Preparatory Study on Ecodesign and Energy Labelling of rechargeable electrochemical batteries with internal storage under FWC ENER/C3/2015-619-Lot 1

TASK 1 Scope

Annex Analysis of available relevant performance standards&methods in relation to Ecodesign Regulation for batteries and identification of gaps.

Scope (Definitions, Standards and Legislation) – For Ecodesign and Energy Labelling

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In cooperation with JRC

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ABBREVIATIONS

Abbreviations	Descriptions
ADR	European Agreement Concerning the International Carriage of Dangerous Goods by Road
AND	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
BEV	Battery Electric Vehicle
BMS	Battery Management System
Cd	Cadmium
CE	European Conformity
CIT	International Rail Transport Committee
CPA	Statistical Classification of Products by Activity
CPT	Cordless Power Tools
CRM	Critical Raw Materials
DC	Direct Current
DG	Directorate General
DoC	Declaration of Conformity
DOD	Depth of Discharge
EC	European Commission
ECHA	European Chemicals Agency
ED	Ecodesign Directive
EDLC	Electrical Double-Layer Capacitor
EGDME	1, 2-dimethoxyethane or ethylene glycol dimethyl ether
ELR	Energy Labelling Regulation
ELV	End of Life of Vehicles
EOL	End of Life
ESS	Electrical Energy Storage Systems
EU	European Union
EV	Electric Vehicle
FU	Functional Unit
HEV	Hybrid Electric Vehicle
Hg	Mercury
HREEs	Heavy rare earth elements
IATA	International Air Transport Association
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IM	Implementing Measure
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
ISO	International Organization for Standardization
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory, which is the data collection and modelling part of an LCA
LCIA	Life Cycle Impact Assessment. In the LCIA, the environmental impact of the LCA model is analysed
LCO	Lithium-ion Cobalt Oxide

Abbreviations	Descriptions
LFP	Lithium-Ion Phosphate
LiB	Lithium ion Battery
Li-Cap	Lithium-ion Capacitor
LMNO	Lithium-Ion Manganese Nickel Oxide
LMO	Lithium-Ion Manganese Oxide
LREEs	Light rare earth elements
LTO	Lithium-Ion Titanate Oxide
LVD	Low Voltage Directive
MEErP	Methodology for Ecodesign of Energy related Products
NACE	Statistical Classification of Economic Activity
NCA	Lithium Nickel Cobalt Aluminium
NiCd	Nickel-Cadmium
NiMH	Nickel-Metal hydride
NMC	Lithium-ion Nickel Manganese Cobalt Oxide
OCV	Open Circuit Voltage
Pb	Lead
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PCM	Protection Circuit Module
PEF	Product Environmental Footprint
PGMs	Platinum Group metals
PHEV	Plug-in Hybrid Electric Vehicle
PRODCOM	Production Communautaire
PTC	Positive Thermal Coefficient
PV	Photovoltaic
REACH	Regulation on the registration, evaluation, authorisation and restriction of chemicals
RID	International Carriage of Dangerous Goods by Rail
RoHS	Restriction of hazardous substances
RRR	Recyclability, Recoverability, Reusability
SOC	State of Charge
SVHC	Substances of Very High Concern
TMS	Thermal Management System
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UPS	Uninterruptible Power Supply
vPvB	Very persistent and very bio accumulative
WEEE	Waste electrical and electronic equipment
WLTP	Worldwide harmonized light vehicles test procedure
WVTA	Whole Vehicle Type-Approval System

General introduction of this annex

The general objective of this annex is to dentify gaps in the available relevant standards in relation to Ecodesign Regulation for batteries. If important gaps exist to obtain critical ecodesign parameters, then transitional measurement methods need to be developed. The test standards are related to the product categories described within the scope of this study, being high energy rechargeable batteries of high specific energy with lithium chemistries for e-mobility and stationary energy storage (see Task 1 "Scope"). Standards are documents drawn up by consensus and approved by a recognised standardisation body. A test standard describes a method of testing in which no pre-given result is required when performing the test.

This task is done in cooperation with JRC and is included as a separate annex to Task 1 (scope).

The standards that have been analysed in detail are:

- IEC 62660-1:2018 — Secondary lithium-ion cells for the propulsion of electrical road vehicles - Performance Testing.
- ISO 12405-4:2018 — Electrically propelled road vehicles --Test specification for lithium-ion traction battery packs and systems -- Part 4: Performance testing
- DOE-INL/EXT-15-34184 (2015) — U.S. DOE Battery Test Manual for Electric Vehicles
- DOE-INL/EXT-07-12536 (2008) — Battery test manual for plug-in hybrid electric vehicles
- SAE J1798:2008 — Recommended Practice for Performance Rating of Electric Vehicle Battery Modules
- ISO/DIS 18243: 2017 — Electrically propelled mopeds and motorcycles -- Test specification and safety requirements for lithium-ion battery system
- IEC 62620: 2014 — Secondary lithium cells and batteries for use in industrial applications
- IEC 61427-2: 2015 — Secondary cells and batteries for renewable energy storage Part 2 On grid applications
- IEC 62984-3-2:2017 — High Temperature Secondary Batteries – Part 3: Sodium-based batteries – Section 2: Performance requirements and tests
- BVES Effizienzleitfaden (2017) — BVES Effizienzleitfaden
- ANSI/CAN/UL 1974:2018 — Standard for evaluation for repurposing batteries
- Nordic Swan Ecolabel (2018) — About Nordic Swan Ecolabelled Rechargeable batteries and portable chargers
- IEC 60086-6 (2017) — Primary batteries: Guidance on environmental aspects
- IEC/TS 62933-4 (2017) — Electrical Energy Storage (EES) Systems - Guidance on environmental issues
- IEC 63218 (under dev.) — Secondary Li-ion, Ni-Cd, and Ni-MH cells and batteries for portable applications - Guidance on environmental aspects

A summary of the contents concerning test methods are given in this annex with help of tables. These standards are about performance testing as needed for ecodesign regulation. Safety tests have been kept out of the scope.

Complementary detailed information about the standards included in this annex and concerns with them can also be found on/in:

- https://www.batterystandards.info/ [1],
- the public document of the MAT4BAT project Deliverable 5.1 'List of relevant regulations and standards' [1],
- the JRC technical report on 'Standards for the performance assessment of electric vehicles batteries' [2],
- the testing document 'White Paper on Test methods for improved battery cell understanding' that was developed by a cooperation between European battery projects [3],
- the JRC report 'Putting science into standards - Driving towards decarbonisation of transport: safety, performance, second life and recycling of automotive batteries for e-vehicles', 2016 [4],
- the JRC technical report 'Sustainability assessment of second life application of automotive batteries (SASLAB)', 2018. [5],
- and of course in the respective standards.

These documents also give information on battery safety and safety tests, what is less the subject of ecodesign.

After this general introduction, this annex covers the following sections:

- Section 1 gives the summary of the identified gaps of relevant battery standards.
- Section 2 starts with a short introduction on standards and standardisation bodies followed sub-sections with lists of battery standards per standardisation committee.
- Section 3 provides a more detailed overview including descriptions of relevant standards by subject, being: measurement and testing, electric vehicle applications, other applications, environment related topics, reuse of batteries, and functioning during use phase.

[1] This website is dedicated in supporting your way through standards on rechargeable batteries and system integration.

1. Identified gaps of relevant battery standards

This section summarises the identified gaps of relevant standards in relation to Ecodesign Regulation for batteries. The structure of this summary follows the structure of the tasks considered within the Methodology for Ecodesign of Energy-related products (MEErP). The gaps come from the analysis on standards in chapter 3 and from gaps given in the above mentioned reports, as far as they relate to ecodesign issues.

For defining the scope, related to Task 1:

- It can be concluded that all definitions for the scope can be done according to IEC/ISO standards, except Calendar life, Specific power / Gravimetric power density and Volumetric Power density.

Concerning performance metrics on product life time and efficiency related to Task 3:

- The performance metrics such as energy content and internal resistance are defined in the standards. However, in each standard and for each application (even within one standard since it can cover several applications) the exact methodology is dissimilar. Also, several methodologies can be given for the same metrics. This means that the capacity (in Ah) can be based on e.g. a 1 h, 5 h or 8 h discharge period or even on a discharge with a specific current profile. Resistance values may be derived from a pulse test, a jump in discharge current, but also from an AC signal.
- Most standards have test clauses to express the capacity in Ah. This unit is prescribed by the European regulation 1103/2010 on capacity labelling of portable secondary and automotive batteries (*i.e.* starter battery, not electric vehicle battery). Few standards prescribe the determination of energy content expressed in kWh, like the proposed functional unit, especially for standards outside automotive.
- The energy involved in heat and cooling of the battery system is not determined in standards.
- The capacity tests in the standards ignore that cells can be charged at several current rates. This is, however, of interest for e.g. quick charging and regenerative braking. It must be noted that charging is mostly not allowed in the same temperature range as discharging if no active heating is present (i.e. only above 0°C).
- The heating and cooling of the battery is within the study's system boundary. However, the needed energy is outside the boundary and will be an arbitrary value. It must be noted that the test standards do not measure this value, what could have been used as a reference.
- For cycle life tests (repeated imposition of a test profile on the battery expressed in current or power) many profiles exist. 14 have been identified in the relevant standards. Each application has a profile and dissimilar standards may have a different profile. The profiles found are always a simplification of real profiles like the battery would undergo during e.g. a WLTP test.
- Most cycle life tests are applied at 25°C but also one at 30 and one at 45°C. One test standard mentions that the cooling system has to be switched on. The reason for the testing temperatures are not given in the standards. [2]
- Cycle life tests do not take into account temperature profiles, like a series of temperature in weekly consecution such as -10°C, 25 and 45°C. Dissimilar charging and discharging temperatures are not considered. Cycle life tests are not combined with calendar life tests. Few standards incorporate calendar life examination anyway. [2]

- The influence of mechanical stresses like vibrations and shocks, so mechanical ageing, is not considered in the relevant standards. [4]
- In European battery development projects often an ageing test programme is performed with a swarm of test conditions being a combination of calendar life testing and cycle life tests with simple profiles. These conditions allow to derive the ageing behaviour comprehensively and goes therefore beyond single use cases. This generic approach is not found in current test standards. [3] [4]
- Several standards give end of life criteria, defining when the battery is not useful anymore. This is mostly related to the specific, application dependent, test cycle: if the profile imposed as cycle life test cannot be performed anymore since the battery voltage hits upper and or lower limit almost immediately, or e.g. that the battery becomes too hot during the cycling, then this is considered as an end of life state.
- No clear definition of SOH exists and it is differently used over applications and manufacturers. Battery degradation is a combination of phenomena as capacity fade, power fade, efficiency reduction, rise in cooling demand and negative incidents. A more elaborate approach to tackle SOH is therefore needed. Even if SOH only refers to capacity fade then still the calculation method has to be clarified since the nominal capacity can be taken or the capacity related to the needed power. [4]
- The indicators for SOH should be openly available from the BMS [4]. Alternatively, a traceability and tracking system for battery packs must be conceived.
- End of life (EOL) information: the BMS has currently no prescribed role in it, although it could give information on remaining capacity, actual power capability (being limited by either the battery resistance or the battery cooling capability) and negative events that happened. This information is of interest for the possibility to repair modules in a battery system and for repurposing batteries to a second life application. The standard ANSI/CAN/UL1974 provides a list with information that a BMS should provide to understand the battery health.
- The standard ANSI/CAN/UL1974 on repurposing of batteries introduces the calendar expiration date. A battery should not be used longer than this date. This date must be provided by the manufacturer. Current battery standards do not require this information. It must be stated that the battery life is much dependent on the use conditions such as the total time being at 100% SOC. Unlike primary batteries such a date is currently not given on secondary batteries.
- SOH determination by advanced techniques like electrochemical impedance measurement can be treated in standards as additional indicators [4].

For material efficiency aspects (life time, repair, recycling, ...), related to Task 4/5:

- There are no voted standards currently and work is in progress within CEN/CLC/JTC 10– 'Energy-related products-Material Efficiency Aspects for Ecodesign'.

For carrying out environmental life cycle assessments (LCA), related to Tasks 5/6:

- There are two ISO standards for drafting LCA studies (ISO 14040 and ISO 14044). However, they leave LCA practitioners with an array of choices that can affect the execution and results of an LCA. A tighter framework is available throuht the CEN/TC 350 EN 15804 standardand through the Product Environmental Footprint (PEF) methodology . However, the first mentioned is specifically for the construction sector, and the latter is not a standard but a harmonised European method. Nevertheless, there is a standard under development that can possibly fill the gap for batteries: prEN 50693 ‘Method for quantitative eco design via life cycle assessment and environmental declarations through product category rules for EEE’.

- Unified guidelines or harmonized approaches for performing LCA do not exist and different analyses may yield conflicting results when second use applications are considered, due to variability in assumptions, scope of the application and scenarios (e.g. considerations for recycling, costs and energy involved in manufacturing) [4].
- Most software and databases are proprietary which could hamper to include LCA results such as a carbon footprint in EC Regulation. The following LCA methods and tool are not standards but can be interesting in order to overcome proprietary issues:
    - openLCA is an open source and free software for LCA. It is developed and hosted by GreenDelta, an independent sustainability consulting and software company in Berlin, Germany. It is sustained by a network of partners, contributors, supporters and a user community. openLCA can offer free databases for use in openLCA and other datasets can be directly imported in case the datasets are in EcoSpold or ILCD format (common LCA dataset formats). It is highly likely that there are no LiB datasets in openLCA.
    - There is a lack of test cases and/or standards to test whether LCA software is calculating correctly. Within the LCA community it is a well-known problem that using a different LCA software can lead to different results even when calculating the same model and using the same dataset.
    - The Life Cycle Data Network is hosted by the EC/JRC and aims to provide a globally usable infrastructure for the publication of quality assured LCA dataset (i.e. LCI datasets and LCIA method datasets) (http://eplca.jrc.ec.europa.eu/). It aspires to include the Environmental Footprint (EF) datasets for representative products and a benchmark (http://eplca.jrc.ec.europa.eu/EF-node/). So far, the datasets for LiB are not publicly available yet.
    - The GREET model of Argonne National Lab is a model for “Greenhouse gases, Regulated Emissions, and Energy use in Transportation”. It is available in excel format and .NET format. The aim is to get a full life cycle carbon emission impact estimate from well to wheels for fuels and raw material mining to vehicle disposal for automobiles (https://greet.es.anl.gov/). It includes recent carbon footprint data for LiB. This public domain model is available free of charge for anyone to use.

For re-sales and repurposing of batteries:

- For a profitable second use of batteries, additional costs as for testing, disassembly and retrofitting need to be minimised [4]. The original battery design and the BMS have a high impact on this. Since a BMS designed for an EV application would probably not be suitable for a second use application, the possibility of uploading adapted firmware must be considered. These issues are not in nowadays standards. Test methods to assess battery reliability, safety and performance at the end of first life use are absent. Criteria and guidelines to determine the suitability for a relevant second use can be developed. Standardised interfaces for hardware and software, including connectors, would support this minimised cost approach [4].
- Use information on the first life application, beyond the remaining capacity, is necessary. The standard ANSI/CAN/UL1974 identifies the information need. This information is

however probably not reachable, partly since it is not stored, partly since a BMS is probably not accessible by third-parties. Open BMS information that includes sufficient use history information can help. A traceability system of battery packs can lead to a similar functionality.

- For repurposing and recycling activity, standardised battery module sizes and pack sizes can help. Size standardisation is currently only at cell level (ISO/PAS 19295: 2016; DIN 91252:2016).

For recycling of batteries:

- Explicit information and guidance on battery recycling is lacking in current standards.
- Little information is available on the material contents of batteries by labelling standards with IEC 62902 being the most important one. The argument is that it should not be too visible which Li-ion battery has most value for recycling. However, a database or traceability system can fulfil this information gap.
- Standards that define battery marking including the principal active materials (i.e IEC 62620, IEC 61960) need to anticipate new active materials like a silicon based anode.
- Harmonised calculation methods for the recycling efficiency to avoid data misinterpretation is welcomed. This should include environmental aspects like waste styreams, incineration with energy recovery and final landfilling or elimination. [4]
- Harmonised quantification of key indicators as CO_2 footprint, recycling percentage, toxicity and recycling cost is needed [4].

2. Overview of relevant standards according to their standardization bodies

2.1. Introduction to standards and standardization bodies

Standards are not written by a government, but by standardisation organisations. These can be public and private. Typically, they refer to product performance or quality assurance. Standards are voluntarily, except if a specific standard is prescribed in a national regulation, which occurs rarely. If standards exist for a certain product group, it is recommendable to investigate if a product complies with it. Standards give a raised confidence if it the standard is about product design and safety. Standards can also lead to better insight in the performance of products by prescribing performance tests.

In Europe a special category of standards exists: the *harmonised standards*. These are commissioned by the European Commission to comply with specific directives, like the machine directive, gas appliances directive and of course the Ecodesign directive. The General product safety directive 2001/95/EC [2] encourages explicitly to use harmonised standards, since products designed accordingly are assumed to be safe.

The harmonised standards are made by the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC). Often CEN and CENELEC take over standards by the International Electrotechnical Committee (IEC) and the International Standards Organisation (ISO) and add clauses to bring the standards in accordance with the European rules on e.g. environmental protection, safety and consumer protection. The complete list of harmonised standards is can be found online[3]. The use of these standards remains voluntary, but manufacturers then have an obligation to prove that their products meet the essential requirements written in each applicable directive.

Standards are made with dissimilar aims and can mix several objectives. These can be:

– design
– performance tests
– safety design
– safety tests
– environmental protection
– classification
– guidance
– recommendation.

A standard can thus be found that guides the battery user in the different types of batteries and installation methods. A standard can explain how to design a battery installation, probably stressing safety aspects whereas other standards can prescribe performance tests and safety tests and often refer to standards with test methods that work out specific test conditions.

Closely related to batteries are standards that involve:

[2] https://eur-lex.europa.eu/legal-content/NL/TXT/PDF

[3] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards_en

– functional safety
– test methods.

Standards can cover different life cycle stages being:

– design
– production
– transport
– installation
– use
– return.

Standardisation on batteries is much broader than the legislation and many bodies are developing standards. The worldwide standardisation organisations that include battery standardisation are:

– International Electrotechnical Commission, IEC
– International Standardisation Organisation, ISO

At European level the European Committee for Electrotechnical Standardization, CENELEC, is involved regarding batteries.

At national level there are also active organisations (e.g. China[4], Japan Electric Vehicle Association Standards (Japan), VDE (Germany), DIN (Germany), ANSI (United States of America)).

Also, commercial organisations and associations develop standards on batteries (e.g. Underwriters Laboratory, UL, Telcordia, SAE, DNV GL, Ellicert, BATSO).

For standards on batteries for electric vehicle standards a work division has been made between IEC, ISO, CEN and CENELEC. IEC TC 21 and SC21A develop standards from cell to pack level. ISO TC22 works on system level. This is visible for example in ISO 14205 series 'Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems'. In the scope it states that ISO 12405 specifies test procedures for lithium-ion battery packs and systems which are connected to the electric propulsion system of electrically propelled vehicles. For the specifications for battery cells, the series refer to IEC 62660-1 to 3 'Secondary lithium-ion cells for the propulsion of electric road vehicles'.

At European level there are two counter parts. For IEC TC21 and SC21A, there is committee (CENELEC) CLC/TC21. This committee has as objectives: to implement IEC/TC 21/SC 21A documents into CENELEC standards; to prepare Product Standards, general requirements and methods of testing included; to prepare Safety Standards and associated Codes of Practice; to consider Environmental Requirements (EC Rules) for the products.

The counterpart for ISO TC 22 is CEN/TC301 'Road vehicles'. It is very explicit on their relation: "Preparation of road vehicle European Standards answering essentially to European mandates. Since the automotive industry is acting globally, the international level (ISO/TC 22 Road vehicles) shall have top priority for any other standardization projects."

[4] http://www.eu-china-standards.cn

2.2. Standards from IEC committees on batteries

An overview of well-known standards and relevant for the Ecodesign preparatory study that are published under each per committee is given here. Additional information on standards under development by the committees is also given.

2.2.1. IEC TC21 Secondary cells and batteries

The scope of this committee is to provide standards for all secondary cells and batteries related to product, safety, testing, and safe application.

- IEC 61427 series - Batteries for renewable energy storage

  They contain:

  - Part 1: Photovoltaic off-grid application
  - Part 2: On-grid applications

- IEC 62485 series - Safety requirements for secondary batteries and battery installations (with parts for Li-ion, lead-acid, …)

  They contain:

  - Part 1: General safety information
  - Part 2: Stationary batteries
  - Part 3: Traction batteries (planned, no document)
  - Part 4: Valve-regulated lead-acid batteries for use in portable appliances (planned, no document)
  - Part 5: Safe operation of stationary lithium-ion batteries
  - Part 6: Safe operation of lithium-ion batteries in traction applications

- IEC/EN 60952 series - Aircraft batteries
- IEC/EN 60896 series - Stationary lead-acid batteries
- IEC/EN 60254-1 - Lead-acid traction batteries
- IEC/EN 61056 series - General purpose lead-acid batteries (valve-regulated types)
- IEC 61982 series Secondary batteries (except lithium) for the propulsion of electric road vehicles

  They contain:

  - Performance and endurance tests (no part number)
  - Part 4: Safety requirements of nickel-metal hydride cells and modules

- IEC 62660 series - Secondary lithium-ion cells for the propulsion of electric road vehicles

  They contain:

  - Part 1: Performance testing
  - Part 2: Reliability and abuse testing for lithium- ion cells
  - Part 3: Safety requirements

- IEC 62932 series - Flow battery systems for stationary applications
- IEC 62984 series - High Temperature Batteries

They contain:

– Part 1: General aspects, definitions and tests
– Part 2: Safety requirements and tests of cells and batteries
– Part 3: Sodium-based batteries – Performance requirements and tests

- IEC 61429 - Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135. (This standard applies to lead-acid batteries (Pb) and nickel-cadmium batteries (Ni-Cd).)
- IEC 62902 - Marking symbols for secondary batteries for the identification of their chemistry. (This standard applies to lead acid (Pb), nickel cadmium (Ni-Cd), nickel metal hydride (Ni-MH), lithium ion (Li-ion), secondary lithium metal (Li-metal).)

2.2.2. IEC SC21A Batteries with alkaline and other non-acid electrolytes

IEC SC21A prepares standards regarding product and test specifications for all secondary cells and batteries of sealed and vented designs containing alkaline or other non-acid electrolytes, being lithium batteries.

IEC/EN 62133 series	Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications.
IEC 62620	Secondary lithium cells and batteries for use in industrial applications
IEC 62619	Safety requirements for secondary lithium cells and batteries for use in industrial applications
IEC 61960 series	Secondary lithium cells and batteries for portable applications
IEC/EN 61951 series	Portable sealed rechargeable single cells (NiCd, NiMH)
IEC/EN 60622	Sealed nickel-cadmium prismatic rechargeable single cells
IEC/EN 60623	Vented nickel-cadmium prismatic rechargeable single cells
Under development	Secondary lithium-ion, nickel cadmium, and nickel metal hydride cells and batteries for portable applications – Guidance on environmental aspects (IEC 63218)
Under development	Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems (IEC 63056)
Under development	Secondary lithium batteries for use in road vehicles not for the propulsion (IEC 63118)
Under development	Safety requirements for secondary lithium batteries for use in road vehicles not for the propulsion (IEC 63057)

2.2.3. IEC TC35 Primary cells and batteries

They are out of scope for rechargeable Li-ion batteries, except their transport standard:

IEC/EN 62281	Safety of primary and secondary lithium cells and batteries during transport

It is almost a copy of UN38.3 except small differences in test preparations. A comparison is found in the table on safety tests on BatteryStandards.info: https://www.batterystandards.info/sites/batterystandards.info/files/safety_tests_detailed.pdf .

IEC 60086 series	Primary batteries Interesting can be Part 6: Guidance on environmental aspects.

2.2.4. IEC TC120 Electric energy storage (EES) systems

This committee works on standardisation in the field of grid integrated EES Systems. It focusses on system aspects on EES Systems rather than energy storage devices.

IEC 62933-1	Electrical Energy Storage (EES) systems - Terminology
IEC 62933-2	Electric Energy Storage (EES) systems - Unit parameters and testing methods of electrical energy storage (EES) system - Part 1: General specification
IEC 62933-3	Planning and installation of electrical energy storage systems
IEC/TS 62933-4	Electrical Energy Storage (EES) Systems - Guidance on environmental issues
IEC/TS 62933-5	Safety considerations related to the integrated electrical energy storage (EES) systems

2.2.5. IEC TC69 Electric road vehicles and electric industrial trucks

The scope of this committee is on the preparation of international standards for road vehicles, totally or partly electrically propelled from self-contained power sources, and for electric industrial trucks.

IEC 62576	Electric double-layer capacitors for use in hybrid electric vehicles - Test methods for electrical characteristics
IEC 61851 series	Electric vehicle conductive charging system; under development are communication protocols
IEC 61980 series	Electric vehicle wireless power transfer (WPT) systems
IEC TS 62763	Pilot function through a control pilot circuit using PWM (pulse width modulation) and a control pilot wire
IEC 62840 series	Electric vehicle battery swap system

2.2.6. IEC TC113 Nanotechnology standardization for electrical and electronic products and systems

IEC TC113 works on standardisation of the technologies relevant to electrotechnical products and systems in the field of nanotechnology.

IEC TS 62607 series	Nanomanufacturing - Key control characteristics
IEC 62565 series	Nanomanufacturing - Material specifications
IEC/TS 62876 series	Nanotechnology - Reliability
ISO/TS 80004 series	Nanotechnologies - Vocabulary

Concerning battery materials, some standards on nano-enabled energy storage are:

IEC TS 62607-4 series Nanomanufacturing - Key control characteristics

It concerns:

- Part 4-1: Cathode nanomaterials for nano-enabled electrical energy storage - Electrochemical characterisation, 2-electrode cell method
- Part 4-2: Physical characterization of nanomaterials, density measurement

Part 4-3: Nano-enabled electrical energy storage - Contact and coating resistivity measurements for nanomaterials

Part 4-4 Thermal Characterization of Nanomaterials, Nail Penetration Method

Part 4-5 Cathode nanomaterials - Electrochemical characterisation, 3-electrode cell method

Part 4-6: Nano-enabled electrical energy storage devices - Determination of carbon content for nano electrode materials, infrared absorption method

Part 4-7: Nano-enabled electrical energy storage - Determination of magnetic impurities in anode nanomaterials, ICP-OES method

Under development — Nanomanufacturing – Part 4-8 Nano-enabled electrical energy storage devices - water content for electrode nanomaterials by Karl Fischer Method (NWP IEC TS 62607-4-8)

2.2.7. Other battery related IEC standards

IEC 60364-5-57 ED1 — Low-voltage installations - Part 5 Selection and erection of equipment - Clause 57 Erection of stationary secondary batteries

2.2.8. IEC TC 111 Environmental standardization for electrical and electronic products and systems

This committee prepares the necessary guidelines, basic and horizontal standards, including technical reports, in the environmental area, in close cooperation with product committees of IEC. It liaises ISO/TC 207 (mentioned later).

IEC 62430 — Environmentally Conscious Design (ECD) - Principles, requirements and guidance

2.3. Standards from ISO committees

2.3.1. ISO TC22 Road vehicles

This committee has several subcommittees dealing with the application of batteries in electric drivetrains.

SC 37 Electrically propelled vehicles

ISO 12405 series — Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems

They contain:

- (Part 1: High-power applications: obsolete and replaced by part 4 in 2018)
- (Part 2: High-energy applications: obsolete and replaced by part 4 in 2018)
- Part 3: Safety performance requirements
- Part 4: Performance testing

ISO 6469 series	Electrically propelled road vehicles -- Safety specifications
ISO/TR 8713	Electrically propelled road vehicle – Vocabulary
ISO/IEC PAS 16898	Electrically propelled road vehicles - Dimensions and designation of secondary lithium-ion cells
ISO 18300	Electrically propelled road vehicles -- Specifications for lithium-ion battery systems combined with lead acid battery or capacitor

ISO/PAS 19295:2016	Electrically propelled road vehicles -- Specification of voltage sub-classes for voltage class B
ISO 20762	Electrically propelled road vehicles – Determination of power for propulsion of hybrid electric vehicles
Under development	ISO/DIS 21782 series Electrically propelled road vehicles -- Test specification for electric propulsion components. They contain: – Part 1: General – Part 2: Performance testing of motor system – Part 3: Performance testing of motor and inverter – Part 6: Operating load testing of motor and inverter
Under development	ISO/DIS 19363 Electrically propelled road vehicles -- Magnetic field wireless power transfer -- Safety and interoperability requirements
Under development	ISO/DIS 21498 Electrically propelled road vehicles -- Electrical tests for voltage class B components

SC 38 Motorcycles and mopeds

ISO 13064-1:2012	Battery-electric mopeds and motorcycles -- Performance -- Part 1: Reference energy consumption and range
ISO 18243	Electrically propelled mopeds and motorcycles – tests and safety requirements Li-ion battery systems
Under development	ISO/AWI 23280 Electrically propelled mopeds and motorcycles -- Test method for performance measurement of traction motor system

SC 32 Electrical and electronic components and general system aspects

ISO 19453 series	Road vehicles – Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles

They contain:

- Part 1: General
- Part 2: Electrical loads
- Part 3: Mechanical loads
- Part 4: Climatic loads
- Part 5: Chemical loads

Under development	ISO 19453 Road vehicles – Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles: Part 6: Traction battery packs and systems

2.3.2. ISO TC207 Environmental management

This committee works on standardisation in the field of environmental management systems and tools in support of sustainable development. It has several working groups and subcommittees including Life cycle assessment.

SC 5 Life cycle assessment

- ISO 14040:2006: Environmental management – Life cycle assessment – Principles and framework
- ISO 14044:2006: Environmental management – Life cycle assessment – Requirements and guidelines

2.4. Specific standards from CEN and CENELEC committees

2.4.1. CENELEC CLC/TC21X Secondary cells and batteries

This committee has as objectives: to implement IEC/TC 21/SC 21A documents into CENELEC standards; to prepare Product Standards, general requirements and methods of testing included; to prepare Safety Standards and associated Codes of Practice; to consider Environmental Requirements (EC Rules) for the products.

EN 50604-1:2016	Secondary lithium batteries for light EV (electric vehicle) applications - Part 1: General safety requirements and test methods
EN 50272 series	Safety requirements for secondary batteries and battery installations. *Note: this standard will be replaced by IEC 62485 series.*
EN 50342 series	Lead-acid starter batteries

2.4.2. CEN/TC301 Road vehicles

This committee is involved in the preparation of road vehicle European Standards answering essentially to European mandates. As counterpart for ISO TC 22 that committee has priority for any other standardization projects.

EN 1987 series	Electrically propelled road vehicles - Specific requirements for safety

For batteries is of interest:

- Part 1: on board energy storage

2.4.3. CENELEC CLC/TC111x Environment

CLC/TC111x deals with environmental aspects for electrical and electronic products and systems. It enhances CENELEC's environmental links with the European legal framework, particularly in the context of standardization aspects of EU environmental regulations and directives. It assists product committees in the elaboration of environmental requirements of product standards.

prEN 50693	Method for quantitative eco design via life cycle assessment and environmental declarations through product category rules for EEE **(under development)**
FprEN 50614	Requirements for the preparing for re-use of waste electrical and electronic equipment **(under development)**

2.4.4. CEN-CENELEC Joint Technical Committee 10 on Energy-related products – Material Efficiency Aspects for Ecodesign

CEN/CLC/JTC 10 is a Joint Technical Committee between CEN and CENELEC in response to the EU Standardization Mandate/543 for Material Efficiency aspects. All standards are in development. They will have numbers EN 4555X.They must be horizontal and generic: not product specific. These standards could serve as a voluntary reference point when designing all kinds of products.

CLC/prTR 45550	Definitions related to material efficiency (under drafting)
CLC/prTR 45551	Guide on how to use generic material efficiency standards when writing energy related product specific standardization deliverables (under drafting)
prEN 45552	General method for the assessment of the durability of energy-related products (under drafting)
prEN 45553	General method for the assessment of the ability to re-manufacture energy related products (under drafting)
prEN 45554	General methods for the assessment of the ability to repair, reuse and upgrade energy related products (under drafting)
prEN 45555	General methods for assessing the recyclability and recoverability of energy related products (under approval)
prEN 45556	General method for assessing the proportion of re-used components in an energy related product (under approval)
prEN 45557	General method for assessing the proportion of recycled content in an energy related product (under approval)
prEN 45558	General method to declare the use of critical raw materials in energy related products (under approval)
prEN 45559	Methods for providing information relating to material efficiency aspects of energy related products (under approval)

2.5. Standards from national bodies

E_VDE-AR-E_2510-50	Sicherheitsanförderungen Stationäre Li-ionspeicher Safety requirements for stationary battery energy storage systems with lithium batteries
E_VDE-AR-E_2510-2	Stationäre_Speicher_ans_NS-Netz About the safe connection of batteries to the low voltage grid
DIN 91252	Electrically propelled road vehicles - Battery systems - Design specifications for Lithium-Ion battery cells (this standard specifies cell formats)

2.6. Standards from private and governmental bodies

UL 1642	UL Standard for Safety of Lithium Batteries
UL 2580	Batteries for Use in Electric Vehicles
UL 2271	Batteries For Use In Light Electric Vehicle (LEV) Applications

UL 2580	Batteries For Use In Electric Vehicles
UL 1973	Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications (the scope of UL 1973 includes batteries for use as auxiliary power in recreational vehicles and for temporary energy storage system applications that are mobile but used as stationary energy storage.)
ANSI/CAN/UL 1974	Standard for evaluation for repurposing batteries
SAE 2288	Life Cycle Testing of Electric Vehicle Battery Modules
SAE J2344	Guidelines for Electric Vehicle Safety
SAE J2289	Electric-Drive Battery Pack System Functional Guidelines
SAE J2464	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
SAE J2929	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells
SAE J2950	Recommended Practices (RP) for Shipping Transport and Handling of Automotive-Type Battery System - Lithium Ion
SAE J2997	Standards for battery secondary use (**under development**)
SAE J2758	Determination of the maximum available power from a rechargeable energy storage system of hybrid electric vehicle (**under development**)
Ellicert Batteries	Certification scheme for battery cells and packs for rechargeable electric and hybrid vehicles – General requirements relating to certification – Application to Lithium based elements
BATSO 01	Manual for evaluation of energy systems for Light Electric Vehicle (LEV) - Secondary Lithium Batteries
BATSO 02	Manual for evaluation of energy systems – Secondary Lithium Batteries (stationary applications)
BVES Effizienzleitfaden für PV-Speichersysteme V1.0.4 (2017)	From 'Bundersverband Energiespeicher' in Germany. It provides test methods to determine the energy efficiency of home solar storage systems. It discerns the efficiency and energy losses of the inverter(s) and the battery separately.
DOE-INL/EXT-15-34184	Battery test manual for electric vehicles
DOE-INL/EXT-07-12536	Battery test manual for plug-in electric vehicles.

Nordic Swan Ecolabel Primary Batteries
: The Nordic Swan is a voluntary official ecolabel in the Scandinavian countries, Denmark and Iceland.

Nordic Swan ecolabelling for rechargeable batteries and portable chargers
: The Nordic Swan Ecolabel focuses on capacity and durability of batteries. Batteries and portable chargers must meet recognized quality and safety standards.

Recharge PEFCR
: Product environmental footprint category rules for high specific energy rechargeable batteries for mobile applications.
Note: a PEFCR is a guideline based on the harmonised PEF method.

3. Overview of relevant standards per topic

3.1. Measurement and test standards

The assessment of the performance of batteries has been dealt with by multiple international organizations, as elaborated in the previous chapter. Depending on the type of application specialized standards have been developed. Although different standards have been created it is commonly found that the same type of testing topics are applied on the battery with different test conditions. This can involve the prescribed current to discharge a battery or the current profile and depth of discharge in a cycle-life test. The testing method independently of the application can be separated into four main categories. These are related with the:

- Characterization tests: electrical and energy performance of the system under different load profiles. For the Ecodesign preparatory study this is of main importance.
- Ageing tests: the behaviour of the system throughout the lifetime that it is being operated. For the Ecodesign preparatory study this is of main importance.
- Safety/Abuse tests: assessment of the safety of the system under different stress conditions for safe utilization and transportation of the system. For the Ecodesign preparatory study this is of low importance.
- Material testing: characterization of the materials incorporated in the system. This category is found in environmentally related standards, on the determination of heavy metals for instance, and are found as individual standards by IEC TC113 on nanotechnology.

3.2. Relevant standards for EV application

The characterization tests and ageing tests are mainly being implemented in the context of Electric Vehicle applications. In the following list the main international standards dealing with the assessment of the electrical performance of high specific energy batteries in Electric Vehicle applications are listed:

- IEC 62260-1:2010: Secondary lithium-ion cells for the propulsion of electric road vehicles;
- IEC 61982:2012: Secondary batteries (except lithium) for the propulsion of electric road vehicles - Performance and endurance tests
- ISO 12405-4:2018: Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 4: Performance testing;
- DOE-INL/EXT-15-34184: Battery test manual for electric vehicles;
- DOE-INL/EXT-07-12536: Battery test manual for plug-in electric vehicles;
- SAE 2288 Life Cycle Testing of Electric Vehicle Battery Modules;
- SAE J1798:2008: Recommended Practice for Performance Rating of Electric Vehicle Battery Modules.

A summary of the different test procedures that are included in these standards is dealt with in section 3.6, specifically by Table 1.

3.3. Relevant standards for other applications

- IEC 61427-2 Batteries for renewable energy storage Part 2 On-grid

This standard contains endurance tests for the following applications:

- frequency-regulation service
- load-following service
- peak-power shaving service
- photovoltaic energy storage, time-shift service

It also describes methods to determine battery properties and electrical performance, being:

- energy content at +25 °C ambient temperature
- energy efficiency during endurance tests at +25 °C ambient temperature
- energy efficiency during endurance tests at the minimum and maximum ambient temperature
- waste heat generated during endurance tests at the maximum ambient temperature
- energy requirements during periods of idle state at +25 °C ambient temperature

- IEC 62620 Secondary lithium cells and batteries for use in industrial applications

This standard is applicable for industrially used batteries. This covers a broad range of applications:

- Stationary applications: telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power and similar applications.
- Motive applications: fork-lift truck, golf cart, AGV, railway, and marine, excluding road vehicles.

It contains performance tests:

- Discharge performance at +25 °C (rated capacity)
- Discharge performance at low temperature
- High rate permissible current
- Charge (capacity) retention and recovery
- Cell and battery internal resistance: AC and DC resistance

It contains two endurance tests:

- Endurance in cycles
- Endurance in storage at constant voltage (permanent charge life)

This standard discerns 4 battery categories:

- High energy (S; <C/8)
- Energy (E; <C/2)
- Medium rate discharge (M; <3.5C)
- High rate (H; >3.5C)

- IEC 62933-2 Electric Energy Storage (EES) systems - Unit parameters and testing methods of electrical energy storage (EES) system - Part 1: General specification

This standard is applicable on the following stationary applications: Frequency regulation, Fluctuation reduction, Voltage regulation, Peak shaving / Peak shifting, Back-up power. It prescribes performance tests for them.

It covers also test methods for the following unit parameters:

- Actual energy capacity
- Input and output power rating
- Round trip energy efficiency
- Expected service life
- System response
- Auxiliary power consumption
- Self-discharge of EESS
- Voltage range
- Frequency range

- IEC 62984-3-2:2017 High Temperature Secondary Batteries – Part 3: Sodium-based batteries – Section 2: Performance requirements and tests

- ISO/DIS 18243 Electrically propelled mopeds and motorcycles -- Test specification and safety requirements for lithium-ion battery system

- ISO 13064-1:2012 Battery-electric mopeds and motorcycles -- Performance -- Part 1: Reference energy consumption and range

The contents relevant for ecodesign of these standards (except the last one) are covered by Table 2 in section 3.6.

3.4. Environment related standards

3.4.1. Battery specific

IEC 63218	Secondary Lithium ion, Nickel Cadmium, and Nickel Metal Hydride cells and batteries for portable applications - Guidance on environmental aspects (**under development**). It describes environmental aspects of batteries and restriction of environmental hazardous materials, especially heavy metals. It also contains an environmental impact assessment and it identifies product environmental aspects. Annex A of the standard gives an overview of battery specific laws and regulations worldwide.
IEC/TS 62933-4	Electrical Energy Storage (EES) Systems - Guidance on environmental issues. It describes three aspects to identify environmental issues, namely life-cycle thinking, system aspects with respect to environment and storage technology

	independency. It also gives environmental guidelines on substance leakage, vibration, earth leakage current, weather conditions and life form invasion.
IEC 61429	Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135. This symbol must be added on batteries.
IEC 62902	Marking symbols for secondary batteries for the identification of their chemistry). For Pb, NiCd, NiMH, Li-ion and Li-metal a marking by colour code is developed. Also, the ISO 7000-1135 recycling symbol must be added if no other recycling symbol is applied on the battery.
IEC 60086-6	Primary batteries - Part 6 Guidance on environmental aspects It sets requirements on heavy metal contents for Hg, Pb and Cd. It sets hazardous waste criteria based on toxicity, ignitability, reactivity and corrosivity. It gives an environmental assessment based on reduction, reuse, recycle, raw material use, manufacturing and disposal. As annex it provides on overview on battery specific laws and regulations worldwide.
Nordic Swan Ecolabel Primary Batteries	The Nordic Swan is a voluntary official ecolabel in the Scandinavian countries, Denmark and Iceland. For batteries it focuses on portable primary batteries. Since the market for primary batteries is extensive and since they have differences in environmental and quality properties, the Nordic Ecolabelling is capable to differentiate and to determine the best ones in terms of environmental and quality properties. The ecolabel prescribes much lower maximum values for toxic metals than the Battery Directive does. It bans the use of PVC. Clear information on the possible application type must be given and the ecolabel discerns 3 drain (discharge) levels.

Nordic Swan ecolabelling for rechargeable batteries and portable chargers

The Nordic Swan Ecolabel focuses on capacity and durability of batteries to ensure long battery life thereby reducing the resource consumption. At the same time, batteries and portable chargers must meet recognized quality and safety standards. The requirements include:

- Threshold values for heavy metals in batteries.
- No use of PVC and a number of flame-retardants in plastic.
- CSR policy to ensure responsible use and sourcing of limited raw materials and “conflict free” minerals.
- Electrical-, safety- and quality testing of batteries/cells, portable and battery chargers.
- Nickel Metal Hydride (NiMH) batteries and cells must be fully charged when leaving the production site.
- Recyclable design of the portable charger.

3.4.2. Material efficiency

As stated in the Mandate M/543 [6]: 'horizontal and generic, not product specific, European standards on material efficiency aspects could serve as a voluntary reference point when designing all kinds of products beyond the scope of Directive 2009/125/EC and its implementing measures'. This activity was taken by CEN and CENELEC as part of the Joint TC 10: CEN/CLC/JTC 10–'Energy-related products-Material Efficiency Aspects for Ecodesign'. The list of standards under preparation (foreseen to be published in 2019) is given in section 2.4.4.

One of the reasons for the relative lack of Ecodesign requirements related to material efficiency in the implementing measures adopted so far is the absence of adequate metrics. The aim of this new workgroup is to:

- Define parameters and methods relevant for assessing durability, upgradability and ability to repair, re-use and re-manufacture of products;
- Address the ability to access/remove certain components, consumables or assemblies from products to facilitate repair or remanufacture or reuse;
- Address reusability/recyclability/recoverability indexes or criteria;
- Address the ability to access/remove certain components or assemblies from products to facilitate their extraction at the end-of-life for ease of treatment and recycling;
- Establish a method to assess the proportion of re-used components and/or recycled materials in products;
- Address the use and recyclability of Critical Raw Materials to the EU, listed by the European Commission; and
- Address the documentation and/or marking regarding information relating to material efficiency of the product taking into account the intended audience.

Proposed standards and status can be found on the CEN server[5].

5 https://standards.cen.eu/dyn/www/f?p=204:22:0::::FSP_ORG_ID,FSP_LANG_ID:2240017,25&cs=1D4156C3D679EE526A476E8463ACFAA98

3.4.3. Life Cycle Assessment (LCA) standards and methodologies

ISO standards

The following two ISO standards are available that provide a general (conceptual) methodological framework for LCA:

- ISO 14040:2006: Environmental management – Life cycle assessment – Principles and framework
- ISO 14044:2006: Environmental management – Life cycle assessment – Requirements and guidelines

These ISO standards prescribe the steps in which an LCA must be performed. However, they also leave LCA practitioners with an array of choices that can affect the execution and results of an LCA.

CENELEC standard (under development)

The following standard is under development:

- prEN 50693 Method for quantitative eco design via life cycle assessment and environmental declarations through product category rules for EEE (under development)

CEN standards

Within the construction sector, voluntary horizontal standardised methods are developed under the responsibility of CEN/TC 350 for the assessment of the sustainability aspects of new and existing construction works and to draft environmental product declarations (EPDs) of construction products. Compared to the two ISO standards, the EN standard prescribe a tighter framework for executing an LCA. The specific standard regarding LCA of construction products is:

- EN 15804:2012+A1:2013: Sustainability of construction works – Environmental production declarations – core rules for the production category of construction products

In some European countries (e.g. Belgium, the Netherlands, and Germany) there are national annexes and/or product category rules applicable to the EN 15804 standard with additional country-specific rules for drafting EPDs in case a manufacturer wants to register their EPD(s) in the national EPD database.

PEF methodology

In addition to the above-mentioned standards, the Product Environmental Footprint was developed by the Institute for Environment and Sustainability (IES) of the Joint Research Centre (JRC), a Directorate General of the EC upon mandate of the EC Directorate General Environment (DG ENV). The PEF is a harmonised methodology for the calculation of the environmental performance of products (i.e. goods and/or services, not within a specific sector) from a life cycle perspective. The PEF methodology is published as:

- European Commission (2013). ANNEX II Product Environmental Footprint (PEF) Guide, in: 2013/179/EU: Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. *Official Journal of the European Union*, L 124, Volume 56, 4 May 2013[6].

[6] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013H0179

Note: the PEF Guide is not a standard, but a common method of which the pilot phase was finished in 2018 based on those tests the EC is currently exploring how to use the PEF methods in policies.

During the pilot phase, stakeholders of several product groups had the possibility to sign up and to follow the development of Product Environmental Footprint Category Rules (PEFCRs). One of these product groups was the product group of 'Rechargeable batteries'. The association Recharge chaired the Technical Secretariat of the batteries PEF pilot. The final PEFCR for "high specific energy rechargeable batteries for mobile applications" was published in February 2018[7]. The PEFCR is applicable for rechargeable single cells or/and batteries used in the following equipment or vehicle:

- E-mobility (e.g., e-bikes, ELV, PHEV, cars, bus/trucks), excluding charging unit,
- Information & Communication Technologies (e.g., tablets and phones, computers, cameras, games), including charging unit,
- cordless power tools (e.g., drills, electric screwdrivers), including charging unit.

Alignment EN standards and PEF

Regarding the CEN/TC 350 standards, DG Environment and DG Growth drafted a first proposal for an amendment of Mandate M/350 on 5 October 2015. The amendment aims to solve, or at least reduce to the maximum extent possible, the differences between the requirements included in the CEN/TC 350 standards and those included in the PEF methodology, in order to align the CEN/TC 350 standards and the PEF as much as possible. The amendment of the CEN/TC 350 standards, the EN 15804 in particular, is still going on (1/2019).

LCA software, models and datasets

Ecodesign EcoReport 2014

This project needs to introduce data regarding lithium-ion batteries for an efficient and correct environmental LCA study for the ecodesign and ecolabelling of these systems. Currently the Ecodesign EcoReport 2014 Excel-based tool is used to calculate the environmental impacts in MEErP format. The EcoReport tool is suitable for not too complex products that can be modelled with the standard materials in the EcoReport, but not for complex products like batteries that are composed of complex chemistries and substances. Another limitation of the EcoReport is that it was developed from 2011 to 2014 and it includes outdated data to calculate the environmental impact.

openLCA software

There are more up-to-date and flexible (but also more complex) software on the market for LCA calculations. openLCA is a free and open source LCA software that can be used for modelling and calculating LCAs, like PEF [8]. It is developed and hosted by GreenDelta, an independent sustainability consulting and software company in Berlin, Germany. It is sustained by a network of partners, contributors and a user community. openLCA can offer free databases for use in openLCA and other datasets can be directly imported in case the datasets are in EcoSpold or ILCD format (common LCA dataset formats). It is highly likely that there are no LiB datasets in openLCA.

Note: this is not a standard but can be seen as an open harmonised method for LCA calculations. It would likely be too complex and would lack the needed flexibility for a standard.

[7] http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_Batteries.pdf

[8] https://www.openlca.org/project/pef/

Using LCA software

An identified gap regarding LCA standards and software is the lack of test cases and/or standards to test whether LCA software is calculating correctly. Within the LCA community it is a well-known problem that using a different LCA software can lead to different results even when calculating the same model and using the same dataset.

The EC/JRC Life Cycle Data Network data sets

Note: This is not a standard, this open data network with harmonized sets of data is a more flexible approach that can benefit from frequent updates.

The Life Cycle Data Network is hosted by the EC/JRC and aims to provide a globally usable infrastructure for the publication of quality assured LCA dataset (i.e. LCI datasets and LCIA method datasets)[9]. It aims to include the Environmental Footprint (EF) datasets for Representative products and a Benchmark [10]. So far, the datasets for LiB are not publicly available yet.

The GREET model of Argonne National Lab

Note: This is not a national standard but a public supported and available method.

The GREET model stands for "Greenhouse gases, Regulated Emissions, and Energy use in Transportation" model. It is available in excel format and .NET format. The aim is to get a full life cycle carbon emission impact estimate from well to wheels for fuels and raw material mining to vehicle disposal for automobiles [11]

For a given vehicle and fuel system, GREET separately calculates the following:

- Consumption of total resources (energy in non-renewable and renewable sources), fossil fuels (petroleum, natural gas, and coal together), petroleum, coal, natural gas and water.
- Emissions of CO2-equivalent greenhouse gases - primarily carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O).
- Emissions of seven criteria pollutants: volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxide (NOx), particulate matter with size smaller than 10 micron (PM10), particulate matter with size smaller than 2.5 micron (PM2.5), black carbon (BC), and sulphur oxides (SOx).

It includes recent carbon footprint data for LiB. This public domain model is available free of charge for anyone to use. It is sponsored by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE).

3.5. Standards on reuse of batteries

- SAE J2758 Determination of the maximum available power from a rechargeable energy storage system of hybrid electric vehicle (under development).

This standard started in 2012 but no information is found about it.

[9] http://eplca.jrc.ec.europa.eu/
[10] http://eplca.jrc.ec.europa.eu/EF-node/
[11] https://greet.es.anl.gov/

- ANSI/CAN/UL 1974:2018 Standard for evaluation for repurposing batteries

This standard covers the sorting and grading process of battery packs, modules and cells and electrochemical capacitors that were originally and used and configured for other purposes, such as electric vehicle propulsion, and that are intended for a repurposed use application.

A basic requirement is that the cells, modules and auxiliary equipment must fulfil the requirements of the envisaged application as given in standards. Also, the battery should not be used longer than the *calendar expiration date*. This date must be provided by the manufacturer. The history of the battery has to be tracked with emphasis on previous misuse situations and on information coming from the BMS on the battery's state of health. The battery must be visually, also including disassembly, without damage, unless it is minor.

The standard prescribes a routine test analysis comprising:

– Incoming open circuit voltage (OCV) measurement;
– Incoming high voltage isolation check;
– Capacity check;
– Internal resistance check;
– Check of BMS controls and protection components;
– Discharge/charge cycle test;
– Self-discharge.

The repurposing manufacturer shall have a system for grading cells, modules and battery packs/systems for repurposing. This must ensure that the new battery combination is balanced and appropriately matched to prevent performance and safety problems in the final assembly.

Finally, marking including mention of 'UL1974' must be provided.

3.6. Standards on functioning during use phase

An ecodesign study needs to know the behaviour of its subject during use phase. Therefore, test methods must exist for parameters like nominal capacity, energy, internal resistance and ageing behaviour. Since one standard can give several test methods for the same parameter there can exist the nominal capacity and additional capacities as function of C-rate and temperature. This holds for other parameters as well. It is not necessarily about a test method, but it can also involve a criterion like the end of life criterion and information agreements like information that is given to determine the state of health, marking of a battery and BMS communication.

The parameters that should be found in standards are:

– nominal capacity and the corresponding C_n-rate, including the reference temperature
– Other capacities
– Energy
– Other energies
– Charge method
– Quick charge
– Power

- Other power
- Internal resistance
- Energy efficiency
- Additional energy efficiency
- Self-discharge at storage
- Charge retention for transport
- Non-load loss
- Energy for heating and cooling
- Cycle life test
- Calendar life test
- Efficiency of life test
- SOH definition(s)
- EOL criterion / lifetime
- EOL information
- Calendar expiration date
- Marking method
- BMS prescriptions
- BMS communication

Apart from these topics, it must be clear what application(s) a standard envisages and for what battery (sub)type it is directed (also called 'chemistry'). Most standards can be used from cell level up to system level and not necessarily only for Li-ion. Some standards only direct themselves at cell level for a certain application. This means that already at cell level performance criteria can be given.

An analysis of the above topics for the identified standards with performance tests is given in Table 1 (on page 40) and Table 2 (on page 42). Per topic and standard a short description of each test clause is given, if the topic is covered. Table 1 focusses on automotive standards and Table 2 on other applications.

In Table 1 the following standards are given:

- IEC 62660-1: 2018 Secondary lithium-ion cells for the propulsion of electrical road vehicles - Performance Testing.
- ISO 12405-4: 2018 Electrically propelled road vehicles --Test specification for lithium-ion traction battery packs and systems -- Part 4: Performance testing
- DOE-INL/EXT-15-34184 (2015) U.S. DOE Battery Test Manual for Electric Vehicles
- DOE-INL/EXT-07-12536 (2008) Battery test manual for plug-in hybrid electric vehicles
- SAE J1798: 2008 Recommended Practice for Performance Rating of Electric Vehicle Battery Modules

In Table 2 are given:

- ISO/DIS 18243: 2017 Electrically propelled mopeds and motorcycles -- Test specification and safety requirements for lithium-ion battery system
- IEC 62620: 2014 Secondary lithium cells and batteries for use in industrial applications
- IEC 61427-2: 2015 Secondary cells and batteries for renewable energy storage Part 2 On grid applications
- IEC 62984-3-2:2017 High Temperature Secondary Batteries – Part 3: Sodium-based batteries – Section 2: Performance requirements and tests
- BVES Effizienzleitfaden (2017) BVES Effizienzleitfaden
- ANSI/CAN/UL 1974:2018 Standard for evaluation for repurposing batteries

The performance metrics such as energy content, internal resistance and cycle life test are defined in the standards as can be seen from Table 1 and Table 2. However, in each standard and for each application (even within one standard since it can cover several applications) the exact methodology is dissimilar. Also, several methodologies can be given for the same metrics.

Several standards give end of life criteria. This is mostly related to the specific test cycle: that it cannot be performed anymore within the allowed voltage limits or e.g. that the battery becomes too hot. In test manuals from the US Department of Energy application specific end of life criteria are given. These are copied in Figure 1 and Figure *2*.

Standard IEC 61427-2 On-grid applications prescribes test profiles for its 4 applications. This is interesting for application-based criteria. The cycles are reproduced in Figure 3. However, no End of Life criteria are given. The battery is considered at the end of life when the user does not accept the behaviour anymore. Real tests results according to these profiles are not available.

Conclusions that can be drawn are:

Concerning performance metrics on product life time and efficiency related to Task 3:

- The performance metrics such as energy content and internal resistance are defined in the standards. However, in each standard and for each application (even within one standard since it can cover several applications) the exact methodology is dissimilar. Also, several methodologies can be given for the same metrics. This means that the capacity (in Ah) can be based on e.g. a 1 h, 5 h or 8 h discharge period or even on a discharge with a specific current profile. Resistance values may be derived from a pulse test, a jump in discharge current, but also from an AC signal.
- Most standards have test clauses to express the capacity in Ah. This unit is prescribed by the European regulation 1103/2010 on capacity labelling of portable secondary and automotive batteries (*i.e.* starter battery, not electric vehicle battery). Few standards prescribe the determination of energy content expressed in kWh, like the proposed functional unit, especially for standards outside automotive.
- The energy involved in heat and cooling of the battery system is not determined in standards.
- The capacity tests in the standards ignore that cells can be charged at several current rates. This is, however, of interest for e.g. quick charging and regenerative braking. It must be noted that charging is mostly not allowed in the same temperature range as discharging if no active heating is present (i.e. only above 0°C).
- The heating & cooling of the battery is within the study's system boundary. However, the needed energy is outside the boundary and will be an arbitrary value. It must be noted that the test standards do not measure this value, what could be used as a reference.
- For cycle life tests (repeated imposition of a test profile on the battery expressed in current or power) many profiles exist. 14 have been identified in the relevant standards. Each application has a profile and dissimilar standards may have a different profile. The profiles found are always a simplification of real profiles like the battery would undergo during e.g. a WLTP test.
- In European battery development projects often an ageing test programme is performed with a swarm of test conditions being a combination of calendar life testing and cycle life tests with simple profiles. These conditions allow to derive the ageing behaviour comprehensively and goes therefore beyond single use cases. This generic approach is not found in current test standards. [3] [4]
- Several standards give end of life criteria, defining when the battery is not useful anymore. This is mostly related to the specific, application dependent, test cycle: if the profile imposed as cycle life test cannot be performed anymore since the battery voltage hits upper and or lower limit almost immediately, or e.g. that the battery becomes too hot during the cycling, then this is considered as an end of life state.
- The following topics appear to be empty:
    - Charge method (only the charge method by the manufacturer)
    - Quick charge (except IEC 62984-3-2 for high temp. sodium batteries)
    - Energy for heating and cooling
    - Efficiency of life test

  - o SOH definition(s)
  - o EOL information (except IEC 62620 prescribes to write the cycle life test result in the battery marking)
  - o Calendar expiration date
  - o Marking method (except IEC 62620)
  - o BMS prescriptions
  - o BMS communication

- No clear definition of SOH exists and it is differently used over applications and manufacturers. Battery degradation is a combination of phenomena as capacity fade, power fade, efficiency reduction, rise in cooling demand and negative incidents. A more elaborate approach to tackle SOH is therefore needed. Even if SOH only refers to capacity fade then still the calculation method has to be clarified since the nominal capacity can be taken or the capacity related to the needed power. [4] The tables show that this topic is empty.
- EOL information: the BMS has currently no prescribed role in it, although it could give information on remaining capacity, actual power capability (being limited by either the battery resistance or the battery cooling capability) and negative events that happened. This information is of interest for the possibility to repair modules in a battery system and for repurposing batteries to a second life application. The standard ANSI/CAN/UL1974 provides a list with information that a BMS should provide to understand the battery health.
- The indicators for SOH should be openly available from the BMS [4]. Alternatively, a traceability and tracking system for battery packs must be conceived.
- The standard ANSI/CAN/UL1974 on repurposing of batteries introduces the calendar expiration date. A battery should not be used longer than this date. This date must be provided by the manufacturer. Current battery standards do not require this information. It must be stated that the battery life is much dependent on the use conditions such as the total time being at 100% SOC.
- SOH determination by advanced techniques like electrochemical impedance measurement can be treated in standards as additional indicators [4].

For re-sales and repurposing of batteries:

- For a profitable second use of batteries, additional costs as for testing, disassembly and retrofitting need to be minimised [4]. The original battery design and the BMS have a high impact on this. Since a BMS designed for an EV application would probably not be suitable for a second use application, the possibility of uploading adapted firmware must be considered. These issues are not in nowadays standards. Test methods to assess battery reliability, safety and performance at the end of first life use are absent. Criteria and guidelines to determine the suitability for a relevant second use can be developed. Standardised interfaces for hardware and software, including connectors, would support this minimised cost approach [4].
- Use information on the first life application, beyond the remaining capacity, is necessary. The standard ANSI/CAN/UL1974 identifies the information need. This information is however probably not reachable, partly since it is not stored, partly since a BMS is probably

not accessible by third-parties. Open BMS information that includes sufficient use history information can help.

- For repurposing and recycling activity, standardised battery module sizes and pack sizes can help. Size standardisation is currently only at cell level (ISO/PAS 19295: 2016; DIN 91252:2016).

Table 1: Test conditions and criteria on information necessary for ecodesign in relevant standards for EV application.

	EV application						
Reference	IEC 62660-1:2010		ISO 12405-4:2018		DOE-INL/EXT-15-34184(2015)	DOE-INL/EXT-07-12536 (2008)	SAE J1798:2008
Title	Secondary lithium-ion cells for the propulsion of electrical road vehicles - Performance Testing.		Electrically propelled road vehicles --Test specification for lithium-ion traction battery packs and systems -- Part 4: Performance testing		U.S. DOE Battery Test Manual for Electric Vehicles	Battery test manual for plug-in hybrid electric vehicles	*Recommended Practice for Performance Rating of Electric Vehicle Battery Modules*
Refined application	Cells for the propulsion of BEV	Cells for the propulsion of HEV	HEV & FCV	BEV & PHEV	BEV	PHEV	BEV
Chemistry	Li-ion	,,	Li-ion	,,	Generic	cell to system level	Generic
Level (cell, module, pack, system)	Cell	,,	Pack, system	,,	cell to system level		module
C_n-rate method (incl. temp.)	1/3 I_t at 0, 25, 45°C; additional tests possible and proposed	1 I_t at 0, 25, 45°C; additional tests possible and proposed	1C, 10C and max. discharge at -18, 0, 25, 40°C.	C/3, 1C, 2C and max. discharge at -18, -10, 0, 25, 40°C.			1C, C/2, C/3 at 45, 25, 0 and -20°C.
nominal capacity	(No, manufacturer value)	(No, manufacturer value)	1C (1 hour discharge capacit	1C (1 hour discharge capacity)	C_3, including check that the capacity deviates <10% from rated capacity.	–	–
Other capacities	See C_n-rate method, and Dynamic discharge capacity at 25 and 45°C.	See C_n-rate method.	See C_n-rate method.	,,		Discharge at highest possible rate from (HPPC) pulse test; discharge with 10kW (or scaled if a battery size factor is applied). Both at 30°C	From C_n-rate method; Dynamic discharge at 25°C
Energy	1/3 I_t at 25°C X U_{avg}	1 I_t at 25°C X U_{avg}			From C/3 discharge		From C_n-rate method
Other energies			See C_n-rate method.	See C_n-rate method.			
Charge method	As declared by manufacturer	,,	As declared by manufacturer	,,	Charging procedure by manufacturer including a default rest period.		By manufacturer
Quick charge				1C, 2C and max.current.	3.2C or defined by manufacturer for 15 min. to reach at least 80% SOC.		
Power	10s pulses at maximum allowed discharge rate followed by maximum allowed charge rate; SOC: 80, 50, 20%; Temp.: 25°C. For 50% SOC also at 40, 0 and-20°C.	,,	18s discharge and 10s charge pulses at max. possible current; 80, 65, 50, 35, 20% SOC; 40, 25, 0, -10 and -18°C	18s discharge pulse at max. possible current followed by 102s at 3/4 of previous current and 20s charge pulse at the latter current; 90, 70, 50, 35, 20% SOC; 40, 25, 0, -10, -18 and -25°C	30s discharge pulse at max. allowed current and 10s harge pulse at 3/4 of this power from 90 to 10% SOC at 30°C (Hybrid Pulse Power Capability test).	10s discharge pulse at max. allowed current and 10s charge pulse at 3/4 of this power from 90 to 10% SOC at 30°C (Hybrid Pulse Power Capability test).	Peak power pulses over 90% DoD at 25°C
Other power	If maximum pulse rate is not given: 10s pulses, both for discharge and charge. Rates: 1/3, 1, 2 and 5 I_t ; SOC: 80, 50, 20%; Temp.: 40, 25, 0,-20°C	If maximum pulse rate is not given: 10s pulses, both for discharge and charge. Rates: 1/3, 1, 5 and 10 I_t ; SOC: 80, 50, 20%; Temp.: 40, 25, 0,-20°C			Previous pulse test at 52, 0, -10, -20 and -30°C. Discharge pulse with 1C and with 3/4 of max.allowed current, at 30°C; peak power test: no rests periods between pulses.	Previous pulse test at temperatures between 52 -30°C, mainly to test thermal management.	
Internal resistance	Slope of voltage-current characteristic from 10s pulse at max. pulse discharge current	,,	From pulses	,,	From pulses	From pulses	From pulses

Reference	*EV application* IEC 62660-1:2010		ISO 12405-4:2018		DOE-INL/EXT-15-34184(2015)	DOE-INL/EXT-07-12536 (2008)	SAE J1798:2008
Energy efficiency	Charge-discharge (1/3 I_t) cycle with SOC window 0-100% at	Charge-discharge (1 I_t) cycle with SOC window 0-100% at	Based on a series of pulses at 65, 50 and 35% SOC at	Based on fast charge rates within requirements by		From pulses: based on 100 efficiency test profiles.	
Additional energy efficiency	Charge-discharge cycle with SOC window 0-70% & 0-80% at	Charge-discharge (1 I_t) cycle with SOC window 0-70% at					
Self discharge at storage	Store cell at 100% SOC and 45°C for 42 days, repeated 3 times.	Store cell at 50% SOC and 45°C for 42 days, repeated 3 times.			30 days at initially 50% SOC and 30°C.	Partly discharged battery at 30°C for a period that should cover 5% capacity	30 days at 100% SOC and at 45 and 25°C
Charge retention for transport	Store cell at 50% SOC and 45°C for 28 days.	,,	30 days at initially 50% SOC. All battery system terminals disconnected. At 45°C.	,,			
Non-load loss			30 days at initially 80% SOC; BCU powered by auxiliary device. This is energy is reported. At 25 and 40°C.	30 days at initially 100% SOC; BCU powered by auxiliary device. This is energy is reported. At 25°C and 40°C.			
Energy for heating&cooling							
Cycle life test	Repeated Dynamic discharge tests for 28 days, repeated 6 times.	Repeated discharge rich and charge rich profiles between 30 and 80% SOC and 45°C for six months.	Repeated discharge rich and charge rich profiles between 30 and 80% SOC at 25°C. Systems only! Cooling must operate.	Repeated Dynamic discharge tests between 20 (or other agreed limit) and 100% SOC. Systems only! Cooling must operate.	Repeated Dynamic stress test at 30°C. Increased temperature allowed.	Repeated Charge-Depleting Cycle Life Test Profile and Charge-sustaining Cycle Life Test Profile; different for minimum and maximum PHEV battery.	
Calender life test					3 or up to 7 temperatures. Highest one such that battery does not age within 2 years. SOC at most challenging level. A daily calendar life test profile is applied.	3 or up to 7 temperatures. Highest one such that battery does not age within 2 years. SOC at most challenging level. A daily calendar life test profile is applied.	
Efficiency of life test							
SOH definition(s)							
EOL criterion / lifetime	80% of initial capacity; temperature too high	80% of initial capacity.	Cycle life test conditions cannot be maintained; the parameter checks are not possible anymore; or in accordance with manufacturer.	,,	Dynamic stress test cycle cannot be performed within voltage limits, intended to be over 1000 DST cycles, 15 years, specific energy and power requirements.	Cycle life test conditions cannot be maintained; the parameter checks are not possible anymore; or in accordance with manufacturer. 300,000 cycles are intended for charge-sustaining mode and 5000 cycles for charge-depleting mode.	
EOL information							
Battery expiration date							
Marking method							
BMS prescriptions							
BMS communication							

Table 2: Test conditions and criteria on information necessary for ecodesign in relevant standards for other applications.

Reference	*Motorcycle* ISO/DIS 18243: 2017	*Industrial* IEC 62620: 2014				*On-grid* IEC 61427-2: 2015				IEC 62984-3-2:2017	BVES Effizienz-leitfaden (2017)	*Repurposing* ANSI/CAN/UL 1974 (2018)
Title	Electrically propelled mopeds and motorcycles -- Test specification and safety requirements for lithium-ion battery system	Secondary lithium cells and batteries for use in industrial applications				Secondary cells and batteries for renewable energy storage Part 2 On grid applications				High Temperature secondary Batteries – Part 3: Sodium-based batteries – Section 2: Performance requirements and tests	BVES Effizienzleitfaden	Standard for evaluation for repurposing batteries
Refined application	Moped and motorcycle	High energy (S; <C/8)	Energy (E; <C/2)	Medium rate discharge (M; <3.5C)	High rate (H; >3.5C)	Frequency regulation service	Load-following service	Peak-power shaving service	PV energy storage / time shift service	Stationary (& on-board (except propulsion))	PV energy storage	All applications but with 2nd life batteries
Chemistry	Li-ion	Li-ion	,,	,,	,,	Generic	,,	,,	,,	Na-based	Generic	Generic
Level (cell, module, pack, system)	pack and system	Cell up to system	,,	,,	,,					pack, system		
C_n-rate method (incl. temp.)	C/3, 1C, 2C and maximum allowed rate at at 40, 25, 0 and <=-10°C.	1/n I_t at 25°C.	1/5 I_t at 25°C.	1/5 I_t and 1/I_t at 25°C.	1/5 I_t and 1/I_t and 5 I_t at 25°C.					C_8 and max. allowed discharge rate		According to standard of 2nd life application
nominal capacity	C_3 or defined by manufacturer	C_n	C_5	C_5	C_5					C_8 (8 hour discharge)		According to standard of 2nd life application
Other capacities	By C_n-rate method.	By C_n-rate method. Also at 10, 0, -10 and -20°C, until capacity is <70% of rated one.	By C_n-rate method. Also at 10, 0, -10 and -20°C, until capacity is <70% of rated one.	By C_n-rate method. 1/I_t capacity >95% C_5 capacity. Also at 10, 0, -10 and -20°C, until capacity is <70% of rated one.	By C_n-rate method. 5/I_t capacity >90% C_5 capacity. Also at 10, 0, -10 and -20°C, until capacity is <70% of rated one.					By C_n-rate method.		
Energy										By C_8 method		Constant power discharge according to repurposing manufacturer
Other energies												
Charge method	As recommended by manufacturer, but within 8h.	As declared by manufacturer								C_8		As declared by repurposing manufacturer
Quick charge										Yes up to allowed voltage		
Power	18s discharge pulse at max.possible rate followed by 102s pulse at 3/4 rate and 20s charge pulse at latter rate. 90 to 20% SOC; 40, 25, 0 and -10°C.			5s discharge pulse of min.6I_t at 100%SOC.	5s discharge pulse of min.20I_t at 100%SOC.							
Other power												
Internal resistance	From pulses.	1kHz AC resistance; DC resistance by jump in current at 50%SOC.	,,	,,	,,							From step in current specified by repurposing manufacturer at 90 and 20% SOC

Reference	*Motorcycle* ISO/DIS 18243	*Industrial* IEC 62620				*On-grid* IEC 61427-2				IEC 62984-3-2:2017	BVES Effizienzleitfaden	*Repurposing* ANSI/CAN/UL 1974
Energy efficiency										Yes, including energy loss for auxiliaries	Yes	
Additional energy efficiency												
Self discharge at storage		28 days at 25°C and initially 100% SOC.	,,	,,	,,							1 day
Charge retention for transport	30 days at initially 50% SOC. All battery system terminals disconnected. At 45°C.											
Non-load loss	30 days at initially 100% SOC; BCU powered by auxiliary device. This is energy is reported. At 25°C and 40°C.											
Energy for heating&cooling												
Cycle life test	1C discharges down to voltage limit by manufacturer at 25°C.	500 cycles with 1/n I_t and 25°C.	500 cycles with 1/5 I_t and 25°C.	,,	,,	Specific cycle at 25, min. and max. ambient temp.	,,	,,	,,	300 cycles; max. 3% capacity loss		
Calender life test		90 days at max.voltage for standby applications.										
Efficiency of life test						Yes, at min. and max. ambient temp.	,,	,,	,,			
SOH definition(s)												
EOL criterion / lifetime	80% of initial capacity.	Capacity > 60% after 500 cycles. Capacity >85% for standby applications.	,,	,,	,,	As acceptable	,,	,,	,,			
EOL information		In marking	,,	,,	,,							
Battery expiration date												
Marking method		Yes										Yes, with repurposed capacity
BMS prescriptions												Prescription of beeded parameters from BMS
BMS communication												

End of Life Characteristics at 30°C	Units	System Level	Cell Level
Peak Discharge Power Density (30 sec)	W/L	1000	1500
Peak Specific Discharge Power (30 sec)	W/kg	470	700
Peak Specific Regen Power (10 sec)	W/kg	200	300
Available Energy Density @ C/3 Discharge Rate	Wh/L	500	750
Available Specific Energy @ C/3 Discharge Rate	Wh/ kg	235	350
Available Energy @ C/3 Discharge Rate	kWh	45	N/A
Calendar Life	Years	15	15
DST Cycle Life	Cycles	1000	1000
Selling Price @ 100K units	$/kWh	125	100
Operating Environment	°C	-30 to +52	-30 to +52
Normal Recharge Time	Hours	< 7 Hours, J1772	< 7 Hours, J1772
High Rate Charge	Minutes	80% ΔSOC in 15 min	80% ΔSOC in 15 min
Maximum Operating Voltage	V	420	N/A
Minimum Operating Voltage	V	220	N/A
Peak Current (30 sec)	A	400	400
Unassisted Operating at Low Temperature	%	>70% Available Energy @ C/3 Discharge rate at -20°C	>70% Available Energy @ C/3 Discharge rate at -20°C
Survival Temperature Range, 24 hr	°C	-40 to +66	-40 to +66
Maximum Self-Discharge	%/month	< 1	< 1

NOTES

i. Values correspond to End-of-Life (EOL).
ii. The targets correspond to commercialization goals in FY 2020.

Figure 1: End of life criteria as defined in DOE-INL/EXT-15-34184(2015) U.S. DOE Battery Test Manual for Electric Vehicles.

Characteristics at EOL (End-of-Life)	Unit	Minimum PHEV Battery	Maximum PHEV Battery
Reference Equivalent Electric Range	miles	10	40
Peak Discharge Pulse Power (2 sec /10 sec) [1]	kW	50/45	46/38
Peak Regen Pulse Power (10 sec)	kW	30	25
Max. Current (10 sec pulse)	A	300	300
Available Energy for CD (Charge-Depleting) Mode, 10-kW Rate	kWh	3.4	11.6
Available Energy for CS (Charge-Sustaining) Mode, 10-kW Rate [2]	kWh	0.5	0.3
Minimum Round-trip Energy Efficiency (CS 50 Wh profile)	%	90	90
Cold cranking power at -30°C, 2 sec, 3 Pulses	kW	7	7
CD Life / Discharge Throughput	Cycles/MWh	5,000 / 17	5,000 / 58
CS HEV Cycle Life, 50 Wh Profile	Cycles	300,000	300,000
Calendar Life, 35°C	year	15	15
Maximum System Weight	kg	60	120
Maximum System Volume	Liter	40	80
Maximum Operating Voltage	Vdc	400	400
Minimum Operating Voltage	Vdc	>0.55 x Vmax [3]	>0.55 x Vmax [3]
Maximum Self-discharge	Wh/day	50	50
Maximum System Recharge Rate at 30°C	kW	1.4 (120V/15A) [4]	1.4 (120V/15A) [4]
Unassisted Operating & Charging Temperature Range 52°C >100% Available Power 0°C >50% Available Power -10°C >30% Available Power -30°C >10% Available Power	°C	-30 to +52	-30 to +52
Survival Temperature Range	°C	-46 to +66	-46 to +66
Maximum System Production Price @ 100k units/yr	$	$1,700	$3,400

Figure 2: End of life criteria as defined in DOE-INL/EXT-07-12536 (2008) Battery test manual for plug-in hybrid electric vehicles.

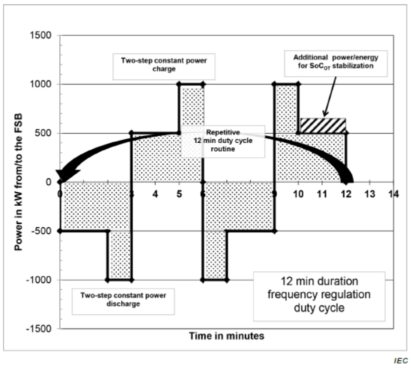

Figure 6 – Frequency regulation service test routine profile (6.2) – Profile a

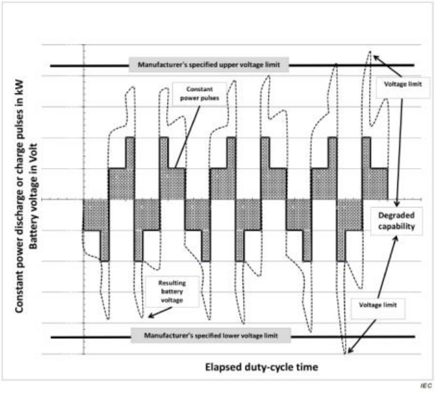

Figure 9 – Schematic view of the evolution of battery voltage over time during cycling with constant power discharge and charge pulses

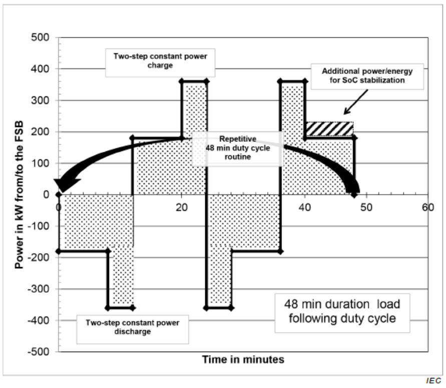

Figure 10 – Load-following service test routine profile (6.3) – Profile a

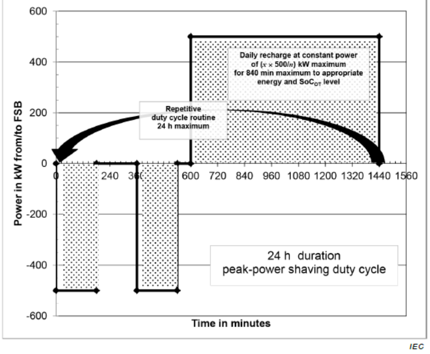

Figure 13 – Daily peak-power shaving service test routine profile (6.4)

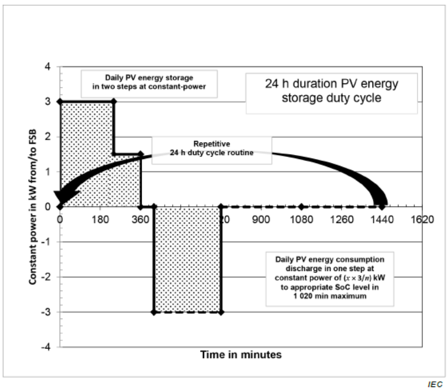

Figure 14 – Daily photovoltaic energy storage time-shift service test routine (6.5) – 3 kW

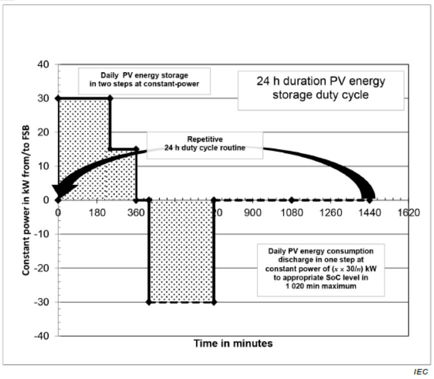

Figure 15 – Daily photovoltaic energy storage time-shift service test routine (6.5) – 30 kW

Figure 3: Test profiles for the 4 applications in IEC 61427-2 On-grid applications. Variants in profiles with different SOC stabilisation methods are not given here.

3.7. Ecodesign topics outside use phase

Performance prescriptions during the use phase are only one aspect of the information that ecodesign needs and on which it can put criteria. A limited list is given in Table 3 for the following standards:

- Nordic Swan Ecolabel (2018) About Nordic Swan Ecolabelled Rechargeable batteries and portable chargers
- IEC 60086-6 (2017) Primary batteries: Guidance on environmental aspects
- IEC/TS 62933-4 (2017) Electrical Energy Storage (EES) Systems - Guidance on environmental issues
- IEC 63218 (under dev.) Secondary Li-ion, Ni-Cd, and Ni-MH cells and batteries for portable applications - Guidance on environmental aspects

The performance test standards as given in the previous tables do not cover these topics.

Gaps for the recycling phase can be derived with help of the table.

- Explicit information and guidance on battery recycling is lacking in current standards.
- Little information is available on the material contents of batteries by labelling standards with IEC 62902 being the most important one. The argument is that it should not be too visible which Li-ion battery has most value for recycling. However, a database or traceability system can fulfil this information gap.
- Standards that define battery marking including the principal active materials (i.e IEC 62620, IEC 61960) need to anticipate new active materials like a silicon based anode.
- Harmonised calculation methods for the recycling efficiency to avoid data misinterpretation is welcomed. This should include environmental aspects like waste styreams, incineration with energy recovery and final landfilling or elimination. [4]
- Harmonised quantification of key indicators as CO_2 footprint, recycling percentage, toxicity and recycling cost is needed [4].

Table 3: Other topics that are needed for an ecodesign study.

===

Category	*Topic*	*Standard / label*			
	Reference	Nordic Swan Ecolabel (2018)	IEC 60086-6 (2017)	IEC/TS 62933-4 (2017)	IEC 63218 (under dev.)
	Title	About Nordic Swan Ecolabelled Rechargeable batteries and portable chargers	Primary batteries: Guidance on environmental aspects	Electrical Energy Storage (EES) Systems - Guidance on environmental issues	Secondary Li-ion, Ni-Cd, and Ni-MH cells and batteries for portable applications - Guidance on environmental aspects
	Aplication	Portable	Portable primary cells and batteries	Electrical energy storage systems	Portable
	Level	Cell up to pack, including charger	Cell up to pack	System	Cell up to pack
Circular economy	Recycle recommendations		Design with ability to separate parts and materials.		
	Disposal recommendations		By marking (collection) on battery and by information on packaging including identification of recyclable parts. Prevent short-circuits.		By marking (collection) on battery including identification Li-ion type. In countries without collection programmes, volantary and co-regulated stewardship programes are encouraged. Prevent short-circuits.
	Dismantling recommendations				
	Minimum technical compatibility with recycling schemes				
	Requirements for repairability				
	Recycling info		Identification of recyclable parts, being electronics and safety devices.		
	Minimum open data BMS				
	Carbon footprint data to be used in applications				
	LCA		LCA according to ISO 14040.		LCA according to ISO 14040.
PEF	Energy & material resources production	yes			
	EOL: collection rate				
	EOL: recycling rate		Minimum 50% by weight.		
	EOL: credits to battery composition				
	Energy & material resources EOL				
	Energy loss over lifetime				
	Waste streams in cycle life stages				
Environment (ecolabel)	Fit for purpose		Determine if rechargeable cells have an environmental advantage.		NiCd remains necessary for low temperatures and emergency equipment.
	Environmental analysis		Assessment needed on reduction, reuse and recycling of materials in design phase, of the manufacturing and of the packaging.	Life cycle thinking; system to environment including leakage, vibration and earth leakage current; environment to system causing malfunction.	Design phase analysis: avoiding inseparable composite materials; minimising number of different materials used; using standardised parts. Assessment needed on reduction, reuse and recycling of materials in design phase, of the manufacturing and of the packaging.
	Energy efficiency requirement				
	Power management	350 cycles for most type of primary battery alternatives. Over 700 for others cells and over 525 for batteries.			
	Limit on hazardous substances	Yes, low, defined amount of mercury, cadmium and lead; arsenic; Requirements on plastic and flame retardants.	Yes, low, defined amount of mercury, cadmium and lead. Exception for button ZnAgO cells and button Zn-air cells.		Yes, low, defined amount of mercury, cadmium (except NiCd) and lead.
	Restriction of substances of very high concern		Check on regulations on banned substances.		Avoid batteries with restricted substances.
	Durability testing for extended lifetime				
	Minimum battery life criterion	60% of initial capacity.			
	Repairability				
	Recyclability				
	Minimum use of recycled material criterion				
	Sourcing of conflict-free minerals				
	Labour condition and human right criterion	yes			
	User instructions				Yes, on transportation, storage, recycling, and disposal.
	Use instructions with environmental advice				Yes on recycle and disposal.
	Use of critical materials	yes, restriction			
	Hazardous waste		Check battery waste on toxicity, ignitability, reactivity and corrosivity by prescribed methods.		
	Marking		Yes, collection symbol		Yes, collection symbol and symbol acc.to IEC 62902. Add Li-ion type to symbol (Cobalt, Manganese, Nickel, Iron).

4. References

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