



BSI Standards Publication

Electrical energy storage (EES) systems

Part 2-201: Unit parameters and testing methods — Review of testing for battery energy storage systems (BESS) for the purpose of implementing repurpose and reuse batteries

National foreword

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A list of organizations represented on this committee can be obtained on request to its committee manager.

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TECHNICAL REPORT



**Electrical energy storage (EES) systems –
Part 2-201: Unit parameters and testing methods – Review of testing for battery
energy storage systems (BESS) for the purpose of implementing repurpose and
reuse batteries**

INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 2-201: Unit parameters and testing methods – Review of testing for battery energy storage systems (BESS) for the purpose of implementing repurpose and reuse batteries

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Full information on the voting for its approval can be found in the report on voting indicated in the above table.

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A list of all parts in the IEC 62933 series, published under the general title *Electrical energy storage (EES) systems*, can be found on the IEC website.

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INTRODUCTION

Battery energy storage systems (BESS) will become an important component of the energy infrastructure in the future as energy demand increases and the transition to sustainable power sources continues. Designing BESS using repurpose and reuse batteries requires a multidisciplinary approach that balances technical, economic, environmental, and regulatory considerations. This document reviews test methods and evaluations related to repurpose and reuse battery integration into BESS. As society seeks solutions to manage the dual challenges of energy storage and waste reduction, BESS evaluation methods become important. This report examines the obstacles to battery reuse based on the legal context and examples and aims to provide valuable insights that facilitate decision-making more efficiently.

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 2-201: Unit parameters and testing methods – Review of testing for battery energy storage systems (BESS) for the purpose of implementing repurpose and reuse batteries

1 Scope

This part of IEC 62933, which is a technical report, focuses on the necessity of using repurpose and reuse batteries in BESS. This document also illustrates, through case studies from various countries, how repurpose and reuse batteries are regulated as per legislation. Furthermore, business examples of BESS using repurpose and reuse batteries are investigated and issues derived in terms of both the design, manufacturing, testing, operation, and maintenance of BESS, considering the anticipated future deployment of BESS¹.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

battery energy storage system

BESS

electrical energy storage system with an accumulation subsystem based on batteries with secondary cells

Note 1 to entry: Battery energy storage systems include flow battery energy systems.

3.2

reuse

operation by which secondary batteries that are not waste are used again in an application

¹ Companies and products named in this document are provided for reasons of public interest or public safety. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC.

3.3 **repurpose**

utilize a product or its components in a role that it was not originally designed to perform

Note 1 to entry: This action deals specifically with products and assemblies and not materials, which fall under recycling.

Note 2 to entry: In some cases, repurposing will lead to a substantial modification, i.e., a new product which has to be placed on the market.

[SOURCE: ISO 8887-2:2023, 3.32]

3.4 **battery module**

group of cells connected together either in a series and/or parallel configuration with or without protective devices (e.g. fuse or PTC) and monitoring circuitry

[SOURCE: ISO 7176-31:2023, 3.3, modified – the term “module” has been removed.]

3.5 **battery pack**

energy storage device that includes cells or cell assemblies normally connected with cell electronics and overcurrent shut-off device including electrical interconnections and interfaces for external systems

Note 1 to entry: Examples for interfaces are cooling, high voltage, auxiliary low voltage and communication.

[SOURCE: ISO 18300:2016, 3.11, modified – the term “lithium-ion battery pack” has been removed.]

3.6 **battery management system** **BMS**

electronic system associated with a battery which has functions to maintain safety and prevent damage

[SOURCE: ISO 7176-31:2023, 3.5]

3.7 **battery rack**

support, stand or grating with one or more levels or tiers for the installation of cells or mono-bloc containers in a stationary battery

[SOURCE: IEC 60050-482:2004, 482-05-24]

4 Background

4.1 BESS market trends

The demand for storage batteries is expected to increase further in the future due to the following reasons:

- A study conducted by the National Renewable Energy Laboratory called the Renewable Electricity Futures Study [1]² showed the predicted storage needs in relation to increase of renewable energy (RE) incorporated into electric grid.

² Numbers in square brackets refer to the Bibliography.

- By 2050, storage capacity was estimated at 28 GW in the Low-Demand Baseline scenario, 31 GW in the 30 % RE scenario, 74 GW in the 60 % RE scenario, and to reach a 90 % renewable energy scenario that included 48 % wind and solar required for around 140 GW of installed storage capacity.
- As the percentage of RE connected to grid system is increased, the need for storage increases accordingly.
- In general, RE is often an unstable power supply. It is considered effective to temporarily accumulate RE in BESS for the purpose of stable supply and to utilize it as needed.

Distribution grid operations can be improved by means of a BESS.

- Network congestion: In locations where network capacity is limited during peak renewable generation hours, a BESS can store the excess energy and release it into the network when renewable generation reduces.
- Power quality: A BESS can be used to absorb the excessive supply of renewable energy and keep the voltage below the upper limit prescribed in the grid code. The BESS can be either a grid-tied or a behind-the-meter installation.

For transmission network operators, a key concern arising from the integration of renewable energy sources is the effect of the variability and intermittence of generation. The various problems created can be addressed with the help of BESS such as: forecast errors, network congestion, and increased ramping requirements during peak hours.

According to a report [2] by Benchmark mineral intelligence predicting how lithium-ion battery megafactories around the world will increase their production capacity toward 2030, lithium-ion battery production capacity is expected to increase by 400 % over the next 10 years.

- The motivators of this increase are the demand for EVs (electric vehicles) and the progress of electrification in industrial equipment.
- Bloomberg's forecast of lithium-ion battery demand and market shares for automotive, consumer, and stationary applications [3] indicates that the market share for stationary storage batteries will remain around 10 % of the total battery market, but total demand will increase significantly to nearly 2 TWh.
- According to an IEA report on global electric vehicle sales from 2010 to 2021 [4], the total number of electric vehicles on the world's roads in 2021 was approximately 16,5 million, three times the number in 2018.
- The IEA's forecast of the global electric vehicle stock for 2020 to 2030 [5] shows that the global electric vehicle stock continues to grow strongly and is expected to reach 175 million units by 2030. The availability of large battery capacities is an opportunity, especially if second-life applications are considered and can be a motivation to explore synergies between electro mobility and battery storage to support renewable energies further.

4.2 Issues on battery supply

Bloomberg NEF forecasts metal demand for lithium-ion batteries from 2020 to 2030 [6], predicting that demand for the key element in LIB cathodes will increase each year and exceed 17,5 million tons by the end of the decade. Demand for lithium is set to grow the fastest, surging more than sevenfold between 2021 and 2030.

In the lithium metal supply and demand forecast scenario reported by Shekhar et al [7], lithium metal demand shows strong growth.

Lithium supply and demand can be considered adequate through 2020, but supply and demand are expected to tighten in the future.

After 2026, it is projected that it will be essential to systematically increase the supply of lithium rapidly from the planned 100 000 tons to a value matching the demand.

The price trend of lithium carbonate in China (Shanghai market) [8] shows that lithium carbonate prices have increased significantly in recent years and are not stable.

Effective supply-demand balancing will require the reuse of waste batteries.

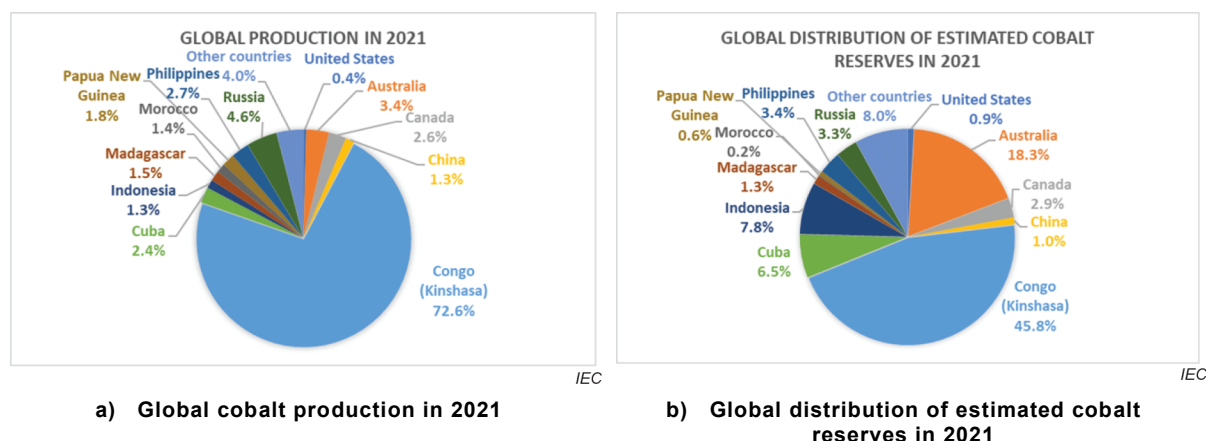


Figure 1 – Regional bias in natural resource reserves

Figure 1 (a) and (b) shows cobalt production and reserves in 2021. The earth's cobalt resources amount to 25 million tons (USGS, 2022) [9].

Most of these resources are located in the Copperbelt, a mining area that includes part of the Kantanga Province in the Democratic Republic of the Congo (DRC).

Considering the production of cobalt is about 170 ktons/year, unless a tremendous improvement in cobalt production, shortage of Co is apparent.

4.3 Motivation for the use of reuse batteries

As one way to compensate for the lack of resources, the use of batteries that are no longer needed in primary use is considered to be effective.

As electrification advances, the amount of battery waste increases.

Some of the used batteries are said to have residual performance that meets the requirement for secondary use.

Estimates of the number of waste batteries and where they originated [10] indicate that a large and rapidly growing number of waste batteries are being generated not only from EVs but also from buses and energy applications. Batteries used secondarily in this way have various histories and are expected to be distributed in the market in various forms.

4.4 Configuration of reuse batteries

There are key stages in the typical process of secondary use of used electric vehicle (EV) batteries (e.g., <https://global.nissanstories.com/en/releases/4r>). The stages include dismount battery pack from EV, refurbishing for reuse, integration of reuse batteries.

Given that the batteries in EV vehicles are in a packed state, the level of refurbishing process affects how the batteries are reused. Specifically, whether the battery is in the smallest cell state, the module state, or in the pack state affects how reuse batteries are incorporated into the secondary use system.

The cell comes in several standard shapes, providing the advantage of utilizing the existing assembly process. On the other hand, if refurbishing costs are taken into account, disassembling down to the cell level can be disadvantageous, especially when aiming for cost-effective reuse batteries.

Since modules and packs are often equipped with circuits designed to control cells, it is essential to ensure that accurate control remains feasible within the secondary use system. Additionally, in most cases, the shape of module and packs conforms to their original purpose, therefore potentially necessitating considerations to rebuilding for secondary use.

There exists a substantial likelihood of encountering batteries with various shapes within the reuse battery market, demanding careful attention during their secondary use [11] (see for example: Recycling 2016, 1, 25-60; doi:10.3390/recycling1010025).

5 Regulatory trends of repurpose and reuse batteries

5.1 Overview

Regulatory trends on repurpose and reuse batteries vary between regions and countries reflecting differences in economic, safety and other environmental priorities (see Table 1). Clause 5 provides a general overview of regulations in different regions. It is important to understand the regulations change over time. For accurate and up-to-date information, it is recommended to refer to official government agencies responsible for these issues.

The purpose of Clause 5 is to understand how varying regional regulations shape criteria for evaluating the efficiency, reliability and performance of BESS using repurpose and reuse batteries. It is also aimed to gain an understanding of evaluation methods needed to balance between compliance requirements and sustainable energy solutions.

Table 1 – Regulatory trends on repurpose and reuse batteries of different regions

Region	Regulatory trends
EU	COM(2020) 798 final: The European Commissions adopted a draft regulation on batteries and waste batteries (COM(2020) 798) to replace the current Battery Directive (2006/66/EC). The final document came into force as EU Battery Regulation 2023/1542 in August 2023 [29].
US	National Blueprint for Lithium Batteries 2021-2030 - Establishing a domestic supply chain for lithium-based batteries. - Solve breakthrough scientific challenges for new materials and developing a manufacturing base that meets the demands of the growing EV and electrical grid storage markets.
China	Promulgation of new energy vehicle power storage battery cascade utilization management measures (2021) - Strengthen management and clarify responsibilities for EV battery recycling (including repurpose and reuse). - Companies cascade usage according to standardization.
Japan	Amendment to Ordinance for Enforcement of the Recycling Law for Electronic Products, etc.in 2021 - Promoting the construction of a collection, storage, and reuse system for used EV batteries. Study Group on Sustainability of Storage Batteries in 2022. - Consideration for building a sustainable storage battery supply chain

5.2 Regulatory trend in China

5.2.1 Battery utilization based on capacity

Subclause 5.2 discusses the application scenarios and industrial policies related to power battery echelon utilization in China. Battery echelon utilization involves repurposing batteries after their capacity declines to decommissioning levels. Echelon utilization refers to the practice of repurposing or reusing items, typically in a hierarchical manner, after their primary use or function has declined or come to an end.

Through power quality, safety, and economic evaluations, these batteries are sorted and reorganized to meet low-standard use scenarios.

Figure A.1 in Annex A shows various applications of power battery echelon utilization, which aims to maximize the remaining capacity of retired batteries and categorize them for specific use cases such as cyclic energy storage and backup power.

The criteria for decommissioning and classification are outlined in the regulation. EV batteries with reduced charge and discharge capacity below 80 % of the initial value are retired due to safety concerns. Decommissioned batteries are classified into Class I (60 % to 80 % capacity), Class II (20 % to 60 % capacity), or recycled (less than 20 % capacity). Referring to established standards enables the elimination of unfit batteries and the classification of those with remaining capacity for various scenarios.

Retired traction batteries with capacities of 80 % to 60 % can be used for load storage, grid connection, and power regulation, while those with capacities of 60 % to 20 % are suitable for backup power in emergency scenarios. These applications include daily lighting, UPS backup, low-speed electric vehicle power supply, and temporary remote power. Subclause 5.2 underscores the importance of repurposing batteries to enhance their value across their entire lifecycle.

5.2.2 Industrial and national policies

National and local government policies, along with industry association assistance, support the development of the power battery echelon utilization industry in China.

China has issued policies since 2012 to support power battery echelon utilization. Policies include energy-saving plans, technical policies for recycling, interim measures for battery recycling administration, pilot implementation plans, and management measures for echelon utilization.

These policies clarify management requirements, focus on quality, support R&D, encourage collaboration, and provide tax incentives.

The Power Battery Recycling and Echelon Utilization Alliance was established in 2019 to explore economy, safety, protection, and resource maximization of power batteries. Alliance activities, industry summits, and group standards have been initiated to promote industry norms and standards.

China has established a standard system framework for traction battery echelon utilization. It includes general standards for battery specifications, coding rules, dismantling specifications, and residual capacity detection. Echelon utilization standards cover requirements at the national level and normative requirements for local utilization.

5.2.3 Local policy (Shanghai) and business models

Shanghai Municipal Government's action plan aims to develop the recycling industry of retired power batteries. It focuses on building a traceability and management recycling network system and promoting recycling technology, equipment, and industry clusters.

Policies, incentives, and demand drive the construction of the power battery echelon utilization industry chain and business models. An authoritative body plays a role in catalysing application scenarios and business models, leveraging the strength of the industry chain. The summarized content provides an overview of battery utilization based on capacity, the role of industrial policies, national and local policies, standardization framework, and business models driving the development of the power battery echelon utilization industry in China.

Detail of policies and business models are provided in Annex A.

5.3 Regulatory trend in the European Union

5.3.1 European Battery Directive

The European Battery Directive is a regulatory framework established by the European Union (EU) to manage the environmental impact of batteries. It aims to reduce the negative effects of batteries on the environment by promoting their proper collection, recycling, and disposal.

In terms of reuse batteries, the directive emphasizes the importance of extending the lifespan of batteries through various means, including reuse. It encourages member states to establish collection systems that allow for the reuse of batteries, provided that safety, health, and environmental requirements are met. The directive also states the need of recycling over disposal and encourages the development of technologies that can enhance the reusability of batteries.

There exist two articles in the European Battery Directive (Article 14 and Article 59) which refer to reuse batteries.

Article 14 is titled "Information on the state of health and expected lifetime of batteries". According to Article 14, industrial and EV batteries over 2 kWh require management systems detailing health and lifespan parameters based on Annex VII. Information on Annex VII is given below in this subclause.

Article 59 is titled "Requirements related to the repurposing and remanufacturing of industrial batteries and electric-vehicle batteries". Among the 6 statements in Article 59 there are 4 statements concerning repurposing and remanufacturing. Regulation introduces requirements related to the repurposing and remanufacturing of electric vehicle and industrial batteries to independent operators carrying out such operations. It also requires parameters in Annex VII for determining the state of health of batteries and expected lifetime of batteries.

The following are parameters for determining the state of health of batteries in Annex VII of the European Battery Directive:

- 1) remaining capacity;
- 2) overall capacity fade;
- 3) remaining power capability and power fade;
- 4) remaining round trip efficiency;
- 5) actual cooling demand;
- 6) evolution of self-discharging rates;
- 7) ohmic resistance and/or electrochemical impedance.

The following are parameters for determining the expected lifetime of batteries in Annex VII of the European Battery Directive:

- a) the dates of manufacturing of the battery and putting into service;
- b) energy throughput;
- c) capacity throughput.

5.3.2 European Automotive and Industrial Battery Association (EUROBAT)

EUROBAT is an association representing the interests of the European automotive, industrial, and energy storage battery industries. It serves as a platform for various battery manufacturers, suppliers, and other stakeholders within the battery value chain. EUROBAT aims to promote sustainable battery technologies, support the growth of the European battery industry, and advocate for policies that foster innovation and competitiveness.

In relation to the European Battery Directive, EUROBAT plays a role in providing input, expertise, and insights from the battery industry to inform policy decisions and regulatory developments. Overall, EUROBAT serves as a bridge between the battery industry and regulatory authorities, working to ensure that the European Battery Directive's provisions align with industry capabilities, advancements, and sustainability goals.

Details of activities are provided in Annex B.

5.4 Regulatory trend in Japan

In Japan, there is a notable trend towards addressing carbon neutrality and greenhouse gas reduction. In October 2020, the Japanese government declared its aim to achieve carbon neutrality by 2050, with zero overall greenhouse gas emissions. This was followed in October 2021 by the Cabinet's approval of a 46 % greenhouse gas reduction target for 2030 compared to 2013 levels.

In response to these goals, the Ministry of Economy, Trade and Industry (METI) established a public-private council to study the storage battery industry strategy in November 2021. The council began its activities and published the Storage Battery Industry Strategy in August 2022. A subcommittee called the Study Group on Sustainability of Storage Batteries was initiated in January 2022 as a part of this council. This subcommittee focuses on topics such as carbon footprint, human rights, environmental due diligence, reuse, and data collaboration.

The Storage Battery Industry Strategy emphasizes the significance of batteries in achieving carbon neutrality by 2050, especially in the context of electric vehicles (EVs) and renewable energy deployment. The strategy includes seven key items, with several related to battery reuse:

- 1) strengthening domestic manufacturing through policy measures;
- 2) forming global alliances and standards;
- 3) ensuring upstream resource availability;
- 4) developing next-generation technologies;
- 5) expanding the domestic market for batteries, particularly EVs;
- 6) enhancing human resources development;
- 7) improving the domestic business environment.

Key efforts in the strategy related to reuse are the formation of global alliances and standards, expansion of the domestic battery market, and improving the domestic business environment.

The Study Group on Sustainability of Storage Batteries focuses on several initiatives:

- a) carbon footprint;
- b) human rights and environmental due diligence;
- c) reuse and recycle;
- d) data collaboration.

Under the carbon footprint initiative, discussions revolve around calculating the carbon footprint of battery products, including areas such as calculation scope, measurement methods, emission intensity, units of comparison, and data exchange among stakeholders. The initiative is supported by a trial project that collaborates with automotive Original Equipment Manufacturers (OEMs) and suppliers to calculate and disclose carbon footprint information.

The human rights and environmental due diligence initiative addresses risks related to the environmental and human rights impacts of battery materials, particularly minerals like lithium, cobalt, nickel, and graphite. A trial project examines risks associated with mining practices, focusing on both environmental and social aspects.

Regarding reuse and recycle, research is ongoing to understand the distribution of used batteries, especially their applications and market conditions after dismantling. The data collaboration initiative explores sharing and utilizing supply chain and value chain data across companies, with an emphasis on maintaining corporate trade secrets and data sovereignty.

Overall, Japan's efforts focus on achieving carbon neutrality, expanding the battery market, and addressing sustainability and environmental concerns in the storage battery industry through initiatives related to carbon footprint, human rights, reuse, and data collaboration.

See Annex C for details.

5.5 Regulatory trend in Korea

In South Korea, the electric vehicle (EV) market is poised for significant growth, projected to surge from \$136 million in 2020 to \$187 million in 2025. In 2022, the Korean EV market saw the distribution of 389 855 electric vehicles, and a forward-looking analysis suggests that by 2032, 20 % of reused batteries could amount to 3,2 million units.

The Korean Battery as a Service (BaaS) industry is strategically focused on repurposing EV batteries for energy storage systems (ESS), fostering a circular economy. Government policies are evolving to support this initiative, including waste regulation exemptions, safety standards, and independent battery supply systems. A BaaS demonstration project is outlined in the industrial innovation base construction roadmap, with the Ministry of Land, Infrastructure and Transport preparing a battery registration system.

Various Korean companies are actively involved in the second life of batteries. Testing and certification centre, such as KTR (Korea Testing Research Institute), is establishing safety and reliability inspection technologies, with plans for a BaaS platform data centre, battery storage facility, and testing facilities to support the growing BaaS market.

This comprehensive approach aims to create a robust ecosystem for battery reuse and repurposing, aligning with the broader goal of sustainable and efficient energy practices in Korea's electric vehicle sector.

See Annex D for details.

6 Case studies for BESS using repurpose and reuse batteries

6.1 General

As mentioned above, BESS are becoming increasingly important for grid stabilization, renewable energy integration, and other energy management applications. Reuse of batteries in BESS involves repurposing used batteries from EVs or other sources for secondary use in stationary energy storage applications. Figure 2 shows a value chain that uses retired EV batteries in a cascade that is being built to improve resource utilization and reduce CO₂ emissions.

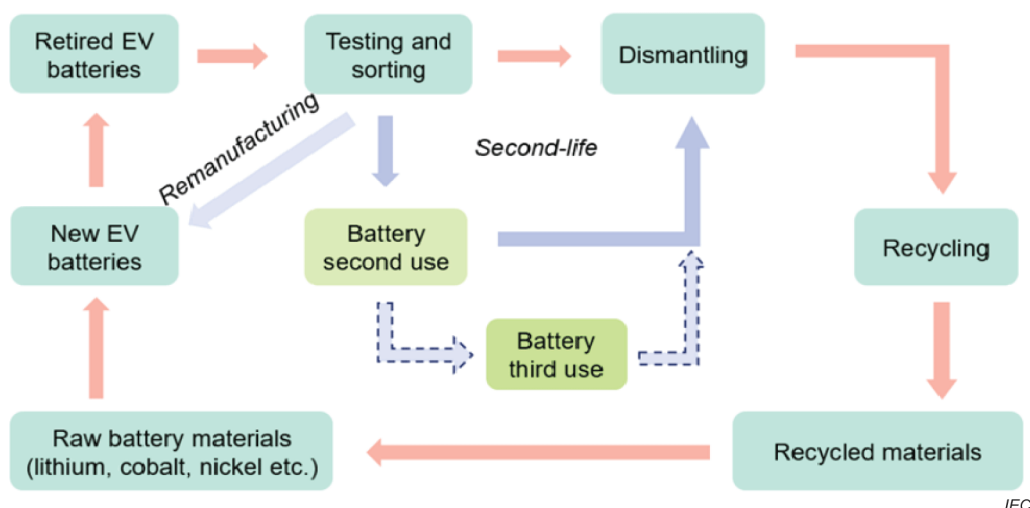


Figure 2 – Close-loop value chain of EV batteries

Table 2 shows examples of repurpose batteries utilized for BESS using batteries in EVs. EV batteries typically have a useful life in vehicles before their capacity declines below a certain level. However, these batteries can still have significant energy storage capacity remaining for stationary applications. Companies have started repurposing retired EV batteries for use in BESS. These batteries might not have sufficient capacity for driving an EV but can be aggregated into energy storage systems to support renewable energy integration, grid stability, and peak demand management.

Table 2 – Examples of repurpose batteries utilized for BESS

Players	Type	Region	MWh	Details
BMW	Automotive OEM	EU	20 ('17~)	Development of MWh-class BESS and progress in connection to the power grid using 500 used BMW i3 batteries. It can supply up to 14 MW of power.
Renault	Automotive OEM	EU	20 ('18~)	Developed a 20 MWh BESS for their own factory using a total of 650 new/used batteries. Plan to use both grid power control & demand power adjustment.
GETEC	Electric utility	EU	13, 18 ('16, '19~)	Constructed a 1,8 MWh class battery plant with a total of 1 000 battery systems. Reuse of 1 920 modules from Daimler EV battery packs in collaboration with Mercedes-Benz Energy.
State Grid	Electric utility	CN	45 ('20~)	Constructed a 45 MWh BESS in Nanjing City using used EV batteries. Started operation from the first half of 2020.
China Tower	Communication	CN	60 ('18~)	Reused 9 600 sets of used EV batteries in Jiangsu Province and effectively utilized the storage capacity of about 60 MWh. Substitutes 1 800 tons of lead acid battery.
B2U	Startup	US	4 ('20~)	To relieve the burden on the power grid due to the introduction of renewable energy with volatile output with used EV battery solutions and battery operations optimization system.

Reuse batteries can also be used in residential energy storage systems. These systems store excess energy generated from solar panels and discharge it when needed. By repurposing EV batteries for residential use, homeowners can take advantage of the remaining capacity in retired EV batteries to power their homes, reduce energy bills, and contribute to grid stability.

In some cases, reuse batteries are used in community-level energy storage projects. These projects might involve using retired EV batteries to create microgrids that can provide backup power during outages or support renewable energy integration within a localized area.

Below are several examples listed, along with their characteristics.

6.2 Case 1 (China)

As mentioned in Clause 5, government and municipal levels have established laws, regulations, and so forth. Operational practices in accordance with these laws and regulations are already in place.

The case study in China on retired power battery utilization highlights several key points:

- 1) Recycling advancement in Shanghai: Shanghai's plan to promote green industries emphasized retired power battery utilization. Concentrated in regions with high electric vehicle ownership, Shanghai had five enterprises aligning with the "New Energy Vehicle Waste Power Battery Comprehensive Utilization Industry Specification Conditions." In July 2022, Shanghai achieved its first localized battery disassembly and utilization line at Shanghai Weixiang Zhongyi New Energy Technology Co., forming a sustainable mechanism for waste battery recycling and setting a benchmark for environmentally-friendly and advanced energy recycling.
- 2) Battery energy storage system (BESS) demonstration: Shanghai Yixin Environmental Protection Co., founded in 2018, focused on recycling, testing, and utilizing retired electric vehicle batteries. They qualified as a national high-tech enterprise and established a robust recycling production line, including rapid testing and sorting platforms. They also introduced the "Baowu Qingneng–Factory Environment Decommissioned Power Battery Energy Storage Demonstration Station" to showcase battery repurposing for energy storage.
- 3) Echelon utilization in 5G base stations: Hangzhou Yuhang District Power Supply Company innovatively supplied stable energy to 5G base stations using retired batteries. By transforming a base station in Chaoshan Scenic Area, they achieved substantial savings. They adapted to peak-shaving and demand-side response, showcasing the potential of retired battery reuse in powering communication infrastructure.
- 4) Future prospects and trends: The trend of diverse battery applications continues, expanding the opportunities for retired battery utilization. The demand for base station backup batteries grew in 2021, indicating a rising need for echelon utilization. Bulk retirement of lithium iron phosphate batteries since 2022 makes a significant volume available for gradual use, fostering continued growth.
- 5) Challenges and opportunities: Technical gaps exist in sorting, reconstitution, consistency assessment, and remaining life detection. Intelligent manufacturing holds promise to overcome these challenges, enhancing the safety and reliability of reused products and industry chain maturity.

These case studies underscore China's strategic approach to retired battery reuse, promoting sustainability and innovation in various sectors, including energy storage and communication infrastructure.

See Annex D for details.

6.3 Case 2 (UK)

The UK case study focuses on an entity that pioneers the repurposing and second life use of BESS. This entity collaborates with partners like a vehicle manufacturer, an energy company, and a venture capital firm. The approach of this entity involves reusing EV batteries for energy storage, contributing to a greener energy alternative and a circular economy. It provides benefits like reducing energy costs, optimizing renewable energy usage, managing peak loads, and generating revenue by offering grid balancing services. The specifications of their BESS include power, capacity, and the use of second life EV batteries. Additionally, this entity collaborates with another entity to deploy transport battery systems into stationary energy storage.

The installations by this entity include repurposing EV batteries for grid load management of electric vehicle rapid chargers and monetizing excess power for an industrial corporation, which bridges power quality gaps and generates revenue. There is also collaboration with an automotive brand that provides stationary energy storage solutions for various applications, including peak load balancing and integration of renewable energies. This automotive brand uses its proprietary Battery Control System to standardize the interface for controlling and operating EV batteries in stationary energy storage applications, ensuring optimal battery state for compliance and longevity. The spare parts store for EV batteries of this automotive brand is transformed into a large stationary storage facility with significant capacity for energy storage and market participation in the primary balancing power market in Germany.

See Annex E for details.

6.4 Case 3 (Japan)

The Japanese case study focuses on repurposing EV batteries for BESS used in virtual power plants (VPPs). An integrated control system was developed to manage multiple EV batteries alongside distributed power sources like renewable energy. This aimed to assess battery responsiveness and degradation. The repurposing scheme involves BESS manufacturers utilizing battery packs selected by a reuse-focused entity, supported by an automotive manufacturer and a trading company. The certified battery packs are transformed into BESS using prior information from the automotive manufacturer. Communication between the BESS control system and battery management unit (BMU) is vital. The study addresses challenges like varying battery conditions by using split DC/DC converters to adjust current distribution and ensure continuous operation.

See Annex G for details.

6.5 Case 4 (Australia)

In Australia, several startup entities have initiated battery repurposing projects for BESS. The collaboration between a battery management and inverter control project and a vehicle manufacturer has resulted in the creation of a project. This project repurposes used EV batteries from a specific vehicle model into a 36 kW, 120 kWh BESS. This BESS is integrated into a broader initiative, which targets the reduction of CO₂ emissions and energy savings at a specific manufacturing facility. The BESS specialist concentrates on battery management and inverter control technologies.

Another endeavour undertaken by a startup based in Melbourne entails the repurposing of used EV batteries from a certain vehicle model to develop a 120 kWh BESS. This BESS is intended to be connected to rooftop solar and other renewable energy sources. It will function as an industrial backup or off-grid power source in the facility owned by the startup entity. This initiative, which is part of a larger corporate group, has plans to introduce this BESS product to the market by March 2024.

See Annex H for details.

As the example shows, the BESS to which the reuse battery is applied is installed with various roles for the power grid. Another characteristic of the two examples is that the reuse battery is supplied from a specific automotive OEM.

6.6 Case 5 (North America)

In North America, several startup companies have launched battery repurposing projects for creating BESS. These initiatives involve a range of activities and applications:

Energy initiatives:

- Developed a 40 kVA to 320 kVA ESS using used batteries.
- Used batteries from a renowned automaker are utilized for 60 kWh ESS units.
- Target applications include commercial and industry, microgrids and off-grid, and utilities.

Innovative power systems:

- Installed a 200 kW rooftop PV at UC San Diego with a 500 kWh ESS.
- Reused batteries are applied in their energy storage system "MOAB."
- MOAB effectively supports the PV system and reduces grid demand after sunset.

Sustainable solutions:

- Developed an ESS with a maximum capacity of 1,2 MWh using EV batteries.
- Used well-known EV battery modules for a 60 kW/275 kWh BESS.
- Targeting commercial and industrial applications, with a product launch planned for 2023.

Resourceful storage solutions:

- Deployed a 25 MWh ESS in Lancaster, California, using 1300 used battery packs.
- Collaborated with various automakers for battery supply.
- BESS is integrated into the hybrid energy storage and solar facility.

Innovative robotics:

- Offers an automated solution for repurposing retired EV batteries.
- Focuses on designing sustainable battery solutions and disassembling batteries for repurposing.
- Potential supplier of repurpose batteries without relying on specific OEMs.

These case studies demonstrate diverse applications of repurpose EV batteries for BESS, contributing to sustainable energy solutions across various sectors and industries.

See Annex I for details.

6.7 Case 6 (Korea)

Korea is prioritizing environmental protection and efficient resource use by intensifying efforts to reuse, repurpose, and recycle batteries, aligning with international regulations such as the Korean government's battery policy and the EU battery law.