LOLABAT

“LOng LAsting BATtery”

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D2.3: Guidelines on regulatory aspects for NiZn batteries

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Table of content

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V0	May 2021	AITEC	Table of contents and initial inputs regarding legislative table applied to the different life cycle stages of the battery
V1.1	July 2021	BCARE	Contributions to manufacturing and use battery stages
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Abstract

Context and objectives of the deliverable

This deliverable is the third deliverable of WP2 “Specification of requirements, norms and standards for the next generation of stationary batteries” and is part of the Task 2.2. “Assessment of norms and standards for NiZn”. The aim of this deliverable is to develop a guideline about regulatory aspects affecting NiZn batteries. With this purpose regulatory issues affecting NiZn battery energy storage technology during its whole life cycle, have been analysed, identifying at the same time main differences with regulations applying to other electrochemical battery technologies. This deliverable together with D2.2. “EU and national standards for NiZn batteries” define the regulatory and standardisation framework that will apply to NiZn batteries as well as the identification of regulatory gaps or areas of improvement.

Content of the deliverable

Within this deliverable the reader will find information about the regulations that apply during the whole life cycle of storage batteries. First, in section 1, a brief introduction explains the importance of batteries in current society and in the development of a sustainable economy and the need to develop this legislation guideline. In section 2, key concepts have been defined indicating the different battery chemistries considered in the analysis as well as the definition of the life stages analysed and their scope. Section 3 defines the main objectives of this document. Next section, section 4, deals with the regulations that apply in each life stage within the scope defined (i.e. international, national, regional) and focusing on those aspects that apply to the battery chemistries selected (i.e. nickel zinc, nickel cadmium, lithium-ion, lead acid, redox flow batteries, sodium batteries, nickel metal hydride, lithium metal polymer). Section 5 makes a summary indicating the main regulations applying in each life stage. Section 6 makes some suggestions of improvement based on the regulatory gaps found. Finally, section 7 highlights the main conclusions.

Attainment of the objectives and if applicable, explanation of deviations

The objectives of the deliverable and of the related task within LOLABAT project (T2.2.) have been achieved as planned.

Glossary

Abbreviation	Description
AC	Alternating current
ADN	Accord Européen relatif au transport international des marchandises Dangereuses par voies de Navigation intérieures // European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
ADR	Accord Dangereux Routier. European regulations concerning the international transport of dangerous goods by road
BMS	Battery Management System

β-Al_2O_3	Beta-alumina
$C_3H_6O_3S$	1,3-propanesultone or 1,2-oxathiolane, 2,2-dioxide
CAS	Chemical Abstracts Service
Cd	Cadmium
CE	Conformité Européenne
CLP	Classification, Labelling & Packaging
COTIF	Convention relative aux transports internationaux ferroviaires // Convention concerning International Carriage by Rail
CSCL	Chemical Substance Control Law
DC	Direct current
DGR	Dangerous Goods Regulations
DRC	Democratic Republic of Congo
EC	European Commission
EU	European Union
ECHA	European Chemicals Agency
EEE	Electrical and electronic equipment
EES	Electrical Energy Storage
EGDME	Ethylene glycol dimethyl ether
EIP	European Innovation Partnership
EMC	Electromagnetic Compatibility
EmS	Emergency sheets
EoL	End-of-Life
ESS	Energy Storage System
EU	European Union
EVs	Electric Vehicles
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GPS	General Product Safety (directive)
H_2O	Dihydrogen monoxide// Water.
H_2SO_4	Sulphuric acid
HEVs	Hybrid electric vehicles
IATA	International Air Transport Association
IEC	International Electrotechnical Commission
IMDG	International Maritime Dangerous Goods
ISHL	Industrial Safety and Health Law
IT	Information Technology
JORF	Journal official de la République française
KOH	Potassium hydroxide
LCO	Lithium cobalt oxide
Li	Lithium
$Li_4Ti_5O_{12}$	Lithium titanate
LIB	Lithium-ion battery
$LiFePo_4$	Lithium-iron-phosphate
$LiMn_2O_4$	Lithium manganese oxide
LMP	Lithium metal polymer

$LiNiCoAlO_2$	Lithium-nickel-cobalt-aluminium oxide
LTO	Lithium titanate (Li4Ti5O12) li-ion battery
LVD	Low Voltage Directive
MHLW	Ministry of Health, Labour and Welfare
Na	Sodium
$NaAlCl_4$	Sodium chloroaluminate // Sodium tetrachloroaluminate
NaCl	Sodium chloride
$NaNiCl_2$	Sodium-nickel-chloride
NaS	Sodium sulfur
NCA	Lithium-nickel-cobalt-aluminium battery
Ni	Nickel
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hydride
NiZn	Nickel Zinc
NMC	Nickel-manganese-cobalt
Pb	Lead
PbA	Lead acid
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PSNs	Proper Shipping Names
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RID	Règlement concernant le transport International ferroviaire des marchandises Dangereuses // Regulations concerning the International Carriage of Dangerous Goods by Rail
RNZB	Rechargeable Nickel Zinc Battery
RoHS	Restriction of Hazardous Substance
RQ	Reportable Quantity
SVHC	Substances of Very High Concern
UN	United Nations
vPvB	very persistent and very bio-accumulative
VRB	Vanadium redox flow batteries
WEEE	Waste from electrical and electronic equipment
Zn	Zinc
ZnO	Zinc oxide

Deliverable content

1 Introduction

Regulations are needed in order to safeguard the interests of the different businesses and of the community, and in order to protect people from safety and security issues that they cannot prevent on their own. Business models and needs evolve with time and regulations should be revised regularly and create new ones when needed.

In terms of batteries, many efforts are being developed in research for the development of new batteries that can help in the development of a more sustainable society. Batteries are seen to have a very important role in the development of a zero-emission mobility and in the use with renewable energy sources for the storage of intermittent energy, being very important for the EU in order to reach their objectives to achieve a climate neutral economy (Halleux, 2021). It is expected that the global battery demand will increase 14-fold by 2030 (Halleux, 2021). The European Commission is working on the development of proposals to modernise EU legislation on batteries considering improvements in batteries for a circular and climate neutral economy. Since 2006, batteries have been regulated by Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators. New technological developments, battery uses, markets and socioeconomic conditions highlight the need to update and modernise current battery regulatory framework (European Commission, 2020).

Therefore, development of guidelines that indicate what is currently covered in existing regulations, and what needs to be improved for the new developing technologies, new arising use cases and market opportunities for batteries, gains special importance as one piece of the solution to progress to a sustainable and climate neutral society.

LOLABAT project is focused on the development of a new promising battery chemistry, Rechargeable Nickel Zinc Battery (RNZB) for stationary energy storage applications. Being a new chemistry, RNZB needs to be covered by the batteries' regulatory framework to be able to enter the battery market. The aim of this document is to analyse current regulatory battery framework focused on nickel zinc batteries and also compared with other electrochemical batteries that are in the market. The types of electrochemical batteries selected for this regulatory analysis were based on the database from the EU Open Data Portal (Directorate-General for Energy, 2020), and include: Nickel Zinc (NiZn), Nickel Cadmium (NiCd), Lithium-ion (Li-ion), Lead acid (PbA), Redox flow batteries (ZnFe, V, ZnBr), Sodium batteries (NaS, NaNiCl), Nickel metal hydride (NiMH) and Lithium metal polymer (Directorate-General for Energy, 2020).

In order to do the comparison of regulations applying to the different electrochemical batteries, they have been differentiated according to the different life cycle stages (raw materials, manufacturing, storage, transport, use, and end of life) since different stages have different legal needs. In addition, the differentiation into stages could help define regulations affecting the definition of costs and environmental impact in WP5 (Environmental and cost analysis).

2 Key concepts definition

Section 4 indicates the different legislations applying to the different electrochemical batteries. This section has been structured considering the different stages of the life cycle of the batteries, as well as the main electrochemical chemistries used for storage purposes. Main electrochemical chemistries used and life cycle stages are defined within this section.

2.1 Electrochemical batteries' chemistries analysed

The types of electrochemical batteries selected for this regulatory analysis were based on the database from the EU Open Data Portal (Directorate-General for Energy, 2020), and include:

- ***Nickel Zinc***: composed of a zinc anode containing a zinc paste made of metal zinc, zinc oxide, additives and adhesives and a current collector made of copper foam or expanded material. The nickel cathode is made of an active paste containing nickel oxy-hydroxide, nickel metal, additives and adhesives, and a nickel foam current collector; and uses an aqueous solution of mainly potassium hydroxide & zinc oxide as electrolyte. NiZn uses an aqueous electrolyte, thanks to which, it has none of the safety issues associated with Li-ion, which uses an organic electrolyte subject to fire and explosion. This emerging technology has shown (Squiller & Brody, 2011) to have significant advantages over other battery chemistries regarding energy and power density, cost, safety, toxicity and recyclability. A comparison with other technologies focusing on the specific energy and the depth of discharge is presented Figure 1. NiZn contains no lead, cadmium, mercury or other toxic heavy metals, is nontoxic and non-combustible, and is easily recyclable (Squiller & Brody, 2011). Figure 2 shows a prismatic NiZn battery formed by one nickel cathode and two zinc anodes.

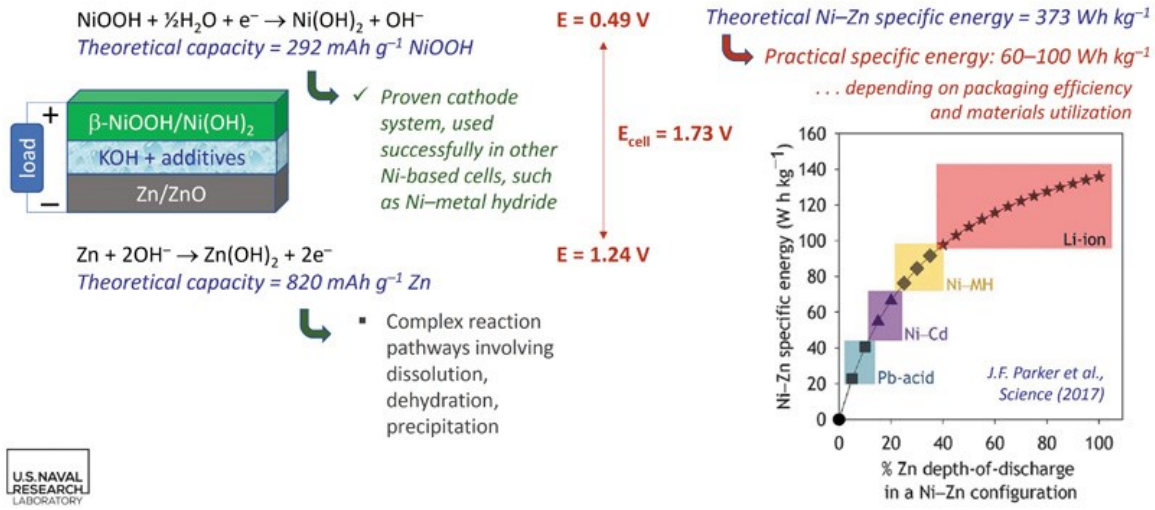


Figure 1. Comparison of nickel-zinc chemistry with established electrochemical couples as a function of depth-of-discharge (DoD). Reproduced from http://www.bestmag.co.uk/content/it%E2%80%99s-time-zinc-swim

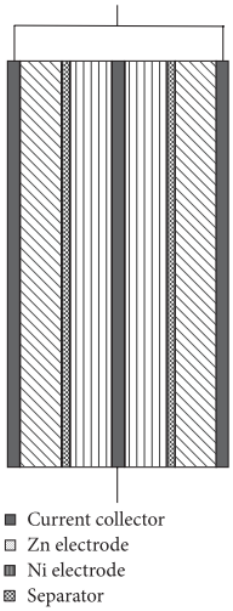


Figure 2. Prismatic NiZn battery with one Ni electrode and two Zn electrodes. Reproduced from (Payer & Ebil, 2016).

- ***Nickel Cadmium***: The components of the battery are a cathode comprised of nickel oxy-hydroxide on a nickel foam, graphite or iron substrate, an anode made of metallic cadmium pressed onto a nickel wire mesh, and potassium hydroxide (KOH) electrolyte (Sullivan & Gaines, 2012). The nickel–cadmium battery presents interesting options for traction purposes: a specific energy nearly twice as high as the lead–acid batteries (50Whkg^{-1} compared to 30Whkg^{-1}), availability of fast charging, good specific power (batteries can be designed specifically for high-power applications) and a good cycle life. Nickel–cadmium batteries equip most of the electric road vehicles manufactured and used in Europe. However, there are environmental concerns about the presence of cadmium (Van den Bossche et al., 2006).

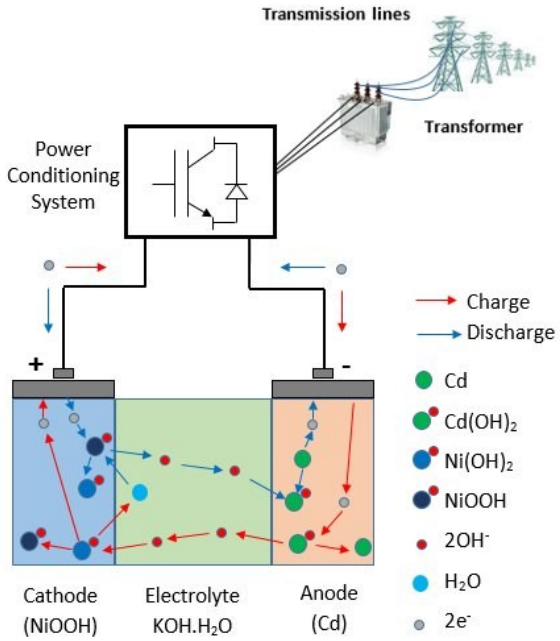


Figure 3. Schematic representation of a nickel cadmium battery. Reproduced from (Poullikkas & Nikolaidis, 2017)

- ***Lithium-ion***: The negative electrode is based on carbon and can be made of graphite or hard carbon, while the positive electrode containing lithium and a host material. Common positive electrode materials are lithium-containing transition metal oxides where the metal is Co, Ni, Fe or Mn. The electrolyte in lithium-ion batteries is a lithium salt solved in an organic solvent. A general representation can be seen in Figure 4. A lithium-ion battery cell has usually a single cell voltage of around 3.6 V, which depends on the battery's chemistry. However, there are many different types of lithium-ion batteries. Some of the most common chemistries (Sundén, 2019) are: LCO (using lithium cobalt oxide as cathode material), see Figure 5; LMO (using lithium manganese oxide as cathode material); NMC (using nickel-manganese-cobalt as cathode material); NCA (using lithium-nickel-cobalt-aluminium oxide as cathode material); LTO (using lithium titanium oxide as anode material and/or LMO or NMC as cathode material); LFP (using lithium-iron-phosphate as cathode material).
  Lithium-ion batteries are the fastest growing technologies on the market with growth expectations of more than 30% per year. Cobalt, lithium and natural graphite, used in these batteries, are considered as critical raw materials (Halleux, 2021). Regarding the end-of-life handling of these batteries, the collection rate is low and their recycling is technologically challenging and costly. Today, almost no lithium is recovered in the EU, since it costs more to recover it from recycling than obtaining it directly as raw material (Halleux, 2021).

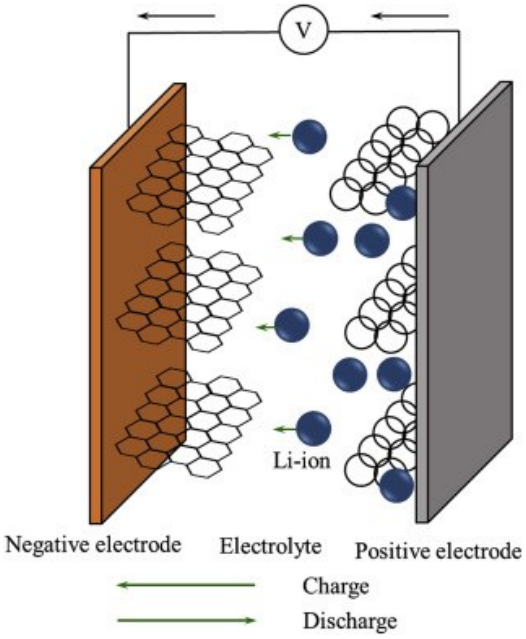


Figure 4. General scheme of a Li-ion battery (Sundén, 2019).

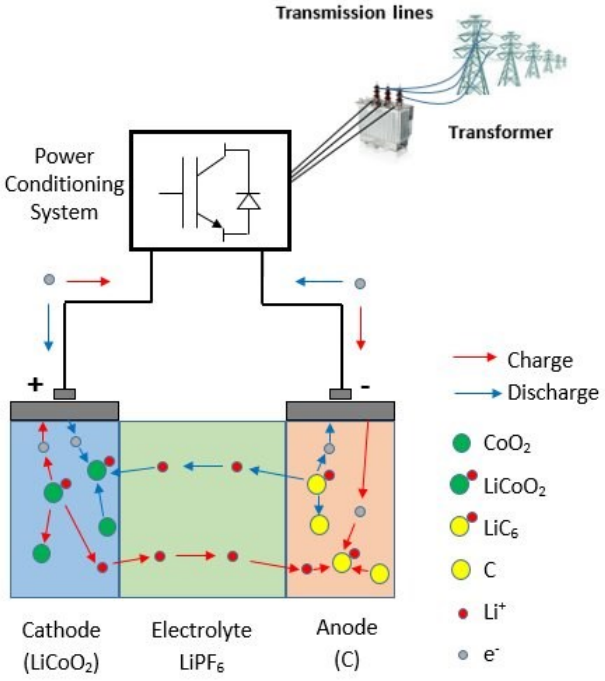


Figure 5. Schematic representation of an LCO battery (Poullikkas & Nikolaidis, 2017)

- ***Lead acid***: this type of battery was invented in 1859, being the oldest type of rechargeable battery. It is considered as one of the best batteries for stationary applications, as it can supply excellent pulsed power (Poullikkas & Nikolaidis, 2017). The cathode is made of lead peroxide on a lead lattice, and the anode of a sponge lead on a lead lattice, while the electrolyte is a solution of sulphuric acid (H_2O + H_2SO_4). The schematic representation of the lead acid battery can be seen in Figure 6.
  In 2018, lead-acid batteries provided 72% of global rechargeable battery capacity and were used mainly in automotive applications, mobile industrial applications and stationary power storage. The antimony is a critical raw material used in the lead acid battery (Halleux, 2021).

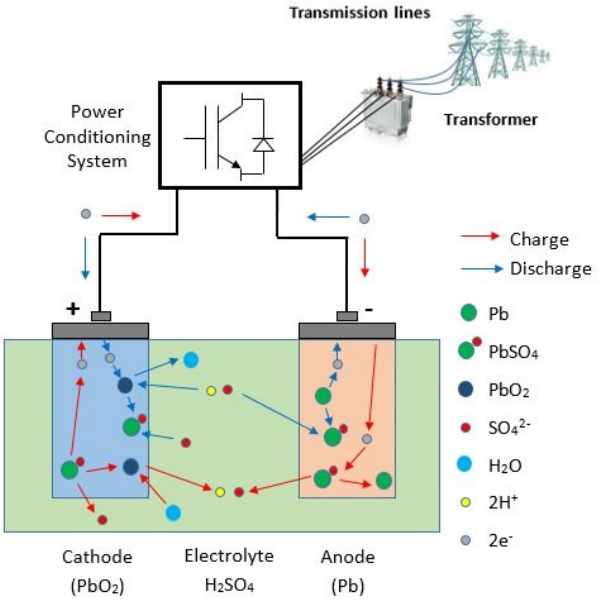


Figure 6. Schematic representation of a lead acid battery (Poullikkas & Nikolaidis, 2017)

- ***Redox flow batteries*** (ZnFe, V, ZnBr): Redox batteries, such as zinc–bromine, are complex electrochemical systems with circulating electrolytes. The heart of the system can be considered as a reversible fuel cell stack (Van den Bossche et al., 2006). Flow batteries may require additional equipment, such as pump sensors and control units (Poullikkas & Nikolaidis, 2017).
  Zinc bromine (ZnBr) is considered a hybrid flow battery[1]. It has two electrolyte loops made of zinc-bromine (Poullikkas & Nikolaidis, 2017). A general scheme of the ZnBr redox flow battery with the charge and discharge flows can be seen in Figure 7. The two compartments are usually separated by a microporous polyolefin membrane. During the charge, metallic zinc (Zn) is plated as a thin film on one side of the carbon-plastic composite electrode, while bromine (Br_2) oil sinks to the bottom of the electrolytic tank at the other side. ZnBr has no self- discharge, can go through deep discharge without degradation and has a narrow temperature operation range, the same as vanadium redox flow battery. Their use in utility-scale Electrical Energy Storage (EES) applications is in the early stage of demonstration (Poullikkas & Nikolaidis, 2017).

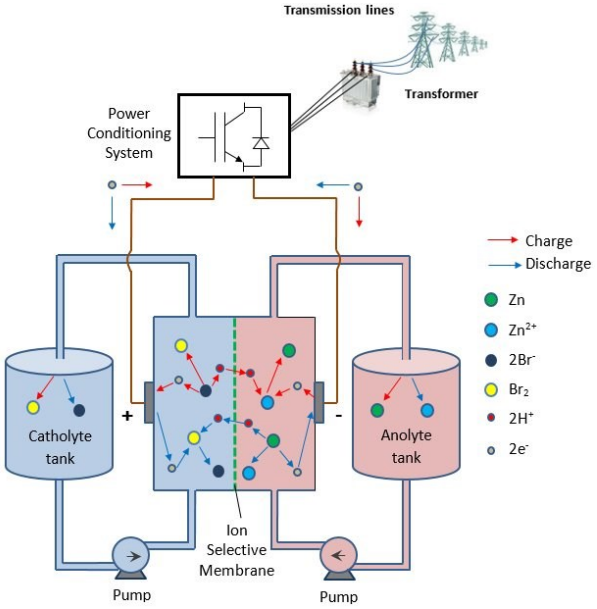


Figure 7. Schematic diagram of zinc bromine flow battery energy storage system (Poullikkas & Nikolaidis, 2017)

The vanadium redox flow battery (VRB) system uses vanadium in sulphuric acid in two electrolyte loops but in different valence states. It uses vanadium redox couples (V^{2+}/V^{3+} and V^{4+}/V^{5+}) in the anolyte and catholyte tanks, respectively. Figure 8 shows a general scheme of the ZnBr redox flow battery showing charge and discharge flows. It uses a hydrogen-ion permeable membrane. The anolyte contains V^{3+} & V^{2+} in the charging & discharging states, respectively, associated with V^{4+} & V^{5+} for the catholyte.
The technical and operational features of a VRB system include 30-50 Wh/kg as specific energy and 80-150 W/kg as specific power, fast response in the order of milliseconds, high cycling capability (>16000 cycles) and relatively high efficiencies of up to 85%. The cell voltage is 1.2-1.6 V and the operating

[1] The difference between hybrid and conventional flow batteries is that in hybrid batteries at least one redox couple species is not fully soluble and may be either a metal or a gas.

temperature in the range of 0-40°C. Also, they have no self-discharge, can withstand deep discharging and require low maintenance (Poullikkas & Nikolaidis, 2017).

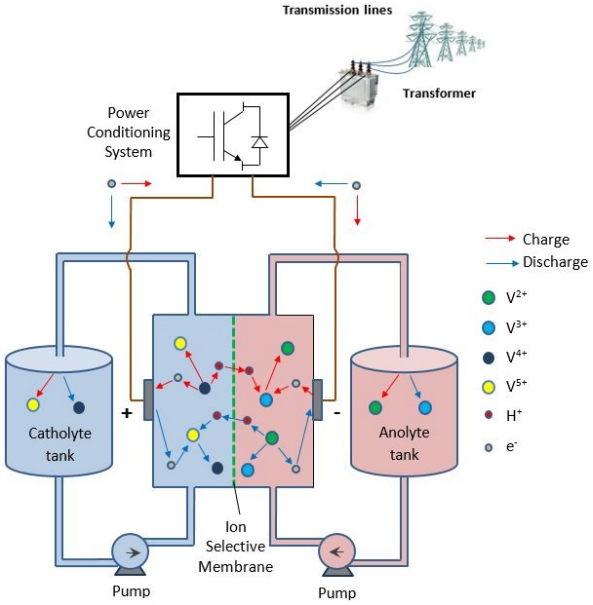


Figure 8. Schematic diagram of vanadium redox flow battery energy storage system (Poullikkas & Nikolaidis, 2017).

- ***Sodium batteries*** (NaS, $NaNiCl_2$): The Na/S batteries were once thought to be the energy source of choice for electric vehicle applications, but unfortunately they have some drawbacks, e.g. they require energy to keep them at operating temperature (300°C), and there are safety concerns about molten sodium and highly corrosive sodium polysulphide on-board vehicles (Sullivan & Gaines, 2010). They are currently being used in Japan for grid energy storage. This battery is different from the others (e.g. PbA battery) in that the electrodes are liquids and the electrolyte is a solid. NaS batteries have a cathode made of molten sulphur, and anode made of molten sodium, and the electrolyte made of solid β-alumina.

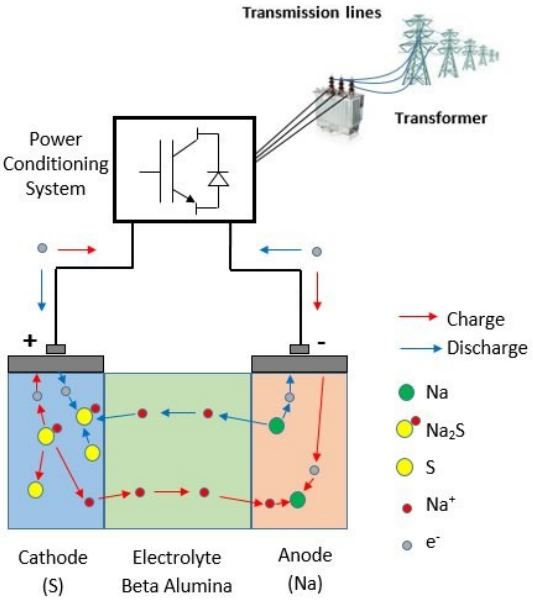


Figure 9. Schematic diagram of NaS battery energy storage system (Poullikkas & Nikolaidis, 2017).

The sodium-nickel-chloride ($NaNiCl_2$) battery is composed of a cathode made, mainly, of solid nickel and sodium chloride (NaCl) and an anode typically made of liquid sodium (Na) (EASE - European Associaton for Storage of Energy, 2016b). They are currently produced by one single manufacturer under the commercial name Zebra. Electrodes are separated by a beta-alumina (β-Al_2O_3) ceramic wall that functions as electrolyte and is conductive vs sodium ions, letting them move between the anode and the cathode, while being insulator vs electrons. To ensure contact between the solid positive electrode and the ceramic electrolyte, the positive electrode is flooded with molten chloroaluminate ($NaAlCl_4$), which is an equimolar eutectic mixture of sodium chloride and aluminium tri chloride (Lemaire-Potteau et al., 2009). During discharge, sodium is oxidized into Na+ ions, forming sodium chloride, and NiCl is reduced to metallic Ni (Lemaire-Potteau et al., 2009). As with the sodium sulphur battery, it needs working temperatures of 270-350ºC to keep the electrodes in a molten state, needing then independent heaters as part of the battery. The $NaNiCl_2$ technology has been introduced into the market over the last decade for electric vehicles (EV), mainly for public transport. Currently a wider range of products is available for stationary backup, railway backup, electric vehicles and on-grid/off-grid energy storage applications. The single battery size ranges from 4 to 25 kWh suitable for a wide range of applications with energy storage capacities from a few kilowatt-hours to several megawatt-hour installations. Due to the ceramic electrolyte, the battery has no electrochemical self-discharge. Efficiency is in the range of 80-95% (EASE - European Associaton for Storage of Energy, 2016b).

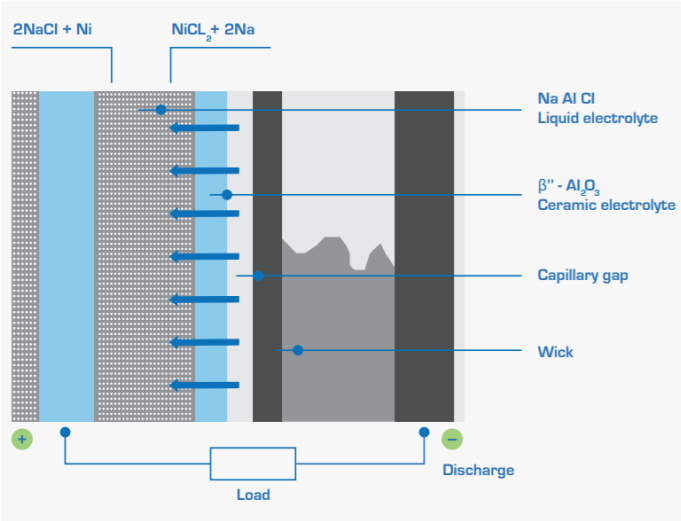


Figure 10. Charging scheme of a NaNiCl2 battery (EASE - European Associaton for Storage of Energy, 2016b)

- ***Nickel metal hydride*** (Lemaire-Potteau et al., 2009): Figure 11 and Figure 12 shows a cylindrical NiMH battery and the electrochemical reactions, respectively. The cathode is made of nickel oxy-hydroxide on a nickel foam, graphite or iron. In the anode, the negative active material, in the charged state, is hydrogen in the form of a metal hydride. As the battery is charged and discharged, a reversible hydrogen absorption–desorption reaction occurs. The electrolyte is aqueous potassium hydroxide, with lithium hydroxide additive to improve the charging efficiency of the positive electrode, by reducing the oxygen evolution. Due to the presence of an aqueous electrolyte, the charging current should be controlled at the end of the charge, to limit the generation of oxygen. Rare earth elements are critical raw materials for this battery type (Halleux, 2021). Nearly all NiMH batteries operating in the field these days employ a Rare Earth Mischmetal–nickel based metal alloy (MmNi5-type) with some fractions of cobalt, manganese, and aluminium. The absence of cadmium makes NiMH a system with the better environmentally compatibility. This also facilitates the recycling procedures of spent products (Koehler, 2019). NiMH batteries appear to be the technology of choice for applications such as hybrid electric vehicles (HEVs), emerging electric vehicles (EVs), and fuel cell EVs (Tsais & Chan, 2013).

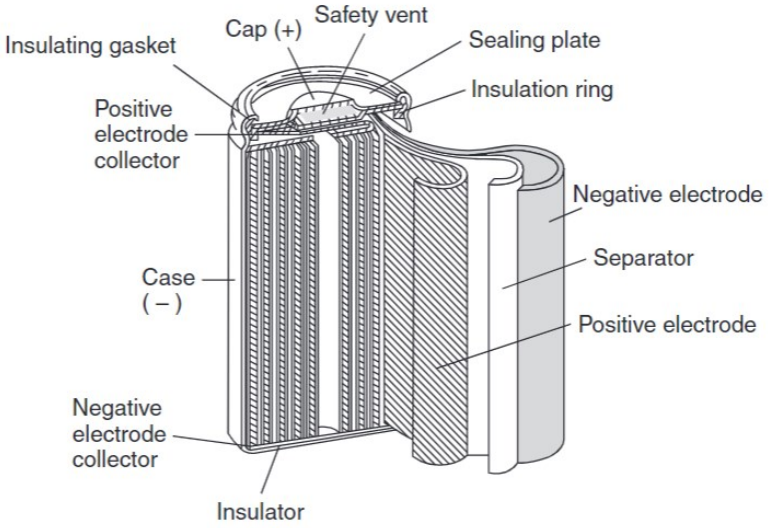


Figure 11. Structure of a cylindrical NiMH battery (Taniguchi, 2001; Tsais & Chan, 2013)

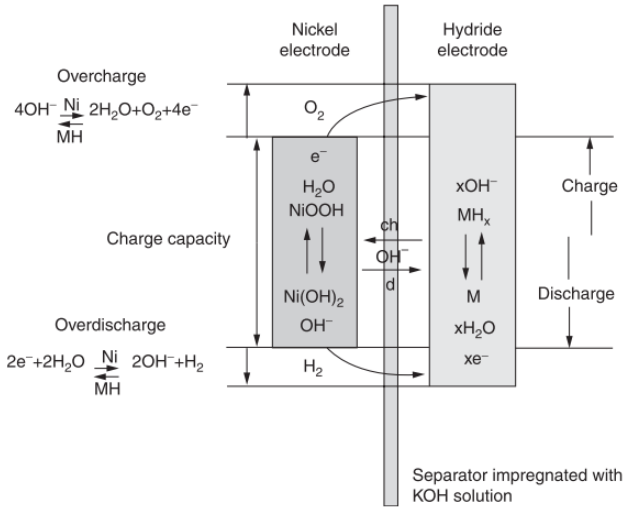


Figure 12. Schematic diagram of electrochemical reactions produced in the NiMH battery (Notten & Latroche, 2009)

- ***Lithium metal polymer (LMP)***: The positive electrode (cathode) is made of a metal oxide intercalation compound and the negative electrode (anode) is made of lithium metal. The electrodes are physically separated by a dry solid polymer. Thermal management system, control system and power conversion system are also components of the battery together with assembly components of cells and modules. The cell reaction is an intercalation of lithium ions into the structure of the cathode during the discharge cycle, and a de-intercalation of lithium ions from the charged cathode and its plating into the anode during the charge cycle. The cell operation needs to run at an internal temperature of 70-80°C (see Figure 13). The LMP is commonly used in EVs but it can also be used for uninterrupted power supplies and for customer and grid storage (EASE - European Associaton for Storage of Energy, 2016a).

Illustration: Charging principle of LMP

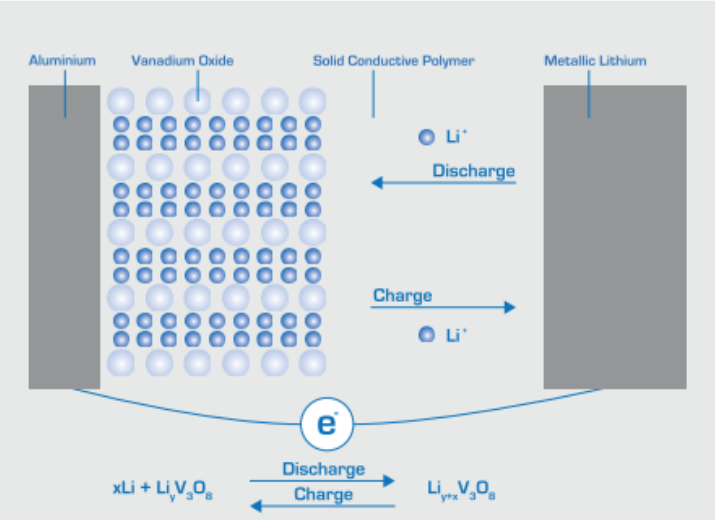


Figure 13. Charge and discharge reactions of the lithium metal polymer battery (EASE - European Associaton for Storage of Energy, 2016a).

2.2 Life cycle stages definition and scope

Legislation was divided according to the different life stages that the battery goes through. Life cycle stages were defined according to the stages defined in the Life Cycle Analysis standards ISO 14040:2006 "*Environmental management. Life cycle assessment".* Within LOLABAT project, the scope is to analyse NiZn batteries considering a cradle-to-grave system boundary, which goes from raw material extraction through product use and disposal. The scope of each life cycle stage was defined based on the life cycle stage requirements and their corresponding level of regulatory framework (international, national and/or regional).

- ***Raw materials***. Raw materials are defined as the basic materials from which a product is made. The essential raw materials for batteries, as defined in (European Commission, 2018) are natural graphite with 69% of the global supply from China, cobalt, nickel, copper with 32% of the global supply from Chile, lithium, and manganese. China hosts the majority of the world's lithium, zinc and cadmium refining facilities (European Commission, 2018; Garside, 2021; Government of Canada, 2019). As a result, China has acquired and is still expanding its dominant position in the lithium-ion battery (LIB) supply chain. Table 1 shows the main mining producers of main materials of the electrochemical batteries defined in section 2.1. Raw materials legislation scope will focus on the international legislations applying to these raw materials and also on the legislation applying to the country with the highest mining production of each main raw material.

Table 1. Main producers of key battery raw materials: cobalt, lithium, zinc, nickel, cadmium and nickel oxides and hydroxides.

Cobalt[2]	Lithium[3,4]	Zinc[5]	Nickel[6,7]	Cadmium[8]	Nickel oxides and hydroxides[9]
Congo (~70%, 95000 metric tonnes (MT) in 2020)	***Australia (~61%, 42000 tonnes in 2019)***	***China (33.7%)***	***Indonesia (~24%)***	***China (8200 metric tons 2020)***	***Japan (~44%)***
Russia (6300 MT in 2020)	Chile (~18%, 18000 tonnes 2019)	Peru (11%)	Philippines (~15%)	South Korea (3000 metric tons 2020)	Netherlands (~10%)
Australia (5700 MT in 2020)	China (7500 tonnes 2019)	Australia (10.2%)	New Caledonia (France) (~9%)	Japan (1800 metric tons 2020)	China (~9%)
Philippines (4700 MT in 2020)	Argentina (6400 tonnes 2019)	India (6.3%)	Russia (~9%)	Canada (1800 metric tons 2020)	Chinese Taipei (~6%)
Cuba (3600 MT in 2020)	Zimbabwe (1600 tonnes 2019)	US (6.1%)	Australia (~7%)	Kazkhstan	Philippines (~5%)
Canada (3200 Mt in 2020)	Portugal (1200 tonnes 2019)	Mexico (5.4%)	Canada (~7%)	Mexico	Sweden (~4%)
Papua New Guinea (2800 MT in 2020)	USA	Bolivia (3.6%)	China (~5%)	Netherlands	Belgium (~3%)
China (2300 MT in 2020)	Bolivia	Canada (2.4%)	Brazil	Russia	US (~3%)

- ***Manufacturing***. The manufacturing stage refers to all the industrial processes needed to convert the raw materials into the final product to be used, i.e. the battery. To analyse the manufacturing legislation applied to the new NiZn battery, Paris (France) has been selected, since an analysis of legislations for all the countries could not be covered. Besides, France would be an initial choice of country where a production of the new NiZn batteries would be installed.

- ***Storage.*** Specific legislation is also applied to the storage phase. Warehouses and materials stored in these warehouses have to comply with some regulations to ensure the safety of the workers and of the surroundings. Since storage facilities are settled in an industrial area of a specific town, international, European and country specific regulations apply. The same as for the manufacturing, Paris (France) has

[2] https://investingnews.com/daily/resource-investing/battery-metals-investing/cobalt-investing/top-cobalt-producing-countries-congo-china-canada-russia-australia/
[3] https://www.nsenergybusiness.com/features/top-lithium-producing-countries/#
[4] https://physicstoday.scitation.org/doi/10.1063/PT.3.4745
[5] https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/zinc-facts/20534
[6] https://www.statista.com/statistics/264642/nickel-mine-production-by-country/
[7]https://www.globaldata.com/covid-19-advancement-indonesias-export-ban-reduce-global-nickel-output-7-4-2020-says-globaldata/
[8] https://www.statista.com/statistics/1023116/refinery-production-cadmium-worldwide-by-country/
[9] Top exporters: https://oec.world/en/profile/hs92/nickel-oxides-and-hydroxides

been selected, since the analysis of legislations of all the countries could not be covered, and that France would be an initial choice of country where a production of the new NiZn batteries would be installed.

- ***Transport.*** This includes the regulations applied to the distribution of main raw materials and the final products, i.e. batteries, from the origin to the destination, using different modes of transport, available (by road, train, waterway, air) for the transport of each type of product.

- ***Use.*** Batteries have different possible uses and can be used all over the world. The new NiZn batteries (rechargeable) will be used for energy storage purposes. Therefore, legislation search will focus on worldwide legislation applicable to rechargeable batteries for energy storage.

- ***Disposal/recycling.*** This phase includes both the recycling in order to convert the used battery or waste material into a new product, and the elimination in a landfill when reuse or recycling is not possible. Since recycling and disposal is made in a specific country, legislation search for this battery life stage is focused on European legislation and Paris (France) has been selected for the search of national applicable regulations, since the analysis of legislations of all the countries could not be covered, and that France would be an initial choice of country where a production of the new NiZn batteries would be installed.

3 Objectives

The aim of this document is to analyse the regulatory issues related to the NiZn battery technology in order to develop a guideline on the current applicable legislation framework. The specific objectives of this deliverable are:

- To analyse the legislations that apply to the RNZB through all its life cycle.
- To analyse the legislations that apply to other electrochemical batteries, such as lithium-ion, lead acid or nickel metal hydride; with the aim of comparing legislations applicable to the RNZB with other kind of batteries.
- To identify regulatory gaps and to suggest improvements for the RNZB legislation.

4 Legislative analysis

4.1 Legislations applicable to batteries regarding their raw materials

As defined in section 2.2., since raw materials for RNZB can come from all over the world, the scope of the analysis is international, and we will focus on main producers of main raw materials for the RNZB and also main differentiating materials of the most important competing batteries. Selected materials can be seen in Table 1, and include: cobalt, lithium, zinc, nickel, cadmium, and nickel oxides and hydroxides (as raw materials for NiZn electrodes).
Next subsections will analyse how each of the identified regulations apply to these raw materials.

4.1.1 Regulation (EC) No 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The purpose of this Regulation is to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of substances, as well as the free circulation of substances in the internal market while enhancing competitiveness and innovation. REACH then

establishes the guidelines to evaluate the potential impacts on human health and environment of each substance and the requirements for its registry and authorisation. The documents considered are:

- **REACH - Regulation (EC) no 1907/2006** of the European Parliament and the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

- **Commission Regulation (EC) No 552/2009 of 22 June 2009 amending Regulation (EC) No 1907/2006** of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards Annex XVII (Text with EEA relevance). Annex XVII to Regulation (EC) No 1907/2006 is amended in accordance with the Annex to this Regulation.

REACH regulation is in charge of informing the clients about the containing elements of the products, considered as dangerous for the human health and the environment, which are called 'Substances of Very High Concern' (SVHC) that are listed on the 'Candidate List' and contained in products in concentrations higher than 0.1% weight per article.

Since this regulation applies to any authorised product, it applies to all the raw materials used for all battery technologies. Annex XVII defines the restrictions on the manufacture, placing on the market and use of certain dangerous substances, mixtures and articles, which in case of batteries relate to nickel, cadmium and lead. The restrictions defined in this Annex do not apply to storage, keeping, treatment, filling into containers, or transfer from one container to another of these substances for export, unless the manufacture of the substances is prohibited.

- ***Nickel*** (CAS No. 7440-02-0, EC No 231-111-4 and its compounds), ***metal***: main hazards include skin sensitizing and it is suspected to be carcinogenic (European Chemicals Agency, 2021). The use of nickel is mainly restricted in piercings and jewellery, i.e. it cannot be in direct and prolonged contact with skin if the release is greater than 0.2-0.5 µg/cm^2/week. Related to its used in the industry, research has shown that the inhalation is produced from the following substances: dust of relatively insoluble nickel compounds, aerosols derived from nickel solutions (soluble nickel) and gaseous forms containing nickel (usually nickel carbonyl) (Cempel M. & Nikel G., 2006). Many measurements conducted at various workplaces at risk (casting, welding, battery manufacture etc.) have revealed that the occupational concentrations may vary in a wide range from micrograms to milligrams of nickel per m^3 of air. In nickel-producing or nickel-using industries, about 0.2% of the workforce may be exposed to considerable amounts of airborne nickel, which may lead to the retention of 100 µg of nickel per day (Cempel M. & Nikel G., 2006). Different nickel compounds and their CAS and EC numbers can be seen in Appendix 1 of REACH regulation pp 250-255.

- ***Nickel hydroxides***:

  - *Nickel dihydroxide* (Index No. 028-008-00-X, EC No. 235-008-5, CAS No. 12054-48-7): Hazards or properties of concern of this type of substance are: carcinogenic, suspected to be mutagenic, toxic to reproduction, skin sensitizing and respiratory sensitizing (European Chemicals Agency - ECHA, 2021e). Release to the environment of this substance can occur from industrial use in the production of articles and as an intermediate step in further manufacturing of another substance (use of intermediates).

  - *Nickel hydroxide* (EC No 234-348-1, CAS No 11113-74-9): Hazards for this substance are the same as for nickel dihydroxide and include: oral, dermal and inhalation toxicity; skin irritation, respiratory

and skin sensitization; reproductive toxicity (may damage fertility), suspected to be mutagenic, carcinogenic, and can cause damage to organs (lungs) through prolonged or repeated exposure. Regarding the environment, it is very toxic to aquatic life in the short and long term (European Chemicals Agency - ECHA, 2021f).

- ***Cadmium*** (EC No 231-152-8, CAS No 7440-43-9): According to the classification provided by companies to ECHA in REACH registrations, this substance is fatal if inhaled, is very toxic to aquatic life with long lasting effects, may cause cancer, causes damage to organs through prolonged or repeated exposure, may cause respiratory irritation, is suspected of causing genetic defects, is suspected of damaging fertility or the unborn child and catches fire spontaneously if exposed to air (European Chemicals Agency - ECHA, 2021a). Appendix 12 establishes a concentration limit by weight of Cd and its compounds in homogenous materials. This limit is established at 1 mg/kg after extraction (expressed as Cd metal that can be extracted from the material). Appendix XVII establishes limitations for Cadmium to be used in plastics, paints, and jewellery being the maximum concentration of 0.01% by weight or a 0.1% for paints with more than a 10% of zinc. Cadmium plating metallic articles uses is also restricted to some uses (e.g. food production, agriculture, household goods, printing sanitary ware, air conditioning), uses that do not include batteries.

- ***Lead*** (EC No 231-100-4, CAS No 7439-92-1): According to the classification provided by companies to ECHA in REACH registrations this substance may damage fertility or the unborn child, causes damage to organs through prolonged or repeated exposure, is very toxic to aquatic life with long lasting effects, may cause cancer, and may cause harm to breast-fed children. Some data submitters have indicated that they consider this substance as Carcinogenic (European Chemicals Agency - ECHA, 2021c). Release to the environment of this substance can occur from industrial use: manufacturing of the substance, formulation of mixtures and formulation in materials. Other release to the environment of this substance is likely to occur from: outdoor use in long-life materials with low release rate (e.g. metal, wooden and plastic construction and building materials) (European Chemicals Agency - ECHA, 2021c). Appendix XVII establishes limitations for its use in jewellery or any other article, if the concentration in the article of its accessible parts is higher than 0.05% by weight. Exceptions for articles with concentrations higher than 0.05% include, between others, portable zinc-carbon batteries and button cell batteries. Lead sulphates cannot be used in paints. Appendix 12 establishes a concentration limit by weight of Pb and its compounds in homogenous materials of 1 mg/kg after extraction (expressed as Pb metal that can be extracted from the material).

- ***Lithium*** (EC No 231-102-5, CAS Nº 7439-93-2): According to the harmonised classification and labelling (CLP00) approved by the European Union, this substance causes severe skin burns and eye damage and in contact with water releases flammable gases which may ignite spontaneously. Additionally, the classification provided by companies to ECHA in classification, labelling and packaging (CLP) notifications identifies that this substance is toxic if swallowed (European Chemicals Agency - ECHA, 2021d). The positive electrode of the Li-ion batteries is usually made of lithium-containing transition metal oxides where the metal is Co, Ni, Fe or Mn. The most common Li-ion chemistries are described in section 2.1.Lithium metal and the compounds used for the electrodes do not have any restriction in REACH legislation.

- ***Zinc***: zinc (EC No. 231-175-3, CAS No. 7440-66-6) and zinc oxide (EC Nº 215-222-5, CAS Nº 1314-13-2) do not have any special restriction in REACH regulation. The only zinc components with restrictions or especially dangerous (carcinogenic) are zinc chromates including zinc potassium chromate and

pentazinc chromate octahydroxide. According to the classification provided by companies to ECHA in REACH registrations, Zn and ZnO (zinc oxide) are very toxic to aquatic life, with long lasting effects (European Chemicals Agency - ECHA, 2021g, 2021h).

- ***Cobalt*** (EC No. 231-158-0, CAS No. 7440-48-4): According to the harmonised classification and labelling (ATP14) approved by the European Union, this substance may cause cancer, may damage fertility, is suspected of causing genetic defects, may cause long lasting harmful effects to aquatic life, may cause an allergic skin reaction and may cause allergy or asthma symptoms or breathing difficulties if inhaled. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that this substance is fatal if inhaled, is very toxic to aquatic life with long lasting effects, is harmful if swallowed, is suspected of damaging fertility or the unborn child, causes serious eye irritation and may cause damage to the organs through prolonged or repeated exposure (European Chemicals Agency - ECHA, 2021b). Within REACH regulation, cobalt compounds within the carcinogenic group (category 1A, known to have carcinogenic potential for humans) are cobalt nickel gray periclase, cobalt nickel dioxide, cobalt nickel oxide, cobalt dimolybdenum nickel octaoxide, cobalt lithium nickel oxide. In addition, cobalt dichloride, cobalt sulphate, cobalt acetate, cobalt nitrate and cobalt carbonate are registered as carcinogens (category 1B, presumed to have carcinogenic potential for humans) and toxic for reproduction.

Another important component for batteries is graphite. Graphite is a component used in some electrodes, e.g. in the anode of Li-ion batteries. REACH regulation does not establish any restriction on graphite (EC No. 231-955-3, CAS No. 7782-42-5).

4.1.2 European Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures

Document considered:

- **European Regulation (EC) No 1272/2008** on classification, labelling and packaging (CLP) of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006

The purpose of this Regulation is to ensure a high level of protection of human health and the environment as well as the free movement of substances, mixtures and articles by:

1. Harmonising the criteria for classification of substances and mixtures, and the rules on the labelling and packaging of hazardous substances and mixtures.
2. Providing an obligation for:
   - Manufacturers, importers and downstream users to classify substances and mixtures placed on the market.
   - Suppliers to label and package substances and mixtures placed on the market.
   - Manufacturers, producers of articles and importers to classify those substances not placed on the market that are subject to registration or notification under Regulation (EC) No 1907/2006.
3. Providing an obligation for manufacturers and importers of substances to notify the Agency of such classifications and label elements if these have not been submitted to the Agency as part of a registration under Regulation (EC) No 1907/2006.
4. Establishing a list of substances with their harmonised classifications and labelling elements at Community level in Part 3 of Annex VI.
5. Establishing a classification and labelling inventory of substances.

The classification and labelling of each of the raw materials used in the different electrochemical batteries are subjected to this legislation. Hazards statements depends on the dangerousness of each chemical (e.g. lithium, lead, nickel, zinc, etc.), as defined in Table 3.1. List of harmonised classification and labelling of hazardous substances can be seen in Table 2.

Table 2. Classification of main raw and differentiating materials of the analysed electrochemical storage batteries. Note: GHS: Globally Harmonized System of Classification and Labelling of Chemicals, Dgr: Danger, Wng: Warning

Index No.	Name – International Chemical Identification	EC No.	CAS No.	Classification		Labelling	
				Hazard class and category code	Hazard statement code	Pictograms signal word Code(s)	Hazard statement Code(s)
028-002-00-7	Nickel	231-111-4	7440-02-0	Carc. 2 Skin Sens. 1	H351 H317	GHS08 GHS07 Wng	H351 H317
028-008-00-X	Nickel dihydroxide	235-008-5	12054-48-7	Carc. 2 Acute Tox. 4 Acute Tox. 4 Skin Sens. 1 Aquatic Acute 1 Aquatic Chronic 1	H351 H332 H302 H317 H400 H410	GHS08 GHS07 GHS09 Wng	H351 H332 H302 H317 H410
048-002-00-0	Cadmium (non-pyrophoric); [1] cadmium oxide (non-pyrophoric) [2]	231-152-8 [1] 215-146-2 [2]	7440-43-9 [1] 1306-19-0 [2]	Carc. 1B Muta. 2 Repr. 2 Acute Tox. 2 STOT RE 1 Aquatic Acute 1 Aquatic Chronic 1	H350 H341 H361fd H330 H372 H400 H410	GHS06 GHS08 GHS09 Dgr	H350 H341 H361fd H330 H372 H410
082-013-00-1	lead powder; [particle diameter < 1 mm]	231-100-4	7439-92-1	Repr. 1A Lact.	H360FD H362	GHS08 Dgr	H360FD H362
082-014-00-7	lead massive: [particle diameter ≥ 1 mm]	231-100-4	7439-92-1	Repr. 1A Lact.	H360FD H362	GHS08 Dgr	H360FD H362
082-001-00-6	Lead compounds with the exception of those specified elsewhere in this Annex	-	-	Repr. 1A Acute Tox. 4 Acute Tox. 4 STOT RE 2 Aquatic Acute 1 Aquatic Chronic 1	H360-Df H332 H302 H373 H400 H410	GHS08 GHS07 GHS09 Dgr	H360Df H332 H302 H373 H410
003-001-00-4	Lithium	231-102-5	7439-93-2	Water-react. 1 Skin Corr. 1B	H260 H314	GHS02 GHS05 Dgr	H260 H314
030-001-01-9	Zinc powder — zinc dust (stabilized)	231-175-3	7440-66-6	Aquatic Acute 1 Aquatic Chronic 1	H400 H410	GHS09 Wng	H410

030-001-00-1	zinc powder — zinc dust (pyrophoric)	231-175-3	7440-66-6	Water-react. 1 Pyr. Sol. 1 Aquatic Acute 1 Aquatic Chronic 1	H260 H250 H400 H410	GHS02 GHS09 Dgr	H260 H250 H410
030-013-00-7	Zinc oxide	215-222-5	1314-13-2	Aquatic Acute 1 Aquatic Chronic 1	H400 H410	GHS09 Wng	H410
027-001-00-9	Cobalt	231-158-0	7440-48-4	Resp. Sens. 1 Skin Sens. 1 Aquatic Chronic 4	H334 H317 H413	GHS08 Dgr	H334 H317 H413

4.1.3 Batteries Directive 2006/66/EC

This Directive is mainly focused on the collection of waste batteries and accumulators and aims to ensure that all collected batteries undergo proper treatment and recycling. However, it also establishes some prohibitions when placing batteries into the market. Therefore, it will be further analysed within the disposal and recycling legislation. However, this Directive prohibits the placing on the market of certain batteries and accumulators containing mercury or cadmium, and therefore presence of these two raw materials in the battery will condition its placing into the market. Without prejudice to Directive 2000/53/EC, Member States shall prohibit the placing on the market of:

1. All batteries or accumulators, whether or not incorporated into appliances, that contain more than 0,0005 % of mercury by weight. This prohibition does not apply to button cells with a mercury content of no more than 2 % by weight.
2. Portable batteries or accumulators, including those incorporated into appliances, which contain more than 0,002 % of cadmium by weight. This prohibition does not apply to portable batteries and accumulators intending for use in:
    - Emergency and alarm systems, including emergency lighting
    - Medical equipment
    - Cordless power tools

4.1.4 Official Journal of the European Communities 88/C 30/01. Council Resolution of 25 January 1988 on a Community action programme to combat environmental pollution by cadmium

This legislation affects only the batteries with cadmium, i.e. NiCd battery. The Council Resolution of 25 January 1988 on a Community action program has the aim to combat environmental pollution by cadmium. It stresses the limitation of the use of cadmium to cases where suitable alternatives do not exist and the collection and recycling of batteries containing cadmium as a major element; a strategy for cadmium control in the interest of protection of human health and the environment.

4.1.5 Directive on General Product Safety Requirements 2001/95/EC

The purpose of this Directive is to ensure that products placed on the market are safe, establishing at Community level general safety requirements for any product placed on the market, or otherwise supplied or made available to consumers, intended for consumers, or likely to be used by consumers under reasonably foreseeable conditions even if not intended for them. In all these cases the products under consideration can pose risks for

the health and safety of consumers which must be prevented. It also establishes obligations of producers and of distributors.
Therefore, this Directive applies to any product used as raw material of the batteries and no specific requirements are set for any kind of product or raw material.

4.1.6 Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment

This Directive lays down rules on the restriction of the use of hazardous substances in electrical and electronic equipment (EEE) with a view of contributing to the protection of human health and the environment, including the environmentally sound recovery and disposal of EEE waste.

This Directive does not apply to:

1. Equipment necessary for the protection of the essential interests of the security of Member States, including arms, munitions and war material intended for specifical military purposes
2. Equipment designed to be sent into space
3. Equipment specifically designed, and to be installed as part of another type of equipment that is excluded or does not fall within the scope of this Directive, which can fulfil its function only if it is part of that equipment, and which can be replaced only by the same specifically designed equipment
4. Large-scale stationary industrial tools
5. Large-scale fixed installations

Categories of EEE covered by this Directive (in the Annex I):

- Large household appliances
- Small household appliances
- IT and telecommunication equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools
- Toys, leisure and sports equipment
- Medical devices
- Monitoring and control instruments including industrial monitoring and control instruments
- Automatic dispensers
- Other EEE not covered by any of the categories above

The Annex II of the Directive indicates the maximum concentration values tolerated by weight in homogeneous materials of some restricted substances, listed below:

- Lead (0.1 %)
- Mercury (0.1 %)
- Cadmium (0.01 %)
- Hexavalent chromium (0.1 %)
- Polybrominated biphenyls (PBB) (0.1 %)
- Polybrominated diphenyl ethers (PBDE) (0.1 %)

These restrictions would then apply to the electric equipment of batteries containing cadmium or lead.

Annex III of the Directive includes a list of applications exempted from the restrictions defined in Annex II. E.g. an exemption is cadmium and its compounds in electrical contacts, lead in dielectric ceramic in capacitors for a rated voltage of 125V AC (alternating current) or 250V DC (direct current) or higher, Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound, Copper alloy containing up to 4 % lead by weight, etc.

Since the energy storage batteries analysed within this document are intended for grid energy storage (also called large-scale energy storage), and then can be included as large-scale stationary industrial tools or large-scale fixed installations, the restrictions set in this Directive do not apply to them. They would only apply if instead of for large scale application it would be intended for other use (e.g. Information Technology (IT), electrical and electronic tools, household or personal use).

4.1.7 Directive 2006/21/EC, OJ L 102, 11.4.2006 on the management of waste from extractive industries and amending Directive 2004/35/EC.

This Directive covers the management of waste resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries, hereinafter 'extractive waste'.
Excluded from the scope of this Directive, are the following types of waste:

1. Waste which is generated by the prospecting, extraction and treatment of mineral resources and the working of quarries, but which does not directly result from those operations.
2. Waste resulting from the offshore prospecting, extraction and treatment of mineral resources; injection of water and re-injection of pumped groundwater as defined in Article 11(3)(j) of Directive 2000/60/EC.
3. Inert waste and unpolluted soil resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries and waste resulting from the extraction, treatment and storage of peat.

This directive applies to the extraction of all raw materials and there is no difference between the raw materials used for each battery technology analysed.

4.1.8 Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment

The aim of this directive is the assessment of the environmental effects of those public and private projects that are likely to have significant effects on the environment. Therefore, it applies to the obtainment and production of any raw material used in batteries.

4.1.9 National legislation: China

China is producer of all main raw materials used in batteries (section 2.2). It is the main producer of cadmium with 8200MT in 2020, and zinc with a portion of 33.7%. It is the third producer of lithium with 7500 tonnes in 2015, the seventh producer of nickel with a portion of 5%, the third producer of nickel oxides and hydroxides with a portion of 9%, and the 8th producer of cobalt with 2300MT in 2019. Main legislations applying in China related to mining are (Wu & Li (Jincheng Tongda & Neal), 2020; Yin et al., 2021):

- **Mineral Resources Law 2009**. National law governing the prospecting for and extraction from mines in China and the registration of mining rights. It was promulgated by the Standing Committee of the National People´s Congress on 19 March 1986 and amended in 1996 and 2009, respectively.

- **Mine Safety Law 2009**. This regulation applies to all kind of mining industry and to the battery materials coming from minerals, with the aim of ensuring health and safety.

- **Administrative Measures for the Block Registration of Mineral Resource Prospecting 2014** (G. (JINCHENG T. & N. Wu & Li, 2020).

- **Administrative Measures for the Registration of Mineral Resources Exploitation 2014** (Ministry of Natural Resources - PRC, 2018; G. (JINCHENG T. & N. Wu & Li, 2020)

- Provisions on **Administration of Mineral Resources Compensation** Collection 1997 (Chinese State Council, 1994; FAO, 1997)

- **Environmental protection law, 2014** (Chinese State Council, 2014). It is a national law formulated for the purpose of protecting and improving environment, preventing and controlling pollution and other public hazards, safeguarding public health, promoting ecological civilization improvement and facilitating sustainable economic and social development. It includes a series of articles with the duties of population and companies to protect the environment. For example, the State adopts policies and measures in terms of fiscal assistance, taxation, prices and government procurement to encourage and support the environmental industries such as environmental protection equipment, comprehensive utilization of resources technics, environmental services and etc. In addition, an environmental impact assessment in accordance with the law is needed to develop any construction or activity.

- **Measures for the Administration of Transfer of Mineral Exploration Rights and Mining Rights 1998, updated in 2014.** Decree of the State Council of the People's Republic of China (No. 242) (Chinese State Council, 1998; G. Wu & Li, 2020)

- **Labour Law 2009.** Applicable to all employees as well as to all employers operating in China.

- **Resource Tax Law of 2020**. Defines basic resource tax rates for certain mineral resources. It defines some taxes depending on the raw material. Resource taxes:
    - copper and nickel (concentrate): 2% to 10% of gross sales
    - graphite (concentrate): 3% to 12%
    - kaolin (ore): 1% to 12%
    - Other taxes include land use taxes (depending on the size of the city), value added tax (11-17%), city maintenance and construction tax, business income tax, education subcharges.

4.1.10 National legislation: Democratic Republic of Congo (DRC)

DRC is the main producer of Cobalt with approx. 70%, 95000 MT in 2020 (see Table 1). Mining conditions in DRC are poor, with low labour costs, loose regulations, and poor governance. Main legislations applying in DRC are:

- The **New Mining Code. Act No. 007/2002** of 11 July 2002 establishing the Mining Code, as **amended by Act No. 18-001 of 9 March 2018**. This code defines the mining rules in Democratic Republic of Congo. The New Mining Code, together with the Mining Regulation, contain several environmental and health and safety regulations. It does not mention differences between different sources or materials.

- **Decree No. 18/24 of 8 June 2018** on Mining Regulation. The Mining Regulation, together with the Mining Code contain several environmental and health and safety regulations. It does not mention differences between different sources or materials.
- **Congolese labour Code Law No. 015/2002**. Applicable to all employees as well as to all employers operating in the DRC. Most health and safety regulations are contained in the Congolese Labour Code, and are therefore not specific to the mining sector, the Mining Regulations do contain specific safety directives regarding the use of explosives.
- **OHADA law** (Organisation for the Harmonisation of Business Law in Africa), 2012. OHADA law is of particular interest to mining companies, as it primarily covers commercial, corporate, loan-guarantee, accounting and arbitration law. It establishes the general rules, and no specific rules are defined for specific materials.

4.1.11 National legislation: Australia

Australia is the first producer of lithium with approx. 61%, 42000 tonnes in 2019 (see Table 1). Main legislations applying in Australia for the obtainment of minerals are:

- Offshore mineral legislation: **Offshore minerals Act 1994**. Legislation from 1994 and last updated in 2016. The Act applies to the obtainment of offshore materials and deals with 2 related matters:
  - Setting up a licensing system for mining and exploration in particular offshore areas
  - Applying State laws to those offshore areas so far as those laws concern mining and exploration activities

- The **Mining Act 1978. Version 09-b0-00 Onshore mineral legislation** (responsible states and territories) - Western Australia, updated in 2020. Defines the procedures and how mining is handled in the state, miners' rights and permits, tenements, licences, mining lease, and registration.

- **Environmental Protection Act 1986. Onshore mineral legislation** (responsible states and territories) - Western Australia, updated in 2021. To protect the environment of the State, having the principles of:
  - Precautionary principle
  - Intergenerational principle
  - Conservation of biological diversity and ecological integrity
  - Principles relating to improved evaluation, pricing and incentive mechanisms
  - Principle of waste minimisation

- **Dangerous Goods Safety Act 2004. Onshore mineral legislation** (responsible states and territories) - Western Australia, updated in 2021. Defines the general duties as to dangerous goods, regulations and codes of practice, exemptions, administrative issues, investigation, audits, legal proceedings, etc.

- **Mines Safety and Inspection Levy Regulations 2010**. Onshore mineral legislation (responsible states and territories) - Western Australia, updated in 2020. A levy is imposed if it exceeds the number of assessed hours in each quarter. (i.e. 5000 h). This law defines who pays, the amount etc.

- **Mines Safety and Inspection Act 1994**. Onshore mineral legislation (responsible states and territories) - Western Australia, updated in 2020. Defines the requirements regarding administration, management of mines, general safety requirements, electricity requirements, explosives, ventilation and control of dust, or radiation safety.

4.1.12 National legislation: Japan

Japan is the main producer of nickel oxides and hydroxides. 44% of the material comes from this country (see Table 1). Hereafter the main regulations of this material, focused on preventing pollution and health problems to the workers and citizens, are indicated:

- **The Mining Act (Act No. 289 of 1950).** (Government of Japan, 1950) Its aim is to provide a basis for a system of mining which can contribute to improvement of public welfare through the development of mineral resources in a reasonable manner. It defines the rights to prospect and extract mineral resources.
  This regulation came into force in 1950 but it was amended in 2012. The amendment act provides different procedures depending on three categories of Specified Minerals:
  - Hydrothermal polymetallic ores on or below the ocean floor (gold copper, lead, bismuth, tin, antimony, zinc, iron, iron sulphide, manganese, tungsten, molybdenum, nickel, cobalt, uranium, thorium, and barite)
  - Sedimentary deposit ores on or below the ocean floor (copper, lead, zinc, iron, manganese, tungsten, molybdenum, nickel and cobalt)
  - Asphalt

- **The Mine Safety Act (Act No 70 of 1949).** This regulation that has not been translated from the Japanese language was introduced in 1949. It was developed to prevent injuries to employees during the extraction of the raw materials and the mining pollution.

- **Act on Special Measures for Pollution caused by the metal mining industry (Act No 26 of 1973).** Although it is similar to The Mine Safety Act (Act No 70 of 1949), this regulation aims to prevent pollution in the environment caused by the metal mining businesses.

- **Industrial Safety and Health Law (ISHL) (Act No 57 of 1972).** (Government of Japan, 1972) ISHL is one of the main laws for implementing GHS in Japan. ISHL designates substances that are prohibited to manufacture or import, substances requiring permission and chemical substances requiring safety data sheets and labels. It also controls new substances and requires manufacturers and importers to notify them to the Ministry of Health, Labour and Welfare (MHLW) prior to production and importation.

- **Chemical Substance Control Law (CSCL) (Act No. 117 of 1973).** (Government of Japan, 1973) Although this law came into force during 1973, it was updated in the Act No 53 of 2017. The main objective of this law is to prevent environmental pollution caused by persistent chemical substances that pose a risk of impairing human health or interfering with the inhabitation and/or growth of flora and fauna. To achieve this objective, the law indicates that a preliminary evaluation of new chemical substances and notification of the quantity of manufacture or import of chemical substances after marketing are required. In addition, the regulations with respect to the manufacture, import permission, usage restrictions, etc., are needed due to the properties of the chemical substance.

- **The air pollution Act (Act No 97 of 1968).** (Government of Japan, 1968) The aim of this regulation is to protect the health of citizens and to protect the living environment from air pollution by controlling emissions, etc., of soot and smoke, volatile organic compounds, particulates, and mercury associated with the business activities of factories and workplace and by setting maximum permissible limits for

automobile exhaust. Business operators having facilities that emit soot and smoke, volatile organic compounds, particulates, and mercury, etc. in the atmosphere need to notify and have a duty to measure the concentration of soot and smoke and volatile organic compounds. Although this regulation comes from 1968, it was updated in 2006.

- **The water pollution prevention Act (Act No 138 of 1970).** The purpose of this Act, which has not been translated from Japanese, is to protect public health and preserve living conditions, by regulating effluent discharged by factories and workplaces into areas of public waters and the permeation of effluent underground. To emit water into public waters, business operators are required to notify and have a duty to implement the examination of water. In 2016 this Act was updated by Act No 47 of 2016. (Government of Japan, 2016)

- **The Soil contamination countermeasures Act (Act No 53 of 2002).** (Government of Japan, 2002) The purpose of this Act, amended in 2009, is to protect the health of the citizens by formulating measures to grasp the situation of soil contamination by designated hazardous substances and measures to prevent harm to human health resulting from such contamination. When facilities that used designated hazardous substances are abolished or there is a risk of harming to human health by such contamination, there is a duty to investigate, report, and prevent soil contamination.

- **The Foreign Exchange and Foreign Trade Act (Act No 228 of 1949).** (Government of Japan, 1949) This Act aims to enable proper expansion of foreign transactions and maintenance of peace and security in Japan and in the international community. In case of conducting export or import of specific kinds of goods, export/import of them to specified countries or regions, as the place of origin or shipment, etc., permission or approval from the Minister of Economy, Trade and Industry is required. When exporting, it is necessary to carry out procedures for goods that fall under the export trade control order and when importing, it is necessary to carry out procedures for goods that fall under the import trade control order. The export trade control order is listed for the target goods and technologies. Goods and technologies that can be used as raw materials for weapons, chemical weapons, and missiles, etc., are regulated.

4.1.13 National legislation: Peru

As shown in Table 1, Peru is the second producer of zinc with a proportion of 11% and it also has some lithium. Currently, the law that applies in Peru for mining is "**Ley General de Minería DECRETO LEGISLATIVO N° 109** (1992)". This Law includes everything related to the use of mineral substances from the soil and subsoil of the national territory, as well as the maritime domicile, including geothermal resources. Petroleum and analogous hydrocarbons, guano deposits and mineral-medicinal waters are excepted from the scope of this Law. Recently, in 2020, they have developed a **draft law 6162/2020-CR**. Law for the exploitation of the strategic **mineral lithium and its derivates** in charge of the state. This law will then only apply to lithium batteries.

4.1.14 National legislation: Chile

Chile is the second producer of lithium with a proportion of 18%, 18000 tonnes 2019 (see Table 1). Regulations that apply to the mining of lithium in Chile and to Li-ion and lithium metal polymer batteries are:

- **New Mining Code 1983, Law 18.248**. In Art. 7 states that lithium is not concessible, adding in Art 9 that concessions can be given to deposits containing concessible substances, and has to notify the state if it encounters non-concessible substances in its deposit. This means that a company has to notify the state if it finds lithium.

- Law is the **Organic Constitutional Law On Mining Concessions**, in 1982 **Law 18.097.** This law granted investors the permission to explore minerals within the limits of an exploration concession, which can be secured with the payment of a nominal fee and for a 4 years period. Exploitation concessions are secured through the payment of yearly fees.
- **Decree Law 2886** (1979). This law declares Li as a state reserved mineral in order to use it for nuclear fusion at a later stage.
- **The Ministry of Mining's Supreme Decree 64** (2018). It establishes special operation contract requirements and conditions for the exploration, exploitation and processing of lithium deposits in the Salar of Maricunga salt flats and surrounding areas located in the Atacama region.

4.1.15 National legislation: Portugal

Portugal mining legislation has been included since it is the country with the highest amount of Lithium in Europe (see Table 1), with 1200 tonnes in 2019. Main legislation applying in Portugal for mining is the **Law No. 54/2015**, of 22 June 2015. This law establishes the basis of the legal regime for the disclosure and enhancement of the existing geological resources in national territory, including those located in the national maritime space, and consists in a general regime for all types of geological resources. It applies to all materials coming from geological resources and there are no differences between the different raw materials of batteries.

4.1.16 National legislation: Indonesia

Indonesia is the first producer of nickel with approximately a 24%. The main law applying in Indonesia to mining is the **Law No. 3 of 2020, the New Mining Law**, which amends the 2009 Mining Law (Law No.4 of 2009 on Mining Mineral and Coal). This law defines permitted licenses, administrative issues, fees, etc. for the extraction of minerals.
The new mining law appears to reflect the government's intention to boost mining investment in Indonesia. It establishes incentives, assurances, and benefits for mining business. Licensing process has been centralized to simplify bureaucracy and minimize conflicts between the central and local governments. This new law also includes the granting of longer terms to undertake mining business and assurances, and the assistance of the government to resolve land issues. However, some uncertainties remain, as some new concepts under the new mining law require implementing regulations to be issued (Johnson et al., 2020).

4.1.17 Other interesting European documents:

- **COM (2020) 474 final**. Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability. The objective of this communication is building on the EU's Raw Materials Initiative, and presents:
  - The EU 2020 list of critical raw materials
  - The challenges for a secure and sustainable supply of critical raw materials and actions to increase EU resilience and open strategic autonomy

This document mainly refers to lithium raw material, and then Li-ion and Li-metal polymer batteries would also be affected. It considers lithium as a critical raw material and indicates that:

- Lithium biggest supplier is Chile
- Main global producers are Chile (44%), China (39%) and Argentina (13%)
- Main EU sourcing countries: Chile (78%), United States (8%), Russia (4%)
- 0% recycled

The Commission also considers some of the materials needed to manufacture batteries to be 'critical' (e.g. cobalt or natural graphite) as they are very important to the EU economy and carry risks if supplies run low.

- **COM (2018) 293 final** Strategic Action Plan on Batteries. This communication does a special mention to raw materials and indicates that it is needed:
  - To secure access to raw materials from resource-rich countries outside the EU
  - To facilitate access to European sources of raw materials, as well as accessing secondary raw materials through recycling in a circular economy of batteries

Within this Communication, the Commission indicates that it will:

- Build on the EU list of Critical Raw Materials, established in 2017, to map the current and future primary raw materials availability for batteries
- Assess the potential within the EU for sourcing battery raw materials including Cobalt (Finland, France, Sweden, and Slovakia), Lithium (Austria, the Czech Republic, Finland, Ireland, Portugal, Spain, and Sweden), Natural Graphite (Austria, Czech Republic, Germany, Slovakia and Sweden), Nickel (Austria, Finland, France, Greece, Poland, Spain and the United Kingdom)
- Assess the potential in the whole EU for sourcing of secondary raw materials and put forward recommendations to optimize the sourcing of batteries´ raw materials
- Use all appropriate trade policy instruments to ensure fair and sustainable access to raw materials in third countries and promote socially responsible mining
- Launch a dialogue with Member States, through the Raw Materials Supply Group and the High-Level Steering Group of the European Innovation Partnership on Raw Materials (EIP Raw Materials), to determine the fitness of their raw materials policies, mining codes and incentives for exploration to address the strategic needs of materials for batteries.

4.1.18 Summary of legislations applicable to batteries regarding the raw materials used for different type of technologies

Table 3 shows a comprehensive overview of the legislations applicable to the raw materials of batteries. Most of them refer to the extraction of mining materials and are common to all batteries, while others refer to the classification and restrictions of the use of some dangerous substances (e.g. Cd, Pb).

Table 3. Summary of raw material legislations

Legislation	*Scope (International, national, regional)*	*Year that came/will come into force*	*NiZn*	*NiCd*	*Li-ion*	*Pb-acid*	*Redox flow (ZnFe, V, ZnBr)*	*Na batt. (NaS, NaNiCl)*	NiMH	Li-metal-Polymer
REACH - Regulation (EC) no 1907/2006	Europe	2006	X	X	X	X	X	X	X	X
Commission Regulation (EC) No 552/2009 amending Regulation (EC) No 1907/2006	Europe	2009	X	X	X	X	X	X	X	X
European Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures	Europe	2008	X	X	X	X	X	X	X	X
Batteries Directive 2006/66/EC	Europe	2006	X	X	X	X	X	X	X	X
Official Journal of the European Communities 88/C 30/01. Community action programme to combat environmental pollution by cadmium	Europe	1988		X						

COM (2020) 474 final. Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability	Europe	2020			X					X
Directive on Product Safety Requirements 2001/95/EC	Europe	2001	X	X	X	X	X	X	X	X
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment	Europe	2011		X		X				
COM (2018) 293 final Strategic Action Plan on Batteries	Europe	2018	X	X	X	X	X	X	X	X
Directive 2006/21/EC the management of waste from extractive industries and amending Directive 2004/35/EC	Europe	2006	X	X	X	X	X	X	X	X
PERU. Proyecto de ley 6162/2020-CR. Ley para la explotación de mineral estratégico litio y sus derivados a cargo del estado (Law for the exploitation of the strategic mineral lithium and its derivates in charge of the state)	National	-			X					X
PERU - Ley General de Minería DECRETO LEGISLATIVO N° 109	National	1992	X	X	X	X	X	X	X	X

CHILE - New Mining Code 1983, Law 18.248	National	1983			X					X
CHILE - Law is the Organic Constitutional Law On Mining Concessions, in 1982 Law 18.097	National	1982			X					X
CHILE - Decree Law 2886 (1979)	National	1979			X					X
CHILE -The Ministry of Mining's Supreme Decree 64	National	2018			X					X
PORTUGAL- Law No. 54/2015, of 22 June	National	2015	X	X	X	X	X	X	X	X
Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment	Europe	2011	X	X	X	X	X	X	X	X
DRC (Democratic Republic of Congo) - The New Mining Code.	National	2018	X	X	X	X	X	X	X	X
DRC (Democratic Republic of Congo) - Decree No. 18/24 on Mining Regulation	National	2018	X	X	X	X	X	X	X	X
DRC (Democratic Republic of Congo) - Congolese labour Code Law No. 015/2002	National	2002	X	X	X	X	X	X	X	X

OHADA law (Organisation for the Harmonisation of Business Law in Africa)	International	2012	X	X	X	X	X	X	X	X
AUSTRALIA - Offshore mineral legislation: Offshore minerals Act 1994	National	1994 (updated 2016)	X	X	X	X	X	X	X	X
AUSTRALIA- Onshore mineral legislation (responsible states and territories) - Western Australia The Mining Act 1978. Version 09-b0-00	National	2020	X	X	X	X	X	X	X	X
AUSTRALIA- Onshore mineral legislation (responsible states and territories) - Western Australia Environmental Protection Act 1986	National	2021	X	X	X	X	X	X	X	X
AUSTRALIA- Onshore mineral legislation (responsible states and territories) - Western Australia Dangerous Goods Safety Act 2004	National	2021	X	X	X	X	X	X	X	X
AUSTRALIA- Onshore mineral legislation (responsible states and territories) - Western Australia Mines Safety and Inspection Levy Regulations 2010	National	2020	X	X	X	X	X	X	X	X
AUSTRALIA- Onshore mineral legislation (responsible states and territories) - Western Australia Mines Safety and Inspection Act 1994	National	2020	X	X	X	X	X	X	X	X

CHINA - Mineral Resources Law 2009	National	1986 (updated 2009)	X	X	X	X	X	X	X	X
CHINA - Mine Safety Law 2009	National	2009	X	X	X	X	X	X	X	X
CHINA - Administrative Measures for the Block Registration of Mineral Resource Prospecting 2014	National	2014	X	X	X	X	X	X	X	X
CHINA - Administrative Measures for the Registration of Mineral Resources Exploitation 2014	National	2014	X	X	X	X	X	X	X	X
CHINA - Provisions on Administration of Mineral Resources Compensation Collection 1997	National	1997	X	X	X	X	X	X	X	X
CHINA - Environmental protection law	National	2015	X	X	X	X	X	X	X	X
CHINA - Measures for the Administration of Transfer of Mineral Exploration Rights and Mining Rights 2014	National	2014	X	X	X	X	X	X	X	X
CHINA - Labour Law 2009	National	2009	X	X	X	X	X	X	X	X
CHINA - Resource Tax Law	National	2020	X	X	X	X	X	X	X	X

INDONESIA - Law No. 3 of 2020 (the new mining law).	National	2009 (amended 2020)	X	X	X	X	X	X	X	X
JAPAN - The Mining Act (Act No. 289 of 1950)	National	1950 (amended in 2012)	X	X	X	X	X	X	X	X
JAPAN - The Mine Safety Act (Act No 70 of 1949)	National	1949	X	X	X	X	X	X	X	X
JAPAN - Act on Special Measures for Pollution caused by the metal mining industry (Act No 26 of 1973)	National	1973	X	X	X	X	X	X	X	X
JAPAN - Industrial Safety and Health Law (ISHL) (Act No 57 of 1972)	National	1972 (Amendment Act No. 25 of 2006)	X	X	X	X	X	X	X	X
JAPAN - Chemical Substance Control Law (CSCL) (Act No. 117 of 1973). Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc	National	1973 (Amendment Act No.53 of 2017)	X	X	X	X	X	X	X	X
JAPAN - The air pollution Act (Act No 97 of 1968)	National	1968 (Amendment Act No.5 of 2006)	X	X	X	X	X	X	X	X

JAPAN - The water pollution prevention Act (Act No 138 of 1970)	National	1970 (Amendment Act No.47 of 2016)	X	X	X	X	X	X	X	X
JAPAN - the Soil contamination countermeasures Act (Act No 53 of 2002)	National	2002 (Amendment Act No.23 of 2009)	X	X	X	X	X	X	X	X
JAPAN - The Foreign Exchange and Foreign Trade Act (Act No 228 of 1949)	National	1949 (Amendment Act No.102 of 2005, new amendment on 2020)	X	X	X	X	X	X	X	X

4.2 Legislations applicable to batteries regarding their manufacturing

The scope of the present section is to identify possible legislations applicable to the process of battery manufacturing, independently of the battery technology considered, focused on regional scenario for Sunergy company (with headquarters in France), manufacturer of NiZn battery cells. However, there are no regulations or directives found at national level (France), neither at international level nor at European level. It is worth to mention that some of the legislations applicable to batteries regarding its use, consider the manufacturing process as the final packing process with a correct labelling.

Regarding the labelling of the batteries, the directive (2006/66/EC) forces to implement an additional label apart from the CE (Conformité Européenne: European Conformity) marking. All the batteries and accumulators must have a mark with the following symbol (see Figure 14**Error! Reference source not found.**) in the battery or in the packaging.

Figure 14. Symbol to label the batteries according to directive 2006/66/EC

Regarding the composition of heavy metals of the batteries, they are not allowed to contain more than 0.0005% of mercury by weight; and portable batteries not more than 0.002% of cadmium by weight. Exceptions are emergency and alarm systems, emergency lighting and medical equipment.

If batteries contain more than 0.0005% mercury, more than 0.002% cadmium or more than 0.004% lead, they must have an extra labelling and must be marked, below the crossed-out dustbin sign, with the chemical symbol for the metal concerned: Hg, Cd or Pb.

Directive 2006/66/EC can be applied to all the batteries, regarding at least the obligation to have specific labelling:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- Pb-acid batteries
- Na based batteries
- NiMH
- NiCd
- NiZn
- Flow batteries

4.3 Legislations applicable to batteries regarding their storage

The scope of this section is to determine the conditions and restrictions that warehouses should fulfil according to the current legislations in order to store batteries and any related hazardous material in a safe way.

The legislation analysed in this project covers on the one hand the European framework and on the other hand the French legislation. Since Sunergy is the manufacturer of NiZn battery cells and its headquarters are in France, French legislation has been chosen instead any other national one.

Hereafter the most relevant documents have been identified:

4.3.1 Directive 2012/18/EU of the European Parliament and of the Council

This Directive (European Commission, 2012), also known as SEVESO, lays down rules for prevention of major accidents involving dangerous substances, and limitation of their consequences for human health and the environment, with a view to ensure a high level of protection throughout the Union in a consistent and effective manner. It underlines the need to ensure that appropriate precautionary action is taken to ensure a high level of protection throughout the Union for citizens, communities, and the environment. Most of the hazards related to the components included in batteries are related to human health (e.g. toxicity, corrosion (e.g. H_2SO_4)) and the environment; see Table 2. Table 4 shows for the different hazard categories, the qualifying limit quantities for the application of this regulation for lower-tier and upper-tier. In addition, Part 2 of Annex 1 defines the qualifying limits for some specific substances. The qualifying limits for the storage of nickel compounds in a powder form, can be seen in Table 5.

Storage establishments are classified into low-tier and upper-tier:

- In 'lower-tier establishment', dangerous substances are present in quantities equal to or in excess of the quantities listed in Column 2 of Table 4 but less than the quantities listed in Column 3 of Table 4. When there is more than one substance, this Directive is applicable if the following summation rule is met:

$$q_1/Q_{L1} + q_2/Q_{L2} + q_3/Q_{L3} + \cdots \geq 1$$

  Where:
  - q_x is the quantity of dangerous substance x (or category of dangerous substances).
  - Q_{LX} is the relevant qualifying quantity for dangerous substance or category x from Column 2.
- In 'upper-tier establishment', dangerous substances are present in quantities equal to or in excess of the quantities listed in Column 3 of Table 4. When there is more than one substance, this Directive is applicable if the following summation rule is met:

$$q_1/Q_{U1} + q_2/Q_{U2} + q_3/Q_{U3} + \cdots \geq 1$$

  Where:
  - q_x is the quantity of dangerous substance x (or category of dangerous substances).
  - Q_{UX} is the relevant qualifying quantity for dangerous substance or category x from Column 3.

Table 4.General categories and limits of classification for the application of lower-tier and upper-tier requirements

Column 1	Column 2	Column 3
Hazard categories in accordance with Regulation (EC) No 1272/2008	**Qualifying quantity (tonnes) of dangerous substances as referred to in Article 3(10) for the application of**	
	Lower-tier requirements	**Upper-tier requirements**
Section 'H' – HEALTH HAZARDS		
H1 ACUTE TOXIC Category 1, all exposure routes	5	20
H2 ACUTE TOXIC — Category 2, all exposure routes — Category 3, inhalation exposure route (see note 7)	50	200
H3 STOT SPECIFIC TARGET ORGAN TOXICITY – SINGLE EXPOSURE STOT SE Category 1	50	200
Section 'E' – ENVIRONMENTAL HAZARDS		
E1 Hazardous to the Aquatic Environment in Category Acute 1 or Chronic 1	100	200
E2 Hazardous to the Aquatic Environment in Category Chronic 2	200	500

Table 5. Dangerous goods related to batteries and associated qualifying limits for lower-tier and upper-tier requirements

Column 1	Column 2	Column 3
Hazard categories in accordance with Regulation (EC) No 1272/2008	Qualifying quantity (tonnes) of dangerous substances as referred to in Article 3(10) for the application of	
	Lower-tier requirements	Upper-tier requirements
Nickel compounds in inhalable powder form: nickel monoxide, nickel dioxide, nickel sulphide, trinickel disulphide, dinickel trioxide		1

4.3.2 European Regulation (EC) No 1272/2008

This regulation has already been explained in section 4.1.2. It has been included as a regulation that applies to the storage process in the way that the classification of the substances has a direct effect on the layout of the warehouse and then on the position of each substance inside the warehouse, the safety requirements, the incompatibilities between products and the design of the warehouse. As mentioned in the raw materials section, this regulation aims to achieve a high level of protection of human health and the environment by harmonising the rules on labelling and packaging for hazardous substances and mixtures.

4.3.3 French legislation

4.3.3.1 Arrêté du 27 mars 2012 - Stockage des déchets dangereux

This French document (Journal officiel de la République française (JORF), 2012) legislates the storage of hazardous waste. Installations classified for the protection of the environment and subject to declaration under heading No. 2710-1 (10715) "Installation for the collection of waste brought in by the initial producer of this waste, collection of hazardous waste" are subject to the provisions of Annex I. Some of the provisions that have to be accomplished include:

- The installation must be set up, built and operated in accordance with the plans and other documents attached to the declaration and must be periodically controlled to verify the compliance of the installation with its requirements.
- Hazardous waste must be stored in specific dedicated premises, sheltered from bad weather, with the exception of oils, lamps, ink cartridges, waste electrical and electronic equipment and batteries.
- The smoke extraction system must be adapted to the particular risks of the installation.

This legislation sets the warehouse requirements in terms of fire resistance of the structure, walls, floors, roof, etc. This legislation would apply mainly to the storage of dangerous waste coming from raw materials or the manufacturing process. In the case of batteries, they become waste as soon as the owner decides that wants to discard it, and therefore the storage of a battery until its treatment is done in the same way as of a new battery.

4.3.3.2 Arrêté du 4 octobre 2010 relatif à la prévention des risques accidentels au sein des installations classées pour la protection de l'environnement soumises à autorisation

This generic French legislation (Journal officiel de la République française (JORF), 2010), refers to the provisions related to the prevention of risks linked to materials in cylindrical overhead tanks, pipes or when stored big volumes, and also applicable to retention basins put in place to prevent accidents. Therefore, this regulation

would mainly apply to the storage of some substances or components needed for the manufacturing of the batteries and not for the storage of finished batteries. In the case of the aging of material stored in cylindrical overhead tanks, application of this legislation depends on the hazard statement and the volume of the tank. For example, focusing on substances used in batteries, nickel has the hazard H351: in this case, tanks with a volume higher than 100 m³ would be subjected to this legislation. Table 6 indicates the quantities over which the provisions set in the legislation apply to vertical cylindrical overhead tanks with some of the components present in batteries, and for which the hazards have been defined in Table 2.

Table 6. Components of batteries and storage quantities above which the provisions set in Order of 4 October 2010 relating to the prevention of accidental risks in classified installations for the protection of the environment subject to authorization (NOR: DEVP1025930A) apply.

Name – International Chemical Identification	Hazard statement code	Stored quantity limits to which provision of this legislation apply (m3)
Nickel	H351 H317	>100
Nickel dihydroxide	H351 H332 H302 H317 H400 H410	>10
Cadmium (non-pyrophoric); cadmium oxide (non-pyrophoric)	H350 H341 H361fd H330 H372 H400 H410	>10
lead powder; [particle diameter < 1 mm]	H360FD H362	>100
lead massive: [particle diameter ≥ 1 mm]	H360FD H362	>100
Lead compounds with the exception of those specified elsewhere in this Annex	H360-Df H332 H302 H373 H400 H410	>10
Lithium	H260 H314	-
Zinc powder — zinc dust (stabilized)	H400 H410	>10
zinc powder — zinc dust (pyrophoric)	H260 H250 H400 H410	>10
Zinc oxide	H400 H410	>10
Cobalt	H334 H317 H413	-

4.3.3.3 Other generic French legislations

The following legislation documents are specific to France for a safe storage in any kind of industry:

- Code du travail. Articles R. 4412-1 à R 4412-164 règles générales de prévention du risque chimique
- Code du travail. Articles R. 4422-1 à R 4422-26 aération et assainissement des locaux. Création Décret n°2008-244 du 7 mars 2008
- Décret no 2009-1570 du 15 décembre 2009 relatif au contrôle du risque chimique sur les lieux de travail
- Code du travail, articles R 4227-1 à R 4227-41 prévention des incendies, évacuation. Création Décret n°2008-244 du 7 mars 2008
- Décret 88-1056 du 14 november 1988 (modifié par décret 95-608 du 6 mai 1995) relatif aux installations électriques (brochure INRS ED 723, 1993)
- Code du travail, articles R4227-42 à R4227-54 (prévention des explosions). Création Décret n°2008-244 du 7 mars 2008

4.3.4 Summary of legislations applicable to batteries regarding the storage for different type of technologies

Table 7 shows a comprehensive overview of the legislations applicable to the storage of batteries and some of their raw materials. French legislations shown are general legislations regarding the storage and not specific for batteries.

Table 7. Summary of storage legislations applicable to the battery industry

Legislation	*Scope (International, national, regional)*	*Year that came/will come into force*	*NiZn*	*NiCd*	*Li-ion*	*Pb-acid*	*Redox flow (ZnFe, V, ZnBr)*	*Na batt. (NaS, NaNiCl)*	NiMH	Li-metal-Polymer
European Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006	Europe	2008	X	X	X	X	X	X	X	X
Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC	Europe	2012	X	X	X				X	
Code du travail. Articles R. 4412-1 à R 4412-164 règles générales de prévention du risque chimique	France	2009	X	X	X	X	X	X	X	X
Code du travail. Articles R. 4422-1 à R 4422-26 aération et assainissement des locaux. Création Décret n°2008-244 du 7 mars 2008	France	2008	X	X	X	X	X	X	X	X
Décret no 2009-1570 du 15 décembre 2009 relatif au contrôle du risque chimique sur les lieux de travail	France	2009	X	X	X	X	X	X	X	X

Code du travail, articles R 4227-1 à R 4227-41 prévention des incendies, évacuation. Création Décret n°2008-244 du 7 mars 2008	France	2008	X	X	X	X	X	X	X	X
Décret 88-1056 du 14 november 1988 (modifié par décret 95-608 du 6 mai 1995) relatif aux installations électriques (brochure INRS ED 723, 1993)	France	1988	X	X	X	X	X	X	X	X
Code du travail, articles R4227-42 à R4227-54 (prévention des explosions). Création Décret n°2008-244 du 7 mars 2008	France	2008	X	X	X	X	X	X	X	X
Arrêté du 27 mars 2012 - Stockage des déchets dangereux	France	2012	X	X	X	X	X	X	X	X
Arrêté du 4 octobre 2010 relatif à la prévention des risques accidentels au sein des installations classées pour la protection de l'environnement soumises à autorisation, abrogeant l'arrêté du 2 février 1998	France	2010	X	X	X	X	X	X	X	X

4.4 Worldwide Legislations applicable to batteries regarding their transport

The scope of this section is to analyse the current legislations applicable to the transport of batteries and related components. Legislation search for this life stage of the product is focused on the international legislations, since the transport of the battery and its raw materials is worldwide.

Hereafter, the most relevant documents have been identified:

4.4.1 Inland transport

4.4.1.1 Directive 2008/68/EC of the European Parliament and of the council of 24 September 2008 on the inland transport of dangerous goods

Directive 2008/68/EC (European Union, 2008) applies to the transport of dangerous goods by road (ADR (Accord Dangereux Routier) regulation in Annex I), by rail (RID regulation (Regulations concerning the International Carriage of Dangerous Goods by Rail) in Annex II) or by inland waterway (ADN regulation (European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways) in Annex III) within or between European Member States, including the activities of loading and unloading, the transfer to or from another mode of transport and the stops required by the circumstances of the transport.

- Annex I: Transport by road (ADR regulation - Annexes A and B)
- Annex II: Transport by rail (RID regulation - Annex to the RID, appearing in Appendix C to the COTIF - Convention concerning International Carriage by Rail)
- Annex III: Transport by inland waterway (ADN regulation - Annexed Regulations to the ADN, as well as Articles 3(f), 3(h), 8(1), 8(3) of the ADN)

4.4.1.2 Code of federal regulations Title 49 (CFR49) (US) for the transport of dangerous goods by road

It is an international legislation developed in the United States in October 2012 (National Archives and Records Administration, 2012). This code provides the reportable quantity (RQ) in kilograms for a list of elements and compounds that are hazardous substances. Among the whole list, it could be highlighted the following main products linked with the production of batteries:

- Nickel: 45.4 kilograms
- Lead: 4.54 kilograms
- Zinc: 454 kilograms

In addition to specific legislation for raw materials, there are also specific requirements for transporting lithium batteries. These requirements differ if they are primary lithium batteries or cells or prototype lithium batteries or cells.

- **Primary lithium batteries and cells** are not the focus of this document since we are focusing on rechargeable storage batteries. However, just as an example, some restrictions to this type of battery include: forbidden for transportation aboard passenger-carrying aircrafts, or when transported aboard cargo-only aircraft, packages containing primary lithium batteries and cells should be transported in accordance with Special Provision A45 and must be marked with ‘‘primary lithium batteries— forbidden for transport aboard passenger aircraft’’ or ‘‘lithium metal batteries— forbidden for transport aboard passenger aircraft’’(marking that it is not required on packages that contain 5 kg net weight or less of primary lithium batteries or cells that are contained in or packed with equipment). Lithium contents per cell and battery are also restricted in lithium metal cell or batteries, with not more than 1.0 g per cell and

not more than 2.0 g per battery; and in lithium-ion cells or batteries, the equivalent lithium content is not more than 1.5 g per cell and not more than 8 g per battery.
The cells and batteries are transported in an outer packaging that is a metal, plastic or plywood drum or metal, plastic or wooden box that meets the criteria for Packing Group I packaging. Each cell or battery is individually packed in an inner packaging inside an outer packaging and is surrounded by cushioning material that is non-combustible, and non- conductive.

- **Prototype lithium batteries and cells** are forbidden for transport aboard passenger aircraft and must be approved by the Associate Administrator prior to transportation aboard cargo aircraft, in accordance with the requirements of Special Provision A55.

4.4.1.3 IMDG Code. Edition 2020, 2018 and 2016

The International Maritime Dangerous Goods (IMDG) code (España. Ministerio de Asuntos Exteriores y Cooperación., 2018) provides instructions for the safe carriage of dangerous goods by sea. This international regulation is updated every two years to reflect biennial revisions in the United Nations (UN) Recommendations on the Transport of Dangerous Goods (UN Model Regulations).

All dangerous goods are uniquely identified for transport by UN Numbers and Proper Shipping Names (PSNs). The UN Number and PSN facilitate rapid and precise identification during transport to ensure correct handling, stowage, segregation etc., and appropriate actions in case of an emergency.

Currently, the codes focus on the regulation of lithium batteries (lithium metal batteries (UN Nº 3090), lithium metal batteries installed in an equipment (UN Nº 3091), Li-ion batteries (including polymeric Li-ion batteries) (UN Nº 3480), Li-ion installed in an equipment (UN Nº 3481), and installed in a transport unit (UN Nº 3536)), nickel metal hydride batteries (UN Nº 3496), wet acid filled electric batteries also known as electric accumulators (UN Nº 2794) (e.g. lead acid), sulphuric acid used as acid electrolyte in batteries with a concentration lower than 51% (UN Nº 2796), wet batteries with alkaline electrolyte (electric accumulator) (UN Nº 2795), in which NiZn batteries would be included, alkaline electrolyte for electric batteries (UN Nº 2797), dry electric batteries with solid potassium hydroxide (electric accumulator) (UN Nº 3028) and batteries which contain sodium (UN Nº 3292). The code establishes instructions and some dispositions for the transport, segregation, and for its stowage and manipulation. Acid and alkaline batteries are classified as class 8, corrosive, lithium batteries are classified as 9, other risks. Sodium batteries main hazard is that they can react dangerously with water (class 4.3).

There is no specific code and requirement for NiZn batteries. Therefore, the code that will apply is 2795, wet batteries with alkaline electrolyte (electric accumulator). Table 8 shows the codes for each type of batteries and the codes for the package instructions, the stowage and manipulation and of special dispositions. The code establishes also some dispositions regarding limited and excepted quantities.

Table 8. UN codes, stowage and manipulation categories, segregation categories and special dispositions and packaging instructions for the transport of electrochemical batteries.

Battery type	*Electrolyte*	UN No	Stowage and manipulation	Segregation	EmS[10]	Special dispositions[11]	Packaging instructions
NiZn	KOH	2795	Category A SW16[12]	SG35[13]	F-A, S-B	295	P801
NiCd	KOH	2795	Category A SW16	SG35	F-A, S-B	295	P801
Lithium metal battery	Dry (solid) polymer	3090, 3091 (if they go inside an equipment)	Category A SW19[14]	-	F-A, S-I	188 230 310 360[15] 376 377 384	P903 P908 P909 P910 LP903 LP904
Li-ion	Lithium salt with organic solvent	3480, 3481 (if they go inside an equipment)	Category A SW19	-	F-A, S-I	188 230 310 348 360[15] 376 377 384	P903 P908 P909 P910 LP903 LP904
Pb-acid	H_2SO_4	2794	Category A SW16	-	F-A, S-B	295	P801
Redox flow (ZnFe, V, ZnBr)	Aqueous and non-aqueous solvents (organic electrolyte)	Not subject to IMDG					

[10] Corresponding emergency sheets against fire (F code) and spills (S code) of the "Guide on emergency sheets: Emergency intervention procedures for ships carrying dangerous goods (EmS guide)"
[11] Defined in chapter 3.3. of the IMDG code
[12] SW16: In the case of unit loads that go in open transport units, stowage category B.
[13] SG35: Stow "separate from" acids.
[14] SW19: In the case of batteries transported in accordance with the provisions of special provisions 376 or 377, category C, unless they are transported on board ships on short international voyages.
[15] Additional disposition for 3091, 3481

Na battery (NaS, NaNiCl)	B-alumina (Al_2O_3), solid	3292	Category A H1[16]	SG26[17]	F-G, S-P	239	P408
NiMH	KOH	3496	Category A SW1[18]	-	F-A, S-I	117 963	SP963

4.4.1.4 ADR Code. Agreement concerning the International Carriage of Dangerous Goods by Road. 2021 Edition

The ADR code (United Nations, 2020) defines the conditions to transport dangerous goods by road. Article 2 defines which dangerous goods banned from carriage by Annex A shall not be accepted for international transport, and which ones need a special authorization and the compliance of some conditions in order to allow their transport. Table 9 shows the transport classification and the maximum quantities per transport unit and the special provisions and packaging instruction for the electrochemical batteries analysed. It should be noted that redox batteries and also nickel metal hydride batteries are not subjected to ADR.

Table 9. Classification codes, transport categories and dispositions according to ADR2021 for electrochemical batteries (reproduced from (United Nations, 2020))

Battery type	UN Nº	Class	Classification code	Transport category	Max. total quantity per transport unit	Special dispositions[19]	Packaging instructions	Limited/excepted quantities
NiZn	2795	8	C11	3	1000	295 598	P801	1 L / E0[20]
NiCd	2795	8	C11	3	1000	295 598	P801	1 L / E0[20]
Lithium metal battery	3090, 3091 (if they go inside an equipment)	9	M4	2	333	188 230 310 360[21] 376 387 390[20] 636	P903 P908 P909 P910 P911 LP903 LP904 LP905	0 / E0[20]

[16] H1 : Stay as dry as possible.
[17] SG26 : Likewise: in the case of goods of classes 2.1 and 3, when they are stowed on the deck of a container ship, a minimum distance of two spaces for container in the transverse direction will be maintained, and when they are stowed on ro-ro ships, a distance of 6 m in the transverse direction shall be maintained.
[18] SW1 : Protected from heat sources.
[19] Defined in chapter 3.3. of the IMDG code
[20] E0 : signifies that no exemption from the provisions of ADR exists for the dangerous goods packed in excepted quantities

[21] Additional disposition for 3091, 3481

						670[20]	LP906	
Li-ion	3480, 3481 (if they go inside an equipment)	9	M4	2	333	188 230 310 348 360[15] 376 377 387[15] 390[15] 636 670[15]	P903 P908 P909 P910 LP903 LP904 LP905 LP906	0 / E0[20]
Pb-acid	2794	8	C11	3	1000	295 598	P801	1 L / E0[20]
Redox flow (ZnFe, V, ZnBr)	Not subject to ADR							
Na batt. (NaS, NaNiCl)	3292	4.3	W3	2	333	239 295	P408	0 / E0[20]
NiMH	3496	9	M11	Not subject to ADR				

In table A of Volume I of the ADR the main restrictions for dangerous goods used in the production of the different batteries can also be found. For example, one can find the classification information, packing group and special provisions and instructions for zinc powder, which could be packaged according to 3 package groups:

- Packing group I is any substance that reacts vigorously with water at ambient temperature and generally the produced gas demonstrates generally a tendency to ignite spontaneously; or any substance that reacts readily with water at ambient temperature such that the rate of evolution of flammable gas is equal to or greater than 10 litres per kilogram of substance over one minute period.
- Packing group II is any substance which reacts readily with water at ambient temperature such that the maximum rate of evolution of flammable is equal to or greater than 20 litres per kilogram of substance per hour, and which does not meet the criteria of packing group I.
- Packing group III is any substance which reacts slowly with water at ambient temperature such that the maximum rate of evolution of flammable gas is greater than 1 litre per kilogram of substance per hour, and which does not meet the criteria of packing groups I or II.

Concerning the packing in excepted quantities, zinc has the following exceptions depending on its packing group:

- Packing group I is an E0 that is not permitted as excepted quantity
- Packing group II is an E2 that means that the maximum net quantity per inner packaging is 30 grams for solids and 30 ml for liquids and gases; and the maximum net quantity per outer packaging are 500 grams for solids and 500 ml for liquids and gases (or sum of grams and ml in case of mixed packing)
- Packing group III is an E1 that means that the maximum net quantity per inner packaging is 30 grams for solids and 30 ml for liquids and gases; and the maximum net quantity per outer packaging are 1000 grams for solids and 1000 ml for liquids and gases (or sum of grams and ml in case of mixed packing)

According to the packaging instructions, packing group I has the packaging instruction P403, group II P410, IBC07 and PP40 (special packing provision) and as special provision TP33, and group III the packing instructions P410, IBC08, R001, B4 (special packaging provision), and the special provision TP33.

When the transport includes a tunnel, specific restrictions are required:

- For packing group I the maximum total quantity is 20 kg per transport unit.
- For packing group II the maximum total quantity is 333 kg per transport unit.
- For packing group III the maximum total quantity is 10000 kg per transport unit.

Other example could be lead dioxide (class 5.1), packing group III, classification code OT2, packing instructions P002, IBC08, LP02, and B3 (special packaging provision), instruction T1 and special provision TP33. Therefore, each dangerous good used for the manufacture of batteries will have its specific instructions for packaging and transport.

4.4.2 Air transport

4.4.2.1 IATA regulations (62th edition)

The International Air Transport Association (IATA) is the trade association for the world's airlines, representing 82% of total air traffic. It supports many areas of aviation activity and helps to formulate industry policy on critical aviation issues. Similarly to IMDG and ADR, this code has for each battery type, its classification (which is the same as that in IMDG and ADR tables, Table 8 and Table 9), hazards, and maximum quantities for transport in passenger and cargo aircrafts.

In addition, some additional documentation is provided for some specific batteries: e.g. nickel-metal hydride and lithium batteries.

4.4.2.1.1 Nickel-Metal Hydride Batteries

This type of battery, labelled as UN 3496 (International Air Transport Association, 2021b), was included in the data regulation in 2014 with its 55th edition of Dangerous Goods Regulations (DGR).

These batteries may be shipped by air transport. The batteries are considered "not restricted" provided that the shipper complies with the requirements of Special Provision A199.

Nickel-metal hydride batteries or nickel-metal hydride battery-powered devices, equipment or vehicles having the potential of a dangerous evolution of heat are not subject to these Regulations provided they are prepared for transport so as to prevent:

- A short circuit (e.g. in the case of batteries, by the effective insulation of exposed terminals; or, in the case of equipment, by disconnection of the battery and protection of exposed terminals)
- Unintentional activation

4.4.2.1.2 Lithium Batteries

Lithium batteries (International Air Transport Association, 2021a) are classified in Class 9 – Miscellaneous dangerous goods as:

- UN 3090, Lithium metal batteries; or

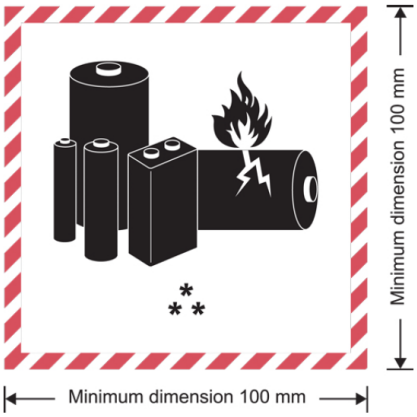
- UN 3480, Lithium-ion batteries

Lithium metal and lithium-ion batteries are forbidden for transport as cargo on passenger aircraft. In addition, their state of charge should not exceed the 30% of their rated capacity.

During the transport of batteries and battery-powered equipment, special attention should be paid to the short-circuit of the battery as a result of the battery terminals coming into contact with other batteries, metal objects, or conductive surfaces. Therefore, batteries must be packed in a strong rigid outer packaging and cells must be separated in a way to prevent short circuits and damage to terminals with the following methods:

- Packing each battery or each battery-powered device in a fully enclosed inner packaging made of a non-conductive material (such as a plastic bag)
- Separating or packing batteries in a manner to prevent contact with other batteries, devices or conductive materials (e.g. metal) in the packaging
- Ensuring exposed terminals or connectors are protected with non-conductive caps, non-conductive tape, or by other appropriate means

The batteries must be marked as shown in Figure 15.



* Place for UN number(s), i.e. UN 3090, UN 3091, UN 3480 and/or UN 3481, as applicable. The UN number(s) indicated on the mark should be at least 12 mm high.
** Place for telephone number

Figure 15. Mark for lithium batteries (International Air Transport Association, 2021a)

The maximum weight is 5 kg of lithium batteries per package for passenger and cargo aircraft and 35 kg of lithium batteries per package for cargo aircraft only. The net quantity shown excludes the weight of the equipment.

4.4.2.2 Technical Instructions for the Safe Transport of Dangerous Good by Air Doc. 9284. International Civil Aviation Organization (ICAO). Ed 2021-2022

Although the Technical Instructions for the Safe Transport of Dangerous Good by Air Doc. 9284 is an international legislation, each country transforms it into a regulation/directive. In Spain, the regulation is published in the BOE in December 2020 with the title “Resolución de 10 de diciembre de 2020, de la Dirección General de Aviación Civil, por la que se publican las Instrucciones Técnicas para el transporte seguro de mercancías peligrosas por vía aérea (Documento OACI 9284/ AN/905), edición 2021-2022” (Ministerio de Transportes, 2020).

The batteries legislated in this regulation are lithium batteries, nickel-metal hydride batteries, and wet and dry batteries. Their requirements and packaging instructions are similar to the ones that are provided in the IATA

legislation. Table 10 shows the special dispositions and packaging instruction codes for the transport by air for different types of batteries.

Among these types of batteries, special attention is given to lithium batteries, with a special section for them (9.3.). Some instructions mention that lithium metal or lithium-ion cells or batteries must be individually protected in such a way that short circuits do not occur when they are not used.

Table 10. Special dispositions and packaging instructions for the transport of batteries by air

Battery type	Nº UN	Class	Special dispositions	Passengers + cargo aircrafts		Cargo aircrafts		State discrepancies
				Packaging instructions	*Max. quantity per parcel*	Packaging instructions	*Max. quantity per parcel*	
NiZn	2795	8	A51 A164 A183	870	30 kg	870	Without limitation	-
NiCd	2795	8	A51 A164 A183	870	30 kg	870	Without limitation	-
Lithium metal battery	3090, 3091 (if they go inside or with an equipment)	9	A48 (UN3091) A88 A99 A154 A164 A181 (UN3091) A183 (UN3090) A185 (un3091) A201 (UN3090) A206 A213	Prohibited (UN3090) 969 (UN3091 - packaged with the equipment, 970 (UN3091 – installed in the equipment)	Prohibited (UN3090) 5 kg (UN3091)	968 (UN3090) 969 (UN3091 - packaged with the equipment), 970 (UN3091 – installed in the equipment)	35 kg (UN3091)	US 2 US 3
Li-ion	3480, 3481 (if they go inside or with an equipment)	9	A48 (UN3481) A88 A99 A154 A164 A181 (UN3481) A183 (UN3480) A185 (UN3481) A201 (UN3480) A206 A213	Prohibited (UN 3480) 966 (UN 3481- packaged with the equipment) 967 (UN3481 – installed in the equipment)	5 kg (UN 3481)	965 (UN 3480) 966 (UN 3481- packaged with the equipment) 967 (UN3481 – installed in the equipment)	35 kg (UN 3481)	US 3

Pb-acid	2794	8	A51 A164 A183	870	30 kg	870	Without limitation	-
Redox flow (ZnFe, V, ZnBr)	Not subject to ICAO							
Na batteries (NaS, NaNiCl)	3292	4.3	A94 A183	Prohibited		492	Without limitation	-
NiMH	3496	9	A199	See Part 3;3, A199[22]				

4.4.2.3 Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council

Generic regulation that lays down detailed rules for commercial air transport operations with aeroplanes and helicopters, including ramp inspections of aircraft of operators under the safety oversight of another State when landed at aerodromes located in the territory subject to the provisions of the Treaty.

This Regulation (European Union, 2012) also lays down detailed rules on the conditions for issuing, maintaining, amending, limiting, suspending or revoking the certificates of operators of aircraft engaged in commercial air transport operations, the privileges and responsibilities of the holders of certificates as well as conditions under which operations shall be prohibited, limited or subject to certain conditions in the interest of safety.

In addition, lays down detailed rules for non-commercial operations and the conditions and procedures for the declaration by and for the oversight of operators engaged in the non-commercial operation of complex motor-powered aircraft.

[22] A199: Nickel-metal hydride batteries or devices, equipment or vehicles powered by these batteries that can produce a dangerous emission of heat are not subject to these Instructions provided they are prepared for transport in such a way as to avoid: a) short circuit (eg, in the case of batteries, by effectively isolating exposed terminals or, in the case of equipment, by disconnecting the battery and protecting exposed terminals); and b) accidental activation. When an air waybill is issued, the term "Unrestricted" and the special provision number A199 must be included in it.

4.4.2.4 Regulation (EU) 2018/1139

The principal objective of this European Regulation is to establish and maintain a high uniform level of civil aviation safety in the Union (European Parliament and Council, 2018).

It contributes to facilitate, in the fields covered by this Regulation, the free movement of goods, persons, services and capital, providing a level playing field for all actors in the internal aviation market, and improve the competitiveness of the Union's aviation industry. In addition, it promotes, worldwide, the views of the Union regarding civil aviation standards and civil aviation rules, by establishing appropriate cooperation with third countries and international organisations.

This regulation is generic and does not pay special attention to either batteries or raw materials.

4.4.3 Summary of legislation applicable to batteries regarding their transport for different type of technologies

Table 11 shows a comprehensive overview of the legislations applicable to the transport of batteries.

Table 11. Summary of transport legislation applicable to the battery industry

Legislation	*Scope (International, national, regional)*	*Year that came/will come into force*	*NiZn*	*NiCd*	*Li-ion*	*Pb-acid*	*Redox flow(ZnFe, V, ZnBr)*	*Na batteries (NaS, NaNiCl)*	NiMH	Li-metal-Polym.
Directive 2008/68/CE of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods (Text with EEA relevance) ADR Code. Agreement concerning the International Carriage of Dangerous Goods by Road. 2021 Edition (ECE/TRANS/300, Vol.I and II and Corr.1 and Corr.2	International	Into force 1 January 2021 (mandatory compliance 1 July 2021)	X	X	X	X	X	X	X	X
CFR49 (US) for the transport of dangerous goods by road	International	2014	X	X	X	X	X	X	X	X
IMDG Code, 2020 Edition	International	1 June 2022 (voluntary 1 January 2021)	X	X	X	X	X	X	X	X
IMDG Code, 2018 Edition	International	1 January 2020	X	X	X	X	X	X	X	X
IATA 62th Edition	International	2021	X	X	X	X	X	X	X	X
Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency	Europe	2018	X	X	X	X	X	X	X	X
Technical Instructions for the Safe Transport of Dangerous Good by Air Doc. 9284. International Civil Aviation Organization (ICAO). Ed 2021-2022	International	2021	X	X	X	X	X	X	X	X

(Each country transforms it into a regulation/directive)										
European Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006	Europe	2008	X	X	X	X	X	X	X	X
Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council	Europe	2012 (last version 2020)	X	X	X	X	X	X	X	X

4.5 Legislations applicable to batteries regarding their use

The scope of the present section is to identify possible legislations applicable to the process of battery use, independently of the battery technology considered. The analysis is done at both European and International Level. Then, European regulations are adjusted/transposed in each European country as a national/regional regulation. France adjusts European regulations with the following extractions from their legislation:

- **Section 7 – Chapter III – Title IV of Book V** of the regulatory part of the Environmental Code.
- **Decree No 2015-849 of 2015** regarding the marketing batteries and accumulators and collecting and processing of used batteries.
- **Order of 26 October 2011** amending Order of 9 November of 2009 related to transit, grouping, selective waste collection and accumulators pursuant to Article R.543-131 of Chapter III of Title IV of Book V of the regulatory part of the Environmental Code.
- **Order to 6 August 2015** amending Order of 18 November 2009 on registering and declaring batteries and accumulators on the national register pursuant to Article R.543-132 of the Environmental Code.
- **Order of 6 August 2015** repealing Order of 6 August 2009 (amended) setting the scenarios and conditions in which the obligations in terms of amounts of cadmium in portable batteries and accumulators do not apply, under Article R.543-126 of Chapter III of Title IV of Book V of the regulatory part of the Environmental Code.
- **Order of 10 August 2015** concerning the approval procedure and specifications of the eco-bodies of the procedure of the waste of portable batteries and accumulators under Articles R.543-128-3 and R.543-128-4 of the Environmental Code.
- **Order of 20 August 2015** concerning the approval procedure and specifications of the individual systems of the procedure of the waste of portable batteries and accumulators under Articles R.543-128-3 and R.543-128-4 of the Environmental Code.

In each directive or regulation presented, firstly the general scope of the specific legislation is described. Then, the issues that can be applied to the field of batteries (either at the level of composition of internal elements, operating ranges, or at the level of auxiliary elements that make up, for example, the battery packs) are mentioned. Lastly, a review is made of the electrochemical energy storage technologies in which the mentioned regulations or directives apply.

4.5.1 Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators

Directive 2006/66/EC is the actual principal regulation for batteries in Europe. The main objective of this directive is to minimise the environmental impact of the batteries.

This directive divides the batteries by defining three main applications for them:

- Portable battery (sealed, portable and no automotive oriented and no industrial oriented)
- Automotive battery (starter/ignition batteries)
- Industrial battery (including batteries for EV)

The following aspects are regulated by means of this directive:

- Labelling of the batteries (see section, 4.2)
- Presence of heavy metals (see section 4.1)
- End-of-Life of portable equipment (collection rates and disposal) (see section 4.6)
- Treatment of the batteries at the End-of-Life (see section 4.6)
- Recycling process (see section 4.6)

This directive can be applied to all the batteries, regarding at least the obligation to have specific labelling:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- Pb-acid batteries
- Na based batteries
- NiMH
- NiCd
- NiZn
- Flow batteries

There are two main modifications to this Batteries Directive:

- **Directive 2008/103/EC**

It is an amendment to the directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators regarding placing batteries and accumulators on the market. The article 6(2) of Directive 2006/66/EC needed to be clarified in order that batteries and accumulators which were legally placed on the market anywhere in the EU before 26 September 2008 and which do not comply with that Directive can still remain on sale in the EU after this date.

- **Directive 2013/56/EU**

It is an amendment to Directive 2006/66/EC. It extends the ban on the placing on the market of portable batteries and accumulators containing cadmium to portable batteries and accumulators intended for use in cordless power tools. These batteries previously benefitted from an exemption. However, this exemption is removed by the 2013 Directive.
The 2013 Directive also prohibits the marketing of button cells with a mercury content of less than 2% by weight. These button cells had previously an exemption that has been removed by the 2013 Directive. The ban is applied in 2015.

Batteries placed on the market for the first time prior to the respective bans can still be sold until stocks are exhausted.

There are three *Commission Decisions* and regulations to establish different specific aspects, pursuant to Directive 2006/66/EC:

- **Commission Decision 2008/763/EC**

Commission Decision of year 2008, establishing a calculation methodology for the annual sales of portable batteries and accumulators to end-users. This methodology is based on the calculation of the annual sales in a given year bearing in mind the weight of portable batteries and accumulators placed in the EU market (in the given year), and excluding the ones that have left the EU's territory in that year before being sold to the end-users.

- **Commission Decision 2009/851/EC**

This Decision establishes the questionnaire to be followed by the EU members to fill their reports concerning the implementation of Directive 2006/66/EC.

- **Commission Regulation (EU) No 493/2012**

This regulation detailed rules regarding the calculation of recycling efficiencies of the recycling processes of waste batteries and accumulators. Basically, it established the minimum recycling efficiencies in lead-acid, nickel-cadmium, among others.

4.5.2 Regulation (EC) No 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

REACH includes the issue of the production and use of chemical substances and their potential impact on human health and the environment. REACH compliance logo is presented in Figure 16**Error! Reference source not found.**.

Figure 16. REACH compliance logo

This regulation is in charge of informing the clients about the containing elements of the products considered as dangerous for the human health and the environment, which are called 'Substances of Very High Concern' (SVHC) that are listed on the 'Candidate List' and contained in products in concentrations higher than 0.1% weight by weight per article.

Regarding the batteries, electrolyte can be the one presenting this type of high concern substances. The regulation forces to inform the client on how use the product safely. The authorization procedure aims to assure that the risks from Substances of Very High Concern are properly controlled and that these substances are progressively replaced by suitable alternatives while ensuring the good functioning of the EU internal market. As it has been stated, the electrolyte is the product in batteries that can present the maximum concern. Concretely, Li-ion batteries can contain two substances that are included in the candidate list of substances:

- 1,2-dimethoxyethane or ethylene glycol dimethyl ether (EGDME, $C_4H_{10}O_2$): electrolyte solvent, very persistent and very bio-accumulative (vPvB)
- 1,3-propanesultone or 1,2-oxathiolane, 2,2-dioxide ($C_3H_6O_3S$): electrolyte fluid in lithium-ion batteries, carcinogenic.

According to the REACH regulation batteries are identified as articles with no intended release of the substances they contain. Battery producers are users of chemicals. Providing a Safety Data Sheet is not mandatory for articles and users of chemicals, but it could be advisable to declare such a leaflet as "Instructions for the safe handling of batteries".

This directive can be applied, specifically and nowadays, to liquid Li-ion batteries, as the candidate list of hazardous substances only includes Li-ion electrolyte solvent related components. However, in the case of NiZn, it will be necessary to check if there is any component suspected of being labelled as dangerous/hazardous.

4.5.3 The European Ecodesign Directive (2009/125/EC) and its implementing regulations

The Ecodesign Directive provides rules for improving the environmental performance of products, such as household appliances, information and communication technologies The Directive sets out minimum mandatory requirements for the energy efficiency of these products and/or on providing information.

It does not apply to the batteries of Electric Vehicles, as Li-ion or Lead-Acid (in the case of starter batteries) batteries exclusively designed for these type of products.

However, there are three specific regulations of this Ecodesign Directive that apply to battery systems:

- Commission Regulation (EU) No 617/2013 with regard to Ecodesign requirements for computers and computer servers: it includes requirements on the extraction and replacement of batteries for these types of products. The review may include requirements on battery durability.
- Potential Commission Regulation and/or Voluntary Initiative within the framework of the Ecodesign Directive 2009/125/EC with regard to Uninterruptible Power Supplies (UPS): The proposed measures of this regulation are based on UPS efficiency with a material resource bonus, hence taking battery efficiency and materials into account. A voluntary agreement has been in place for about ten years, namely the Code of Conduct for AC Uninterruptible Power Systems.
- Ecodesign Study on Photovoltaic Systems: it also includes battery storage regulation.

This directive can be applied to all the batteries, except the ones specifically designed for the use in Electric Vehicles:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- Pb-acid batteries
- Na based batteries
- NiMH
- NiCd
- NiZn
- Flow batteries

Implemented Commission Regulation:

- **Commission Regulation (EU) No 617/2013 with regard to Ecodesign requirements for computers**

Implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for computers and computer servers.

4.5.4 Directive on the Restriction of Hazardous Substance (RoHS)

This directive restricts the use of hazardous substances in electrical and electronic equipment. As other directives, the main objective of RoHS, whose compliance logo is presented in Figure 17, is optimizing the use of these types of products and manage and increase the recycling options.

Figure 17 ROHS compliance logo

Batteries are currently not in the scope of this directive; however, it might apply to some parts of a battery system such as the battery management system (BMS), depending on the materials it is made of. As this regulation does not apply to the battery system itself, there are some batteries as NiCd or Lead Acid that are totally out of the scope of this regulation. Therefore, this directive can be applied to the following batteries:

- Li-ion batteries (including liquid electrolyte and solid electrolyte) – with BMS systems
- Na batteries (Na-ion) – with BMS systems
- NiZn – with BMS systems
- Flow batteries – with BMS systems

4.5.5 The EU Energy Labelling Framework Regulation (2017/1369)

This EU Regulation establishes a protocol for energy labelling, simplifying and updating the energy efficiency labelling requirements for products sold between the European Union members.

For the products containing batteries, it is not clear to what should the labelling be applied. In the case of Electrical Vehicles, the item itself is not considered as a product, but it is not clear for the batteries including in this type of Electric Vehicles. So, it is not possible to assess the batteries to which this regulation may apply.

4.5.6 Regulation (EU) No 1103/2010. Regulation on capacity labelling of portable secondary and automotive batteries

This regulation establishes rules on the labelling of portable rechargeable batteries and automotive batteries. The capacity label shall include both the numerical value of the capacity and its units expressed in Ah or mAh. It has to appear either on the battery label, the battery casing and/or the packaging. In order to establish a reference to calculate the capacity value that appears in the labelling, the capacity should be determined on the basis of IEC/EN 61951-1, IEC/EN 61951-2, IEC/EN 60622, IEC/EN 61960 and IEC/EN 61056-1 standards depending on chemical substances contained therein.

Furthermore, more labels should be included in the batteries regarding materials, power capability and recycling issues.

As it has been mentioned, this regulation is applicable to the labelling for portable and vehicle rechargeable batteries.

This directive can be applied to all portable rechargeable and automotive batteries:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- Pb-acid batteries
- Na based batteries
- NiMH
- NiZn

4.5.7 Directive on Product Safety Requirements 2001/95/EC

This Directive implements general safety requirements for any product placed on the market for consumers or for any product that is likely to be used by them. This also includes all products that provide a service.
Batteries that are intended or foreseeable to be used by consumers are covered by the General Product Safety Directive 2001/95/EC (GPS). The manufacturer of the product, and the battery, is responsible for informing consumers about the dangers and hazards of the product through the normal period of use and the ones that are not immediately obvious without adequate warning.

For the products that conform to listed standards, the presumption of conformity applies. At present, no battery standards are listed.

4.5.8 Ecolabel Regulation 66/2010

The EU Ecolabel is a voluntary award scheme for the most environmentally friendly products on the market. New legislation (Regulation 66/2010) published recently has tried to improve the use and process of awarding the label, as well as creating a designated body responsible for Ecolabel enquiries.

It includes Electrochemical tests (endurance tests among others) included in IEC EN 61960 (portable applications – coin cells).

As this is a voluntary regulation and as the IEC standards are not obligatory, and are only oriented (in the specific case of IEC EN 61690) to portable applications and coin cells, the batteries to which can apply this regulation are:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- NiMH

4.5.9 Alternative Fuels Infrastructure Directive 2014/94/EU

Current recharging interface technologies include cable connectors, for example, however, the future technologies included in the electromobility area are not taking into account the wireless charging or battery swapping that need to be considered as well. Legislation needs to ensure that technological innovation is facilitated. This Directive should therefore be appropriately updated in order to take into account future standards for technologies such as wireless charging and battery swapping.

This Directive is oriented to EV and charging infrastructure. Therefore, only batteries oriented to this type of applications are considered as:

- Li-ion batteries – electromobility
- Na batteries (NaNiCl batteries) - electromobility
- Redox Flow Batteries – Charging Infrastructures

4.5.10 Directive 2014/30/EU on the harmonization of the laws of the Member States relating to electromagnetic compatibility

This EMC Directive ensures that all electrical and electronic equipment (in the EU market) comply with the allowed adequate level of electromagnetic compatibility (EMC).

Batteries are not under the EMC Directive, but when a battery is equipped with electrical circuits (e.g., protection electronics for secondary lithium batteries) EMC-interferences are possible in principle, and the battery is potentially within the scope of the directive. This depends on each case. For instance, lithium batteries are designed with high-frequency impedance and electromagnetic interference, due to the rapidly changing current and voltage. Therefore, lithium batteries must comply with the EMC Directive as they could cause significant disturbance to other electrical devices.

Therefore, this directive can be applied to the following batteries:

- Li-ion batteries (including liquid electrolyte and solid electrolyte) – with BMS systems
- Na batteries (Na-ion) – with BMS systems
- NiZn - with BMS systems
- Flow batteries – with BMS systems

4.5.11 Directive 2014/35/EU on the harmonization of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits

The Low Voltage Directive (LVD) ensures that the electrical equipment provide a high level of protection of health and safety of persons, and of domestic animals and properties. Any battery-charger coupled to the battery as well as equipment with integrated power supply unit within the voltage ranges of the Directive are in the scope of the LVD.

It applies to electrical equipment designed for use at a nominal voltage between 50-1000 V for AC and 75-1500 V for DC. Batteries that fall in one of these ranges underlie the requirements of the LVD and should be labelled with the CE marking.

This directive can be applied to all the batteries in the low voltage range zone:

- Li-ion batteries
- Pb-acid batteries
- Na based batteries
- NiMH
- NiCd
- NiZn
- Redox Flow batteries

4.5.12 New Battery Regulation (EU) 2020/353

This is a new directive regarding batteries and accumulators that is going to replace the Directive 2006/66/EC. The directive will come into force in 2023.
The proposal has three main objectives:

- Promote a circular economy in the EU market
- Reduce environmental and social impacts throughout all stages of the battery life cycle – regarding safety, for instance (including restrictions on the use of hazardous substances, in particular mercury and cadmium; carbon footprint rules; mandatory recycled content targets for cobalt, lead, lithium and nickel; performance and durability parameters; removability and replaceability of portable batteries; safety of stationary battery energy storage systems).
- Establish common set of rules for the market of batteries (regulate processes, waste batteries, etc.).

This directive includes more requirements for the end-of-life management of batteries. It sets for instance new collection targets for waste portable batteries (65% in 2025 and 70% in 2030), and establishes requirements to facilitate the repurposing of industrial and electric-vehicle batteries as stationary energy storage batteries.

This directive considers the creation of a battery passport, to create a system for the electronic exchange of information. And, on the other hand, it includes the obligations of battery producers, distributors, etc. with regard to the battery recovery processes, quality protocols, recycling, end of life, etc.
This directive can be applied to all batteries:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- Pb-acid batteries
- Na based batteries
- NiMH
- NiCd
- NiZn

- Flow batteries

4.5.13 Directive 2009/72/EC on Electricity

In 2009, this directive was adopted in order to further open and integrate the energy market. This Directive is also referred to as the Electricity Directive and is part of the "EU third energy package". Energy storage systems (ESS) are incorporated as a separate component in the energy model. The result is that ESS is generally treated as a generation system.

It is understood that it does not apply directly to any type of electrochemical energy storage system.

4.5.14 Directive 2009/28/EC Renewable Energy Directive

This Directive was implemented in 2010, and established ambitious targets for all Member States, such that the EU had to reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. It also aimed to improve the legal framework for promoting renewable electricity, requiring national action plans that establish pathways for the development of renewable energy sources and creating cooperation mechanisms to help to achieve the target costs effectively, beside establishing sustainability criteria for biofuels.

It is understood that it does not apply directly to any type of electrochemical energy storage system.

4.5.15 Directive 2012/27 Energy Efficiency Directive

The goal of this Directive was established for 2020. It established a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. The goal was consisting in having overall EU energy consumption not being more than 1483 million tons of oil equivalent (Mtoe) of primary energy or 1086 Mtoe of final energy. Under the directive, all EU countries are required to use energy more efficiently at all stages of the energy chain.

It is understood that it does not apply directly to any type of electrochemical energy storage system.

4.5.16 Regulation (EU) No 347/2013

Regulation (EU) No 347/2013 is focused on guidelines for trans-European energy infrastructure. It is a part of a larger regulatory framework in order to present a number of barriers to the implementation of European Energy Infrastructure and integrated energy networks.

Amending regulations to this mentioned regulation are:

- **Regulation (EC) No 713/2009**

This Regulation sets up the Agency for the Cooperation of Energy Regulators, in order to assist the regulatory authorities in the field of the internal market in electricity and natural gas. The tasks of the Agency include monitoring and reporting on the electricity and natural gas sectors.

- **Regulation (EC) No 714/2009**

It establishes the conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003.

4.5.17 European Regulation (EC) No 1272/2008 – CLP (Classification, Labelling & Packaging)

The CLP Regulation applies to the businesses that manufacture, import, use or distribute chemical substances or mixtures into the EU market. However, the batteries have no obligation based on the CLP hazard class.

However, for example, in the context of batteries, it must be noted that e.g., separately bottled battery acid ("acid packs") which are usually sold with motorcycle batteries, should be labelled according to this European Regulation. So, it could be expected that external bottles of electrolyte (for instance, to refill non sealed Lead-Acid batteries, NiCd batteries or NiZn batteries) are subjected to the CLP regulation.

This directive can be applied to the external components of the following batteries:

- Pb-acid batteries
- NiCd
- NiZn

4.5.18 Summary of legislations applicable to batteries regarding their use for different types of technologies

As it has been already mentioned, in each directive or legislation section, the electrochemical battery technologies to which each legislation can apply are listed, taking into account the electrochemical energy storage technologies close to the NiZn, such as NiCd or NiMH batteries, as well as usual batteries used in the stationary market, such as Pb-acid, Na batteries (Na-S) and redox-flow batteries, and other emerging technologies for mentioned stationary market, as liquid electrolyte and solid electrolyte containing Li-ion batteries or Na-ion batteries.

Table 12. Summary of the legislation applicable to batteries regarding its use for different type of technologies

Legislation	*NiZn*	*NiCd*	*Li-ion*	*Pb-acid*	*Redox flow*	*Na batteries*	NiMH	Li-metal-Polymer
Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)	X	X	X	X		X	X	X
Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators	X	X	X	X	X	X	X	X
Regulation (EC) No 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	X		X					
The European Ecodesign Directive (2009/125/EC) and its implementing regulations	X	X	X	X	X	X	X	X
Directive on the Restriction of Hazardous Substance (RoHS)	X		X		X	X		X
The EU Energy Labelling Framework Regulation (2017/1369)								
Regulation (EU) No 1103/2010. Regulation on capacity labelling of portable secondary and automotive batteries	X		X	X		X	X	X
Directive on Product Safety Requirements 2001/95/EC	X		X	X		X	X	X
Ecolabel Regulation 66/2010			X				X	X
Alternative Fuels Infrastructure Directive 2014/94/EU			X		X	X		X
Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility	X		X		X	X		X
Directive 2014/35/EU on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits	X	X	X	X	X	X	X	X
New Battery Regulation (EU) 2020/353	X	X	X	X	X	X	X	X
Directive 2009/72/EC on Electricity								
Directive 2009/28/EC Renewable Energy Directive								
Directive 2012/27 Energy Efficiency Directive								
Regulation (EU) No 347/2013								
European Regulation (EC) No 1272/2008 – CLP (Classification, Labelling & Packaging)	X	X		X				

NOTE: Blank places mean that those regulations do not apply directly to any type of electrochemical energy storage system

4.6 Legislation applicable to batteries regarding their disposal/recycling

The investigation on applicable legislations for the disposal/recycling of RNZB focuses on the international or rather European level as nowadays the framework does not significantly differ between the member states of the EU and future developments are driven by the European Commission.

4.6.1 Directive 2006/66/EC

From a battery-recycler's-point of view, the most important regulation still in place is the so-called Battery Directive 2006/66/EC. Coming into force in 2006, the member states of the EU had to implement the directive into national law by September 2008.

In this regulation the European legislator defines, inter alia, binding collection targets, specific recycling procedures and recycling efficiencies depending on the battery type or rather its chemistry. Disposal of industrial and automotive batteries is prohibited when batteries are not treated before the disposal state. However, if a suitable treatment and recycling in accordance with this regulation has been carried out, residues of these processes might be incinerated or taken to a landfill.

Regarding the End-of-Life, specifically the collection rates for portable equipment, the members of European Union were forced to achieve the following collection rates, in the 2012 and 2016 years, 25% and 45%, respectively. Then, regarding the disposal of the collected wastes (Annex III), the members must prohibit the disposal in landfills or by incineration of waste industrial and automotive batteries. However, there is an exception for residues of any batteries and accumulators that have undergone both treatment and recycling may be disposed of in landfills or by incineration. In the last case, on the one hand, their treatment has to include removal of all fluids and acids. Their treatment or storage, at treatment facilities shall take place in sites with impermeable surfaces and suitable weatherproof covering or in suitable containers. On the other hand, recycling processes have established minimum recycling efficiencies, as the followings:

- Lead-Acid batteries and accumulators: recycling of 65% by average weight of lead-acid batteries and accumulators (including recycling of the lead content to the highest degree that is technically feasible while avoiding excessive costs).
- Nickel-Cadmium batteries and accumulators: recycling of 75% by average weight of nickel-cadmium batteries and accumulators (including recycling of the cadmium content to the highest degree that is technically feasible while avoiding excessive costs).
- General batteries: recycling of 50% by average weight of other waste batteries and accumulators. This means that Li rechargeable batteries must be recycled for at least 50% by average weight.

Many of the European Union members have the Batteries Directive implemented in the national legislation of each country. As directive 2006/66/EC does not present a regulation, national implementations of this directive in the member states might slightly vary.

4.6.2 Commission Regulation 493/201

Commission Regulation 493/2012 defines the methodology for calculating recycling efficiencies for the recycling process:

$$R_E = \frac{\sum m_{output}}{m_{input}} [mass\ \%]$$

The input fraction can be considered as the total mass of dried waste batteries and accumulators fed into the process including fluids, acids and the external jacket, but excluding the outer casing of battery packs. Further definitions on which fractions can be considered as output – in addition to the mass leaving the recycling process, which actually results from the input material – comprises:

- Carbon, which is later used as a reducing agent in metallurgical processes
- Oxygen, which is later used as an oxidising agent in metallurgical processes
- Materials contained in a metallurgical slag, which can be further used for recycling purposes

4.6.3 Procedure 2020/353/COD

In December 2020 a proposal for a regulation concerning batteries and waste batteries has been published by the EC, repealing directive 2006/66/EC. As the RNZBs in the LOLABAT project are considered to be categorised as industrial batteries (> 5 kg) there are several changes which are currently under consideration by the EC in the future. Currently, different options are being discussed.
The most important changes for industrial batteries include:

- carbon footprint of the battery has to be declared / maximum carbon footprint requirement is set to enter the market
- information on performance and durability has to be published / minimum performance and durability thresholds are defined
- minimum extended producer responsibility obligation is intended
- level of recycled content in active materials has to be declared by 2025 / minimum levels of recycled content in active materials are determined by 2030 and 2035
    - 4 wt% of nickel in 2030 and 12% of nickel by 2035
    - 85 wt% of lead in 2035
    - 12 wt% of cobalt in 2030 and 20 wt% of cobalt by 2035
    - 4 wt% of lithium in 2030 and 10 wt% of lithium by 2035
- Minimum level of recovered elements from industrial lithium-ion batteries
    - 90 wt% nickel by 2026 and 95 wt% by 2030
    - 90 wt% cobalt by 2026 and 95 wt% by 2030
    - 90 wt% copper by 2026 and 95 wt% by 2030
    - 90 wt% nickel by 2026 and 95 wt% by 2030

4.6.4 Directive 2008/98/EC

Repealing Directive 2006/12/EC, the European Union updated general definitions and handling of different kinds of waste in 2008 with Directive 2008/98/EC. Due to the fact that the batteries become waste after their end of life, and partially hazardous, they have to be considered here as well. Some major points are:

- Recycling is defined as "*any recovery operation by which the waste materials are reprocessed into products, materials or substances whether for the original or other purposes*".
- The directive gives a more general information about priorities in waste handling, which gives the prevention of waste the highest priority before re-using, recycling, energetic recovery and disposal follow.
- Batteries, like every other substance or object, become waste as soon as their owner discards, intends or must discard.
- Different criteria for hazardous waste are listed. In contrast to NiCd- and lead-acid batteries, RNZB is not considered to be classified as hazardous waste due to the absences of toxic elements.

4.6.5 Regulation 2006/1013/EC

This regulation is effective in all countries of the European Union and is based on the Basel Convention. It specifies tasks and responsibilities for all parties involved in the shipment of waste (producers, transporters, disposers and the relevant authorities), so that they all have the necessary detailed information about the shipment of the waste at their disposal to the stakeholders and the public. Transporting hazardous waste always requires a notification which includes the corresponding authorities. However, as RNZB is not considered to be classified as hazardous waste, end-of-life RNZB can be transported without a legal notification, unless they are sent to another country.

4.6.6 Directive 2000/53/EC

In this directive the European Commission sets a legislative framework for the handling of end-of life vehicles. As batteries are part of automotive vehicles, directive 2000/53/EC also covers the procedure of batteries when the vehicles become end-of life. However, due to being developed for stationary energy storage applications, this directive does not have any implications for the recycling of RNZBs.

4.6.7 Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)

This European Directive establishes the measures to protect the environment and human health by means of prevention or reduction of the bad impacts of generation and management of waste from electrical and electronic equipment, which is identified as WEEE, apart from reducing general effects of the use of resources and improving the efficiency of the use of these types of products.

Concretely, in this directive, the following notes apply to batteries:

- It requires that batteries be removed from any separately collected WEEE. The specific treatment for the batteries shall be consulted in the Batteries Directive (Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators).
- It requires that batteries, in sites for treatment of WEEE, to be stored in appropriate containers.
- It refers to Batteries Directive (Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators) to apply more specific requirements for batteries in terms of waste.

This directive can be applied to the batteries capable of being a part of electrical and electronic equipment, as:

- Li-ion batteries (including liquid electrolyte and solid electrolyte)
- Pb-acid batteries
- Na batteries (Na-ion)
- NiMH
- NiCd
- NiZn (if applied to electrical and electronic equipment)

4.6.8 Summary of legislations applicable to batteries regarding their use for different type of technologies

Taking all of the legislations into account, one can conclude that the disposal and recycling of batteries is already highly regulated in different areas (e.g. transport or recycling processes). However, with the proposal for a revised battery regulation being discussed right now, the market of battery recycling specifically and the battery value chain generally, will be most probably highly affected.

Table 13 shows a comprehensive overview of the legislations applicable to the recycling of batteries. Although there might be differences between individual procedures, such as the recycling efficiency to be achieved, the presented legislations address all battery systems, no matter their chemistry, size or application.

Table 13: Legislations applicable to the recycling of batteries

Legislation	*NiZn*	*NiCd*	*Li-ion*	*Pb-acid*	*Redox flow*	*Hydrogen batteries*	*Na batteries*	NiMH	Li-metal-Polymer
Directive 2006/66/EC	X	X	X	X	X	X	X	X	X
Regulation 493/2012	X	X	X	X	X	X	X	X	X
Procedure 2020/353/COD	X	X	X	X	X	X	X	X	X
Directive 2008/98/EC	X	X	X	X	X	X	X	X	X
Regulation 2006/1013/EC	X	X	X	X	X	X	X	X	X
Directive 2000/53/EC	X	X	X	X	X	X	X	X	X
Directive 2012/19/EU	X	X	X	X	X	X	X	X	X

5 Main legislations applied to NiZn batteries

Among the legislations described in the previous sections, Table 14 gathers the ones that are important for NiZn battery in each stage of its cycle life.

Table 14. Main legislations applying to RNZB

Raw materials legislation	Manufacture legislation
- REACH Regulation EC Nº 1907/2008 and amendment 552/2009 - CLP Regulation 1272/2008 for classification, labelling and packaging - Strategic Action Plan on batteries COM (2018)293, and its influence on new regulations and actions. - Indonesian and Japanese regulations for the extraction of nickel and nickel oxides, as the main extracting countries. - Chinese regulations for the extraction of Zn, as the main extracting country.	- Regarding the labelling: Directive 2006/66/EC
Storage legislation	**Transport legislation**
- Directive 2012/18/EU for dangerous substances (storage of raw materials of batteries) - CLP Regulation 1272/2008 for classification, labelling and packaging. - FRANCE: Arrêté 4 octobre 2010 relatif à la prévention des risques accidentels au sein des installations	- Directive 2008/68/EC for the inland transport of dangerous goods - IMDG code (rail) - ADR code (road) - IATA regulations// ICAO (Doc 9284) with technical instructions for safe transport of dangerous goods by air
Use legislation	**Disposal/recycling legislation**
- Directive 2012/19/EU, WEEE - Directive 2006/66/EC and modifications - European Ecodesign Directive 2009/125/EC - Directive Restriction of Hazardous Substance (RoHS) - Regulation EU 1103/2010 - Directive 2001/95/EC - Directive 2014/30/EU (for BMS system) - Directive 2014/35/EU - New battery regulation EU 2020/353 - CLP Regulation 1272/2008 for classification, labelling and packaging	- Directive 2006/66/EC - Commission Regulation 493/201 - Procedure 2020/353/COD - Directive 2008/98/EC - Regulation 2006/1013/EC

The indicated raw materials legislations apply mainly to the extraction and/or obtainment of the different raw materials needed to manufacture a battery. Since all materials could not be analysed, the main legislations have been defined for the main differentiating components between the different battery technologies in order to assess the differences. In Table 14, worldwide, European and national legislations of the countries with the highest amount of extracted raw materials for NiZn batteries are indicated (i.e. China, Japan and Indonesia). Regarding manufacturing process, there is no specific legislation for the manufacturing of NiZn batteries; the only specification is related to the labelling and packaging of the battery according to its elements and subjected to Directive 2006/66/EC.

Regarding the legislations applying to the transport and storage stages, there are many generic regulations in the international and European framework that refer to the storage and transport of dangerous goods, including the battery as a whole and also the raw materials (considered dangerous) that are needed to build a battery e.g. Nickel (Ni), Lead (Pb) and Zinc (Zn).

When referring to the transport, the most important European documents are: IMDG Code (maritime); RID Code (rail); IATA regulations and ICAO for the aviation transport and ADR for transporting dangerous goods by road.

Storage related legal documents also provide limitations and conditions for the raw materials and the whole battery, according to their classification into dangerous goods. European legislation has been transposed to different countries. The storage regulations considered in this deliverable are the French ones, since a first manufacturing site for the NiZn battery would be most probably France. Main documents to consider for the storage stage include Directive 2012/18/EU for the storage of dangerous substances (storage of raw materials of batteries), CLP Regulation 1272/2008 for classification, labelling and packaging and in France the Arrêté 4 octobre 2010 relatif à la prévention des risques accidentels au sein des installations, which is a general regulation for warehouses with dangerous substances, in order to keep safety.

The legislations corresponding to the end use of NiZn batteries include a series of directives and regulations that aim to ensure, on the one hand, that the products (batteries) are safe and suitable for use by people without endangering their health. On the other hand, a series of European Union directives are collected to ensure the compliance with the appropriate electrical and electronic standards, which finally allow a transfer towards energy efficiency and the use of renewable energies.

The already strongly regulated market of battery recycling will be influenced by the revised battery directive (Procedure 2020/353/COD) even more in the future. For industrial batteries like RNZB, this includes e.g. mandatory levels of recycled content in the active materials or extended producer responsibility. However, the proposal document being discussed right now focuses on lithium-ion batteries, where future requirements for recycling technologies are even stricter. Due to the absence of toxic components, the legal requirements for both transport and recycling of end-of-life RNZB are manageable with reasonable efforts.

6 Suggestions for improvement of the current regulatory landscape

6.1 Raw materials regulatory gaps

The main problem in the regulation of raw materials is the differences that exist between the countries and the lack of a common framework for extractive industries. Each country has its own requirements, economic advantages and safety regulations. For example, Japan or Australia have put in place a lot of regulations for a safe and sustainable extraction of minerals, while for example in the Democratic Republic of Congo the mining conditions are poorer, the labour costs are lower, and the regulations are looser; Indonesia has implemented in 2020 its new mining code which tries to boost the investments, giving incentives and benefits for the mining business.

6.2 Manufacturing regulatory gaps

In this subsection, some regulatory gaps that could exist in the regulation for the manufacturing of NiZn batteries are indicated:

- ✓ Establishment of minimum criteria in each of the manufacturing steps of the NiZn cell and battery preparation, to be accomplished in order to have an optimal quality control (taking also into account the external components at system level).
- ✓ Minimum manufacturing standards should be established for both prototype and final product, both products having the same final appearance in spite of having different uses.

6.3 Storage regulatory gaps

After the analysis of main legislations applying to the storage of batteries, we have found that the main gap is the absence of specific requirements for the storage of batteries; the requirements and instructions are mainly focused on the packaging, labelling and transport. Requirements for a safe storage of some battery components/raw materials considered as dangerous can be found (e.g. nickel oxides, cadmium, nickel, lead powder and lead compounds, lithium, zinc oxide, zinc and cobalt), but there is no specific document for the safe storage of batteries.

6.4 Transport regulatory gaps

A lot of regulations and codes have already been developed for a safe transport of batteries and their different components. Currently, there are no specific requirements for NiZn batteries; and therefore, the wet batteries with alkaline electrolyte requirements would be applied for them. Safety of these batteries should be assessed and if any additional concern or requirement is needed (e.g. maximum transportation quantities, special packaging conditions, etc.), current regulations and codes would need to be updated.

6.5 Usage regulatory gaps

In this subsection, some regulatory gaps that could exist in the regulation for the usage of NiZn batteries are indicated:

- ✓ Legislations in terms of safety aspects in operation (and storage) to take into account for NiZn batteries/modules. Establishment of minimum standards or certifications to be passed in each application.

- ✓ Establishment of criteria for the End-of-Life of NiZn batteries depending on the use case/application.

- ✓ Establishment of the possibility to obtain a kind of green certification if the Life Cycle Analysis of the NiZn battery functional unit corresponds to minimum values of output parameters (as CO_2 emissions, etc.).

- ✓ Establishment of a legislation to incorporate same output parameters to be defined for NiZn products in order to compare similar products of this type of technology (energy throughput, energy density) and the conditions in which these parameters are measured.

- ✓ Establishment of legislation regarding the cybersecurity aspects of the system (in the case of having a complete NiZn with electronics and communication system), in order to produce safe energy systems against cyber-attacks.

6.6 Disposal/recycling regulatory gaps

Spent batteries in Europe have been collected and recycled according to the existing European Directive EU/66/2006 or rather its national implementations for more than 15 years. Although this directive has initiated and promoted the recycling of all battery types, an updated version could surely help to improve the battery recycling in all Europe. While Directive EU/66/2006 focuses on the segregation and utilisation of batteries with dangerous contents (Hg, Cd, Pb) the explosion increase in selling volumes of lithium-ion batteries require a new legislative framework focussing on critical metals like Li, Co and Ni.

Having published the proposal for a new battery regulation in December 2020 (Procedure 2020/353/COD) the European Commission already covers most of the critics that have arisen in the past. However, even if this regulation came into force in the same version as the proposal, from a recycler's perspective the legislation would still lack binding statements regarding the following issues:

- ✓ Verifiability of Recycling Efficiency reports
- ✓ Recycling efficiency reports have been mandatory for battery recycling companies to prepare since directive EU/66/2006 came into force. An extensive review of reported recycling efficiencies by the legislator or corresponding representatives, however, has not been implemented. Responsible regional monitoring authorities are overburdened with the technical and personnel resources to carry out more in-depth checks on the recycling efficiency. In order to relieve both, legislator and authorities, commissioning an independent auditor to investigate the recycling efficiency scientifically would be reasonable from a cost and effort point of view.
- ✓ Deposit
    - The usefulness of a deposit must be considered differentiated according to application and user group. It should refer to market-relevant areas, i.e., especially rechargeable batteries, which already dominate in terms of sales volume and valuable resources. Considering electromobility (four-wheeled vehicles) and large stationary applications, the monetary amount of a deposit is insignificant compared to the value of the battery itself, and thus loses its controlling effect. The same goes for large stationary applications. On the other hand, it can significantly improve the orderly return of rechargeable batteries in consumer applications. The proposal of a deposit limit measured by the number of volts is not sensible. An orientation of the deposit amount to the weight of the battery seems feasible and does not necessarily require a lower limit.

- A deposit should be technically unambiguous and tamper-proof, and the deposit amount needs to cover a minimal incentive to return the batteries. Neutral clearing would be necessary, to be carried out by independent institutions.

✓ Calculation of collection rates

- The calculation of the collection rates to be achieved still refers to the quantities sold in the previous three years instead of considering other approaches like how many batteries are available for collection. This method is only accurate when market conditions remain the same. If sale volumes change significantly, the collection rate does not reproduce the collected volumes in a representative way. As RNZBs are considered to be industrial and industrial batteries are not included in collection calculations, this paragraph does not address RNZBs as planned in this project. However, the consortium would like to point out the inadequate handling of this matter.

7 Conclusion

Although the French market has been taken as a reference, it was concluded that they do not have any specific regulation regarding batteries. All regulations and standards to be taken into account should be those that affect the European market.

Raw materials are subjected to national regulations, covering safety, environmental and health regulations, and extraction regulatory procedures and permits. Poorer countries (e.g. Democratic Republic of Congo) have poorer mining conditions, with lower labour costs and looser regulations regarding safety, health, environment and sustainability. This should be improved in order to build a sustainable battery supply chain.

After analysing all the regulations concerning the manufacture and use of electrochemical batteries, it is difficult to establish a differentiation between those that apply to each technology. There is a greater number of standards referring to the final use of the batteries.

In the absence of specific regulations on NiZn, it should be noted that the most similar technology is NiCd. However, each application should be studied individually.

A series of recommendations and suggestions have been made to be taken into account for future revision of the standards. These recommendations were done based on the own know-how of NiZn.

Regarding transport and storage, there is no specific document with instructions for the storage of batteries and any special requirement is based on the hazards that each battery might contain. On the other hand, the transportation regulations and codes for a safe transport of dangerous goods by road, rail, waterborne or air clearly define the packaging instructions, segregation dispositions and any special provision for a safe transport of different types of batteries, i.e. lithium metal, lithium-ion, nickel metal hydride, wet batteries with acid electrolyte, wet batteries with alkaline electrolyte, and sodium containing batteries. Therefore, transport regulation is quite developed, and it should be updated regarding NiZn batteries if there are safety requirements and battery characteristics differing from those classified as wet batteries with alkaline electrolyte.

The future market environment for the recycling of waste batteries will strongly depend on the European proposal for a revised regulation on batteries and waste batteries (Procedure 2020/353/COD). Currently, the legislative framework (Directive 2006/66/EC) defines a recycling efficiency of 50 wt% for RNZB to be achieved. However, according to Procedure 2020/353/COD, in the future a nickel recovery rate of 90-95% must be realised by battery recycling companies. In the same procedure, it is also being discussed that the industrial batteries in general, and therefore the RNZB for stationary applications in specific, must include a minimum of 4% of recycled nickel by 2030 and 12% by 2035. These ambitious goals require extensive R&D work followed by an industrial

implementation of promising recycling technologies in order to fulfil the targets set by the European Commission. Although most of the recycling related critics on the current regulatory landscape are covered by the proposal for a revised battery regulation, ACCUREC still sees a potential for an improvement of current regulations. For example, a verifiability of recycling efficiencies, a deposit on larger batteries and a modified methodology for calculating collection rates could be implemented.

References

Cempel M., & Nikel G. (2006). Nickel: A Review of Its Sources and Environmental Toxicology. *Polish Journal of Environmental Studies*, *15*(3), 375–382. http://www.pjoes.com/Nickel-A-Review-of-Its-Sources-and-Environmental-Toxicology,87881,0,2.html

Chinese State Council. (1994). *Decree No. 150 of the State Council. Provisions on Administration of Collection of Mineral Resources Compensation Fees*. http://www.lawinfochina.com/display.aspx?lib=law&id=12168&CGid=&EncodingName=big5

Chinese State Council. (1998). *Measures for the Administration of Transfer of Mineral Exploration Right and Mining Right*. http://lawinfochina.com/Display.aspx?lib=law&Cgid=19700&EncodingName=big5

Chinese State Council. (2014). *Environmental Protection Law of the People's Republic of China*. https://doi.org/10.1007/978-981-13-2538-0_630

Directorate-General for Energy. (2020). *Database of the European energy storage technologies and facilities*. https://data.europa.eu/data/datasets/database-of-the-european-energy-storage-technologies-and-facilities?locale=en

EASE - European Associaton for Storage of Energy. (2016a). *Lithium-metal-polymer battery*. https://ease-storage.eu/wp-content/uploads/2016/07/EASE_TD_Electrochemical_LMP.pdf

EASE - European Associaton for Storage of Energy. (2016b). *Sodium-nickel-chloride Battery. Electrochemical energy storage. Energy Storage Technology Descriptions*. https://ease-storage.eu/wp-content/uploads/2016/07/EASE_TD_Electrochemical_NaNiCl2.pdf

España. Ministerio de Asuntos Exteriores y Cooperación. (2018). Enmiendas de 2016 al Código Marítimo Internacional de mercancías peligrosas (Código IMDG) adoptadas en Londres el 13 de mayo de 2016, mediante Resolución MSC.406(96). *Boletín Oficial Del Estado*, *100*(25 de abril).

European Chemicals Agency. (2021). *Nickel*. https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.283

European Chemicals Agency - ECHA. (2021a). *Cadmium*. https://echa.europa.eu/es/brief-profile/-/briefprofile/100.028.320

European Chemicals Agency - ECHA. (2021b). *Cobalt*. https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.325

European Chemicals Agency - ECHA. (2021c). *Lead*. https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.273

European Chemicals Agency - ECHA. (2021d). *Lithium*. https://echa.europa.eu/es/brief-profile/-/briefprofile/100.028.274

European Chemicals Agency - ECHA. (2021e). *Nickel dihydroxide*. Substance Information. https://echa.europa.eu/es/substance-information/-/substanceinfo/100.031.813

European Chemicals Agency - ECHA. (2021f). *Nickel hydroxide*. https://echa.europa.eu/es/brief-profile/-/briefprofile/100.031.213

European Chemicals Agency - ECHA. (2021g). *Zinc*. https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.341

European Chemicals Agency - ECHA. (2021h). *Zinc oxide*. https://echa.europa.eu/es/substance-information/-/substanceinfo/100.013.839

European Commission. (2012). *Directive 2012/18/EU of the European Parliament and of the Council of 4 july 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC*. 1–37.

European Commission. (2018). Report on Raw Materials for Battery Applications SWD(2018) 245/2 final. *Commission Staff Working Document*, 48. http://www.innoenergy.com/%0Ahttps://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/swd20180245.pdf

European Commission. (2020). *Green Deal: Sustainable batteries for a circular and climate neutral economy*. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2312

European Parliament and Council. (2018). Regulation (EU) 2018/1139 of the European Parliament and of the Council. *Official Journal of the European Union*, *2018*(July), 1–122.

European Union. (2008). Directive 2008/68/EC of the European Parliament and of the Council of 24 September

2008 on the inland transport of dangerous goods. *Official Journal of the European Union*, *L 230*(September), 13–59. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:260:0013:0059:en:PDF

European Union. (2012). Commision Regulation (EU) No 965/2012 of the European parliament and the Council of the European Union. *Official Journal of the European Communities*, *L269*(September 2000), 1–15.

FAO. (1997). *FAOLEX Database - Administrative provisions on the collection of mineral resources compensation fee*. FAO - Food and Agriculture Organization of the United Nations. http://www.fao.org/faolex/results/details/en/c/LEX-FAOC068134/

Garside, M. (2021). *Cadmium production globally by country 2020*. Statista. https://www.statista.com/statistics/1023116/refinery-production-cadmium-worldwide-by-country/

Government of Canada. (2019). *Zinc facts*. Government of Canada. https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/zinc-facts/20534

Government of Japan. (1949). *Foreign Exchange and Foreign Trade Act (Act No . 228 of. 1*, 1–71.

Government of Japan. (1950). *Mining Act (Act No . 289 of 1950)*.

Government of Japan. (1968). *Air Pollution Control Act, 1954* (Issue 97, pp. 1–28).

Government of Japan. (1972). *Industrial Safety and Health Act (Act No . 57 of 1972)*. 1–154.

Government of Japan. (1973). *Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture , etc . (Article 4 of the Supplementary Provisions unenforced , etc .)*. *117*, 1–50.

Government of Japan. (2002). Soil Contamination Countermeasures Act (Act No . 53 of 2002). In *Environment*.

Government of Japan. (2016). *Water Pollution Prevention Act Plan*. *47*, 1–59.

Halleux, V. (2021). *New EU regulatory framework for batteries*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689337/EPRS_BRI(2021)689337_EN.pdf

International Air Transport Association. (2021a). *Lithium Battery Guidance Document: Transport of Lithium Metal and Lithium Ion Battery*. 1–27.

International Air Transport Association. (2021b). *Nickel-Metal Hydride Batteries Guidance on the air transport of UN 3496 , Batteries , nickel-metal hydride*. *January*, 3496.

Johnson, M., Djarot, D., & Rifdaan, R. (2020). Indonesian mining bill passed into law , poses new challenges and opportunities. In *Hogan Lovells* (Issue 4). https://www.hoganlovells.com/~/media/hogan-lovells/pdf/2020-pdfs/2020_06_24_ierp_alert_indonesian_mining_bill_passed_into_law_poses_new_challenges_and_opportunities.pdf

Journal officiel de la République française (JORF). (2010). *Arrêté du 4 octobre 2010 relatif à la prévention des risques accidentels au sein des installations classées pour la protection de l'environnement soumises à autorisation*. https://www.legifrance.gouv.fr/loda/id/JORFTEXT000023081900/

Journal officiel de la République française (JORF). (2012). *Arrêté du 27/03/12 relatif aux prescriptions générales applicables aux installations classées pour la protection de l'environnement soumises à déclaration sous la rubrique n° 2710-1 (Installations de collecte de déchets dangereux apportés par leur product*. https://aida.ineris.fr/consultation_document/3489/3489#Annexe_I ()

Koehler, U. (2019). General Overview of Non-Lithium Battery Systems and their Safety Issues. In *Electrochemical Power Sources: Fundamentals, Systems, and Applications* (pp. 21–46). Elsevier. https://doi.org/10.1016/B978-0-444-63777-2.00002-5

Lemaire-Potteau, E., Perrin, M., & Genies, S. (2009). BATTERIES | Charging Methods. In *Encyclopedia of Electrochemical Power Sources* (pp. 413–423). Elsevier. https://doi.org/10.1016/B978-044452745-5.00885-6

Ministerio de Transportes, M. y agenda urbana. (2020). *Resolución de 10 de diciembre de 2020, de la Dirección General de Aviación Civil, por la que se publican las Instrucciones Técnicas para el transporte seguro de mercancías peligrosas por vía aérea (Documento OACI 9284/ AN/905), edición 2021-2022.* 975.

Ministry of Natural Resources - PRC. (2018). China Mineral Resources 2018. *Ministry of Land and Resources People's Republic of China*, 1–58. https://www.gov.cn/xinwen/2018-10/22/5333589/files/01d0517b9d6c430bbb927ea5e48641b4.pdf

National Archives and Records Administration. (2012). *Code of Federal Regulations Title 49 Transportation* (p. 916). Office of the Federal Register National Archives and Records Administration as a Special Edition of the Federal Register. https://www.gpo.gov/fdsys/pkg/CFR-2012-title49-vol2/pdf/CFR-2012-title49-vol2.pdf

Notten, P. H. L., & Latroche, M. (2009). SECONDARY BATTERIES – NICKEL SYSTEMS | Nickel–Metal Hydride: Metal Hydrides. In *Encyclopedia of Electrochemical Power Sources* (pp. 502–521). Elsevier.

https://doi.org/10.1016/B978-044452745-5.00164-7
Payer, G., & Ebil, Ö. (2016). Zinc Electrode Morphology Evolution in High Energy Density Nickel-Zinc Batteries. *Journal of Nanomaterials*, *2016*, 1–9. https://doi.org/10.1155/2016/1280236
Poullikkas, A., & Nikolaidis, P. (2017). A comparative review of electrical energy storage systems for better sustainability. *Journal of Power of Technologies*, *97*(3), 220–245.
Squiller, D., & Brody, R. (2011). Nickel-zinc batteries for hybrid electric vehicles and stationary storage. *Technical Proceedings of the 2011 NSTI Nanotechnology Conference and Expo, NSTI-Nanotech 2011*, *1*, 690–693. http://www.scopus.com/inward/record.url?eid=2-s2.0-81455133603&partnerID=40&md5=0f751a82e007f50374d0a933362d2ab7
Sullivan, J. L., & Gaines, L. (2010). *A review of battery life-cycle analysis: State of knowledge and critical needs*. https://publications.anl.gov/anlpubs/2010/11/68455.pdf
Sullivan, J. L., & Gaines, L. (2012). Status of life cycle inventories for batteries. *Energy Conversion and Management*, *58*, 134–148. https://doi.org/10.1016/j.enconman.2012.01.001
Sundén, B. (2019). Battery technologies. In *Hydrogen, Batteries and Fuel Cells* (pp. 57–79). Elsevier. https://doi.org/10.1016/B978-0-12-816950-6.00004-X
Taniguchi, A. (2001). Development of nickel/metal-hydride batteries for EVs and HEVs. *Journal of Power Sources*, *100*(1–2), 117–124. https://doi.org/10.1016/S0378-7753(01)00889-8
Tsais, P.-J., & Chan, L. I. (2013). Nickel-based batteries: materials and chemistry. In *Electricity Transmission, Distribution and Storage Systems* (Issue March 1899, pp. 309–397). Elsevier. https://doi.org/10.1533/9780857097378.3.309
United Nations. (2020). *ADR 2021. Vol. 1* (p. 666). United Nations.
Van den Bossche, P., Vergels, F., Van Mierlo, J., Matheys, J., & Van Autenboer, W. (2006). SUBAT: An assessment of sustainable battery technology. *Journal of Power Sources*, *162*(2 SPEC. ISS.), 913–919. https://doi.org/10.1016/j.jpowsour.2005.07.039
Wu, G., & Li, Y. (Jincheng Tongda & Neal) (2020). Mining in China: overview. *Practical Law*, 1–17. https://uk.practicallaw.thomsonreuters.com/w-011-1348?transitionType=Default&contextData=(sc.Default)&firstPage=true&comp=pluk&bhcp=1
Yin, X., Chai, J., & Zhang, Y. (2021). *The Mining Law Review: China*. Tian Yuan Law Firm. https://thelawreviews.co.uk/title/the-mining-law-review/china-mining-law