Quality Infrastructure for Electromobility

Fundamentals of Electric Vehicles and Specifics for Passenger Vehicles

GPQI

Dialogues for Innovation and Trade

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About this publication

The Global Project Quality Infrastructure (GPQI) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) enables technical policy dialogues with Germany's important trading partners worldwide. In cooperation with Brazil, China, India, Indonesia and Mexico, the project is implemented with the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

In this context, this publication was developed within the framework of the German-Mexican Dialogue on Quality Infrastructure, established between the BMWK and the Mexican Ministry of Economy. This bilateral dialogue is a platform that brings together representatives from relevant ministries, quality infrastructure institutions, and companies as well as industry associations and chambers from both countries to address topics of mutual interest in the field of quality infrastructure.

This publication is the result of a collaboration since 2019 between stakeholders of the bilateral expert group within the project line 'Strategic cooperation on electromobility: standardisation, certification and technical regulation', which was agreed in the German-Mexican Dialogue on Quality Infrastructure's joint work plan.

This is the third document in a series of four publications on quality infrastructure in the field of electromobility. This series will address four priority topics: 1) charging infrastructure, battery safety and disposal; 2) heavy-duty vehicles for transporting passengers and goods; 3) fundamentals of electric vehicles and specifics for passenger vehicles; and 4) micromobility (two-wheelers).

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List of abbreviations

AC	**alternating current**
ANCE	**Asociación de Normalización y Certificación A.C.** *Standardisation body in Mexico*
ANSI	**American National Standards Institute**
AVAS	**Acoustic Vehicle Alerting System**
BMWK	**Bundesministerium für Wirtschaft und Klimaschutz** *German Federal Ministry for Economic Affairs and Climate Action*
CAP	**Conformity Assessment Procedure**
CB	**Certification Body**
CO_2	**Carbon dioxide**
CSA	**Canadian Standards Association**
DC	**direct current**
DIN	**Deutsches Institut für Normung** *German Institute for Standardization*
DKE	**Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE** *German Commission for Electrical, Electronic & Information Technologies of DIN and VDE*
EV	**electric vehicles**
EU	**European Union**
EU COM	**European Commission**
EUR	**euro**
EVS	**Electric vehicle safety**
FMVSS	**Federal Motor Vehicle Safety Standards**
g	**gram**
GIZ	**Deutsche Gesellschaft für Internationale Zusammenarbeit**
GTR	**Global technical regulations**
ICE	**Internal Combustion Engine**
IEC	**International Electrotechnical Commission**
IECEE	**IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components**
IMNC	**Instituto Mexicano de Normalización y Certificación A.C.** *Mexican Institute of Standardisation and Certification A.C.*

ISO	**International Organization for Standardization**
km	**Kilometer**
kW	**Kilowatt**
kWh	**Kilowatt-hour**
NCB	**National Certification Body**
NEC	**National Electrical Code®**
NEMA	**National Electrical Manufacturers Association**
NOM	**Norma Oficial Mexicana** *Mexican technical regulation*
NMX	**Norma Mexicana** *Mexican Standard*
NFPA	**United States National Fire Protection Association (NFPA)**
NHTSA	**National Highway Traffic Safety Administration**
NYCE	**Normalización y Certificación NYCE S.C.** *Standardisation body in Mexico*
OEM	**Original equipment manufacturer**
QI	**Quality infrastructure**
RESS	**Rechargeable Energy Storage System**
RRF	**Recovery and Resilience Facility**
SAE	**Society of Automotive Engineers**
SEMARNAT	**Secretaría de Medio Ambiente y Recursos Naturales** *Ministry for the Environment and Natural Resources*
SENER	**Secretaría de Energía** *Mexican Ministry of Energy*
SICT	**Secretaría de Infraestructura, Comunicaciones y Transportes** *Ministry of Infrastructure, Communications and Transport*
SME(s)	**small and medium-sized enterprise(s)**
UNECE	**United Nations Economic Commission for Europe**
UL	**Underwriters Laboratories**
US	**United States**
VDE	**Verband der Elektrotechnik Elektronik Informationstechnik e.V.** *Association for Electrical, Electronic & Information Technologies*

1. Introduction

In response to the global commitment to mitigate climate change and reduce Greenhouse Gas (GHG) emissions, the transportation sector is experiencing a transformative shift towards electromobility. According to data from the International Energy Agency (IEA), the first quarter of 2023 saw an increase in global electric vehicle (EV) sales compared to the same period in 2022. In the context of Mexico, the sale of hybrid and EVs in May 2022 was 2.5% higher than in May 2021 . This growth trajectory is expected to deeply transform this industry by integrating new value chain components related to the EV powertrain, as well as reducing the need for 5 million barrels of oil a day—which are now being consumed by internal combustion engine (ICE) vehicles—by 2030[2].

To consolidate its position in the automotive manufacturing sector and make the most of the economic prospects arising from this transition, Mexico, the seventh-largest vehicle producer worldwide, must harmonise its Quality Infrastructure (QI) with the technical demands of EVs.

The QI system, comprising technical regulation, standardisation, conformity assessment, accreditation, metrology and market surveillance, plays a pivotal role in ensuring product safety and quality. However, for the purposes of this white paper, the focus is set on technical regulation, standardisation and conformity assessment.

The mandatory **technical regulations** establish essential public interest protection goals by laying down characteristics for products, processes, production methods or services[3]. Voluntary **standards** provide, "for common and repeated use, rules, guidelines or characteristics for products or related processes and production methods"[4] and may become mandatory if referenced directly in a technical regulation. Lastly, an adequate **conformity assessment procedure (CAP)** enforcement is key for an effective implementation of technical regulations and standards through a set of testing, inspection and verification activities that serve to evidence compliance.

Electric vehicle production.

Internationally standardised QI frameworks can streamline trade processes by minimising duplicated testing and harmonising technical regulations and CAPs. This, in turn, enhances commercial efficiency across borders by cutting costs for businesses, which otherwise would need to show compliance with various regulations.

The objective of this white paper is to identify opportunities for the harmonisation of Mexican standards, technical regulations, and CAPs with international equivalents, fostering competitiveness and innovation in the field of electromobility in Mexico. The document's scope and content were discussed and agreed upon with the bilateral expert group overseeing the 'Strategic cooperation on electromobility: standardisation, certification and technical regulation' project line, within the German-Mexican Dialogue on Quality

Infrastructure. It lays out the current challenges and presents recommendations for strengthening the Mexican panorama of standards, technical regulations, and conformity assessment schemes for EVs.

This document focuses on **three primary areas of interest:** 1) **charging infrastructure**, 2) **operational safety** of EVs and 3) **circularity** of the value chains of EV batteries and other vehicle components. Strengthening the relevant QI framework of these areas is essential for advancing the shift towards electromobility, ensuring that the technical regulations, standards and CAPs underpinning the dependability, safety and sustainability of EVs are in place.

This publication is part of a series addressing various aspects of electromobility and QI, including (1) **charging infrastructure and batteries**, (2) **heavy-duty vehicles for transporting passengers and goods**, (3) **EV fundamentals and specifics for passenger vehicles** and 4) micromobility (two-wheelers).

To promote an enhanced understanding of the national and international QI frameworks, the document provides a mapping of existing technical regulations and standards globally and from Mexico, the European Union (EU), Germany and the United States (US), as well as international best practices for the three primary topics. Given the transversality of CAPs, we dedicate Chapter 4 to it. Based on the status quo in Mexico and the international best practices mapped, Chapter 5 contains the recommendations made by industry stakeholders, which are essential to strengthen the QI framework for the successful expansion of the EV industry in Mexico.

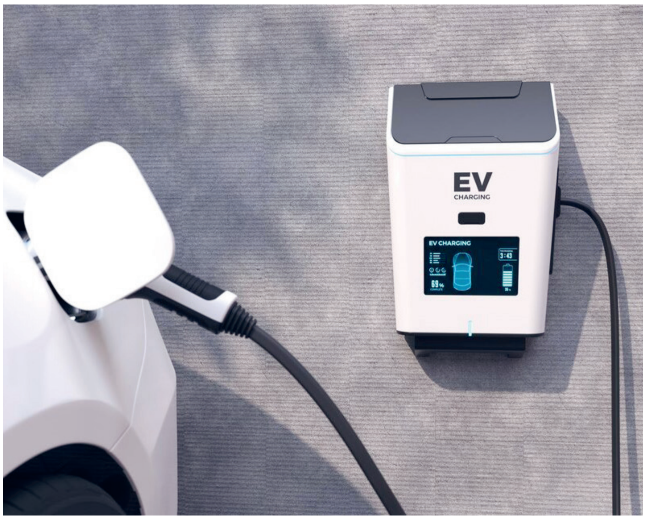
1. Three pillars for the transtion towards electromobility

The availability of **charging infrastructure, operational safety of the vehicles** and **circularity** of their production and parts are key elements in driving a successful and sustainable adoption pathway of electric vehicles. While the access to charging infrastructure is important to address the common range anxiety with respect to EVs[5], guaranteeing operational safety of the vehicles in light of the particular risks associated with their high-voltage batteries is key to ensuring consumer protection. Given the reliance of the technology on non-renewable resources, particularly in the batteries and the powertrain, developing circularity strategies around EVs and their components is necessary both to gradually reduce EVs environmental footprint and ensure the availability of the raw materials underpinning electrification of the automotive industry.

The functional, safe and efficient development of these three pillars, in turn, depends on the existence, robustness and level of international harmonisation of QI frameworks, particularly technical regulations, standards and conformity assessment procedures. In the following, we discuss in further detail what concerns are to be resolved within these pillars to promote a greater adoption of electric vehicles and expansion of the EV industry in Mexico and how a QI approach is not only helpful, but necessary to address them.

Charging Infrastructure

As stated in the white paper volume on "Quality Infrastructure for Electromobility – Charging Infrastructure, battery safety and disposal"[6], charging infrastructure is a critical element to promote the transition towards electromobility in Mexico and internationally. Therefore, and considering its deep interrelation with EVs, this topic is reexplored in this paper with a focus on the specific needs of passenger vehicles.



Electric vehicle charging

Firstly, **accessibility to charging infrastructure** continues to be one of the major concerns of both users and manufacturers. The *EV Driver Survey Report 2023*[7] informed that 50% of respondents across Europe highlighted range anxiety –meaning the concern about the distance that could be traveled on a single charge and the fear of getting stranded during the journey– as a top-three barrier to EV adoption yet representing a 10% decrease in contrast to the 2022 report. In the case of Mexico, according to a Frost & Sullivan study published in 2023, there are currently 1,336 public charging stations distributed throughout the country, with a total of 3,206 connectors[8].

The majority of these charging stations are located in Mexico City, with approximately 221 stations. Jalisco and Nuevo León closely follow, with approximately 110 and 100 stations, respectively. In contrast, the Mexican Association of the Automotive Industry (AMIA) reported 10,206 electric and plug-in hybrid vehicles sold between January and December 2022, representing a 120% increase in comparison to 2021[9]. This illustrates the urgent need to deploy additional charging infrastructure to satisfy market demand. Therefore, expanding the charging infrastructure –not only in urban areas, but also throughout highways– is key for users to be confident of having charging points available throughout their journeys, thereby encouraging the adoption of EVs to achieve the transition towards low- and zero-emission mobility.

Additionally, **defining the type of EV charging connectors, sockets and plugs** required by the country –considering market demand and characteristics of the national electric system– is crucial to ensure national and regional **interoperability and effective access of customers of different EV brands** charging infrastructure in Mexico and increase the efficiency of infrastructure investment. This is also relevant to the **improvement of user safety**, as well as of the vehicles, the charging infrastructure and electric grid, by reducing the need of using adaptors and thus the probability of an accident derived from a human or technical error while charging.

A **proper and safe installation** of charging infrastructure is another critical aspect to address, with the aim of reducing electrical hazard incidents such as electric shocks or short circuits, which could damage not only users and connected EVs, but also the charging infrastructure and even the electric grid. In that regard, expert personnel with specialised training for the installation, operation and maintenance of charging infrastructure is also essential.

For all the above-mentioned priority topics regarding charging infrastructure, **technical regulations, standards and CAPs** play an essential role to guarantee compliant, high quality and safe products and services. Relevant best practices already exist at the international level, offering Mexico accessible references containing consensus-based technical guidelines for charging infrastructure, among other products within the electromobility ecosystem. These are briefly presented in chapter 2.1, as further detailed information is available in the white paper volume on the charging infrastructure, battery safety and disposal.

Operational Safety

The surge in EV popularity has also come with a set of **safety concerns related to** both their **mechanical and software components**. If left unattended, these issues could affect not only the **safety of drivers** but also that of **first responders** and **pedestrians** and may have **negative impacts on the trust of consumers into EVs**. Thus, it is essential to address these global EV-related risks from a QI perspective, given the interconnected nature of the international EV production industry.

One significant distinction between EVs and ICE vehicles lies in the voltage level of their batteries (400-800V) for EV's and (12V) for ICE. The significantly higher voltage at which EVs operate, presents risks such as electric shock and explosions, which can have severe consequences under certain conditions. Additionally, the increased weight of EVs poses risks for other traffic participants in the event of an accident.

Among the prominent technical factors contributing to incidents involving EVs are general EV damage, high-voltage circuit malfunctions, equipment wear and weathering. The most common causes of incidents stem from excessive usage, internal faults, technical faults during charging, submersion in water and collisions with other vehicles and objects[10]. Moreover, the escalating software complexity in EVs, necessary for tasks like autonomous driving and connectivity, underscores the need for robust security strategies to protect users against potential cyber threats.

Therefore, the implementation of technical regulations and standards is key to mitigate risks associated with both the hardware and software aspects of EVs.

Circularity

The transition to electromobility has become a key component of decarbonisation strategies worldwide. While the shift from ICE vehicles to electric ones offers great potential for emission reduction and directly reduces local air pollution, other environmental risks associated with EVs need to be highlighted.

Goal	Strategy	Description
Smart product use and manufacture	R0 – Refuse	Make product redundant by abandoning its function or offering same function with radically different product
	R1 – Rethink	Make product use more intense (e.g. product-sharing, multi-funcational product)
	R2 – Reduce	Increase efficiency in product manufacture or use by consuming fewer natural ressources and materials
Extend lifespan of product and its part	R3 – Reuse	Reuse of functional discarded product by another consumer
	R4 – Repair	Repair and maintenance of defective product to restore its original function
	R5 – Refurbish	Restore an old product to bring it up to date
	R6 – Ramanufacture	Use product or parts in a new product with its orginal function
	R7 – Repurpose	Use product or parts in a new product with a different function
Useful application of materials	R8 – Recycle	Process the materials to obtain the same (high grade) or lower(low grade) quality
	R9 - Recover	Incinerate materials to recover energy

Figure 1: The 9 R-Strategies for the transition towards a circular economy.

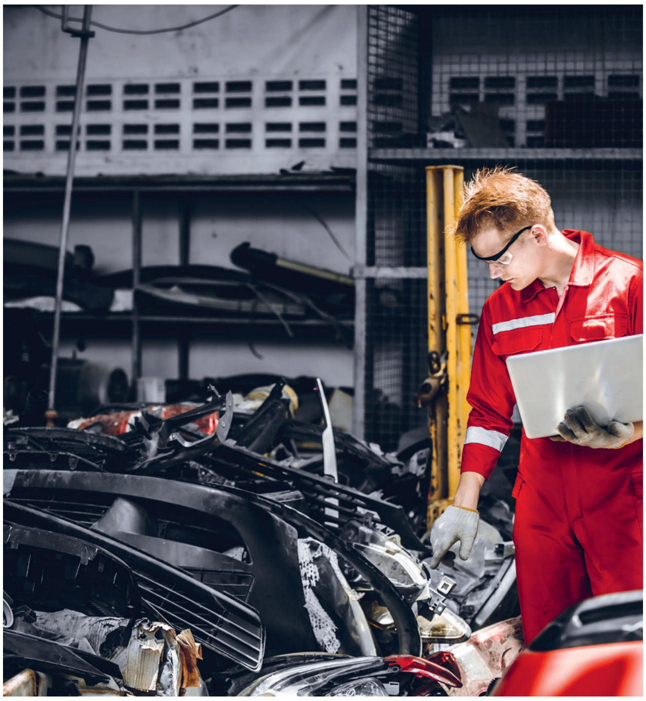
Particularly, the production of Lithium-Ion-Batteries and electric motors containing rare earth metals require highly geographically concentrated non-renewable minerals like lithium, cobalt, neodymium and praesodymium that are energy-intensive to mine and often extracted in regions with low enforcement of environmental standards. This adds to the contamination potential of EV components that can also be found in conventional ICE vehicles like industrial plastics, electric components and tires. Additionally, due to the heavier weight of EVs, components like tires also tend to wear out more quickly, contributing to increased waste generation.

To minimise EVs environmental footprint, it is **necessary to develop Circular Economy strategies** for the different EV components that allow to circulate them at their highest value. Differentiated strategies to reduce their environmental footprint will need to be developed based on the state of maturity of circularity approaches and technologies for the respective component value chain in Mexico, combining different R-strategies (see figure 1).

Adopting relevant technical regulations, standards and conformity assessment procedures is key for an economy-wide implementation of R-strategies around different vehicle components. For the effective implementation of these R-strategies, in turn, **ensuring traceability of components and materials** as they undergo transformative processes and circulate between different actors emerges as a main challenge that has led in Europe to the development of an innovative tracking solution, the **Digital Product Passport (DPP)**. By storing important product-related data such as manufacturing details, ownership or recycling instructions, the DPP facilitates the exchange of information along global value chains. What differentiates DPPs from traditional tracking solutions is their ability to be updated throughout a product's lifecycle, accounting for changes in product characteristics or uses.

While for some strategies corresponding QI-approaches are still to be developed at the international level where technologies are still being refined, as in the case of EV battery recycling, there are already some international and national standards offering standardised technical solutions for the **repurposing of EV batteries or recycling processes** of other components[11]. On the other hand, countries and regional associations have started to develop technical regulations aiming at the reduction of EVs environmental footprint and the promotion of circular value chains, for example through mandatory levels of recycled content for batteries[12]. With regard to component traceability, the European Commission has opted for promoting the DPP as a key tool to accelerate the transition towards a circular economy: under the new proposal for the **Ecodesign for Sustainable Products Regulation (ESPR)**[13], by 2026, sectors such as the automotive industry, the chemical industry and the plastics industry that are related to EV-value chains will be obliged to use the Digital Product Passport for products sold in the EU.

These proposed or already implemented international best practices in technical regulation, standardisation and conformity assessment will be mapped and contrasted with the Mexican status quo in the second part of this white paper, with the objective of identifying possible next steps to strengthen QI for the circularity of EV value chains in Mexico.



Cars sustainability.

2. Mapping of national and international technical regulations and standards for the three pillars

2.1. Charging Infrastructure

As anticipated in the first chapter, detailed information on relevant standards, technical regulations and conformity assessment procedures for EV charging infrastructure and battery safety and disposal in Mexico, Germany, the EU, the US, and at the international level is available in the white paper volume on "Quality Infrastructure for Electromobility – Charging Infrastructure, battery safety and disposal". Therefore, some of the information presented there is included under this section in a summarised manner, along with complementary information.

Technical Regulations

Mexico

Technical regulations in Mexico are known as Norma Oficial Mexicana (NOM). They are developed by regulatory authorities in their respective fields of competence. Competent regulatory authorities in the field of electromobility are the Ministry of Economy (Secretaría de Economía), the Ministry of Energy (Secretaría de Energía – SENER), the Ministry of Infrastructure, Communications and Transports (Secretaría de Infraestructura, Comunicaciones y Transportes – SICT) and the Ministry for the Environment and Natural Resources (Secretaría de Medio Ambiente y Recursos Naturales – SEMARNAT).

Currently, in Mexico no technical regulations specifically for charging infrastructure has been developed yet. Electrical safety requirements for EV charging infrastructure are established through technical regulations which apply in general to electrical installations and products. For example, **NOM-001-SEDE-2012**[14] for electrical installations establishes the technical specifications and guidelines these must meet to be safe for people and their property. EV charging equipment is also covered in this NOM. Parameters concerning ground fault are an example of one of the main elements covered by this regulation which are particularly relevant for the protection of users, for instance against leakages of current. The updated version of this NOM was tabled in 2018, but as of 2023 has not been published yet. However, it is expected to be included as part of the National Quality Infrastructure Programme (Programa Nacional de Infraestructura de la Calidad – PNIC) 2024 to resume its final publication and entry into force. Due to the electrical safety scope of the NOM, the publication of its updated version is deemed necessary to guarantee the protection of users as well as of the electric grid.

NOM-003-SCFI-2014[15] sets characteristics and safety specifications for electrical products imported to or commercialised in Mexico. The general requirements established in the NOM cover the principles of protection against product hazards and those caused by external factors, as well as the safe functioning of the product, and information on the usage, preservation, and labelling. This NOM references several Mexican standards (NMX) that must be applied, depending on the product in question, to prove compliance with NOM-003-SCFI-2014. Among them, **standards NMX-J-668/1-ANCE-2013** Electric Vehicles (EV) – Personnel protection systems for supply circuits – Part 1: general requirements and **J-668/2-ANCE-2013** Electric Vehicles (EV) – Personnel protection systems for supply circuits – Part 2: Particular requirements for protection devices for use in charging systems are also included. NOM-003-SCFI-2014 was inscribed in PNIC 2020 to undergo a modification process. However, the updated version of the NOM has not been published yet.

International

Globally, there are no technical regulations yet for off-board charging. This is rather guided by international standardisation, mainly in the International Electrotechnical Commission (IEC). The summary of relevant IEC standards for charging infrastructure identified by the bilateral expert group is presented in the upcoming Standards section under this chapter.

European Union/Germany

In the case of the EU, **European Directive 2014/94/EU** addresses the deployment of alternative fuels infrastructure. It introduces measures for the implementation of such infrastructure in the EU and outlines the minimum criteria for its development, including electric vehicle charging points. It also establishes standard technical specifications for these charging and refuelling points, as well as user information and labelling requirements.

United States

Public Law No. 114-94 instructed the US Department of Transport to designate national corridors for electric vehicles (EVs) and other alternative fuels, aiming to identify the necessary infrastructure for charging EVs, among other alternative fuel vehicles, at strategic locations along major highways in the country.

Title 16, Part 309 of the **Code of Federal Regulations** establishes the requirements for labelling certain vehicles that are powered by alternative fuels, including EVs. According to this regulation, specific information must be disclosed on the labels, such as the kilowatt (kW) capacity, voltage, type of current (alternating current (AC) or direct current (DC)), electric current limits, and charging mode (conductive or inductive).

Standards

Mexico

Currently, Mexican standards (NMX)[16] may be published by Ministries for their respective areas of mandate of private standardisation and certification bodies. The national standardisation bodies responsible for developing voluntary technical documents, known as NMX, in the automotive sector, are ANCE (Asociación de Normalización y Certificación A.C.), IMNC (Instituto Mexicano de Normalización y Certificación, A.C.), and NYCE (Normalización y Certificación NYCE, S.C.).

Some Mexican standards (NMX) apply to both the charging infrastructure and the vehicle due to its scope, for example NMX-J-678-ANCE-2020 and NMX-J-683-1-ANCE series regarding plugs, socket outlets and couplers. These are shown in further detail in the "Operational safety" section. The NMX applicable to charging infrastructure include the following:

International

At the global level, the **International Organisation for Standardisation (ISO)** and the **International Electrotechnical Commission (IEC)** are prominent standardisation bodies in which relevant standardisation developments in the field of electromobility take place.

Standards on communication protocols, as well as on plugs, socket-outlets, vehicle connectors and inlets, key components of the charging infrastructure, not only apply to them, but also to the EVs itself, because of their interrelation. Therefore, these standards are detailed in the "operational safety" section.

European Union/Germany

Following the principles of EU harmonisation legislation, several European and German standards are derived from international standards. In Germany, the responsible bodies for standardisation are the **German Institute for Standardization (DIN)** and the **German Commission for Electrical, Electronic & Information Technologies of DIN and VDE (DKE)**. In this regard, information on the relevant internationally harmonised German standards that apply to both the charging

Theme	Mexican standard	Concordance with international standards
	Charging infrastructure	
Personnel protection systems for supply circuits	NMX-J-668/1-ANCE-2013 Electric Vehicles (EV) – Personnel protection systems for supply circuits – Part 1: General requirements	Regionally harmonised with the Council for Harmonization of Electrotechnical Standards of the Nations in the Americas (CANENA).
	NMX-J-668/2-ANCE-2013 Electric Vehicles (EV) – Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits – Part 2: Particular Requirements for Protection Devices for Use in Charging Systems	
Supply equipment	NMX-J-677-ANCE-2020 Electric Vehicles – Supply equipment	
Electric vehicle conductive charging system	NMX-J-684-ANCE (series), including: • NMX-J-684-1-ANCE-2021 Electric vehicle conductive charging system – Part 1: General requirements • NMX-J-684-21-1-ANCE-2021 Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply. • NMX-J-684/22-ANCE-2014 Electric vehicle conductive charging system - Part 22: AC electric vehicle charging station. (Note on status: This NMX is expected to be withdrawn in its the next revision due to the withdrawal of IEC 61851-22).	Modified concordance with IEC international standards, respectively: IEC 61851 series Electric vehicle conductive charging system – • IEC 61851-1 Part 1: General requirements, ed3.0 (2017-02). • IEC 61851-21-1:2017 Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply. • IEC 61851-22 Part 22: AC electric vehicle charging stationed1.0 (2001-05). Note on status: Withdrawn in 2017.
Electric vehicles – inductive charging systems	NMX-J-725-1-ANCE-2016 Electric vehicles – Inductive charging systems – Part 1: General requirements	Modified concordance with international standard IEC 61980-1, Electric vehicle wireless power transfer (WPT) systems – Part 1: General requirements, ed1.0 (2015-07).

Table 1: Mexican standards applicable to charging infrastructure and batteries for EVs

infrastructure and the EVs is presented in the corresponding section of operational safety.

United States

The National Electrical Code® (NEC)[17] is developed and published by the **National Fire Protection Association (NFPA)** on a three-year cycle. The **American National Standards Institute (ANSI)** is responsible of approving it as a national standard in the US. NEC sets the minimum electrical code requirements that govern electrical safety in residential, commercial, and industrial occupancies to assure safety from potential electrical hazards. As a national code, complying with NEC becomes mandatory when it is adopted at a municipal or state level. The current NEC edition was published in 2023. NEC also covers the installation of EV charging systems in its **Article 625**[18].

The **National Electrical Manufacturers Association (NEMA)**[19] is another standardisation body in the US. It congregates representatives from the private sector, mainly from electrical, engineering, and scientific sectors, to develop and publish electrical and medical imaging standards and technical documents.

Additionally, the **Society of Automotive Engineers (SAE)** International and **Underwriters Laboratories (UL)** are two standardisation bodies that create voluntary standards for various industries, including automotive. As in the previous cases, several of the standards for charging infrastructure are also applicable to EVs because of their interrelation. Therefore, these are presented in the corresponding "operational safety" section.

2.2. Operational Safety Technical regulations

Mexico

In Mexico, there are currently no technical regulations specifically for EVs. However, there are NOMs that consider EVs in their scope, or are applicable to these type of vehicles because of the broad scope of the NOM:

- **Safety devices** NOM-194-SE-202 Essential Safety Devices in New Vehicles - Safety Specifications.
- **Maximum Noise Emission** NOM-080-ECOL-1994, Establishing maximum permissible limits for noise emissions from the exhaust of motor vehicles, motorbikes and motor tricycles in circulation and the method of measuring them.

International

At the international level, the **World Forum for Harmonization of Vehicle Regulations (WP.29)** is engaged in developing technical regulations for vehicles, including EVs. It oversees the **1958 Agreement** concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations, as well as the **1998 Agreement** on UN Global Technical Regulations. The 1958 Agreement, initially limited to European subscribers, gradually expanded to encompass countries such as Japan, South Africa, and Malaysia, now comprising 58 participating nations. Serving as the basis for Economic Commission for Europe of the United Nations (UNECE) Vehicle Regulations, this agreement is legally binding for all contracting parties, with a total of 160 regulations published to date.

In contrast, the 1998 Agreement on UN Global Technical Regulations laid the groundwork for the development of United Nations Global Technical Regulations (UN GTRs), which establish harmonised performance criteria and test procedures for vehicles and their components. However, unlike UNECE regulations, UN GTRs require incorporation into national or regional law to achieve legal enforcement. To date, 38 countries are part of the 1998 Agreement, with 24 UN GTRs published in the Registry of Global Technical Regulations administered by WP.29. Both UNECE regulations and UN GTRs are accessible to the general public.

The following UN GTRs and UNECE regulations are relevant to EVs:

- **General Safety Requirements for EVs** UN GTR No. 20 Global Technical Regulation on the Electric Vehicle Safety (EVS)

- **Lighting** UNECE No. 48 — Uniform provisions concerning the approval of vehicles with regard to the installation of lighting and light-signalling devices.
- **Power** UNECE No. 100 — Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train.
- **Sound Emission** UNECE No. 138 — Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility.

UNECE Regulation No. 100 outlines specific provisions for the approval of vehicles concerning the electric power train, emphasising safety requirements for electrically powered road vehicles, excluding those permanently connected to the grid. It covers vehicle and Rechargeable Energy Storage System (RESS) requirements, along with corresponding test methods to ensure the RESS's safety performance. The third revision of this regulation was published and implemented on 25 March 2022.

UNECE Regulation No. 51 addresses the approval of motor vehicles with a minimum of four wheels regarding their sound emissions. It includes specifications for the sound reduction system, sound levels, and exhaust systems containing fibrous materials.

Regulation No. 138 establishes standardised provisions for the approval of Quiet Road Transport Vehicles, emphasising reduced audibility.

European Union/Germany

EU member states are automatically bound by UNECE regulations, including 14, 16, 48, 100, and 138, due to their participation in the 1958 Agreement. These regulations serve as pertinent EU Technical Regulations, establishing essential safety standards for EVs within the EU.

In addition, **Regulation (EU) 2018/858** serves as the legal framework for the certification process for specific types of vehicles, systems, components, or separate technical units. This regulation outlines administrative provisions and technical requirements for the type-approval and market introduction of these products, along with regulations for their market surveillance. It applies to motor vehicles falling under categories M (passenger transport), N (goods transport), and O (trailers).

Regarding sound emissions, **Regulation (EU) 2017/1576** stipulates the inclusion of an acoustic vehicle alerting system (AVAS) in every new model of electric and hybrid vehicles. This system is programmed to generate a sound automatically when the vehicle is moving at speeds between 0 and 20 km/h, as well as during reverse movements, to warn pedestrians of the vehicle's presence.

United States

In the US, the **National Highway Traffic Safety Administration (NHSTA)** serves as the federal government body tasked with the establishing and implementing the **Federal Motor Vehicle Safety Standards (FMVSS)**. These standards delineate compulsory minimum safety prerequisites for vehicles, some of which pertain specifically to EVs, while others are relevant to vehicles in general. Manufacturers are obligated to certify their vehicle or equipment to demonstrate FMVSS compliance if they intend to market their vehicles and components in the US.

The following list gives an overview over the technical regulations applicable to electric vehicles.

- **Controls and displays** FMVSS No. 101 Controls and Displays
- **Lighting** FMVSS No. 108 Lamps, Reflective Devices, and Associated Equipment
- **Brakes**
  FMVSS No. 116 Motor Vehicle Brake Fluids
  FMVSS No. 105 Hydraulic and electric service brake systems
- **Crash protection**
  FMVSS No. 301 Fuel System Integrity
  FMVSS No. 302 Flammability of Interior Materials
- **Electric shock** FMVSS No. 305 Electrolyte spillage and electric shock protection
- **Sound emission** FMVSS No.141 Minimum sound level requirements for low-speed operation of hybrid and electric vehicles

FMVSS no. 305 sets electrical safety requirements for the operation and post-crash performance of vehicles equipped with high voltage sources. These requirements aim to protect vehicle occupants, rescue personnel and individuals who may contact the vehicle after a crash against electric shock.

FMVSS no. 141 outlines minimum sound level requirements for low-speed operation of hybrid and electric vehicles, including multipurpose passenger vehicles, trucks and buses. This regulation also establishes as band range for the sound that the vehicle must emit.

FMVSS no. 105 establishes the braking distance specifications for ICE and EV equipped with hydraulic brake systems, electric and regenerative service brakes and parking brake, considering the behavior to be met in case of eventual failure of any of its components. Its aim is to ensure safe braking performance under normal and emergency conditions. It applies to multi-purpose passenger vehicles, trucks, and buses with a gross vehicle weight rating (GVWR) greater than 3,500 kilograms (7,716 pounds), equipped with hydraulic or electric brake systems.

Standards

Mexico

The following table includes NMX that, while not exclusive to EVs, apply to them and address the topics of brakes, ergonomics, and lighting systems. They are accompanied by the international standards they are harmonised with. Also, standards pertinent to the charging infrastructure, given their impact on the vehicle's safety, are included. Since some of these standards were already mentioned in the white paper on charging infrastructure, they are presented here in a summarised manner.

Theme	Standard	Harmonised with
	Charging infrastructure	
Cords and cables	NMX-J-436-ANCE-2021 Wires and cables – Flexible cords and cables – Specifications	Regionally harmonised standard with US standard UL 62 and Canada standard
	NMX-J-738-ANCE-2020 Wires and cables – Electric vehicle cable – Specifications and test methods	Regionally harmonised standard with US standard UL 2263 and Canada standard CSA 332.
Plugs, socket outlets, vehicle connectors and inlets.	NMX-J-677-ANCE-2020 Electric Vehicles – Supply equipment	Modified concordance with international standard IEC 62196-1 Plugs, socket outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 1: General requirements, ed3.0 (2014-06). (Note on status: updated to ed 4.0 in May 2022).
	NMX-J-683-1-ANCE-2020 Electric vehicle – Plugs, socket outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 1: General requirements.	Modified concordance with international standard IEC 62196-2 Plugs, socket outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories, ed2.0 (2016-02).
	NMX-J-683-3-ANCE-2020 Electric vehicles – Plugs, socket outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles. Part 3: Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers.	Modified concordance with international standard IEC 62196-3 Plugs, socket outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 3: Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers, ed1.0 (2014-06).

Table 5: Mexican standards for EV.

Theme	Standard	Harmonised with
	Charging infrastructure	
Protection equipment	NMX-J-612-ANCE-2018 Protection against electric shock – Common aspects for installation and equipment	Modified concordance with international standard IEC 61140:2016 ed4.0 (2016-01).
Brakes	NMX-D-313-IMNC-2015: Air brake systems	Partially harmonised with: • Regulation from the US: 49 Code of Federal Regulations (CFR) 571.121 Standard No. 121 (FMVSS 105) - Air brake systems • Standards from the American Society for Testing and Materials ASTM – an international standards development organization–: • ASTM E1337-19 - Standard Test Method for Determining Longitudinal Peak Braking Coefficient (PBC) of Paved Surfaces Using Standard Reference Test Tire • ASTM E1136-19 – Standard Specification for P195/75R14 Radial Standard Reference Test Tire
Lighting systems	NMX-D-233-IMNC-2021: Products for use in carriers – Exterior lights	Partially harmonised with: • Regulation from the US: 49 CFR 571.108 Standard No. 108 • US Standard SAE J759.

Table 5: Mexican standards for EV.

International

The standards that were identified as most relevant for the operational safety of EV's considering the scope of this white paper are listed below. They cover the themes of protection against electric shock for persons inside and outside the vehicle and safe driving automation features.

Regarding communication protocols, the Open Charge Point Protocol (OCPP) is an open-source communication system which enables the interaction between charging stations and the Charging Station Management System (CSMS). OCPP enables bilateral communication between EV chargers and software backend systems, allowing the exchange of information such as meter values and charging events. Additionally, OCPP supports smart charging functionality, enabling the transmission of charging commands from the CSMS to the EV charger. However, it must be noted that this protocol is not an official international standard, but is advocated by the Open Charge Alliance (OCA), formed by public and private charging infrastructure providers[20].

Additionally, regarding battery testing, the United Nations Manual of test and criteria addresses in its Part 3, Section 38.3 (also known as UN/DOT 38.3) the requirements applicable to lithium cells and batteries[21]. It also includes information on the specific tests applicable to these products, such as altitude simulation, thermal test, vibration test shock test, external short circuit, impact/crush test, overcharge test and forced discharge test[22].

Theme	Standard
	Charging infrastructure
Communication protocols	ISO 15118-1:2019: Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition
	ISO 15118-2:2014: Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements
	IEC 63110-1:2022: Protocol for management of electric vehicles charging and discharging infrastructures - Part 1: Basic definitions, use cases and architectures.
Supply of electric energy to electric road vehicles	ISO 17409:2020 Electric safety requirements for conductive connection of electrically propelled road vehicles to external electric circuits.
	ISO/DIS 5474-1 Electrically propelled road vehicles — Functional and safety requirements for power transfer — Part 1: General requirements for conductive power transfer. (Note on status: The voting on the draft of the international standard closed on 28 July 2022).
	ISO 6469-1:2019 Electrically propelled road vehicles — Safety specifications – Part 1: Rechargeable energy storage system (RESS)
	IEC 61851-23:2014: Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station. (Note on status: Edition 2.0 is forecasted to be published in December 2023).
Performance	IEC 62660-3:2022 Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements
Plugs, socket-outlets, vehicle connectors and inlets	IEC 62196 series - Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles.
	IEC 62752 In-Cable Control and Protection Device for mode 2 charging of electric road vehicles (IC-CPD)
Protection of individuals	ISO 6469-3:2011 Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons inside and outside the vehicle against electric shock.
Autonomy	ISO 26262-1:2018: Road vehicles — Functional safety — Part 1: Vocabulary
	ISO 21448:2022: Road vehicles — Safety of the intended functionality

Table 6: Identified International standards for EVs.

European Union/Germany

Based on the principles of the EU harmonisation legislation, numerous European and German standards are based on international standards. In that sense, the following table displays the international-

ly harmonised German standards based on the international standards listed above. **United States**
The table below displays specific standards created by SAE and UL for EVs, which aim to enhance their operational safety. These standards encompass general safety guidelines, safety measures for batteries, and cybersecurity.

Theme	German / European standard
Communication protocols	DIN EN ISO 15118-1:2019-08: Road vehicles - Vehicle to grid communication interface - Part 1: General information and use-case definition (ISO 15118-1:2019)
	DIN EN ISO 15118-2:2016-08 Road vehicles - Vehicle-to-Grid Communication Interface - Part 2: Network and application protocol requirements (ISO 15118-2:2014)
	DIN EN IEC 63110-1:2023-07 VDE 0122-110-1:2023-07 Protocol for management of electric vehicles charging and discharging infrastructures - Part 1: Basic definitions, use cases and architectures (IEC 63110-1:2022)
Supply of electric energy to electric road vehicles	DIN EN ISO 17409:2020-10: Electrically propelled road vehicles - Conductive power transfer - Safety requirements
	DIN EN IEC 61851-1:2019-12 VDE 0122-1:2019-12 Electric vehicle conductive charging system - Part 1: General requirements (IEC 61851-1:2017); German version EN IEC 61851-1:2019
Plugs, socket-outlets, vehicle connectors and inlets	DIN EN 62196 VDE 0623-5 series Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles (IEC 62196-1:2014, modified)

Table 7: Internationally harmonised German/EU standards identified as relevant.

United States

The table below displays specific standards created by SAE and UL for EVs, which aim to enhance their operational safety. These standards encompass general safety guidelines, safety measures for batteries, and cybersecurity.

- **Automation**
  SAE J3016: Levels of Driving Automation

- **Cables**
  UL62 Standard for Safety for Flexible Cord and Fixture Wire, UL 62 in the United States, Mexico, and Canada.

- **Cybersecurity**
  SAE J3061_202112: Cybersecurity Guidebook for Cyber-Physical Vehicle Systems

  UL 2900-1: Standard for Software Cybersecurity for Network-Connectable Products, Part 1: General Requirements

- **Guidelines for EV safety**
  SAE J2344_202010: Guidelines for Electric Vehicle Safety

- **Battery**
  UL 2580 UL Standard for Safety Batteries for Use in Electric Vehicles

- **Rechargeable energy storage system (RESS)**
  SAE J2929 Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells

  SAE J2464_202108: Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

International

The standards that were identified as most relevant for the operational safety of EV's considering the scope of this white paper are listed below. They cover the themes of protection against electric shock for persons inside and outside the vehicle and safe driving automation features.

Regarding communication protocols, the Open Charge Point Protocol (OCPP) is an open-source communication system which enables the interaction between charging stations and the Charging Station Management System (CSMS). OCPP enables bilateral communication between EV chargers and software backend systems, allowing the exchange of information such as meter values and charging events. Additionally, OCPP supports smart charging functionality, enabling the transmission of charging commands from the CSMS to the EV charger. However, it must be noted that this protocol is not an official international standard, but is advocated by the Open Charge Alliance (OCA), formed by public and private charging infrastructure providers[20].

Additionally, regarding battery testing, the United Nations Manual of test and criteria addresses in its Part 3, Section 38.3 (also known as UN/DOT 38.3) the requirements applicable to lithium cells and batteries[21]. It also includes information on the specific tests applicable to these products, such as altitude simulation, thermal test, vibration test shock test, external short circuit, impact/crush test, overcharge test and forced discharge test[22].

European Union/Germany

Based on the principles of the EU harmonisation legislation, numerous European and German standards are based on international standards. In that sense, the following table displays the internationally harmonised German standards based on the international standards listed above.

2.3. Circularity

While Mexico has very strong records in the implementation of circularity strategies for some materials like PET, where recycling rates are above 50%, circularity strategies for automotive parts in general and EV components in particular are less explored. However, as the sales of hybrid (both plug-in and non-PHEV) and electric passenger vehicles reached 52.983 in 2022, promoting circularity solutions based on international best practices and standards becomes an imperative. This chapter discusses the current state of technical regulations, standards and conformity assessment the for the three R-strategies Rethink, Repurpose and Recycle, as well as traceability solutions in Mexico, contrast it with the panorama in the EU, the US and available international standards.

Technical Regulation

Mexico

While in Mexico there are currently no active technical regulations specifying circularity or sustainability requirements for electric vehicle components, in 2022 the first draft technical regulation regarding circular economy strategies for electric and electronic devices and EV batteries was published by the Ministry of Economy.

The proposal for this preliminary draft regulation **ANTEPROY-NOM-XXX-SE-2022**, „Circular Economy - Safety specifications for electrical and electronic equipment and batteries for electric and hybrid electric vehicles" pursues the objective is to establish specifications to be met by electrical equipment, electronic equipment and batteries for electric and hybrid electric vehicles to increase their durability. It makes reference to the international standard *IEC 62430*: *Environmentally conscious design (ECD)* and the *United Nations Global Technical Regulation (UN GTR) No. 22.* on In-vehicle Battery Durability for Electrified Vehicles.

As adopted from UN GTR No. 22, if this draft is ratified, manufacturers would be required to install state of certified range (SOCR) und state of certified energy status (SOCE) monitors on board of the vehicle that allow consumers to oversee the performance level of the EV batteries over their life cycle. Minimum performance requirements for EV batteries at different stages of their life cycle are also adopted from UN GTR No. 22 and are displayed in table 2. Accordingly, until a life of 5 years or a driven distance of 100.000 km, whichever of the two thresholds is reached first, the battery is required to still retain 80% of its original energy capacity.

Additionally, and beyond the scope of UN GTR No. 22, according to the NOM draft manufacturers, importers and traders would need to provide the necessary information for the correct repair and reuse of their products, and bear the economic and physical responsibility for their products. They are also made responsible for the traceability of electrical and electronic waste to its destination or final disposal. Additionally, distributors and marketers would be obliged to take back products in the categories they sell in order to ensure a second life. However, these obligations are not yet further specified.

Another technical regulation relevant to the circularity of EVs, even it is not specific to EVs and their components, is the **NOM-161-SEMARNAT-2011**. This technical regulation defines the list of materials that are considered special handling wastes, as well as the guidelines for the elaboration of management plans for this waste types that companies are obliged to develop. In the current state of the regulation, residual EV batteries are defined as special waste[23] as the concentration of hazardous substances is below the threshold defined in NOM-052-SEMARNAT-2005[24] that establishes the characteristics of hazardous wastes.

EV life cycle stage	Battery Energy Capacity
From start of life to 5 years or 100,000 km, whichever comes first	80%
Vehicles more than 5 years or 100,000 km, and up to whichever comes first of 8 years or 160,000 km	70%

Table 9: Minimum Performance Requirements in terms of Battery Energy Capacity for different stages of the EV life cycle.

In consequence, lithium-ion batteries fall under the scope of the requirements of the NOM-161-SEMARNAT. Amongst other elements, the waste management plans defined in the NOM have to disclose information on the main materials composing the waste, current management of the waste, identification of the potential use or exploitation of the waste in other productive activities, targets for the coverage of the plan, recovery or use of the waste during the implementation of the management plan and mechanisms of operation, control and monitoring for the follow-up, as well as for the evaluation and improvement of the management plan. Once the management plan has been elaborated, it must be submitted to the Federal Entity that corresponds to the territorial scope of implementation. However, no conformity assessment procedure is defined to verify compliance with the technical regulation.

The **NOM-024-SCFI-2013** defines commercial information for packaging, instructions and warranties for electronic, electrical and household appliance products, and can thus be related to the R-strategy of repairing. In the scope of NOM-024-SCFI-2013, electric products are defined as equipment that is used for the purposes of generation, conversion, transmission, distribution or utilisation of electrical energy, which includes batteries. The NOM defines that the duration of the warranty cannot be less than three months in the case of electrical and electronic products and, in the case of household appliances, cannot be less than one year. The warranty minimum requirements offer an entry point to define warranty requirements specific to EV batteries to incentivize designs for durability and repairability. In the case of the California Advanced Clean Cars Regulation, which is explained in the upcoming US section, warranties are related to minimum performance requirements as those that are to be established in the draft Circular Economy NOM.

International

As mentioned in the previous chapters, at the global level there are UN Global Technical Regulations (UN GTR), which, however, need to be transposed in national law to become mandatory in a specific country. The relevant UN Global Technical Regulation for the environmental performance of electric vehicles is the aforementioned **United Nations Global Technical Regulation No. 22** on In-vehicle Battery Durability for Electrified Vehicles, on which Mexico's Technical Regulation Proposal NOM PROPANTEPROY-NOM-XXX-SE-2022, „Circular Economy - Safety specifications for electrical and electronic equipment and batteries for electric and hybrid electric vehicles" is partly based.

UN GTR No. 22 contains requirements for displaying battery health information and usage data from the vehicle, minimum durability criteria for EV batteries expressed in terms of two indicators SOCE (State of Certified Energy) and SOCR (State of Certified Range), as well as testing procedures for different vehicle types to assess their conformity to the Technical Regulation by means of a Pass/Fail test. The minimum durability requirements are the same that can be observed in table 9.

European Union/Germany

The EU has recently introduced or announced new Technical Regulations (EU Regulations or Directives) that are relevant for the promotion of different R-strategies for electric vehicles and their components. Because of their pioneering role at the global level, this overview will focus on the EU Battery Regulation and the EU Ecodesign Directive.

The **EU Battery Regulation (Regulation 2023/1542)** concerning batteries and waste batteries entered into force 17 August, 2023, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC. It takes a full lifecycle approach to assessing and reducing the environmental footprint of different types of batteries, addressing raw material sourcing, manufacturing, use and recycling. Because of its comprehensive character, it is expected to become the global benchmark for technical regulation promoting the circularity of battery value chains.

The main provisions included in the new EU Battery Regulation that are relevant to electric vehicle batteries can be observed in table 10.

Additionally, from 2025 onwards, the Regulation will gradually introduce performance classes and

Theme	Provisions applicable to EV batteries under Regulation 2023/1542
Disposal	Total prohibition on landfilling waste batteries, – including EV batteries. They must be collected by Economic Operators free of charge for end-users, regardless of the nature, chemical composition, condition, brand or origin of the waste battery in question.
Labelling	All EV batteries with a capacity of more than two kWh must have a „clearly legible and indelible" carbon footprint declaration and label, indicating amongst others, the levels of recycled cobalt, lead, lithium and nickel used in the battery production.
Raw materials	Restricts the use of mercury, cadmium and lead in EV batteries.
Recycled content	Compulsory minimum levels of recycled content for reuse in new EV batteries: six per cent for lithium and nickel, 16 per cent for cobalt and 85 per cent for lead. Every battery will be required to specify the amount of recycled content it contains.
Digital Battery Passport	EV batteries, with more than two kWh will need a „digital battery passport", with information on the battery model, the specific battery and its use. All batteries must have labels and QR codes detailing their capacity, performance, durability and chemical composition, as well as show the „separate collection" symbol.

Table 10: Main provisions in EU Battery Regulation relevant to EV batteries

maximum limits on the carbon footprint of electric vehicles and light means of transport.

Besides this regulation which already entered into force, in 2022 and 2023 two regulation proposals were published by the EU Commission that contain relevant provisions for promoting the circularity of EV value chains: **The End-of-life vehicles regulation proposal, and the Ecodesign for Sustainable Products Regulation.**

The End-of-life vehicles (ELV) regulation proposal[25], published July 13, 2023, forms part of the EU Circular Economy Action Plan. It expands, and will ultimately replace, Directive 2000/53/EC on end-of-life vehicles and Directive 2005/64/EC on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability. While the regulation proposal is not specific to EVs, it covers components and materials common to both ICE and electric vehicles, such as plastics, steel and aluminium. The proposal aims to promote the transition of the automotive sector to the circular economy, taking a full life cycle approach considering all stages the design to end-of-life-treatment. Amongst others, the proposal introduces the following measures relevant to EV:

The proposal further promotes extended producer responsibility, including financial responsibility for vehicles at their end-of-life, and obliges manufacturers to develop circularity strategies for each new vehicles type.

On 30 March 2022, the proposal for the **Ecodesign for Sustainable Products Regulation (ESPR)**[26] was published. It aims to expand the existing Ecodesign Directive 2009/125/EC, which currently only covers energy-related products, towards most products placed on the internal market, exempting only food, medical products and living organisms. Aiming to make products last longer and be easier to repair, upgrade, and recycle, it is a key element of the EU Commission's approach to more environmentally sustainable and circular products.

Theme	Provision description
Recycled content	Mandatory minimum of 25% of recycled content of plastics used in new vehicles. Additionally, the EU commission is empowered to set minimum recycled contents for other materials such as steel in the future. These must be based on feasibility studies.
Toxic substances	Maximum concentration levels of lead, cadmium, mercury and hexavalent chromium in vehicles are defined: Concentrations of up to 0,1 % by weight in homogeneous material for lead, hexavalent chromium and mercury and up to 0,01 % for cadmium will be tolerated. (ANNEX III)
Design requirements	The design of new vehicles must not hinder the removal of parts and components that have an important potential for reuse. EVs should be designed in such a way that batteries and electric motors can be replaced both during the use and the disposal phase.
Monitoring of ELV	Improvement of the monitoring of ELV through more inspections, improving interoperability of national vehicle registration systems, improved distinction of used vehicles from end-of-life vehicles and a ban on exporting ELVs that are not roadworthy anymore to non-OECD countries.
Circularity Vehicle Passport	Establishes a circularity vehicle passport, a digital tool used to improve the provision of information on the safe removal and replacement of vehicle parts and components, while being interoperable with other digital information tools and platforms that already exist or are under development in the automotive sector.

Table 11: Provisions applicable to EVs under the ELV regulation proposal

The proposal establishes a framework to set ecodesign requirements for specific product groups to significantly improve their circularity, energy performance and other environmental sustainability aspects. Ecodesign working plans guide the route towards the final versional of the ESPR.

While vehicles are not yet included in the priority product groups that are to be addressed in the first phase, the list includes important industry inputs such as steel, aluminium, tyres and paints. As in the other introduced regulations, the ESPR will mandate the use of **Digital Product Passports** for the regulated product groups. These are to contain information relevant for economic operators and other actors like repairers and recyclers, as well as for consumers to allow informed purchasing decisions based on sustainability indicators.

United States

To date, the US has no federal circularity requirements for EVs. However, at the subnational level, states like California have started to take important steps towards promoting the circularity of EV value chains through durability and traceability requirements.

The Advanced Clean Cars II regulations in California set battery durability regulations that go beyond the minimum requirements established in UN GTR No. 22 (see above). Accordingly, EVs for model year 2026–2029 electric vehicles will be required maintain at least 70% of their certified test-cycle range for 10 years or 240,000 km (150,000 miles), whichever occurs first[27]. This requirement will gradually be increased over time: For 2030 and subsequent electric vehicle model years, the requirement is increased to 80% of their certified test-cycle range for the same age or usage level. Similarly to UN GTR No. 22, the regulation will also require a monitoring of the state of health (SOH) of the battery accessible to buyers and users. Based on this metric, EV manufacturers will be obliged to clearly specify the SOH percentage that qualifies for warranty repair.

Further, and in line with the requirements established in the EU Battery Directive, California will start requiring electric vehicles registered from 2026 onwards that batteries are labelled with a digital identifier that links to online information on the battery chemistry, manufacturer, date of manufacture, minimum voltage, and rated capacity.

Standards

Mexico

Private Mexican Standardisation and Certification Bodies like ANCE and NYCE have been active in the development of national standards and the adoption of international standards that are relevant for the implementation of circularity strategies for EVs.

The first one, **NMXJ-692-ANCE-2014 (07/05/2015) Guidelines for end-of-life information provided by manufacturers and recyclers for recyclability rate calculation of electrical equipmen**t, is a generic standard applicable to EV powertrain and other electric components that can also be found in ICE vehicles. It is based on the international standard IEC/TR 62635 ed1.0 (2012-10) that goes by the same name and provides a methodology for the exchange of information involving manufacturers and recyclers of electrical equipment and for the calculation of recyclability and recoverability rates. **NMXJ-692-ANCE-2014** aims to enable recyclers to implement suitable treatment operations and end-of-life optimisation, to enable manufacturers to implement effective environmentally conscious design guidelines that facilitate the recycling of materials and evaluate recyclability and recoverability rates based on product attributes.

The Mexican standard **NMX-E-285-NYCE-2021 Plastics Industry – Guidelines for the Recovery and Recycling of Waste Plastics** published by the standardisation and certification organisation NYCE applies to the plastic components of EVs and ICE vehicles. It provides generic guidance for the development of standards and specifications covering the recycling of different types of plastic waste, including different management options for post-consumer and post-industrial plastic waste, where the latter is the one relevant for the automotive industry. This standard sets out the quality requirements to be considered in all steps of the recycling process, and provides general guidelines for inclusion in material standards, test methods and product specifications. It is based on International Standard ISO 15270:2008 Plastics - Guidance for the recovery and recycling of plastics waste.

International

At the international level, several standards relevant to the implementation of circularity strategies for EVs have been developed in the Technical Committee No. 21 concerned with battery standardization inside IEC and the TC No. 323 of ISO. They address different components of EVs and different R-strategies.

Second Life

Current retirement criteria for lithium-ion batteries in electric vehicles cite 75-80% capacity for end-of-first-life, as the range of EVs is significantly impacted at that point. However, while they are no longer fit for powering EVs, the batteries may be used as industrial batteries or perform energy-storage services equilibrating the intermittent energy generation of renewable energies, also referred to as "second life" of the battery. Recent studies indicate that the carbon footprint of an electric vehicle lithium-ion battery can be reduced by up to 17% if it is reused in a second life[28].

As the use of retired EV batteries as industrial batteries implies both a different purpose and environment of application, the battery must be assessed to the applicable safety and performance standards for the new industry. Table 12 shows the relevant standards for a second life of EV batteries published by the IEC together with a short description as the table is no longer set directly below it.

Standard	Description
IEC 62620:2014: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications	Specifies marking, tests and requirements for lithium secondary cells and batteries used in industrial applications including stationary and motive applications. Stationary applications include telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, and emergency power, amongst others. Motive applications include fork-lift truck, golf cart, AGV, railway, and marine, excluding road vehicles. Applies to cells and batteries.
IEC 61427-1:2013: Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application	This standard is part of the series IEC 61427. It provides general information regarding the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the methods of test used for the verification of battery performances. This part deals with cells and batteries used in **photovoltaic off-grid applications**. It is applicable to all types of secondary batteries.
IEC 61427-2:2015: Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 2: On-grid applications	This standard is part of the IEC 61427 series. It provides associated testing methods for the verification of endurance, properties and electrical performance of secondary batteries used in **on-grid Electrical Energy Storage (EES) applications**. In on-grid applications, batteries are connected to an electricity grid and act as energy sources and absorbers to stabilize the grids' performance in face of fluctuations of electrical energy generated from renewable energy sources. It is applicable to all types of secondary batteries.
IEC 62933-4-4: Electrical energy storage (EES) systems - Part 4-4: Standard on environmental issues battery-based energy storage systems (BESS) with reused batteries – requirements	The document provides details and requirements for identifying and preventing environmental issues in each life cycle stage, i.e., from the design to the disassembly of such reused batteries in a battery-based energy storage system (BESS).

Table 12: Relevant standards for second life of EV batteries

However, it must be noted that only the last one of these standards is specific to reused batteries. While the previous standards in principle apply to all kinds of batteries, ultimately it will be important to develop standards specific to repurposed EV batteries due to higher hazard risks associated with aged Lithium-Ion batteries.

Recycling

While, as discussed above, recycling strategies and technologies for EV batteries are still under development, there are well-proven international standards providing guidance on recycling methods for other EV components. In table 13, we present IEC/TR 62635:2012: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation

Standard	Description
IEC/TR 62635:2012: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment	This standard provides a methodology for information exchange involving EEE manufacturers and recyclers, and for calculating the recyclability and recoverability rates.
ISO 15270:2008: Guidelines for the recovery and recycling of plastics waste	This standard provides guidance for the development of standards and specifications covering plastics waste recovery, including recycling. The standard establishes the different options for the recovery of plastics waste arising from pre-consumer and post-consumer sources. It also establishes the quality requirements that should be considered in all steps of the recovery process, and provides general recommendations for inclusion in material standards, test standards and product specifications.

Table 13: Relevant International standards for end-of-life information and for the recovery and recycling of plastic waste

of electrical and electronic equipment and ISO 15270:2008: Guidelines for the recovery and recycling of plastic waste as examples that are referenced by the standardisation bodies ANCE and NYCE in Mexico. To explore other relevant international standards relevant to the recycling of electronics or plastics integrated in EVs, consult the Standardisation Roadmap Circular Economy by the German standardisation bodies DIN and DKE, that provides a full mapping of published international and national standards.

European Union/Germany

In the EU, EU standardisation bodies **European Committee for standardisation (CEN)** and the **European Committee for Electrotechnical Standardization (CENELEC) have a Joint Technical** Committee responsible for developing circularity standards for energy-related products, the **TC 10 „Energy-related products - Material Efficiency Aspects for Ecodesign“**[29].

The Technical Committee has the mandate to develop European standards and publications concerning material efficiency aspects for products in the scope of the Ecodesign Directive 2009/125/EC and the proposed Ecodesign for Sustainable Products Regulation (see above). Key topics addressed by the Committee are the extension of product lifetime, reusability of product components and recyclability of materials, and integration of reused components and recycled materials in new products. Thus, the committee takes an integral approach towards circularity that goes beyond recycling, with publications corresponding to multiple R-strategies including also rethinking (increasing durability), repairing, reusing, remanufacturing, and refurbishing.

The TC 10 developed a series of eight European Standards (EN) containing generic principles regarding the application of these R-strategies to energy-related products. While these are not specific to EVs, in containing generic principles applicable to any energy-related product, they are nonetheless relevant and may set the base for the development of more specific standards for EV batteries and powertrains. Some of the standards like EN 45553:2020 (WI=65686) and EN 45555:2019 (WI=JT010001) require product-specific information for a correct selection and application of the assessment methods included.

A selection of the standards developed by CEN-CENELEC TC 10 can be observed in the table on page 32.

Circularity Strategy	Standard	Description
Information provision Recycling	EN 45558:2019 (WI=65687) General method to declare the use of critical raw materials in energy-related products	This standard describes requirements for the appropriate declaration of information on the use and recyclability of critical materials contained in energy-related products.
Information provision	EN 45559:2019 (WI=65688) Methods for providing information relating to material efficiency aspects of energy-related products	This standard describes guide-lines for providing appropriate information related to material efficiency in the documentation and/or marking of energy-related products.
Recycling	EN 45557:2020 (WI=JT010002) General method for assessing the proportion of recycled material content in energy-related products	This standard provides a general methodology for assessing the proportion of recycled material in energy related products.
Recycling	EN 45555:2019 (WI=JT010001) General methods for assessing the recyclability and recoverability of energy-related products	This standard provides a general methodology for assessing the recyclability of energy related products, their recoverability, the ability to access or remove com-ponents and the recyclability of contained critical raw materials. While it addresses these issues in a generic, cross-product way, a correct assessment has to be product-specific. Accordingly, the standard defines parameters to consider when calculating pro-duct-specific recycling and reco-verability rates.
Repair Reuse Refurbish	EN 45554:2020 (WI=65685) General methods for the assessment of the ability to repair, reuse and upgrade energy-related products	This standard defines parame-ters and methods for assessing the ability to repair and reuse products, to upgrade products, access or remove certain com-ponents or assemblies to facili-tate repair, reuse or upgrade. It also defines reusability indexes or criteria.
Remanufacture	EN 45553:2020 (WI=65686) General method for the assessment of the ability to remanufacture energy-related products	This standard provides a general methodology for the assessment of the ability to re-manufacture energy related products. However, a correct assessment needs to be product-specific.

Table 14: CEN/CENELEC standards developed within TC 10 on Energy-related products.

Standard	Description
DIN VDE V 0510-100, "Safety of lithium-ion batteries from electrically propelled road vehicles for use in stationary applications".	This draft national pre-standard provides basic safety requirements for this repurposing, e.g., in industry as temporary or auxiliary storage. The draft was published in 2021.
VDI 2343 series "Recycling of electrical and electronic products"	Parts 1 to 7 of the VDI 2343 series of guidelines provide all concerned parties with recommendations for action on the recycling of electrical and electronic products. It specifies the terms used in waste electrical and electronic equipment (WEEE) recycling, describes the necessary planning and processes of logistics and the structures for the efficient collection of WEEE, the operation of collection points and/or transfer points as well as the transfer to treatment plants from an economic and ecological point of view.
DIN SPEC 91446 "Classification of recycled plastics by Data Quality Levels for use and (digital) trading".	The DIN SPEC establishes a system for classifying recycled plastics according to the data depth of their description, which removes obstacles to their industrial use. This allows material to be classified according to four different data quality levels.
DIN/TS 54405 "Construction adhesives - Guideline for separation and recycling of adhesives and substrates from bonded joints".	This specification states the processes commonly available for separating and recovering adhesives from bonded joints. It applies to commonly used metal and plastic surfaces and non-metallic inorganic joining part surfaces. This Technical Specification thus contributes to the better recyclability of resources.

Table 15: CEN/CENELEC standards developed within TC 10 on Energy-related products.

In addition to the work done by the European Standardisation Bodies CEN and CENELEC, the German Standardisation Bodies (SBs) DIN and DKE, as well as the Association of German Engineers (VDI) and the Association of German Electrotechnicians (VDE) have published several standards and guidelines relevant to the implementation of circularity strategies for EVs.

They cover different components of EV, including the battery and power train, but also industrial plastics and adhesives used to bond metallic and non-metallic parts in vehicles. They address the R-strategies of reusing and recycling.

United States

In the US, the UL, a Standards Development Organization (SDO) accredited by the American National Standards Institute (ANSI) is an active developer and promoter of standards to enhance the circularity of EV value chains.
The two relevant standards identified concern EV batteries and cover the R-strategies of reusing and rethinking (increasing durability).

UL 1974: Creating a Safe Second Life for Electric Vehicle Batteries addresses sorting and grading processes of used battery packs, modules and cells that are to be repurposed in different applications, such as energy storage systems. It includes guidance to determine the state of health

(SOH) of the battery to decide on the viability and safety of further use and protocols to measure the condition, safety and energy capacity of each individual battery pack before it can be integrated into a stationary energy storage system.

The second relevant standard published by UL **is UL 2580: Electric Vehicle Battery Testing and Certification.** It offers guidelines for assessing battery performance, thermal management, design, and construction. Amongst the testing methods to avoid potential hazards like overheating, short-circuiting, and mechanical failure, UL 2580 includes mechanical testing to evaluate a battery's **durability** and resistance to common hazards on the road. Ensuring that the batteries suffice minimum durability requirements is important to avoid a premature end-of-life and maximize the time that the batteries can be used for the propulsion of EVs before entering a potential second life as industrial batteries or energy storage systems.

- **Automation**
  SAE J3016: Levels of Driving Automation

- **Cables**
  UL62 Standard for Safety for Flexible Cord and Fixture Wire, UL 62 in the United States, Mexico, and Canada.

- **Cybersecurity**
  SAE J3061_202112: Cybersecurity Guidebook for Cyber-Physical Vehicle Systems

  UL 2900-1: Standard for Software Cybersecurity for Network-Connectable Products, Part 1: General Requirements

- **Guidelines for EV safety**
  SAE J2344_202010: Guidelines for Electric Vehicle Safety

- **Battery**
  UL 2580 UL Standard for Safety Batteries for Use in Electric Vehicles

- **Rechargeable energy storage system (RESS)**
  SAE J2929 Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells

  SAE J2464_202108: Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

2.3. Circularity

While Mexico has very strong records in the implementation of circularity strategies for some materials like PET, where recycling rates are above 50%, circularity strategies for automotive parts in general and EV components in particular are less explored. However, as the sales of hybrid (both plug-in and non-PHEV) and electric passenger vehicles reached 52.983 in 2022, promoting circularity solutions based on international best practices and standards becomes an imperative. This chapter discusses the current state of technical regulations, standards and conformity assessment the for the three R-stra-

3. Conformity assessment procedures

Conformity assessment procedures (CAPs) consist of a set of actions 'used, directly or indirectly, to determine that the relevant requirements in technical regulations or standards are fulfilled'[30]. These procedures include sampling, testing and inspection, evaluation, verification and assurance of conformity, as well as approval, among others. As CAPs are transversal to the effective implementation of any of the technical regulations and standards discussed in the previous section, we dedicate this special chapter to contrasting Conformity Assessment Procedures in Mexico, at the international level, in the EU and the US.

Mexico

The **Law on Quality Infrastructure** in Mexico establishes that **NOMs** must include within the regulation which is the applicable CAP according to the level of risk or required protection to safeguard the legitimate objectives of public interest that the NOM intends to fulfil. In the case of **standards**, they must contain a CAP when appropriate –according to the provisions stated in the ordinance of the QI Law, which is currently under development– depending on the nature of the good, product, process or service. When the NMX does not include nor defines a specifically applicable CAP, whomever is responsible for the good, product, process or service may carry out a **self-declaration of conformity** provided that they imply a low level of risk. The ordinance of the QI Law will also establish the terms in which a self-declaration of conformity be used.

In Mexico, there are **four conformity assessment procedures** that can be used according to the level of risk or required protection to safeguard the legitimate objectives of public interest:

1. Laboratory tests: These are carried out by accredited testing laboratories according to NMX-EC-17025-IMNC-2018 "General requirements for the competence of testing and calibration laboratories"[31]. Regarding NOMs, the testing laboratory must have the approval of the regulatory authority which issued the NOM in question. Foreign testing laboratories may also be recognised and their test reports accepted if there is a mutual recognition agreement, mutual recognition arrangement or equivalence agreement in force.

2. Inspection: This procedure is carried out by inspection bodies duly accredited in accordance with NMX-EC-17020-IMNC-2014 "Conformity Assessment – Requirements for the operation of different types of bodies performing inspections", and approved by the competent regulatory authority. The process consists of the visual verification through sampling, measurement, laboratory tests or examination of documents that is carried out by the inspection units to assess conformity at a certain time and at the request of an interested party. These conformity assessment bodies (CABs) generally issue certificates of compliance with NOMs concerning commercial information for importation purposes.

3. Certification: Certification bodies (CB) –which by nature are third party– are responsible for this CAP. CBs must be accredited according to NMX-EC-17065-IMNC-2014 "Conformity Assessment – Requirements for bodies certifying products, processes and services". In the case of NOMs, CBs must have the approval of the regulatory authority that issued the concerning NOM. These conformity assessment bodies issue certificates of conformity for the purposes of product importation. This CAP is used when the NOM involves a high level of risk.

4. Self-declaration: This procedure is carried out by a first party, meaning the supplier of the product, process or service, to declare compliance with NOMs or standards. It is generally used for NOMs when the level of risk is considered low by the corresponding regulatory authority. The self-declaration is usually accompanied by accredited and approved laboratory tests, as well as other requirements to be determined in the ordinance of the QI Law.

5. Other mechanisms adopted by Mexico to boost international trade are Mutual Recognition Agreements (MRA), mutual recognition arrangements and Equivalence Agreements (EA). These mechanisms contribute to saving costs, time and resources implied in importation and exportation.

A **MRA** is an intergovernmental agreement that specifies the conditions under which CABs are mutually recognised and their CAPs results are accepted in the territory of the other partner country.

A **Mutual recognition arrangement or multilateral recognition arrangement** is an international or regional arrangement between accreditation bodies to mutually recognise the results of the signatory conformity assessment bodies or the equivalence of accreditation systems based on peer review.

An **Equivalence Agreement** is a resolution that specifies the conditions under which foreign technical regulations, sanitary and phytosanitary measures or the conformity assessment results – with at least the same degree of conformity to achieve the legitimate objectives of public interest pursued by the corresponding NOM– are unilaterally or reciprocally recognised.

These three mechanisms also help to generate trust among economic actors. To achieve this, the requirements and guidelines established by the technical regulations and standards from the countries signatory to these agreements should be commensurate. For example, an advantage of the CAPs in Mexico is the recognition of the certificate of origin to prove compliance with a particular NOM, when the requirements of the regulation from the country of origin are comparable to those of the NOM. This facilitates trade by eliminating the need of double testing and certification and helps to generate trust on product quality and safety.

Regarding **charging infrastructure**, even though safety and quality are assured through the compliance with NOMs, the lack of a specific technical regulation for EV charging infrastructure hinders functionality, as well as the development of conformity assessment infrastructure. Testing laboratories are crucial to prove that products are compliant with regulations and standards. However, conformity assessment infrastructure requires significant investment to be developed and maintained, which is in turn dependant on the demand of CA services. Therefore, the necessary technical regulations to cover minimum safety and quality requirements, as well as adequate CAPs for both charging infrastructure and EVs must be developed in order to strengthen and further develop capacities and infrastructure of testing laboratories, which at the same time must also be accredited.

International

Harmonised CAPs help to reduce trade barriers, as they increase reliability and objectivity with regard to the safety and quality of products and services. Thus, the acceptance of foreign conformity assessment results and certificates can be increased, helping to reduce costs and facilitating international trade. Conformity assessment standards and guides developed by ISO and IEC are an example of the efforts being made to promote the harmonisation of CAPs.

European Union/Germany

In the European Union, the **Whole Vehicle Type-Approval System (WVTA)** enables a manufacturer to obtain certification for a vehicle type in one EU country[32]. Through the process of type approval, national authorities certify that a model of a vehicle complies with all EU requirements regarding safety, environmental (e.g. noise and emissions) and production aspects. These approvals issued by Member States are mutually recognised within the EU, thus enabling manufacturers to market the approved vehicle type throughout the EU without additional testing. The **Regulation (EU) 2018/858**[33] is the legal basis of the EU vehicle type-approval framework.

EU countries appoint **type approval authorities** and notify them to the European Commission. These approval authorities have competence for the whole process of approval of a type of vehicle, system, component or separate technical unit, as well as the authorisation process. They are also responsible for the issuing and, when appropriate, withdrawing or refusing approval certificates. They act as the contact point for the approval authorities of other EU countries, designate the technical services and ensure that the manufacturer meets its obligations regarding the conformity of production. In Germany, the **Federal Motor Transport Authority (Kraftfahrt-Bundesamt - KBA)** is the national type approval authority[34].

For their part, the national approval authority designates **technical service organisations or bodies** as testing laboratories to carry out tests. They can also be designated as a CAB to carry out the initial assessment and other tests or inspections on behalf of the approval authority. EU countries must notify the European Commission the name and details of designated technical services for motor vehicles, their trailers, systems and components, among other types of vehicles.

Compliance with EU law and EU type-approval requirements is proven through the **certificate of conformity** (CoC) issued by the **manufacturer** for every vehicle[35]. This certificate enables the registration of the vehicle anywhere in Europe[36]. CoC shall include the description of the vehicle's main characteristics, its technical performance and the date of manufacture. It shall be delivered to the buyer, together with the vehicle.

The type-approval system offers manufacturers the advantage of free circulation of goods in the single market of the EU. Once the authority of an EU member country has issued its approval, this is valid in all the other member countries.

United States

Title 15 of the US **Code of Federal Regulations** concerns commerce and foreign trade. In its chapter II on National Institute of Standards and Technology, Department of commerce, **section 287.2**. states the definition of conformity assessment: A demonstration, either direct or indirect, that the specified requirements related to a product, process, system, person or organism are met[37]. Requirements for products, services, systems, people, and organizations are those defined by law or regulation, by a regulatory or procurement agency, or a policy established by the agency. It is important to note that conformity assessment does not include mandatory administrative procedures (such as notification of registration) for granting permission for a good or service to be produced, marketed or used for a stated purpose or under established conditions.

Law 15 CFR 287[38] also indicates the responsibilities of each Federal Agency regarding the conformity assessment of regulations. The agency in charge of road safety in the US is the **National Highway Traffic Safety Administration (NHTSA)**.

	Function				
Party	**Supplier's Declaration of Conformity (SDoC) Who declares**	**Testing**	**Inspection**	**Certification**	**Accreditation**
First-party	Manufacturer/ supplier	Manufacturer/ supplier	Manufacturer/ supplier	–	–
Second-party	–	–	Buyer	–	–
Second-party	–	Independent testing laboratory	Independent control body	Independent certification body	Accreditation entity

Table 16: Summary of the CA stages and the actors responsible for them in the US

According to the Federal Motor Vehicle Safety Standard (FMVSS) and Federal Motor Carrier Safety Administration (FMCSA) regulations –which depend on the Department of Transportation (DOT)–, NHTS is responsible for elaborating and publishing the corresponding regulations of vehicle safety or to review the published regulations for their update. This with the purpose of reducing accidents, material and human damage and fatalities involving heavy trucks and buses. Both agencies work in coordination.

NHTSA regulations establish how to carry out conformity assessment for ground vehicles. OEMs perform the tests deemed as necessary to comply with the regulations and it does not have to submit results reports to the DOT. In contrast, imported vehicles do need the certification from NHTSA proving compliance with safety regulations FMVSS and FMCSA[39]. Table 6 below shows which parties may carry out which functions during the CAPs[40].

As part of the NHTSA, the Office of Vehicle Safety Compliance (OVSC) is responsible for developing the test procedures (TP). TPs are a guide to interpret the regulation, test method, registry and presentation of results. It is important to note that, in contrast to NOMs in Mexico, US regulations only establish what are the requirements that products must comply with, but not how to comply with them or which CAP to use.

In contrast to the EU, in the US conformity assessment does not need to be carried out by third-party verification units or bodies but is rather optional. According to US policy, accreditation of conformity assessment bodies is not mandatory either. Testing laboratories, certification bodies and inspection bodies choose whether or not to be accredited based on the needs and requirements of their customers (e.g. manufacturers, regulators, consumers, suppliers, etc.).

Certification of verification units is also voluntary. Section 280.101 of law 15CFR[41] states the process for the approval of documents related to certification, accreditation of people and laboratories. The approval of accreditation bodies is done through National Institute Standard and Technology (NIST).

4. Recommendations

In the previous sections, important elements of the existing QI framework were identified for the three focus areas charging infrastructure, operational safety and circularity in Mexico. Also, technical regulations, standards and conformity assessment procedures at the international level as well as in the EU, Germany and the US were mapped.

Contrasting the status quo in Mexico and international developments, a set of recommendations for each focus area were identified that aim at guiding the next steps in strengthening the Quality Infrastructure for E-mobility.

1. Recommendations for Charging Infrastructure

Reinforcing the recommendations stated in the white paper volume on charging infrastructure, battery safety and disposal, and in complement with their interrelation to EVs, recommendations to strengthen technical regulations and standards related to charging infrastructure, their electrical safety, functionality and interoperability are presented in the following:

Concerning technical regulations

Modifications of existing technical regulations

As a first step, it is suggested to **update current regulations NOM-001-SEDE-2012** and **NOM-003-SCFI-2014**, which address fundamental electrical aspects, also applicable to EV charging infrastructure. Considering that, due to regional alignment the Mexican national electrical system is based on UL/NEMA standards, it is important that Mexican regulations' updates are in line with international developments. As the current version of NOM-001-SEDE dates from 2012 and takes the NEC® 2011 as a reference, it becomes more relevant to update such NOM according to the current version of the NEC® that has been published in 2023.

It is suggested for the updates of such NOMs to include the following aspects:

- **NOM-001-SEDE-2012** on electrical installations:

  o Should include new technical guidelines specifically for EV charging infrastructure installation to guarantee not only safety but also functionality.
  o Requirements should be included for EV charging hubs in condominiums, particularly regarding energy distribution. Required power and infrastructure characteristics should also be considered from the planning of the installation in order to assure an effective energy supply.

- **NOM-003-SCFI-2014 on electric products and safety specifications:**

  o Include additional references to already existing Mexican standards for EV charging infrastructure specifically.

New technical regulations

As stated in the other volumes of this series of white papers, **vehicle connectors and socket outlets** is a crucial topic the minimum safety requirements of which must be established in a **new NOM**. Mexico should define, based on market demand and the characteristics of the electrical grid, which type of connector(s) and socket outlet(s) will be used in the country. This is important to ensure interoperability, safe charging process and access to charging infrastructure for al EV users. The use of is associated with high risk of accidents, given the high voltage and the difficulty to eliminate the possibility of human errors in the use of the adapter. The regulation must be adaptable to facilitate a swift adoption of future technological developments regarding connectors and socket outlets. This way, the need for an extensive regulatory review may also be avoided.

Similarly, a **new NOM on communication protocols** is identified as necessary. This should consider an open-source communication protocol standard to facilitate effective interaction and data exchange between the charging infrastructure and the EV, as well as to enable swift updating processes. **IEC 63110-1:2022** should be used as a reference, as it covers aspects which are also part of the Open Charge Point Protocol (OCPP), such as:

- management of energy transfer during charging sessions, including reporting and information exchanges related to energy usage, grid usage, contractual data, and metering data.
- asset management of the charging infrastructure, including its controlling, monitoring, maintaining, and firmware updates.
- authentication, authorization, and payment of charging and discharging sessions, including roaming, pricing, and metering information.
- cybersecurity.

New standards

- Regarding **standardisation**, the **development of a standard in Mexico** to certify technicians specifically for EV charging infrastructure installation and maintenance is recommended. This way, technicians may ensure they possess the necessary knowledge and skills to carry out their tasks safely and effectively. Standardised certification also guarantees a consistent level of quality and professionalism in the industry, instilling confidence in both consumers and manufacturers.

2. Recommendations for operational safety

Concerning technical regulations

Modifications of existing technical regulations

Minimum noise emission of EVs is a relevant safety factor for pedestrians and other people in circulation routes. However, in Mexico, there are currently no minimum noise emission levels defined for EVs. Accordingly, it is recommended to update **NOM-079-SEMARNAT-1994** that specifies the maximum permissible noise emission limits of new motor vehicles and their measurement method should be updated to include a requirement for **minimum noise emission levels for EVs** at slow speeds. The international technical regulations **UNECE R138** that establishes minimum noise emission levels should be used as a reference to avoid the creation of technical barriers to trade and impose additional costs on the automotive industry from differing regulations.

New technical regulations

The EV battery is the principal new component of EVs associated with security risks for users and other actors such as maintenance technicians. Due to the risk of electric shock and leakage of toxic substance, we recommend the development of a new NOM establishing minimum requirements for batteries of new and retrofitted EV concerning protecting against electric shock and liquid leakage, adequate structural support of the battery, caution and warning labels, and handling and storage indications. The international technical regulations **UN GTR No. 20 on the Electric Vehicle Safety (EVS)** and **UNECE R100: "Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train"** are recommended as references for his new NOM.

Concerning standards

Regarding **battery safety and performance testing**, Mexico should also keep close attention to and actively get involved in internationally harmonised standards on such matter for its later adoption. Standardised testing ensures rigorous and consistent procedures, which guarantees reliability and safety for users. This would also facilitate trade through common and mutually recognised sets of testing procedures. At the same time, this would generate demand which would in turn promote the further development of capabilities and infrastructure of testing laboratories. The UN Manual of test and criteria: Lithium Battery Testing Requirements is suggested as a reference.

Given the increased interconnectivity of vehicles and devices, and particularly taking into account the safety risks associated with the EV power train, it is recommended to adopt a cybersecurity standard for vehicles in Mexico that specifies guidelines for the prevention of cyberattacks aiming to take control of the vehicle. Above, we listed **SAE J3061_202112: Cybersecurity Guidebook for Cyber-Physical Vehicle Systems** and **UL 2900-1: Standard for Software Cybersecurity for Network-Connectable Products, Part 1: General Requirements** as important references from the US that could be adopted by Mexican standardisation bodies. At the same time, efforts should be undertaken to sensibilise and inform industry stakeholders and users about cybersecurity risks associated with EVs and thereby promote the active demand of the use of these standards in the development of the vehicles' software components by both end-users and manufacturers.

3. Recommendations for Circularity

Based on the mapping of international best practices, in the following, we will present a series of recommendations to strengthen technical regulations and standards related to the promotion of the circularity strategies, including the topics of battery durability, second life of EV batteries, traceability and safe handling and storage of end-of-life batteries, but also other EV components.

Concerning technical regulations

Modifications of existing technical regulations

A transversal aspect for the successful implementation of post end-of-life circularity strategies is the safe handling of aged EV batteries, given their increased risk to enter a thermal runway and cause battery fires. In this regard, the Working Group for the Electrification of Transport of the Ministry of Foreign Affairs recommended to **modify the NOM-052-SEMARNAT-205** that defines the criteria for classifying hazardous wastes[44], as it excludes Lithium-Ion batteries from this class in its current form. Aligned with the recommendation of the Working Group for the Electrification of Transport, it is considered important to update this classification to ensure adequate safety conditions in the handling, transport and storage of retired EV batteries containing hazardous substances. If the NOM-052 was be modified as suggested, this would imply that EV batteries fall into the scope of the technical regulation NOM-055-SEMARNAT-2003, establishing the requirements for sites to be used for controlled confinement of hazardous waste, mitigating security risks in the storage of end-of-life batteries.

New technical regulations

Regarding the topic of battery durability, the bilateral expert group recommends to **elaborate a new NOM specifying minimum requirements of battery performance and the respective test procedures based on UN GTR No. 22 "In-vehicle Battery Durability for Electrified Vehicles"**. Setting mandatory minimum requirements regarding durability that are gradually extended as EV batteries evolve is an important circularity strategy for EVs in the current context where recycling technologies are still lacking market maturity. UN GTR No. 22 represents a solid international framework of reference not only for specifying the minimum requirements (see above), but also introduces the relevant conformity assessment procedures (CAPs) including detailed specifications for the tests to be carried out to evaluate compliance with the regulation and permissible threshold levels.

Concerning standards

A second relevant R-strategy for EV batteries in absence of recycling standards is the repurposing of used EV batteries for energy storage in industrial plants or renewable energy parks. However, as of today, in Mexico there is limited experience and awareness about the practice of EV battery repurposing at the end of first life. Due to the absence of a relevant regulation or standard, where repurposing is practiced, it is done without necessarily observing safety guidelines in the handling of end-of-life EV batteries. The lack of reliability implied for potential customers of second life batteries represents an obstacle for the creation of markets for retired EV batteries and the establishment of second life EV batteries as safe and reliable alternatives to new industrial batteries. To address this problem, it is recommended to introduce a standard on safety requirements for second life applications of EV batteries in Mexico. As possible references the group recommends to consider DIN VDE V 0510-100, „Safety of lithium-ion batteries from electrically propelled road vehicles for use in stationary applications", UL 1974: Creating a Safe Second Life for Electric Vehicle Batteries, the IEC 61427 series "Secondary cells and batteries for renewable energy storage" and the IEC 62933 series on Electric energy storage (EES) systems.

General recommendations

Finally, an important prerequisite for the effective implementation of different circularity strategies is the availability of relevant information on the battery, such as its material composition and instructions for its safe handling. While in the EU a Battery Passport is promoted as container of this information, it is still under development and several standardisation issues such as data formats and the specific information to be included are still under discussion. Here, the recommendation is to wait for the respective results and new standards before setting own regulations, engage in international exchanges on the technological and standardisation advances of the Battery Passport and strengthen existing measures to actively promote the digitalisation of SMEs in the sector, which will be a prerequisite for the adoption of the Battery Pass, and ultimately, for getting access to the growing EV markets in the EU.

5. Conclusions

Around the globe, the commitment to limit the emission of Greenhouse Gases (GHG) is transforming the automotive industry towards electromobility. Mexico, already the seventh-largest vehicle producer in the world, is candidate for becoming an important hub for EV manufacturing in the context of the current trend towards nearshoring. However, a necessary step for a successful transition towards electromobility and materialisation of the opportunities offered by the double-trend of e-mobility and nearshoring is the alignment of the relevant Quality Infrastructure (QI) in Mexico with the specific technical demands of EVs and relevant international standards to ensure the safety and sustainability of such vehicles.

In this sense, this white paper explored possible modifications to the existent QI, particularly technical regulations, standards and conformity assessment procedures that are necessary to facilitate a safe evolution of electromobility in Mexico and to remove regulatory barriers that persist for the proliferation of electric passenger vehicles in particular.

Based on a comparative mapping of the state of technical regulations, standards and conformity assessment procedures for electric passenger vehicles in Mexico, at the international level, in the EU and the US, the bilateral expert group identified a series of recommendations to strengthen and harmonise Mexican Quality Infrastructure for electromobility with international standards. Given their importance for ensuring that EVs are reliable, safe and have a limited environmental footprint, the mappings and recommendations were grouped into the three thematic areas of 1) Charging Infrastructure, 2) Operational Safety, comprising both mechanical safety and cybersecurity, and 3) Circularity of EV value chains.

Electric cars charging.

The resulting recommendations include modifications of existing technical regulations in Mexico that currently do not consider specific features of EVs, making compliance impossible or failing to guarantee basic safety standards of EVs. Also, the introduction of new technical regulations adopting for example minimum durability criteria for EV batteries already defined in international technical regulations, and suggestions for international standards that could be adopted in Mexico to, for example, strengthen the cybersecurity of EVs and promote the safe repurposing of EV batteries after their end of life.

These recommendations present specific and feasible steps that can be taken to adapt the Quality Infrastructure, particularly technical regulations and standards in Mexico to the needs of electric passenger vehicles, thereby promoting a safe, reliable, and sustainable transition towards electromobility and contributing to the competitiveness of Mexico as key location for electric ve-

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