DEFACTO - battery DEsign and manuFACTuring Optimisation through multiphysic modelling

D8.9 Report on the standardization landscape and applicable standards

Date: 30 June 2020

This document describes the standardization landscape and applicable standards to be adopted by the DEFACTO project. The relevant standards are listed and analysed to allow partners to adapt to the standards' expectations, understand the standardisation landscape and know the organisations involved.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 875247.

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Project details

Project acronym	DEFACTO	**Start / Duration**	*01/01/2020 (42 months)*
Topic	LC-BAT-6	**Call identifier**	*H2020-LC-BAT-2019-2020*
Type of Action	Research and Innovation Action (RIA)	**Coordinator**	*CIDETEC*
Contact persons	*Elixabete Ayerbe*		
Website	**www.defacto-project.eu**		

Deliverable details

Number	***D8.9***		
Title	*Report on the standardization landscape and applicable standards*		
Work Package	*8*		
Dissemination level	PU	**Nature**	*R*
Due date (M)	M6	**Submission date (M)**	*M6*
Deliverable responsible	**UNE, ABEE**	**Contact person**	***José Antonio Jiménez Caballero jjimenez@une.org***

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Document History

Date	Version	Name	Changes
05/05/2020	V1	Mahdi Soltani (ABEE) José A. Jiménez (UNE)	Updating the list of standards
18/05/2020	V2	Mahdi Soltani (ABEE) José A. Jiménez (UNE)	Updating the list of standards
25/05/2020	V3	Mahdi Soltani (ABEE) José A. Jiménez (UNE)	Updating the list of standards Regulations added
29/05/2020	V4	Ana Martínez (SIE)	Editing changes
17/06/2020	V5	All	Minor editorial changes
22/06/2020	V6	Mahdi Soltani (ABEE)	Authors table updating
25/06/2020	V7	Ana Martínez (SIE)	Final review and quality check

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1 Executive Summary

In this deliverable, an initial analysis of the standardization landscape has been performed by UNE and ABEE. The report starts with reviewing the existing standards for characterisation, manufacturing process, and performance testing from the material level to the final cell for Lithium-Ion Battery (LIB). Moreover, the related standardization committees and organizations involved are introduced. This deliverable covers the needs of all work packages at the beginning of the project. The availability of this information at the beginning of the projects will help using existing standards to perform the required characterisation and experimental test for giving useful input for model development and validation. Moreover, the alignment with current and underdevelopment standardization works facilitates the compatibility of the proposed modeling tool with the current market practises and helps to accelerate cell development and the R&I process.

Additionally, some standards related to the ICT part of the project have been introduced.

Finally, an overview of the European/International Regulation applicable to the batteries has been included in this deliverable.

This deliverable has been drafted within subtask 8.5.1: Analysis of the applicable standardization landscape (M1-M6).

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2 Introduction

In order to regulate the battery application in industry and make it easy and safe for the battery manufacturer and consumers, many standards and regulations have been developed by nongovernmental organisations. The standard is a voluntary technical document drafted to be used as a rule, guideline or definition. Standards bring together all interested parties such as manufacturers, consumers and regulators of a particular material, product, process or service. All parties benefit from standardization through increased product safety and quality as well as lower transaction costs and prices. In this deliverable based on the review on existing standards for LIBs material characterisation, manufacturing and performance testing, most relevant standards have been selected. As the DEFACTO project focuses on multiphysics and multiscale modelling tools to better understand the material, manufacturing process and final cell behaviour, only standards related to these subjects useful in WPs have been analysed and introduced in this deliverable.

3 Standard Committees and organisations

Standard organisations can be either international or national organisations. These organizations are listed in the following table.

Name	Worldwide	Regional
International Electrotechnical Commission (IEC)	*	
International Organisation for Standardisation (ISO)	*	
European Committee for Standardisation (CEN)		*
European Committee for Electrotechnical Standardisation (CENELEC)		*
Society of Automotive Engineers International (SAE)	*	
British Standards Institution (BSI)		*
American Society of Testing and Materials (ASTM)		*
UL Standards		*

4 Available standards for the required tests

In WP2, advanced electrochemical and physicochemical characterisations are performed to provide useful data for other technical WPs. To develop multiphysic and multiscale models and to better understand the material, cell, and manufacturing process, key measurements on material properties and mechanisms is pre-requisite.

Moreover, characterisation is required during the aging of the cell as changes of the atomic structure and stoichiometry at interfaces can occur as a result of chemical instability and electrochemical ageing during repeated cycling. For this purpose, the required parameters will be collected based on ageing tests results on NMC811/G-Si prototypes and LMNO/G-Si prototypes.

In this section, the available standards for these characterisations are briefly studied and summarised.

The technical committee responsible for each standard or project of standard is identified for dissemination purposes later during the project (Subtask T8.5.2).

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4.1 Material characterization test

ISO/TC 229 Nanotechnologies			
Particle size distribution through FESEM image			
STANDARD REFERENCE	**TITLE**	**SCOPE**	**TECHNIQUE**
ISO/DIS 19749	Measurements of particle size and shape distributions by scanning electron microscopy	This International Standard specifies methods of determining nanoparticle size and shape distributions by acquiring and evaluating scanning electron microscope images and by obtaining and reporting accurate results.	Suitable sample preparation is essential to obtaining high-quality electron microscope images and preferred techniques often vary with the sample material. It is equally important to make sure that the SEM itself is suitable to carry out the measurements with the required uncertainty. Typical guidance suggests that a large number, several hundreds or thousands of particles need to be measured for statistically sound size and shape distribution results.
NOTE 1 This International Standard applies to particles with a lower size limit that depends on the required uncertainty and on the suitable performance of the SEM, which must be proven first - according to the requirements described in this document. NOTE 2 This International Standard applies also to SEM-based size and shape measurements of larger than nanoscale particles.			

ISO/TC 35 Paints and varnishes		
Battery Internal resistance evolution test using EIS test		
STANDARD REFERENCE	**TITLE**	**SCOPE**
ISO 16773-1: 2016	Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens	This standard describes the application of electrochemical impedance spectroscopy (EIS). Although this International Standard was originally developed for coatings and major sections are specific for coatings, the general guidelines can be used also for uncoated samples. For uncoated samples extra information can be found in ISO/TR 16208.
NOTE ISO 16773 consists of the following parts, under the general title Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens: — Part 1: Terms and definitions — Part 2: Collection of data — Part 3: Processing and analysis of data from dummy cells — Part 4: Examples of spectra of polymer-coated and uncoated specimens		

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ASTM Subcommittee E27.02 on Thermal Stability and Condensed Phases		
Cp and thermal properties of materials through ARC test		
STANDARD REFERENCE	**TITLE**	**SCOPE**
ASTM E1981 - 98(2020)	Standard Guide for Assessing Thermal Stability of Materials by Methods of Accelerating Rate Calorimetry	This guide covers suggested procedures for the operation of a calorimetric device designed to obtain temperature and pressure data as a function of time for systems undergoing a physicochemical change under nearly adiabatic conditions.
NOTE E487 provides Test Methods for Constant-Temperature Stability of Chemical Materials		

ISO/TC 201 Surface chemical analysis			
Quantitative analysis of homogeneous material through XPS analysis and sensitivity factor			
STANDARD REFERENCE	**TITLE**	**SCOPE**	**Method**
ISO 18118:2015	Surface chemical analysis — Auger electron spectroscopy and X-ray photoelectron spectroscopy — Guide to the use of experimentally determined relative sensitivity factors for the quantitative analysis of homogeneous materials	This International Standard gives guidance on the measurement and use of experimentally determined relative sensitivity factors for the quantitative analysis of homogeneous materials by Auger electron spectroscopy and X-ray photoelectron spectroscopy.	Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) are surface-analytical techniques that are sensitive to the composition in the surface region of material to depths of, typically, a few nanometres (nm). Both techniques yield a surface-weighted signal, averaged over the analysis volume.

ISO/TC 107 Metallic and other inorganic coatings			
Porosity and pore size distribution			
STANDARD REFERENCE	**TITLE**	**SCOPE**	**Method**
ISO/TR 26946:2011	Standard method for porosity measurement of thermally sprayed coatings	This Technical Report describes a method for characterizing the porosity of thermally sprayed coatings by metallographic examination.	This method is particularly applicable to oxide coatings, such as Al2O3, ZrO2 and TiO2, produced by plasma spray. It also considers the purposes to test the size, shape and density of pores for thermally sprayed coatings.

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ISO/TC 164 Mechanical testing of metals			
Material mechanical properties			
STANDARD REFERENCE	**TITLE**	**SCOPE**	**Method**
ISO 6892-1:2019	Metallic materials — Tensile testing — Part 1: Method of test at room temperature	This document specifies the method for tensile testing of metallic materials and defines the mechanical properties which can be determined at room temperature.	In this document, there are two methods of testing speeds available. The first, method A, is based on strain rates (including crosshead separation rate) and the second, method B, is based on stress rates. Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results.

ISO/TC 61 Plastics			
Wettability			
STANDARD REFERENCE	**TITLE**	**SCOPE**	**Method**
ISO 15989:2004	Plastics — Film and sheeting — Measurement of water-contact angle of corona-treated films	This International Standard specifies a method of measuring the contact angle of water droplets on coronatreated polymer film surfaces and subsequently determining the wetting tension of the film.	In this method, energy associated with the intermolecular forces at the interface between two surfaces, measured as free energy per unit area.

4.2 Cell characterization (performance and safety)

In this section a selection of the main international lithium ion battery performances' testing standards for high power applications (EV, renewable energy storage, general industrial applications) at cell and module level are introduced. Moreover, the ageing standards suitable to evaluate the battery performance degradation over time by charge and discharge cycles or by calendar tests are explained.

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NOTE: Standards for batteries for low power aplications, Light EV, and space applications have been disregarded.

IEC TC 21 Secondary cells and batteries		
Characterisation and lifetime performance testing – cell level		
STANDARD REFERENCE	**TITLE**	**SCOPE**
IEC 62660-1:2018	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing	IEC 62660-1:2018 specifies performance and life testing of secondary lithium-ion cells used for propulsion of electric vehicles including battery electric vehicles (BEV) and hybrid electric vehicles (HEV). This document specifies the test procedures to obtain the essential characteristics of lithium-ion cells for vehicle propulsion applications regarding capacity, power density, energy density, storage life and cycle life. This document provides the standard test procedures and conditions for testing basic performance characteristics of lithium-ion cells for vehicle propulsion applications, which are indispensable for securing a basic level of performance and obtaining essential data on cells for various designs of battery systems and battery packs.
IEC 62660-2:2018	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing	IEC 62660-2:2018 specifies test procedures to observe the reliability and abuse behaviour of secondary lithium-ion cells and cell blocks used for propulsion of electric vehicles including battery electric vehicles (BEV) and hybrid electric vehicles (HEV). This document specifies the standard test procedures and conditions for basic characteristics of lithium-ion cells for use in propulsion of battery and hybrid electric vehicles. The tests are indispensable for obtaining essential data on reliability and abuse behaviour of lithium-ion cells for use in various designs of battery systems and battery packs. This document provides standard classification of description of test results to be used for the design of battery systems or battery packs.

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IEC TC 21 Secondary cells and batteries		
Characterisation and lifetime performance testing – cell level		
STANDARD REFERENCE	**TITLE**	**SCOPE**
IEC 62660-3:2016	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements	IEC 62660-3:2016 specifies test procedures and the acceptance criteria for safety performance of secondary lithium-ion cells and cell blocks used for the propulsion of electric vehicles (EV) including battery electric vehicles (BEV) and hybrid electric vehicles (HEV). This International Standard intends to determine the basic safety performance of cells used in a battery pack and system under intended use, and reasonably foreseeable misuse or incident, during the normal operation of the EV. The safety requirements of the cell in this standard are based on the premise that the cells are properly used in a battery pack and system within the limits for voltage, current and temperature as specified by the cell manufacturer (cell operating region). The evaluation of the safety of cells during transport and storage is not covered by this standard.
IEC TR 62660-4:2017	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 4: Candidate alternative test methods for the internal short circuit test of IEC 62660-3	IEC TR 62660-4:2017(E) provides the test data on the candidate alternative test methods for the internal short circuit test according to 6.4.4.2.2 of IEC 62660-3:2016. The internal short circuit test in this document is intended to simulate an internal short circuit of a cell caused by the contamination of conductive particle, and to verify the safety performance of the cell under such conditions. This document is applicable to the secondary lithium-ion cells and cell blocks used for propulsion of electric vehicles (EV) including battery electric vehicles (BEV) and hybrid electric vehicles (HEV). This document does not cover cylindrical cells.

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IEC TC 21 Secondary cells and batteries		
Characterisation and lifetime performance testing – cell level		
STANDARD REFERENCE	**TITLE**	**SCOPE**
IEC 61427-1:2013	Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application	IEC 61427-1:2013 is part of a series which gives general information relating to the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the typical methods of test used for the verification of battery performances. This part deals with cells and batteries used in photovoltaic off-grid applications. This standard is applicable to all types of secondary batteries.
IEC 61427-2:2015	Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 2: On-grid applications	IEC 61427-2:2015 relates to secondary batteries used in on-grid Electrical Energy Storage (EES) applications and provides the associated methods of test for the verification of their endurance, properties and electrical performance in such applications. The test methods are essentially battery chemistry neutral, i.e. applicable to all secondary battery types. On-grid applications are characterized by the fact that batteries are connected, via power conversion devices, to a regional or nation- or continent-wide electricity grid and act as instantaneous energy sources and sinks to stabilize the grids performance when randomly major amounts of electrical energy from renewable energy sources are fed into it. Related power conversion and interface equipment is not covered by this part of IEC 61427.

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IEC TC 21 Secondary cells and batteries		
Characterisation and lifetime performance testing – cell level		
STANDARD REFERENCE	**TITLE**	**SCOPE**
IEC 62619:2017	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications	IEC 62619:2017 specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications including stationary applications. When there exists an IEC standard specifying test conditions and requirements for cells used in special applications and which is in conflict with this document, the former takes precedence (e.g., IEC 62660 series on road vehicles). The following are some examples of applications that utilize cells and batteries under the scope of this document. - Stationary applications: telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power, and similar applications. - Motive applications: forklift truck, golf cart, auto guided vehicle (AGV), railway, and marine, excluding road vehicles. Since this document covers batteries for various industrial applications, it includes those requirements, which are common and minimum to the various applications. Electrical safety is included only as a part of the risk analysis of Clause 8. In regard to details for addressing electrical safety, the end use application standard requirements have to be considered. This document applies to cells and batteries. If the battery is divided into smaller units, the smaller unit can be tested as the representative of the battery. The manufacturer clearly declares the tested unit. The manufacturer may add functions, which are present in the final battery to the tested unit.

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IEC TC 21 Secondary cells and batteries		
Characterisation and lifetime performance testing – cell level		
STANDARD REFERENCE	**TITLE**	**SCOPE**
IEC 62620:2014	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications	IEC 62620:2014 specifies marking, tests and requirements for lithium secondary cells and batteries used in industrial applications including stationary applications. When there exists an IEC standard specifying test conditions and requirements for cells used in special applications and which is in conflict with this standard, the former takes precedence. (e.g. IEC 62660 series on road vehicles). The following are some examples of applications that utilize the cells and batteries under the scope of this standard. - 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. This standard applies to cells and batteries. If the battery is divided into smaller units, the smaller unit can be tested as the representative of the battery. The manufacturer clearly declares the tested unit. The manufacturer may add functions, which are present in the final battery, to the tested unit.

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IEC TC 21 Secondary cells and batteries		
Characterisation and lifetime performance testing – cell level		
STANDARD REFERENCE	**TITLE**	**SCOPE**
IEC 63056:2020	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems	IEC 63056:2020 specifies requirements and tests for the product safety of secondary lithium cells and batteries used in electrical energy storage systems (Figure 2) with a maximum DC voltage of 1 500 V (nominal). Basic safety requirements for the secondary lithium cells and batteries used in industrial applications are included in IEC 62619. This document provides additional or specific requirements for electrical energy storage systems. Since this document covers batteries for various electrical energy storage systems, it includes those requirements which are common and minimum to the electrical energy storage systems. Examples of appliances that are within the scope of this document are: telecommunications, central emergency lighting and alarm systems, stationary engine starting, photovoltaic systems, home (residential) energy storage systems (HESS), and large energy storage: on-grid/off-grid. This document applies to cells and batteries for uninterruptible power supplies (UPS). This document does not apply to portable systems 500 Wh or below, which are covered by IEC 61960-3.

ISO/TC 22 Road vehicles		
Performance testing- pack and system level		
STANDARD REFERENCE	**STANDARD REFERENCE**	**STANDARD REFERENCE**
ISO 12405-4:2018	Electrically propelled road vehicles —Test specification for lithium-ion traction battery packs and systems — Part 4: Performance testing	This document specifies test procedures for the basic characteristics of performance, reliability and electrical functionality for the battery packs and systems for either high-power or high-energy application. Unless otherwise stated, the test applies to both applications.

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		NOTE 1 Typical applications for high-power battery packs and systems are hybrid electric vehicles (HEVs) and some type of fuel cell vehicles (FCVs). NOTE 2 Typical applications for high-energy battery packs and systems are battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and some type of fuel cell vehicles (FCVs). NOTE 3 Testing on cell level is specified in IEC 62660 series.
NOTE ISO 12405 Series of standards currently consists of only part 4. Former parts 1, 2 and 3 have been replaced as follows: ISO 12405-1:2011 revised by ISO 12405-4:2018; ISO 12405-2:2012 revised by ISO 12405-4:2018; ISO 12405-3:2014 revised by ISO 6469-1:2019 (see below).		
ISO 6469-1:2019	Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS)	This document specifies safety requirements for rechargeable energy storage systems (RESS) of electrically propelled road vehicles for the protection of persons. It does not provide the comprehensive safety information for the manufacturing, maintenance and repair personnel. NOTE 1 Requirements for motorcycles and mopeds are specified in ISO 13063 and ISO 18243. NOTE 2 Additional safety requirements can apply for RESS that can be recharged by means different from supplying electric energy (e.g. redox flow battery).
IEC TC 9 Electrical equipment and systems for railways		
IEC 62928:2017	Railway applications - Rolling stock - Onboard lithium-ion traction batteries	IEC 62928:2017 specifies the design, operation parameters, safety recommendations, data exchange, routine and type tests, as well as marking and designation for onboard lithium-ion traction batteries for railway applications. Battery systems described in this document are used for the energy storage system (ESS) for the traction power of railway vehicles such as hybrid vehicles as defined in IEC 62864-1:2016.

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SAE		
STANDARD REFERENCE	**TITLE**	**SCOPE**
SAE J2464_200911	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing	This SAE Recommended Practice is intended as a guide toward standard practice and is subject to change to keep pace with experience and technical advances. It describes a body of tests which may be used as needed for abuse testing of electric or hybrid electric vehicle Rechargeable Energy Storage Systems (RESS) to determine the response of such electrical energy storage and control systems to conditions or events which are beyond their normal operating range. Abuse test procedures in this document are intended to cover a broad range of vehicle applications as well as a broad range of electrical energy storage devices, including individual RESS cells (batteries or capacitors), modules and packs. This document applies to vehicles with RESS voltages above 60 volts. This document does not apply to RESS that uses mechanical devices store energy (e.g., electro-mechanical flywheels).
SAE J2929_201302	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells	This SAE Standard defines a minimum set of acceptable safety criteria for a lithium-based rechargeable battery system to be considered for use in a vehicle propulsion application as an energy storage system connected to a high voltage power train. While the objective is a safe battery system when installed into a vehicle application, this Standard is primarily focused, wherever possible, on conditions which can be evaluated utilizing the battery system alone. As this is a minimum set of criteria, it is recognized that battery system and vehicle manufacturers may have additional requirements for cells, modules, packs and systems in order to assure a safe battery system for a given application. A battery system is a completely functional energy storage system consisting of the pack(s) and necessary ancillary subsystems for physical

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SAE		
STANDARD REFERENCE	**TITLE**	**SCOPE**
		support and enclosure, thermal management, and electronic control.
SAE J2288_200806	Life Cycle Testing of Electric Vehicle Battery Modules	This SAE Recommended Practice defines a standardized test method to determine the expected service life, in cycles, of electric vehicle battery modules. It is based on a set of nominal or baseline operating conditions in order to characterize the expected degradation in electrical performance as a function of life and to identify relevant failure mechanisms where possible. Accelerated aging is not included in the scope of this procedure, although the time compression resulting from continuous testing may unintentionally accelerate battery degradation unless test conditions are carefully controlled. The process used to define a test matrix of accelerated aging conditions based on failure mechanisms, and to establish statistical confidence levels for the results, is considered beyond the scope of this document. Because the intent is to use standard testing conditions whenever possible, results from the evaluation of different technologies should be comparable. End-of-life is determined based on module capacity and power ratings. This may result in a measured cycle life different than that which would be determined based on actual capacity; however, this approach permits a battery manufacturer to make necessary tradeoffs between power and energy in establishing ratings for a battery module. This approach is considered appropriate for a mature design or production battery. It should be noted that the procedure defined in this document is functionally identical to the USABC Baseline Life Cycle Test Procedure.

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UL Standards		
STANDARD REFERENCE	**TITLE**	**SCOPE**
UL 2580	Batteries for Use In Electric Vehicles	1.1 These requirements cover electrical energy storage assemblies such as battery packs and combination battery pack-electrochemical capacitor assemblies and the subassembly/modules that make up these assemblies for use in electric-powered vehicles as defined in this standard. 1.2 This standard evaluates the electrical energy storage assembly's ability to safely withstand simulated abuse conditions and prevents any exposure of persons to hazards as a result of the abuse. This standard evaluates the electric energy storage assembly and modules based upon the manufacturer's specified charge and discharge parameters at specified temperatures. It does not evaluate the assembly's interaction with other control systems within the vehicle. 1.3 This standard does not evaluate the performance or reliability of these devices.

Overview of cell characterisation test according to the different standards.

Test item	Test type	Condition	IEC 62660	ISO 12405-4:2018
Preconditioning	Cycling	Temperature (°C)	25	25
		Charge	Standard charge	Standard charge
		Discharge	0.2C	2C
		cycles	5	5
Energy and capacity	Constant current discharge	Temperature (°C)	−20, 0, 25, 45	−18, 0, 25, 40
		Charge	standard charge	standard charge
		Discharge	1C, 10C, 20C, Imax	1C, 10C, 20C, Imax
		cycles	2	2
Power and resistance	charge/ discharge Pulse test	Temperature (°C)	−20, 0, 25, 45	−18, 0, 25, 40
		Discharge	0.2C, 1C, 5C, 10C	Imax, dis
		Duration	10 s	0.1 s, 2 s, 10 s, 18 s
		Charge	1/3C, 1C, 5C, 10C	0.75*Imax, dis
		Duration	10s	0.1 s, 2 s, 10 s
		SOC	50%	80%, 65%, 50%, 35%, 20%

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Test item	Test type	Condition	IEC 62660	ISO 12405-4:2018
Energy efficiency	Pulse charge/ discharge	Temperature (°C)	–20, 0, 25, 45	0, 25, 40
		Discharge	1/3C, 1C, 5C, 10C	Time dependent
		Duration	10s	
		Charge	1/3C, 1C, 5C, 10C	Time dependent
		Duration	10 s	
		SOC	50%	65%, 50%, 35%

Overview of the cycle life test according to the different standards.

Standard	Condition
IEC 62660	***BEV cycle-life*** **Before the cycling test:** - Capacity test @ 25°C, Dynamic discharge capacity test @ 25°C and 45°C and Power test @ 25°C @ 50% SoC **Life cycling: @ 45°C** 1- Cycling with two different dynamic discharge profile until the discharged capacity reaches equivalent to 50 % and 80% of the initial dynamic discharge capacity measured at 45°C. The test profile is repeated for 28 days then periodical measurement of performance (same as the before cycling test only @ 25°C) is performed.
	HEV cycle-life test **Before cycling test:** - Capacity test @ 25°C and power test @ 25°C @ 50% SoC **Life cycling: @ 45°C** Cycling from 80% SoC to 30% SoC with the defined profile Test profile is Repeat for 22 hours then rest for 2 hours Every 7 days perform power test @ 25°C @ 50% SoC Every 14 days, perform a capacity test End of test after 6 months or the performances decreased less than 80%.
ISO 12405-4:2018	**Before cycling:** 1C capacity test @ 25°C **Cycling** between 80% SOC and 30% SOC for 22 hours following with 2 hours rest. Repeat the test 7days Every 7 days: pulse test Every 14 days: 1C capacity test and pulse test
SAE J2288	**Before cycling** and every 28 days, the following measurement shall be performed: 1- capacity test at the C/3 constant current rate, dynamic capacity test to a maximum of 100% of rated capacity and peak power test. **Discharge** to 80% DoD with the dynamic capacity test then **full charge**. Repeat the test 28 days **End-of-life limit** capacity (either static or dynamic) goes less than 80% of rated capacity, or,

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	the peak power capability is less than 80% of its rated value at 80% depth-of-discharge

Overview of calendar life test according to the different standards.

Standard	Condition
IEC 62660	**Charge retention test** @ 45°C @ 50% SoC Capacity test every 28 days ***Storage life test*** **Before test** Capacity test, Power density test and Regenerative power test **Calendar life test**: @ 45°C @ 100% SoC for BEV and 50% SoC for HEV The 'Before cycling test' is performed every 42 days and is repeated for 3 times.
ISO 12405-4:2018	**SoC loss at storage** @ 45°C @ 50% SoC for 30 days The remaining capacity is measured by a C/3 discharge test.

Overview of battery safety test according to the different standards.

Test	SAE J2929	ISO 6469 -1	IEC 62660 -2
Mechanical	Mechanical shock and vibration test at the cell level are covered	Mechanical shock, immersion, crush and vibration only at pack and vehicle level	Mechanical, crush and vibration at the cell level
Electrical	External short circuit and overcharge/over discharge at pack level	External short circuit and overcharge/over discharge at pack level	External short circuit, Internal short circuit and overcharge/over discharge at pack level
Environmental	Thermal shock, overheat and the fire is covered at pack level	Thermal shock and fire is covered at pack level	Thermal stability and thermal shock is covered at cell level
Chemical	Emission and flammability	*	*

5 ICT standards

This chapter contains a list of standards that may be useful for the ICT part of the project. The standards in this chapter are intended to increase the confidence of the future clients on the result of the project in the developed solution, guaranteeing the security of their shared data and the quality of the developed product.

5.1 ICT security

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ISO/IEC JTC 1/SC 27 Information security, cybersecurity and privacy protection		
STANDARD REFERENCE	**TITLE**	**SCOPE**
ISO/IEC 27000 Series	Information technology — Security techniques — Information security management systems	Information Security Management system (ISMS) family of standards. Through the use of the ISMS family of standards, organizations can develop and implement a framework for managing the security of their information assets, including financial information, intellectual property, and employee details, or information entrusted to them by customers or third parties. These standards can also be used to prepare for an independent assessment of their ISMS applied to the protection of information.

5.2 Software quality

ISO/IEC JTC 1/SC 7 Software and systems engineering		
STANDARD REFERENCE	**TITLE**	**SCOPE**
ISO/IEC 25000 Series	Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE)	ISO/IEC 25000 series of standards provide requirements and recommendations for an organization responsible for implementing and managing the systems and software product quality requirements specification and evaluation activities through the provision of technology, tools, experiences, and management skills.

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5.3 Other useful documents

CEN-CENELEC Workshop "Monsoon - Predictive management of data intensive industrial processes"		
STANDARD REFERENCE	**TITLE**	**SCOPE**
CWA 17492:2020	Predictive control and maintenance of data intensive industrial processes	This document contains a methodology detailing the machine/deep learning techniques that should be employed, through the different steps to be followed, with the aim to predict industrial processes or equipment drifts and trigger alarms and potentially help to improve overall equipment effectiveness or the workshop performances. NOTE The triggered alarms are related to the process in such a way a small deviation affecting the production can be detected in advance, but these alarms are not related to safety. This document can be used as a guide by: - Manufacturing plant managers: it contains two examples of real use cases that show the possibilities offered by machine/deep learning techniques applied to the control and optimization of manufacturing processes and to the predictive maintenance of plant machinery; - Data Scientists: The actual use cases shown reflect the problems they will face when applying these techniques in an industrial environment, which has its own characteristics.

6 Regulations

6.1 United Nations

6.1.1 UN Regulation No. 100 - Electric power trained vehicles

This regulation includes safety requirements with respect to the Rechargeable Energy Storage System (REESS), of road vehicles of categories M and N equipped with one or more traction motors operated by electric power and not permanently connected to the grid (Part II of the Regulation).

Available at https://www.unece.org/?id=39145 (Tab 100).

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6.1.2 UN Manual of Tests and Criteria (UN Transportation Testing)

The "Manual of Tests and Criteria" contains criteria, test methods and procedures to be used for the classification of dangerous goods according to the provisions of the "United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations", as well as of chemicals presenting physical hazards according to the "Globally Harmonized System of Classification and Labelling of Chemicals (GHS)". It therefore also supplements national or international regulations which are derived from the Model Regulations or the GHS. Section 38.3 presents the procedures to be followed for the classification of lithium metal and lithium ion cells and batteries.

Available at https://www.unece.org/ru/trans/areas-of-work/dangerous-goods/legal-instruments-and-recommendations/un-manual-of-tests-and-criteria/rev7-files.html (Seventh revised edition).

6.2 European Union

6.2.1 Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC.

Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02006L0066-20180704

6.2.2 Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02011L0065-20200301

6.2.3 Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast)

Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0019-20180704

The abovementioned Directives do not contain technical requirements relevant for the project.

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