FACTSHEET 3

Second-life Lithium-ion batteries


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About the Sustainable Energy Solutions Catalogue

The Sustainable Energy Solutions Catalogue provides an introduction to the solutions deployed during the SESA project. The catalogue targets energy practitioners, policy makers and civil society, especially at local level. In the catalogue, readers can find key facts about specific sustainable energy solutions (technologies, business models, impact areas), or learn about approaches and concepts that help ensure the viability and long-term success of sustainable energy in the African context.

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1 Introduction

During the next decades, the strong uptake of electric vehicles (EVs) will result in the availability of batteries that can no longer be used in EVs but are still useful for stationary applications. Extending the lifetime of EV batteries has significant economic and environmental benefits and is an important piece of Africa's energy transition. This factsheet reviews the potential for use of Lithium-ion (Li-ion) second-life batteries (SLBs) in the context of sustainable energy solutions currently emerging in the African context. It sums up key technologies, business models and impacts, and presents examples of SLB use across the continent.

Please note that this factsheet is closely linked to other factsheets in the SESA solutions catalogue, such as the ones on E-waste, Circularity and Sustainable E-mobility.

2 The technology

Li-ion batteries are currently the most commonly used type of battery in EVs. They have one of the highest energy densities of any battery technology today, can deliver large amounts of current for high-power applications, and have comparatively low maintenance requirements.

Li-ion batteries are designed for approximately a decade of useful life in an EV. At the end of the first life of an EV battery, manufacturers and users have three options: they can dispose of it, recycle the valuable metals, or reuse it (Figure 1). This factsheet focuses on the reuse option (please see E-waste and Circularity factsheets for details on disposal and recycling routes).

Stationary energy storage is key for the functioning of off-grid solar photovoltaic (PV) applications such as mini-grids and standalone systems. Li-ion batteries are well suited for storing energy from off-grid solar because the batteries can be charged quickly and are lighter, more compact and can hold higher amounts of energy than other battery types (The Earth Awards, 2019).

Reusing Li-ion batteries, however, often requires a reconditioning process (Figure 2). The first step is to test the battery's health. Batteries deemed fit for a second life are dismantled to extract the battery cells. These undergo a series of further tests and are then reassembled in the new application. It is important to achieve a balance in the health of battery cells within the new system (Pyper, 2020).

Figure 1: **Second life for former EV batteries in stationary energy storage** (Falk et al., 2020)

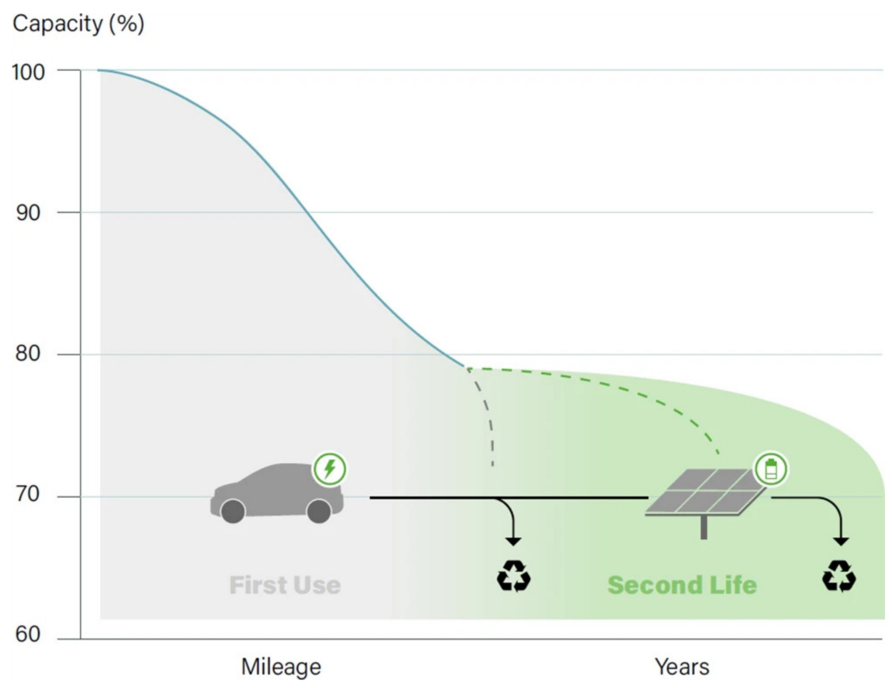
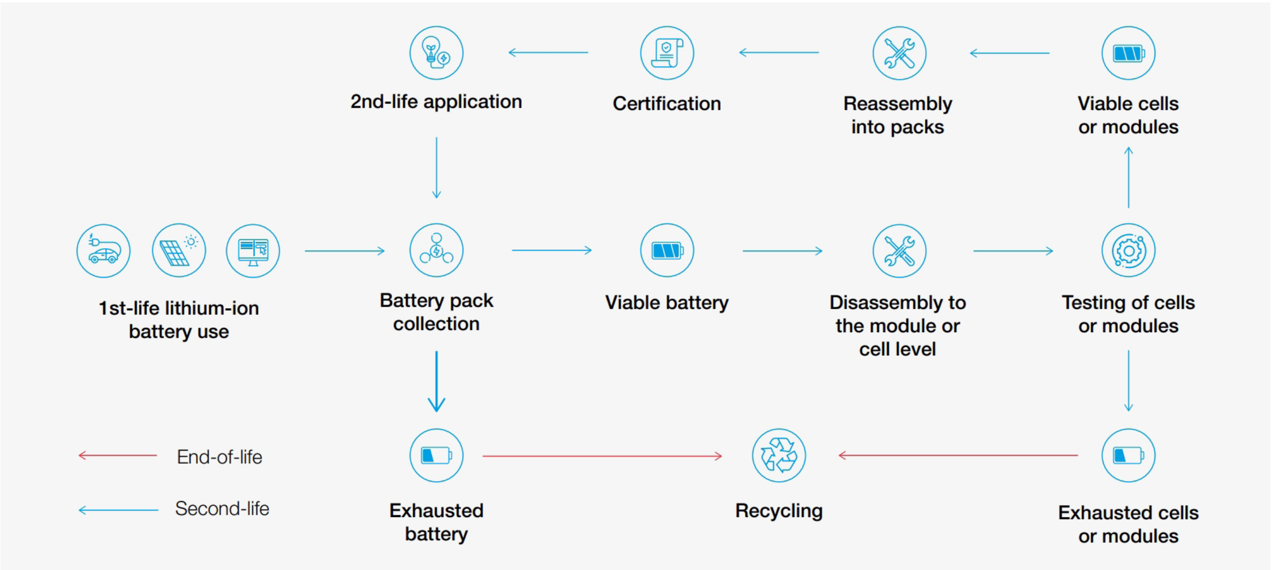


Figure 2: **Overview of the battery repurposing value chain** (Angliviel et al., 2021)



3 Business and financing models

Business models for the use of SLBs in solar off-grid applications are recently emerging, and they vary depending on the type of application and local context (Kendall et al., 2023). The cost of new batteries, the lack of standards, and the reliability of supply of SLBs are some of the factors that affect the viability of SLBs business models in the African context. These are discussed here in turn.

3.1 Cost

The advantage of using SLBs is their lower cost compared to purchasing a new Li-ion battery. Estimates of the total cost of a SLB range from USD 40 to 160 per kWh, while a new EV battery pack cost around USD 157 per kWh at the end of 2019 (Clean Technica, 2020). Therefore, using SLBs can increase the affordability of solar off-grid systems, such as a mini-grid or rooftop PV installation. However, as the cost of new batteries continues to decrease in the future, the cost difference between used and new batteries will narrow (McKinsey, 2019). Hence, a growing number of start-ups are working on ways to lower the cost of the battery reconditioning process. For example, the reconditioning process can be shorter if the battery health has been continually monitored during the life of the EV.

3.2 Need for standards

A challenge for SLB businesses is the complexity of reconditioning batteries that vary widely in size, chemistry and format. Currently, batteries are designed to meet the needs of a given EV vehicle model, rather than a stationary application. McKinsey (2019) estimates that up to 250 new EV models will exist by 2025, featuring batteries from more than 15 manufacturers. EV manufacturers such as Nissan and Renault have recently started to design their vehicles with second-life applications in mind. Moreover, a number of initiatives are underway to increase standardisation of batteries as well as to streamline the disclosure of the state-of-health of a battery that has reached the end of its first life. In 2019, the first international standard for evaluating and repurposing batteries was created in the United States, but this is still lacking in Europe and Africa (Bustamante et al., 2020). A recent EU regulation includes battery durability and tracking requirements, including the battery passport (European Parliament, 2022).

An immature regulatory regime is also an obstacle to viable SLB business models. Most African countries lack regulations specific to SLBs or delineations of responsibility between the producer and the consumer. This creates uncertainties for manufacturers, second-life-battery businesses and eventually also for customers (McKinsey, 2019). The classification of SLBs as hazardous waste under the Basel Convention also poses a significant challenge for their shipping.

3.3 Reliability of supply

SLB businesses need a reliable supply of used EV batteries. Businesses can either engage directly with a supplier, for example an EV manufacturer (see REVOV example below) or a battery company. There is also the possibility of establishing a collection system. Collection systems can be facilitated with Information and Communication technologies (ICT) and Internet-of-Things (IoT) elements, for example through the monitoring of battery health and monetary incentives to take back batteries (for more information on take-back schemes, see the E-waste and Circularity factsheets of the catalogue).

Examples of application in the African context 1

Inno-Neat, Mombasa, Kenya

The idea: Analyses, recycles and repurposes used lithium-ion battery cells into Solar Ready battery packs for use in solar applications targeting low-income communities.

Areas of expertise and innovation:
- Recycling, cell testing, refurbishing, battery packs

The business model:
- Circular economy approach via battery collection and sale of stationary storage batteries at reduced prices

The impact:
- Reduced environmental impact and cost
- Local value chain and employment creation

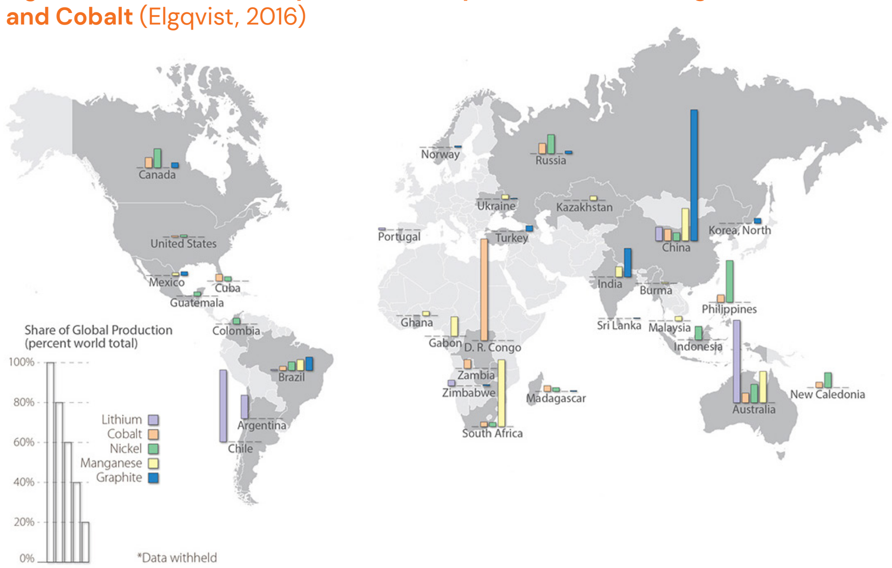
For further information visit:
→ https://energy.innoneat.co.ke

4 Socio-economic and sustainability impacts

Using SLBs reduces the need for harmful mining (Figure 3), avoids the environmental impacts of improper battery disposal, and can create employment. These impact areas are treated here in turn.

Lithium extraction through evaporation ponds uses large quantities of water and this can lead to water shortages that damage ecosystems and threaten the livelihoods of local communities (Figure 4). It is estimated that over 2 million litres of water are needed to produce one ton of lithium (UNCTAD, 2020). Moreover, lithium mining can lead to soil degradation and a loss of plant diversity (Agusdinata et al., 2018).

Figure 3: **Production of key Li-ion battery materials, including Lithium and Cobalt** (Elgqvist, 2016)



The mining of cobalt used in Li-ion batteries is also associated with severe health, environmental and human rights impacts. An increased use of SLBs can reduce the impacts of mining for lithium, cobalt and other raw materials needed in Li-Ion batteries.

The impacts of improper disposal of Li-Ion batteries are relatively less severe than those of other types of batteries such as lead-acid. However, leaks of heavy metals such as cobalt, nickel or manganese from Li-ion batteries can lead to significant contamination of soil and groundwater (Jacoby, 2019). Moreover, improper disposal can lead to fires that release toxic gases (Mrozik et al., 2021).

The adoption of circular economy approaches with efficient SLB collection, recycling and repurposing processes can create new employment opportunities. To establish a local industry for SLB repurposing, skills, infrastructure and the necessary capital are needed (Charles et al., 2019). Furthermore, creating local value chains for SLB repurposing can reduce the dependence on battery imports (Godfrey et al., 2021).

Figure 4: **Aerial view of the Rockwood Lithium mine in Nevada, United States** (Getty Images)

5 Scaling-up

There is significant potential for scaling up the use of SLBs in the solar off-grid sector. It is estimated that demand for EV batteries will increase from 15-30 GWh in 2015 to 300-1,000 GWh by 2030 (Falk et al., 2020). This in turn will lead to an increase in SLBs availability.

Battery manufacturers, second-life battery companies and automotive manufacturers can contribute significantly to the scale up of SLBs. For example, vehicle manufacturers can design their batteries already having in mind their second-life application and they can help streamline circular economy approaches (McKinsey, 2019). Policies play an important role in the uptake of SLBs as well, due to the fact that standards and regulations need to be established for the reduction of barriers to a widespread use of SLBs in Africa (Clean Technica, 2020).

Examples of application in the African context (2)

REVOV, Johannesburg and Cape Town, South Africa

The idea: Repurposing second-life lithium iron phosphate (LiFePO4) batteries for stationary off-grid applications, or back-up power.

Areas of expertise and innovation:
- Testing and refurbishing imported used batteries from BYD (world leader in EV manufacture) for use in different sectors

The business model:
- Import for refurbishment and then distribute through different local partners

The impact:
- Reduced waste creation and environmental impact
- Inclusion through targeting rural and low-income population by providing batteries for backup power supply at reduced costs

For further information visit:
→ https://revov.co.za/2ndlife

6 Second-life battery solutions in SESA

Implemented in nine African countries, the EU-funded SESA project is developing and testing solutions to accelerate the energy transition in Africa. The focus of the project is on the exploration of innovative technologies and services in urban and rural contexts. SESA partners in various countries are working on second-life Li-ion battery solutions. Their activities are briefly outlined below.

6.1 Kenya Living Lab

SESA partner WeTu is developing innovative solutions that test the use of second-life batteries as part of the SESA Kenya Living Lab. The main objective in this Living Lab is to demonstrate sustainable energy access solutions that are relevant for both urban and rural contexts in Africa, centred around solar PV off-grid electricity generation for multiple uses (fishing sector, water pumping, water purification, e-mobility), e-waste management, and integration of local Info Spots for digital access to information on energy, climate change and digital skills.

The Living Lab comprises two sites: Kisegi, a rural village in Homa Bay County, and Katito, a peri-urban community in Kisumu County. The solar charging hub in Katito uses a lead-acid battery bank and conventional inverter system, while Kisegi tests a hybrid inverter system with Li-ion storage and "hot swapping" system. The generated energy is used for a range of needs within the local communities, among others the recharging of solar lanterns for fishermen. The Li-ion battery cells from these solar lanterns are tested and reconfigured for a second use case in other appliances once they do not reach the required capacity for their primary use.

6.2 South Africa Living Lab

The SESA South Africa Living Lab is located in two sites: the Eastern Cape township of Alicedale and the semi-rural area KwaNonzwakazi on the outskirts of Alicedale. Although the areas have access to electricity, the supply is unreliable and there are prolonged blackouts. Access to reliable, affordable mobility is also a challenge for the majority of the population. Furthermore, there is a lack of access to ICT infrastructure.

In the Living Lab, SESA partner u-Yilo deploys solutions for sustainable electricity production and storage. The Living Lab comprises a containerised off-grid renewable energy system, a local Info Spot for internet access, and two micro-utility EVs. The Living Lab will also demonstrate the repurposing potential of EV batteries for stationary storage applications by investigating the performance of the SLBs, their technical and financial viability as well as scalability. The demonstration action will also identify the commercial potential for local authorities to invest in these solutions and study the potential of repurposing EV batteries for energy storage as a means to create jobs.

7 Climate-proofing

Climate proofing is a term that refers to a process of mainstreaming climate change into mitigation and/or adaptation strategies and programmes (Climate Policy Info Hub, 2022). The goal of climate proofing is to ensure that climate-related risks and opportunities are integrated into the design, operation, and management of products and infrastructure. In order to do this, projects have to be screened for climate risks, vulnerabilities and opportunities early in the design stages.

The climate-proofing ofSLB solutions will depend on the location and context. However, some general guidelines include:

- High ambient temperature is the most important factor that influences battery aging and can cause its premature failure (Riello Elettronica, 2022). Li-ion batteries have a rated design life capacity based on an optimum operating temperature, so that increases in temperature above this recommendation result in a reduction in service life. This fact counts as much for SLBs as for batteries in first life applications.
- Power sources used to charge SLBs used in stationary storage are also vulnerable to climate change. For charging the SLBs, low-carbon electricity can be obtained in two ways: off-grid solar PV applications, or the grid. The main climate threats to power supply sources relate to changes in radiation and ambient temperature, and extreme weather events that could cause physical damage to the infrastructure such as floods and forest fires.

8 Relevant tools and capacity building materials

Battery Second-Use Repurposing Cost Calculator

The National Renewable Energy Laboratory of the U.S. Department of Energy developed a calculator for the determination of repurposing costs for the second use of EV batteries. The tool accounts for factors such as module ownership, transportation, handling and testing time as well as costs, staff and required revenues.

→ www.nrel.gov/transportation/b2u-calculator.html

Dealing with the End-of-Life Problem of Electric Vehicle Batteries – Insights and Recommendations for Kenya

A comprehensive e-mobility strategy requires the management of batteries after the end of their use in EVs. Smart reuse and recycling systems need to be put in place as they can help to prolong the life cycle of such used batteries and provide significant business opportunities. This short paper gives an overview of the topic and ties it to the Kenyan context.

→ https://changing-transport.org/wp-content/uploads/202107_GIZTraCS_DealingwithEoLLiBs-1.pdf

Repurposing of Lithium-Ion Batteries – Technology & Market Insights

This study identifies the key drivers and barriers for adoption of Second Life Batteries (SLB). The challenges include handling the diversity of electric vehicle (EV) battery packs in the market, costly battery transportation, development of grading and disassembly processes, difficulty in accessing historical data of used batteries, and the lack of unified standards for used battery repurposing. The study examines 33 case studies of SLB implementation in various applications, such as reuse by EV OEMs, energy storage systems (ESS) for grid stabilization, back-up power systems, smart grids, home ESS, and portable power.

→ www.batteryconsortium.sg/sites/default/files/2021-04/REPURPOSING%20OF%20LITHIUM-ION%20BATTERIES.pdf

9 Bibliography

Agusdinata, D. B., Liu, W., Eakin, H., Romero, H., 2018. Socio-environmental impacts of lithium mineral extraction: towards a research agenda. Environmental Research Letters, 13(12), 123001. https://doi.org/10.1088/1748-9326/aae9b1

Angliviel, S., Betz, J., Manhart, A., Sahni, A., Soomro, F, 2021. Closing the Loop on Energy Access in Africa. https://www3.weforum.org/docs/WEF_Closing_Loop_Energy_Access_2021.pdf

Bustamante, X., Orfanos, A., Tedesco, R., Zill, M., 2020. The Positive Side of Batteries —The Role of Standards in Supporting Sustainability Requirements for Batteries. ECOS. https://ecostandard.org/publications/the-positive-side-of-batteries-the-role-of-standards-in-supporting-sustainability-requirements-for-batteries

Charles, R. G., Davies, M. L., Douglas, P., Hallin, I. L., Mabbett, I., 2019. Sustainable energy storage for solar home systems in rural Sub-Saharan Africa – A comparative examination of lifecycle aspects of battery technologies for circular economy, with emphasis on the South African context. Energy, 166, 1207–1215. https://doi.org/10.1016/j.energy.2018.10.053

Clean Technica, 2020. The 2nd Life Of Used EV Batteries. (Accessed Nov 15, 2022). https://cleantechnica.com/2020/06/06/the-2nd-life-of-used-ev-batteries

Climate Policy Info Hub, 2022. Climate proofing - Climate Policy Info Hub. (Accessed Nov 15, 2022). https://climatepolicyinfohub.eu/glossary/climate-proofing

European Parliament, 2022. Batteries: deal on new EU rules for design, production and waste treatment. (Accessed May 22, 2023). www.europarl.europa.eu/news/en/press-room/20221205IPR60614/batteries-deal-on-new-eu-rules-for-design-production-and-waste-treatment

Falk, J., Nedjalkov, A., Angelmahr, M., Schade, W., 2020. Applying Lithium-Ion Second Life Batteries for Off-Grid Solar Powered System—A Socio-Economic Case Study for Rural Development. Zeitschrift Für Energiewirtschaft, 44(1), 47–60. https://doi.org/10.1007/s12398-020-00273-x

Godfrey, L., Roman, H., Smout, S., Maserumule, R., Mpofu, A., Ryan, G., Mokoena, K., 2021. Unlocking the Opportunities of a Circular Economy in South Africa. In S. K. Ghosh & S. K. Ghosh (Hrsg.), Circular Economy: Recent Trends in Global Perspective, 145–180. Springer Nature. https://doi.org/10.1007/978-981-16-0913-8_5

Jacoby, M., 2019. It's time to get serious about recycling lithium-ion batteries. (Accessed Nov 15, 2022). https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28

Kendall, A., Dayemo, K., Helal, N., Iskakov, G., Pares, F., Slattery, M., Fulton, L., 2023. Electric Vehicle Lithium-ion Batteries in Lower- and Middle-income Countries: Life Cycle Impacts and Issues. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-23-09

Elgqvist, E., 2016. Lithium Ion Battery Key Elements — More Than Just Lithium. (Accessed May 22, 2023). www.manufacturingcleanenergy.org/blog-20160413.html

McKinsey, 2019. Second-life EV batteries: The newest value pool in energy storage. (Accessed Nov 15, 2022) www.mckinsey.com/industries/automotive-and-assembly/our-insights/second-life-ev-batteries-the-newest-value-pool-in-energy-storage

Mrozik, W., Ali Rajaeifar, M., Heidrich, O., Christensen, P., 2021. Environmental impacts, pollution sources and pathways of spent lithium-ion batteries. Energy & Environmental Science, 14(12), 6099–6121. https://doi.org/10.1039/D1EE00691F

Pyper, J., 2020. Second Life: Carmakers and Storage Startups Get Serious About Reusing Batteries. (Accessed Nov 15, 2022). www.greentechmedia.com/articles/read/car-makers-and-startups-get-serious-about-reusing-batteries

The Earth Awards, 2019. What are Lithium-Ion Batteries Used for? The Earth Awards. (Accessed Nov 15, 2022). www.theearthawards.org/the-common-uses-of-lithium-ion-batteries

UNCTAD, 2020. Developing countries pay environmental cost of electric car batteries. (Accessed Nov 15, 2022). https://unctad.org/news/developing-countries-pay-environmental-cost-electric-car-batteries

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