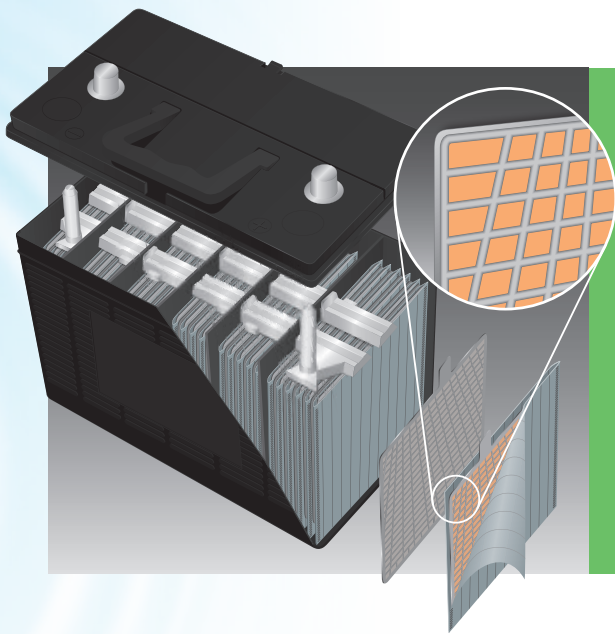
100% US-designed, engineered, and manufactured

All done at our ISO 9001:2015-certified headquarters in Fremont, OH, USA. You get American-made quality, dependability, and performance – and increased uptime, value, and life.



Robotic assembly reduces scrap and raw material usage

For instance, proprietary robotic intercell welding allows for 3,960 more adjustments than manual welding. This eliminates waste from improper welds – and prevents common mechanical failure modes. So robotic assembly boosts longevity, reliability, and performance.



“ACTIVE MATERIAL” EXPLAINED IN 30 SECONDS:

Active material is a chemical paste that stores energy. A mixture of recyclable lead and additives (that enhance charging and other characteristics) is pasted into metal grids (“plates”) that hold it in place – picture rebar-strengthening concrete. These plates are precisely heated and dried in a curing oven, then inserted into the battery case. Once assembled, batteries go through “formation,” which activates the raw materials, turning this paste into active material.

“Plates” are metal grids that hold energy-storing material. We gravity-cast the industry’s thickest and heaviest positive and negative plates – to help prevent the #1 cause of battery failure.

Gravity casting is a way to make a plate (metal grid) in a mold. Because gravity casting floats impurities to the top for removal, there’s near-zero porosity. This helps prevent internal short-circuiting caused by plate corrosion, the leading cause of AGM and lead-acid battery failure. Gravity-cast plates also charge better and require less maintenance.

By comparison, common budget techniques like stamping simply trap impurities inside the battery, and lifespan suffers. That means more wasted batteries and more wasted money.

Automated acid recirculation systems maximize longevity, capacity, and consistency – by eliminating overheating damage. Our low-current formation optimizes fluid levels, current and voltage, gravity, and temperature. It also slashes electrical consumption compared to older methods still in widespread use.

“Crown’s reliability eliminated about 95% of our warranty batteries – and made a huge impact to our bottom line.”



– Ben Sverdlow
President of Jeffrey Allen Inc.

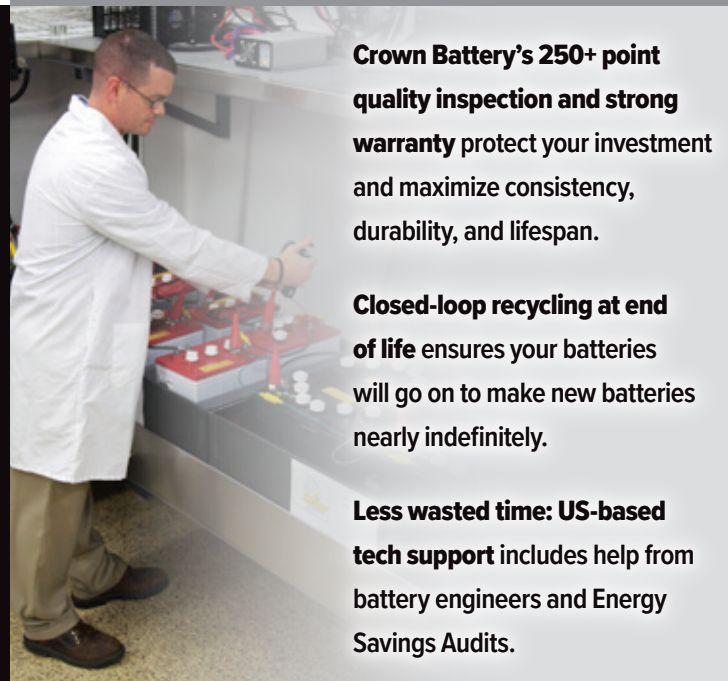
One of the foremost authorized Club Car dealers in the USA; distributor of golf cars, parts, and batteries to OEM and independent dealers, and golf courses.



Before choosing Crown Battery, Buckeye Power Sales compared popular batteries side-by-side:

“We pulled out a grid from Crown, and we pulled out a grid from a competitor, and it was a huge difference. Crown’s grids were thick [gravity-cast] and fully wrapped by robotics. The competitor’s battery grids were as thin as paper and flimsy. It looked like they were just stamped and cut to size.”

– Jeremy White
General Parts Manager
Buckeye Power Sales



Crown Battery’s 250+ point quality inspection and strong warranty protect your investment and maximize consistency, durability, and lifespan.

Closed-loop recycling at end of life ensures your batteries will go on to make new batteries nearly indefinitely.

Less wasted time: US-based tech support includes help from battery engineers and Energy Savings Audits.

HOW TO CLOSE THE RECYCLING GAP

And What's Next For Zero Battery Waste

As battery demand and raw material prices increase, we're hopeful that Li-ion battery recycling will expand, mature technologically, and reach profitability.

But it'll take more than optimism to transition from landfilling Li-ion batteries to rolling out a closed-loop recycling system.

Li-ion batteries can't reduce waste if every battery requires brand-new materials

We can't fight climate change or create jobs if spent batteries are dumped. And we can't just flip a switch and turn on nationwide Li-ion recycling.

Crown Battery advocates all efforts to close the Battery Recycling Gap

We've supported lead-acid recycling since its infancy. We've seen how recycling creates good jobs, improves supply chain stability, reduces carbon emissions, and turns old batteries into new ones. And we agree with scientists, environmentalists, and policymakers that **every** battery should be recycled.



And we need to push hard now for universal battery recycling...

...for strong policies, robust collection infrastructure, and new recycling technologies for Li-ion.

After all, full battery recycling is the right move for our environment, our communities, our economy, our society — and our future.

DID YOU KNOW?

Crown Battery was the only energy storage company to publicly comment on the California Assembly Bill (AB) 2832, about Lithium-ion Car Battery Recycling.



Crown Battery's 5-Year Zero-Waste goals and benchmarks include:

- ▶ Source even more previously-recycled lead – 90%
- ▶ Minimize manufacturing plant water usage further, to just 35% of 2018 consumption – while building even more batteries
- ▶ Expand 100% renewable energy beyond our HQ and manufacturing plant to the entire company (all branches, subsidiaries, and warehouses). Where local renewable energy isn't available and power companies are unable to supply it, offset with renewable energy certificates (RECs)
- ▶ Further increase support and continue to push for stronger recycling regulations in emerging markets
- ▶ Continue partnerships with government laboratories including the Argonne National Laboratory, private companies, and leading universities to decrease battery waste and improve lifespan and performance
- ▶ Help create legislation to ensure all battery chemistries are recycled – not landfilled

ZERO BATTERY WASTE



“Battery recycling conserves nonrenewable resources – and ensures we and future generations can enjoy fresh air, clean drinking water, and a high quality of life. We’ve invested heavily above and beyond recycling – to reduce waste and ensure no battery is left behind.”

– Hal Hawk,
President
Crown Battery

CROWN BATTERY PRODUCTS REDUCE WASTED MATERIALS – AND HELP SAVE YOU MONEY:

CROWN BATTERIES ARE:

99.3%
RECYCLABLE

99%
RECYCLED

100%
MANUFACTURED
USING RENEWABLE
ENERGY

They’re proven since 1926 in 1,000,000+ installations on six continents, including everything from Fortune 500 warehouses and Department of Energy pilot projects to North America’s largest off-grid school, military bases, and Central Asia’s biggest microgrid.

And with US engineering, manufacturing, customer service, and technical support – they’ll save you time and money, too.

**DON’T TAKE OUR WORD FOR IT
HERE’S WHAT OUR CLIENTS IN TOUGH APPLICATIONS SAY:**



“I love that [Crown Battery] uses mostly recycled content in their batteries... [and] I have a 24-year-old Crown battery bank that powers my off-grid ranch. I went with Crown Battery because, number one, they’re reliable. I’m living proof.”

– Mark Snyder
Owner and Master Electrician
Mark Snyder Electric

Independent system designer and installer with more than 30,000 renewable energy installations, who’s consulted with NASA, DreamWorks, and NREL



“Living off-grid, it’s important to me to take care of the environment. I like Crown Battery’s 99% recycling rate. That way, old batteries can be made into new ones for decades and decades – with no accumulation in a landfill.”

– Pippi Peterson
RV Expert with leading
YouTube channel for RV living



“Crown’s achievements in renewable energy manufacturing help Cart Mart and our customers meet sustainability goals. And because Crown’s recycling programs slash waste and minimize the environmental impact, we expect to make a great impact on our customers and society at large.”

– Brian Rott
CEO
Cart Mart, Inc.

NOW IT'S YOUR TURN:

To learn more about how Crown batteries reduce waste –
and your operating costs

Visit www.crownbattery.com/zerowaste



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