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Grayway

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Advanced Materials Will Transform the Lithium Battery Market

Expanding the Life of Lithium-Ion Batteries Through Research and Recycling

Advanced Science Drives Innovation in the Lithium-Ion Battery Market

Welcome.

Stephen Gray
President and Chief
Executive Officer
GRAY, INC.

Energy is one of the top concerns of society today. Lithium-ion batteries have revolutionized electronics and created the mobile lifestyle upon which we all depend. The challenge comes into play when these batteries reach their limits for energy capacity and chargeability.

In this issue of the **Grayway**, we dive into this dilemma and share how research teams around the world are making discoveries that will make lithium-ion batteries more powerful and last far longer. We also look at the sustainability process and how new technologies will make it easier to recycle these batteries safely, providing lithium, and other materials needed for the batteries of the future.

Not only will lithium-ion batteries power our vehicles and electronics in the future, they will do so in a much more sustainable way to make the world better for all us.

Gray practices methods which protect our environment.

Researchers Improve the Performance and Environmental Sustainability of Lithium-Ion Batteries

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As more people drive electric vehicles, there will be a huge increase in depleted lithium-ion batteries, as well as a pressing need for new ones. Innovation in recycling processes and battery designs will make it easier and less costly to recycle these batteries safely.

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India-based Bharat Forge, a leading automotive forging company, selected Gray to design and build a 98,070 s.f. greenfield facility that will manufacture automobile components.

Advanced Materials Will **Transform the Lithium Battery Market**

$44B

CURRENT LITHIUM-ION BATTERY MARKET VALUE

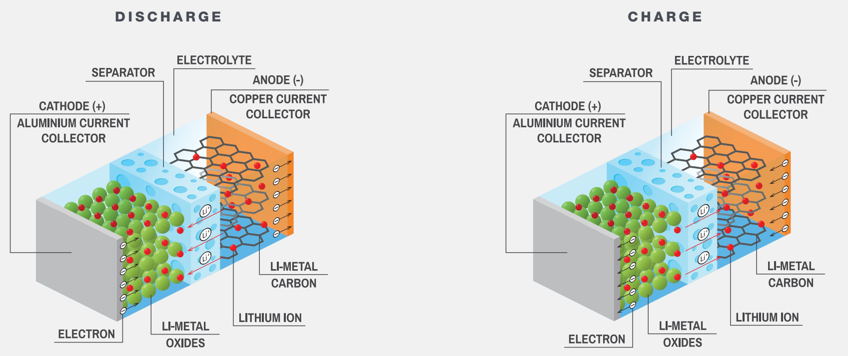
$94.4B

ESTIMATED LITHIUM-ION BATTERY MARKET VALUE FOR 2025

Rechargeable lithium-ion batteries power almost all our electronic needs, ranging from portable devices such as watches and cell phones to larger-scale equipment such as electric vehicles. Industrial applications include power plants and data centers. With this kind of demand, it is no surprise the lithium-ion battery market is estimated to grow from $44 billion in 2020 to $94.4 billion by 2025—a compound annual growth rate of 16.4%.

As popular as they are, however, lithium-ion batteries have significant limitations. Storage capacity and energy density are still limited—for example, cell phones typically last only a day and electric cars cannot go much beyond 300 miles on a single charge. These batteries also rely on unstable materials that, if damaged or defective, can catch fire or explode, causing serious damage. Lithium-ion batteries also use heavy metals that are toxic and hazardous to the environment. Supplies of lithium and cobalt, two key chemical components, are also dwindling, creating price volatility. Some cobalt is also produced in less-stable countries, causing supply chain risks as well.

Components of a Lithium-ion Battery



New Materials, Better Batteries

To meet consumer demands, researchers are working to improve the safety, efficiency, and storage capacity of rechargeable lithium-ion batteries, largely by developing new materials for the electrodes and the electrolyte, the solution that carries the lithium ions back and forth between the electrodes, creating electricity.

The most common electrode chemistries are lithium-cobalt oxide for the cathode and graphite for the anode. Not only do scientists want to improve existing battery chemistries, they want to find metal alloys and other materials that improve energy capacity and performance that are also easy to manufacture, at lower cost. Promising discoveries include:

- **Lithium-sulfur batteries.** Scientists at Monash University in Australia have developed a lithium-sulfur battery with the potential to double the range of an electric vehicle or power a cell phone for up to five days, on a single charge, compared to standard lithium-ion batteries. "These batteries are also extremely low-cost to manufacture, using water-based processes, and can lead to significant reductions in environmentally hazardous waste," states lead researcher Matthew Hill.
- **Lithium-silicon batteries.** This alternative type of lithium-ion battery uses silicon, a plentiful and inexpensive material, for the anode, instead of graphite, boosting battery performance by up to 40% compared to standard lithium-ion batteries. Silanano is a technology start-up company that is commercializing this product, with significant investment from major automotive companies such as BMW.
- **Manganese-titanium electrodes.** Engineers at Yokohama National University have developed a new electrode material that boosts the performance of lithium-ion batteries. A mixture of lithium, oxygen, manganese, and titanium nanoparticles allows the battery to disperse more charge over a longer time period. "Titanium and manganese are also abundant elements, meaning we can make cost-effective lithium batteries, without nickel and cobalt ions," says researcher Naoaki Yabuuchi.

Improved Safety

Instead of using flammable liquid electrolytes, another approach is making electrolytes from more inert materials that are less likely to combust, but still carry the lithium ions back and forth efficiently.

Aqueous batteries, for example, rely on water-based electrolytes that are nonflammable and nontoxic, but historically have been unable to hold enough charge to be effective. However, researchers at Johns Hopkins University Applied Physics Laboratory have created a lithium salt-polymer electrolyte that can triple the electric potential of aqueous batteries from around 1.2 volts to 4 volts, which is comparable with commercial lithium-ion batteries. Because these batteries are also flexible and very durable, they could also be incorporated into fabrics or wearable electronics.

Electrolytes can also be made from nonflammable solid materials.

Ionic Materials, a Woburn, MA-based company, has developed an ionically conductive, fire-retardant solid polymer that can replace the liquid electrolyte in a lithium-ion battery. The material is flexible, low-cost, and durable, eliminating safety risks while boosting battery capacity and performance.

> "By eliminating liquids, these new batteries will enable substantial improvements in energy density, cost, and safety, and make possible the use of chemistries that have been considered 'the holy grail' for batteries."

Mike Zimmerman, CEO
IONIC MATERIALS

Several automotive manufacturers are looking at second-life battery solutions such as stationary energy storage systems that utilize aged electric vehicle batteries.

Moving Beyond Lithium

Researchers believe that traditional lithium-ion battery technology is nearing its limits in terms of energy density and storage capacity. Scientists are working to improve existing batteries by creating new lithium composite chemistries, as well as methods for improving storage capacity and speed. For example, scientists at WMG at the University of Warwick have developed a new process that allows current lithium-ion batteries to be charged up to five times faster by monitoring battery temperature.

Battery specialists are also developing new chemistries and nanostructures for batteries that do not involve lithium at all. For example, Rensselaer Polytechnic Institute researchers have created a potassium-based battery that performs nearly as well as a lithium-ion battery; an added benefit is that potassium is an abundant and inexpensive material compared to traditional lithium and heavy-metal chemistries.

These and other R&D advancements will help meet both industrial and consumer demands for more powerful, longer-lasting, and safer next-generation batteries to power our energy needs in the future.

An aerial view of the lithium evaporation ponds at San Pedro de Atacama in Chile.

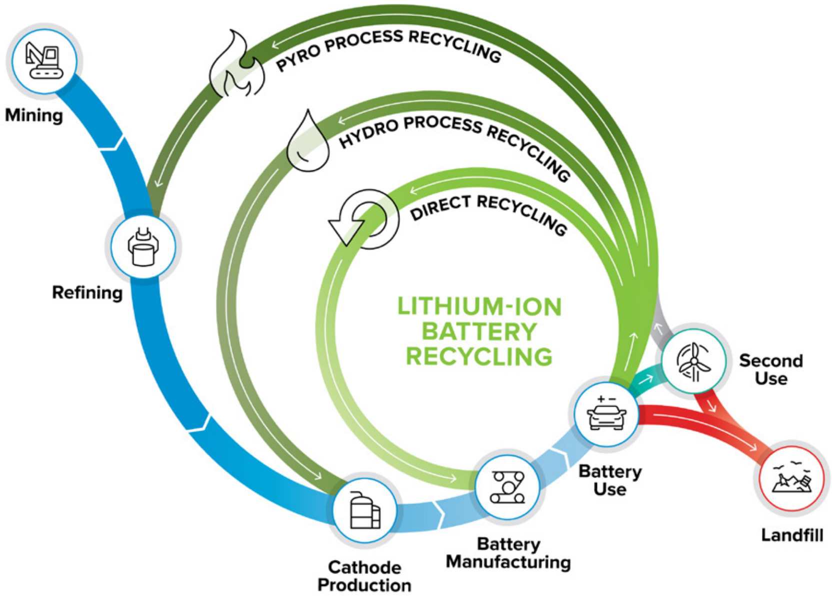
Expanding the Life of Lithium-Ion Batteries through Research and Recycling

Using lithium-ion batteries in electric vehicles (EV) is a huge factor in reducing greenhouse gas emissions. Analysts predict electric vehicles have the potential to reduce emissions by 50% when compared with gas-powered vehicles. Because EV cars reduce the need for gasoline as a fuel, they also lessen the overall environmental impacts resulting from the processing of petroleum into gasoline.

As more people drive electric vehicles, there will be a huge increase in depleted lithium-ion batteries in the coming years, as well as a pressing need for new ones. Industry analysts predict that more than 11 million metric tons of these batteries will reach the end of their service life by 2030.

It is, however, challenging and costly to recycle these batteries. Due to current technical and economic barriers, less than 5% of these are recycled today, with many of them simply thrown away in landfills.

Lithium-ion Battery Lifecycle



The multi-stage recycling process involves collecting the used batteries, burning off the flammable components, neutralizing the battery, smelting, refining, purification, and disposal of remaining waste. Some of these steps also utilize toxic cleaning solvents. Once the battery is completely broken down, the valuable materials are recycled—largely cobalt, lithium, and nickel.

A goal of the ReCell Center is to drive toward closed-loop recycling, where materials from spent batteries are directly recycled, minimizing energy use and waste by eliminating mining and processing steps. Image courtesy of Argonne National Laboratory.

A big challenge is that most recycling companies do not have the resources or time to complete this complex process and still generate a profit; therefore, there is an extreme shortage of facilities in the U.S. that can recycle these batteries.

There are also global environmental and social consequences to not being able to recycle lithium-ion batteries. Because these materials are not being recovered through recycling, mining operations are under pressure to produce more lithium, cobalt, and other heavy metals used in these batteries. Most lithium production occurs in the "Lithium Triangle," an arid region located in Bolivia, Chile, and Argentina. Lithium is recovered from extensive, large-scale strip and open-pit operations, which consume huge amounts of water, depleting the water resources for the local communities by up to two-thirds. There is no question that lithium production comes at an environmental cost.

Extending the Life Cycle of Lithium Batteries

Lithium-ion electric vehicle batteries started gaining popularity in 2011; because these batteries usually last about eight to ten years, there has been little demand to invest in recycling centers that can efficiently recover lithium and cobalt. Over the coming years, expended batteries will continue to be dumped in landfills or shipped to China. Thus, it is important to develop domestic capacity for recycling these batteries. This includes modernized infrastructure and recycling processes (less complexity, lower cost) and building more centers.

Battery manufacturers can improve the situation by moving away from chemistries that contain cobalt and other toxic materials. For example, York University researchers have created a new carbon-based organic molecule that can replace cobalt in the cathodes of lithium-ion batteries, without sacrificing performance, stability, and storage capacity. "Organic electrode materials are extremely promising materials for sustainable batteries with high power capabilities," says York University researcher Thomas Baumgartner.

To drive innovation in lithium-battery recycling, the U.S. Department of Energy (DOE) launched the ReCell Center at Argonne National Laboratory in Illinois in February 2019. Funded by DOE's Office of Energy Efficiency and Renewable Energy, the $15-million lithium-ion battery recycling research center is focused on perfecting methods for recycling the components of these batteries, making it more profitable to run recycling centers in the U.S. This includes eliminating the use of toxic cleaning materials from the recycling process. Key research areas are direct cathode recycling, recovering other materials, design for recycling, and modeling and analysis.

Organic electrode materials are extremely promising materials for sustainable batteries with high power capabilities.

Thomas Baumgartner, Researcher
YORK UNIVERSITY

By 2022, ReCell hopes to launch pilot-scale demonstrations of new recycling technologies that can translate to commercial adoption. "The pivotal discoveries we are making in recycling processes and battery designs will increase the global competitiveness of the U.S. recycling industry, reduce battery costs for consumers, and increase national energy security by limiting our reliance on foreign sources for these materials," says Jeff Spangenberger, group leader for materials recycling at ReCell.

Bharat Forge

SANFORD / NORTH CAROLINA

India-based Bharat Forge, a leading automotive forging company, selected Gray to design and build a 98,070 s.f. greenfield facility that will manufacture automobile components.

The new facility in Sanford will be part of a larger manufacturing center that will bring as many as 460 jobs to the region. The project is expected to be complete in the spring of 2021.

"We are delighted to make our biggest overseas investment in North America, in the state of North Carolina. This investment will help us create a strong global manufacturing footprint as part of our aluminum strategy, spanning Europe, Asia, and the United States," says Mr. Amit Kalyani, Deputy Managing Director, Bharat Forge Ltd.

"We are delighted to make our biggest overseas investment in North America, in the state of North Carolina."

Mr. Amit Kalyani,
Deputy Managing Director
BHARAT FORGE LTD.

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