IEC TR 62933-2-201

Edition 1.0 2024-09

TECHNICAL REPORT

colour inside

Electrical enery 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

IEC TR 62933-2-201:2024-09(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TR 62933-2-201

Edition 1.0 2024-09

TECHNICAL REPORT

colour inside

Electrical enery 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
COMMISSION

ICS 13.020.30; 29.220.99

ISBN 978-2-8322-9516-8

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 62933-2-201 has been prepared by IEC technical committee 120: Electrical Energy Storage (EES) systems. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
120/366/DTR	120/379/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 BESS[1].

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.

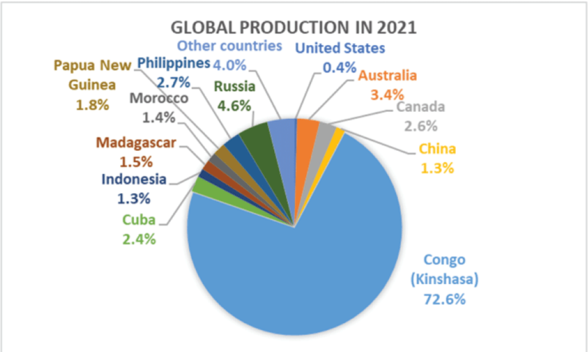
In the lithium metal supply and demand forecast scenario reported by Shekhar et al [7], lithium metal demand shows strong growth.

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

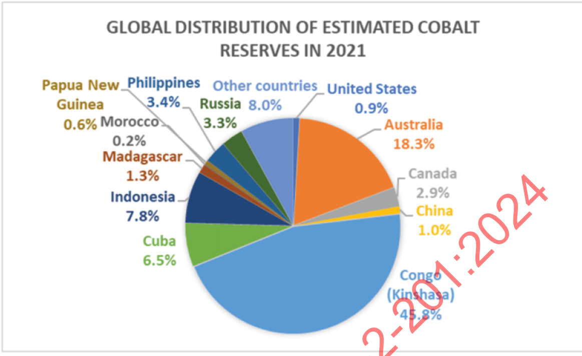
After 2026, it is projected that it will be essential to systematically increase the supply of lithium rapidly from the planned 100 000 tons to a value matching the demand.

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.



a) **Global cobalt production in 2021**



b) **Global distribution of estimated cobalt reserves in 2021**

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 (2066/66/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 CO_2 emissions.

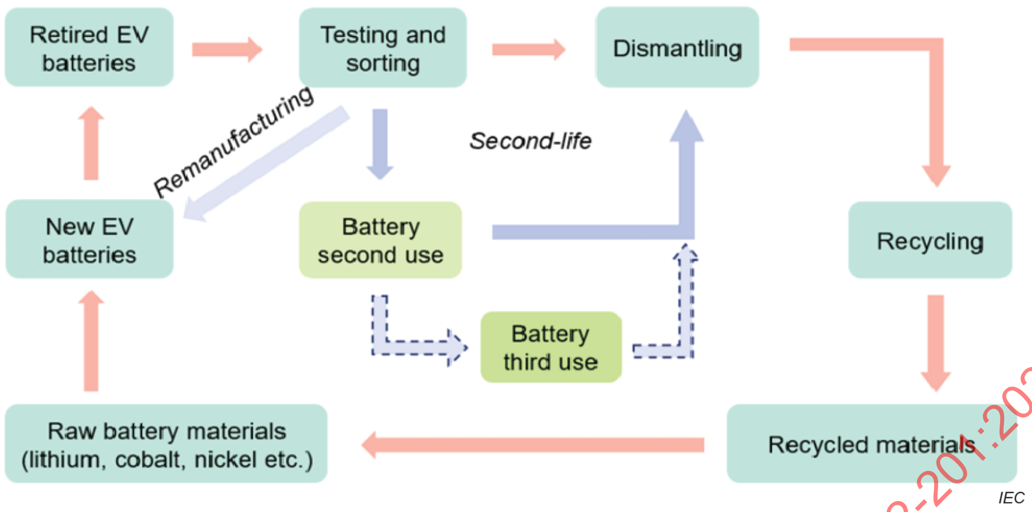


Figure 2 – Close-loop value chain of EV batteries

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 CO_2 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.

The government is actively establishing battery-related centres across regions. Companies in Korea evaluate battery performance based on State of Health (SOH) to make informed decisions on reuse, repurposing, and recycling, contributing to environmentally friendly and economically efficient battery use. Ongoing advancements in battery condition estimation technology and life prediction models by government organizations and companies aim to enhance the accuracy of SOH estimation techniques, improving the quantity and quality of recyclable batteries.

The activation of the Battery as a Service (BaaS) industry in Korea aims to create a sustainable business model and extend the life of batteries while promoting an eco-friendly approach. Notably, Korea's collaborative efforts between the government and companies are yielding positive results in the sustainable direction of the battery industry.

See Annex J for details.

6.8 Summary of case studies

A comparison of the BESS manufacturing process flow using new batteries with a BESS manufacturing example using repurpose and reuse batteries described above can be summarized as in Figure 3.

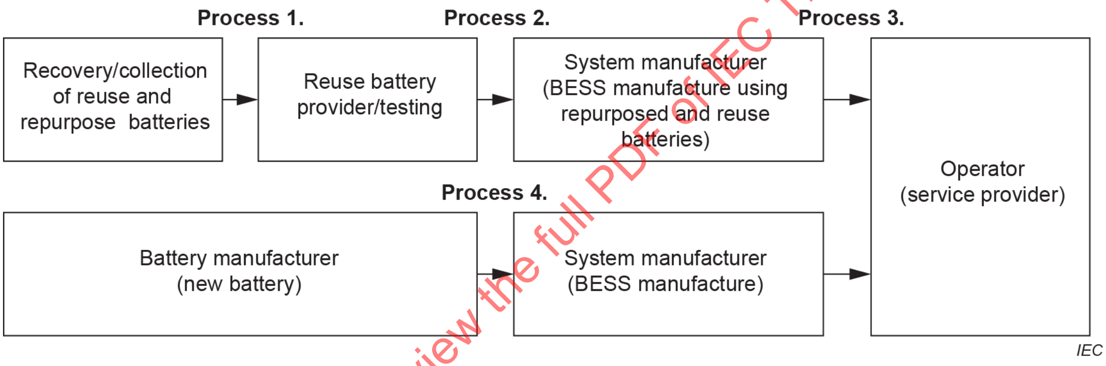


Figure 3 – Flow of BESS manufacture and service

In the process 2 of accepting reused batteries, as illustrated in the aforementioned cases, it can be inferred that the degree of preparation varies for "Recovery/collection of reuse and repurpose batteries" and "Reuse battery provider/Testing," each performed by different entities.

As shown in the process 4 of Figure 3, when dealing with new batteries, the battery manufacturer provides batteries that conform to the system specifications. On the other hand, when utilizing repurpose and reuse batteries, the BESS manufacturer implements them based on the testing results of the "Reuse battery provider."

As seen in the cases above, the "Reuse battery provider" can involve automotive OEMs that can provide a certain level of information about the batteries' primary use. However, there is a possibility where there are no automotive OEMs engaged in the process. When automotive OEMs are involved, the manufacturer can receive accurate information. However, in cases where OEMs are not involved, the BESS manufacturer is expected to make decisions based on their own judgment.

Therefore, compared to using new batteries, avoiding malfunctions in a BESS using reuse batteries compared to using new batteries requires additional precautions and considerations due to the unique challenges posed by repurpose and reuse batteries. The following compares steps to take for each process:

a) Using new batteries:
   - Standard testing: New batteries come with well-defined specifications and performance characteristics. Manufacturers can rely on standardized testing procedures to ensure their suitability for the BESS.
   - Reliable source: Purchase new batteries from established battery manufacturers or authorized distributors, ensuring their quality and compliance with safety standards.
   - Predictable performance: The BESS is designed with confidence, knowing that the new batteries will perform within expected parameters, reducing the risk of malfunctions.
   - Warranty protection: Leverage warranties provided by battery manufacturers to cover potential malfunctions, replacements, and repairs.
   - Standard design guidelines: Follow industry-standard design guidelines and practices to integrate new batteries into the BESS with minimal risk of malfunctions.
b) Using repurpose and reuse batteries:
   - Comprehensive testing: Conduct thorough and specialized testing on repurpose and reuse batteries before integration to uncover hidden defects, weaknesses, and performance variations.
   - Reputable sources: Source repurpose and reuse batteries from reliable and reputable recycling facilities or vendors with a track record of quality repurposing.
   - Stringent selection criteria: Establish strict criteria for selecting repurpose and reuse batteries based on factors such as capacity, age, performance, and safety records.
   - Safety protocols: Develop and implement safety protocols specifically designed for the use of repurpose and reuse batteries to minimize the risk of malfunctions.
   - Enhanced monitoring: Utilize advanced battery management systems (BMS) or power control systems (PCS), or both, that can handle the unique characteristics of repurpose and reuse batteries and provide real-time monitoring and early warning systems. It is noted that the specific characteristics of reused batteries can vary based on the reprocessing methods and the type of original battery being reused. The detail will be described in Clause 8.
   - Performance thresholds: Define performance thresholds and alarms in the BMS to trigger protective actions or shutdowns if repurpose and reuse batteries exhibit abnormal behavior.
   - Redundancy and isolation: Incorporate redundancy and isolation mechanisms in the BESS design to mitigate the impact of repurpose battery malfunctions on critical systems.
   - Frequent maintenance: Implement a proactive maintenance schedule that includes regular inspections and testing of repurpose and reuse batteries to identify potential issues early.
   - Advanced data analytics: Use data analytics tools to monitor the performance of repurpose and reuse batteries over time and identify any patterns that could lead to malfunctions.
   - Emergency response plan: Develop a comprehensive emergency response plan specifically tailored to repurpose and reuse batteries to manage malfunctions and safety risks.
   - Vendor collaboration: Collaborate closely with repurposing and reuse battery vendors or experts to ensure proper integration and ongoing support for repurpose batteries.
   - Continuous evaluation: Continuously evaluate the performance and reliability of repurpose and reuse batteries within the BESS and be prepared to transition to new batteries if ongoing issues arise.

Avoiding malfunctions with repurpose batteries involves specialized testing, stringent selection processes, enhanced safety protocols, advanced monitoring systems, and a proactive approach to maintenance and evaluation. While using new batteries offers more predictability and fewer challenges, repurpose batteries can be incorporated successfully with careful planning, testing, and ongoing vigilance to ensure the reliable and safe operation of the BESS.

7 Issues from the viewpoint of utility and user

7.1 Overview

The contribution of BESS to the power grid can be considered to depend on the size of the BESS. Both large and small-scale grid operators contribute to overall grid stability and efficiency, but the scale and complexity of their responsibilities vary based on the size of the grid they manage. The following are issues from the viewpoint of utility and user of large-scale BESS and small-scale BESS.

7.2 Grid operator and large-scale BESS user's point of view

A large-scale grid operator bears a comprehensive set of responsibilities aimed at ensuring the robust and efficient operation of a regional or national electricity grid. At the core of their role is the responsibility to maintain grid stability by effectively balancing the supply and demand of electricity, regulating parameters like frequency and voltage, and preventing disruptions that could impact both consumers and industry. A redundant design is required as a system. In addition, it is important to reduce the maintenance and batteries exchange time. The repurpose battery system will be required the best O&M manuals and the handing training.

The operator's scope encompasses managing the complexity of energy flow within the grid, strategically coordinating the generation sources to meet varying demand patterns and overseeing the distribution of power to residential and commercial sectors. The responsibility extends to the management of high-voltage transmission networks that facilitate the long-distance transport of electricity, as well as the administration of lower-voltage distribution networks that deliver energy to end-users and integrate decentralized energy resources such as renewable energies. In order to avoid limitation of the operation, it is important to accurately measure the repurpose battery's BESS parameters such as state of energy (SOE) and state of health (SOH).

In the case of emergencies, a large-scale grid operator is tasked with swift response and recovery, aiming to restore power promptly and safeguard public safety. They navigate the complexities of integrating renewable energy sources into the grid, optimizing their contributions while managing the intermittency inherent in sources like solar and wind. Engaging in energy markets, ensuring regulatory compliance, making data-driven decisions, planning infrastructure upgrades, and embracing technological advancements are all key components of their multifaceted responsibilities.

7.3 Small-scale BESS user's point of view

Operating a small-scale, localized BESS with repurpose and reuse batteries entails to ensure efficient and safe energy storage within the local grid. The primary considerations revolve around battery evaluation and selection, emphasizing the need for meticulous assessment to choose batteries with optimal health and performance characteristics. Continuous performance monitoring becomes crucial, enabling operators to promptly identify any signs of degradation or inefficiencies and make informed decisions.

Safety and risk mitigation stand as paramount aspects in the operation of a localized BESS with reused batteries. Users need to be aware that repurpose batteries have a greater risk than new batteries and have a risk of fire, explosion, and toxic gas poisoning. Users need to be knowledgeable of safety manual for the use of repurpose and reuse batteries and prepare for the risks. Rigorous implementation of safety measures is imperative due to the potential variability in the condition of reused batteries. Operators must be vigilant in managing associated risks to protect both local communities and the environment, ensuring that the BESS operates securely within the grid infrastructure.

Regulatory compliance is also a concern, as operators need to fulfil specific requirements related to repurpose and reuse batteries. Complying with industry regulations and safety standards is essential to ensure legal compliance and uphold the safety and reliability of the localized BESS. Lifecycle management is also critical for the long-term efficiency of the system in consideration of mean time between failure (MTBF) and mean time to failure (MTTF). Small-scale operators must ensure that the reused batteries selected can maintain consistent, reliable performance over time, aligning with the BESS's operational span.

In addition to these technical considerations, localized BESS operators should prioritize seamless integration with the local grid, actively engage with consumers to foster understanding and trust regarding the use of reused batteries and remain attentive to environmental responsibilities by responsibly managing the end-of-life disposal or recycling of batteries. Collectively, these aspects form a comprehensive approach to operate a small-scale BESS effectively and responsibly with repurpose and reuse batteries within a localized energy ecosystem.

7.4 Summary

Grid operators' responsibilities differ based on the size of the grid they oversee. Large-scale grid operators manage expansive regional or national grids, emphasizing grid stability, renewable integration, market participation, and infrastructure planning. Their intricate role involves coordinating diverse energy sources, maintaining grid stability, integrating significant renewable capacities, participating in complex energy markets, and shaping regional energy policies through regulatory compliance.

Small-scale grid operators focus on localized distribution grids serving specific communities. Their responsibilities revolve around efficient energy distribution, managing local demand, and integrating distributed energy resources. These operators prioritize voltage regulation, load balancing, and rapid response to local emergencies to ensure reliable power supply to their serviced areas. Consumer engagement and promoting energy efficiency are also crucial aspects, with a narrower scope of regulatory adherence compared to their larger counterparts.

While both types of operators contribute to grid stability, large-scale operators bear the complexities of managing diverse energy sources on a regional or national scale, while smaller-scale operators concentrate on ensuring reliability within their localized service areas, incorporating distributed renewables, and engaging directly with local consumers to promote efficient energy consumption.

The stability and reliability required for these BESS, whether using new batteries or reused batteries, need to achieve the same level of performance. However, when using repurpose and reuse batteries, due to the higher uncertainty on the battery side, there will be a greater burden on the user and operator in terms of operations and maintenance (monitoring, inspection, maintenance).

In other words, since the various margins and safety factors inherent in BESS using new batteries cannot be expected when using reused batteries, they must be supplemented through system design and operation (operations and maintenance).

Therefore, it is essential to investigate and propose standardizations for these aspects in advance. In particular, the effective treatment of the uncertainty of the tested performance of repurpose and reuse batteries during the BESS operation is significant, which will be described in Clause 8.

8 Comprehensive testing with intensive monitoring of BESS

8.1 Current status of testing methods

IEC 62933-2-1 to IEC TS 62933-2-3 implement the following tests for ESS systems including BESS.

IEC 62933-2-1, *Electrical energy storage (EES) systems – Part 2-1: Unit parameters and testing methods – General specification*

IEC TS 62933-2-2, *Electrical energy storage (EES) systems – Part 2-2: Unit parameters and testing methods – Application and performance testing*

IEC TS 62933-2-3[3], *Electric Energy Storage (EES) Systems – Part 2-3: Unit parameters and testing methods – Performance assessment test after site operation*

BESS using repurpose batteries can encounter difficulties that cannot be covered by the above items. On the other hand, the following two prior documents, i.e. IEC 63338 and IEC 63330-1, have contained the testing procedure of repurpose battery for accumulation subsystems.

IEC 63338[4], *General guidance on reuse and repurposing of secondary cells and batteries*

IEC 63330-1[5], *Repurposing of secondary batteries – Part 1: General requirements*

IEC 63338 provides an overview of a flow of battery evaluation for reusing or recycling secondary batteries.

IEC 63330-1 [19] specifies the classification of repurpose batteries. It shows the required performance to be assessed for repurposing the batteries after original use; for example operating range, history of failure, residual capacity, residual usable period. Residual capacity and usable period are used to classify batteries to be repurpose to other applications such as BESS (see Figure 4). Also, it describes the concept for estimating the residual usable period after repurposing. If the load conditions are the same as to those of original use, the residual usable period can be estimated by extrapolating the trajectory (performance-duration). If the load conditions of the new application using repurpose batteries are lighter or heavier, the residual usable period should be extended or shortened.

When considering the design, installation and operation of BESS with the repurpose and reuse batteries, some issues in systems perspective are still pending, which are not covered by either IEC 63338 [20] or IEC 63330-1 [19] and thus, are within the scope of this document. In 8.2, the technical issues will be reported, which is based on performance uncertainty of the accumulation subsystem consisting of repurpose and reuse batteries. In 8.3, the system architecture including accumulation subsystem, power conversion subsystem and control subsystem to mitigate the issues will be investigated.

3 Under preparation. Stage at the time of publication: IEC CC 62933-2-3:2024.

4 Under preparation. Stage at the time of publication: IEC FDIS 63338:2024

5 Under preparation. Stage at the time of publication: IEC FDIS 63330-1:2024.

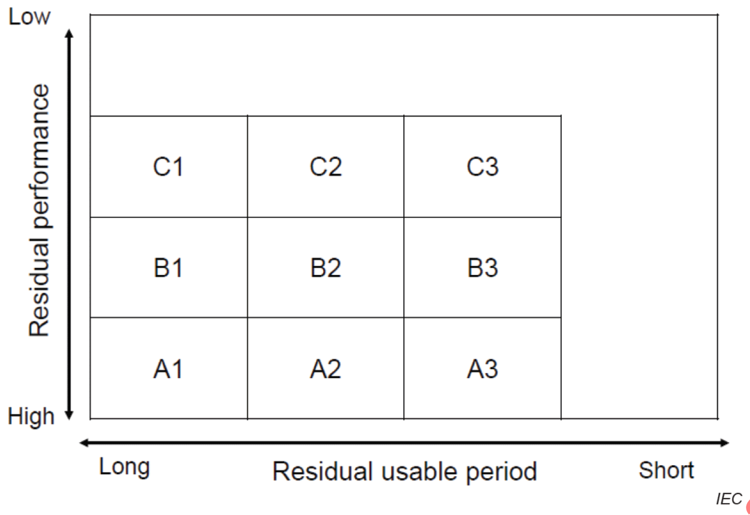


Figure 4 – Categorization of used batteries in terms of residual performance and usable period (IEC 63330-1 [19])

8.2 Issue on testing and design for BESS with repurpose and reuse batteries

8.2.1 Performance uncertainty of new and repurpose batteries

Figure 5 shows differences in battery and BESS performance between the case for new batteries and repurpose and reuse batteries. Generally, the usable capacity, defined as the capacity charged or discharged between the upper and lower voltage limit, depends on the applied power. For example, in Figure 5 (a) and (d), the usable capacity under maximum power is smaller than that of rating power due to the larger voltage drop. In the case of new batteries, information on dependence of the usable capacity on the applied power (as solid line in Figure 5 (b)) is provided by the battery manufacturer and it can be utilized in BESS design at beginning of the primary use. In the BESS design process, the performance information at end of life in primary use is also necessary. Not only the initial profile as solid line in Figure 5 (a), but also the change in profile after the degradation under a specific operation condition as the dashed line in Figure 5 (a) can be provided by the battery manufacturer. Based on this information, BESS design can consider the system performance (capacity-power relationship) from beginning to end of the primary use (as shown in Figure 5 (c)).

On the other hand, the accessibility of the performance information of repurpose and reuse batteries is limited. The voltage-capacity profiles of repurpose and reuse batteries are changed by the operation history and environment in the primary use. Therefore, even if it is the same new product, the resultant profiles are varied. At present, there is no countermeasures for accurately grasping and providing all profiles of usable capacity in plural repurpose batteries used in the BESS.

As described in 8.1, IEC 63330-1 [19] introduces how to categorize the repurpose and reuse batteries by testing them in terms of residual performance and residual usable period. By classifying the repurpose and reuse batteries into the same category (e.g. B2 in Figure 4) for one BESS, the initial performance of the BESS can be designed but there will be the performance uncertainty during its operation. In addition, even when following the category, the dependence of the usable capacity on the applied power and BESS performance at the end of the repurposing is unspecified as shown in Figure 5 (e) and (f). In conclusion, it is difficult to design a BESS using the repurpose and reuse batteries in the same manner as new batteries.

The performance uncertainty of repurpose and reuse batteries can be seen in a prior technical article by Baumhofer, et al. [21] reported the battery cell degradation under the constant operation condition. In this article the capacity ageing trajectories in a charge-discharge cycle test for 48 cells of the same specification were shown. The trajectories were almost the same at the initial stage (small number of charge/discharge cycles). However, when the cycle number was beyond a certain amount, the capacity was rapidly decreased and the performance distribution among the cells got significant, as schematically illustrated in Figure 6 (a). In this report [21], there were multi-modal distribution of residual capacity after the degradation while the narrow-shaped monomodal distribution was seen before the test (Figure 6 (b)).

This situation can be seen as both an original use of new batteries and a new application use of repurpose batteries. But the duration from the operation start to the significant degradation can be shorter for the repurpose batteries. Namely, even if the residual performances of the batteries are almost the same in the initial stage of the repurposing (stage(i) in Figure 6 (a)), they can drastically degrade soon with the wider distribution(stage(ii)). As shown in Figure 6 (a), the capacity trend can be predicted with a sufficient accuracy at the initial stage. When the capacity degrades rapidly (stage(ii)), the prediction accuracy can get worse.

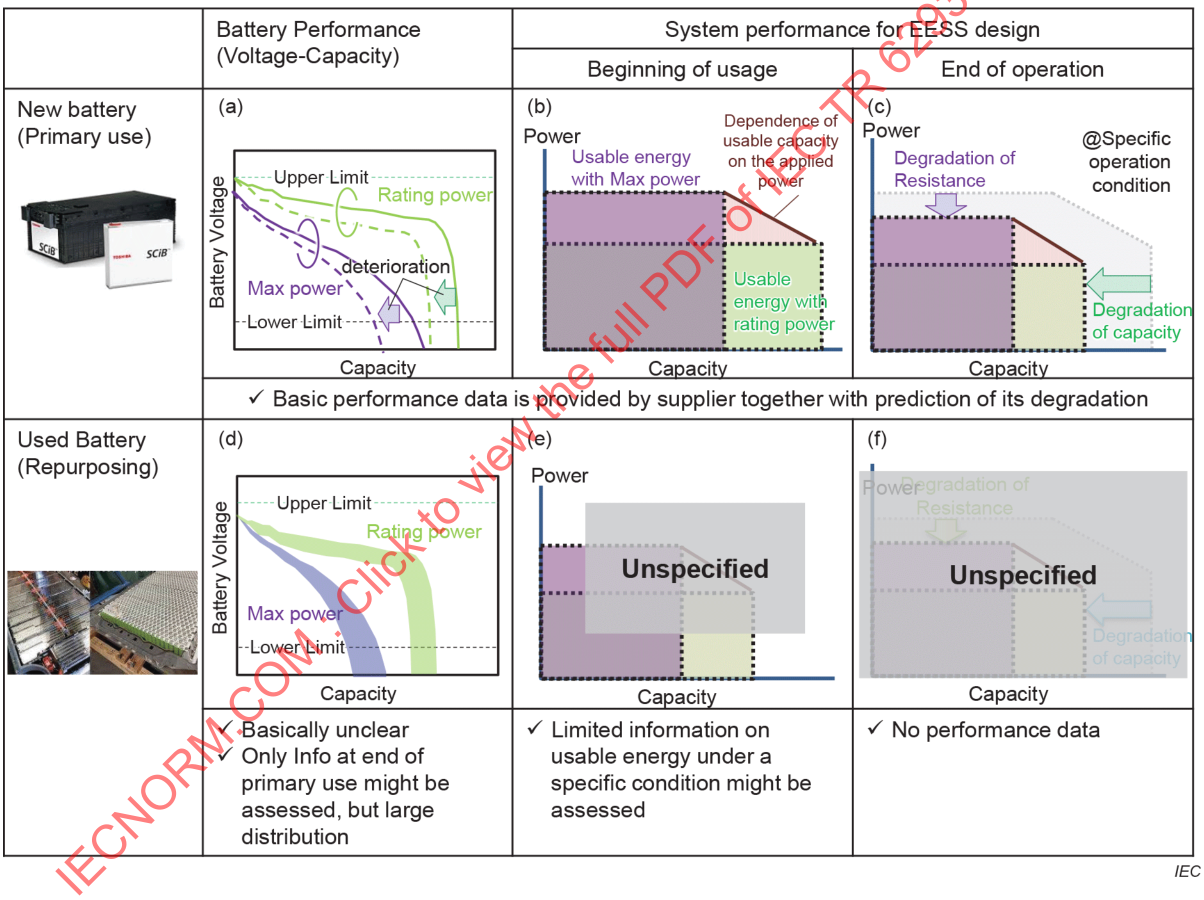


Figure 5 – Differences in battery and system performance of BESS between new batteries and repurpose batteries

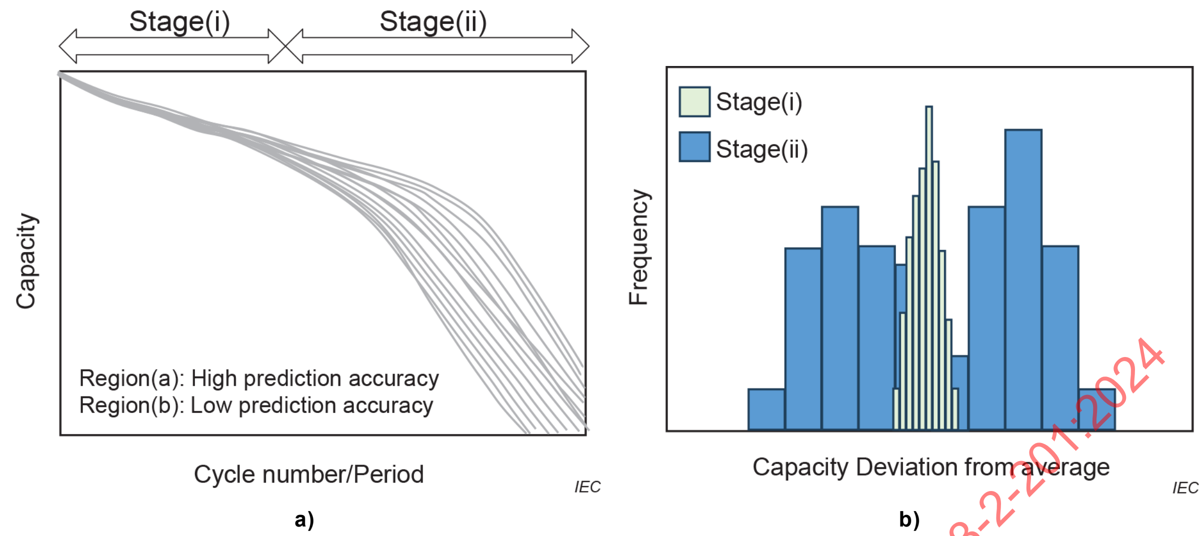


Figure 6 – Schematic illustration of (a) a capacity degradation trend and (b) capacity distribution depending on the degradation stages

8.2.2 Prediction accuracy of battery performance in BESS

Figure 7 shows a schematic illustration of performance distribution between new batteries and repurpose batteries in a BESS.

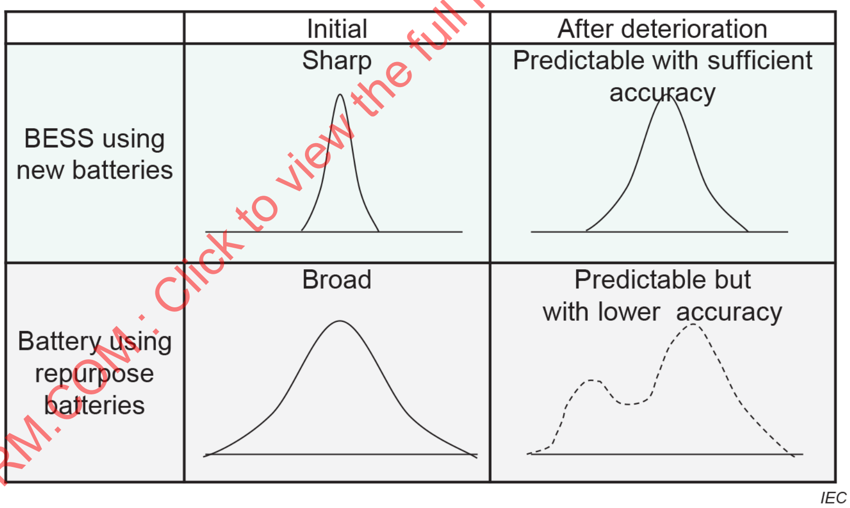


Figure 7 – Differences in performance distribution

In case of BESS with new batteries, the initial performance of batteries is homogenous; hence, distribution of performance appears sharp, and the performance distribution after deterioration can be predictable based on the ageing model developed by using the battery deterioration data provided by the battery supplier.

On the other hand, the initial performance distribution of repurpose and reuse batteries appears broad as shown in Figure 7. Also, the homogeneity will get lower during BESS operation and its curve is sometimes changed (e.g. multimodal shape). This is because the operation histories of the original use are not necessarily the same for all the batteries in one BESS. Also, in some case as indicated in 6.6, there are various batteries produced by different suppliers in one BESS. In these cases, the degradation trajectories of the batteries are not the same even under the constant load condition in one BESS. Consequently, it is hard to predict the performance distribution after deterioration with a sufficient accuracy, especially when used under severe conditions beyond the original use.

8.2.3 Summary of testing and design issues

If such a difference between new batteries and repurpose and reuse batteries could be solved, it would be possible to build and operate the BESS using repurpose and reuse batteries with a sufficient reliability.

a) Testing issue: Specifically, it is envisioned that the test items will be the homogeneity of the initial performance and the difference in load conditions between the original use and the repurposing use in order to predict the performance after deterioration. However, IEC 62933-2-1 [16] to IEC 62933-2-3 [18] and IEC 63330-1 [19] and IEC 63338 [20] do not show the test items related to the above.

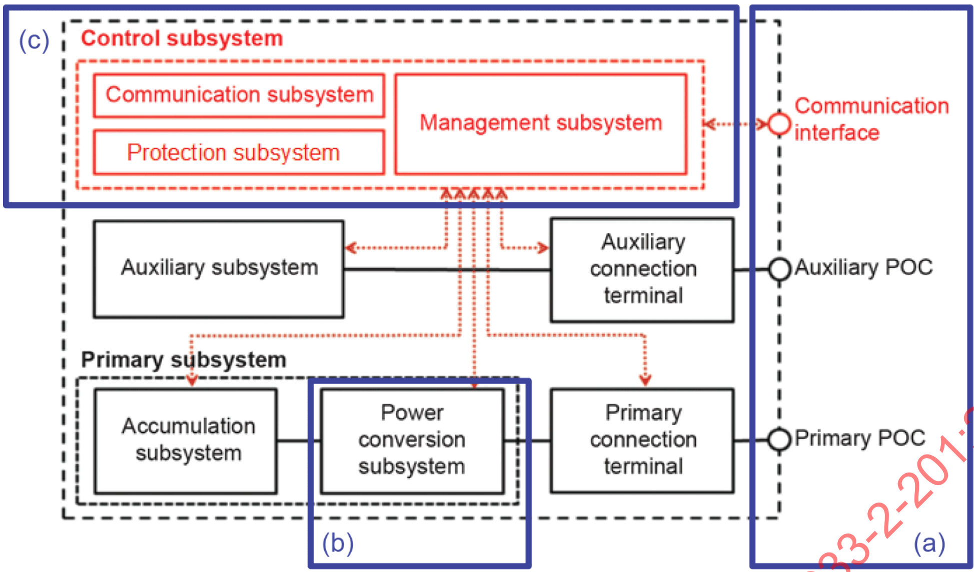
b) Design issue: Alternatively, it is possible to design and build a BESS on the assumption that distributions of the performances at the initial stage and after deterioration are unknown. In that case, it is necessary to monitor intensively the status of BESS and specify the degradation trends of the batteries for identifying a risk in advance.

8.3 System investigation for BESS implementation

8.3.1 General

The existing project on BESS with repurpose battery has suggested how to address the issues on the uncertainty and inhomogeneity of the performance degradation during repurpose and reuse batteries. The use case from Australia (https://www.relectrify.com/technology) has introduced the Relectrify's CellSwitch technology where the health state of the battery cell is extensively monitored and then control for the cell operation is optimized to equalize the performance degradation among the battery cells and then maximized for the system lifetime. In this case, the system configuration of battery cells, BMS, and inverters were totally different from the conventional ones. This use case suggests that investigation of the system architecture including the power conversion subsystem and control subsystem to minimize the uncertainty and distribution is necessary to ensure the system reliability.

Figure 8 shows a schematic illustration of the system architecture of a BESS which is described in IEC 62933-2-1 [16] to IEC TS 62933-2-3 [18], where the items to be addressed for BESS with repurpose batteries are highlighted.



(a) Intensive monitoring of BESS
(b) Architecture of power conversion subsystem
(c) Architecture of control subsystem

IEC

Figure 8 – Schematic illustration of system architecture for discussion for BESS with repurpose batteries

8.3.2 Testing and intensive monitoring of performance distribution in BESS

In the system, the testing and intensive monitoring during BESS operation will be significant to understand the performance degradation trend of batteries inside the accumulation subsystem. Figure 9 shows the BESS design method in combination with monitoring the battery status. As shown in the left illustration (a) of Figure 9, the plural sets of repurpose batteries categorized in the same rank (B2 in this case) are implemented to plural sets of accumulation subsystems, named as System(S)-1, S-2 and S-N, respectively. Figure 9 (b) illustrates the performance distribution in the case that the new batteries are implemented to the S-1 to S-N. Although the distribution at initial stage is narrow, each subsystem shows the different degradation rate (corresponding to the slope of the solid and dashed arrows), which resulted in the wider performance distribution. Since the degradation rate can be estimated by using the modelling based on the degradation data provided from the battery supplier. Figure 9 (c) illustrates the performance distribution in the case that the repurpose batteries are implemented to the S-1 to S-N. The distribution at initial stage is wider than that of new batteries, and the degradation rate of the battery in each subsystem is hard to predict due to the uncertain operation history of each accumulation subsystem, leading to much wider performance distribution than that of new batteries. In this case, it is probable that the performance of some of the subsystems do not meet the application performance requirement (red dashed line in Figure 9 (b) to (d)), which causes serious issues in system reliability. One of the approaches to avoid the issues is intensive monitoring of the battery performance during BESS operation. Figure 9 (d) shows the concept of the monitoring, where some parameters relating to performance inhomogeneity can be diagnosed and an effective maintenance is executed when the parameters reach the lower criteria (red dashed line).

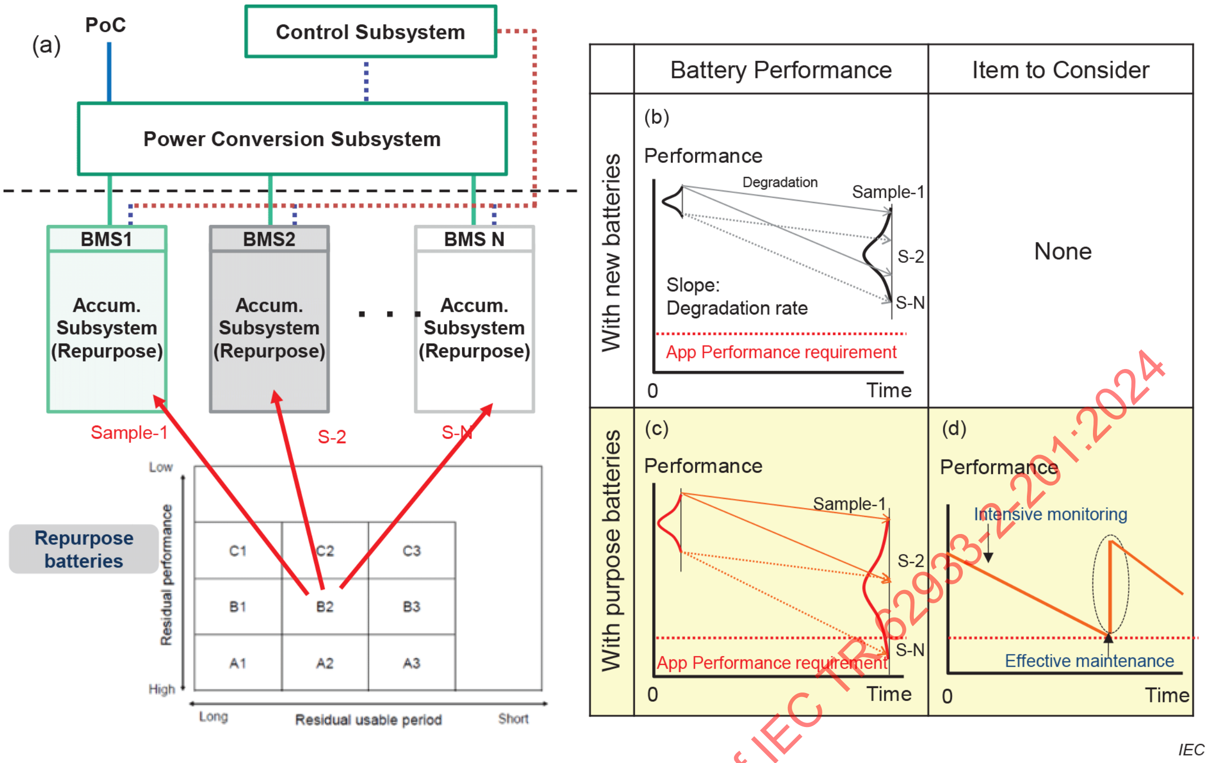


Figure 9 – BESS design method by monitoring the battery status

8.3.3 System design consideration

8.3.3.1 Architecture of power conversion subsystem

When there is a performance inhomogeneity for each of the plurality of accumulation subsystems as shown in Figure 9, the controlling of the operation plan and load current should be controlled to minimize the inhomogeneity. In the case that the performances of some accumulation subsystems do not meet the product criteria, the low-performance subsystem should be preferentially checked and replaced with new one in the regular maintenance. Accordingly, the power conversion subsystem needs to be reconsidered to realize the intensive dispatch of load current to the plural accumulation subsystems based on their performance degradation trend. Also, it should have well-defined circuit switch to disconnect the low-performance accumulation subsystem to recover the performance.

8.3.3.2 Architecture of control subsystem

To monitor the performance degradation during the operation and optimize the load dispatch to the accumulation subsystem to minimize the degradation inhomogeneity, the battery information inside the subsystem should be collected, and control strategy should be determined based on the information. In many case studies in this report, the primary use of the most repurpose batteries is electric vehicle application. An example of BMS architecture of electric vehicle is shown in the prior article [e.g. Energies 2022, 15(12), 4227; https://doi.org/10.3390/en15124227] [24]]. The difficulties in utilizing the BMS developed for EV application are relating to "interface" and "software". As for interface issues, the method of designing the interface with multiple BMS differs depending on whether cooperation with an OEM that understands the functions of the BMS is possible or not. In particular, it is necessary to allocate CAN communication addresses and IP addresses to several BMSs. In addition, when the plural battery module/packs with different BMSs are implemented in one system, the information items and their definition from the different BMS should be aligned. Also, as for BMU/BMS software issue, the existing software used in the primary use in not always compatible with repurposing as BESS. To solve these issues, the BESS control architecture where the battery information from the existing BMS is attached with the repurpose batteries should be developed. This should be the unique challenges for BESS with repurpose batteries.

8.4 Summary

In Clause 8, the issues on testing of BESS necessary for system design and its operation when using repurpose and reuse batteries have been reviewed. The existing standard such as in [19] stipulates a testing procedure of repurpose and reuse batteries prior to their application to the accumulation subsystem, which enables to triage the repurpose and reuse batteries for BESS. On the other hand, the usage histories of the batteries in the primary use are different, and even if they are operated under the same conditions in repurpose and reuse batteries, the deterioration trends of the batteries are not uniform. Further, when the performances of battery cells such as capacity tend to deteriorate rapidly after long-term usage, the performance distribution will get wider. Since the BESS performance is dominated by the lowest performance among the constituent batteries, and it is hard to predict with a sufficient accuracy.

In order to solve this testing issue and ensure reliable operation of BESS over the long term, it is necessary to consider the entire system investigation. To grasp the performance that is difficult to predict with a high accuracy, both testing in the BESS installation and intensive monitoring of the cell/module deterioration information during the operation are significant. In addition, it is significant to investigate the system configuration and algorithm to control the load on each battery with respect to the obtained deterioration information including its distribution. Based on the monitoring results, predictive maintenance such as battery replacement is also required. The above survey suggests the necessity of standardization of the system configuration and its test and monitoring method to ensure the reliability of BESS using repurpose and reuse batteries.

9 Suggestion for future discussion

9.1 General

From an economic perspective, including considerations for BESS supply and demand, as well as from an environmental standpoint, there is a significant potential for the utilization of repurpose and reuse batteries. Furthermore, in anticipation of these factors, it has been observed that in several regions, efforts are being made to establish and examine regulations, including those aimed at actively promoting the utilization of repurpose and reuse batteries. Research has also revealed that worldwide, the manufacturing and utilization of BESS using repurpose and reuse batteries have already begun to align with these trends. (See Clause 4, Clause 5, and Clause 6.)

There has been a discussion about the distinct challenges in utilizing repurpose and reuse batteries compared to new batteries. Even in cases where traceability is ensured for repurpose and reuse batteries, the combination of usage history and the intended reuse method can result in variations in performances that differ from new batteries, and therefore, the performances might not be guaranteed. Especially when considering instances where intermediaries such as automotive OEMs are absent, it has been argued that relying solely on traceability to guarantee BESS performances could be challenging. Furthermore, it has been recognized that BESS play various roles within the power grid and need to provide services with corresponding responsibilities based on those roles. (See Clause 7 and Clause 8.)

In 9.4, while organizing these aspects, the key points to consider when utilizing reused storage batteries will be summarized.

9.2 Issues related to accuracy of measurements related to operation and management

Operating BESS with repurpose and reuse batteries requires measurement accuracy for the system's successful operation and management, as seen in Clause 8. This is related to the variability in battery performance, difficulties in accurately assessing degradation and health, voltage and current measurement inconsistencies, temperature monitoring issues, and the complexities of SOH estimation and capacity evaluation. Addressing these concerns is crucial to ensure the reliability, safety, and efficiency of the BESS.

To mitigate these challenges, BESS operators must implement strategies that enhance measurement accuracy. This begins with the adoption of an advanced battery management system (BMS) equipped with sophisticated algorithms capable of accommodating performance differences among reused batteries. Individual cell monitoring within battery packs aids in identifying performance variations, contributing to more precise measurement readings. Regular calibration and correction of measurement sensors counteract inaccuracies by accounting for the variability inherent in reused battery behaviour.

One of the simplest methods to measure the performances of repurpose and reuse batteries is utilization of the BMS built in the battery system for the primary usage, for example BMS used in EV battery pack. However, using the information from the existing BMS alone cannot ensure measurement accuracy. Figure exemplifies the risk of poor measurement accuracy of usable energy capacity of a battery pack in a used EV. The usable energy capacity is a key parameter to be used for right sizing of BESS in the secondary use and its operation and maintenance, and it can be obtained by multiplying initial usable energy capacity and the values of SOH and SOC from the existing BMS. However, the usable energy capacity strongly depends on not only the BMS readings but also on 1) power consumption of auxiliary devices and 2) error factors due to PCS DC under voltage limit and DC-CT measurement drift. In addition, the measured values of the existing BMS tend to be inaccurate when significant battery degradation takes place as described in Clause 8. To overcome the above-mentioned issues on inaccuracy of measurement using the existing BMS, an investigation is done of the system configuration to calibrate and correct the measured values of existing BMS. Also, the new BMS system is specially designed for the BESS using repurpose and reuse batteries.

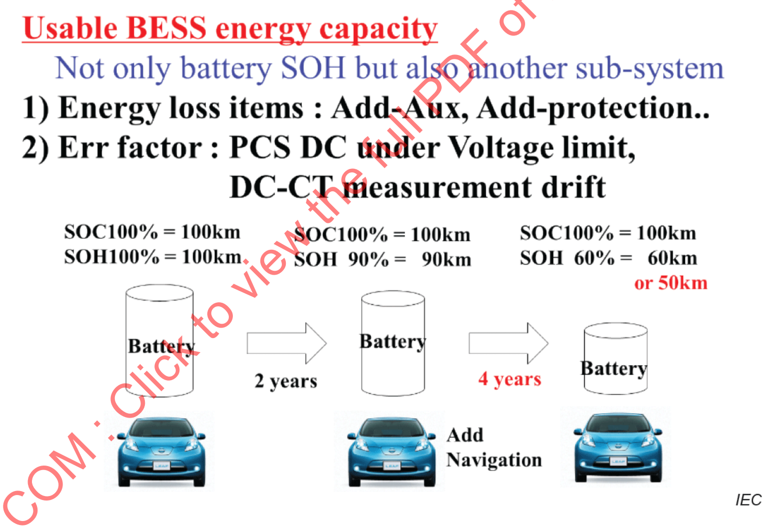


Figure 10 – Accuracy of information from BMS

Incorporating these measures allows BESS operators to overcome the challenges tied to measurement accuracy when utilizing reused batteries. By doing so, they enhance the reliability and longevity of the BESS, promoting effective energy storage and contributing to the overall stability of the grid.

9.3 Consideration of BESS application

BESS can be deployed in different ways within the grid, either behind the meter (customer-side) or in front of the meter (utility-side), each offering distinct roles and benefits. Following are the various roles of BESS based on their deployment location (see Figure 11).

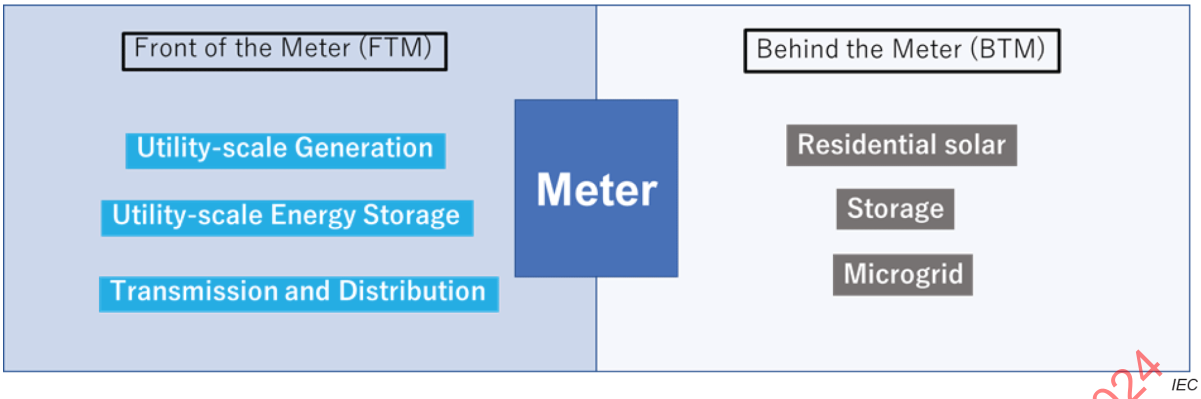


Figure 11 – Front of the meter and behind the meter and its examples

a) Behind the meter (customer-side):

1) Peak demand reduction: BESS installed behind the meter can help commercial and industrial customers manage their peak electricity demand. By discharging stored energy during peak demand periods, customers can reduce their demand charges, which are based on the highest power usage within a billing cycle.
2) Load shifting: Customers can use BESS to shift their electricity consumption from high-cost peak hours to low-cost off-peak hours. This can help them optimize their energy costs by purchasing electricity when prices are lower.
3) Microgrid support: BESS can provide backup power to critical facilities during grid outages. Hospitals, data centres, and other essential services can maintain operations even when the main grid is down.
4) Renewable self-consumption: BESS can store excess energy generated from on-site renewable sources (such as solar panels) and discharge it when needed, maximizing the consumption of self-generated clean energy.
5) Demand response participation: BESS can participate in demand response programs where customers curtail their energy consumption during peak demand events in exchange for financial incentives.
6) Voltage support: In areas with voltage fluctuations, BESS can help stabilize voltage levels by injecting or absorbing power as needed, improving power quality for the customer.

b) Front of the meter (utility-side):

1) Grid frequency regulation: BESS located on the utility-side can respond rapidly to grid frequency fluctuations, helping to stabilize the grid by injecting or absorbing power as needed to maintain a stable frequency.
2) Renewable Integration: Utility-scale BESS can smooth out fluctuations in renewable energy generation by storing excess energy during peak generation and releasing it during low generation periods, helping integrate renewables more effectively.
3) Peak shaving: Utility-scale BESS can reduce peak demand on the grid by discharging stored energy during periods of high demand, thus relieving stress on generation and transmission resources.
4) Ancillary services: BESS can provide ancillary services like spinning reserves, voltage support, and reactive power to maintain grid stability and reliability.
5) Black start capability: Utility-scale BESS can provide essential power for restarting critical grid components in the event of a complete blackout, helping to restore power more quickly.
6) Congestion relief: BESS strategically placed at congested grid points can alleviate transmission congestion by providing additional power where it is needed most.
7) Grid resilience: Utility-scale BESS can enhance grid resilience by providing rapid response capabilities during disturbances, ensuring stable grid operation during unexpected events.

8) Wholesale market participation: BESS can participate in electricity markets by buying low-cost energy during off-peak times and selling it back to the grid during high-demand periods, potentially generating revenue.

Both behind-the-meter and utility-side BESS have valuable roles in enhancing grid stability, efficiency, and sustainability. The choice of deployment depends on factors such as customer goals, grid needs, and regulatory environment.

The regulatory framework for BESS can vary based on whether the system is deployed behind the meter or in front of the meter (especially in the US). These terms refer to the location of the BESS in relation to the utility's meter.

1) Behind-the-meter (BTM) regulations:
   a) Consumer focus: Regulations governing BTM BESS tend to prioritize consumer rights and benefits. Customers deploying BTM BESS are often subject to less stringent regulatory requirements compared to utilities, as they are primarily using the system to optimize their own energy consumption and reduce costs.
   b) Distributed energy resources (DERs): BTM BESS regulations are often designed to encourage the integration of distributed energy resources, such as rooftop solar panels and energy storage, into the grid. These regulations can include incentives, net metering programs, and simplified interconnection processes.
   c) Rate structures and incentives: Customers with BTM BESS can benefit from favorable rate structures, such as net energy metering (NEM), which allows them to offset their energy consumption with the excess energy they generate. Incentives and tax credits for residential and commercial energy storage installations are also commonly available.
   d) Grid interaction: BTM BESS typically have fewer requirements for grid support services, as their primary function is to serve the individual customer's needs. However, some regulations can encourage BTM BESS to participate in demand response programs for grid stability.
2) Front-of-the-meter (FTM) regulations:
   a) Grid integration: FTM BESS are subject to more comprehensive grid integration regulations, as they play a direct role in supporting the overall grid operations. These regulations are aimed at ensuring the smooth integration of utility-scale storage into the grid's infrastructure.
   b) Grid services: FTM BESS regulations often require these systems to provide specific grid services, such as frequency regulation, voltage control, and grid stabilization. These services contribute to maintaining grid reliability and stability.
   c) Market participation: FTM BESS regulations can allow these systems to participate in electricity markets, providing services such as energy arbitrage (buying low and selling high) and providing ancillary services. This often requires adherence to more complex market rules and participation agreements.
   d) Grid operator control: Regulations for FTM BESS can include provisions for grid operators to have more direct control over the operation and dispatch of the systems to ensure grid stability. This level of control is often not present for BTM BESS.

The difference of regulation strictness generally depends on the specific aspect being considered. BTM BESS regulations are often more consumer-friendly and can involve fewer technical requirements, allowing customers more flexibility in how they use and deploy their energy storage systems. FTM BESS regulations are more focused on ensuring grid reliability, stability, and integration, which can result in stricter technical and operational requirements.

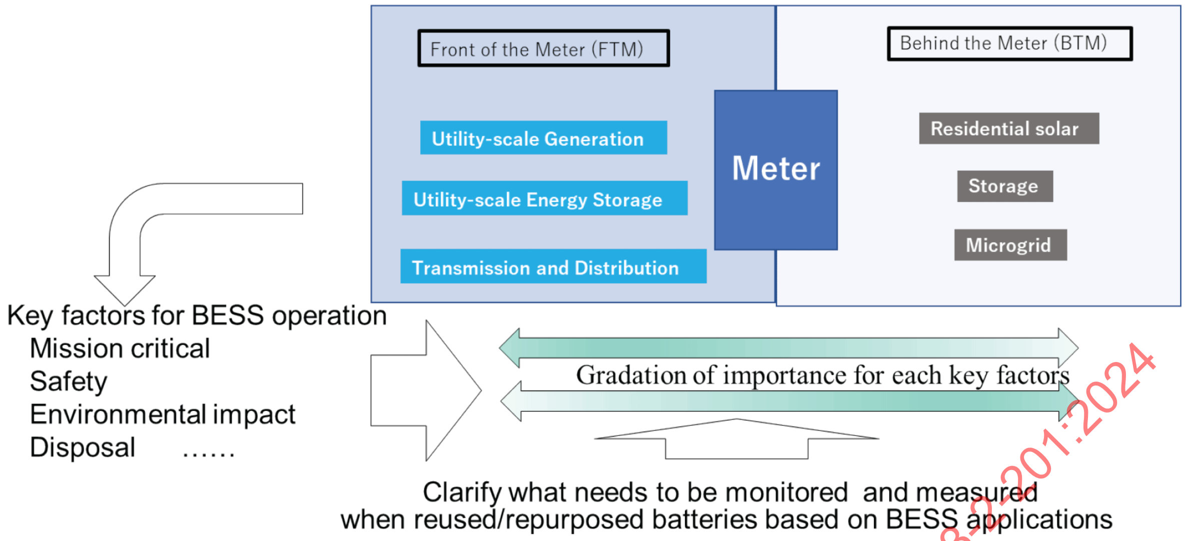


Figure 12 – Reuse batteries that can be utilized to BESS in recognition of the role in the grid network

Figure 12 summarizes the concept of how to decide the use of repurpose and reuse batteries for BESS. However, it is important to note that the regulatory landscape is continually evolving, and the specific regulatory environment can differ significantly from one jurisdiction to another. It is recommended to consult local regulatory authorities and experts to understand the precise regulations applicable to BTM and FTM BESS deployments in a particular area.

9.4 Issues related to information required for BESS design and operation

Figure 13 shows the difference in flow between new and used batteries used in the system.

For the system operator, if the battery is new, it can be received from the manufacturer, but if it is a used battery, it will be received through the intermediary of the collector and its provider.

At this time, the information obtained at process 4 and 2 process in Figure 13 are not necessarily the same.

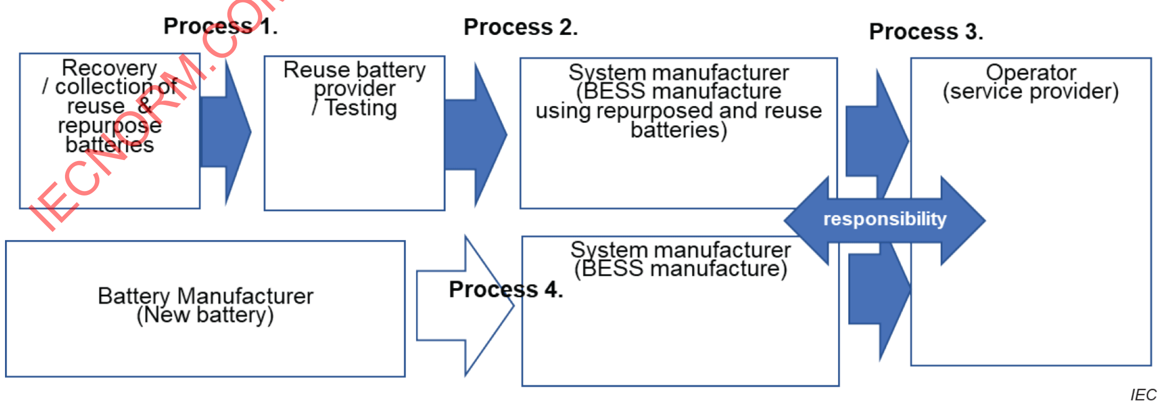


Figure 13 – Difference in flow between new and used batteries

The amount of information and certainty obtained will depend on the reuse battery provider. In the case of a new battery, the information required will be obtained from the manufacturer. On the other hand, the condition of the battery depends on process 2.

There are cases where it is not certain who is responsible for checking the condition of the battery related to process 2. For example, reuse battery providers can be independent or individual. In addition, it will be assumed that there can be a case in which one company performs system assembly from collection.

In any case, the system manufacturer will provide the service to the operator and be responsible for the service. Therefore, the acceptance of the system to function normally regardless of the form of process 2. or process 4, and the obligation to provide stable service to the operator are imposed.

It has been seen in Clause 6 that there are cases where repurpose and reuse batteries are used in BESS to overcome these challenges. There are some special circumstances where reliability is cited, such as using the same affiliated company to obtain information related to process 2 and process 4 above.

Furthermore, as shown in Figure 14, it is necessary to assume that repurpose and reuse batteries will be distributed in various system levels and configurations. In such a situation, it is necessary to assume that the information obtained in "process 2" in Figure 13 is not sufficient.

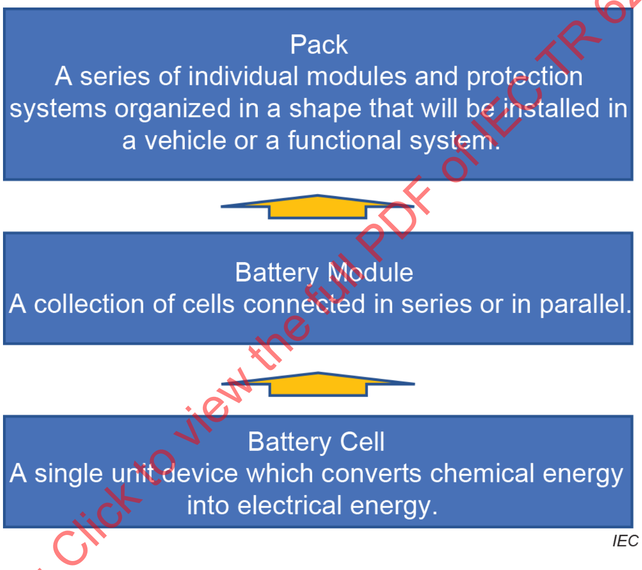


Figure 14 – Battery cells, module and pack

It is important to make a rule that prohibits the use of rechargeable batteries if a collector or a provider of repurpose and reuse batteries fails to provide the necessary information. On the other hand, the effectiveness of the rule is uncertain if there are no concurrent rules under which the provider of information responds to the request. To address these concerns, the requirements for data traceability and data provision in battery repurposing are specified in IEC 63330-1 [19]. At the same time, it has been seen in Clause 8 that the condition of the battery varies depending on the history of its use, making it difficult to make a complete prediction.

It is necessary to examine the acceptance conditions, design and operation methods for the operators that use it as a system to fulfil their responsibilities to the operator. In addition to the stable control during service provision, it is also important to consider how to dispose of it after use when considering the life cycle of a system.

Annex A
(informative)

Application scenarios and industrial policies in China

A.1 Power battery echelon utilization and its main value scenarios

Echelon utilization refers to the reuse of a power battery after its capacity decay reaches the decommissioning condition, and after power quality and safety and economic evaluation it meets other low standard use scenarios through sorting and reorganization. Figure A.1 shows scenarios for power battery echelon utilization.

The remaining capacity potential of retired power batteries are brought into play and are classified them for use in suitable scenarios such as "cyclic energy storage and backup power" with low and medium capacity requirements, so as to enhance the application value of power batteries in the whole life cycle.

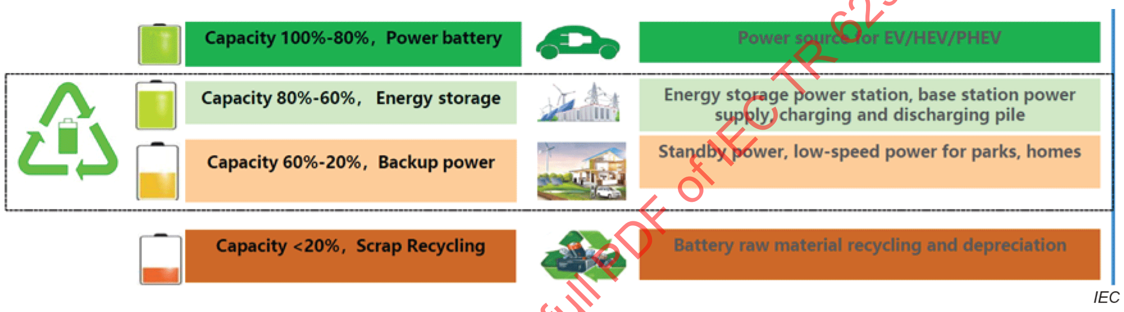


Figure A.1 – Scenarios for power battery echelon utilization

The decommissioning conditions and echeloning classifications are as follows.

– Decommissioning conditions: For EVs with lithium iron phosphate and other power batteries, if the charge and discharge capacity is reduced to 80 % of the initial value, that is, the energy efficiency is less than 80 %, they will meet the conditions for retirement based on safety and reliability considerations.

– Criteria of classification：Decommissioned batteries with a capacity of 60 % to 80 % are classified as Class I, 20 % to 60 % are classified as Class II, and those with a capacity less than 20 % are recycled.

By referring to typical standards, not only can unqualified batteries be eliminated, but batteries can also be classified according to their remaining available capacity, for application in different scenarios. Retired traction batteries with a remaining capacity of 80 % to 60 % of the rated value can be used for power system source network load storage linkage based on battery packs or modules. They can participate in new energy grid connection and thermal power frequency regulation on the generation side and be matched with distributed power sources and microgrids on the user side, as well as serve as energy storage devices for parks and households. Due to low charging efficiency, retired traction batteries with a remaining capacity of 60 % to 20 % of the rated value are mainly based on their low-speed discharge capacity and used as backup and low-speed power supply for emergency scenarios, such as daily lighting, UPS backup power supply, low-speed electric vehicle power supply, and temporary power supply in remote scenarios.

A.2 Industrial policies

National and local government policies and industry association assistance facilitate the development of power battery echelon utilization industry in China.

A.3 National policies

Since 2012, China has issued a series of policies to support the echelon utilization of power batteries. Some of the representative policies are shown in Table A.1.

Table A.1 – National policies of echelon utilization in China

Issue date	Main issue dept.	Documents	Content
June 28th, 2012	State Council	Energy-saving and New Energy Automobile Industry Development Plan (2012-2020)	Clear requirements are put forward for the construction of power battery recycling system and echelon utilization management system.
January 5th, 2016	National Development and Reform Commission	Technical Policy for the Recycling of Electric Vehicle Power Battery (2015 Edition)	A guiding document which aims to guide the enterprises to reasonably carry out the design, production and recycling of electric vehicle traction batteries, and to establish a power battery recycling system formed by upstream and downstream enterprises.
January 26th, 2018	Ministry of Industry and Information Technology	Interim Measures for the Administration of Recycling of New Energy Vehicle Power Battery	It specifies the responsible entities and their responsibilities for the design, production, recycling, echelon utilization of electric vehicle power batteries.
February 22nd, 2018	Ministry of Industry and Information Technology	Pilot Implementation Plan for Recycling and Utilization of New Energy Vehicle Traction Battery	Announcement to carry out pilot work on the recycling of new energy vehicle power batteries in some selected regions of Beijing, Tianjin, Hebei Province, the Yangtze River Delta, the Pearl River Delta, and the central region of China, including building recycling system, exploring diversified business models, promoting advanced technology innovation and application, and establishing and improving policy incentive mechanism.
August 19th, 2021	Ministry of Industry and Information Technology	Management Measures for the Echelon Utilization of New Energy Vehicle Power Battery	Clarify the management requirements for echelon utilization and recycling enterprises, and the quality requirements for echelon use battery products.
December 30th, 2021	Ministry of Finance and State Taxation Administration	Announcement on Improving the Value Added Tax Policy for Comprehensive Utilization of Resources	From March 2022, the value-added tax rebate ratio of traction battery recycling and battery disassembly enterprises will be increased from 30 % to 50 %, providing tax incentives for the traction battery reuse and recycling industry.
March 2nd, 2023	State Administration for Market Regulation and Ministry of Industry and Information Technology	Announcement on conducting certification of new energy vehicle traction battery echelon utilization products	Announcement to carry out voluntary certification of new energy vehicle power battery echelon utilization products, and to establish a publicly accessible database for certified echelon utilization products.

Policy points are listed as follows:

– Clarify the management requirements of the echelon utilization of new energy vehicle power batteries, involving the enterprises and products of echelon utilization, recycling specifications

– Focus on the quality of echelon use battery products.

– Support the research and development of key generic technologies and equipment for echelon use batteries to promote their application.

– Guide the collaboration between industry, universities, research institutes and users, and encourage the construction of new business model innovation and demonstration projects for echelon utilization.

Based on the policy, the series of standards for power battery recycling GB/T 34015 and dismantling specification GB/T 33598 are under continuous development and publication.

The parts in power battery recycling GB/T 34015 are mainly related to the "automotive power battery recycling, gradual utilization Part 3: Gradual utilization requirements" (GB/T 34015.3-2021), "automotive power battery recycling, gradual utilization Part 4: Gradual utilization product marking" (GB/T 34015.4-2021).

A.4 Local policy (Shanghai Government policy)

On July 11th 2022, Shanghai Municipal People's Government issued a key document titled "Shanghai Action Plan Aiming at the New Track to Promote the Development of Green and Low-carbon Industries".

The policy points are listed below:

- proposal to develop the recycling industry of retired power batteries;
- building of the traceability and management recycling network system of the whole power battery industry chain in the city;
- promoting the development of power battery recycling technology, process, equipment, and industry cluster.

As of November 16, 2022, the Ministry of Industry and Information Technology has released the list of four batches of enterprises that meet the industrial specifications for the comprehensive utilization of waste power batteries, a total of 88 enterprises, including 4 enterprises in Shanghai that meet the specifications and standards.

A.5 Other initiatives

On 18th April 2019, a cross-industry and non-profit alliance, Power Battery Recycling and Echelon Utilization Alliance was established, including new energy vehicle enterprises, battery manufacturing / recycling and echelon utilization enterprises and upstream and downstream enterprises in the industry chain, universities, scientific research institutions and social groups.

It aims to explore the economy, safety, protection and resource maximization of power battery, promote the construction of industry norms and standards, and share and exchange experience with peers around the world.

Alliance activities and industry summits are routinely carried out, and 13 group standards such as "General Requirements for the Production of Recycling Enterprises of Used Power Batteries" have been initiated.

A.6 Standard system framework of traction battery echelon utilization in China

Clause A.6 provides an overview of echelon utilization standards and screening standards in China.

At present, China has constructed the standard system framework of traction battery echelon utilization. In terms of general standards, it is mainly for the requirements of vehicle traction battery specifications, coding rules, dismantling specifications, and residual capacity detection issued by the General Administration of Quality Supervision and Quarantine. In terms of echelon utilization standards, there are mainly relevant requirements for echelon utilization of vehicle traction batteries at the national level and normative requirements for local utilization. The following two tables list (Table A.2 and Table A.3) representative standards.

Table A.2 – General standards of echelon utilization in China

	Std. No.	Name	Content	Issue Dept.
General standards	GB/T 33598-2017	Recycling of traction battery used in electric vehicle – Dismantling specification	Terms and definitions, general requirements, operating procedures, storage and management requirements for the dismantling of used traction battery packs and modules	General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China
	GB/T 34013-2017	Dimension of traction battery for electric vehicles	Specifications and dimensions of traction battery units, modules and standard boxes	
	GB/T 34014-2017	Coding regulation for automotive traction battery	The object, code structure composition, code structure representation method and data carrier of automobile traction battery coding	
	GB/T 34015-2017	Recycling of traction battery used in electric vehicle – Test of residual capacity	Definitions, symbols, detection requirements, process and detection methods of residual energy detection of residual capacity	

Table A.3 – National level and normative requirements for local utilization in China

	Std. No.	Name	Content	Issue Dept.
Echelon uitilization standards	GB/T 34015.3-2021	Recovery of traction battery used in electric vehicle – Echelon use – Part 3:Echelon using requirement	General requirements, appearance and performance requirements of echelon utilization of traction battery	State Administration for Market Regulation
	DB34/T 3077-2018	Technical specifications for the discharge of battery-recycling used in electric vehicles	General requirements of discharge before disassembly of used lithium-ion traction batteries	Anhui Provincial Bureau of Quality and Technical Supervision
	DB31/T 1053-2017	Specification for recovery and utilization of traction batteries for electric vehicles	Basic principles, of traction battery recycling, and the conditions of disassembly, detection and echelon utilization of used traction battery	Shanghai Municipal Bureau of Quality and Technical Supervision
	DB44/T 1203-2013	Specification of recycling lithium-ion batteries for electric vehicles	General requirements for the collection, storage, transportation, treatment and recycling of used lithium-ion batteries	Guangdong Provincial Bureau of Quality and Technical Supervision

A.7 Business models

Policies incentives and demand traction promote the construction of power battery echelon utilization industry chain and business models.

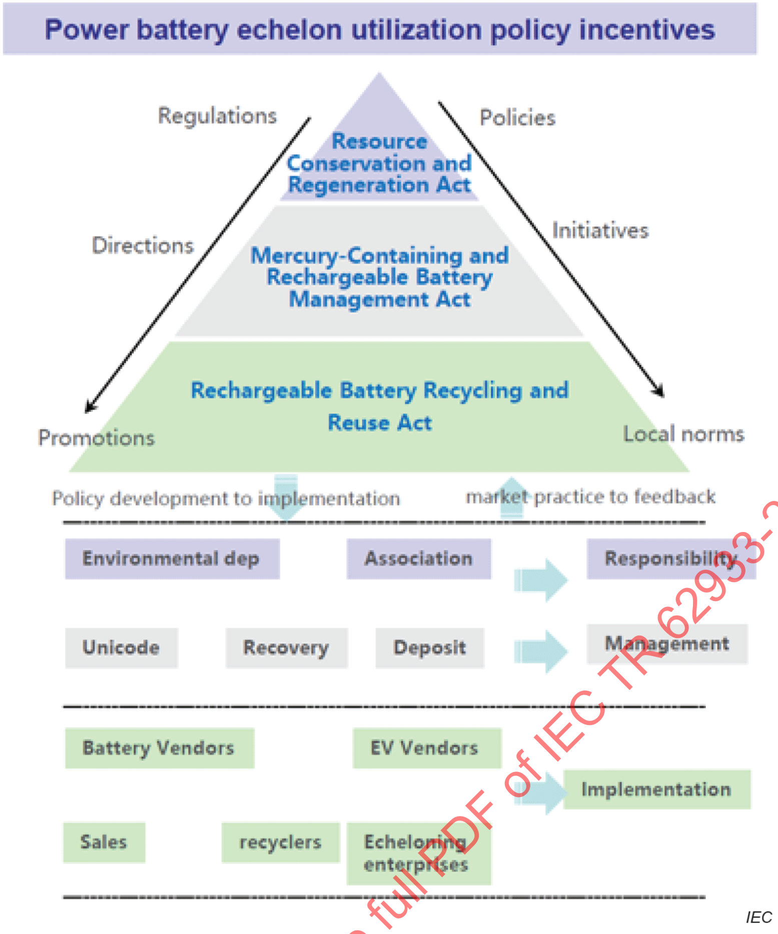


Figure A.2 – Power battery echelon utilization policy incentives

Figure A.2 shows power battery echelon utilization policy incentives in China and Figure A.3 shows the business model of power battery echelon use industry.

The current industry cultivation is mainly based on the demonstration and drive of benchmark projects supported by national policy incentives and local preferences; participating enterprises have not yet formed economies of scale.

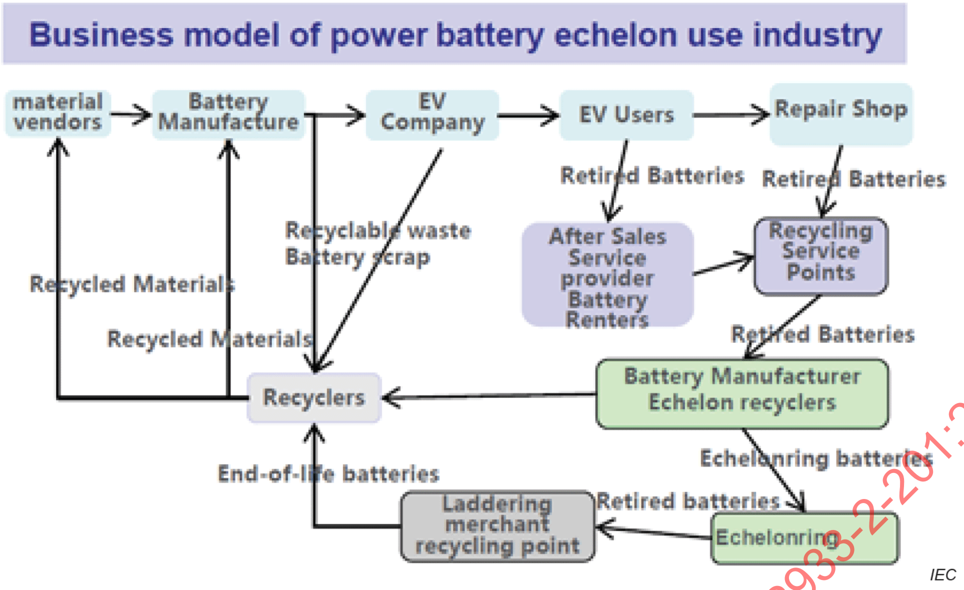


Figure A.3 – Business model of power battery echelon use industry

There are opportunities for improvement where an authoritative body plays the leading role of white-listed enterprises to catalyse application scenarios and business models and gather the strength of the whole industry chain around representative battery manufacturers and EV manufacturers to form a breakthrough.

Annex B
(informative)

EUROBAT (Association of European Automotive and Industrial Battery Manufacturers)

EUROBAT (Association of European Automotive and Industrial Battery Manufacturers) is the leading association for European automotive and industrial battery manufacturers, covering all battery technologies to study all matters of interest to storage battery manufacturers and their sub-contractors in Europe, the Middle East and Africa (https://www.eurobat.org/wp-content/uploads/2022/03/Joint_industry_paper_future_Batteries_Regulation_January_2022_FINAL.pdf).

The Technical Annex to the EUROBAT White Paper 'Battery Innovation Roadmap 2.0' [23] provides the reader with more in-depth technical background on the state-of-play and innovation potential of the mainstream lead-, lithium-, nickel- and sodium-based batteries, as well as on promising future battery technologies with a horizon up to 2030.

The Annex consists of two main parts.

The first part analyses the state-of-the-art and potential for improvement of each identified battery technology in relation to their intrinsic performance, safety and environmental aspects.

As batteries are designed to be used in particular applications, the second part of the Annex is even more important and analyses the mainstream battery technologies used in critical applications in support of the objectives of the Green Deal. In this part II, the battery KPIs are considered per application as the innovation priority areas for the different mainstream battery technologies are strongly linked to this.

As the safety aspect for the auxiliary services is also crucial, lead will generally remain the preferred option, both flooded and AGM battery types. For lithium-based batteries, LFP and LTO batteries will become the anode chemistry of choice for such applications.

No international standard is currently available for auxiliary batteries. However, IEC TC 21 WG2 of TC 21 is working on a standard for this battery type (both lead and Li-ion batteries) focusing on test methods and requirements, dimensions and functional safety / diagnosability.

Annex C
(informative)

Regulatory trends in Japan

C.1 Overview

In October 2020, the Japanese government declared its goal of becoming carbon neutral, which means that overall greenhouse gas emissions will be zero by 2050.

In October 2021, the Cabinet also approved a greenhouse gas reduction target for 2030 of 46 % below the 2013 level.

In response to these policies, the Ministry of Economy, Trade and Industry (METI) launched a public-private council to study the storage battery industry strategy and began its activities on November 18, 2021 and published the Storage Battery Industry Strategy on August 31, 2022.

In January 2022, the Study Group on Sustainability of Storage Batteries was launched as a subcommittee of the above council.

In this study group, discussions on carbon footprint and human rights and environmental due diligence are particularly advanced.

C.2 Storage Battery Industry Strategy

C.2.1 General

The first part of the strategy describes the importance of storage batteries.

Batteries are key to achieving carbon neutrality in 2050 and are the most important technology in EV and so on.

In order to make renewable energy the main source of power, it is essential to deploy batteries.

The batteries are an essential piece of infrastructure supporting the foundations of a digital society (e.g., a back-up power source for 5G communication base stations and data centres).

There are 7 items in the Battery Industry Strategy [11], [25]:

1) policy package for further expansion of domestic base to achieve manufacturing targets;
2) strategic formation of global alliances and global standards;
3) securing upstream resources;
4) development of next-generation technologies;
5) expansion of a domestic market;
6) strengthening human resources development;
7) improving the domestic business environment.

Items 2), 5), and 7) will be introduced as items related to reuse of batteries in this document.

C.2.2 Strategic formation of global alliances and global Standards

Promotion of the following items to establish international rules and to form global standards for safety.

The Storage Battery Industry Strategy by METI examines carbon footprint calculation method and risk assessment and reduction in the supply chain (due diligence). At the same time, there is harmonization with overseas systems while starting trial projects.

Consideration of measures such as standardization of battery safety and promotion of third-party testing and verification services.

C.2.3 Expansion of a domestic market

It is important to stimulate domestic demand for batteries in parallel with the strengthening of the supply side.

To promote EVs, active support of the purchase of EVs and the development of recharging infrastructure to achieve 100 % EVs in new car sales by 2035.

To promote stationary battery systems, in addition to providing support for the introduction of storage batteries for stationary use, improvement of the environment, including institutional review of storage battery facilities installed alongside power generation, will be considered in light of the clarification of the position of storage batteries under the revised Electricity Business Act.

Ensuring safety and the security required for infrastructure systems for stationary storage battery systems connected to the power grid.

C.2.4 Improving the domestic business environment

Promotion of the following items to strengthen the environment for the manufacture and use of storage batteries in Japan.

To promote recycling and reuse of batteries, examine measures to strengthen the collection of used batteries, revitalize the reused battery market, and establish a domestic recycling infrastructure and system by 2030.

As efforts to ensure sustainability, investigation of the calculation of CFP, assessment and reduction of risks in the supply chain, promotion of reused and recycling, and the data platform required for these. A trial initiative was launched in 2022.

On May 31, 2023, the Ministerial Ordinance of the Fire and Disaster Management Agency was revised. Previously, batteries of 4 800 Ah cell or more were subject to the Fire Act, but those of 10 kWh or less and those of 20 kWh or less with fire prevention measures taken are now excluded from the regulation.

C.3 Study Group on Sustainability of Storage Batteries

C.3.1 General

The following four items have been identified as initiatives of the Study Group on Sustainability of Storage Batteries [26]:

- carbon footprint
- human rights and environmental due diligence
- reuse and recycle
- data collaboration

C.3.2 Carbon footprint

As for CFP, issues such as the scope of calculation, measurement of activities, emission intensity, units of comparison, and exchange of information among stakeholders are being discussed in depth, and a trial project has been started in 2022 (see Figure C.1).

Automotive OEMs ask upstream suppliers to perform calculations, and suppliers provide the information to downstream companies via the secretariat in METI. The automotive OEMs will compile the results and submit the final results to the secretariat.

AIST's (National Institute of Advanced Industrial Science and Technology) IDEA (Inventory Database for Environmental Analysis) is used for calculation.

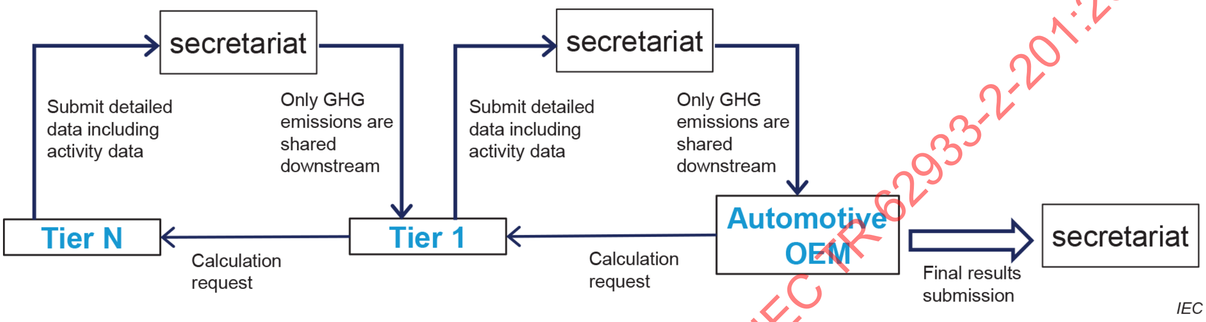


Figure C.1 – Trial project on CFP

Current perceptions in the study group include the following:

- Proposed CFP calculation method for automotive batteries, presenting a framework of possible CFP calculation levels.
- A wider range of products and businesses should be targeted.
- Cooperation from a large number of suppliers, including overseas businesses, is necessary, but the current voluntary framework is limited in its ability to involve a large number of businesses.

Future issues to be considered are as follows.

– The calculation method will continue to be improved.
– Incentives are needed to engage a wider range of businesses (e.g., subsidy requirements for end-product installations, legal action, etc.)
– Consideration of a mechanism for third-party certification of calculation results.
– Mechanisms for data information exchange and collaboration need to be considered.

Regarding making CFP a requirement: Consider making it a phased requirement, for example, start with calculation only, then proceed to information disclosure.

1) First, consider not publishing the CFP value and report the results to METI.
2) Several support measures are already underway to consider making CFP a requirement.

The first is a requirement under the Act on the Promotion of Economic Security for a project to support the strengthening of the storage battery manufacturing SC, and it has already been introduced. In this requirement, the CFP will be reported to METI and is not disclosed.

The second is a requirement in the Clean Energy Vehicle Introduction Promotion Subsidy, which is under consideration for introduction. Hearings are scheduled with related businesses with the aim of introducing the system in 2024 or later.

C.3.3 Human rights and environmental due diligence

For due diligence, discussions are being deepened while also taking into account the study of the "Study Group on Guidelines for Respecting Human Rights in the Supply Chain", and a trial project has been started in 2022.

In the project, the target materials are lithium, cobalt, nickel, and graphite as mineral substances for which demand is expected to grow with the increase in storage batteries.

There are two parts to the target risks: environmental and human rights.

The following risks are listed for the environment.

– atmospheric effects by dust from mining area;
– effects on water by pumping up large amount of water;
– effects on water and soil by chemicals used for mining;
– impact on biodiversity by deforestation;
– health hazard and impact on local communities by contaminated water, soil, and air.

The following risks are listed for human rights:

– impact on occupational health and safety and risks of forced labor caused by toxic materials and inadequate protective equipment and safety measures;
– risks of child labour due to livelihood dependence on mining in poor areas.

The risk identification procedure is as follows (see Figure C.2).

a) check with suppliers to see if there are any environmental or social impacts; if not
b) confirming the checking method (with or without interviews with local companies).

The first trial will focus on whether the framework works.

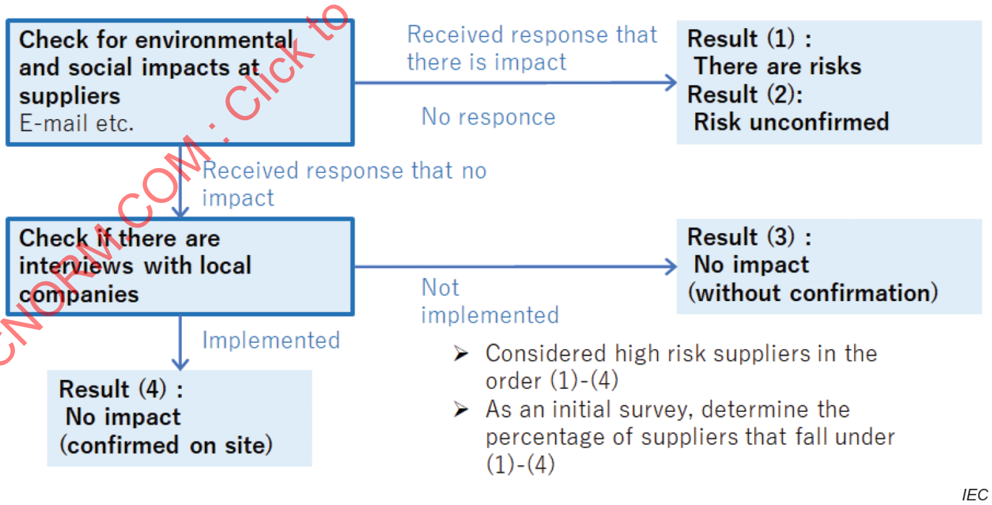


Figure C.2 – Risk identification procedure

C.3.4 Reuse and recycle

Research is underway on the distribution of used batteries. It was found that 51 % of the batteries were reused after dismantling. Details on the distribution situation after intermediate treatment and the reuse market are unknown. Continue to investigate the details of the actual distribution situation.

Scope of future research:

a) Reuse facts:
   - applications (automotive, others);
   - actual market conditions (price, quality).
b) Actual condition after intermediate treatment:
   - treatment method;
   - distribution of incineration residue.

C.3.5 Data collaboration

As for data collaboration, specific use cases in CFP and DD are being discussed.

The issues dealt with are as follows.

1) identification of required data;
2) identification of basic requirements for system design;
3) cooperation with overseas.

The details of each item are listed in Table C.1.

Table C.1 – Discussion points in CFP and DD use cases for storage batteries

Issues	CFP of storage batteries	DD of storage batteries
(1) Identification of required data	**Activity** Emission intensity etc. (to be considered in the trial project)	**Environmental risks** Human rights risks (to be considered in the trial project)
(2) Identification of basic requirements for system design	Identification method, scope of data sharing, Open API, costs, Standardization of data sets, security, participation of SMEs	
(3) Cooperation with overseas	Coordination with overseas regulations (EU Battery Regulation) Coordination with foreign platforms (e.g. Catena-X)	

Organize a mechanism to link data from the operational aspect of trade secrets to the technical aspect of data propagation, ensuring scalability and economic rationality while maintaining corporate trade secrets and data sovereignty, so that data in the supply chain and value chain can be shared and utilized across companies.

Annex D
(informative)

Regulatory trends in Korea

D.1 Market trend in Korea

The EV market will surge from $136 million in 2020 to $187 million in 2025, and it will lead the growth and scale of domestic battery market. Figure D.1 shows the growth of the battery market in terms of market. It is clear that EV batteries will dominate the market demand in Korea.

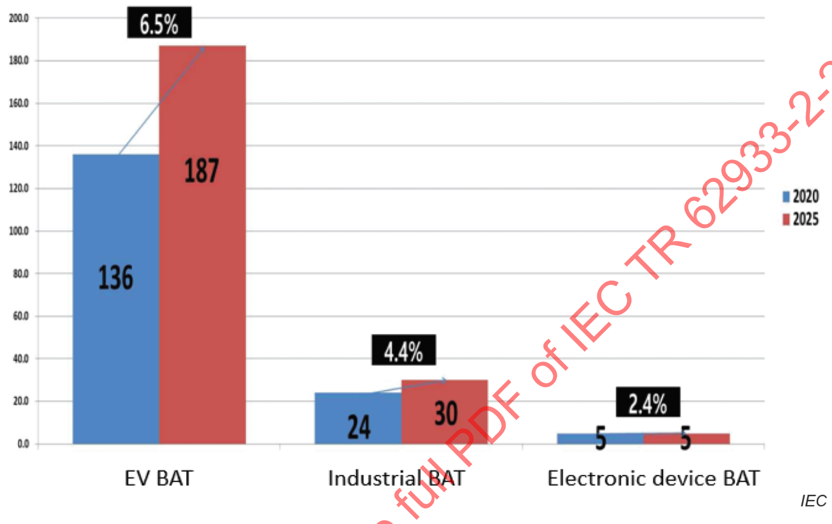


Figure D.1 – Electric vehicle battery market trend in Korea

The Korea EV market continued to grow, led by Hyundai Motor Group, while Tesla's sales declined as it raised vehicle prices and lost subsidies. Figure D.2 illustrates a comparison among different companies, with a particular emphasis on the significant growth of Korean automakers.

BRAND	2020		2021		2022		Growth rate (20–21)	Growth rate (21–22)
	Sales	M/S (%)	Sales	M/S (%)	Sales	M/S (%)		
Hyundai motor group	27,888	59.5	71,897	71.1	120,438	73.9	157.8%	67.5%
Hyundai	18,952	40.4	42,899	42.4	71,019	43.6	126.4%	65.5%
IONIQ5	–	–	22,671	22.4	27,399	16.8	–	20.9%
POTER2EV	9,037	19.3	15,805	15.6	20,418	12.5	74.9%	29.2%
KIA	8,936	19.0	28,998	28.7	49,419	30.3	224.5%	70.4%
EV6	–	–	11,023	10.9	24,852	15.2	–	125.5%
BONGO EV	5,357	11.4	10,728	10.6	15,373	9.4	100.3%	43.3%
TESLA	11,826	25.2	17,828	17.6	14,571	8.9	50.8%	△18.3%
MODEL3	11,003	23.5	8,898	8.8	7,323	4.5	△19.1%	△17.7%
MODELY	–	–	8,891	8.8	7,248	4.4	–	△18.5%
BENZ	608	1.3	1,363	1.3	5,006	3.1	124.2%	267.3%
BMW	152	0.3	366	0.4	4,888	3.0	140.8%	1,235.5%
POLESTAR	–	–	–	–	2,794	1.7	–	–
AUDI	601	1.3	1,553	1.5	2,771	1.7	158.4%	78.4%
ETC	5,834	12.4	8,105	8.0	12,519	7.7	38.9%	54.5%
Total	46,909	100	101,112	100	162,987	100	115.5%	61.2%

IEC

Figure D.2 – Electric vehicle sales in Korea

In 2022, a total of 389 855 electric vehicles were present in Korea as shown in Figure D.3. Based on the number of EVs introduced by year, if 20 % of reuse batteries are collected, it is expected that there will be 0,9 million units in 2030, 1,9 million units in 2031, and 3,2 million units in 2032.

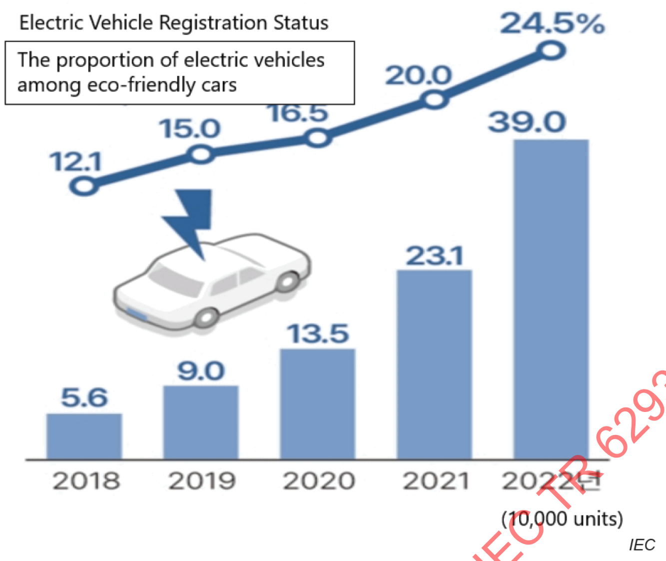


Figure D.3 – Electric vehicles presence in Korea

As mentioned above, there is an increasing number of batteries from electric vehicles circulating in the market. On the other hand, reuse and repurpose stage, as illustrated in Figure D.4, is being considered. In order repurpose and reuse the batteries, battery performance needs to be measured and stability needs to be endured when batteries reach EOL for EVs.

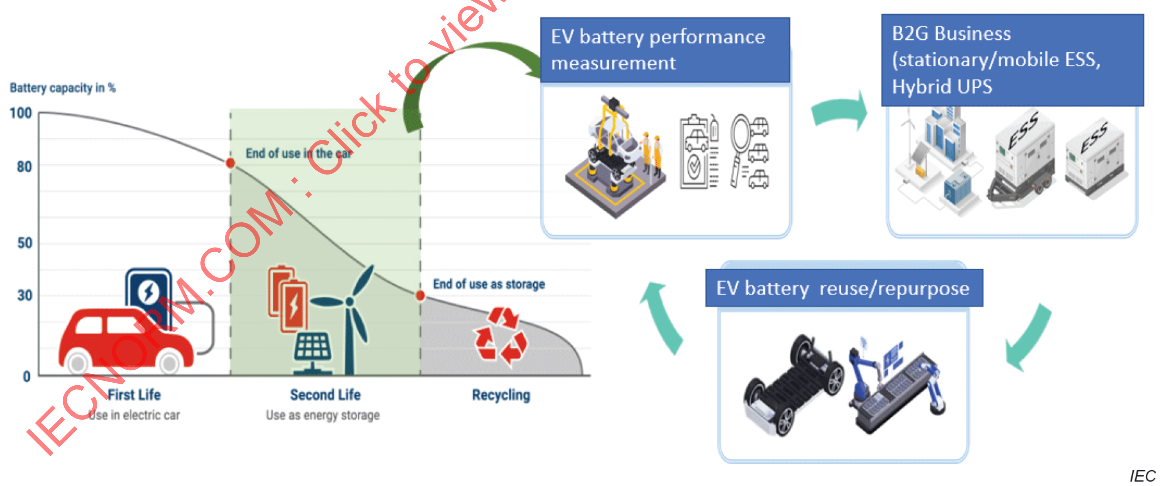


Figure D.4 – Stages of repurpose and reuse batteries from electric vehicles in Korea

D.2 BaaS industry development in Korea

D.2.1 Policy development in Korea

The BaaS demonstration project was announced in the '203 to 2025 industrial innovation base construction roadmap by Ministry of Trade, Industry and Energy (MOTIE). As shown in Figure D.5, the Ministry of Land, Infrastructure and Transport (MOLIT) is preparing a separate registration/management system for batteries when registering electric vehicles.

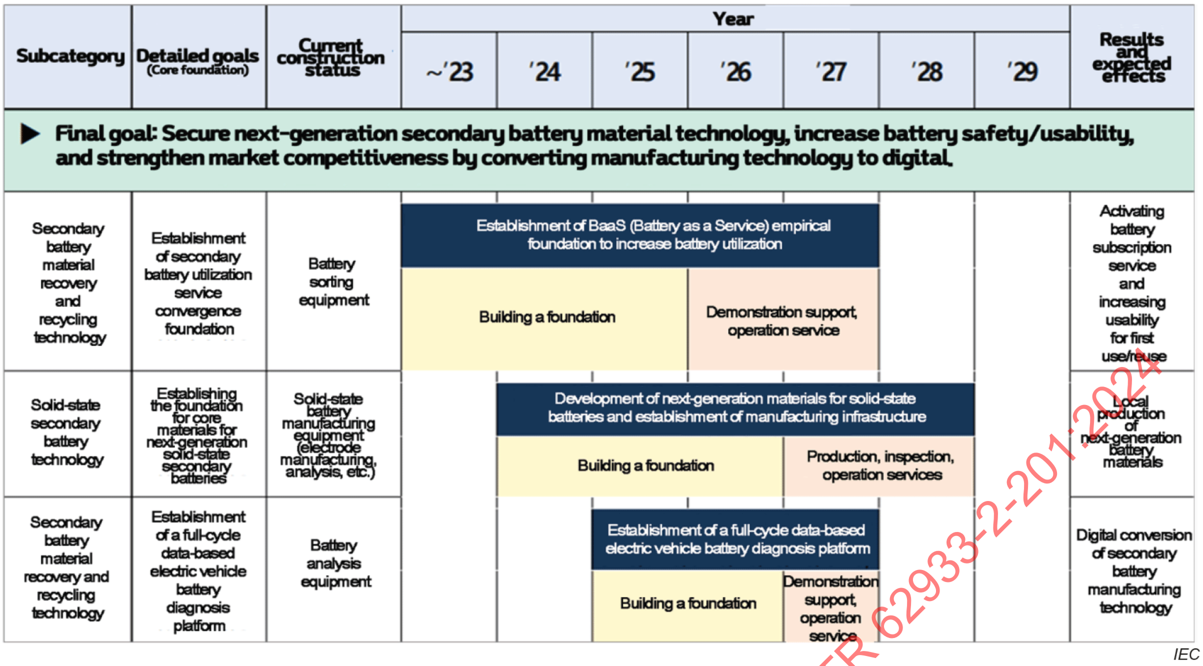


Figure D.5 – Policy development in Korea

D.2.2 Battery and electric vehicle companies based on repurpose and reuse batteries

Battery and electric vehicle companies are developing and preparing for commercialization of various application products and services based on repurpose and reuse batteries (see Table D.1).

Table D.1 – Battery and electric vehicle companies based on repurposed and reuse

Company	Description	Classification
SungEl HiTech	LGES, Samsung SDI, SK ON, 3 domestic battery makers, Hyundai Motor Company, etc.	Reuse
Hyundai Glovis	Development of renewable energy power grid models and complexes to achieve carbon neutrality and improve power grid utilization efficiency. Establishment of energy storage utilizing used batteries and supply of electricity linked to renewable power generation in Shinan County	Reuse
EcoPro CnG	Signed a long-term supply contract with LG Energy Solutions for waste batteries in 2019. Started the Battery Recycle Plant (BRP) in Pohang, Korea	Repurpose
POSCO HY Clean Metal	Established a joint venture with China's Huayu Cobalt Co. (Recycling business to extract NCM cathode materials and supply them as cathode materials)	Repurpose
IS DONGSEO	Invested 5 % equity in Canadian battery recycler Recion (with patented wet smelting technology) as a strategic investor	Repurpose
PMGROW	Built 'Battery Green Cycle Camp' in Pohang, including design and manufacturing of electric vehicle battery packs and ESS utilizing used batteries.	Reuse
POEN	Receive defective battery packs from Hyundai or EV owners, inspect them, and repackage only the defective modules for sale to application manufacturers. Selectively replace and repackage only defective battery modules and sell them to application manufacturers.	Recycle
Power Logics	Establishing a pilot production facility for ESS reuse with Hyundai Motor Company	Reuse

D.2.3 Testing and certification center for BaaS system (KTR)

Figure D.6 is an example of establishment of battery status tracking (history management) system that can predict battery safety/reliability inspection technology and remaining life to revitalize the BaaS market which is organized by Korea Testing & Research Institute (KTR).

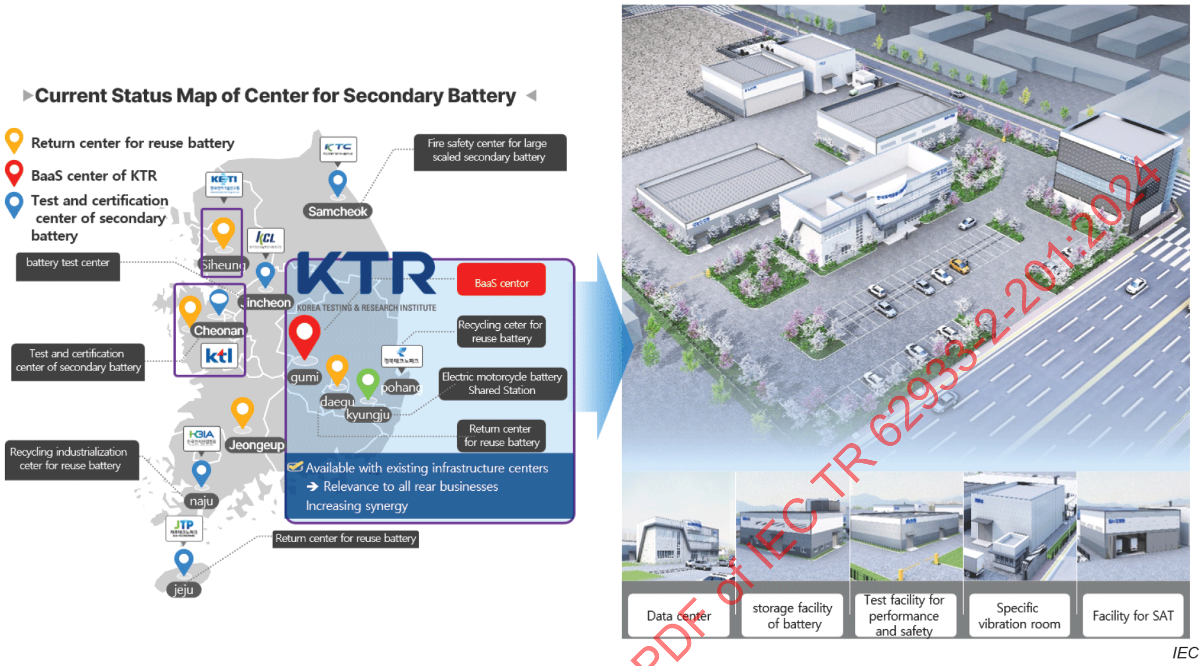


Figure D.6 – Current status map of centre for battery in Korea

Table D.2 describes detail of the testing and certification function in KTR. It can be seen that all necessary functions are integrated into one site.

Table D.2 – KTR testing and certification centre for BaaS System

New buildings	Description
Data centre	Establishment of a BaaS platform data centre that receives used battery samples and manages the BaaS life cycle history (ID number and status information of using and used batteries, test results, and operational specifics, etc.)
Storage facility of battery	Establishment of a centre that classifies received used battery pack samples by pre-treatment, diagnoses the disassembly and primary performance of packs and modules, and automatically stacks and stores batteries by sectors.
Test facility for performance and safety	Establishment of a centre that accurately diagnoses KC tests of used batteries (packs, modular units) using multi-purpose charging and discharging machines and environmental/performance/safety tests using stationary chambers and charging and discharging machines.
Specific vibration room	Establishment of a centre that conducts vibration/shock tests to confirm the adequacy of transportation and mobility applications of used batteries (packs, modular units).
Facility for SAT	Data-based battery condition diagnosis result reliability verification, field test for BaaS application, type test for fault verification, and on-site maintenance support.

Figure D.7 illustrates the operation of life-cycle status tracking data platform centre to provide subscription-type battery/battery system history management, analysis, and diagnosis services for BaaS:

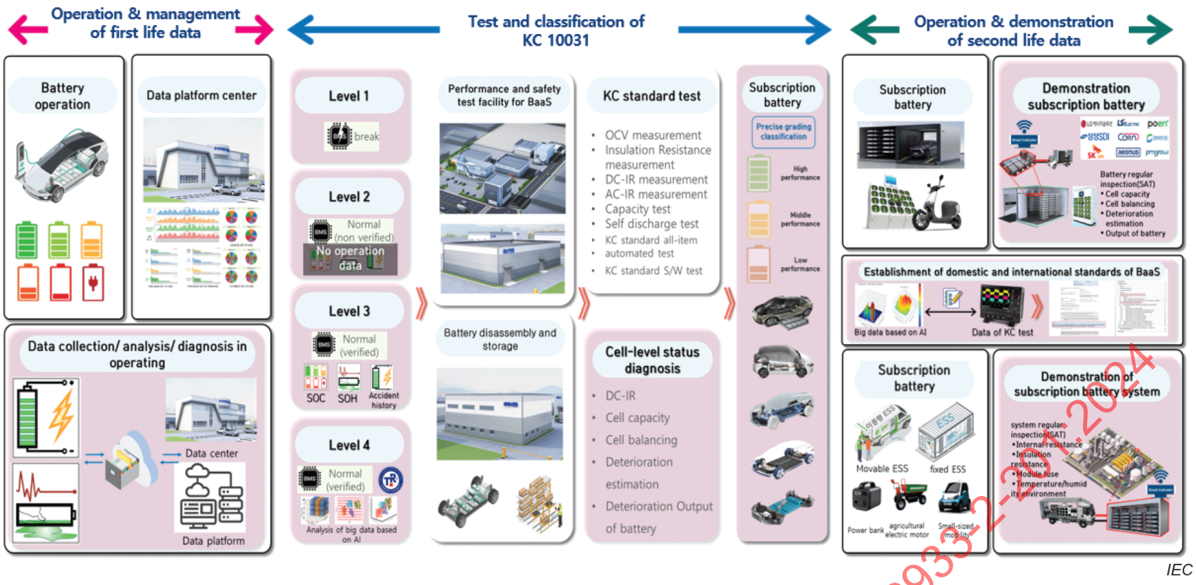


Figure D.7 – Battery life cycle data historical management

The following are details of each stages in Figure D.7.

1) Operation and management of first life data

- Collect BMS data from more than 2 000 EV vehicles on the road. At this time, not only new vehicles with 100 % SOH value, but also vehicles that have deteriorated to 80 % to 90 % over a long period of time, and collect and analyze battery data during use.
- Installation of a communication module device to transmit data from the EVs' local BMS to a real-time BaaS platform.
- Development of AI-based learning model technologies such as battery abnormality detection, future performance and life prediction, and condition monitoring.

2) Test and classification of KC 10031

- Condition diagnosis and residual value rating evaluation according to battery life/application.
- Develop and standardize battery health inspection process and BaaS system performance/safety test procedures by grading the safety level according to the BMS condition in the battery system and classifying the test method accordingly.
- Perform KC 10031(Safety requirements for lithium rechargeable batteries for reuse of spent batteries) testing.

3) Operation and demonstration of second life data

- Demonstration of subscription-type BaaS system and establishment of regular maintenance inspection system through real-time data collection/diagnosis/evaluation activities for subscription-type battery/battery system operators by application.
- Consistency verification of e-mobility data analysis and battery condition estimation results.
- Verification of applicability/utilization of BaaS application through mobile ESS demonstration operation.

Annex E
(informative)

Case study in China

E.1 First power battery disassembly and utilization line in Shanghai

Shanghai Action Plan Aiming at the New Track to Promote the Development of Green and Low-carbon Industries (2022- 2025), clearly proposed to accelerate the development of retired power battery echelon utilization:

- China's power battery decommissioning recycling and echelon utilization industry is mainly concentrated in Beijing, Shanghai, Tianjin, as well as other cities with a large number of new energy vehicles in Yangtze River Delta, and Pearl River Delta regions.Shanghai has five enterprises in line with the "New Energy Vehicle Waste Power Battery Comprehensive Utilization Industry Specification Conditions" (88 nationwide).
- In July 2022, Shanghai's first localized power battery disassembly and utilization line was completed, forming a long-term mechanism for localized waste power battery recycling and utilization, and setting a benchmark for a safe, environmentally friendly and technologically advanced energy recycling economy. It shows the production line for battery recycling in the used case. (https://www.lqqpy.com/show-57-4948-1.html)

E.2 Factory Environment Decommissioned Power Battery Energy Storage Demonstration Station

An enterprise engaged in retired power battery recycling and reuse in Shanghai has built a production line for echelon utilization of retired power batteries with annual processing capacity of 10 000 tons (700 MWh), as well as a rapid detection and sorting platform for retired power batteries and a comprehensive evaluation laboratory for batteries. It constructed a retired power battery recycling network for car dismantling factories and developed a decommissioned power battery energy storage station in factory environment with a total capacity of 1,574 MWh. (https://www.shyxhbkj. com/chanpinzhongxin/18.html)

E.3 Energy supply to 5G base stations based on the echelon utilization of retired batteries

A power supply compony in Hangzhou provides stable energy supply to 5G base stations based on the echelon utilization of retired batteries.

This 5G base station is an important communication base station shared by three national communication operators. The original backup power supply in this station is 24 lead-acid batteries with a total capacity of 20 kWh, and the new capacity of 100 kWh retired battery pack for double backup.

The 5G backup power storage station is adapted to peak-shaving and demand-side response. Annual savings amount to 36,000 yuan for the communication operators. According to predictions in 2021, China's 5G base station backup power storage load will reach 78,6 GWh in the future.

5G construction and base station energy storage applications open up a large market for the secondary use of retired batteries, and the scale of 5G base stations is expected to be 8 million in 2025, with a standby power storage demand of nearly 80 GWh.

E.4 Development trends and future prospects

Diversified power battery applications continue to expand the echelon utilization of supply space. Figure E.1 shows a schema of key technologies and factors for evolution.

The demand for backup batteries for base stations in China was 21,2 GWh in 2021, showing a growing demand for echelon utilization products.

Lithium iron phosphate batteries have been retired in bulk since 2022, with a forecasted volume of more than 32 GWh available for gradual use in 2025.

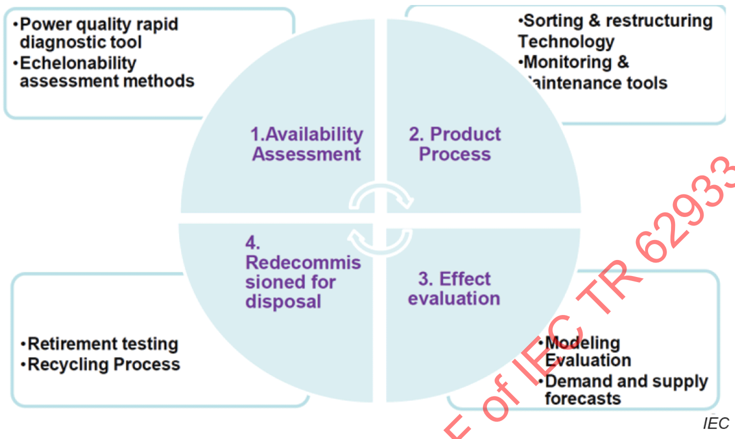


Figure E.1 – Key Technologies and factors for evolution

Drawbacks: Insufficient technical maturity for sorting and reconstitution, consistency assessment, and remaining life detection, etc.

Opportunities for improvement (OPI): Relying on intelligent manufacturing to break through the key technology process, improve the safety and reliability of echelon use products and industry chain maturity.

Annex F
(informative)

Case study in UK and EU

F.1 UK case study of repurpose/second life BESS

An organization known for its use of repurpose and second-life battery energy storage systems (BESS) was recognized in 2019 as one of the fastest-growing businesses in the United Kingdom. More information can be found about this organization at https://connected-energy.co.uk/.

This organization has been an early advocate of the repurpose or reuse battery approach, actively contributing to the promotion of this sustainable system. Their efforts not only advance the circular economy but also assist businesses in achieving decarbonization targets and optimizing their use of renewable resources. Battery supply partners are companies, including automobile manufacturers, a major player in energy solutions, a venture capital firm associated with a leading heavy machinery manufacturer, and an energy technology company.

This company in the UK specialises in battery energy storage systems that provide businesses flexibility over their power usage demands by providing repurpose and reuse batteries from electric vehicles.

Benefits are as follows:

- Reduction in energy cost: Using energy from the battery when tariffs are at their peak.
- Optimization of renewable energy sources: Renewable energy technology including solar and wind to store surplus generation and use as and when needed.
- Management of peak load: Supporting energy-intensive equipment including EV charging (see later slide for example).
- Overcoming capacity constraints: Avoiding expensive grid upgrades.
- Generation of additional revenue: Providing balancing services to grid operators.
- Demand response: With battery linking to site energy management systems.

The following is an example of BESS specifications:

– power: 300 kW
– capacity: 360 kWh
– 20 ft container
– using 24 second-life Renault EV batteries
– single or multiple systems working together

F.2 Other example installation of BESS system

F.2.1 EV charger

The use of a BESS (e.g. https://connected-energy.co.uk/battery-energy-storage/) to handle grid load management for multiple electric vehicle (EV) rapid chargers has gained popularity as an effective solution to address the costly grid upgrade challenge. This system combines two advanced technologies: repurpose EV batteries, which contribute to the circular economy, and sophisticated control software that efficiently optimizes available energy.