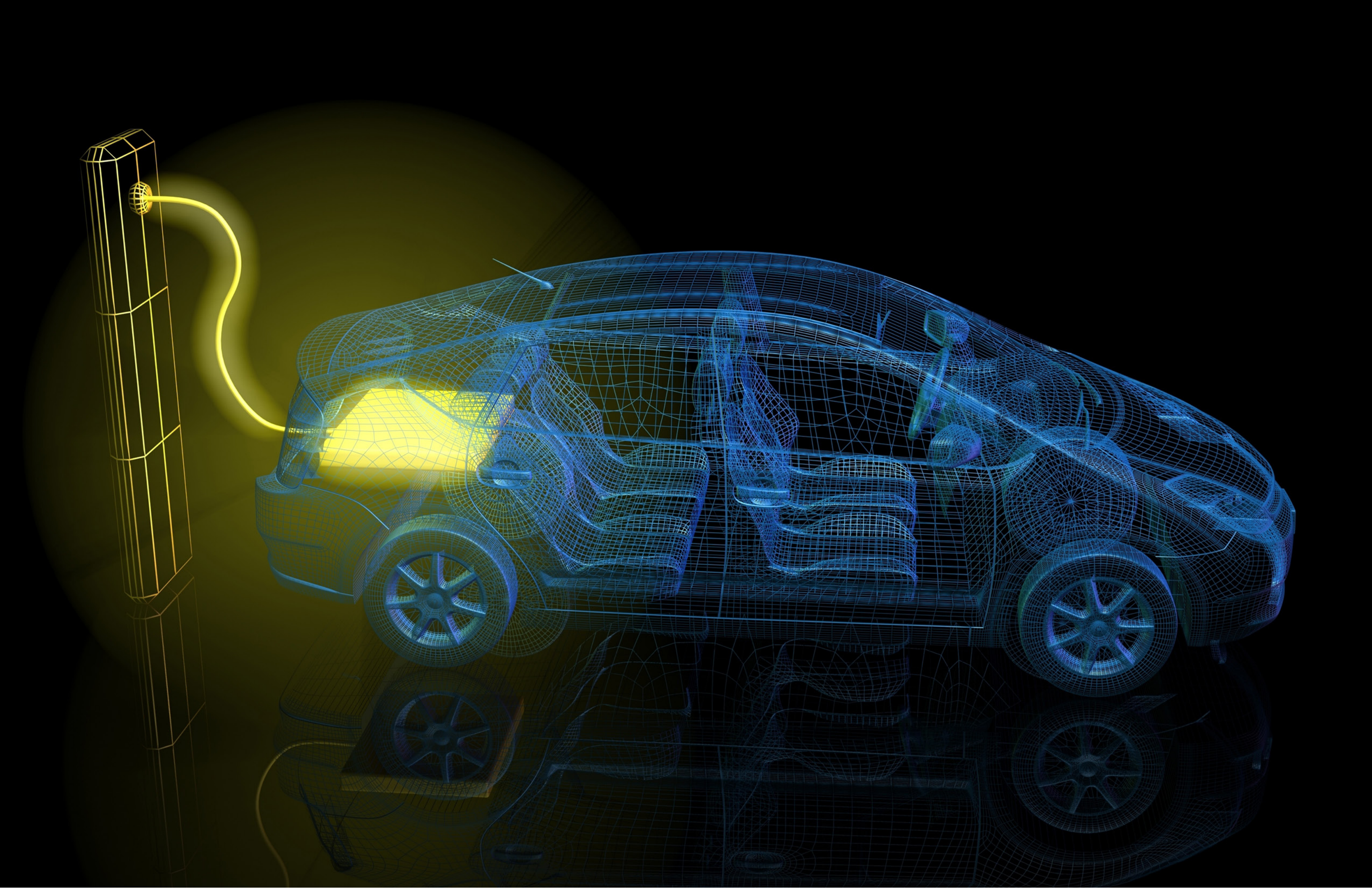
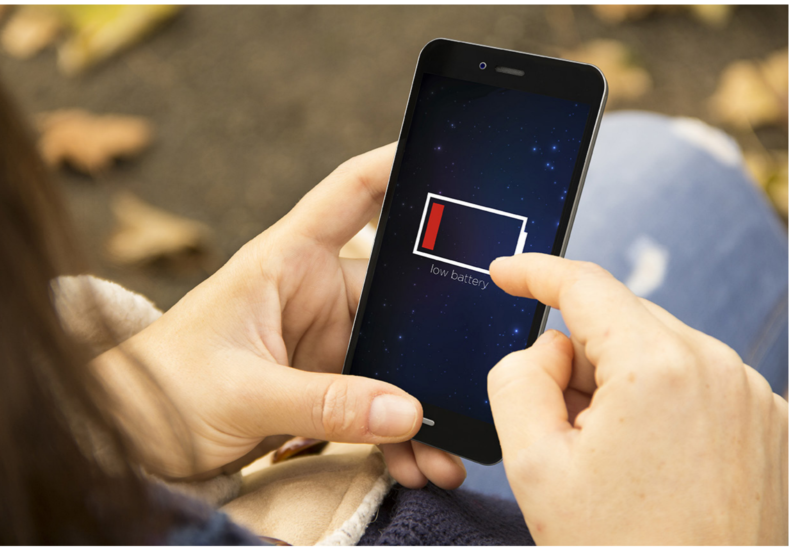


MAKING MORE POWERFUL, LONGER-LIVED BATTERIES

Lithium ion batteries power your phone, your laptop, and the growing number of electric vehicles on the road. Such batteries are also critical to the rapidly expanding market for airborne drones. However, current versions of these batteries don't hold as much power as their users would like, need frequent recharging (a lengthy process, especially for vehicles), and wear out in a few years when the materials in the battery degrade. To understand why and to find better materials, the U.S. Department of Energy's Office of Science funded an Energy Frontier Research Center (EFRC), the Center for Electrochemical Energy Science, led by Argonne National Laboratory with Northwestern University and other university partners.

About the image: Wire frame rendering of an electric car charging its battery (highlighted in yellow) *(vrx / Shutterstock)*



Top: Farmers are using battery-powered drones for terrain scanning, monitoring soil hydration, checking on crop conditions, and much else—including sending data to the cloud for analysis. *(MONOPOLY919 / Shutterstock)*

Bottom: Consumers would welcome batteries for their devices that held more power. *(Georgejmclittle / Shutterstock)*

Upper Right: Silicon nanoparticles protected by a graphene coating enable better lithium ion batteries. *(Nanograf)*

The initial research phase focused on the battery's negative terminal or anode. The team of researchers studied how lithium ions flowed into and interacted with anodes made of materials ranging from traditional graphite (carbon) to silicon and silicon/carbon composites. The structure and performance of these materials were studied using a coordinated series of computational calculations and laboratory studies with advanced analytical tools. The key breakthrough was the creation of an anode composed of nanoparticles of silicon, each coated with a protective layer of a material called graphene—a sheet of carbon just one atom in thickness. These materials are now under commercial development for use in next-generation lithium ion batteries by Nanograf, a U.S. startup spun out of Northwestern.

They consist of anodes with many layers of such coated particles, each layer sandwiched between thin sheets of copper foil.

This structure significantly enhances battery performance in two ways. Micropores in the graphene allow lithium ions to penetrate readily, enabling faster charging. Graphene is also flexible and expands readily, enabling the silicon to swell as it absorbs more lithium ions, thus increasing the battery's energy storage capacity (and an electric vehicle's driving range) by as much as 30 to 50 percent. The batteries are also expected to be lighter and safer (because of greater chemical stability) than existing lithium ion batteries.

The second phase of research built on the earlier work but focused on the battery's positive terminal, the cathode. A key problem with current batteries is that the organic solvent that transports lithium ions between the terminals also reacts chemically with the cathode. These reactions create a barrier around the cathode and also eventually cause the cathode to dissolve, both of which limit a battery's useful lifetime. Here again, coordinated studies allowed the process to be thoroughly understood and a solution developed: coating each particle of cathode material with a few sheets of graphene. The coating stabilized the chemistry, further boosted the amount of energy the battery could store, enabled still faster charging and, importantly, looks likely to significantly extend battery lifetimes. Commercialization of such cathodes is now underway by a second U.S.-based startup company—Volexion—also spun out of Northwestern. The graphene-encapsulated anode and cathode materials also enable lithium ion batteries to function at temperatures well below freezing—critical if you want an electric car but live in a cold region.

The lithium ion battery industry is now primarily based in Asia, but the EFRC research and subsequent commercial developments that license those discoveries have given the U.S. a potentially key advantage: intellectual property critical to the emerging electric vehicles revolution.

Center for Electrochemical Energy Science (CEES)
Winner — Technologies and Tools Award
www.science.osti.gov/bes/efrc/Centers/CEES