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Sodium-Ion and sodium Metal Batteries for efficient and sustainable next-generation energy storage

GRANT AGREEMENT No. 963542

SODIUM-ION AND SODIUM METAL BATTERIES

SIMBA – Deliverable Report

<< D 1.2 – Regulations and Standards Review >>

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Publishable summary

The SIMBA project covers nearly all aspects regarding the sodium-ion technology, starting from material development to module assembly, including safety test and life cycle assessment (LCA). For handling and commercialization of the sodium-ion technology, it is essential to cover standardization aspects.

In a world of constantly changing technologies, norms and standards are not only a measure to make technologies safer, but they also provide manufacturers and researchers with a guideline on which they can base their handling of the new materials, thus steadily advancing the landscape of development and industrialization. In the sodium-ion technology considered here, the path is currently leading from prototype production to market maturity, and well-known manufacturers are announcing larger-scale production. Hence with the knowledge of project partners, it is mandatory to go deeper into this topic.

There is a long history of refinements in norms and standards regarding battery cells and battery systems. Standards are used for safety in transport, protection of the environment and to protect people in different applications.

The enormous increase in energy density and cycle life in lithium-ion technology led to a success story and to a variety of standards for transport, design, and application of the new technology. Figure 1 Overview on Standards and RegulationsThe content of this document is based on the project's definition and refers to sodium-ion batteries with liquid or solid electrolyte for stationary usage. So called "classic" sodium batteries that are usually operated at "high-temperatures" like Na-S or Na–$NiCl_2$ are neglected here, as they are already covered in standards.

Where appropriate, standards from the mobile sector are also used.

When looking at sodium-ion technology, it is noticeable that many materials are very similar to those used in the lithium-ion cell, e.g., the carbon-based anode, $Li(Na)PF_6$ as the basis of the electrolyte and Al as the material for the arresters. In addition, energy storage is via intercalation and deintercalation of ions, with lithium replaced here by sodium[1].

The materials for encapsulation and sealing are adopted from the lithium-ion technology, as are tools. One difference, however, is the voltage level, due to the approx. 0.3 V higher electrode potential of Na^+/Na vs. Li^+/Li as well as changed reaction kinetics.

Furthermore, with Sodium-Ion cells it is possible to use Al instead of Cu for the arrester of the anode. A dissolution of the Cu collector and thus the risk of dendrite formation and short circuit is not given. Sodium-Ion cells can be stored and transported at low charge states and even deep discharged which minimizes the risk. However, for each combination of anode / cathode / electrolyte / separator, a new assessment of the risk in case of e.g. overcharge and heating will have to be made.

Therefore, with the still low TRL level (2022) of Sodium-Ion technology and the associated lack of standardization documents, the report is based on the foundations of Li-ion technology. There is a rapid progress in Sodium-ion batteries, however standards and regulations have some delay in development and are just evolving with products that are available on the market. It is possible to classify the standards and regulations to classification, transportation, and safety standards.

They might also be divided into:

- Regulations that name sodium-ion batteries explicitly (e.g. "Agreement 6/2021 referring to sodium-ion batteries" and "Multilateral agreement M340" as amendments to RID and ADR).
- Regulations that are specific to e. g. stationary storage or covering general aspects regarding batteries and are agnostic to the battery technology (e.g. UL1973)
- Regulations that are basic for transportation and might be easy amended for stationary storage with sodium-ion batteries.
- Standards and regulations with the scope "lithium-ion batteries" in general. The process of cell manufacturing and production of storage is very similar and some contents regarding safety might be crucial in the future, depending on safety assessment results Most standards might be transferred to sodium-ion technology (e.g. IEC 62619).

The project team will track the development of the standardization process and will contact Standardization Organizations to facilitate the dissemination of sodium-ion technology. Details will depend on the results of safety assessments for different material combinations. Also, collaboration with standardization organizations worldwide, e.g. in China, are proposed to break up limitations in knowledge.

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1.1 Document structure

1.2 Deviations from original description in the Grant Agreement Annex 1 Part A

1.2.1 Descriptions of work related to deliverable in GA Annex 1 – Part A

T1.2 Regulations and Standards (Lead: FHG partners: Altris, SAFT, UBham) [M6-M42]

The regulations and standards for batteries are constantly being updated and changed. With the introduction of new technologies into the market, these will need to be monitored and updated. Work with the BSI and the Faraday Challenge by UBham will be expanded upon. Best practice documents for LIB and alternative battery manufacturing, will be monitored and changes suggested for integration of alternative sodium solid state batteries. The differences between the different technologies and the use cases will help to further influence the standards especially around transport for sodium ion batteries. This will be monitored by all companies and every 6 months the relevant contributions reported to the other partners.

Role partners: FHG supported by UBham will monitor and report on changes in EU regulation and standards.

1.2.2 Time deviations from original planning in GA Annex 1 – Part A

There is no time deviation to the original planning.

1.2.3 Content deviations from original plan in GA Annex 1 – Part A

There is no content deviation to the original planning.

2 Introduction

Many aspects are covered in the SIMBA project, starting from material development to module assembly, including safety test and life cycle assessment (LCA). For handling and commercialization of the sodium-ion technology, it is essential to cover standardization aspects.
In a world of constantly changing technologies, norms and standards are not only a measure to make technologies safer, but they also provide manufacturers and researchers with a guideline on which they can base their handling of the new materials, thus steadily advancing the landscape of development and industrialization. In the sodium-ion technology considered here, the path is currently leading from prototype production to market maturity, and well-known manufacturers are announcing larger-scale production. Hence with the knowledge of project partners, it is mandatory to go deeper into this topic.
Most batteries contain materials that are hazardous, flammable, or harmful. Electrical energy is stored by chemical processes. There have been safety hazards along the history of batteries and with each new technology there is a long history of refinements in norms and standards regarding battery cells and battery systems. Standards are used for safety in transport, protection of the environment and to protect people in different applications.
As an example, Lead Acid batteries might produce hydrogen as a spin-off product and so proper ventilation leads to a safe usage and the design of ventilation ducts was established in public standards.
A major step in the battery development was the invention and industrialization of lithium-ion batteries by Sony. The enormous increase in energy density and cycle life lead to a success story that is still ongoing. However, boosting a product that contains a flammable electrolyte and brings in the possibility of a so-called thermal runaway [1] brought with it the need to reassess the hazard situation and led to a variety of standards for transport, design, and application of the new technology. Figure 1 Overview on Standards and RegulationsFigure 1 gives an overview about the standards, their classification, and dependencies.

Figure 1 Overview on Standards and Regulations

3 Scope

The content of this document is based on the project's definition and refer to sodium-ion batteries with liquid or solid electrolyte for stationary usage. So called "classic" sodium batteries that are usually operated at "high-temperatures" like Na-S or Na–$NiCl_2$ are neglected here, as they are already covered in standards.

This is done in parallel with the world of lithium-ion batteries, in which the so-called lithium-metal battery is classified differently due to its modified mode of operation.

Additionally, this document is intended to give an overview of standards on stationary storage. Where appropriate, standards from the mobile sector are also used.

The history of standards development shows that disruptive innovations are rare, so that new standards are often based on proven existing standards and definitions. When looking at Sodium-Ion technology, for example, it is noticeable that many materials are very similar to those used in the lithium-ion cell, e.g., such as the use of graphite for the anode, $LiPF_6$ as the basis of the electrolyte and Al as the material for the arresters. In addition, energy storage is via intercalation and deintercalation of ions, with lithium replaced here by sodium. [2]

The materials for encapsulation and sealing are adopted from lithium-ion technology, as are tools.

One difference, however, is the voltage level, due to the approx. 0.3 V higher electrode potential of Na^+/Na vs. Li^+/Li as well as changed reaction kinetics.

Furthermore, with Sodium-Ion cells it is possible to use Al instead of Cu for the arrester of the anode. A dissolution of the Cu collector and thus the risk of dendrite formation and short circuit is not given.

Sodium-Ion cells can be stored and transported at low charge states and even deep discharged which minimizes the risk. However, for each combination of anode / cathode / electrolyte / separator, a new assessment of the risk in case of e.g. overcharge and heating will have to be made.

Therefore, with the still low TRL level (2022) of Sodium-Ion technology and the associated lack of standardization documents, it will be built on the foundations of Li-ion technology.

4 Terms, definitions and abbreviations

4.1 Terms and Definitions

For discussion about standards there are already a lot of definitions available that are applicable to sodium-ion batteries.

Term	Definition	Source
Cell	Basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy.	IEC 60050-482:2004, 482-01-01
Secondary Cell	Cell which is designed to be electrically recharged Note – The recharge is accomplished by way of a reversible chemical reaction.	IEC 60050-482:2004, 482-01-03
Alkaline cell	Cell containing an alkaline electrolyte	IEC 60050-482:2004, 482-01-08
(Cell) electrode	Electrode, electrically connected to one terminal of a cell, in electric contact with the electrolyte of that cell and on which the electrode reaction occurs Note 1 – For "electrode", see 151-13-01. Note 2 – The active material may be part of the electrode.	IEC 60050-482:2004, 482-02-21
Negative terminal	Accessible conductive part provided for the connection of an external electric circuit to the negative electrode of the cell	IEC 60050-482:2004, 482-02-24], 482-02-21
Positive terminal	Accessible conductive part provided for the connection of an external electric circuit to the positive electrode of the cell	IEC 60050-482:2004, 482-02-24
Anode	By convention, cell electrode at which an oxidation reaction occurs Note – The anode is the negative electrode during discharge and the positive electrode during charge.	IEC 60050-482:2004, 482-02-27
Cathode	By convention, cell electrode at which, a reduction reaction occurs Note – The cathode is the positive electrode during discharge and the negative electrode during charge.	IEC 60050-482:2004, 482-02-28
Active material	Material which reacts chemically to produce electric energy when the cell discharges Note – In secondary cells, the active material is restored to its original state during charge.	IEC 60050-482:2004, 482-02-33
Active material mix	Blend containing a material which reacts chemically to produce electrical energy with other constituents and additives	IEC 60050-482:2004, 482-02-34
Side reaction	Additional and unwanted reaction in a cell that causes charging inefficiencies and loss of capacity, service life or performance	IEC 60050-482:2004, 482-03-13
Rated capacity	Capacity value of a battery determined under specified conditions and declared by the manufacturer	IEC 60050-482:2004, 482-03-15
Nominal voltage	Suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system	IEC 60050-482:2004, 482-03-31
Venting	Release of excessive internal pressure from a cell, module, battery pack, or battery system in a manner intended by design to preclude rupture or explosion	
Thermal runaway	Unstable condition arising during constant voltage charge in which the rate of heat dissipation capability, causing a continuous temperature increase with resulting further charge current increase, which can lead to the destruction of the battery Note – In lithium batteries thermal runaway may cause melting of lithium.	IEC 60050-482:2004, 482-05-54
Cell block	Group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or PTC) and monitoring circuitry Note 1 to entry: It is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.	IEC 62619:2017, 7
Battery pack	Energy storage device, which is comprised of one or more cells or modules electrically connected Note 1 to entry: It has a monitoring circuitry which provides information (e.g. cell voltage) to a battery system. Note 2 to entry: It may incorporate a protective housing and be provided with terminals or other interconnection arrangement.	IEC 62619:2017, 8
Battery system	Battery system which comprises one or more cells, modules or battery packs Note 1 to entry: It has a battery management system to cut off in case of overcharge, overcurrent, overdischarge, and overheating.	IEC 62619:2017, 8

Term	Definition	Source
	Note 2 to entry: Overdischarge cut off is not mandatory if there is an agreement between the cell manufacturer and the customer. Note 3 to entry: The battery system may have cooling or heating units.	
Battery management system (BMS)	Electronic system associated with a battery which has functions to cut off in case of overcharge, overcurrent, overdischarge, and overheating Note 1 to entry: It monitors and/or manages its state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life. Note 2 to entry: Overdischarge cut off is not mandatory if there is an agreement between the cell manufacturer and the customer. Note 3 to entry: The function of the BMS can be assigned to the battery pack or to equipment that uses the battery. (See Figure 5) Note 4 to entry: The BMS can be divided and it can be found partially in the battery pack and partially on the equipment that uses the battery. (See Figure 5) Note 5 to entry: The BMS is sometimes also referred to as a BMU (battery management unit)	IEC 62619:2017, 8

5 Limitation to specific regions and applications

For reasons of practicability this document is limited to the most important business regions, especially Europe, the United States and other countries where ISO, UL and IEC standards are applicable. The scope of this document is stationary storage and focusses on the safe transport and usage of the batteries and cells.

6 Classification Criteria for batteries and battery materials

Classification of batteries and cells according to standards is usually done by material composition of the cell and battery, sometimes also the operating temperature serves as an indicator of the operating principle. This document refers to cells where sodium-ions serve as charge carrier, containing no metallic sodium and a non-aqueous electrolyte. The electrolyte may be either solid in a polymer form or liquid with a separator blocking the direct contact between anode and cathode.
It refers not to the so called “classic” sodium batteries that are usually operated at “high- temperatures like Na-S or Na–NiCl2 and that contain metallic sodium.

6.1 UN transport classification

The “Recommendation on the Transport of Dangerous Goods” consists of three parts:

- “Recommendation on the Transport of Dangerous Goods, Model regulations”
- “Recommendation on the Transport of Dangerous Goods, Manual of Tests and Criteria”
- “Globally Harmonized System of Classification and Labelling of Chemicals (GHS)”

This gives a way to globally classify and label substances and products to ensure proper packaging and ensure product safety. The labelling done in the UN transport classification is reflected in the subsequent chapters for the transport on road, rail, sea and air.
Until now, there is no direct classification for Sodium-Ion based cells and batteries in the UN Transport Classification.

6.2 Section 38.3 of the Manual of Tests and Criteria

However, for the technology most comparable, Li-Ion technology, in Part 3, Section 38.3 of the Manual of Tests and Criteria the requirements that apply to lithium-ion cells and batteries are addressed. It is crucial to have in mind that transport standards for road, air, street and rail refer to the UN transport classification, so specification and test regimes might be also extended to sodium-ion technology in the future **Error! Reference source not found.** gives an overview over the mandatory testing regime for lithium-ion cells according to UN 38.3 .
Subsequently two examples will be shown where this testing regimes will apply for Sodium-ion batteries.

6.3 IEC 62902: Secondary cells and batteries -marking symbols for identification of their chemistry

This standard specifies methods for clear identification of secondary cells, including battery modules and so called monoblocs. It is valid for devices exceeding 900cm³. However, sodium-ion batteries are not mentioned in the scope, but for recycling purposes and safe handling a knowledge of the chemistry is essential. Also, the details of the marking is defined in the document.
It contains lead-acid, nickel-cadmium, nickel-metal hydride, lithium-ion and lithium metal batteries.
It could be easily amended to integrate sodium-ion batteries.

6.4 Cell materials

Battery cells consist of a wide variety of materials. In cells that work according to the principle of intercalation and deintercalation, as in the sodium-ion battery, these are essentially anode and cathode for storing the ions and an electrolyte for transport. Anode and cathode are electrically separated by a separator. The active materials are deposited on aluminum or copper foils as current collectors. In the sodium-ion batteries considered here, both the cathode and the anode are deposited on aluminum foils; this allows cheaper production and avoids the problem of copper dissolution during deep discharges. The cathode, anode, electrolyte, and separator are housed in a metal or polymer casing depending on the cell format (cylindrical or pouch). Suitable electrical tabs are provided for electrical connections.

6.4.1 Anode

Various materials based on group 14 and 15 elements, and some transition metal oxides are being explored for high energy density anode materials for Sodium-Ion batteries. These materials are classed into three categories depending on their Na storage mechanism: (i) intercalation-type which typically includes carbonaceous materials and Ti-based oxide materials, (ii) alloy-type materials consisting of group 14 and 15 elements (P, As, Sb, Bi, Si, Ge, Sn and Pd) which can for binary alloys (Na_xM_y) with Na and (iii) conversion-type which includes oxides, sulphides, selenides, and phosphides of transition metals. The conversion reaction follows the equation M_aX_b + (b.z) Na ↔ a M + b Na_zX, where M is a metal, X is a non-metal, and z is the formal oxidation state of X. The materials undergoing insertion-type mechanism are limited by specific capacity and poor rate capability. However, alloy- or conversation-type materials have demonstrated enhancement in the specific discharge capacities. Although an enhancement in specific capacity has been achieved by going to alloy- or conversation-type materials, these materials are marred with the problem of large volume change during charge/discharge processes due to self-pulverization resulting in deterioration of the electrode material. Therefore, the quest for anode materials with superior electrochemical performance requires different approaches to mitigate the above shortcomings. Nano-engineering has proven as effective strategy to mitigate the above shortcomings. The additional potential benefits that it brings are reduced diffusion lengths for intercalating ion and improved electron percolation. The increased surface area and porosity helps with the wettability of the electrolyte, thereby increasing the rate capability. Moreover, hierarchical nanostructures such as core-shell or yolk-shell structures have proven beneficial in supressing not only volume change but also prevent nanoparticles' aggregation. [3] However, these kinds of materials negatively impact the volumetric energy density because of low tap density but the increased specific capacity due to alloying or multi-electron conversion processes negates this to some extent. Hence, nano-engineering, and nanostructured materials could be the way forward in achieving high specific capacity and high-rate NIB anode materials with long cycle life. Some of the key developments in this aspect have been outlined.

Table 1 Electrochemical performance of various anode materials in Na-half cells.

	Anode materials	Nanostructure	Components (A:B:C)	Electrolyte	Initial capacity (mAh/g)	Capacity remaining (%)	Ref
Alloying mechanism	Red P	Quantum dots	80:10:10 PVDF	1M $NaClO_4$ in EC/PC (1 : 1 v/v) and 10 % FEC	1161@200 mA/g	77% after 250 cycles	[4]
	Red P embedded in C nanofiber	Nanofiber	Free standing	1M $NaClO_4$ in PC and 5 % FEC	767@2000 mA/g	81% after 1000 cycles	[5]
	Graphene-P-Graphene	2D layered	Powder pressed on Cu mesh	1M $NaPF_6$ in EC/DEC (1:1 v/v)	1085@800 mA/g (2nd cycle)	93% after 350 cycles	[6]
	Sn embedded in C	Nanoparticles	70:15:15 CMC	1M $NaClO_4$ in EC/DEC (1:1 v/v)	420@1000 mA/g	99% after 500 cycles	[7]
	N-doped graphene caged MOF-derived SnSe	Nanoplate	70:10:20 CMC	1M $NaClO_4$ in EC/PC (1:1 v/v) and 5% FEC	570@200 mA/g	88% after 100 cycles	[8]
	Bi@C	Nanoplate	80:10:10 CMC	1M $NaClO_4$ in EC/DMC (1 : 1 v/v)	509@100 mA/g	39% after 200 cycles	[9]

	Anode materials	Nanostructure	Components (A:B:C)	Electrolyte	Initial capacity (mAh/g)	Capacity remaining (%)	Ref
				and 5 % FEC			
Conversion mechanism	MoS_2	Nanosheet	70:10:20 PVDF	1M $NaClO_4$ in EC/PC (1:1 v/v)	530@40 mA/g	73% after 100 cycles	[10]
	SnO_2@graphene	Nanoparticles	80:10:10 PVDF	1M $NaClO_4$ in EC/PC (1:1 v/v)	407@100 mA/g	66% after 100 cycles	[11]
	SnO	Nanosheets forming microsphere	70:10:20 PVDF	1M $NaClO_4$ in EC/PC (1:1 v/v)	525@20 mA/g (2^{nd} cycle)	77% after 50 cycles	[12]
	Fe_2O_3@rGO	Nanoparticles	80:10:10 PVDF	1M $NaClO_4$ in EC/PC (1:1 v/v)	389@50 mA/g	74% after 50 cycles	[13]
	$SbVO_4$	Nanoparticles	70:10:20 PAA	1M $NaClO_4$ in EC/PC (1 : 1 v/v) and 5% FEC.	386@200 mA/g	82% after 50 cycles	[15]
	Co_3O_4-rGO-Ni foam	Hierarchical porous array	Free standing	1M $NaPF_6$ in EC/PC (1:1 v/v) with FEC	780@100 mA/g	89% after 400 cycles	[16]
	SbO_x encapsulated in Carbon flakes	Nanoplate	70:15:15 CMC	1M $NaPF_6$ in EC/DEC (1:1 v/v) and 5 % FEC	441@100 mA/g	98% after 100 cycles	[17]
Intercalation	Carbon	Nanofiber	80:10:10 PVDF	1M $NaClO_4$ in EC/PC (1:1 v/v)	173@200 mA/g	97% after 200 cycles	[18]
	Carbon	Hollow nanofiber	80:10:10 PVDF	1M $NaClO_4$ in EC/EMC (1:1 v/v)	251@50 mA/g	82% after 400 cycles	[19]
	S-doped Carbon	3D scaffolding	70:10:20 PVDF	1M $NaClO_4$ in EC/DEC (1:1 v/v) and 5% FEC	220@5000 mA/g	96% after 2000 cycles	[20]

6.4.2 Cathode

According to [1] there is a lot of options for cathode materials. Most promising materials nowadays are transition-metal oxides and Prussian-blue analogs, e.g. Prussian white.

Table 2 based on (A) gives an overview on cathode materials used.

Table 2 Electrochemical performance of various cathode materials in Na-half cells

Cathode type	Structure	Category	Cathode material	Potential (V)	Discharge capacity ($mAhg^{-1}$)
Transition metal oxides	Cubic close-packed arrangement with 1D-, 2D- or 3D-type tunnels	P2-layered	$Na_{2/3}Mn_{1-y}Mg_yO_2$	1.5–4.0	140
		P2-layered	$Na_{2/3}[Mn_{2/3}Ni_{1/3}]O_2$	2.9–4.0	161
		O2-layered	$Na_{2/3}[Mn_{0.8}Ni_{0.2}]O_2$	2.0–4.3	162
		O3-layered	$Na_{0.78}Li_{0.18}Ni_{0.25}$ $Mn_{0.583}O_w$	1.5–4.5	240
		P2-layered	$Na_{2/3}[Mn_{0.72}Mg_{0.28}]O_2$	1.5–4.4	~180
		P2-layered	$Na_{2/3}Mn_{0.7}Zn_{0.3}O_2$	1.5–4.6	190
		P2-layered	$Na_{2/3}Mn_{0.8}Fe_{0.1}Ti_{0.1}O_2$	2.0–4.0	144.16
Transition metal fluorides	Weberite-type	Sodium metal fluorides	Na_2FeTiF_7	3.26	190
Polyanionic compounds	Olivine structure with rhombohedral R-3 symmetry	Phosphates and NASICON type	$NaFePO_4$ $Na_3V_2(PO_4)_3$ $Na_3V_2(PO_4)_2O_2F$	3 3.3 3.8	150 117 128
		Fluorophosphate	NASCITON-type $Na_3V_2(PO_4)_2F_3$	1.6–4.6	111
		Sulfates	$Na_2Fe_2(SO_4)_3$@C@GO	3.8	107.9
Prussian blue analogs	Face-centered cubic geometry and open-framework lattice	Binder free cathode - Fe-HCF NSs@GR	Sodium iron hexacyanoferrate (FeHCF)	2.0–4.2	110
		High-quality PB nanocrystals	$Na_{0.61}Fe[Fe(CN)_6]_{0.94}$	4.0–2.7	170
		Ferrocyanide	$Na_{1.92}Mn[Fe(CN)_6]_{0.98}$	3.34	105.7
		Poly (hexaazatrinaphthalene)	PHATN	1.0–3.5	Reversible capacity of 220

Cathode type		Structure	Category	Cathode material	Potential (V)	Discharge capacity ($mAhg^{-1}$)
			$C_6R_4O_2$ Molecules (R = F, Cl, Br)	Quione-derivative, $C_6Cl_4O_2$	~2.72 V vs. Na/ Na+	161

6.4.3 liquid electrolyte and solid electrolyte

The state-of-the-art liquid electrolyte for SIBs is a 1M solution of sodium hexafluorophosphate ($NaPF_6$) in a mixture of carbonate-based solvents such as ethylene carbonate (EC), dimethyl carbonate (DMC), and propylene carbonate (PC), similar to its lithium analogue.

For non-aqueous Sodium-Ion batteries a widely used electrolyte is a beyond state-of-the-art ion mobility, using novel SIPE to inhibit the mobility of the anion by incorporating it as part of the polymeric side chain ensuring exclusive mobility of the sodium ions. The use of the SIPE ensures a higher safety and low toxicity, due to the absence of fluorinated groups, thermal runaway events and elimination of dendrite formation pathways (no concentration gradients).

6.4.4 Other Materials

Materials for the production process not mentioned above are standard materials used in the production process of lithium-ion cells, e.g. separator, tabs, cans, sealing materials.
Materials used are the same as in the lithium-ion technology.

7 Cell manufacturing standards

There are no direct standards for the manufacturing process of cells, despite there are a lot of regulations regarding health, environmental and quality management.
To fill the Gap a PAS has been launched in 2021 by the British Standards Institution (BSI). By declaration on their website a PAS is a "fast-track standardization document – the result of an expert consulting service from BSI. It defines good practice for a product, service or process. It's a powerful way to establish the integrity of an innovation or approach."
The approach is comparable to the "Anwendungsregel (AR)" published by German DKE/ VDE to bring a fast standardization process on track which can be done in a timeframe of around a year with the option for the "Anwendungsregel (AR)" to serve as a base for an IEC standard.

7.1 PAS 7062:2021 Electric vehicle battery cells – Health and safety, environmental and quality management considerations in cell manufacturing and finished cell – Code of Practice

The PAS 7062 is a comprehensive document with the main scope on li-ion based cells and electric vehicles battery cells. However, there is an Annex A referring to alternative battery types.
It is common knowledge that a lot of manufacturers use the same battery cell type on the EV and the stationary battery market, so cell manufacturing is the same in this case.
The PAS7062:2021 could be easily amended to integrate technology steps that are unique to SIB to cover this future technology and stationary storage application.

8 Waste, recycling, and environmental protection

8.1 EU Battery directive

The EU Battery directive (Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020) is setting up standards in the following items:

- develop common specifications on: (i) performance and durability for non-rechargeable portable batteries; (ii) performance and durability for rechargeable industrial batteries; and (iii) for safety for stationary battery energy storage systems.
- support the development of harmonised calculation rules for: (i) the carbon footprint declaration (including the revision of the product environmental footprint category rules (PEFCR) for electric vehicle batteries and rechargeable industrial batteries); and (ii) the calculation of carbon footprint performance classes for electric vehicle batteries and rechargeable industrial batteries;
- support the development of harmonised calculation rules for: (i) recycled content in electric vehicle batteries and rechargeable industrial batteries; (ii) recycling efficiencies, (iii) recovered materials, and (iv) waste classification;
- draw up guidance on the removability and replaceability of portable batteries;
- set up an electronic information exchange system for submitting information related to electric vehicle batteries and rechargeable industrial batteries;
- develop green public procurement criteria on batteries;
- amend the list of waste in Commission Decision 2000/532/EC21;
- conduct a risk assessment on – and manage the risk of – substances used in batteries;

The EU directive is focusing on Lithium, nickel, cobalt and Cu as critical raw materials and mercury and cadmium as hazardous materials. For the first materials recycling quotes for the next years are proposed. Natural graphite is also classified as a critical raw material, however there are no suggestions for recycling rates.

Active cathode materials found in SIB are so far not concerned by the directive, however there are other implications for these types of batteries:

- Carbon footprint
- Collection rate
- Carbon footprint for industrial and EV batteries
- Performance and durability
- Provision of information (passport scheme)

The data for recycling rates is required for any battery technology on the market.

9 Safety standards for stationary storage

• The application guide VDE-AR-E 2510-50 specifies the safety requirements for stationary battery energy storage systems (BESS) with lithium batteries. This VDE AR-E 2510-50
application guide “Anwendungsregel” applies only for battery energy storage systems (BESS) with batteries based on Li-ion cells.

• VDE AR-E 2510-
This VDE application guide specifies the safety requirements for the planning, erection, operation, disassembly and disposal of stationary energy storage systems connected to the low voltage grid. Thus, it specifies those grid connection requirements to be fulfilled by installation companies which have not been specified in DIN EN 50272-2.

• IEC 62619
Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications.

This is one of the most important standards for stationary lithium-ion storage and the content has to be double-checked when safety issues of SIB are valid to transfer into a Sodium-Ion specific standard or to include this technology.

• UL 1973
Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications. This standard must be fulfilled agnostic to cell technology.

• IEC 62984-3:2020 specifies performance requirements and test procedures for high¬-temperature batteries based on sodium for mobile and/or stationary use and whose rated voltage does not exceed 1 500 V.02
This standard is related to high-temperature batteries and is referred here only for reference.
• UL9540A
The test methodology in this document evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway. The data generated will be used to determine the fire and explosion protection required for an installation of a battery energy storage system intended for installation, operation and maintenance in accordance with the International Fire Code (IFC), the Fire Code, NFPA 1, the National Electrical Code, NFPA 70, the National Electrical Safety Code (NESC), IEEE C2, other energy storage system codes, and the manufacturer's installation instructions.

The standard seems to be directed to li-ion batteries, however as the safety aspects of Sodium-Ion batteries are unclear this standard could not be neglected.

• UL2054
These requirements cover portable primary (non-rechargeable) and secondary (rechargeable) batteries for use as power sources in products. These batteries consist of either a single electrochemical cell or two or more cells connected in series, parallel, or both, that convert chemical energy into electrical energy by chemical reaction.

This standard is not applicable for stationary storage system and is listed for reference here.

Findings on safety standards:

The “AR-E 2510-50” and the “AR-E 2510-2” contain a lot of safety aspects along the chain from the Li-ion cell to the erection and the disassembly of stationary storage systems. They are more specific in some aspects than the IEC 62619 but the focus is limited to stationary storage.
The “2510-2” has a lot of aspects that are crucial to any storage technology, so this standard should apply or be transferred to each on coming technology. However, a transfer to Sodium-Ion batteries of the “AR-E 2510-50” and the IEC 62619 will strongly depend on the safety issues related to this technology.
If the result of a comprehensive safety analysis reveals an inertial safety of Sodium-Ion cells “AR-EE 2510-50” and IEC 62619 could not be considered as “crucial”.

The UL standards listed above are more aligned to the application rather than to the technology, so the UL 1973 and UL 9540A are important standards for stationary sodium-ion storage

10 Transportation standards

For safety reasons there are worldwide standards that cover the logistic chain of substances that might be harmful, explosive, flammable and radioactive. The content is similar but according to the transportation there are different standards for aviation, road, rail and maritime transport.

10.1 ADR

The ADR is the so called “Agreement Concerning the International
Carriage of Dangerous Goods by Road” with a distinct Territorial applicability.
ADR is an Agreement between States, and there is no overall enforcing authority.
States that negotiating the ADR cover whole Europe and surrounding countries (e.g. UK, Russia, Morocco, …) so to fullfill ADR restrictions is mandatory to be part in the western business world.
For transportation of sodium or sodium-related articles batteries there are only few findings in the document. They are listed as
“There are Substances which, in contact with water, emit flammable gases “
under the clause 3292 along with the packaging instruction P 408. However, this is related to high-temperature Sodium batteries and not to Sodium-ion batteries

3292	BATTERIES, CONTAINING SODIUM or
3292	CELLS, CONTAINING SODIUM
3543	ARTICLES CONTAINING A SUBSTANCE WHICH IN CONTACT WITH WATER EMITS FLAMMABLE GASES, N.O.S

Figure 2Excerpt from ADR; sodium cells and batteries

P408	PACKING INSTRUCTION	P408
This instruction applies to UN No. 3292.		
The following packagings are authorized, provided that the general provisions of **4.1.1** and **4.1.3** are met: (1) For cells: Drums (1A2, 1B2, 1N2, 1H2, 1D, 1G); Boxes (4A, 4B, 4N, 4C1, 4C2, 4D, 4F, 4G, 4H1, 4H2); Jerricans (3A2, 3B2, 3H2). There shall be sufficient cushioning material to prevent contact between cells and between cells and the internal surfaces of the outer packaging and to ensure that no dangerous movement of the cells within the outer packaging occurs in carriage. Packagings shall conform to the packing group II performance level. (2) Batteries may be carried unpacked or in protective enclosures (e.g. fully enclosed or wooden slatted crates). The terminals shall not support the weight of other batteries or materials packed with the batteries. Packagings need not meet the requirements of 4.1.1.3.		
Additional requirement: Cells and batteries shall be protected against short circuit and shall be isolated in such a manner as to prevent short circuits.		

Figure 3 Excerpt from ADR , packaging instruction for clause 3292

10.1.1 Multilateral Agreement M 340 referring to sodium-ion batteries

The Multilateral agreement M340 with the title

“under section 1.5.1 of ADR concerning the carriage of SODIUM-ION BATTERIES and SODIUM-ION CELLS USING AN ORGANIC ELECTROLYTE or SODIUM-ION BATTERIES and SODIUM-ION CELLS USING AN ORGANIC ELECTROLYTE CONTAINED IN EQUIPMENT or PACKED WITH EQUIPMENT”

describes the Integration of Sodium-Ion batteries in the existing structure of safety test according to UN 38.3 and the regulations for transport on street in the ADR.
It is declared that those Sodium-Ion Batteries and cells as described in 9.1.2 may be transported

• Similar to Lithium-Ion batteries like described in the ADR by just replacing Lithium-Ion with Sodium-Ion from the wording in special clauses and shipping those batteries without UN Number but marked with Number 9A and tunnel restriction code E. Precaution is that those batteries are tested according to UN 38.3 as described in the annex of multilateral agreement M340. There is also information on packaging.

• Without applying any provisions of ADR provided if cells are short-circuited and packaging instructions are followed and transport documents shall be marked with "Carriage in accordance with Multilateral Agreement M340 (7)".

10.2 RID railway

The Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) forms Appendix C to OTIF and has an annex. The Regulation applies to international traffic. OTIF stands for „Intergovernmental Organisation for International Carriage by Rail2".
The RID 2021 has the same scope as the ADR but is specific for railway transports.
RID is an Agreement between States, and there is no overall enforcing authority.
States that negotiating the ADR cover whole Europe and surrounding countries (e.g. UK, Russia, Morocco, …). However, it is crucial to face that there are states that are member of OTIF but are not member of the RID standard. The Scope of application of RID is depicted in Figure 2

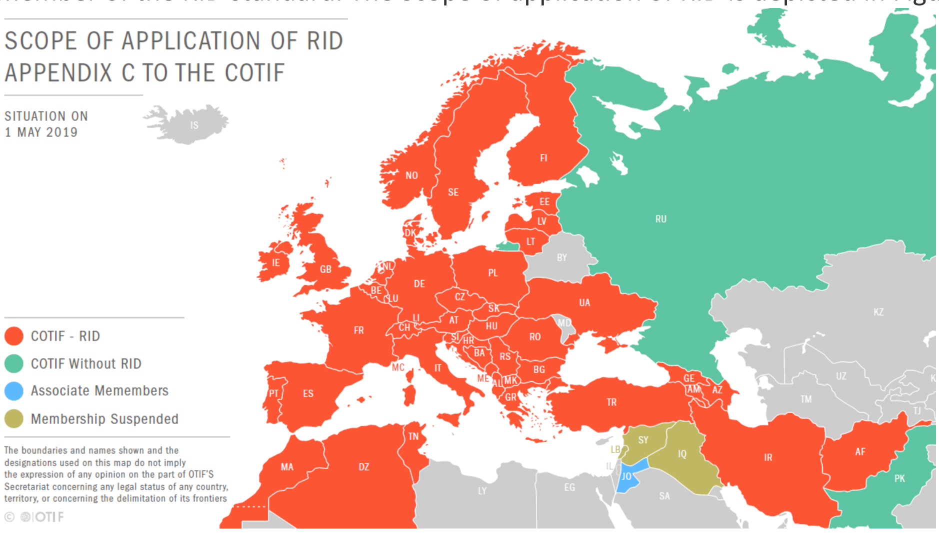

Figure 4 Scope of application of RID Appendix to the COTIF

10.2.1 Agreement 6/2021 referring to sodium-ion batteries

The "Agreement 6/2021 referring to sodium-ion batteries" with the title:

"under section 1.5.1 of RID concerning the carriage of SODIUM-ION BATTERIES and SODIUM-ION CELLS USING AN ORGANIC ELECTROLYTE or SODIUM-ION BATTERIES and SODIUM-ION CELLS USING AN ORGANIC ELECTROLYTE CONTAINED IN EQUIPMENT or PACKED WITH EQUIPMENT" describes the Integration of Sodium-Ion batteries in the existing structure of safety test according to UN 38.3 and the regulations for transport on rail in the RID.

The "Agreement 6/2021 referring to sodium-ion batteries" has the same content for the RID as the "Multilateral agreement M340" for road transport. References to UN numbers are exactly the same, and also section and subsection numbers of RID and ADR are the same. The only difference is that in the Agreement 6/2021 no Tunnel code for transportation is given.

10.3 IATA Dangerous Goods Regulations (DGR)

The IATA Dangerous Goods Regulations (DGR) manual is the global reference for shipping dangerous goods by air and the only standard recognized by airlines.
This regulation is the most rigid regulation compared to other transportation guidelines. As an example, the transport of lithium-ion batteries is generally forbidden in passenger aircrafts for safety reasons. Comparable to ADR up to now sodium-ion cells and batteries are not listed, but high temperature batteries as cell or battery containing sodium.

10.4 International Maritime Dangerous Goods Code (IMDG-Code)

The International Maritime Dangerous Goods Code (IMDG-Code) is the regulation for transport of dangerous goods in the maritime sector.
In the latest amendments on the IMDG (International Maritime Organization 2020) there are results on sodium and sodium batteries which refers to “high temperature batteries „ in this document, but so far, no findings for sodium-ion batteries.

11 Standardization Organisations

11.1 IEC

IEC, the International Electrotechnical Commission, is a nonprofit organization that develops and publishes standards. The headquarter of IEC is Geneva, Switzerland. It is a widely respected organization over 150 countries working on standards for electrical technologies. IEC plays the crucial role standardization rule by coordinating efforts carried out in different. It is the main organization for standardization in the western world.

11.2 DKE

DKE describes themselves as the “expertise centre for electrotechnical standardization in Germany”. The history of safety regulation is more than a hundred years old, and the organization, which is headed in Offenbach am Main (Germany) is picking up emerging technologies and is working with voluntary members from science and industry to guarantee the safety of electrical products and systems. DKE is a member of the IEC, of CENELEC and the ETSI (European Institute for telecommunication standards).

Depending on the maturity of the regarding technology and the urge to bring standards out, DKE decides to publish either “Anwendungsregeln”, which is the fastest way or to address directly the process of developing national or international IEC standards.

11.3 CENELEC

The European Committee for Electrotechnical Standardization (CENELEC) is also a private international non-profit organization. They describe the stakeholders working on European standardization on their webpage.

“A variety of stakeholders are involved in CEN and CENELEC work, amongst others business, industry and commerce, service providers, public authorities, regulators, academia and research centres, European trade associations and interest groups representing environmentalists, consumers, trade unions as well as small and medium enterprises, and other public and private institutions.”

They cooperate internationally with ISO and IEC.

11.4 JEITA

The Japan Electronics and Information Technology Industries Association (JEITA) is a Japanese organization for the standardization of electronic components and devices based in Chiyoda, Tokyo.

JEITA is an association of 527 electronic component and equipment manufacturers and was established in 2000.

It is based on the former organizations Development Association (JEIDA) and the Electronic Industries Association of Japan (EIAJ).

The purpose of the organization is described as follows.

“ (JEITA) is to promote the healthy manufacturing, international trade and consumption of electronics products and components in order to contribute to the overall development of the electronics and information technology (IT) industries, and thereby further Japan's economic development and cultural prosperity.”

11.5 BSI

BSI was founded in 1901 as the Engineering Standards Committee and is the national standards organization in the United Kingdom. BSI is also the publisher of British standards documents. BSI is headquartered in London, but now operates as a global organization with offices in 31 countries, developing standards but also evaluating processes and management systems. BSI supports companies on their way to process efficiency and sustainability. As a standardization institution, BSI can very efficiently launch standardization documents with its PAS, if required, to close gaps and

11.6 UL

Founded in 1894, Underwriters Laboratories (UL) is an independent organization that tests and certifies products for safety. The company is headquartered in Northbrook, Illinois. UL tests and certifies products for compliance with UL guidelines, which represent a quasi-standard. Typical of UL standards is that for a product to be certified to carry a UL Mark, the production process and conformance to the sample is also inspected on an unannounced regular basis. UL standards are often application-oriented in the battery sector and also include tests for mechanical properties and fire protection. UL certification is not legally established for the American market but is essential in practice for reasons of product liability and local regulations.

12 Conclusion

There is a rapid progress in Sodium-ion batteries, however standards and regulations have some delay in development and are just evolving with products that are available on the market. It is possible to classify the standards and regulations to classification, transportation, and safety standards generally. They might also be divided into:

- Regulations that name sodium-ion batteries explicitly (e.g "Agreement 6/2021 referring to sodium-ion batteries" and "Multilateral agreement M340" as amendments to RID and ADR)
- Regulations that are specific to e. g. stationary storage or covering general aspects regarding batteries and are agnostic to the battery technology (e.g. UL1973)
- Regulations that are basic for transportation and might be easy amended for stationary storage with sodium-ion batteries.
- Standards and regulations with the scope "lithium-ion batteries" in general. The process of cell manufacturing and production of storage is very similar and some contents regarding safety might be crucial in the, depending on safety assessment results Most standards might be transferred to Sodium-Ion technology (e.g. IEC 62619).

Table 3 gives an overview on standards and regulations regarding sodium-ion batteries and the need for adaption to this technology.

Table 3 Essential standards regarding sodium-ion technology

Standard	Intended for Sodium.Ion batteries	Applicable to Sodium-Ion batteries	Adaption / Integration of sodium-ion batteries in the relevant standard
IEC 60050-482	-	+	No adaption needed
IEC 62619:	-	-	Adaption depends on safety assessment
IEC62902	-	-	Adaption to sodium-ion batteries useful
UN Manual of test and criteria	-		Adaption depends on safety assessment
PAS 7062:2021	-	-	Extension to stationary storage and sodium-ion technology
EU Battery directive	-	+	Adaption depending on use of hazardous or raw materials
VDE-AR-E 2510-50	-	-	Adaption depends on safety assessment
VDE AR-E 2510-2	-	+	Agnostic to cell technology
UL9540A	-	+	Agnostic to cell technology
ADR	-	+	Agnostic to cell technology
Multilateral agreement M340	+	+	Adaption depends on safety assessment
RID	-	+	Agnostic to cell technology
Agreement 6/2021 referring to sodium-ion batteries	+	+	Adaption depends on safety assessment
IATA Dangerous Goods Regulations	-	+	Adaption depends on safety assessment

It is recommended to contact Standardization Organizations to track the development of the standardization process and facilitate the dissemination of sodium-ion technology. Details will depend on the results of safety assessments for different material combinations. Also, collaboration with standardization organizations e.g. in China are proposed to break up limitations in knowledge.

13 Risk Register

Risk No.	What is the risk	Probability of risk occurrence[1]	Effect of risk[2]	Solutions to overcome the risk
WP1.2	Describe the risks here!! And please refer to the section of the text in the document dealing with this.	Indicate the level	Indicate the level	Give a description how to overcome the risk / describe give possible solution(s)
1	Manufacturer might hold back information on material properties essential for standardization	3	3	Wide-ranging discussion with a variety of manufacturers and manufacturers' associations to gain in-depth expertise
2	Withholding of knowledge by organizations to delineate markets for economic reasons	3	3	Worldwide discussions with associations and trade organizations to clarify the importance of the topic and to convince all standardization organizations

[1] Probability risk will occur: 1 = high, 2 = medium, 3 = Low
[2] Effect when risk occurs: 1 = high, 2 = medium, 3 = Low

14 References

1 C. Mikolajczak, M. Kahn, K. White, R.T. Long, The fire protection research foundation (2011) 1–126.
2 D. Karabelli, S. Singh, S. Kiemel, J. Koller, A. Konarov, F. Stubhan, R. Miehe, M. Weeber, Z. Bakenov, K.P. Birke, Front. Energy Res. 8 (2020). https://doi.org/10.3389/fenrg.2020.605129.
3 I. Hasa, J. Hassoun and S. Passerini, *Nano Res.*, 2017, **10**, 3942–3969.
4 G. Zeng, X. Hu, B. Zhou, J. Chen, C. Cao and Z. Wen, *Nanoscale*, 2017, **9**, 14722–14729.
5 Y. Liu, N. Zhang, X. Liu, C. Chen, L. Z. Fan and L. Jiao, *Energy Storage Mater.*, 2017, **9**, 170–178.
6 C. Zhang, X. Wang, Q. Liang, X. Liu, Q. Weng, J. Liu, Y. Yang, Z. Dai, K. Ding, Y. Bando, J. Tang and D. Golberg, *Nano Lett.*, 2016, **16**, 2054–2060.
7 Y. Liu, N. Zhang, L. Jiao, Z. Tao and J. Chen, *Adv. Funct. Mater.*, 2015, **25**, 214–220.
8 C. Lu, Z. Li, Z. Xia, H. Ci, J. Cai, Y. Song, L. Yu, W. Yin, S. Dou, J. Sun and Z. Liu, *Nano Res.*, 2019, **12**, 3051–3058.
9 J. Xiang, Z. Liu and T. Song, *ChemistrySelect*, 2018, **3**, 8973–8979.
10 D. Su, S. Dou and G. Wang, *Adv. Energy Mater.*, 2015, **5**, 1–6.
11 S. Li, Y. Wang, J. Qiu, M. Ling, H. Wang, W. Martens and S. Zhang, *RSC Adv.*, 2014, **4**, 50148–50152.
12 D. Su, X. Xie and G. Wang, *Chem. - A Eur. J.*, 2014, **20**, 3192–3197.
13 X. Liu, T. Chen, H. Chu, L. Niu, Z. Sun, L. Pan and C. Q. Sun, *Electrochim. Acta*, 2015, **166**, 12–16.
14 Q. Peng, X. Hu, T. Zeng, B. Shang, M. Mao, X. Jiao and G. Xi, *Chem. Eng. J.*, 2020, **385**, 123857.
15 H. Yang, P. Wang, J. Zhang, L. Zhang and J. Yan, *Ionics (Kiel).*, , DOI:10.1007/s11581-019-03308-7.
16 K. Wu, B. Geng, C. Zhang, W. Shen, D. Yang, Z. Li, Z. Yang and D. Pan, *J. Alloys Compd.*, 2020, **820**, 153296.
17 W. Li, K. Wang, S. Cheng and K. Jiang, *J. Mater. Chem. A*, 2017, **5**, 1160–1167.
18 T. Chen, Y. Liu, L. Pan, T. Lu, Y. Yao, Z. Sun, D. H. C. Chua and Q. Chen, *J. Mater. Chem. A*, 2014, **2**, 4117–4121.
19 Y. Cao, L. Xiao, M. L. Sushko, W. Wang, B. Schwenzer, J. Xiao, Z. Nie, L. V. Saraf, Z. Yang and J. Liu, *Nano Lett.*, , DOI:10.1021/nl3016957.
20 G. Zhao, D. Yu, H. Zhang, F. Sun, J. Li, L. Zhu, L. Sun, M. Yu, F. Besenbacher and Y. Sun, *Nano Energy*, 2020, **67**, 104219.
21 D. Sun, G. Zhang, D. Li, S. Liu, X. Jia and J. Zhou, *Sustain. Energy Fuels*, 2019, **3**, 3163–3171.
22 C. G. Hawkins and L. Whittaker-Brooks, *J. Mater. Chem. A*, 2018, **6**, 21949–21960.
23 K. H. Nam and C. M. Park, *J. Power Sources*, 2019, **433**, 126639.
24 Z. Li, L. Zhang, X. Ge, C. Li, S. Dong, C. Wang and L. Yin, *Nano Energy*, 2017, **32**, 494–502.

15 Appendix A - Table of Abbreviations

Symbol / Shortname	
IMDG	International Maritime Dangerous Goods
IATA	International Air Transport Association
SIB	Sodium-Ion Battery
ADR	Accord européen relatif au transport international des marchandises Dangereuses par Route
BMS	Battery Management System
IEC	International Electrotechnical Commission
DKE	Deutsche Kommission Elektrotechnik
VDE	Verband der Elektrotechnik Elektronik Informationstechnik e. V.
GHS	Globally Harmonised System
DGR	Dangerous Goods Regulation
IATA	International Maritime Dangerous Goods Code
BSI	British Standards Institution
UL	Underwriter Labs
CENELEC	Comité Européen de Normalisation
JEITA	Japan Electronics and Information Technology Industries Association
BESS	Battery Energy Storage System
PAS	Publicly Available Specification
IFC	International fire Code
LCA	Life Cycle Assessement
IEEE	Institute of Electrical and Electronics Engineers
COTIF	Convention concerning International Carriage by Rail
NFRA	Nationwide Fire Risk Assessement
ISO	International Organization for Standardization
PTC	Positive Temperature Coefficient Thermistor
AR	Anwendungsregel

16 Appendix B- Acknowledgement

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Project partners:

#	Partner	Partner Full Name
1	TUDa	TECHNISCHE UNIVERSITAT DARMSTADT
2	UU	UPPSALA UNIVERSITET
3	UBham	THE UNIVERSITY OF BIRMINGHAM
4	WMG	THE UNIVERSITY OF WARWICK
5	KIT	KARLSRUHER INSTITUT FUER TECHNOLOGIE
6	CEA	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
7	IFE	INSTITUTT FOR ENERGITEKNIKK
8	SAS	USTAV ANORGANICKEJ CHEMIE SLOVENSKA AKADEMIA VIED (Institute of Inorganic Chemistry, Slovak Academy of Sciences)
9	FHG	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
10	JM	JOHNSON MATTHEY PLC
11	Elkem	ELKEM AS
12	YUN	YUNASKO-UKRAINE LLC
13	SAFT	SAFT
14	Altris	ALTRIS AB
15	Recupyl	TES RECUPYL SAS
	UNR	UNIRESEARCH BV

Appendix D – Disclaimer/Acknowledgement

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Appendix E Quality Assurance

The following questions should be answered by all reviewers (WP Leader, peer reviewer 1, peer reviewer 2 and the technical coordinator) as part of the Quality Assurance Procedure. Questions answered with NO should be motivated. The author will then make an updated version of the Deliverable. When all reviewers have answered all questions with YES, only then the Deliverable can be submitted to the EC.
NOTE: For public documents this Quality Assurance part will be removed before publication.

Question	WP Leader	Peer reviewer 2	Technical Coordinator
	Stephan Lux	Ivana Hasa	Dr. Prof. Ralf Riedel
Do you accept this deliverable as it is?	Yes	Yes	Yes
Is the deliverable completely ready (or are any changes required)?	Yes	Yes	Yes
Does this deliverable correspond to the DoW?	Yes	Yes	Yes
Is the Deliverable in line with the SIMBA objectives?	Yes	Yes	Yes
WP Objectives?	Yes	Yes	Yes
Task Objectives?	Yes	Yes	Yes
Is the technical quality sufficient?	Yes	Yes	Yes