# EVERLASTING

Electric Vehicle Enhanced Range, Lifetime And Safety
Through INGenious battery management

# D8.15 – White Paper 12

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# LIST OF ABBREVIATIONS AND ACRONYMS

| ACRONYM | DEFINITION |
|---|---|
| BMS | Battery Management System |
| CAN | Controller Area Network |
| EOL | End of Life |
| EN | European standards |
| EU | European Union |
| EV | Electric Vehicle |
| OCV | Open Circuit Voltage |
| $I^2C$ | Inter-integrated Circuit |
| IEC | International Electrotechnical Commission |
| ISO | International Organization for Standardization |
| ITU | International Telecommunication Union |
| LV | Low Voltage |
| R&D | Research and Development |
| RUL | Remaining Useful Life |
| SAE | Society of Automotive Engineers |
| SOA | Safe Operating Area |
| SoC | State of Charge |
| SoF | State of Function |
| SoH | State of Health |
| SoP | State of Power |
| SPI | Serial Peripheral Interface |
| UL | Underwriters Laboratories |
| USABC | United States Advanced Battery Consortium |
| WP | Work package |

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# 1 WHITE PAPER: INTRODUCTION

In the scope of the EVERLASTING project (http://everlasting-project.eu/), innovative technologies to improve the reliability, lifetime, and safety of lithium-ion batteries are developed. It is done particularly by designing more accurate and standardized battery monitoring and management systems, that allow predicting the battery behaviour in all circumstances and over its full lifetime and enables pro-active and effective management of the battery. The reliability and safety are increased by preventing of issues rather than mitigating them. To raise the awareness of the vital and positive role of Battery Management Systems (BMS), a three-monthly white paper is being published by EVERLASTING partners on different BMS topics, aimed at a general technical public.

This twelfth issue of the white paper focuses on the topic “BMS standardization”.

# 2 WHITE PAPER 12: BMS STANDARDIZATION

## 2.1 INTRODUCTION

This white paper intends to address the standardization of Battery Management Systems. It includes the scope and significance of standardization and its positive impact on the technical, economic and societal grounds.

## 2.2 WHAT DOES STANDARDIZATION MEAN?

Standardization can be generally defined as the process of formulating and implementing a standard for the purpose of achieving a certain optimal degree of uniformity in a given contextual process, product or field.

International Organization for Standardization (ISO) defines a standard as follows:
”A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. International Standards bring technological, economic and societal benefits. They help to harmonize technical specifications of products and services making industry more efficient and breaking down barriers to international trade”. [1]

Therefore, a standard can be considered to be a set of guidelines that, when strictly followed, can result in improvement of efficiency as well as technological and economic benefits of the intended process or product. However, standardisation can contribute not only to improvement but also to understanding the problem in the first step. If standardized processes are followed, problems can be identified, and solutions can be found easily.

There are several organisations which are responsible for and involved in standardization processes across different domains and fields. Such organizations operating at European level and globally are listed in Table 1 and Table 2 respectively:

**Table 1: Standardization organisations at EU level [2]**

| Abbreviation | Short description |
|---|---|
| **CEN** | European Committee for Standardization (CEN) is a platform for the development of products, materials, services and process-related European standards and CEN supports standardization activities across various fields including: defence and security, air and space, chemicals, construction, consumer products, energy, the environment, food and feed, health and safety, healthcare, machinery, materials, services, transport etc. |

| | |
|---|---|
| **CENELEC** | European Committee for Electro-technical Standardization (CENELEC) is responsible for standardization in the electro-technical engineering field. CENELEC prepares voluntary standards, which help facilitate trade between countries, create new markets, cut compliance costs and support the development of a single European market. |
| **ETSI** | European Telecommunications Standards Institute (ETSI) is an independent, non-profit association whose 740 member companies and organizations, drawn from 62 countries across 5 continents worldwide, produce globally applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, aeronautical, broadcast and internet technologies. |

**Table 2: Standardization organisations worldwide [2]**

| Abbreviation | Short description |
|---|---|
| **ISO** | International Organization of Standardization is an independent, non-governmental organization, the members of which are the respective standards organizations of the 164 member countries. It is the world's largest developer of voluntary international standards and facilitates world trade by providing common standards between nations. |
| **IEC** | International Electro-technical Commission is the world's leading organization for the preparation and publication of international standards for all electrical, electronic and related technologies. |
| **ITU** | International Telecommunication Union (ITU) is the specialized agency of the United Nations, developing international standards in the field of telecommunications, information and communication technologies (ICTs). |

For automotive purposes, there exists a specific industry standard which is listed in Table 3.

**Table 3: Automotive industry-specific standard [2]**

| Abbreviation | Short description |
|---|---|
| **AUTOSAR** | AUTomotive Open System ARchitecture (AUTOSAR) is an alliance of OEM manufacturers and Tier 1 automotive suppliers for development of de-facto open automotive industry standards. |

## 2.3 Why is Standardization required?

The significance of standards is specific to the context of their application. In scientific research activities, standardization helps to increase the validity and reliability of findings/results achieved. It also facilitates the comprehensibility of results and publications. It prevents misunderstandings or fatal mistakes, if both, author and reader, can refer to the same common standards of measurements, values, etc.

In product design, innovation and engineering related R&D activities, standardization instigates innovation through pre-structured standard guidelines for design, development, data and testing procedures. For some applications, it is not only crucial that certain actions take place, but also the exact way and order of performing, as pictured in Figure 1. This is valid for the structure of data and documents as well.

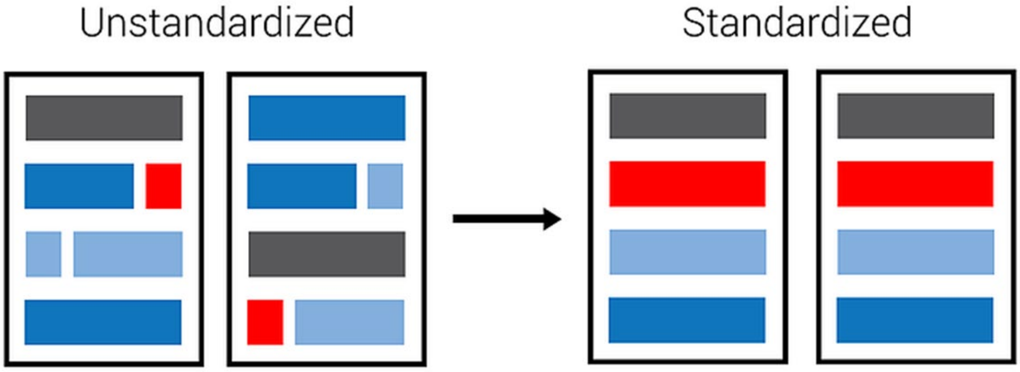

**Figure 1: Standardization of data and processes [3]**

Products developed by following such standardized procedures comply with standards, making them a better fit for the purpose they are designed for. Such a standardized product/service/system builds up market acceptance and trust. Standardization also facilitates combining several products/components from different manufacturers as they all have the same standard of interfaces/ ways of communicating etc.

There are also further collective benefits of standardization, which will be explained in Chapter 2.5.

## 2.4 STANDARDIZATION WITH FOCUS ON BMS

This section lists the standardization efforts and published standards related to battery system applications employing BMS. Although several standardization efforts have been carried out, with advancements in battery technology and evolving application requirements, there is still a lot of room for extending standardization. Such existing gaps in BMS standardization are also identified in this paper and proposals are given to bridge them.

### 2.4.1 EXISTING STANDARDS

Some of the most significant standards already existing for applications served by BMSs are listed in this section.

The non-application-specific standards related to battery systems are listed in the following Table 4:

**Table 4: Standards related to battery systems in general [2]**

| Standard | Description |
|---|---|
| **IEC 61508** | Design and safety requirements to be considered while designing a programmable electric and electronic system, with major focus on assuring its safe operation. |
| **IEC 60068-2** | Functional and safety tests, defined to study the behaviour of electronic equipment under the influence of operating ambient conditions like humidity, temperature, vibration, shock, etc. |
| **CENELEC CLC/TC 21X** | Tests defined for validating the performance and safety requirements of batteries used across applications. |
| **EN 62485** | Tests to validate safe operation of battery systems, safety precautions and facilities to be present in the installations of the battery system applications. |
| **UL 1974** | A set of potential 2nd life applications for electric vehicle (EV) batteries and the requirements that should be satisfied by an EV battery in order to efficiently serve the intended 2nd life application. The tests required to validate the application-specific battery system requirements are also mentioned. |

In Table 5, the EV-application-specific standards related to battery systems can be found:

**Table 5: Standards related to EV battery systems [2]**

| Standard | Description |
|---|---|
| **SAE J1798** | Performance tests to estimate parameters of an electric vehicle battery pack like deliverable capacity at various discharge currents, discharge power, operating temperatures, dynamic load profiles, etc. Test procedure to study the temperature dependence of self-discharge, charge-acceptance and peak power capability. |
| **SAE J2288** | Life cycle test methods to predict EV battery cycle life. Procedure for characterization of degradation in battery's electrical performance as a function of life and by identification of the relevant failure mechanisms under nominal operating conditions. |
| **UL 2271** | Abuse tests to ensure safe operation of the energy storage assemblies (battery pack/battery pack and ultra-capacitor etc.), applicable only to light electric vehicle applications like e-bikes, e-wheelchairs, e-scooters, etc., which are not intended to be driven on highways. |
| **UL 2580** | Abuse tests to ensure safe operation of the energy storage assembly (battery pack/battery pack and ultra-capacitor etc.), applicable to medium and heavy electric vehicles like passenger cars, trucks etc. |
| **USABC test procedure manual** | Safety, abuse and performance tests required for validation of battery systems for electric vehicle applications. |
| **EN 61982** | Performance and endurance tests for validation of secondary batteries (except lithium) for the propulsion of electric road vehicles. |
| **EN 50604-1** | Test procedures for validating the safety and performance functionalities of battery systems for implementation in light electric vehicle batteries. |
| **SAE J2929** | Safety standard functionalities that must be satisfied by lithium-ion battery systems used in electric and hybrid vehicle propulsion. |
| **SAE J2380** | Set of requirements, test profiles and test procedures for performing vibration tests on electric vehicle batteries. |
| **SAE J2464** | Safety and abuse tests for validation of rechargeable energy storage systems used in electric and hybrid electric vehicles. |
| **SAE J1766** | Crash integrity requirements of passenger vehicles namely electric vehicles, fuel cell and hybrid electric vehicles. The tests for assuring the safety aspects like prevention of electric shock, exposure to high voltage, exposure to electrolyte spillage, etc. are defined. |
| **ISO 16898** | Guidance on tailoring a battery system design for a specific application and adopting its dimensions to fit into the designated application. This standard deals with dimensioning and designation of secondary lithium-ion cells for electric vehicles. |
| **ISO 6469-3** | Safety demands and tests for validating the passenger safety requirements of electrically-propelled road vehicles with focus on prevention of electric shock due to internal short circuit or crash. |
| **ISO 6469-2** | Safety and performance functionality requirements of components and subsystems present in electrically propelled road vehicles and respective validation methods. |
| **ISO 12405** | Reliability, abuse and performance tests for validation of lithium-ion batteries for use in high energy and high-power applications. |
| **ISO 26262** | An automotive standard adapted from IEC 61508 specific to series production passenger cars with a maximum gross vehicle mass up to 3500 kg, focusing on the safety lifecycle of systems comprising of electrical, electronic and software components. |
| **IEC 62660** | Safety and performance requirements for cells used in an electric vehicle battery. Remaining useful life estimation and a set of tests to validate system functionalities. |

| | |
|---|---|
| **IEC JWG 69 Li TC69/21/ 5C21A** | General requirements for the lithium-ion battery systems used in automotive applications. Sets of tests are specified for testing safety, performance functionalities and battery pack's eligibility for serving a 2nd life application. |
| **IEC 62619** | Test procedures for validating the safe operation of industrial battery systems namely stationary and motive applications (forklifts, line mover etc.). It contains the requirement that the BMS should be designed according to the Functional Safety approach. |

In Table 6, grid-storage application-specific standards related to battery systems can be found:

**Table 6: Standards related to grid-connected stationary battery systems [2]**

| Standard | Description |
|---|---|
| **IEC 61427 series** | A set of tests required for validating the performance and safety demands of a battery system employed in on-grid/off-grid applications. Its primary focus is on battery performance and safety. Additionally, BMS-related aspects like battery-to-grid communication protocol and adoption of an end-of-life EV-battery system are defined. |

The portable application-specific standards related to battery systems are listed in Table 7:

**Table 7: Standards related to battery systems for portable applications [2]**

| Standard | Description |
|---|---|
| **IEC 62133 series** | Safety, performance requirements and validation tests for the safe operation of rechargeable cells and batteries across chemistries and formats for portable applications. |

The automotive application-specific standards related to electrical/electronic systems can be found in the following Table 8:

**Table 8: Standards related to electrical and electronic equipment for automotive applications [2]**

| Standard | Description |
|---|---|
| **ISO 20653** | Validation tests for protection and safety requirements to be satisfied by electrical equipment used in road vehicles in case of crash, water intrusion or unauthorised external access. |
| **CENELEC CLC/TC 69X** | General requirements for electrical systems used in EVs. |
| **LV148 automotive standard** | General requirements for electrical systems used in automotive applications operating at 48 V voltage level. Performance and safety functionalities validation tests of such systems. |
| **LV124 automotive standard** | General requirements for electrical systems used in automotive applications operating at 12 V voltage level. Performance and safety functionalities validation tests of such systems. |

### 2.4.2 IDENTIFIED GAPS AND STANDARDIZATION POTENTIAL OF BMS

Although a considerable number of standards for battery served applications already exists, adopting and interpolating them with a focus on BMS seems challenging.

Hence, the standards listed in section 2.4.1 were analysed to identify the inadequacies and issues that should be bridged for a complete standardization of various aspects of BMS development. In this section, the multiple aspects of BMS functionalities, which can be improved through standardization, are explained in short. [2] [4]

#### *2.4.2.1 Monitoring of voltage, current and temperature*

Monitoring cell parameters namely voltage, current and temperature is a vital functionality of a BMS in order to maintain the safety of the battery pack. These measurements/values are elements of the so-called BMS Safe Operating Area (SOA) that are indeed the inputs to the battery state estimation algorithms, including State of Charge (SoC) and State of Health (SoH), to name a few.

Factors like the way the sensors are placed, allowed measurement tolerance, minimum sampling rate, measurement levels (cell/module/pack) etc. have to be explicitly defined for each application.

Defining a standard of sampling rate, measurement tolerance etc (adapted for an application) would make measurement results more comparable and reliable. Any comparison made between results, which have been measured with sensors placed at different spots, are to be considered. This is important as comparison can be invalid without a defined standard.

#### *2.4.2.2 Cell balancing*

The cells in a battery pack can differ in their voltage level due to inconsistencies in production, different storage time before implementing or different charging/discharging cycles experienced due to varying internal resistances. This may lead to several problems, limiting the charge and discharge capabilities of the pack.

Therefore, they have to be balanced to homogenize their SoCs, so that complete charging and discharging of the battery pack can be achieved.

There exist several methodologies for balancing cells namely:

- Dissipative balancing: Bypass resistor
- Non-dissipative balancing: Bidirectional multiple transformers, bidirectional switched transformers etc
- Reconfiguration network etc. [5]

Irrespective of the application, few factors namely the maximum voltage/SoC difference between cells to initiate balancing and the maximum allowed temperature rise across balancing resistors (in case of dissipative balancing) have to be defined by a standard. This would encourage implementation of improved balancing functionality across applications and help in attaining maximal utilization of battery pack charge & discharge capabilities.

#### *2.4.2.3 Galvanic isolation*

Galvanic isolation is the separation of electrical systems/subsystems with different ground potentials. No direct current flow is permitted as it would pose a safety issue, but information can still be exchanged. The functional sections of the BMS should be galvanically isolated by using isolation transformers, capacitor-based semiconductor isolators, and transformer-based isolators, optocouplers etc. depending upon application/functional requirements and isolated components.

With respect to galvanic isolation, the following factors need to be defined by a standard:

- minimum allowable isolation resistance
- maximum allowable safe ground loop current
- sections of the battery system and BMS which need to be galvanically isolated and
- application/operating voltage range specific requirements for implementing galvanic isolation.

Standardization of such factors not only improves safety through galvanic isolation, but also helps in minimizing the electrical noise arising from the flow of ground loop current, which may interfere with the operation of connected electrical circuits.

#### *2.4.2.4 State estimation functions*

To estimate the state of a battery, special algorithms are needed as well as parameters like voltage limits etc. Those parameters and the methodologies of determining the battery state, vary between different BMS providers.

**SoC**: SoC is the measure of the level of charge a battery/cell contains relative to its capacity. Various discrepancies exist in the definition of battery/cell capacity between different providers/algorithms /methodologies, since it is a function of temperature, C-rate and also ageing. A unified definition for the cell capacity shall be achieved with concurrence of the cell manufacturers. Additionally, a unified definition of the test procedure for determining cell capacity should be set. Capacity update with cell ageing shall be made a mandatory part of SoC algorithm. Application-specific tolerances in the accuracy of the estimated SoC shall also be defined.

**SoH:** It is an indicator of the degradation a battery has undergone compared to a new battery. There are many factors based upon which SoH shall be estimated and the most widely accepted methods are based on battery capacity and impedance [6]. Additionally, for high power applications, SoH based on power capabilities shall also be defined. Depending on the application served, SoH shall be defined based on either capacity (high energy applications) or impedance (high power applications). Though, since each of the listed parameters affects the performance of the battery in various means, a unified definition of battery SoH based on just one of those parameters is not sufficient and it would not be possible to compare those values.

(i.e.) SoH (capacity) ≠ SoH (resistance).

The limits of impedance and capacity for reaching end-of-life criteria shall also be explicitly defined for the applications served (EV, stationary storage, power tools, 2nd life applications, etc.). Application-specific tolerances in the accuracy of estimated SoH shall also be defined.

**SoP:** SoP is an indicator of how much power shall be drawn from or fed into a cell without violating any of its operating limits (voltage, current & temperature). SoP highly depends on battery resistance, which in turn has to be updated continuously concerning cell ageing. Both continuous and peak power limits are defined based on the time horizon for which the estimated power can be delivered. Such power limit definition concerning time horizon shall be defined in a unified way. A standard shall also define application-specific tolerances in the accuracy of estimated SoP.

**SoF:** SoF is a parameter stating whether a battery system can serve an application or not. It combines SoC, SoH, SoP and also load conditions to estimate the power capability of a battery system to serve that particular load. Application and load cycle (high power/high energy demanding) specific definitions shall be proposed regarding the weightage given to SoC, SoH and SoP parameters. Application-specific tolerances in the accuracy of an estimated SoP shall also be standardized.

The process of the state estimation methodologies is in a state of flux, hence being not standardized as of yet. However, some factors can be standardized separately for each application:

- the allowed tolerances in the estimation

- resolution of estimation
- data format for representation (0-1 or 0-100%)
- internal parameters and their end of life limit based on which the states are estimated throughout the battery lifetime

Unified definition of state estimation parameters such as state of charge (SoC), state of health (SoH), state of power (SoP), state of energy (SoE) and state of function (SoF) has to be done.

#### 2.4.2.5 Vehicle cloud integration

With a growing need for sophisticated BMS functionalities, namely complex state estimation algorithms, usage history-related data recording and storage, advanced diagnostics functionalities, etc., the requirement on computational and memory resources keeps mounting. Providing such intensive resources on an on-board BMS increases its cost significantly.

Hence cloud-connected BMSs are gaining attention, in which data storage and also such complex BMS functionalities are transferred to a remote server connected with the BMS. Such cloud connected servers also facilitate future updates in features/capabilities of the BMS without the need of increasing/modifying the existing BMS hardware and the possibility to implement updates over the air.

The vehicle-cloud integration concept for EV BMSs offers several possibilities/chances/holds excellent potential for standardization:

1. The set of data to be transferred to a cloud server for post-processing
2. The database format and duration of storage of the transferred data
3. Cyber security
4. Data privacy policy etc.

#### 2.4.2.6 Thermal management

Thermal management is a critical aspect for battery packs, to assure long battery life as well as for safety concerns. A wide temperature gradient in between individual cells within a battery pack leads to dissimilar ageing of those cells. The cells experiencing higher temperature gradient age faster and limit the overall pack performance.

Hence application-specific temperature and temperature gradient limits have to be defined, so that the thermal management systems can be designed to maintain the temperature and gradient within those limits. In case of applications without thermal management systems, battery pack design shall be the focus to reduce the temperature gradient.

#### 2.4.2.7 Data formats and sign convention

During the operation of a BMS, several data needs to be transmitted and stored, either within the BMS or with external systems connected with the BMS both on-board and on a remote server, depending upon the application served.

Within the data transmission and storage functionality, the following topics have to be standardized:

**Data transmission:** The data format in which the measured signals are transferred to the BMS components as well as to external systems has to be standardized to avoid any misperception between systems from different manufacturers or when integrating 3rd party functionalities.

**Data storage:** The transmitted data is stored either on-board or on a server. The format of the database, nature of data to be saved, the duration of storing, accessibility to the data for users &

stakeholders etc. have to be defined in an application-specific manner. The memory constraints have to be considered but not on the loss of accuracy.

Regarding BMS, the following proposals for standardization shall be considered:

**Voltage:** Measured voltage values have to be multiplied with a scaling factor, to maintain accuracy compared to a floating-point value. Such scaling factors shall be unified.

**Temperature:** In addition to unification of the multiplication scaling factor, the unit of cell temperature should also be standardised, to avoid any misinterpretation.

**SoX estimates:** The representation of state estimation parameters like SoC, SoH etc. is made either in (0-1) scale or (0-100%) scale. This has to be standardised, to avoid any misinterpretation.

#### *2.4.2.8 Specification from cell manufacturers*

Cell manufacturers provide specification documents with parameters like capacity, internal resistance, maximum allowed discharge & charge current, cycle life etc. Those parameters, their tolerances, the test conditions and procedures followed while measuring, termination conditions etc. should be standardized, to avoid misconception and to ensure comparability of such parameters.

The test procedures followed to estimate various parameters of a cell/battery mentioned in the respective data sheet namely capacity, internal resistance, OCV-SoC relationship, cycle life, calendar life etc., differ between manufacturers, research institutes, battery solution providers as well as geographic regions served. Such discrepancies result in the unnecessary repetition of tests done by various stakeholders with slightly different test procedures, resulting in added cost and testing time.

Hence, the following areas shall be standardized:
- Standard full charge and standard cycles have to be clearly defined.
- Application-specific remaining useful life (RUL) definition has to be done.
- The load cycles used for cycling, validation and estimation of battery performance, should be standardised such that they closely replicate the real-world load conditions of the application served.
- Test procedures to obtain cell data sheet parameters and tolerances in the estimated parameter values should be standardized.

#### *2.4.2.9 Functionality validation test procedures*

The test procedures followed to validate the BMS functionalities differ from standard to standard and region to region. Such differences result in the conduction of additional validation tests specific to a region or application. Hence application-specific unified BMS validation test procedures shall be developed with global participation from industries and standardizing organisations.

#### *2.4.2.10 Tamper proofing BMS*

Hardware and software of the BMS should be made tamper-proof. Standards shall be developed for making both BMS hardware and software tamper-proof as well as guidelines for detecting authorised access and guidelines for BMS access limitation between BMS manufacturers and users shall be clearly defined.

#### *2.4.2.11 Communication interfaces*

The protocols of a BMS which are used for both internal (within BMS modules) and external (with external systems) communication have to be deterministically standardized for various applications.

The aspects which should be standardized include:

- The type of protocol
- Priority assigning guidelines for functionalities
- Transmission rate
- Electromagnetic Interference (EMI) resistant data transfer guidelines
- Data encryption and cyber security measures for data transfer with external systems etc.

The internal, external and 2nd life communication interfaces present in a BMS application should be flexible and universal for easy interfacing with microcontrollers and other components used in the network, which are likely to come from different manufacturers.

1. Internal interfaces: Internal interfaces are essential communication channels between the central controller and measurement modules, which enable both transfer of data and control commands. Serial Peripheral Interface (SPI) or Inter-integrated Circuit ($I^2C$) interfaces are widely used and the communication lines need to be isolated from power lines in order to avoid electromagnetic interferences.
2. External interfaces: CAN interfaces are widely adopted and preferred for being highly universal, flexible, and it is easy to integrate components from different manufacturers. Presence of USB interfaces is highly recommended for diagnostics and external data logging purposes.
3. 2nd life interfaces: With the reuse of EV batteries in second life stationary applications gaining acceptance, suitable bridging mechanisms for the EV BMS have to be provided, to communicate with various subsystems that could be present in a 2nd life application.

#### *2.4.2.12 End of life definition*

In EVs, End of life (EOL) or RUL estimations are generally done based on its full range performance (capacity) or power capability (internal resistance). The reliability of such estimates highly depends on the driving behaviour, charging behaviour, ageing and operating ambient conditions of the EV.

Long term prognostics shall be implemented for estimation of the SoH or RUL of the battery pack, which, in addition to estimating its full-range performance, also estimates the performance required from it, to fulfil the user needs under the load cycle and its operating environmental conditions.

For example: Let us assume a scenario where a user owns an EV with 300 Km range at a full charge but has a daily driving distance of around 100 Kms and occasional long trips. The EV battery can deliver a range of around 240 Kms even after reaching its end of life. The criteria for defining end of life is specific to EV manufacturer. Here for illustration purpose, we assume that end of life is reached when pack capacity<= 80% of its initial value [6]. Provided that the cells in the pack are tested safe to be used further, the user can still cover his daily driving range and even his long-distance driving needs with the same battery pack, but with an increased number of charges. Hence, the EV battery needs not to be replaced, reducing both the cost of ownership for the user, as well as the warranty costs for the EV manufacturer.

#### *2.4.2.13 Identification of and repurposing for 2nd life applications*

Repurposing an EV battery pack into a 2nd life application is one of the promising ways of reducing the cost of ownership and also the environmental impact on dumping a functional battery. Hence,

- Future/further/possible potential applications have to be explored in addition to the well-known stationary storage application
- Application-specific requirements and standards have to be defined for the identified 2nd life utilizations
- Standardization of communication protocols for various sub-components of 2nd life applications
- Portability of EV BMSs to 2nd life applications along with the EV battery pack has to be analysed.

#### *2.4.2.14 Safety standards*

Conventional safety standards mostly view system failures as a result of a malfunction of just the individual components present within the system. With rapid advancements in battery technologies and application requirements, the role of the BMS software in improving system safety, performance and user experience are prominent and inevitable.

Hence, in addition to BMS hardware failures, malfunction of the BMS software functions should also be considered as a source of battery system failure and addressed in the safety standards.

#### *2.4.2.15 Open BMS platform*

Development and existence of a standardized open BMS architecture would provide an ideal platform for extensive participation and innovations, which in turn helps in reducing the BMS development time. Requirements and standards should be defined for the development of open, flexible BMS platforms.

## 2.5 COLLECTIVE BENEFITS OF BMS STANDARDIZATION

The standardization of Battery Management Systems would affect a whole range of collective benefits for manufacturers and users. The following chapter describes the most important aspects like cost, quality and usage benefits which, amongst others, can be found in Figure 2.

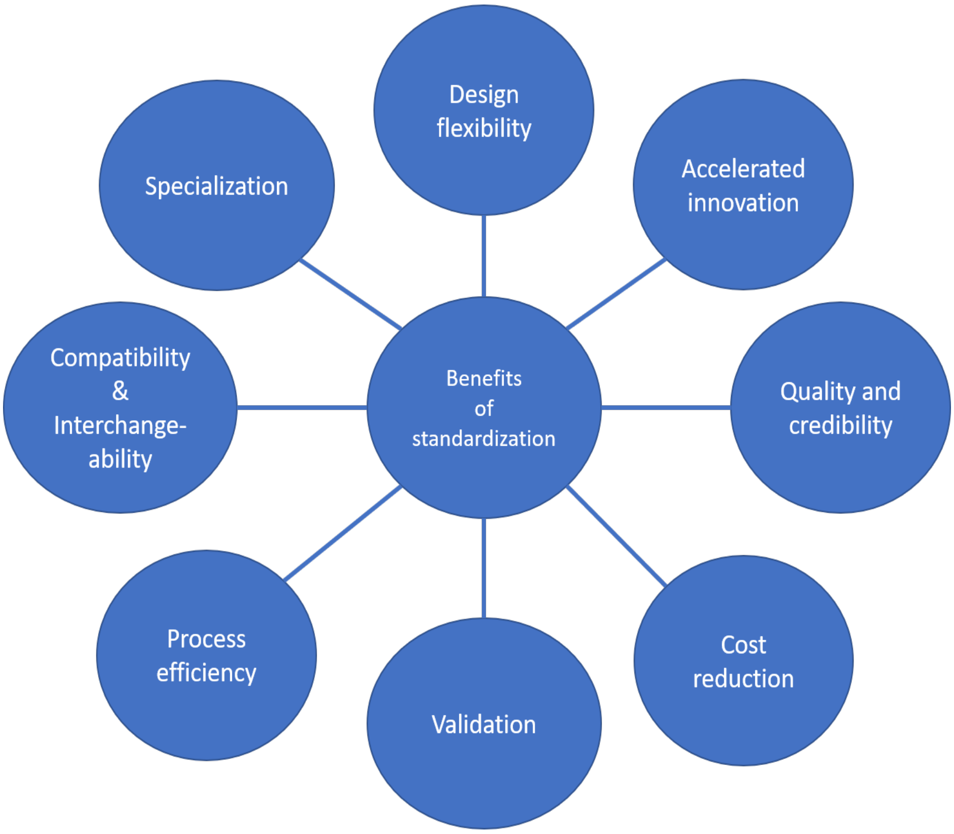

**Figure 2: Benefits of Standardization**

Further detailed sensitivity analysis and statistics of socio-economic impacts of BMS and battery system related standardization is presented in [4].

### 2.5.1 DESIGN FLEXIBILITY AND INNOVATION

Design-based standards might inhibit innovation due to design restrictions, but performance-based standards offer more flexibility in product design, still meeting the performance requirements. Standardization at component level enables broad participation from small and medium-sized companies in areas where they have expertise in. Allowing of more companies to work in parallel brings diversity of thoughts and can speed up the innovations.

### 2.5.2 R&D EFFICIENCY AND RELIABILITY

Standardized information (verified, evaluated and widely accepted publications, databases, terminologies etc.) for describing and standardised measurement and test methods for quantifying and evaluating product attributes are highly essential to replicate & verify the R&D results. This increases reliability, helps in attaining funding & speeds up the commitment of R&D to commercialization.

### 2.5.3 SPECIALIZATION AND DEVELOPMENT TIME

Standards mainly set the essential characteristics/quality levels a product should have. Such component/system standardizations encourage the manufacturers to develop standard compliant-products to maintain/increase their market share. Such basic set of characteristics/quality levels helps the competitors in specializing in it quickly rather than diverging away from the common framework. This highly reduces the development time and hence the cost of development.

### 2.5.4 QUALITY & CREDIBILITY

A standard sets the minimum level of performance/quality required from a product. Using that as a guideline, the competitors can pursue product development, assuring that the developed product conforms with the level of quality stated by the standard.

Standards can bring comparable metric for benchmarking functional features/performance of the product and such a product developed, manufactured and validated through standardized methods, turns out to be more reliable.

### 2.5.5 COST REDUCTION THROUGH COMPETITION

In cost-competitive markets, the contestants compete for the price of the product with the minimum set of features according to the standard. In cost-insensitive markets, products which include more features than stated by the standard are also produced.

Thus, standard reduces the product cost through competition and assures similar or better quality/ performance in comparison to benchmarks.

### 2.5.6 COST REDUCTION THROUGH RE-USABILITY

Standardization of a BMS system in terms of architecture, interfaces etc. can reduce the non-recurring engineering (R&D + validation) costs to a larger extent. It is because modification and future updates can be made upon the validated underlying architecture with minimal additional costs compared to developing it from scratch.

A standardized embedded system should enable re-usability of both its hardware and software platforms across applications. A family of standardized architectures sharing common features can comply across applications.

Adopting a comprehensive architecture to a  limited application might seem to increase the cost per unit of the low-end application product, but such an over-dimensioned system enables adaptability for future updates/additions with less effort.

### 2.5.7 COST REDUCTION THROUGH LEVERAGE

Standardization at component level increases the number of suppliers with products in compliance with the standard. This benefits the system manufactures through high possibilities of price bargaining. Such a distributed supply chain reduces the need for purchasing and storing components in bulk. This, in turn, reduces the cost of inventory. There is also less probability of failure of standardized components as they are developed and optimized to a great extent, which reduces the need for rigorous quality checking.

### 2.5.8 REDUCTION OF NON-RECURRING ENGINEERING COSTS

Standardization of the hardware architecture can reduce non-recurring engineering costs. Since the investment needed for the state-of-the-art electronic fabrications is also extremely high, upon standardization of the hardware architecture, the basic framework of the fabricated electronics remains the same. So, investment cost can be compensated by high production volumes. Modifications upon such fabrications according to application needs can be made without many additional costs.

### 2.5.9 COMPATIBILITY AND INTERCHANGEABILITY

Technical standards specify properties that a product/component/system/service should have, to work with other connected systems. Standardized interfaces between components of a system ensure their compatibility within a more extensive system.

Such interface standards don’t affect the design flexibility of components on either side of the interface, thus enabling the manufacturers to innovate and optimize such systems. Without those interface standards, modification/re-engineering of components from different suppliers would be required, to make them work together. The full functionality of the components might get affected because of lack of knowledge of the system from a competing supplier.

Such an effort on modification would contribute to increased development/optimization time and high prices to the consumer.

Having standard interfaces might also accommodate backward compatibility of the peripherals of a BMS system and reduce the wastage of material caused by incompatibility.

### 2.5.10 VALIDATION

The difference in validation methods results in increased time and cost for the validation of BMSs. This reflects in higher consumer prices and slow market penetration. Standardization of validation methods saves time and cost, resulting in quicker validation and easier benchmarking of comparable products in the market.

## SUMMARY

The definition and necessity of standardization have been addressed in this white paper, along with a list of organisations responsible for developing standards. Several standards relating to battery and EV applications were listed, and the gaps were identified and summarized. Bridging of such gaps can bring significant technological and cost-related benefits. Various aspects of BMSs which can be improved through standardization, were discussed. Finally, the positive impacts of standardization on both technical and economic grounds were highlighted. In conclusion, standardization of BMS can reduce the development time and cost into market significantly, facilitating its quicker market penetration through innovation and affordability.

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