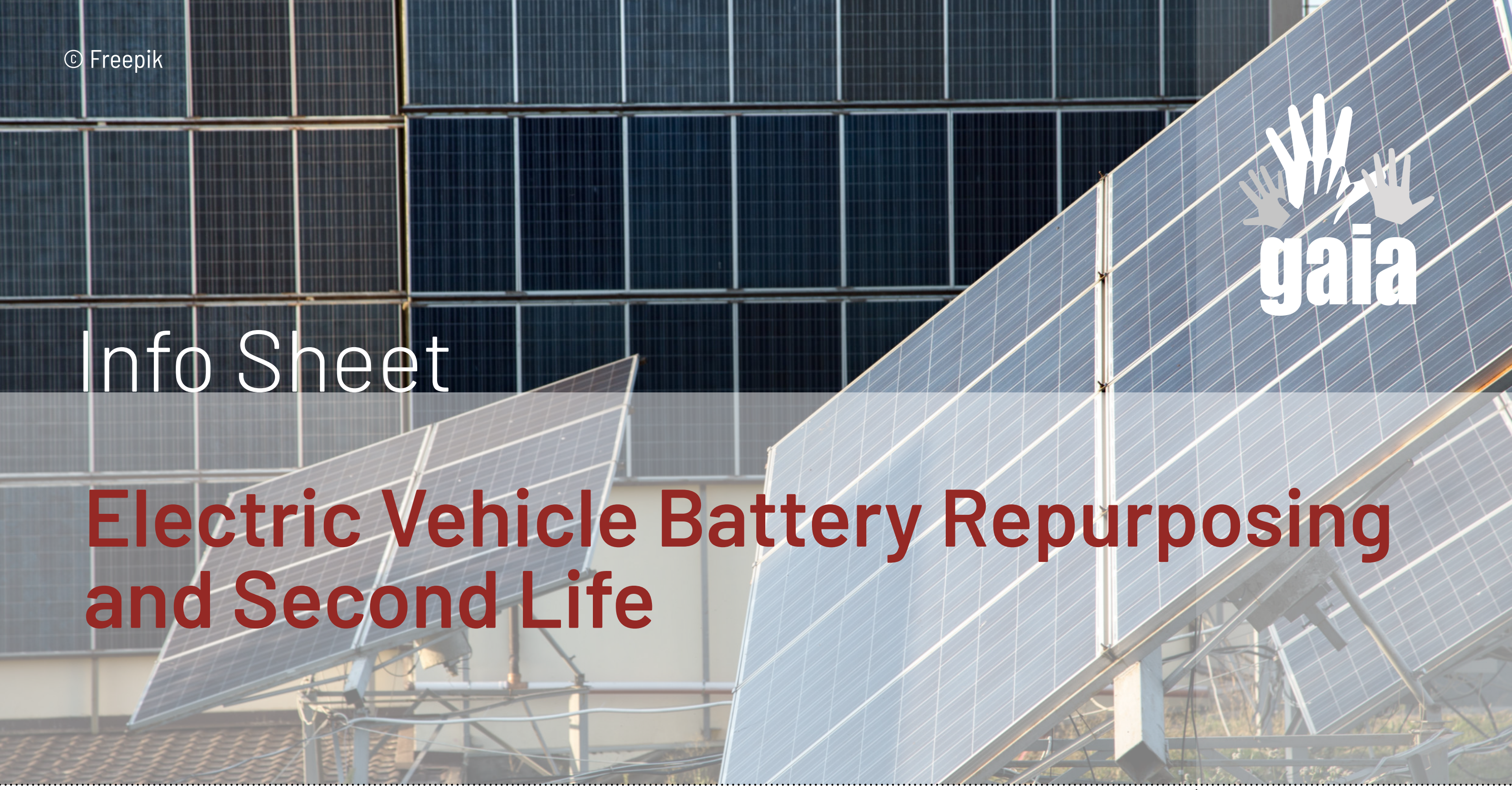


Info Sheet

Electric Vehicle Battery Repurposing and Second Life

What is electric vehicle repurposing and second life?

When an electric vehicle (EV) battery reaches "end-of-life" at about 80%[1] of its original battery capacity and can no longer support a vehicle, it still has the potential to provide energy storage in different applications, such as through grid services, residential storage, microgrids, EV charging support, and charging small personal devices. Repurposing the battery can give it a second life, a process which reduces hazardous waste and saves material and energy when compared to the recycling process.

EV battery repurposing also has broader environmental justice implications. Repurposing extends the battery's life and has the potential to reduce demands for mining precious metals such as lithium, nickel, and cobalt. These minerals are mined from Global South countries (where there are less environmental and social protections), in a process that negatively impacts local and Indigenous communities, their lands, livelihoods, environment, and security.[2] Repurposing also potentially provides an alternative for countries that lack the proper facilities and complex waste management system necessary to process and recycle lithium-ion batteries.[3]

1 Zhu, J., Mathews, I., Ren, D., Li, W., Cogswell, D., Xing, B., Sedlatschek, T., Sai, Yi, M., Gao, T., Xia, Y., Zhou, Q., Wierzbicki, T., & Bazant, M. Z. 2021. End-of-life or second-life options for retired electric vehicle batteries. Cell Reports Physical Science, 2(8), 100537-100537. https://doi.org/10.1016/j.xcrp.2021.100537.

2 Grossman, A., Matías Enrique Mastrangelo, Camilo, & Mónica Blanco Jiménez. 2023. Environmental Justice Across the Lithium Supply Chain: A Role for Science Diplomacy in the Americas. The Journal of Science Policy & Governance, 22(02). https://doi.org/10.38126/jspg220205.

3 Sustainability for All? The challenges of predicting and managing the potential risks of end-of-life electric vehicles and their batteries in the Global South. 2022. ResearchGate. https://doi.org/10.21203//rs.3.rs-1510523//v1.

Examples of EV battery repurposing

There are many different possible second-life options for EV batteries. For example, EV batteries can be repurposed for energy storage systems in residential, industrial, and grid-scale storage. When paired with solar, they can provide stability and resilience to homes or businesses that cannot access solar power at night. In addition, repurposed EV batteries can be used for peak shaving on the grid. This is when batteries are charged during non-peak hours/with solar energy, and then energy is discharged during peak hours. This can save people money and provide resiliency to the grid when energy is in high demand. In addition, repurposed EV batteries can be paired with renewable energy sources and microgrids to provide energy access to rural communities, which could impact energy poverty areas. A study in Scientific Reports found that second-life EV batteries were a viable and cost effective option for electrifying rural primary schools in Kenya.[4] Other applications of repurposed batteries include energy storage for personal devices, e-forklifts and manufacturing machinery, and EV charging stations.

There are a variety of startups in the U.S. and abroad that focus on repurposing EV batteries in different contexts – from software and hardware companies focusing on improving the repurposing process, to innovation labs, to microgrids. In the U.S., ReJoule has commercialized a proprietary hardware and software solution to quickly assess the state of health of EV batteries, so their customers can easily find batteries with similar characteristics and match them together.[5] Another startup in Europe, Mobility House has used repurposed EV batteries, for a 3 MWh storage system for a soccer stadium in Amsterdam that pairs with solar[6] and a 1.6 MWh system that pairs with wind energy to provide grid services in Berlin.[7] In Canada, the startup Moment Energy repurposes EV batteries to create energy storage systems that use renewable energy sources to provide energy in rural and off-grid locations.[8]

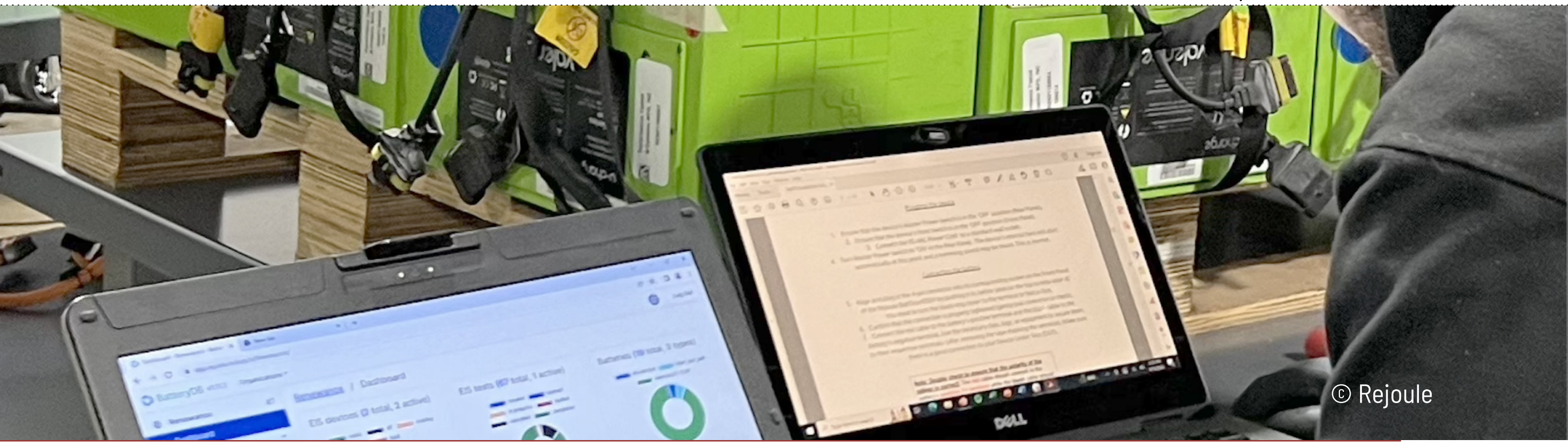
4 Nisrine Kebir, Leonard, A., Downey, M., Jones, B., Rabie, K., Sivapriya Mothilal Bhagavathy, & Hirmer, S. A. 2023. Second-life battery systems for affordable energy access in Kenyan primary schools. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-28377-7.

5 ReJoule. 2024. https://rejouleenergy.com. For more on how to maximize the value of an EV and its battery, please see ReJoule's white paper that was co-published with the Automotive Recyclers Association: https://rejouleenergy.com/automakers.

6 The Mobility House. 2018. https://www.mobilityhouse.com/int_en/our-company/newsroom/article/johan-cruijff-arena-3mw-energy-storage-system-launch.

7 (The Mobility House, 2018)

8 Moment Energy's Projects. 2021. https://www.momentenergy.com/our-projects.



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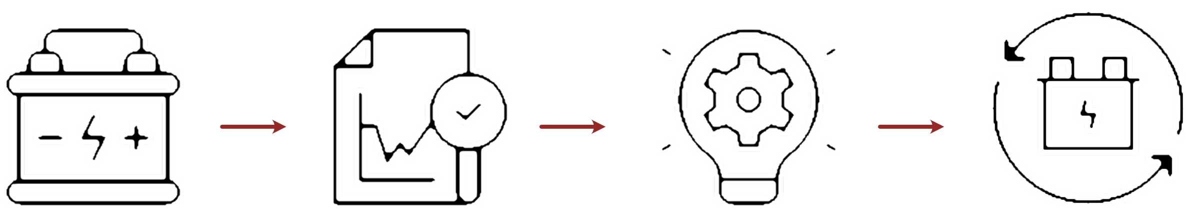
What are the steps required to repurpose EV batteries?

The process of repurposing a lithium-ion battery requires four steps: **(1) assessing the state of health of the battery, (2) evaluating the battery's viability for a second life, (3) deciding on a configuration, and (4) reassembling the battery pack in the new configuration**. Battery disassembly is necessary throughout the process in order to conduct tests and access different parts of the battery. This can be difficult and very inaccessible, as manufacturers currently do not design EV batteries with repurposing in mind (see more in GAIA's Info Sheet: Electric Vehicle Battery Disassembly). Throughout the disassembly process, there are a variety of environmental justice concerns surrounding worker safety, such as working with hazardous chemicals, risk of fires, and electric shock. In the U.S. the repurposing facility must be certified by UL 1974, the standard for evaluation of repurposing EV batteries. This certification involves "requirements for the sorting and grading process of batteries that are intended for repurposing... [and] application-specific requirements for repurposed battery packs/systems and battery packs/systems utilizing repurposed modules, cells and other components." [9] The certification process can be very time consuming but is necessary in order to ensure safe repurposing processes.

9 UL Certification Helps Promote Repurposing of Electric Vehicle (EV) Batteries. (2022). UL Solutions. https://www.ul.com/news/ul-certification-helps-promote-repurposing-electric-vehicle-ev-batteries.

FIGURE: Four steps of battery repurposing



STEP 1
Assessing Battery State of Health

STEP 2
Evaluating Battery Viability for a Second Life

STEP 3
Deciding on a Configuration

STEP 4
Reassembling the Battery Pack in the New Configuration

STEP 1: Assessing Battery State of Health

A thorough evaluation of battery state of health is necessary in order to measure an EV's viability for repurposing. If possible, useful information (distance driven, age, charging and discharging rates, or state of health) can be measured during the first life of the battery while it is still in-use in the car. This information is accessible in a vehicle's battery management system, but those systems can often be unreliable. Another emerging option to access this information is in a digital label or a battery passport. Once a battery is removed from a vehicle, third-party repurposing companies can have difficulty accessing this information. In this case, they would need to test the battery pack – usually through capacity and internal resistance tests, called cycling. This cycling process can take up to 2 days and require trained technicians to monitor a full charge and discharge of the battery.[10]

Discharging a battery is the process of intentionally draining the battery in order to perform work on it. Because of the variety of designs of EV batteries, each battery has specific guidelines from the manufacturer on how to discharge the battery safely and correctly. Also, because of this variety, the process is very difficult to automate and the dismantling must be done by hand. In order to discharge the battery, the technician must know the battery's state of health, capacity, state of charge, allowed voltage, and current range. This process has electrical, thermal, chemical, and kinetic hazards.[11]

STEP 2: Evaluating Battery Viability for a Second Life

Once the battery has been tested for key characteristics, its viability for repurposing can be determined. Characteristics such as battery capacity, max power, weight, volume, Energy Management System (EMS), thermal management, and possible battery configurations are all considered when determining how the battery can best be repurposed for a second life. For example, in order to get a higher battery capacity with second-life battery cells, more battery cells would need to be installed, leading to a higher weight battery. This extra weight would have implications for a mobile device or vehicle, but it wouldn't matter for a stationary product.[12]

There are also cost considerations when determining repurposing viability and which configuration would suit the battery best. For example, configurations that involve more disassembly have increased costs. This is because of the time and energy it takes to disassemble the battery as well as the cost of new equipment (connectors, case, etc.). For grid services, there are also costs associated with installing a Battery Energy Storage System (BESS).

10 Montes, T., Maite Etxandi-Santolaya, Eichman, J., Victor José Ferreira, Lluís Trilla, & Corchero, C. 2022. Procedure for Assessing the Suitability of Battery Second Life Applications after EV First Life. Batteries, 8(9), 122–122. https://doi.org/10.3390/batteries8090122.

11 Nembhard, N. (n.d.). Safe, Sustainable Discharge of Electric Vehicle Batteries as a Pre- treatment Step to Step to Crushing in the Recycling Process. https://www.diva-portal.org/smash/get/diva2:1339943/FULLTEXT01.pdf.

12 (Montes et al. 2022).

STEP 3: Deciding on a Configuration

Battery pack stacking

Battery Pack Stacking requires the least amount of disassembly, as it uses entire battery packs which are connected in parallel to create the final second-life battery. The battery packs must have similar characteristics, as the performance of the second-life battery will be affected by the worst performing modules and cells. In order to account for unexpected current flows between batteries, a power converter is often added to the battery, which can be expensive. This cost can increase if the Battery Management System (BMS) cannot communicate with the power converter and manufacturers need to create a gateway. The stacking battery packs configuration works best when a large battery capacity is necessary, such as grid services.[13]

Refurbishing Battery Modules

If the cells in a battery pack are divided into modules, these modules can be refurbished and reconfigured into a second-life battery. The battery pack must be disassembled into modules, which are tested for their performance and combined into a new battery pack. The modules must have similar characteristics. It also requires modification to the thermal management system. Module batteries are simpler to repair because modules can be swapped out, but it can be difficult to source components for repair and maintenance. In addition, these second-life batteries can be more reliable because modules with poor performance can be removed before creating the new battery. However, the new battery is still affected by the worst performing cell. This configuration can be used for high energy demands, but it is also very flexible depending on energy needs of the final configuration.[14]

Refurbishing Battery Cells

To refurbish battery cells, this requires disassembly down to the battery cell level. The battery cells are then configured into new modules and systems. There is a lot of flexibility on the size of the configuration, which makes it useful for small electronic devices. These systems are more reliable because the best cells can be selected and used. However, many cells can be damaged during the disassembly process, and more waste is generated as many parts of the battery are no longer used.

13 Ibid.

14 Ibid.

STEP 4: Reassembling the Battery Pack in the New Configuration

Many variables must be considered when batteries are reassembled and stacked for use in stationary storage for renewable energy such as solar or wind, mini-grids that provide power for off-grid communities as well as for storage for utility grid back up.

The used batteries are typically stacked in an array and housed in shipping container-like structures for stationary storage. The challenge is that batteries can be of different makes, car models, ages and state of degradation. All of the different types of batteries must work in sequence so that the older batteries do not slow down the entire system. Software is used along with the controller monitors for all the batteries' variables during charge and discharge cycles. The software enables the repurposed batteries to achieve efficient energy yields despite the variance in capacity inherent in the batteries. Some repurposers work with selective car makers so that their storage system can be designed based on specific shapes, sizes and dimensions to create a plug and play system.

Startups such as Smartville are developing proprietary software, hardware and diagnostics tools for the use of repurposed batteries stationary storage applications for business and and utility customers.

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Challenges and Recommendations

There are multiple challenges with EV battery repurposing and opportunities in order to improve accessibility, safety, and viability:

Standardization: Because this is a relatively new space, there is a lack of standardization across policy and processes. For example, policies relating to warranty, insurance, ownership of batteries, access to battery data, and permitting are often unclear, non-existent, or difficult to find. In addition, there is no standard process for repurposing EV batteries. Although there are general steps, the specific processes vary depending on the type of battery, access to proprietary software, configuration, and application. There is also no standardized process for deciding when to repurpose or recycle batteries.

Designing for Disassembly: Disassembly can be very difficult due to strong adhesives, specific tooling, and complicated designs. In addition, some battery packs are not organized into modules, which makes them more difficult to be repurposed. Through intentional designing for disassembly, the process can be faster, safer, and more accessible (see more in GAIA's Info Sheet: Electric Vehicle Battery Disassembly).

Universal and fair access to battery state of health and related information: Access to reliable and accurate battery state of health information while in the vehicle and after the battery's removal is critical to its repurposing. Onboard vehicle battery management systems must be required to meet more stringent accuracy and reliability requirements, and additional techniques should be standardized to make testing of batteries removed from a vehicle more quick, reliable and affordable.

Safety: It is currently difficult to find safety information for specific processes, such as discharging the battery, disassembly, and running specific battery tests. The need for an information center with clear safety guidelines for all steps in the repurposing process is especially true in energy poor areas, where those working on repurposing EV batteries may not have access to UL 1974 certification.

Competition over battery scrap: Both production scrap and post-consumer batteries are in demand for battery repair, repurpose and recycling. This competition with recycling companies for waste feedstock can economically hinder battery repurposing practices, especially when large-scale recycling companies have capital strength and partnerships with battery manufacturers and car makers. Providing regulatory support and incentives for battery second-life applications can effectively address these challenges.

Copyright as a challenge: As with battery repair, copyright laws can present a barrier to battery repurposing when the Original Equipment Manufacturers use proprietary battery management systems hardware and software. Access to a battery's state of health and other information is a crucial element for battery second-life applications.

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See GAIA's Battery Info Sheet Series at: www.no-burn.org/batteries.