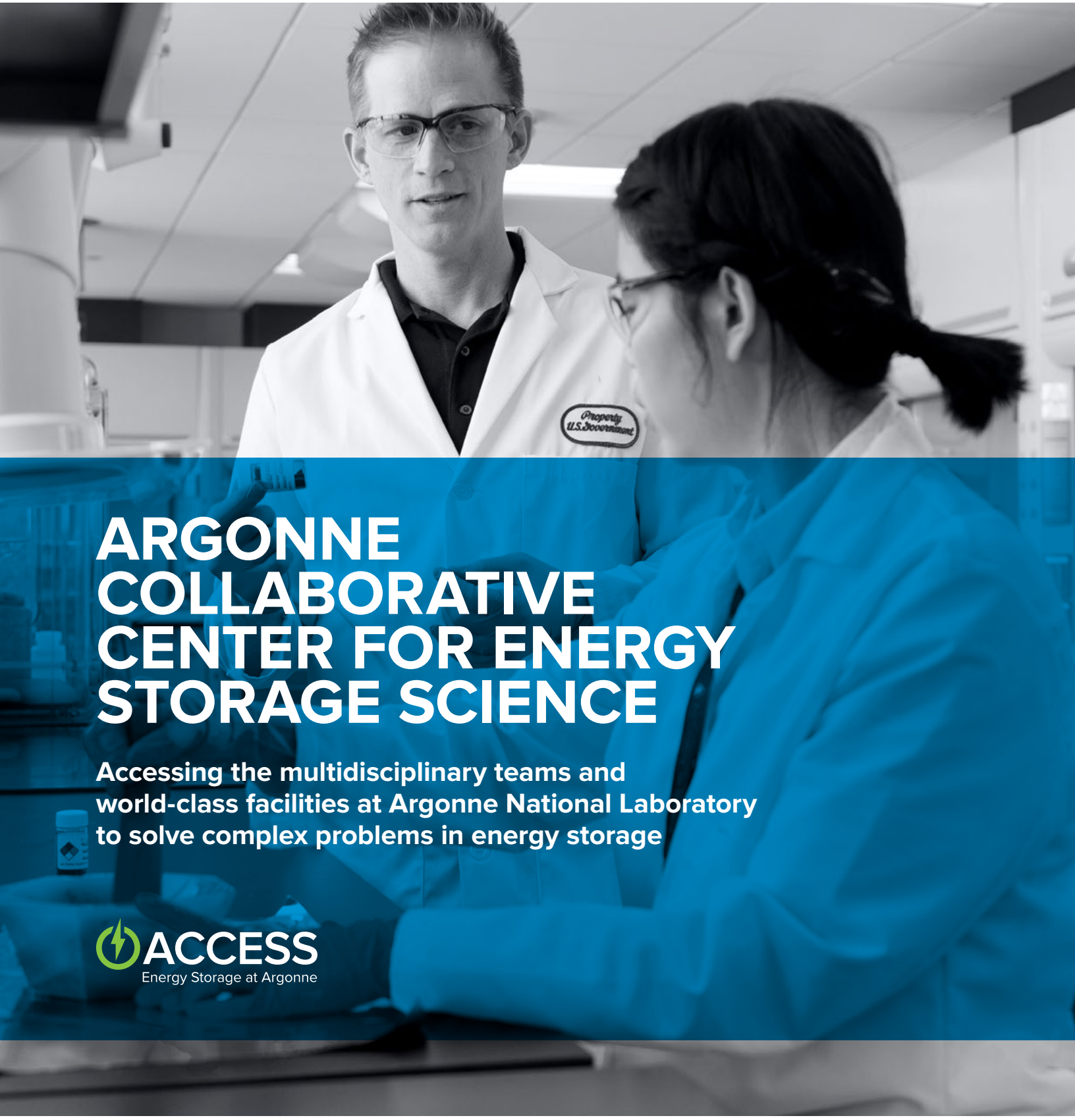
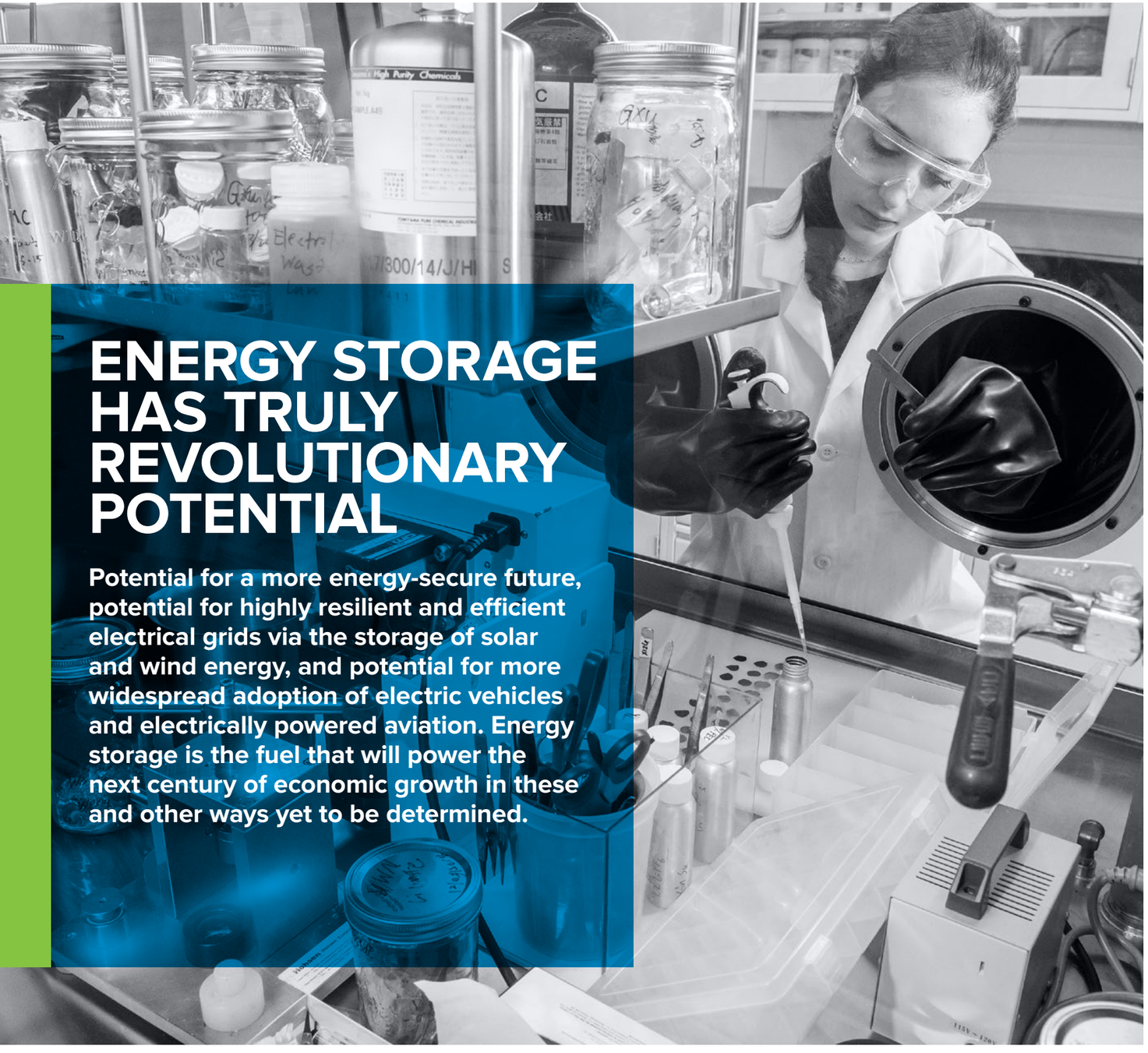
Argonne NATIONAL LABORATORY



ARGONNE COLLABORATIVE CENTER FOR ENERGY STORAGE SCIENCE

Accessing the multidisciplinary teams and world-class facilities at Argonne National Laboratory to solve complex problems in energy storage

ACCESS
Energy Storage at Argonne



ENERGY STORAGE HAS TRULY REVOLUTIONARY POTENTIAL

Potential for a more energy-secure future, potential for highly resilient and efficient electrical grids via the storage of solar and wind energy, and potential for more widespread adoption of electric vehicles and electrically powered aviation. Energy storage is the fuel that will power the next century of economic growth in these and other ways yet to be determined.

With more than 250 battery technologies available for licensing and thousands of publications in scientific journals, Argonne is the global leader in energy storage research.

Over the past fifty years, Argonne scientists and engineers have been helping public- and private-sector customers turn scientific discoveries in energy storage into new technologies. Argonne's expertise runs the gamut from lithium-ion batteries to beyond-lithium-ion systems such as sodium-ion, multivalent, lithium-sulfur, lithium-air, and flow batteries.

In the last decade, Argonne has licensed its new technologies to leading companies—including General Motors, BASF, LG Chem, General Electric, and TODA America—to mass-produce Argonne's patented materials for advanced batteries. These agreements have already led to the construction of new manufacturing plants and the creation of numerous jobs in the U.S. Our expertise, capabilities, intellectual property, and industrial partnerships have put us at the forefront of addressing new challenges in applications that span the energy storage landscape.

Argonne can help you in many ways: license technology from our vast battery portfolio, solve your problems in readying new battery technology to enter the marketplace, address issues in battery manufacturing, and develop new battery technologies from the ground up.

Argonne continues to pursue trailblazing battery research.

- Advanced lithium-ion battery with a low-cost anode based on a mixture of silicon and graphite
- Advanced lithium-ion battery that can be charged in only 15 minutes
- Advanced lithium-ion battery with a nickel-manganese-cobalt cathode that produces much higher energy and voltage
- Advanced solid-state batteries in which novel ceramic and polymer materials replace the typical liquid electrolyte, improving both safety and performance
- Next-generation, beyond-lithium-ion batteries (lithium-air, redox flow, lithium-sulfur, and multivalent)
- Methods for recycling the millions of electric vehicle batteries that will soon be reaching the end of their useful lives

ARGONNE'S ENERGY STORAGE CAPABILITIES

Argonne wields a comprehensive array of capabilities and facilities to address energy storage problems at every link of the energy storage chain, from the analysis of raw materials for impurities to battery end of life and recycling. Collaborators can access this expertise and facilities for any or all of the capabilities displayed.

Argonne's capabilities and facilities can address energy storage challenges at every point on the value chain, from discovery to application.

Material Discovery
Material Characterization
Electrodes and Cells

It all starts with Argonne's renowned scientists and engineers in the discovery and synthesis of new battery materials. Through the interplay of theoretical modeling and applied scientific approaches, Argonne researchers design and synthesize candidate materials and assemble them into electrodes and test cells for characterization at a faster rate and greater depth than any other research institution in the world.

Argonne has world-class facilities for material characterization, such as the Electrochemical Discovery Laboratory, Advanced Photon Source, and Center for Nanoscale Materials, where in-depth analysis is conducted before, during, and after the material has undergone cycling in test cells. Equally impressive are the capabilities for modeling to predict the properties of new or improved materials with extreme accuracy, which can be aided by the Argonne Leadership Computing Facility. These predictions then help to overcome materials shortcomings that arise throughout the discovery process.

Material Process R&D and Scale-up
Large Format Devices
Standardized Testing
Cell Diagnostics and Modeling

Once the most promising materials are identified, Argonne researchers optimize the synthesis process for scale-up to economical commercial production. Argonne's Materials Engineering Research Facility enables the development of manufacturing processes to produce advanced battery materials for industrial testing.

Argonne researchers keep the discovery-to-industry pipeline moving by fabricating commercial-grade, prototype electrodes and battery cells in Argonne's Cell Analysis, Modeling, and Prototyping facility, then testing the new materials in the Electrochemical Analysis and Diagnostics Laboratory.

After standardized testing, the cell and electrodes are sent for advanced characterization and post-test analysis in Argonne's Post-Test Facility, which entails dissecting, harvesting, and analyzing materials in an air-free environment. With knowledge of the causes of performance decline and/or failure, battery developers use this critical feedback to further improve batteries.

Recycling
System-level Analysis

The need to recycle millions of pounds of vehicle batteries is on the horizon as the first generation of plug-in electric vehicles will soon reach the end of their useful lives. In addition, the huge number of consumer electronics device batteries and the use of energy storage on the grid will increase the need to recycle. The Department of Energy recently named Argonne as the lead for the ReCell Center focused on developing cost-effective processes to recycle advanced materials for batteries, including lithium ion.

Argonne has also developed modeling tools that combine performance parameters with cost for various types of batteries aimed at high-energy applications such as transportation or the electric grid. These models can be used to quantify the cost reduction from R&D advances and help better focus future work.

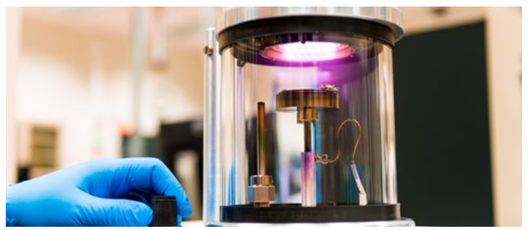
For example, Argonne's EverBatt is an Excel-based model that evaluates cost and environmental impacts for the various lifecycle stages of a lithium-ion battery. It is available open source for download.

ACCESS TO WORLD-CLASS FACILITIES

Discovery labs provide understanding, at atomic and molecular levels, of the chemical changes that occur during battery charging and discharging.

Electrochemical Discovery Laboratory (EDL)

Synthesizes high-quality materials for testing in beyond-lithium-ion batteries, and characterizes their properties with state-of-the-art analytical techniques down to the atomic and molecular scale. This lab makes it possible for scientists to synthesize liquid electrolytes with unparalleled control over water content and other impurities.



The reaction calorimeter gives Argonne researchers the ability to precisely measure how much heat is generated by a chemical reaction.

Materials Engineering Research Facility (MERF)

Enables the development of manufacturing processes for producing advanced battery materials in sufficient quantity for industrial testing. MERF helps bridge the gap between bench-top science and industrial production by using cutting-edge tools to scale up production of newly discovered materials.

Argonne's dry room plays a critical role in the assembly and performance of a finished battery cell.

Cell Analysis, Modeling, and Prototyping Facility (CAMP)

Designs, fabricates, and characterizes high-quality prototype cells using anode, cathode, and electrolyte materials for high-energy batteries. CAMP-manufactured cells enable realistic, consistent, and timely evaluation of candidate chemistries in an industrial format.

Information on important battery characteristics such as cycle life and calendar life come from simulations on state-of-the-art, custom-built equipment.

Electrochemical Analysis and Diagnostics Laboratory (EADL)

Provides battery developers with reliable and independent performance testing of their cells, modules, and battery packs. EADL can conduct more than 240 concurrent advanced battery studies under operating conditions that simulate various electric vehicle and utility grid applications, among others. Data is then used for modeling and battery life estimation.

Argonne combines expert battery staff with unmatched R&D facilities for the synthesis of battery materials and the testing and failure analysis of cells and batteries.

An Argonne scientist analyzes results from battery sample testing that includes characterization in an inert "glovebox" and in a scanning electron microscope.

Post-Test Facility

Enables researchers to dissect cycled battery cells and perform a variety of characterization techniques to determine reasons for performance decline and failure mechanisms without ever exposing the battery materials to oxygen.

The ReCell Center has four focus areas, including the development of new ways to recycle cathode material in a manner that allows direct reuse in new batteries and the recovery of materials not currently targeted.

ReCell Center

Includes an advanced battery recycling R&D facility where experts from national laboratories, academia, and industry are developing cost-effective processes to recycle advanced battery materials.

Cutting-edge scientific research also demands access to world-class user facilities that can characterize materials at the atomic and molecular scale and simulate and model materials behavior. Argonne's energy storage researchers benefit from access to these resources.

Advanced Photon Source (APS)
Provides ultra-bright, high-energy X-ray beams for materials research at the forefront of science, including battery materials.

Argonne Leadership Computing Facility (ALCF)
Provides high-performance computing that is 10 to 100 times more powerful than computing systems typically used for scientific research. This powerful capability is being exploited for the atomic- and molecular-scale modeling of battery processes.

Center for Nanoscale Materials (CNM)
Offers a wide range of capabilities designed to enhance the study and creation of materials, including those related to battery materials.

A LONG TRADITION OF UNRIVALED EXCELLENCE IN ENERGY STORAGE INNOVATION

60s

Argonne's nuclear energy expertise with molten salts leads to exploratory studies of lithium sulfur and lithium phosphorus cells.

70s

Argonne initiates R&D on lithium alloy/metal sulfide batteries with molten salt electrolytes for transportation and electric grid.

DOE establishes National Battery Test Laboratory at Argonne.

80s

Argonne provides technical management of industrial R&D projects on aqueous batteries and initiates R&D on sodium batteries.

90s

Argonne executes R&D agreements with industrial partners on lithium aluminum/iron sulfide and lithium polymer batteries.

Argonne initiates R&D program on advanced lithium-ion batteries that operate at room temperature.

Argonne researchers develop the nickel-manganese-cobalt (NMC) composite cathode—a major leap in lithium-ion battery technology.

2008

TODA America, Inc., licenses Argonne's NMC technology.

2009

BASF Corporation licenses the NMC technology and invests in further R&D and facilities to produce NMC-based products.

Argonne wins a DOE Energy Frontier Research Center (EFRC) for basic research on lithium-ion batteries, the Center for Electrochemical Energy Storage (CEES-I).

2010

Construction begins on TODA's lithium-ion cathode materials plant in Battle Creek, Michigan.

Argonne wins funding to construct CAMP, MERF and Post-Test Facility.

2011

LG Chem licenses the NMC technology.

General Motors licenses NMC for use in the Chevrolet Volt, the first mass-produced plug-in hybrid electric vehicle.

2012

Argonne wins the Joint Center for Energy Storage Research, a DOE Energy Innovation Hub (five years, $120M), for R&D on beyond-lithium-ion batteries.

2014

DOE renews Argonne's EFRC, now denoted the Center for Electrochemical Energy Science (CEES-II).

2017

General Motors uses Argonne's NMC cathode in the battery of the Chevy Bolt, the successor to the Volt.

2018

DOE renews JCESR at $120M for five more years.

DOE names Argonne as the lead for the ReCell Center focused on developing cost-effective processes to recycle advanced battery materials.

ACCESS
Energy Storage at Argonne

Battery Technologies Available for Licensing

- High-energy Cathodes
- Silicon Anodes
- High-voltage Electrolytes
- Additives
- Battery-related Atomic Layer Deposition
- Lithium Sulfur
- Flow Batteries
- Sodium Ion
- Magnesium Ion
- Solid-state/Lithium Metal

Learn more about how the laboratory collaborates with organizations of all sizes.

Argonne has extensive experience in performing proprietary and collaborative research with industrial firms. Licensing and contractual agreements vary based on the particular situation.

For more information about working with Argonne, visit **www.anl.gov/technology/partnerships**

ARGONNE NATIONAL LABORATORY

- U.S. Department of Energy research facility
- Operated by the University of Chicago
- Midwest's largest federally funded R&D facility
- Located in Lemont, IL, about 25 miles (40 km) southwest of Chicago, IL (USA)
- Conducts basic and applied research in dozens of fields
- Unique suite of leading-edge and rare scientific user facilities

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