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**Innovative energy storage technology for stationary use;**
**Part 2: Battery**

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# Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

The present document is part 2 of a multi-part deliverable covering Innovative energy storage technology for stationary use, as identified below:

Part 1: "Overview";

**Part 2: "Battery";**

Part 3: "Supercapacitor".

# Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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# Executive summary

The present document is a part (Part 2: Battery) of a series of standards (the other standards in the series being ETSI TS 103 553-1 [1] and ETSI TS 103 553-3 [i.19] on innovative energy storage systems for stationary power systems of telecom/Information and Communication Technology (ICT) equipment used in telecom networks, data centres and Customer Premises Equipment (CPE). The present document introduces technologies and methods for evaluating, selecting and testing battery systems for defined applications.

# Introduction

Conventional Valve Regulated Lead Acid (VRLA) batteries are widely used for their low cost, mature technology and infrequent and easy maintenance. However, with the continuous development of broadband network technologies (wireless base stations or optical access sites) associated with higher energy density core network sites and data centres, traditional bulky batteries are gradually exposed to higher ambient temperatures and other stresses.

As alternatives, new battery technologies may provide better performances in size, weight, temperature range, cycling, high-rate charging and discharging, environmental protection and many other advantages.

Other applications of stationary rechargeable batteries are now observed for resilience of customer home or office telecom/ICT installations, that can be associated with renewable energy sources in countries with unstable AC grids. More recently new requirements for uninterrupted power for Internet of Things (IoT) and Machine to Machine (M2M) devices have also emerged using rechargeable batteries rather than primary batteries due to advantages in size, costs and issues of replacement frequency.

However as discussed in IEEE Intelec2018 [i.23], the increasing demands on stationary batteries are driving innovation and many new battery technologies are being developed. Consequently there is a need for a method to discriminate the most appropriate technologies and products for one or several applications and for this purpose additional evaluations and tests are still required.

The present document introduces basic requirements and tests methods for evaluating new batteries (lithium, nickel based, etc.) for stationary use in power supply systems of ICT equipment. The present document also complements existing general International Electrotechnical Commission (IEC) standards of electrochemical battery products.

In each family of technologies, a typical chemistry is taken as a basis for improved description, e.g. lithium iron phosphate is in the lithium battery family, nickel-zinc is in the nickel based family, etc.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5 and is published respectively by ITU and ETSI as Recommendation ITU-T L.1221 [i.17] and the present document, which are technically equivalent.

# 1 Scope

The present document contains the main requirements for evaluating appropriate innovative batteries for stationary use for powering ICT equipment in telecom sites, active network units and data centres or customer premises with standardized power interfaces in -48 V, up to 400 VDC or 12 V.

Based on the general selection and evaluation method proposed in ETSI TS 103 553-1 [1], the present document introduces the main battery technologies, characteristics and the method to select, evaluate and test battery products adapted to a defined application.

The present document describes the selection criteria and possible tests for making the appropriate or optimal choice of battery technology for an ICT stationary application. This includes mechanical performance, electrical performance, (voltage, current, power and capacity ratings, efficiency and self-discharge, etc.), environmental performance (temperature range), lifetime performance (cycling and calendar life, tolerance of partial charge and depth of discharge), installation, operation and maintenance complexity (parallel operation), safety (risk to and protection of humans and environment, error and fault tolerance), management/monitoring (including anti-theft solution) at battery and cell level and Total Cost Ownership (TCO) assessment.

The present document specifies evaluation methods and tests which complement those of existing relevant standards requirements.

# 2 References

## 2.1 Normative references



References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.



Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 553-1: "Environmental Engineering (EE); Innovative energy storage technology for stationary use; Part 1: Overview".

[2] ETSI ES 202 336-11 (V1.1.1) (2014): "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (Power, Cooling and environment systems used in telecommunication networks); Part 11: Battery system with integrated control and monitoring information model".

[3] IEC 60896-21:2004: "Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test".

[4] IEC 60896-22:2004: "Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements".

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.


[i.1] Recommendation ITU-T L.1001 (2012): "External universal power adapter solutions for stationary information and communication technology devices".

[i.2] Recommendation ITU-T L.1200 (2012): "Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment".

[i.3] Recommendation ITU-T L.1201 (2014): "Architecture of power feeding systems of up to 400 VDC".

[i.4] ETSI ES 203 474: "Environmental Engineering (EE); Interfacing of renewable energy or distributed power sources to 400 VDC distribution systems powering Information and Communication Technology (ICT) equipment".

[i.5] ISO/IEC 17025 (2017): "General requirements for the competence of testing and calibration laboratories".

[i.6] 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".

[i.7] IEC 61960-3 (2017): "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications - Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them".

[i.8] UN38.3 (ed.5 amendment 1): "Recommendations on the TRANSPORT OF DANGEROUS GOODS - Manual of Tests and Criteria".

[i.9] Translated from Chinese Standard (GBT 2423.17-2008, GB/T2423.17-2008, GBT2423.17-2008): "Environmental Testing for Electric and Electronic Products - Part 2: Test Methods - Test Ka: Salt Mist".

[i.10] IEC 60068-2-11 (1981): "Basic environmental testing procedures - Part 2-11: Tests - Test Ka: Salt mist".





[i.11] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 2: Operated by -48 V direct current (dc)".

[i.12] ETSI EN 300 132-3-1 (2012): "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V; Sub-part 1: Direct current source up to 400 V".

[i.13] ETSI TR 103 229 (2014): "Environmental Engineering (EE) Safety Extra Low Voltage (SELV) DC power supply network for ICT devices with energy storage and grid or renewable energy sources options".

[i.14] ETSI TR 102 532 (V1.1.1) (2009-06): "Environmental Engineering (EE) The use of alternative energy sources in telecommunication installations".

[i.15] The European Association for Advanced Rechargeable Batteries Roadmap (2013): "E-mobility Roadmap for the EU battery industry".

[i.16] IEC 60050-482 (2004): "International Electrotechnical Vocabulary - Part 482: Primary and secondary cells and batteries".

[i.17] Recommendation ITU-T L.1221: "Innovative energy storage technology for stationary use; Part 2: Battery".

[i.18] IEC 62620: "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications".

[i.19] ETSI TS 103 553-3: "Environmental Engineering (EE); Innovative energy storage technology for stationary use; Part 3: Supercapacitor".

[i.20] Recommendation ITU-T L.1205(2016): Interfacing of renewable energy or distributed power sources to up to 400 VDC power feeding systems.

[i.21] SooGREEN European Project (2016-2018): "Service-oriented optimization of Green mobile networks", Invited paper, Rocha et alii.et alii Orange, Nokia, KTH, Royal Institute of Technology Netherland, Electrum Tele2 Sweden, Institut Mines Telecom, France, Eurico Ferreira Portugal, 2017.

NOTE: Available at http://opendl.ifip-tc6.org/db/conf/wiopt/wiopt2017/1570349026.pdf.

[i.22] David Linden, Thomas B. Reddy: "Handbook of batteries-4th edition Library of Congress Cataloging-in-Publication Data".

[i.23] D. Marquet et alii Orange, C. Campion (3C projects): "How to transform innovative battery opportunities in field operational solutions for Telecom/IT application IEEE Intelec 2018", Torino.

[i.24] IEC 60896-11:2002: "Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests".

[i.25] IEC 61427-1: "Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application".

[i.26] EUROBAT 2015.

[i.27] IEC 62485-2: "Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries".

[i.28] IEC 62259: "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Nickel-cadmium prismatic secondary single cells with partial gas recombination".

[i.29] IEC 61434: "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Guide to designation of current in alkaline secondary cell and battery standards".

[i.30] IEC 60623: "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells".



# 3 Definition of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the following terms apply:

**Battery Management System or Unit (BMS, BMU):** electronic system associated with a battery which monitors and/or manages its state, calculates secondary data, reports that data and/or controls its environment to influence the battery's performance and service life and has the functions to cut off in case of abnormal conditions (e.g. over charging, over current and over heating and charge balancing between cells or parallel cells blocks)

NOTE 1: Depending on the application and its size, the function of the BMS/BMU can be assigned to the battery cell, module, string, pack or system and equipment using the battery. A common implementation is a BMS/BMU made of several electronic modules located at different levels of the system.

NOTE 2: A Battery Management System (BMS) is sometimes also referred to as a Battery Management Unit (BMU).

NOTE 3: Definition adapted from IEC 60050-482 [i.16] and IEC 62620 [i.18].

**battery module:** group of cells or blocks connected together either in a series and/or parallel configuration with or without protective devices (e.g. fuse or PTC) and electronic circuitry

NOTE 1: Typically, this is parallel/serial arrangement of small cylindrical e.g. Lithium-ion or Ni based cells often named mSnP module.

NOTE 2: Definition adapted from IEC 60050-482 [i.16] and IEC 62620 [i.18].

**battery pack:** energy storage device, which is comprised one or more cells or modules electrically connected together inside a mechanical pack with electronics as required for safety and operation

NOTE 1: The battery pack may incorporate a protective housing and be provided with terminals or other interconnection arrangement. It may include protective devices and control and monitoring required for safe and proper operation. A typical example of a battery pack may be built by using 6s2p Lithium-ion module. It may provide detailed information (e.g. cell voltage, temperature, capacity) to a higher level battery system management device.

NOTE 2: Definition adapted from IEC 60050-482 [i.16] and IEC 62620 [i.18].

**battery string:** group of cells or battery modules of same technology and capacity connected in series to match the battery system voltage

NOTE: Strings can work in parallel with or without protective device (e.g. fuse or PTC) depending on the technology and safety risk.

**battery system:** system which incorporates one or more battery cells, modules, strings or battery packs and has one or more BMS or BMU

NOTE 1: The battery system is generally defined for high power and capacity batteries made of several battery strings or packs of blocks or modules it may include cooling or heating units and gas exhaust arrangement.

NOTE 2: Definition adapted from IEC 60050-482 [i.16] and IEC 62620 [i.18].

**cell, accumulator cell:** cell where electrical energy is accumulated by electrochemical reactions between the negative electrode and the positive electrode

NOTE: Definition adapted from IEC 60050-482 [i.16] and IEC 62620 [i.18].



**cells block:** group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or PTC) and electronic circuitry, generally not ready for use as battery system as not yet fitted with its final housing, terminals arrangement, etc.



NOTE 1: Typically, this is parallel arrangement of n small cells e.g. Lithium-ion or Ni based cells often named nP configuration.

NOTE 2: Definition adapted from IEC 60050-482 [i.16] and IEC 62620 [i.18].

**charge recovery:** charge capacity (generally in Ah) that a cell or battery can deliver after the charge following the charge retention test

NOTE: As defined in IEC 62620 [i.18].

**charge retention:** charge capacity (generally in Ah) that a cell or battery can deliver after storage, at a specific temperature, for a specific time without subsequent recharge as a percentage of the rated capacity

NOTE: As defined in IEC 62620 [i.18].

**cumulative discharging energy (kWh):** discharging energy (kWh) in the whole cycle life ending at a defined remaining capacity e.g. 70 % of rated capacity under defined normal working condition (including the working temperature, charging and discharging rate, and DoD)

**end-of-discharge voltage:** specified closed circuit voltage at which the discharge of a cell or battery is defined as terminated by the manufacturer

NOTE: Definition adapted from IEC 60050-482] [i.16] and IEC 62620 [i.18].

**genset:** generator producing electricity by using fuel e.g. a diesel generator

NOTE: When associated with a battery system in a Hybrid Genset Battery (HGB) system the system energy efficiency is optimized and thus the fuel consumption to produce the same electrical HGB system output is reduced.

**nickel based battery:** aqueous battery that uses nickel metal and hydroxide in electrodes such NiFe, NiCd, NiMH and NiZn batteries

**nominal voltage:** suitable approximate value of the voltage used to designate or identify a cell or a battery

NOTE 1: The cell or battery manufacturer may provide the nominal voltage.

NOTE 2: The nominal voltage of a battery of n series connected cells is equal to n times the nominal voltage of a single cell.

NOTE 3: As defined in IEC 62620 [i.18].

**rated capacity:** capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

NOTE 1: The rated capacity is the quantity of electricity Cn Ah (ampere-hours) declared by the manufacturer which a single cell or battery can deliver during a period of n hours when charging, storing and discharging under specified conditions by the manufacturer.

NOTE 2: As defined in IEC 62620 [i.18].

# 3.2 Symbols

For the purposes of the present document, the following symbols apply:

| | |
|---|---|
| **A** | ICT equipment power feeding interface of -48 VDC |
| **A3** | ICT equipment power feeding interface of up to 400 VDC |

NOTE: As defined in Recommendation ITU-T L.1200 [i.2].



| | |
|---|---|
| $\mathbf{C_n}$ | Battery capacity in Ah in n hours discharge rate |
| $\mathbf{I_n}$ | Battery discharge current in n hours discharge rate |



# 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| AC | Alternating Current |
| AGM | Absorbent Glass Mat |
| Ah | Ampere hour |
| B | Battery Block |
| BMS | Battery Management System |
| BMU | Battery Management Unit |
| BMU (B) | Battery Management Unit (Block) |
| BMU (M) | Battery Management Unit (Module) |
| BMU (S) | Battery Management Unit (String) |
| BS | Battery System |
| CAPEX | Capital Expenditure |
| CPE | Customer Premises Equipment |
| DC | Direct Current |
| DoD | Depth of Discharge |
| E | Evaluation |
| EoL | End of Life |
| EUT | Equipment Under Test |
| HARB | Hybrid Aqueous Rechargeable Battery |
| HGB | Hybrid Genset Battery system |
| ICT | Information and Communication Technology |
| IoT | Internet of Things |
| LA | Lead-Acid |
| LCO | Lithium Cobalt Oxide |
| LFP | Lithium Iron Phosphate |
| LMO | Lithium Manganese Oxide |

| | |
|---|---|
| LTO | Lithium Titanate Oxide |
| M | Module |
| M2M | Machine to Machine |
| NCA | Nickel Cobalt Aluminium |
| NCM | Nickel Cobalt Manganese |
| NiCd | Nickel Cadmium |
| NiFe | Nickel Fer (Nickel-Iron in English) |
| NiMH | Nickel Metal Hydride |
| NiZn | Nickel Zinc |
| NMC | Nickel Manganese Cobalt |
| OPEX | Operational Expenditure |
| OPZS | Ortsfest (stationary) PanZerplatte (tubular plate) Flüssig (flooded) |
| OPZV | Ortsfest (stationary) PanZerplatte (tubular plate) Verschlossen (closed) |
| PbC | Lead-Carbon |
| PSoC | Partial State of Charge |
| PSU | Power Supply Unit |
| PTC | Positive Temperature Coefficient resistor |
| PV | PhotoVoltaic |
| RES | Renewable Energy System |
| S | System |
| SCPS | SCPS laboratory |
| SELV | Safety Extra Low Voltage |
| SoC | State of Charge |
| SoH | State of Health |
| T | Test |
| TCO | Total Cost Ownership |
| U | Unit |
| UPS | Uninterrupted Power Supply |
| VDC | Volt Direct Current |
| VRLA | Valve Regulated Lead Acid |
| Wh | Watt hour |



# 4 Battery configurations and stationary applications

A battery is an assembly of cells contained in a more or less sealed jar made of:

- negative and positive electrodes having active material on electric collectors;
- separator between the electrode making galvanic insulation and containing ionic electrolyte;
- electrolyte allowing the movement of ions making the electric charge/discharge reactions (the electrolyte can change its nature or not during the change of charge of the cell);
- electrical connection from interior to exterior of the jar from soldered set of negative and positive electrodes to external poles.

Figure 1 shows some examples of battery cell structures. Some of these battery cells can be used both in stationary and in mobile applications. Many battery cell structures, such as the common cylindrical cells, can be found in Linden [i.22] and in Roadmap 2013 [i.15].

**Internal structure of Lithium-ion Battery**

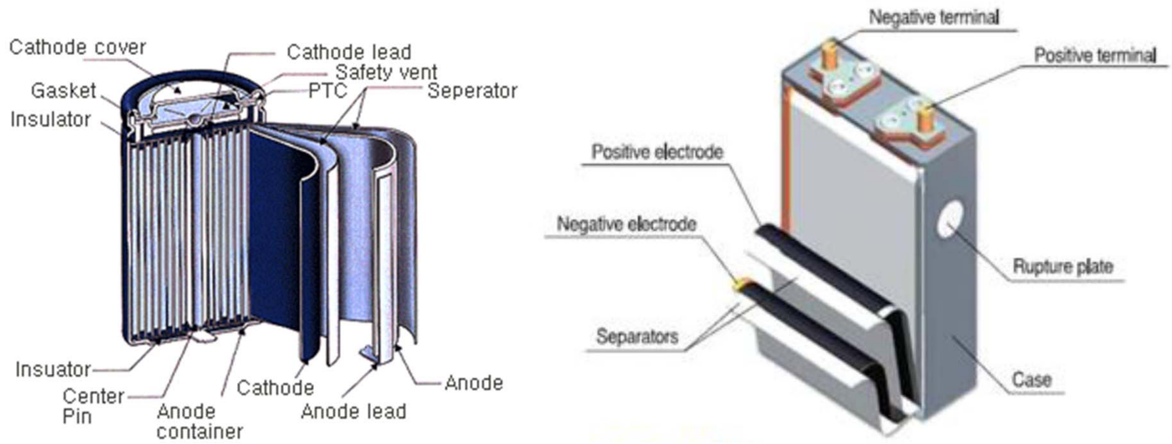


**Figure 1:Typical constitution of cylindrical and prismatic Lithium-ion cell**

The stationary batteries are used for stationary application of power supplies of ICT equipment in telecom sites or active network units, data centres or customer premises with standardized power interfaces in -48 V ETSI EN 300 132-2 [i.11], up to 400 VDC [i.2] or ETSI EN 300 132-3-1 [i.12], or other voltages such as 12 V as defined in Recommendation ITU-T L.1201 [i.3] for stationary use telecom termination devices.

The use modes include:

- back-up of electric grids of different quality;
- cycling use on intermittent public grids or Renewable Energy Systems (RESs) or engine generator sets (HGB);
- peak power shaving to reduce permanent power sizing of power supplies or remote lines.



Typical applications are as follows:

- telecom rectifier-battery DC systems;
- AC Uninterrupted Power Supply (UPS);
- renewable energy systems with charge-controller between generator, battery and load as presented in Recommendation ITU-T L.1205 [i.20], ETSI ES 203 474 [i.4] and also in ETSI TR 102 532 [i.14];
- hybrid engine generator set with battery (HGB);
- power supply with back-up for fixed terminals;
- peak power shaving;
- Customer Premises Equipment (CPE) back-up network in a Safety Extra Low Voltage (SELV) circuit as presented in ETSI TR 103 229 [i.13].

Typical implementation examples are given in Annex A.

# 5 Overview of battery technologies

## 5.1 Types of technologies

There are many types of battery technologies.

The main ones are:

- Aqueous ionic electrolyte:
  - Acid:
    - Lead:
      - Flooded or vented Lead-Acid (LA)
      - VRLA type
      - Lead-carbon (PbC)
      - Pure lead, bipolar LA
    - Other metal acid batteries.
  - Alkaline:
    - Nickel based:

      NiFe

      NiCd

      NiZn

      NiMH

      (NiMn, NiNi in research state)
  - Neutral salt:
    - Flow battery (vanadium, iron-boron, iron-iron, etc.)
    - Sodium sulfate, etc.
    - Metal-air (zinc, aluminium, magnesium, calcium other alloys, etc.)
- Non aqueous electrolyte (organic or low temperature solid) works by an insertion mechanism (change of solid oxide crystal charge with ion insertion or intercalation rather than aqueous reduction/oxidation of metal/ion couples):
  - Lithium-ion (LCO, LMO, NCA, NMC, LFP, LTO)
  - metal-air (lithium, sodium, potassium, other alloys, etc.)
- Hybrid Aqueous Rechargeable Battery (HARB) that uses both mechanisms (aqueous oxydo-reduction and ion insertion). It may apply to aluminium-ion or zinc-ion solutions.
- Hot temperature solid (metal electrodes and melted salt electrolytes):
  - hot temperature: nickel chloride-sodium, sodium-sulfur operating at much higher temperature than ambient temperature with some melted material inside (e.g. sodium or sulfur at higher temperatures than 150 °C).
- Solutions with other separation mechanisms (e.g. by gravity) such as liquid bi-metal medium temperature alloy battery are under research.

NOTE: The initial edition of the present document will not cover all the technologies emerging from recent intensive research related to electric vehicles and renewable energy storage, but many considerations and evaluation methods defined within, such as electrical characterization for an application, are applicable.

## 5.2 Lithium ion battery cells

### 5.2.1 Cell types

There are two types of lithium ion battery cells, these are known as hard case and soft case types.

The hard case types are typically of cylindrical or prismatic case type. The soft case type is a pouch.

In terms of the cathode and anode material, several types exist:

- For the cathode material: LCO, LMO, NCA, NMC, LFP, lithium-metal, etc.
- For the anode material: Graphite and LTO type, etc.

NOTE 1: Lithium metal cells have in general a solid electrolyte separator ensuring safety, but requiring operation at higher than ambient temperature for improving electrical conductivity and output power. Due to heating, energy efficiency is lower than on lithium-ion cell operating at ambient temperature.

NOTE 2: New aluminium, sodium, magnesium and potassium ion cells could provide a low cost alternative to lithium-ion for stationary applications where the highest energy density is not required, if they prove to be safe, reliable and use very few rare materials.

### 5.2.2 Characteristics of lithium ion battery cells



The lithium ion battery cells have the following main characteristics:



- High gravimetric and volumetric energy density
- Higher voltage than aqueous technologies (> 2 V)
- No memory effect and negative effect of Partial State of Charge (PSoC)
- Moderate environmental impact depending on chemical composition and features (less cobalt, less toxic electrolyte, better recycling)
- High rate discharge
- Fast charge and long life cycle
- Safety
- Wide temperature ranges

NOTE: For some lithium technologies, permanent high State of Charge (SoC) and high voltage can accelerate ageing effect compared to Partial State of Charge (PSoC).

### 5.2.3 Nominal voltage of lithium ion battery cells

Lithium-ion technologies used in portable devices can be used as a stationary battery and have a well-known high nominal voltage of 3,6 V. Annex C lists standard secondary lithium cells defined in IEC 61960-3 [i.7].

Battery manufacturers are developing technologies to increase the nominal voltage to 3,7 V or 3,8 V in order to increase the energy density enabling market for mobility and portable devices. However the nominal voltage varies depending on the cathode and anode material chemical composition and some technologies that have a lower voltage are targeting high capacity for stationary energy storage applications requiring high safety, long lifetime and good TCO. Here weight and volume performances are less critical than for mobile applications.

Table 1 shows the nominal voltages for different cathode or anode materials.