BATTERY COUNCIL INTERNATIONAL

ESSENTIAL ENERGY EVERYDAY

INFORMATION BRIEF

The Circular Economy of Lead Batteries

As our need for energy storage in the renewable energy, automotive and digital technology sectors grows, so does our need for batteries — and a mix of battery chemistries — to meet the demand. Long ignored, environmental impact must rival performance and cost criteria when evaluating the types of battery chemistries available.

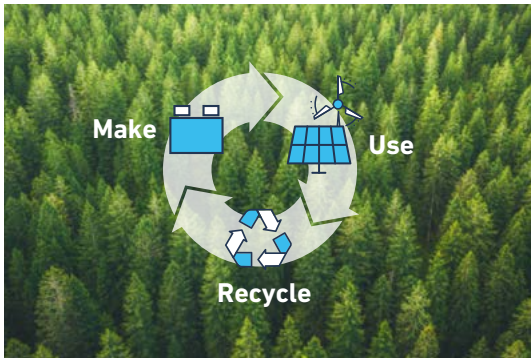
The goal: A battery industry that fosters a circular economic model that simultaneously reduces GHG emissions and stays commercially competitive to meet our existing and future energy storage needs.

Introduction

Many batteries are designed, used and disposed of using a linear economic model, meaning a take-make-use-waste extractive industrial pattern. The opposite is a circular economic model. It promotes sustainable materials management throughout the lifecycle of a battery, using a make-use-recycle-remanufacture (or closed-loop) pattern.

A circular economic model:

- Promotes the sustainable management of our natural resources through critical mineral recovery and reuse.
- Moves us toward decarbonization and net-zero goals.
- Protects national security.
- Supports economic growth and job creation without depleting natural resources.



Research shows that 62% of U.S. firms plan to move to a circular economy. The lead battery industry leads the curve by being in the 16% who already have.

The Purpose of this Information Brief

- Explain the benefits of a circular economy, i.e., not just recycling, but also the remanufacturing of recycled components.
- Illustrate the circular business model of lead batteries and why it should serve as a blueprint for other battery chemistries and industries.

A Call to Action

We encourage all stakeholders who evaluate, purchase, regulate and invest in energy storage technology to:

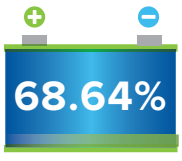
- Consider the complete lifecycle impact of battery chemistries – compare their recycling rates, materials reuse, and overall sustainable practices.
- Recognize the urgency to reduce consumption of resources to mitigate their depletion and the effects of climate change.
- Support governmental investment to help sustainable lead batteries reach their full potential.

Ranking Sustainability: Lead Batteries Among Best

Top 5 Most Sustainable

Evaluating circularity requires translating the science of sustainability into quantifiable metrics and practical tools. The Sustainability Consortium (TSC), a global non-profit, puts **lead batteries among the top five consumer products in sustainability.**

Lead-Acid Batteries
AVERAGE KPI SCORE



About the Report

TSC's mission is to help make consumer products worldwide more sustainable. Annually, TSC evaluates over 180 different product categories for sustainability key performance indicators (KPIs). The TSC 2017 Impact Report, titled "The Call for Collective Action Across Supply Chains," ranks lead batteries as one of only five consumer product categories to make the elite club scoring 64 and over (top score was 100).

Lead batteries scored high KPIs in product stewardship and recycled content, demonstrating an industry-wide commitment to closing the manufacturing loop. See SustainabilityConsortium.org.

THE SUSTAINABILITY CONSORTIUM™

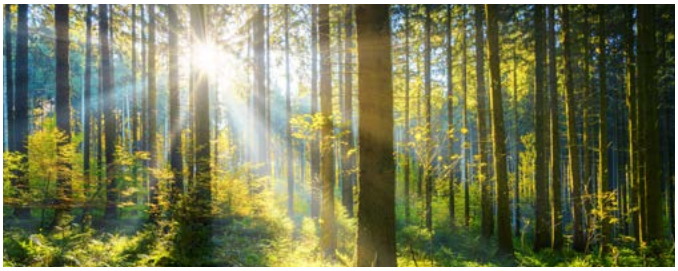
> "Lead batteries close the loop more effectively than any other product in the consumer goods space. We'd like to leverage the lessons of this industry to help others reach the same type of performance for their end-of-life products."
>
> — Dr. Carole Mars, TSC Director of Technical Development & Innovation

Circular Economy Benefits

Conserves Resources, Creates New Value

In a circular economy, the value of products and materials is maintained for as long as possible, and, in some cases, infinitely; waste and resource use is minimized. When a battery has reached its end of life (EOL), its materials are kept within the economy, to be used again. This creates further value and fuels the closed loop.

- **99%** The recycling rate of lead batteries in the U.S.
- **80%** A new lead battery is typically comprised of 80% recycled material.



Reduces Carbon Emissions

A more circular economy, like the lead battery industry, can help reduce CO_2 emissions, decarbonize materials production, and achieve an industrial base compatible with a low-carbon future.

- **4 X Less** The environmental impact of manufacturing a lead-based automotive battery is four times less than manufacturing a similar lithium-iron phosphate automotive battery.
- **99%** Using secondary lead instead of ore reduces CO_2 emissions by 99%.

Maintains National Security

Global competition for finite resources will intensify as world population and economies grow.

Using recycled materials fosters energy independence and contributes to a more reliable secondary supply chain. This improves the security of power grids, Internet services, databanks, etc. as they confront the challenges of an increasingly digital economy.

- **83%** The approximate amount of lead that U.S. lead battery manufacturers source domestically from recycling facilities in the North America.

Boosts the Economy

Many batteries are not recycled (or recycled profitably) because the cost to recover and recycle their materials exceeds the price of their virgin materials. The exception is lead batteries.

- **100 years** Lead batteries have been recycled for more than 100 years and model a profitable closed- loop system for other batteries — and industries.
- **$4.5 trillion** The predicted amount of additional economic output generated by the circular economy by 2030.

Lead Batteries: A Circular Economy Model

Research and Innovation

The lead battery industry collaborates with the Department of Energy's national laboratories, academic institutions and within the industry on significant research to reach a lead battery's full potential. Maximizing its performance and longevity can further reduce the use of natural resources and climate impact.

- Lead battery life has increased by 30 to 35% over the last 20 years.
- Major U.S. lead battery manufacturers and suppliers are working with Argonne National Laboratory on a fundamental research program to enhance battery performance efficiency.
- Another collaboration includes a cohort of U.S. lead battery companies, Argonne National Laboratory and the University of Toledo working to extend the life of a lead battery.

Design for Recycling and Efficiency

Lead battery manufacturers collaborate with recyclers to design batteries for streamlined recycling and resource efficiency, and reuse of components.

- Research shows that 80% of a product's environmental impact is influenced by decisions made at the design stage.
- 100% of a lead battery's three components (lead, plastic, acid) are recyclable.

Sustainable Practices

The lead battery industry continually deepens its sustainability practices to further lessen environmental impact. That includes incorporating renewable energy, stormwater capture, minimizing waste and more. See *"Sustainability Examples"* on page 6-8.

Following a lead battery's cradle-to-cradle (vs. cradle-to-grave) process demonstrates its circularity. In comparing sustainable practices across all life stages, no other battery chemistry equals lead batteries' closed-loop process and remanufacturing success.

Lead Batteries: A Circular Economy Model

Step 1: Manufacturing

Using a steady supply of recycled lead battery components, battery manufacturers use safe, sustainable practices to make innovative, new batteries. The established industry has high standards for creating more pure recycled byproducts.

Step 2: Use

The world entrusts nearly 45% of its rechargeable energy storage needs to lead batteries. Worldwide, nearly every hybrid and electric vehicle uses a lead battery. They're also essential to medical, data and telecom, renewable energy, military and other applications.

Step 3: Collection

The EPA ranks lead batteries as the most recycled product in the U.S. A nationwide distribution and collection infrastructure, high recycling awareness, and the value of lead battery components ensures that consumers and industries return spent lead batteries. This supplies manufacturers with a steady stream of materials for reuse.

Step 4: Recycling

Modern, closed-loop recycling keeps more than 160 million lead batteries from landfills each year. A strictly regulated lead battery recycling industry follows best practices to receive and process spent lead batteries.

- Lead from spent lead batteries is melted, refined and poured into molds to create ingots (lead bricks). These are shipped to lead battery manufacturers to make new batteries.
- The plastic covers and cases of spent batteries are crushed, melted and formed into pellets to make new battery covers and cases.
- Spent acid is recycled for new battery use. It is neutralized into water, or converted into sodium sulfate, an odorless powder used in laundry detergents, textiles and glass.

Step 5: Sourcing & Materials Efficiency

A typical new lead battery is comprised of 80% recycled material and the lead from lead batteries can be infinitely recycled with no loss of performance. That, coupled with the battery's high recycling rate, greatly reduces the mining of virgin materials.

Why Few Lithium-ion Batteries Are Recycled

Lithium-ion and Lithium iron phosphate batteries face complex financial, technological and legislative challenges to recycling. Disassembly requires trained technicians, making widespread recycling cost-prohibitive; recycling for LI and LFP is often unprofitable (e.g., virgin lithium is six times cheaper than recycled lithium). There's also no nationwide recycling infrastructure or legislation for LI and LFP batteries. To date, researchers have made only modest progress improving recyclability, so relatively few Li-ion batteries are recycled.

- In recognition of the challenges and need to recycle lithium-ion batteries, the U.S. Department of Energy has established a $10 million prize to "accelerate the development of [lithium- ion battery recycling] solutions from concept to prototype to demonstration."

Linear Economic Model

Lead Battery Industry: Sustainability Examples

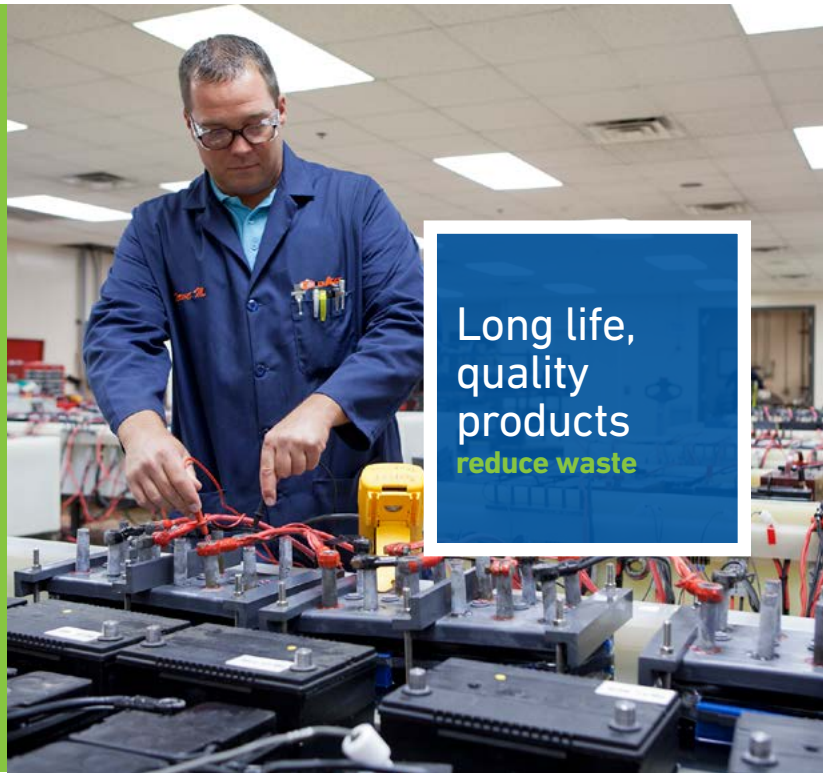
The lead battery industry is incorporating many sustainability practices that contribute to a circular economy and lessen the environmental pressures exerted by battery manufacturing and recycling.

Advanced Battery Concepts, Michigan: Designing Efficiency

Michigan-based Advanced Battery Concepts has taken lead battery sustainability to a new level. The company developed and patented GreenSeal® technology, which reduces the amount of lead by 46%, making the battery lighter, with quicker charging, higher power, and saving the average vehicle 20 to 30 gallons of fuel per year. Even better news: GreenSeal batteries remain 100% recyclable and easily fit into existing recycling processes.

East Penn, Pennsylvania: Minimizing Waste

East Penn Manufacturing is the largest single-site lead battery manufacturer in the world. It creates sustainability by designing high quality products that are built to last and are manufactured with innovations implemented to conserve natural resources. For instance, the company was the first to invent a patented process for recycling acid and now recycles millions of gallons annually for use in new batteries. In addition, 100% of the company's industrial wastewater is recycled through a zero- discharge system (31.5 million gallons of water recycled and reused annually). The company also produces a liquid fertilizer solution for agricultural use from the sulfur fumes created during lead smelting.



Lead Battery Industry: Sustainability Examples

Crown Battery Manufacturing Company, Ohio: Manufacturing with Solar and Wind Energy

Crown Battery is a cornerstone of America's lead battery energy storage industry. It has nearly a century of expertise, innovation and growth in the global energy storage industry. The company has also made lead batteries even greener through responsible, renewable manufacturing. In 2020, Crown Battery switched to 100% solar and wind energy for manufacturing, and in 2021, it became the first U.S. battery company to completely power its manufacturing using 100% renewable energy – and the first battery manufacturer recognized by the U.S. EPA's Green Power Partnership program.

Teck Resources Limited, British Columbia, Canada: Responsible Production

Teck is one of Canada's leading mining companies and a leader in sustainability and responsible resource development. External recognition of Teck's sustainability practices includes being named to the Global 100 Most Sustainable Corporations list for the past six years. The company is working toward disposing zero industrial waste by 2040 as part of its overall goal to be carbon neutral by 2050. Teck's Trail Operations, one of the world's largest fully integrated zinc and lead smelting and refining complexes, has been recognized with the Zinc Mark in recognition of environmentally and socially responsible production practices.

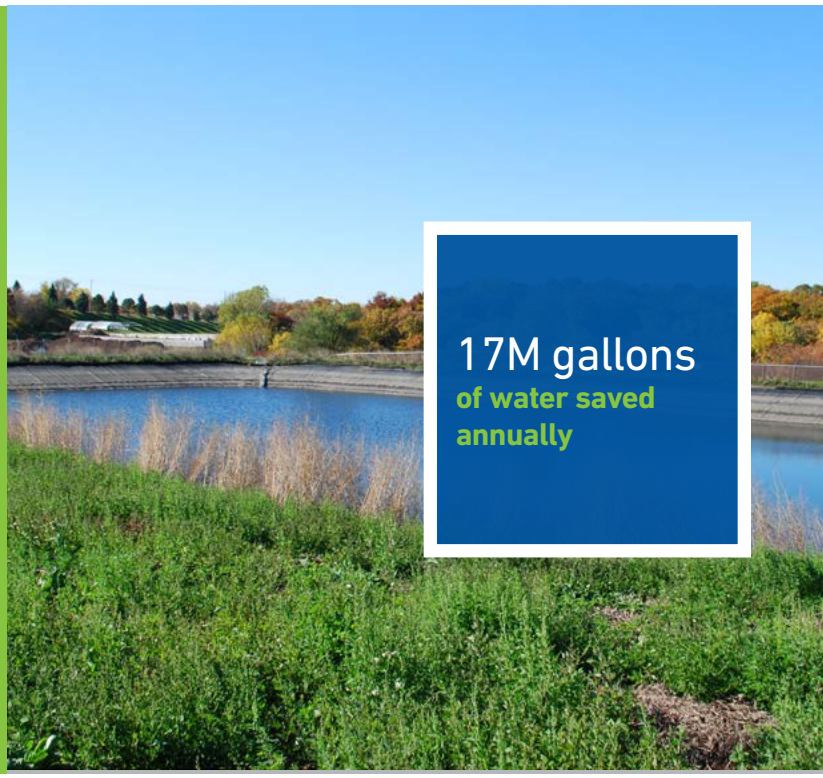
Lead Battery Industry: Sustainability Examples

EnerSys, Pennsylvania: Energy Reduction Goals and Strategies

As one of the world's leading manufacturers of energy storage solutions for industrial applications, EnerSys recognizes its responsibility to minimize the company's climate impact. Between 2019 and 2022, the company cut its Scope 1 GHG emissions from company facilities and vehicles by nearly 25%, marking considerable progress toward the company's 2040 neutrality goal. EnerSys is committed to reducing its CO_2 emissions using several key strategies: increasing operational efficiency, exploring more renewable energy opportunities, such as the 5MW solar array being built at its HQ, and electrifying operations where possible. That includes replacing the traditionally gas-fired lead heating process with electricity increasingly produced from zero-carbon sources.

Gopher Resource, Minnesota: Renewing Resource

For over 75 years, Gopher Resource has been protecting the earth and preserving natural resources through innovative recycling solutions for lead batteries. The company set a sustainability example by investing nearly $5 million in a storm water collection and reuse distribution system. Annually, the system replaces nearly 17 million gallons of water with collected storm water. Gallon for gallon, that is groundwater left in the aquifer for other uses.



Conclusion

Maximizing sustainable technologies like renewable energy and EVs requires supporting them with sustainable battery chemistries. That will require battery manufacturers to move from a linear to a circular economic model, and stakeholders to prioritize a battery's lifecycle environmental footprint when selecting a battery technology. The lead battery industry, with its established circular infrastructure, is a model for other battery chemistries — and industries — in how to responsibly source, use, reuse and sustainably manage materials.

BATTERY COUNCIL INTERNATIONAL Recently celebrating its 100th anniversary, BCI was formed in 1924 and joins together battery manufacturers and recyclers, marketers and retailers, suppliers of raw materials and equipment, and battery distributors from across North America and around the world. BCI members are committed to responsible manufacturing and recycling processes, and serve as a unified voice for environmental, health and safety stewardship.

Learn more at BatteryCouncil.org

Visit BatteryCouncil.org/sources to view source information.

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