Argonne NATIONAL LABORATORY

# BATTERY SECOND LIFE

*Frequently Asked Questions*

For lithium-ion batteries that have outlived their automotive value, second-life applications show promise for the provision of energy, supporting sustainability.

## WHAT ARE THE MOTIVATIONS FOR BATTERY SECOND LIFE?

Electric vehicles contain lithium-ion batteries (LIBs) that are both large and expensive, and these LIBs likely have significant storage capacity remaining when they no longer meet the power and energy demands of a typical vehicle application. That remaining LIB capacity could provide a financial opportunity to many individuals and institutions along the possible value chain: This could include vehicle owners (value recovery), battery repurposers (who collect, evaluate, and repackage used LIBs), battery second-life users (grid operators, businesses, hospitals, etc.), and, ultimately, battery recyclers (who recover valuable battery materials via physical, thermal, and chemical methods).

## WHAT DOES SECOND-LIFE MEAN VS REFURBISHED OR REMANUFACTURED?

Second life refers to a new, nonautomotive use of an automotive LIB after its initial use in a vehicle. Refurbished or remanufactured batteries are those LIBs that have come out of service, were evaluated and repaired if needed, and were graded as meeting application specifications and made available to the original LIB application.

## WHAT ARE THE PARTS OF AN AUTOMOTIVE LITHIUM-ION BATTERY?

- An LIB is complex and consists of many separate parts, including: cells, modules, battery management systems (BMS), thermal management systems, and packaging.
- The entire LIB in a vehicle is referred to as the pack. The pack contains a collection of LIB modules, which are further composed of individual LIB cells.
- The cells are the smallest individual element that can hold energy (a description of how these work is available at www.energy.gov/eere/articles/how-does-lithium-ion-battery-work).
- Most applications treat the LIB module as the smallest element for design and implementation.
- LIBs also require a BMS to measure, manage, and control the charge of all of the LIB cells, and to monitor the temperature of the pack.
- The LIB will also have a mechanism for cooling the battery (either liquid or air cooling) and an enclosure that packages all of the elements.

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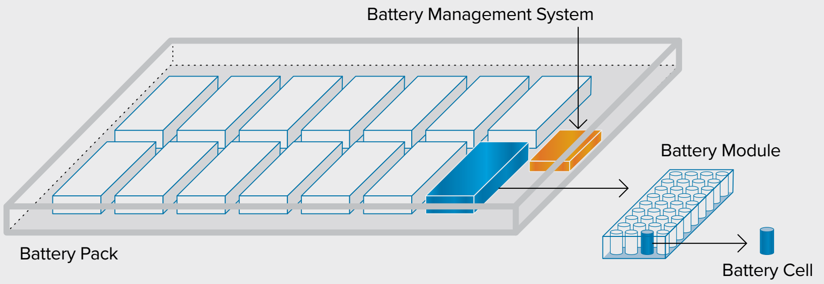
**Components of an LIB Battery Pack**




## ISN'T THE BATTERY "USED UP" AFTER ITS USE IN A VEHICLE?

An LIB may still have ~80% of its usable energy capacity remaining at its vehicle-application end of life. While the LIB may no longer meet the power and energy demands of a vehicle, it may still be capable of significant energy storage and have up to 10 years of life remaining in different applications.[1]

## WHAT TYPES OF SECOND-LIFE APPLICATIONS ARE AVAILABLE TO THESE BATTERIES?

- **Behind-the-meter (BTM) storage services**: These are residential, commercial, and industrial applications that are primarily used to provide backup power, or smooth the electrical peak demand, mostly to reduce electricity costs. BTM means that the electricity has come through the meter to the user; most homes are "behind the meter."
- **Front-of-the-meter (FTM) storage services**: These are utility-scale services that target applications for frequency regulation, voltage support, and excess renewable energy storage. FTM means that the application functions prior to the electricity going through the meter to its end user.
- **Telecommunications and data center backup services**: Power for telecommunications towers is currently the largest second-life application in the world. Data centers, which need stable power, represent a potential market.
- **Electric vehicle charging**: 50–300-kWh battery systems that facilitate direct current (DC) fast charging to decrease peak demands from the grid can result in lower charging costs for the charging station operator and the vehicle user. Demand charges, which are related to the rate of electricity delivery (kW), as opposed to the total amount delivered (kWh), are a driver of electricity cost for DC fast-charger applications.
- **Low-power electric vehicles**: While automotive LIBs may have exhausted their life within a passenger vehicle, which must meet high acceleration and long driving-distance demands, these LIBs may still be viable for electric golf carts, as well as some industrial/commercial vehicles (e.g., forklifts) since these applications require less power.

## ARE THERE ANY EXAMPLES OF SECOND-LIFE APPLICATIONS CURRENTLY IN THE MARKET?

- Some end-use plans are already in place, but these vary by market. The European and Japanese markets currently have formalized plans between vehicle manufacturers and second-life applications.
- In the United States, automakers are responsible for LIBs for a specified time via warranty, so they provide repair and refurbishment of LIBs (often via a third party). One automaker uses second-life LIBs for an energy-storage system.
- Other examples include:
  - Second-life batteries to store solar power and integrate with a fuel cell system to provide electricity to convenience stores.
  - Second-life batteries to store solar power at a national park.
  - Used battery modules to power stand-alone solar-powered LED lights.

## WHAT ARE THE CHALLENGES TO SECOND-LIFE APPLICATIONS?

- Because LIBs are classified as a Class 9 hazardous material, transportation of LIBs can be challenging. These batteries must be handled in a specific way by individuals with the proper certifications, increasing the cost of shipping.
- The BMS that the LIB uses in its automotive application will likely not be appropriate for a second-life use. Each application needs a properly engineered BMS that will monitor and control the LIB modules for that new use.
- Battery modules vary from one vehicle LIB to another, and these differences (form factor, chemistry, etc.) may not be well suited for mixing modules within a second-life application, as it adds variability.
- If modules from an LIB pack perform well enough at their end of life, they could be refurbished or remanufactured into a new-vehicle LIB pack. This would reduce the flow of LIB modules for second-life applications. So, while beneficial to extending LIB life, it would represent a challenge to the second-life market.

## CONTACT

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1. E. Martinez-Laserna, et al., "Battery second life: Hype, hope or reality? A critical review of the state of the art," Renew. Sustain. Energy Rev., vol. 93, pp. 701–718, Oct. 2018.