Preparatory Study for Ecodesign of Electric Vehicles Chargers

Draft report (tasks 1 to 3)

implementing the Ecodesign Working Plan 2022 -2024

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List of abbreviations and acronyms

AC	Alternating Current
AFIR	Alternative Fuel Infrastructure Regulation
AI	Artificial Intelligence
AP	Acidification Potential
avg	Average
BAT	Best Available Technology
BAU	Business As Usual
B2B	Business-to-Business
BC	Base Case
BNAT	Best Not yet Available Technology
BOM	Bill of Materials
BPT	Bidirectional Power Transfer
CA	Control Accuracy
CAPEX	Capital Expenditure
CEN	European Committee for Normalisation
CENELEC	European Committee for Electro technical Standardization
CO_2	Carbon Dioxide
CS	(Re-)charging Station
CSMS	Charging Station Management System
DER	Distributed Energy Resources
ED	Ecodesign Directive
EE	Energy Efficiency
EED	Energy Efficiency Directive
Elec	Electricity
ELR	Energy Labelling Regulation
EMS	Energy management system
EN	European Norm
Epac	Electrically pedal assisted cycle
EoL	End of Life
ErP	Energy related Products
EU	European Union
EV	Electrical Vehicle
EVSE	Electric Vehicle Supply Equipment
FU	Functional Unit
GER	Gross Energy Requirement
GDP	Gross Domestic Product
GPP	Green Public Procurement
GWP	Global Warming Potential
HDV	Heavy duty vehicle
I/F	Interface
I/O	Input/Output
IC-CPD	In-Cable Control and Protection Device
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organization for Standardization
KPI	Key Performance Indicators
kWh	Kilowatt hour
kWp	kilowatt peak (power output of PV panels)
lBAC	local building controls
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LDV	Light duty vehicle
LLCC	Least Life Cycle Costs
LED	Light emitting diode

LMT	Light Means of Transport
MEErP	Methodology for Ecodesign of Energy-related Products
n.e.c.	not elsewhere classified
NM	Not modelled
NPV	Net Present Value
OBC	On-board charger
OCPP	Open Charge Point Protocol
OFBC	Off-board charger
O&M	Operation and Maintanence
OPEX	Operational Expenditure
PE	Primary energy
PEF	Primary energy factor
PEP	Profil Environnemental Produit
PID	proportional–integral–derivative controller
PLC	Power-Line Communication
PRxODCOM	Production Communautaire
PSR	Product Specific Rules
PV	Photo-voltaic panels (solar panels)
PWM	pulse width modulation
RCCB	Residual Current Circuit Breaker
RCD	Residual Current Device
RES	Renewable Energy Sources
SG	Smart Grid
SRI	Smart Readiness Indicator
SRT	Smart Readiness Technologies
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TOR	Terms of Reference
TP	Twisted Pair
TS	Technical Specification
V2G	Vehicle to grid
VA	Volt-ampere
WAN	Wide Area Network
WEEE	Waste Electrical & Electronic Equipment

Colour codes used in this draft document:

Text in blue background will be updated in the final version.

Text in green background needs special attention from the stakeholder.

Executive summary

This study was done under a framework contract (771/PP/GRO/IMA/19/1131/11061) for preparatory studies on specific product groups listed in the Ecodesign Working Plans adopted under the Ecodesign Directive (2009/125/EC) and involved analysing the technical, economic, environmental, market and societal aspects of Vehicle Chargers on behalf of the European Commission Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs.

According to the principle of better regulation, preparatory studies will collect evidence, explore all policy options and recommend the best policy mix, if any, to be deployed on the basis of the evidence and stakeholder input. For some of the identified product groups, there is the possibility that overlaps exist with a number of on-going preparatory studies and regulations due for review. In this context, an exploratory scoping study was undertaken to confirm that from the energy and environmental perspective, Vehicle Chargers offer a high energy saving potential of 1.4 $TWh_{electricity}$/year in the utilisation phase by 2030 and a potential increase in annual energy savings of up to 9.5 TWh/year in 2050 when compared to today's implemented technology (concerning standby losses and AC/DC conversion loss if applicable). The exploratory study concluded that Ecodesign product regulation could play an important role in ensuring that product information allows optimal EV Charger solutions to be specified.

In contrast to previous ecodesign preparatory studies, this study will be carried out within the forthcoming ESPR (Ecodesign for Sustainable Products Regulation) context. Together with the 2022-2024 Working Plan, the proposal of the Ecodesign for Sustainable Products Regulation (ESPR) was published in March 2022[1]. The ESPR Regulation builds on the previous Ecodesign Directive, expanding the ecodesign requirements for specific product groups as it enables the setting of performance and information requirements for almost all categories of physical goods placed on the EU market. The framework will allow for the setting of a wide range of requirements, including on:

- product durability and reliability;
- product reusability;
- product upgradability, reparability, maintenance and refurbishment;
- the presence of substances of concern in products;
- product energy and resource efficiency;
- recycled content in products;
- product remanufacturing and recycling;
- products’ carbon and environmental footprints
- products’ expected generation of waste material

Accordingly, the study will examine the potential environmental improvements and sustainability, energy- and resource-efficiency aspects that can be considered for the product, including aspects relevant to the circular economy as well as standardisation requirements and other relevant features specific to this product, such as data interoperability features for smart charging and bidirectional charging in as far as they stem from the interoperability and standardised functionality requirements regulated elsewhere.

The basis for this investigation constitutes the application of a revised Methodology for Ecodesign of Energy-related products (MEErP) approach and the revised EcoReport tool.

Generic structure of the MEErP:

Task 1 – Scope (definitions, standards and legislation);

[1] https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en

Task 2 – Markets (volumes and prices);

Task 3 – Users (product demand side);

Task 4 – Technologies (product supply side, includes both BAT and BNAT);

Task 5 – Environment & Economics (Base case LCA & LCC);

Task 6 – Design options;

Task 7 – Scenarios (Policy, scenario, impact and sensitivity analysis).

In a multi stakeholder consultation, a number of groups and experts provided comments and input on a preliminary draft of this report. The report was then revised, benefiting from stakeholder perspectives and input. The views expressed in the report remain those of the authors, and do not necessarily reflect the views of the European Commission or the individuals and organisations that participated in the consultation. A list of stakeholders that participated in this consultation and further information on project meetings, project website[2] and comments can be found in Annexes ….

Task 1

The Task 1 report analyses the scope, definitions, standards and assessment methods as well as other legislation of relevance to the product group and to assess their suitability for classifying and defining products for the purposes of analysing Ecodesign and Energy Label requirements. The main finding of Task 1 is that …

Task 2

The Task 2 report presents an economic and market analysis of Electric Vehicle Charger products. The key findings of Task 2 are: …

Task 3

The Task 3 report presents … reference Chargers that are considered in the subsequent Task 4. The technical details and assumptions for these reference Chargers are described in the Task 3 report.

[2] https://ecodesign-ev-charger.eu/ecodesign/

0 General introduction to the study

In the last Ecodesign Working plan 2020-24, electric vehicle chargers were selected, among a list of 31 promising candidate products, as one of the energy-related product groups to be studied for potential Ecodesign and energy labelling regulation. This is due to their high energy saving potential of 1.4 $TWh_{electricity}$/year in the utilisation phase by 2030 and a potential increase in annual energy savings of up to 9.5 TWh/year in 2050 when compared to today's implemented technology. The savings arrive mainly from standby losses and in less extent to AC/DC conversion loss if for public fast-chargers. ‘Hence, it is reasonable to consider setting requirements before large volumes of potentially inefficient chargers are installed’. The tables about the savings (energy, emissions, money) as published in the Working plan is given in Figure 0-1.

Additionally, the European Commission proposed a new regulation on Ecodesign for Sustainable Products Regulation (ESPR), repealing the above-mentioned Ecodesign Framework Directive. The potential approval of this new regulation has been looked at, as well as the findings of the study would define the possible Ecodesign requirements that could presumably be implemented under this new framework.

Electric recharging stations are already regulated, in particular under the Directive on the deployment of alternative fuels infrastructure (Directive 2014/94/EU, as known as AFID[3]) and delegated acts adopted under that directive. The AFIR Regulation (EU) 2023/1804[4] repealed the Directive and entered into force on 12 October 2023. The work under this study shall not target aspects/typologies of requirements already covered by that regulation or by existing or upcoming delegated acts to be adopted under that regulation.

The study will also investigate the potential environmental improvements that can be introduced to the product, including relevant aspects to the circular economy (upgradability, durability, reparability...), as well as standardization requirements. This study will provide the necessary information for the identification of the policy options to be analysed in the subsequent impact assessment.

Overall objectives of the study could be summarised as follows:

— Conduct an Ecodesign preparatory study analysing the technical, economic, environmental, market and societal aspects of electric vehicles recharging stations following the MEErP methodology Tasks 1-7;
— Based on the findings of the study, where appropriate, provide input and support to the development of draft proposal of Ecodesign Regulation and/or Energy Energy Labelling Regulation for electric vehicles chargers.
— Provide ad-hoc technical expertise.

Figure 0-2 gives a clear overview of the different phases within the study resulting in a draft for the Ecodesign or Energy Label Regulation.

[3] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance. OJ L 307, 28.10.2014, p. 1–20

[4] Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, OJ L 234, 22/09/2023, p. 1–47

Table 300: Potential electricity savings (TWh/year) and total primary energy savings (PJ/year, CC: 2.1) EU-27 based on the stock in the particular years[826]

TWh/year	2020	2030	2040	2050
Simple AC wallbox connector	0.02	0.26	0.60	0.63
Smart AC wallbox connector	0.01	0.46	2.48	4.49
Public "low" speed AC charger	0.02	0.44	1.70	2.69
Public "high" speed DC charger	0.01	0.28	1.05	1.67
Total electricity savings, TWh/year	**0.06**	**1.44**	**5.84**	**9.49**
Primary energy savings, PJ/year	**0.4**	**11**	**44**	**72**

Table 301: Potential GHG savings EU-27 based on the stock in the particular years[826]

MT CO2eq/year	2020	2030	2040	2050
Simple AC wallbox connector	0.01	0.09	0.18	0.16
Smart AC wallbox connector	0.00	0.16	0.75	1.17
Public "low" speed AC charger	0.01	0.15	0.51	0.70
Public "high" speed DC charger	0.00	0.09	0.32	0.43
Total	**0.02**	**0.49**	**1.75**	**2.47**

Table 302: Monetary saving EU-27 based on the stock in the particular years[826]

Million EUR/year	2020	2030	2040	2050
Simple AC wallbox connector	3.88	55.33	128.66	131.84
Smart AC wallbox connector	1.22	98.52	534.62	939.11
Public "low" speed AC charger	3.89	94.45	366.10	562.70
Public "high" speed DC charger	2.41	58.42	226.45	348.06
Total	**11.39**	**306.73**	**1255.83**	**1981.71**

Figure 0-1: Tables about the savings (energy, emissions, money) as published in the Ecodesign Working plan 2022-2024.

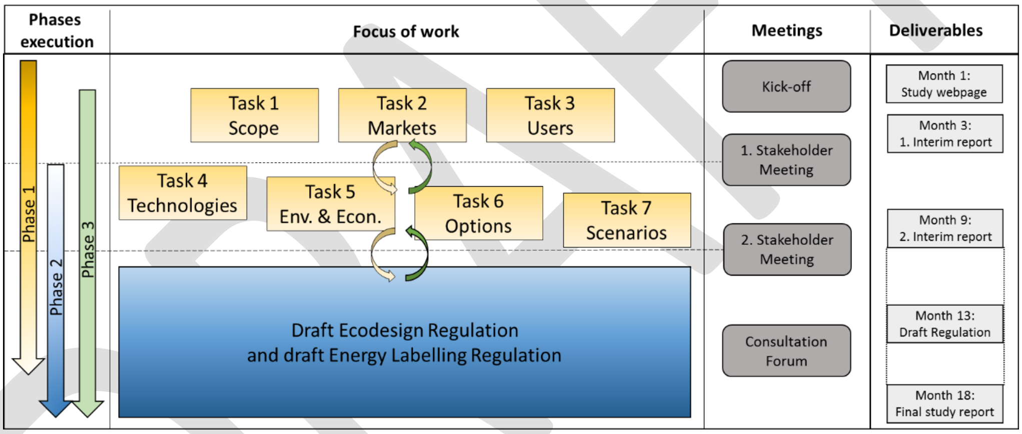

Figure 0-2: Approach and phases of this Ecodesign Preparatory Study

According to the terms of reference, all types of AC and DC recharging stations for electric vehicles of M, N categories as defined in Annex II to Directive 2007/46/EC 6 are considered in the study. Other type of private or public charging infrastructure for electric vehicles not covered by this categorization such as L-category vehicles as defined in Annex I of Regulation (EU) No 168/20137, and light weight electromobility (i.e. e-bikes, e-scooters...) that represent a significant share of the market in the short and medium term, with enough potential for environmental savings, are also analysed. The scope of the study following the MEErP methodology integrates an analysis at the system level[4]. The study also considers that complementary components are located inside the vehicle, such as the On-Board Charger (OBC)for AC recharging within the vehicle. However, it must be noted that components inside the vehicle are in principle outside the scope of the European Ecodesign Directive (and its implementing Regulations) and are mostly regulated by UNECE[5].

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5 https://unece.org/

1 Scope

1.0 Summary of Task 1

The aim of this task is to provide a clear definition of the product group covered including the functional unit and basic parameters for further analysis.

It includes the following subtasks:

- Definition of the product scope by assessing Prodcom categories, standards and initiatives according to the MEErP
- Analysis of test standards (EU, Member State and third country level) relevant for Ecodesign aspects
- Analysis of legislation (EU, Member State and third country level) relevant for Ecodesign aspects

From the section about the product scope it becomes clear that the EV charging infrastructure entails many elements and that all references have different naming and approaches. It should be noted that even when talking about EV chargers, they can take many different forms, which are reflected in their design, use and energy consumption.

Depending on their main purpose they are only required for private use in the form of a wall-mounted charging station at home or they are accessible to the public, e.g., for charging at service stations and free-standing. The charging power required also depends on the charging use-case and application, whether it is an e-bike or a long-haul tractor. Accordingly, EV chargers are offered with power outputs ranging from less than 7.4 kW to more than 150 kW. For light duty EV charging protection devices are always needed for phase overload, undervoltage and residual currents, while other components are also required depending on the application. For use in public areas, for example, RFID chips may be required to prevent the use of the column by unauthorised persons, or liquid cooling may be required for arduous charging powers. Also, MID certified meters must be installed for public charging points. In addition to 'conventional' EV chargers with plugs, there are also other energy supply concepts, such as wireless induction or a pantograph reaching power contacts. Apart from further digitalisation of the recharging stations, the focus is also on their increased interoperability with the smart domestic or public electricity grid, and new concepts such as bi-directional charging or direct charging via the PV system are gaining in importance. Our study looks at those aspects as far as important for the Ecodesign characteristics. The mentioned varieties are summarized in Figure 1-1.

Several types of connectors exist and sometimes specific socket versions exist as well, but generally, EU regulation has meanwhile clarified this area for interoperability. An overview is given in section1.6.

This broad extent requires more effort to define the preliminary product definitions, the primary performance parameter with its "functional unit" and the secondary performance parameters.

This is a 1st working draft version of the Task 1 for review and commenting in the stakeholder meeting. A summary will be added in the draft final version.

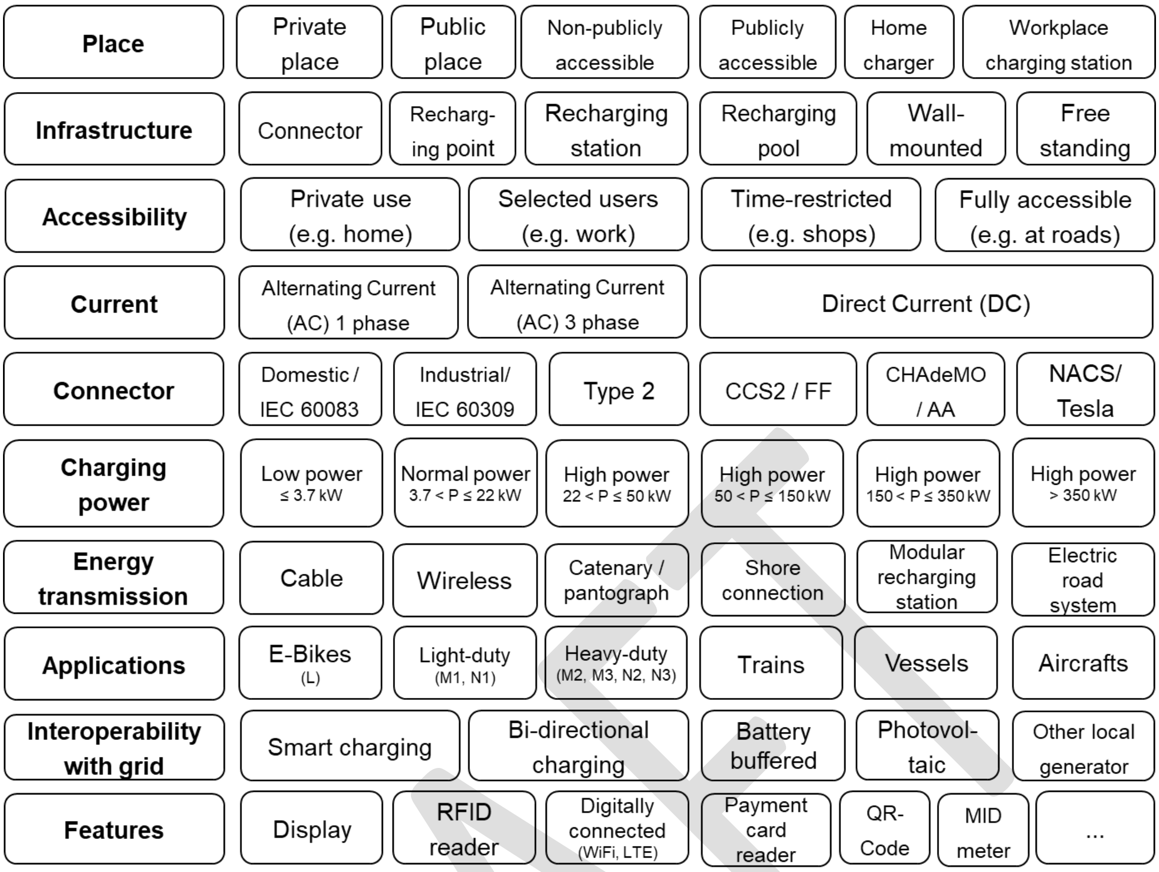

Figure 1-1: Overview of recharging infrastructure variations (own figure)

1.1 Product scope

1.1.1 Definition of the product categories for the scope

The aim of the Ecodesign preparatory study is to study 'EV chargers'. This means the equipment needed to charge electric vehicles (or "*Electric vehicle supply equipment, EVSE*, in American English). This has first to be defined better and ideally in close relation to international standards and European legislation. After the scope definition the product categories can be worked out.

1.1.1.1 Aim of product categories and scoping

According to the MEErP the aim is to define preliminary product scope, including preliminary product definitions, considering that categorization shall preferably be linked to **primary performance parameter (the "functional unit").** If needed sub-categorization can take place on the basis of **secondary performance parameters** and for indirect ErPs the affected energy system(s).

Therefore, it identifies relevant:

- Prodcom category or categories (Eurostat);
- categories according to EN- or ISO-standard(s);
- labelling categories (EU Energy Label or Eco-label), if not defined by the above.
- Similar initiatives to Ecodesign

1.1.1.2 PRODCOM categories

PRODCOM categories need firstly to be considered in accordance with the MEErP. Herein generic economic data refers to data that is available in official EU statistics[6]. These data could help to identify and report on the EU EV charging infrastructure product consumption and market size. Moreover, in a later stage it could help to track the impacts of Ecodesign policy measures through analysis of the official Eurostat PRODCOM data.

For AC charging equipment the following PRODCOM categories apply:

- **27.12.40 Parts of electricity distribution or control apparatus**
    - 27.12.40.30 Boards, panels, consoles, desks, cabinets and other bases for apparatus for electric control or the distribution of electricity (excluding those equipped with their apparatus)
    - 27.12.40.90 Other parts of apparatus of HS 8535, 8536, 8537
- **27.90.44 Appliance cords, extension cords, and other electrical cord sets, for a voltage ≤ 1 kV, with insulated wire and connectors**
    - 27.90.44.00 Appliance cords, extension cords, and other electrical cord sets, for a voltage ≤ 1 kV, with insulated wire and connectors

For DC charging equipment the following PRODCOM categories apply:

- **27.90.41 Inverters, rectifiers, converters**
    - 27.90.41.30 Rectifiers (excluding of a kind used with telecommunication apparatus, automatic data-processing machines and units thereof)
    - 27.90.41.53 Inverters having a power handling capacity ≤ 7,5 kVA
    - 27.90.41.55 Inverters having a power handling capacity > 7,5 kVA
    - 27.90.41.70 Static converters (excluding polycrystalline semiconductors, converters specially designed for welding, without welding equipment, accumulator chargers, rectifiers, inverters)
    - 27.90.41.80 Accumulator chargers
    - 27.90.41.90 Parts of static converters, n.e.c. (excl. electronic assemblies of a kind used with telecommunication apparatus, automatic data-processing machines and units thereof)
    - 27.90.41.30 Rectifiers (excluding of a kind used with telecommunication apparatus, automatic data-processing machines and units thereof)
    - 31.10.43.30 DLP (dry low power) transformers: transformers, nes [not elsewhere specified] , 16 kVA < power handling capacity < 500 kVA Note: this category is of importance in case of DC charging above 500 V where the AC voltage is first raised upwards with help of an external transformer.

For onboard chargers (OBC) in vehicles the following categories apply:

- 29.32.30.90 Other parts and accessories, n.e.c., for vehicles of HS 8701 to 8705

[6] https://ec.europa.eu/eurostat/web/prodcom

Preliminary conclusion:

The PRODCOM product categories today are too generic and do not contain sufficient disaggregation of recharging points to provide useful data and to support the analysis.

It is therefore suggested that a future update of Eurostat product classes might consider adding new subclasses for recharging infrastructure, especially in accordance with the standard IEC 61851-1.

1.1.1.3 Relevant product definitions in the Alternative Fuel Infrastructure Regulation ((EU) 2023/1804) ('AFIR')

1.1.1.3.1 EV charging infrastructure definitions

Electric Vehicle (EV) chargers are still a comparatively young product group, but they will play a decisive role in the comprehensive electrification of mobility, as key component of the infrastructure for EV. The most important 'EV chargers' definitions in the new Alternative Fuel Infrastructure Regulation (AFIR) ((EU) 2023/1804) are:

- (12**) 'connector'** means the physical interface between the recharging or refuelling point and the vehicle through which the fuel or electric energy is exchanged;
- (48**) 'recharging point'** means a fixed or mobile, on-grid or off-grid interface for the transfer of electricity to an electric vehicle which, although it may have one or more connectors to accommodate different connector types, is capable of recharging only one electric vehicle at a time, and which excludes devices with a power output less than or equal to 3,7 kW the primary purpose of which is not the recharging of electric vehicles;
- (31) **'high-power recharging point'** means a recharging point with a power output of more than 22 kW for the transfer of electricity to an electric vehicle;
- (52) **'recharging station'** means a physical installation at a specific location, consisting of one or more recharging points;
- (51**) 'recharging pool'** means one or more recharging stations at a specific location;
- (49) **'recharging point, station or pool dedicated to light-duty vehicles'** means a recharging point, station or pool intended for the recharging of light-duty vehicles, due to the specific design of the connectors/plugs or the design of the parking space adjacent to the recharging point, station or pool, or both;
- (50) **'recharging point, station or pool dedicated to heavy-duty vehicles'** means a recharging point, station or pool intended for the recharging of heavy-duty vehicles, either due to the specific design of the connectors/plugs or to the design of the parking space adjacent to the recharging point, station or pool, or both;

The following Figure 1-2 shows all the mentioned components of a recharging station and pool.

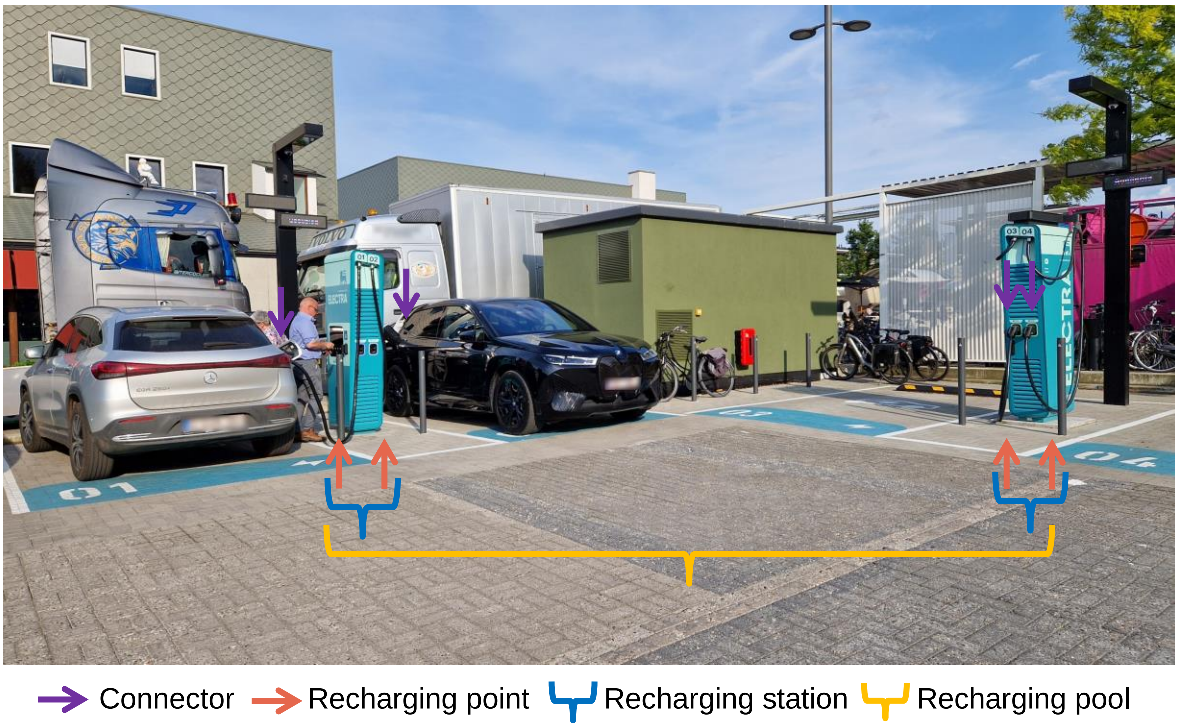

Figure 1-2: Components of a recharging pool with its components (own photo)

1.1.1.3.2 Other important AFIR definitions for this study

(11) **'bi-directional recharging'** means a smart recharging operation [see (65)] where the direction of the electricity flow can be reversed, allowing that electricity flows from the battery to the recharging point it is connected to;

(17) '**digitally-connected recharging point'** means a recharging point that can send and receive information in real time, **communicate bi-directionally with the electricity grid** and the electric vehicle, and that can be remotely monitored and controlled, including in order to start and stop the recharging session and to measure electricity flows.

(42) **'payment service'** means a 'payment service' as defined in Article 4, point (3), of Directive (EU) 2015/2366 [Payment Services Directive] of the European Parliament and of the Council.

(44) **'power output'** means the theoretical maximum power, expressed in kW, that a recharging point, station or pool, or a shore-side electricity supply installation can provide to vehicles or vessels connected to that recharging point, station, pool or installation;

(45) **'publicly accessible alternative fuels infrastructure'** means an alternative fuels infrastructure which is located at a site or premises that are open to the general public, irrespective of whether the alternative fuels infrastructure is located on public or private property, whether limitations or conditions apply in terms of access to the site or premise and irrespective of the applicable use conditions of the alternative fuels infrastructure.

(64) **'shore-side electricity supply'** means the provision of shore-side electrical power through a standardised fixed or mobile interface to seagoing ships or inland waterway vessels, moored at the quayside;

(65) **'smart recharging'** means a recharging operation in which the **intensity of electricity delivered to the battery is adjusted in real-time, based on information received through electronic communication**;

Within AFIR's Annex III on reporting requirements on deployment of electric vehicles and publicly accessible recharging infrastructure also subcategories are defined (see Table 1-1).

Table 1-1: Reporting requirements on deployment of electric vehicles and publicly accessible recharging infrastructure

Category	Sub-category	Maximum power output	Definition pursuant to Article 2 of this Regulation
Category 1 (AC)	Slow AC recharging point, single-phase	P < 7,4 kW	Normal-power recharging point
	Medium-speed AC recharging point, triple-phase	7,4 kW ≤ P ≤ 22 kW	
	Fast AC recharging point, triple-phase	P > 22 kW	High-power recharging point
Category 2 (DC)	Slow DC recharging point	P < 50 kW	
	Fast DC recharging point	50 kW ≤ P < 150 kW	
	Level 1 - Ultra-fast DC recharging point	150 kW ≤ P < 350 kW	
	Level 2 - Ultra-fast DC recharging point	P ≥ 350 kW	

1.1.1.4 Relevant definitions in the Energy Performance of Buildings Directive (EPBD) (EU/2024/1275)

The EPBD will not only increase the rate of building renovation, but also give obligations for the digitalisation of energy systems for buildings and the roll-out of infrastructure for sustainable mobility.

(33) **Recharging Points**: refers to definition 48 in the AFIR (see previous section).

(34) Pre-Cabling: means all measures that are necessary to enable the installation of recharging points, including data transmission, cables, cable routes and, where necessary, electricity meters;

(35) ‘roofed car park’: means a roofed construction, with at least three car parking spaces, that does not use energy to condition the indoor environment

(37) ‘smart recharging’ means smart recharging as defined in Article 2, second paragraph, point (14m), of Directive (EU) 2018/2001 [Renewable Energy Directive (RED II)]

(38) ‘bi-directional recharging’ means bi-directional recharging as definition (11) in the AFIR (see previous section)

(64) ‘bicycle parking space’ means a designated space for parking at least one bicycle

(65) ‘car park physically adjacent to a building’ means a car park which is intended for the use of residents, visitors or workers of a building and which is located within the property area of the building or is in the direct vicinity of the building

1.1.1.5 IEC 61851-1:2017 ‘Electric vehicle conductive charging system - Part 1: General requirements’

The main standard about the EV recharging infrastructure is the IEC 61851 series. Part 1 ‘General requirements’ defines:

- ‘**EV supply equipment’** (**EVSE** (often used acronym, but not mentioned in the standard)) as ‘conductors, including the phase, neutral and protective earth conductors, the EV couplers, attachment plugs, and all other accessories, devices, power outlets or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the EV and allowing communication between them if required’.

- A '**charger**' as 'power converter that performs the necessary functions for charging a battery'.
- An **'off-board charger'** (OFBC (own acronym)) as 'charger connected to the premises wiring of the AC supply network (mains) and designed to operate entirely off the vehicle. In this case, direct current electrical power is delivered to the vehicle'.
- An **'on-board charger'** (OBC (own acronym)) as 'a charger mounted on the vehicle and designed to operate only on the vehicle'.
- An **'AC EV charging station'** as all equipment for supplying AC current to EVs, installed in a cabinet(s) and with special control functions.
- A **'DC EV charging station'** as all equipment for supplying DC current to EVs, installed in an enclosure, with special control and communication functions and located outside the vehicle.

Of special interest are the 4 modes that the standard defines (see Figure 1-3):

- **Mode 1 - Standard socket outlet - domestic installation**
- **Mode 2 - Standard socket outlet with an AC EV supply equipment– domestic**
- **Mode 3 - AC EV equipment permanently connected to an AC supply network**
- **Mode 4 - DC EV Supply equipment**

Mode 1 is a low power external charger that fits into a standard wall socket, typically used for an e-bike but not for larger electric vehicles. The definition of recharging point in the AFIR (above 3.7 kW) excludes this mode.

Mode 2 and 3 are closely related and contains in principle the same functions but mode 2 can rely on a standard socket, domestic (IEC 60083) and industrial (IEC 60309), and has the necessary protection and communication functions incorporated in the cable. Mode 2 and 3 is only AC voltage supply equipment. The AC into DC current conversion and control of the charging current is done by the onboard charger (OBC). For Mode 2 charging several car makers offer a flexible or universal cable systems that allows connecting to a variety of sockets, see Figure 1-4.

Mode 4 is also called **DC fast charger**. The EV charging station includes the charger (converting the current) and supplies controlled DC current to the vehicle battery. For this it needs higher level communication with the EV, that permits to keep the DC-voltage and the DC-current always optimised in function of the state-of-charge of the EV's battery and the charging demand.

It should be noted that some **charging losses (6-10%) are caused by the current conversion (primarily rectification) and control electronic circuitry, which** for mode 2 and 3 is located inside the vehicle and for mode 4 inside the charging station. If a step-up transformer is used, this also leads to an additional loss.

Preliminary conclusion:

The 4 charging modes defined in IEC 61851-1 provide important subcategories to consider in this study since they discern different types of charging stations.

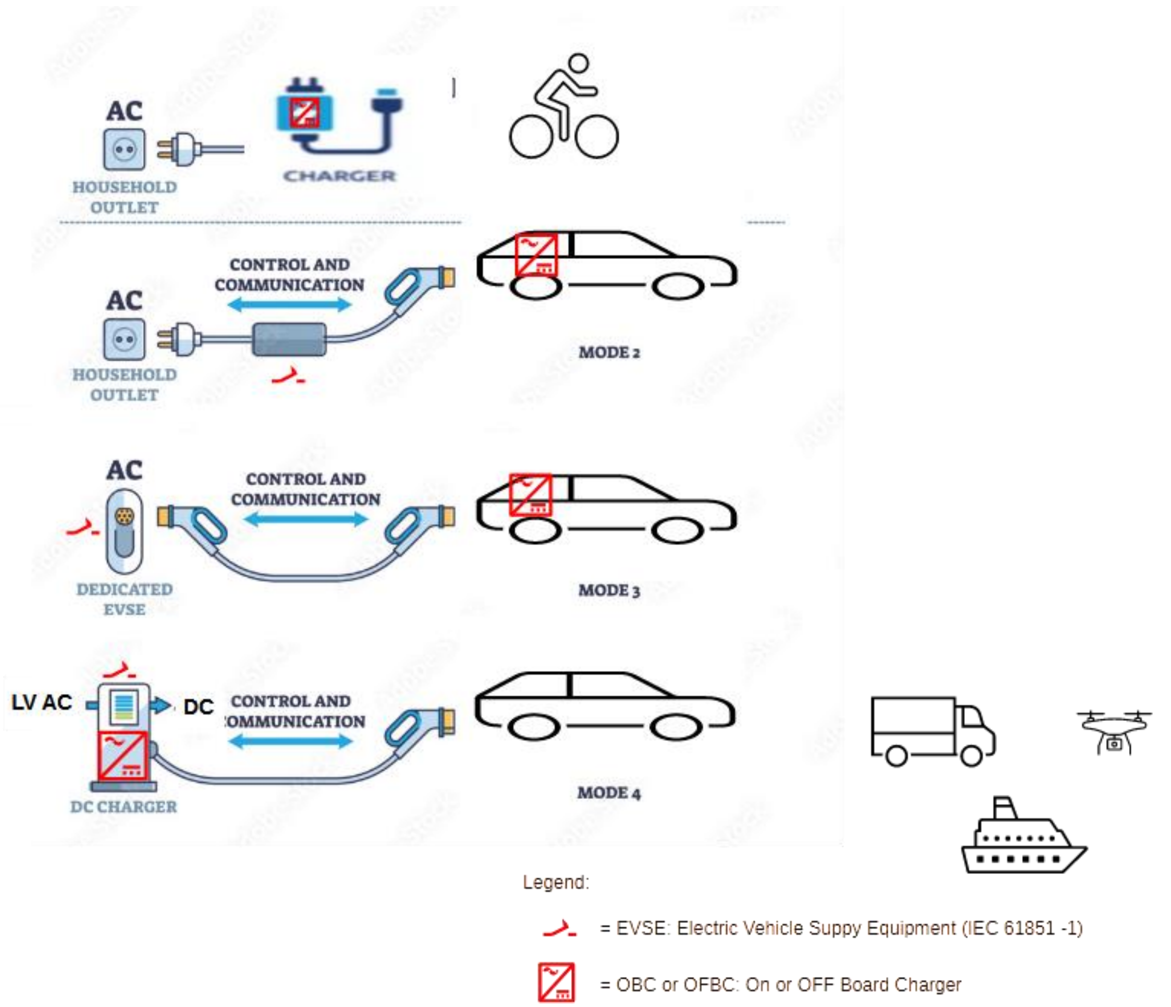

Figure 1-3: IEC 61851-1 about electric vehicle conductive charging systems, with charging modes 1-4 (own figure)

Figure 1-4: Mode 2 charging cables with adapters for different sockets. A: Tesla Gen 2 Universal Mobile Connector (up to 7,4 kW); B: BMW Flexible Fast Charger 2.0 (up to 11 kW); C: Mercedes Benz Flexible Pro charging system (up to 22 kW). Copyright Tesla, BMW, Mercedes-Benz

1.1.1.6 *Product categories defined in the French PEP ecopassport® for EV charging infrastructure (PSR-0018)*

The environmental impact (LCA) of EV charging stations has been worked out by the French PEP Association[7][8]. The PEP ecopassport® programme includes product specific rules (PSR) for charging infrastructure (PSR-0018). Note: the English version is not an exact translation of the French one. Especially the primary functional unit is different in both versions (in May 2024).

In France the Type 2 socket is not allowed at private premises. Instead the variant Type 2S is needed. It has child protection above the pins and locks the charging cable. See section 0.1 for an overview of connectors and sockets.

1.1.1.6.1 Product families

The rules define the following 5 product families:

- "Domestic socket", it is used for IEC mode 1 and 2 charging (16A max.).
  It is a reinforced version of the domestic socket for EVs that can stand with 16A load for long periods.
  It delivers 3,7 kW as reference case.
- "Private or semi-public station", it is used for IEC mode 3 charging and has 3 subfamilies:
  - Wall-mounted AC charging station with :
    1 or 2 sockets of type 2S or with 1 or 2 cables & 1 or 2 controllers & a housing.
    It delivers 3,7 up to 22 kW as reference case.
    Options:
    electrical protection devices & communication devices.
  - Free-standing AC charging station private or semi-public car park with:
    1 or 2 sockets of type 2 or 2S or with 1 or 2 cables & 1 or 2 controllers & a housing+base.
    It delivers 3,7 up to 22 kW as reference case.
    Options:
    electrical protection devices & communication devices & metering & display.
  - Free-standing DC charging private or semi-public car park with:
    1 or more cables for CCS and/or CHAdeMO & 1 controller & 1 protection & 1 inverter & a housing+base.
    It delivers 24, 43 kW or more if technically possible as reference case.
    Options:
    electrical protection devices & communication devices & metering & display & access control like RFID.

  Note 1: despite the above use of semi-public this term does not exist in EU legislation. The only distinction is between publicly accessible and non-publicly accessible.

  Note 2: According to AFIR every recharging point must have a CCS2 connector. CHAdeMO is a voluntary addition. In the EU it is now deprecated.
- Public station on a base and has 2 subfamilies:
  - Free-standing AC charging with:
    1 or 2 sockets of type 2S & 1 or more controllers & electrical protection for each socket & a housing+base.
    It delivers 22 kW as reference case.

[7] http://www.pep-ecopassport.org/create-a-pep/produce-a-lca/
[8] http://www.pep-ecopassport.org//fileadmin/webmaster-fichiers/PSR-0018-ed1-FR-2021_09_13.pdf

Options:
communication devices & metering & display & access control like RFID & payment service & etc.

  - Free-standing DC charging with:
    1 cable for CCS and/or CHAdeMO & 1 or more controllers & 1 or more electrical protections.
    [inverter & a housing+base are not prescribed, although necessary elements]
    It delivers 50 kW as reference case.
    Options:
    1 socket of type 2S (AC charging) & communication devices & metering & display & access control like RFID & payment service & supervising equipment.

- Charging system with industrial sockets for industrial environment.
  No general reference case is defined.

- Combination of charging points.
  They can consist of AC and DC charging points that function simultaneously.

1.1.1.6.2 Functional unit and description of the reference flow

The functional unit is: to put at disposition 1 kWh to an EV according to the reference case including the reference lifetime at a charging point. Note: charging point is not explicitly defined but seems to be a single socket or cable. [The English version mentions 1 kW as unit].

Declared units are allowed to create scenarios like a large parking place. The declared unit can be: to assure EV charging with help of 1 or more charging points during the reference lifetime

The reference product is the recharging system with housing and all included installation elements. If there is no attached cable, then a cable to the EV can optionally be included.

For each of the product families a reference scenario is defined. A reference lifetime of 10 years is taken. The total time is divided into active period (charging the EV), idle period (connected but finished with charging) and off-mode (no EV connected) for each charging point. The active period and its involved energy consists of the number of charging actions, the charging power and the total time per charge. Also the connection time to the recharging point is defined per charging action. It is assumed that the charging point needs a different power for each of these 3 modes, leading to a total intrinsic energy need. The charging itself leads to additional dissipative loss.

1.1.1.6.3 Examples

AC charging station

The PEP ecopassport® includes one AC charging or mode 3 charging station with 7 kW charging power. The reported climate change impact (kg.eq.CO_2) per delivered kWh is $1.1 \cdot 10^{-2}$ in total from which 81% in the use phase and 19% in the production phase. No energy consumption is explicitly given to deliver 1 kWh.

DC charging station

The information regarding the environmental impact of EV chargers given by the PEP ecopassport® for a 184 kW DC fast charger or mode 4 recharging station, indicates that almost all impact over all indicators appear during the use phase. The reported climate change impact (kg.eq.CO_2) was $1.9 \cdot 10^{-2}$ in total from which $1.88 \cdot 10^{-2}$ (98,9 %) in the use phase. This means that for a fast charging (184 kW) DC EV recharging station that relies on an off-board charger the losses of the converter are by far dominant. The calculated energy consumption is 0,059 kWh/kWh$_{delivered}$. For another 25 kW DC charger an energy consumption of 0,078 kWh/kWh$_{delivered}$ is given. The reported climate change impact (kg.eq.CO_2) is $1.3 \cdot 10^{-2}$ in total from which 62% in the use phase and 37% in the production phase. So, in this case the fabrication is not negligeable. Note: different LCA databases are used for both charging stations, making the results not 1:1 comparable.

1.1.1.7 Product definitions in the U.S.Energy Star® Program

Energy Star® is a joint program of the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE) that helps consumers and businesses save energy while also protecting the environment. It works on certification of products, of new homes and apartments but also gives guidance on energy management for businesses.

The Energy Star® program on energy efficient products has a specification for Electric Vehicle Supply Equipment[9].

1.1.1.7.1 EV charging infrastructure definitions

The definitions are intended to be consistent with SAE standards.

- Electric Vehicle Supply Equipment (EVSE) : The conductors, including the ungrounded, grounded, and equipment grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of transferring energy between the premises wiring (if available) to the electric vehicle. Charging cords with NEMA 5-15P and NEMA 5-20P attachment plugs [i.e. domestic plugs] are considered EVSEs. Excludes conductors, connectors, and fittings that are part of the vehicle.
- Level 1: A galvanically connected EVSE with a single-phase input voltage nominally 120 volts AC and maximum output current less than or equal to 16 amperes AC.
- Level 2: A galvanically connected EVSE with a single-phase input voltage range from 208 to 240 volts AC and maximum output current less than or equal to 80 amperes AC.
- DC-output: A method that uses dedicated direct current (DC) electric vehicle/plug-in hybrid electric vehicle (EV/PHEV) supply equipment to provide energy from an appropriate off-board charger to the EV/PHEV in either private or public locations.
- Wireless / Inductive: An EVSE which transfers energy to the vehicle without a galvanic connection between the vehicle and EVSE.

1.1.1.7.2 Other important definitions for this study

EVSE Functions:

1) Primary Function: Providing current to a connected load.
2) Secondary Function: Function that enables, supplements, or enhances a primary function. For EVSE, examples of Secondary Functions are:
    a) Automatic Brightness Control (ABC): The self-acting mechanism that controls the brightness of a display or lamp as a function of ambient light.
    b) Full Network Connectivity: The ability of the EVSE to maintain network presence while in Partial On Mode.
    c) Occupancy Sensing: Detection of human or object presence in front of or in the area surrounding an EVSE.
    d) Communicating with the vehicle;

[9] https://www.energystar.gov/products/spec/electric_vehicle_supply_equipment_version_1_1_pd

   e) Illumination of display, indicator lights, or ambient lighting;
   f) Public access control (RFID card, authorization, etc.);
   g) Control Pilot Signal; and
   h) Wake-up function.

3) Tertiary Function: Function other than a primary or a secondary function.

   Example: An EMC filter and status indication provides their function in No Vehicle Mode, Partial On Mode, and On Mode.

4) In-use: Indicates the presence of a feature that is enabled and ready to provide a service in standby mode even if other components of the EVSE are powered down. The feature must not be disabled by hardware or software during testing.

DC-output EVSE Product Configurations:

1) Distributed Product Configuration: A DC-output EVSE that has its functional components distributed between more than one separate enclosures.
   a) Minimum Distributed Product Configuration: The minimum configuration of a DC-output EVSE which provides current to a connected load. The product may have more than one port.
2) All-in-One Product Configuration: A DC-output EVSE that has all of its components in one enclosure.

EVSE Operational Modes and Power States:

1) Disconnected: Condition of the equipment during which all connections to power sources supplying the equipment are removed or galvanically isolated and no functions depending on those power sources are provided. The term power source includes power sources external and internal to the equipment.

2) No Vehicle Mode: Condition during which the equipment is connected to external power and the product is physically disconnected from vehicle (mode can only be entered or exited through manual intervention). No Vehicle Mode is intended to be the lowest-power mode of the EVSE.

3) On Mode: Condition during which the equipment provides the primary function or can promptly provide the primary function.

a) Operation Mode: Condition during which the equipment is performing the primary function.

b) Idle Mode: Condition during which the equipment can promptly provide the primary function but is not doing so.

4) Partial On Mode: Condition during which the equipment provides at least one secondary function =but no primary function.

1.1.1.7.3 Scope of the U.S. Energy Star Program

Products that meet the definition for EVSE and fall into one of the following categories:

i. Level 1 EVSE.
ii. Level 2 EVSE.
iii. Dual Input Level 1 and Level 2 EVSE.
iv. DC-output EVSE with output power less than or equal to 350 kW.

1.1.1.7.4 Functional unit and description of the reference flow

This Energy Star® Program does not involve an LCA. It does not define a functional unit. It is focusing on the losses for each of the operation modes.

1.1.1.8 Definition of the preliminary product scope

1.1.1.8.1 Product scope

The subject of this Ecodesign preparatory study, electric vehicle chargers, have to be defined more precisely. Moreover, charger is most often used for an energy conversion device (AC current to DC).

The definitions from IEC 61851-1 are widely used and applicable for Europe. Its definitions are more used than the terminology in AFIR. Those definitions are also used in the product descriptions themselves, especially concerning the charging modes. The AFIR does not cover Mode 2 charging. Therefore, we propose electric vehicle supply equipment (EVSE) combined with the charging modes.

EV supply equipment' (EVSE) [IEC 61851-1]: as 'conductors, including the phase, neutral and protective earth conductors, the EV couplers, attachment plugs, and all other accessories, devices, power outlets or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the EV and allowing communication between them if required'.

Charging mode 1 is commonly discouraged for EVs, being a kind of emergency solution with limited power but they are important for light means of transport, however:

- Specific rules for light means of transport will already be elaborated within the context of the Battery Regulation (2023/1542), see section 1.3.1.9. Hence, this has already been decided and there is no need to restart a full preparatory study for this again.
- As mentioned in later section 1.3.1.2, the efficiency of chargers can also be addressed by simply updating the Ecodesign requirements for external power supplies. Hence, there is no need to restart a full preparatory study for this again.

Thus, as a conclusion, EVSE mode 1 is out of scope of this study.

For EVSE mode 4 the study team has doubts whether it should be analysed into detail in Tasks 4 to 6 and to be included in the scope, because:

- According to our interpretation of AFIR Art. 3 (3) and Art. 5 (4), AFIR requires indirectly the measurement of EVSE mode 4 losses for most of EVSE above 50kW, see section 1.3.1.5. Thus, there is already an incentive for charge point operators to minimize losses.
- For a prospective ESPR on EVSE mode 4 losses it could create redundant work related to market surveillance and redundant regulation in comparison to the AFIR approach, if not properly aligned.
- Likely the most important stand by losses related to the roll out of mode 4 EVSE are within their MV/LV power transformers, but this can be addressed by updating the existing power transformer regulation, see section 1.3.1.3.
- Mode 4 conversion loss measurement standards still have some gaps (see 1.2.2) and it might be difficult to reliable compare improvement options in Task 6 and to already propose a clear policy benchmark in Task 7.
- EMC is an important issue which is interrelated to mode 4 conversion losses, this might complicate to comparing data without knowing the up time and reliability of the charging station and therefore also to set a clear benchmark in Task 7, see section 1.2.2.1.

- Mode 4 EVSE are not consumer products and sold in a business-to-business environment and therefore the added value and feasibility on market surveillance of an ESPR on mode 4 could be questioned and should be checked with CPO, EVSE suppliers and Member States. See also section 1.2.2.1 that casted doubt.

Therefore, we ask the opinion of stakeholders with regards to including EVSE mode 4 within the scope of future tasks 4 to 7 and if included to provide accurate data which will be needed for considering improvement options in Task 6 and setting a clear policy benchmark in Task 7.

Consequently, mode 2 and 3 EVSE are proposed to be in the scope, but limited to 22 kW (32 A, 3 phase) to remain in the consumers' area. This matches AFIR's category 1: normal-power recharging point.

- EVSE for mode 2:
  Mode 2 charging cable that can be connected to domestic (IEC 60083) and industrial (IEC 60309) sockets. It delivers 3,7 up to 22 kW depending on the socket. It contains electrical protection devices & communication devices.
- EVSE for mode 3:
  It is an 'AC EV charging station' according to IEC 61851-1 definition (all equipment for supplying AC current to EVs, installed in a cabinet(s) and with special control functions). It can has 1 or 2 charging outputs, that can be sockets or cables. Each of them is indicated as 'charging point' in this study. It has electrical protection devices and 1 or 2 controllers It delivers 3,7 up to 22 kW. If there are sockets, then the cable is assumed to belong to the EV, not to the EVSE. Options: EMC filter, communication devices, metering, illumination and display.

EVSE with mixed charging mode: these include a mix of mode 3 and 4 charging. When, mode 4 charging is excluded, then the mixing mode is implicitly excluded too.

Wireless charging is excluded from the product scope since not being generally on the market (see task 2). The same holds for catenary charging. This product is less developed currently and mostly used in a commercial environment.

Notes:

- The reference use scenario at the charging point will be defined in Task 3.
- This Task 1 defined scope is based on clear technical product definitions which is most suitable for later policy because they are unambiguous and not allow circumvention.
- In later tasks other market or application product categories can be defined, such as target market in Task 2 (e.g. company cars) or charging profile in Task 3 (e.g. fast charging, ..). Nevertheless, these categories are avoided for later policy making because they can be circumvented as long as they are sold for 'other' purposes.
- Also, this preliminary proposed scope can be further limited based on market (Task 2), user (Task 3) and improvement potential data (Task 4).
- Since EVSE mode 3 devices have options, these must be stated explicitly when they are assessed for Ecodesign calculations.

Stakeholder questions related to definitions and scoping:

1) Are there other suggestions for the product scope?
2) Is there agreement to exclude EVSE for mode 1?
3) Is there agreement to exclude EVSE for mode 4 (and mixed mode)?
4) Is there agreement to exclude wireless charging and catenary charging?
5) Are CPO and/or mode 4 EVSE suppliers willing to provide accurate data which will be needed for considering improvement options in Task 6 and setting a clear policy benchmark in Task 7?

    Important notes:

    This data can be anonymized and/or aggregated.

    Therefore, to supply data, a secrecy agreement can be provided.

6) Other remarks?

1.1.2 Definition of the functional unit and performance parameters

1.1.2.1 Goal and scope of Life Cycle Analysis and Functional Unit or primary performance parameter

The new Ecodesign for Sustainable Products Regulation (ESPR) focuses on circularity, energy performance, environmental sustainability, and the Digital Product Passport: The basis of the assessment is performing an LCA. In standard ISO 14040 on life cycle assessment (LCA) the functional unit is defined as “the quantified performance of a product system for use as a reference unit in life cycle assessment study”. According to the MEErP, the primary purpose of the functional unit is to provide a calculation reference to which environmental impacts (such as energy use), costs, etc. can be related and to allow for comparison between functionally equal systems. This is especially important in later Task 6 to consider improvement options. Further product segmentations will be introduced in this study to allow appropriate equal comparison and therefore secondary functional parameters can be added. Note that an Ecodesign preparatory study is always built on a single functional unit and a corresponding product group to allow a consistent analysis according the MEErP in Tasks 3 to 6. Consequently, considering different applications with different requirements and functional unit is not an option, it would require different studies. According to the MEErP, this should be the yardstick for clustering products in one preparatory study and to apply specific Ecodesign measures that are technology-neutral.

1.1.2.2 Review of existing LCAs

The PEP ecopassport® program is an LCA methodology. It includes product specific rules (PSR) for charging infrastructure (PSR-0018). It has been covered in section 1.1.1.6, including the the functional unit.

Note that up to our knowledge EPD Italy has no specific EV charging infrastructure product specific category rules (checked in April 2024[10]). The Nordic Swan Ecolabel[11] neither contains EV charge supply equipment.

In the scientific literature there is a related LCA study: 'Life cycle environmental assessment of charging infrastructure for electric vehicles in China', Z.Zhang e.a., Journal of Cleaner Production, Volume 227, 2019[12]. It discerns 4 product categories:

- Home charger (7–40 kW)
- public alternating current (AC) (7–40 kW)
- direct current (DC) chargers (60–360 kW)
- public mix chargers

The aim of this study is to compare the energy consumption and greenhouse gas emissions of four types of chargers in China within the whole life-cycle of manufacturing, use, and end-of-life, and determine the proportion of environmental impacts of chargers to that of EVs. The functional unit is 1 kWh delivered to an EV.

1.1.2.3 Proposal of primary performance parameter (functional unit)

Both LCA studies refer to the energy delivered to the EV taking into account the energy that the EVSE consumes and its energetic loss during charging. The advantage of energy is that it does not matter if slow charging like 3,7 kW or medium power charging like 22 kW is used. Both lead to the same result of a recharged EV and their LCA results can be compared with each other.

The functional unit defines the purpose of a product or system. It represents a quantifiable measure of what the product is intended to achieve.

The primary performance parameter (functional unit) of an EVSE is: **to put at disposition 1 kWh to an EV according to the reference case including the reference lifetime at a charging point**.

Note:

- The reference scenario and lifetime for each EVSE type is defined in Task 3.
- An EVSE can have 1 or 2 charging points (i.e. sockets or cables). The energy is attributed to a charging point.

1.1.2.4 Secondary performance parameters

1.1.2.4.1 Aim of secondary performance parameters

The aim of this secondary performance parameters is to allow to identify sub-categories of products, thus typically also a performance metric specified at the time of purchasing. These secondary performance parameters will serve in Tasks 4/6/7 to consider improvement options with equal functionality. Thus, for example removing a display could result in energy savings but the product won't have the same functionality. These secondary performance parameters can also help in Task 7 when proposing a policy measure (if any) to identify secondary if there is no negative impact on product performance (if any). Thus, in Task 7 will need to scrutinize for

[10] https://www.epditaly.it/en/

[11] https://www.nordic-swan-ecolabel.org/

[12] https://doi.org/10.1016/j.jclepro.2019.04.167

compliance against Article 5 (5) and Article 6 (2) within the new proposed ESPR regulation[13], see sections hereafter in **bold**.

ESPR Article 5 (5) stipulates that requirements shall meet the following criteria:

a. there shall be **no significant negative impact on the functionality of the product**, from the perspective of the user;

b. there shall be no adverse effect on the health and safety of persons;

c. there shall be no significant negative impact on consumers in terms of the affordability of relevant products, also taking into account access to second hand products, durability and the life cycle cost of products;

d. there shall be no disproportionate negative impact on the competitiveness of economic actors, at least of SMEs;

e. there shall be **no proprietary technology imposed** on manufacturers or other economic actors;

f. there shall be no disproportionate administrative burden on manufacturers or other economic actors.

ESPR Article 6 (2) stipulates that performance requirements shall be based on the product parameters, as appropriate, include:

a. minimum or maximum levels in relation to a specific product parameter referred to in Annex I or a combination thereof;

b. non-quantitative requirements that aim to improve performance in relation to one or more product parameters referred to in Annex I;

c. requirements related to **the functional performance of a product**:

1.1.2.4.2 Secondary performance parameters and/or functions

First, the most important secondary performance parameter for the end user is likely the maximum power output which can be defined according to AFIR as:

- 'power output' which means the theoretical maximum power, expressed in kW, that a recharging point, station or pool, or a shore-side electricity supply installation can provide to vehicles or vessels connected to that recharging point, station, pool or installation (AFIR definition).

Second, are the 4 modes defined in IEC 61851-1, see section 1.1.1.5.

Finally, the study team also identified the performance parameters to identify further subcategories to consider. This is important since future implementing measures shall have no significant negative impact on the functionality of the product, from the perspective of the user. Therefore, we try to quantify all those features. That will also be important in Task 6 when discussing improvement options. They are the following:

- 'bi-directional recharging' function [Yes/No] (source: AFIR)
- 'connector' [type see Figure 1-3] (source: IEC 61851-1)
- 'digitally-connected recharging point' [Yes/No] (source: AFIR)
- 'high-power recharging point' (>22 kW) [Yes/No] (source: AFIR)
- 'payment service' [Yes/No] (source: AFIR)

[13] https://data.consilium.europa.eu/doc/document/ST-7854-2022-INIT/en/pdf

- ‘publicly accessible alternative fuels infrastructure’[Yes/No] (source: AFIR)
- ‘smart recharging’[Yes/No] (source: AFIR)
- DC/Single phase AC/Three Phase AC [DC/ 230 VAC/ 3x400 VAC]
- number of charging points per EVSE
- fixed cable attached to the EVSE [Yes/No]
- display included [Yes/No]
- signage lighting included [Yes/No]
- ‘recharging point, station or pool dedicated to light-duty vehicles’ or ‘recharging point, station or pool dedicated to heavy-duty vehicles’ or ‘shore-side electricity supply’ [LD /HD /OPS C] (own definition)

Stakeholder questions related to definitions and scoping:

7) Any other proposal for functional unit?
8) Is the list of secondary functions and parameters complete?
9) Any other suggestions?

1.1.3 Additional remarks

Two remarks are given hereabout issues generally being neglected.

Wall-mounted AC charging stations (EVSE mode 3) are in many countries called ‘wallbox’. However, this is a tradename. Its use as a generic term is discouraged by its owner. Therefore, it is not used in this report.

Although the EVSE can deliver a certain power, it is the battery management system of the EV battery that decides how much power can be absorbed. This information is given to the on-board charger or communicated to the off-board charger in case of mode 4 charging. So, the charging power is limited by the EVSE but not determined by the EVSE. In case of smart charging, the EVSE can communicate a lower limit than physically possible.

1.2 Overview of the most relevant Test Standards

1.2.1 Objective

According to the MEErP the aim of this task is to: identify and shortly describe EN or ISO/IEC test standards, mandates issued by the European Commission to the European Standardisation Organisations (ESOs), test standards in individual Member States and third countries (if relevant) regarding the test procedures for primary and secondary functional performance parameters on: resources use, emissions, safety, noise and vibrations (if applicable) or other factors that may pose barriers for potential Ecodesign measures. The purpose is also to conduct a comparative analysis for overlapping test standards. Finally, the aim is also to: analyse and report new test standards under development; identify possible problems concerning accuracy, reproducibility and to what extent the test standards reflect real-life conditions; draft outlines of mandate(s) to the ESOs as appropriate; and identify differences between standards covering the same subjects (comparative analysis).

The emphasis is of course on test standards. Other types of standards exists for EVSE. This is covered in the annex on standards, section 1.7.

1.2.1.1 Energy consumption and power loss

Test standards are needed to measure the energy consumption and charging loss of EVSE. Several features are related to this and must be taken into account. They are listed below.

1.2.1.2 Function state

The EVSE can switch between different function states. This influences the energy consumption. It is proposed to follow the 3 states according to the PEP ecopassport® :

- Off state: no EV connected for each charging point
- Idle state: connected but finished with charging
- Active state: charging the EV at one or both charging points.

Each state needs a certain power leading to an intrinsic energy need. The charging itself leads to additional dissipative loss.

1.2.1.3 EMC filter

Avoiding electromagnetic interference (EMI) is important. Especially for mode 4 charging it appears that insufficient filtering leads to perturb the internal EV communication. There is a direct relation between EMI and EMC performance and energy efficiency in EVSE for mode 4 because the EMI filters included and the switching frequency contribute to the converter losses. Nevertheless, testing and designing EVSE mode 4 for EMC compliance is time consuming and expensive.

1.2.1.4 Reactive power

If an electrical device creates reactive power, this leads to power loss in the electricity distribution system. The rules on power quality also contain requirements on reactive power. Nevertheless, it appears that some EV models are not conform, especially at low charging power (see section 1.2.3.3.1).

1.2.1.5 Screen brightness

The Energy Star® program takes the brightness of the display into account. This leads to e.g. lm/size of the screen.

1.2.2 Identification of key test standards related to the sustainability of the EVSE

1.2.2.1 IEC

1.2.2.1.1 IEC 61851-21 series

The IEC standards for EVSE (IEC 61851 series; see section 1.7) have no test methods for energy use or efficiency. However, it has 2 parts that are about EMC requirements. Important for this study is Part 21-2: 'EMC requirements for off board electric vehicle charging systems'. This standard deals with Electro-Magnetic Compatibility (EMC) requirements in order to reduce Electro-Magnetic Interference (EMI) between the EV and EVSE.

Note that EVSE mode 3 and 4 are **fixed installations** and therefore the art. 6 of the EMCD (see 1.3.1.13) requires in principle only essential requirements, nevertheless this standard applies because of the importance of EMI for EV charging.

Especially for EVSE mode 4 this is an important performance standard, because successful DC fast charging will depend on the reduction of EMI caused by the power converters included in mode 4 EVSE. There are still reports of unsuccessful mode 4 charging which could be related to EMI and therefore further research and updates cannot be excluded. Mode 2 and 3 EVSE rely on board chargers (OBC) included in the EV and this simplifies their EMI design and compliance. For this Part 21-1 gives requirements.

Conclusion:

EN IEC 61851-21-2 is an important performance standard to consider when introducing minimum energy efficiency requirements because it might further complicate the product compliance procedure and therefore increase product design cost and time.

1.2.2.1.2 IEC 62301:2011 Household electrical appliances - Measurement of standby power

The methods defined in this standard[14] are intended to cover low power modes. They are not intended to be used to measure power consumption of products during active mode. The test method of Energy Star® (see section 1.2.2.4) refers to this standard.

Conclusion:

IEC 62301 is an important standard to measure standby power.

1.2.2.2 ISO

ISO is mainly concentrating on the communication for EVSE, see section 1.7.

1.2.2.3 PEP ecospassport product specific rules for charging infrastructure (PSR-0018)

The PEP ecopassport® program has been covered in section 1.1.1.6 concerning its product categories and functional unit. The losses are attributed to power needed for the function states (active, idle and off) and dissipative loss during charging.

The measurement method of the power states is not defined. The manufacturers give the power in Watt for each state. The dissipative loss for an AC charging station is based on the internal resistance of the station. How the internal resistance is measured, is not defined. From the charge current in the defined reference case and the resistance, the dissipative heat loss is determined.

[14] https://webstore.iec.ch/preview/info_iec62301%7Bed2.0%7Db.pdf

For a DC charging station it is based on the converter efficiency. A single value is used for this. [So, no dependency on output power and output voltage].

1.2.2.4 Energy Star® Test Method for Electric Vehicle Supply Equipment

The Energy Star® program Requirements for Electric Vehicle Supply Equipment is dealt with in section 1.1.1.7. A specific document exists for the test method[15]. In the Energy Star®, for each function state, the voltage, current and their differential values are measured, see the schematical representation in Figure 1-5. The input voltage and the differential current leads to the AC power of the internal components of the EVSE. The differential voltage for each phase and the input current leads to the power loss over the EVSE. Network connection capabilities, if present, must be activated, including Wi-Fi, ethernet and cellular modem. The EVSE must be coupled to its Wide Area Network if present.

The power meter needs to have a frequency response of at least 3 kHz. The current crest factor, i.e. the ratio between peak value and RMS value, must be at least 3. The minimum measurable current must be 10 mA. The accuracy must be ±0,1% of reading plus ±0,1% of full scale.

The illuminance meter (needed for measuring the display) must be accurate to ±2% (±2 digits) of reading.

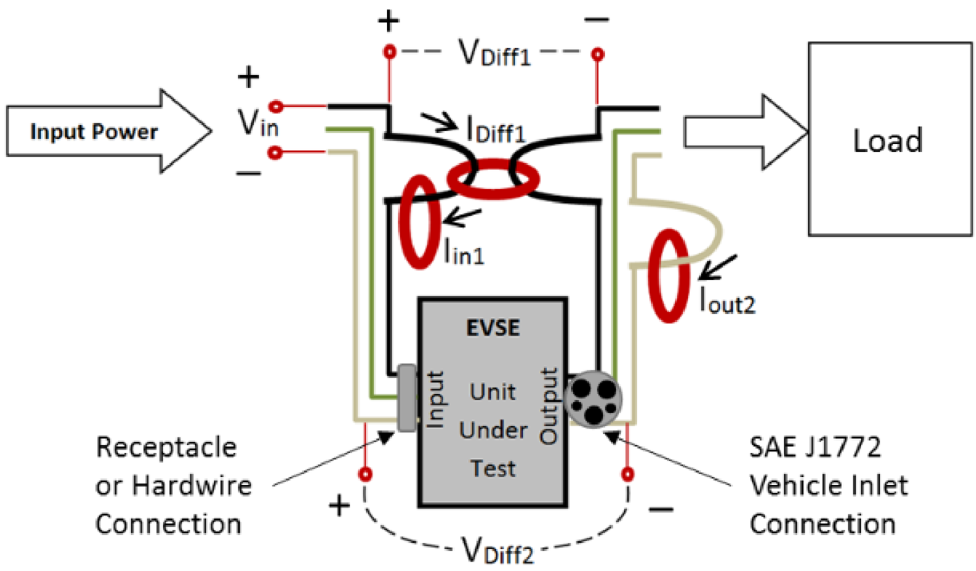

Figure 1-5: Schematic of test set-up in Energy Star® for EVSE (figure 1b)

1.2.2.5 Electricity meters in general

Electricity meters fall under the standard series IEC 62053. To comply with the MID regulation the standard series EN 50470 exists, from which a part is under development, especially for DC metering. For DC meters a class 0,5 and 0,1 will be defined.

For a larger overview see the footnote[16].

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15 https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20AC%20EVSE%20Final%20Test%20Method_0.pdf

16 https://nmi.nl/wp-content/uploads/2021/12/WP_Standards-For-Electricity_20211128.pdf

Notes:

- These standards are not valid for portable meters and laboratory and meter test equipment.
- Specific standards for electric mobility are discussed in the next section 1.2.2.6.

1.2.2.6 prEN 50732 Electric mobility - Measuring systems for supply equipment

This standard under development defines the metering-related and system-related minimum requirements for devices that measure energy and time for stationary conductive direct-current and alternating-current supply equipment, such as those in accordance with IEC 61851, in the supply of electricity to non-stationary electrical equipment e.g. electrical vehicles. It must enhance European consumer protection during the charging process and the payment process.

It specifies terms and definitions, configuration and requirements. It contains minimum requirements as well as criteria for evaluating measuring system. The purpose of the standard is to detail requirements for measuring systems for stationary supply equipment's in support to the MID (directive 2014/32/EU), especially regarding:

- Delivery point (usually the Plug (IEC 62196), not the terminals of the meter) (MID Annex I No. 7.2 & Annex V No. 3)
- Protection against corruption (MID Annex I No. 8.)
- Indication of result (MID Annex I No. 10.)
- Durable proof of the measurement result and the information to identify the transaction (MID Annex I No. 11.2.)
- Further processing of data to conclude the trading transaction in the absence of one of the trading parties (MID Annex I No. 11.1.(b))

This standard does also not apply to the requirements for the AC and DC meter itself, which is specified in EN 50470-3 and prEN 50470-4, respectively.

Figure 1-6 shows the development approach.

It is not expected to include energetic losses or efficiency.

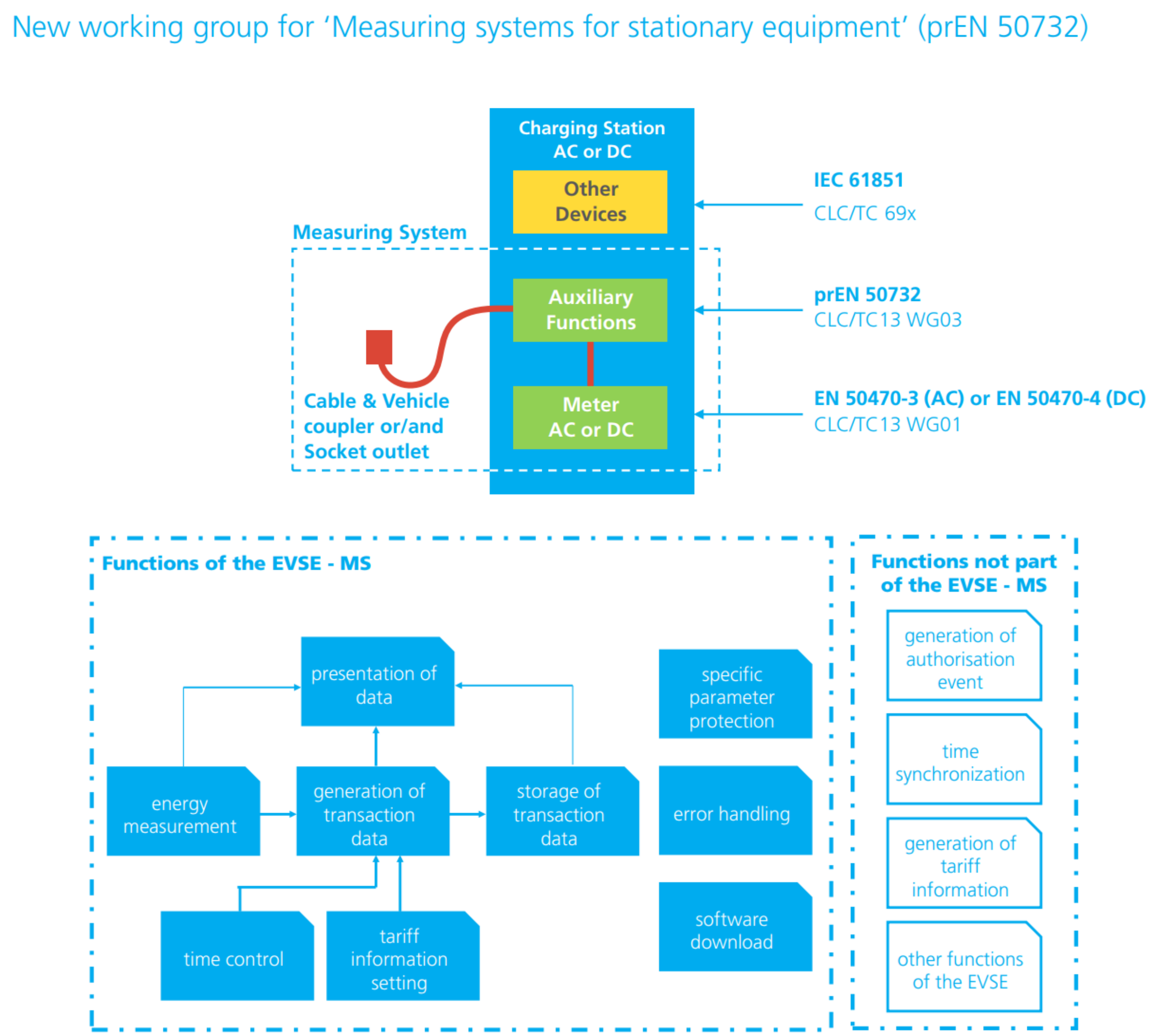

Figure 1-6: Scope of prEN 50732 in relation to the EVSE components and other standards. (Source: NMi WEBINAR: Developments in standards for electricity meters and EV Supply Equipment, 11-12-'23)[17]

1.2.2.7 VDE-AR-E 2418-3-100 Anwendungsregel:2020-11 Electric mobility: Measuring systems for charging stations

This VDE application guide[18] specifies the minimum requirements for measuring and calibrating energy and time measurement equipment for conductive AC and DC charging stations for the supply of electricity to or from electric vehicles that are placed on the market in accordance with the applicable product standards, e. g. DIN EN 61851 series.

This VDE application guide defines terms, pictograms, configurations, requirements and tests for this purpose. It contains minimum requirements and criteria for the evaluation of measuring equipment. The term "minimum requirements" means that technical rules and legal regulations may result in more far-reaching requirements. This product standard provides requirements for EV Charging Systems and also contains a dedicated Annex A for DC meters. This Annex is to some extent quite similar as the 62053-41.

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[17] https://nmi.nl/portfolio_page/developments-in-standards-for-electricity-meters-and-ev-supply-equipment/

[18] https://www.vde-verlag.de/standards/0400436/vde-ar-e-2418-3-100-anwendungsregel-2020-11.html

Conclusion:

The major advancement of this guidance is to implement the German regulation for **EVSE 4 metering** and requires **metering of the delivered DC electricity and thus excluding the losses**.

1.2.3 Other relevant EV charge infrastructure test initiatives

1.2.3.1 ADAC EVSE testing

The ADAC Technik Zentrum measured the charge losses for 4 different EVs. Also different charging methods were applied: domestic socket (2,3 kW), wall-mounted EVSE (11 kW; 22 kW but also with half power (e.g. for PV power charging or when the available power is divided over 2 vehicles))[19]. The tests took all loss places into account:

- Domestic electricity distribution board
- Cable to EVSE
- EVSE (domestic socket or wall-mounted EVSE)
- Charging cable
- On board charger in vehicle
- High voltage cable
- High voltage battery
- Battery temperature conditioning
- 12 V auxiliary power in car, as far as additionally active for the charging operation.

So, this goes well beyond the losses of the EVSE only.

The exact measurement method is not given.

1.2.3.2 WALLBOX-INSPEKTION

This is a German research initiative 'Wallbox Inspektion' that involves ADAC, Fraunhofer ISE which focuses on bidirectional charging of electric vehicles and more in particular methods to quantify conversion losses in V2H operation of bidirectional charging solutions in private households under close to real conditions [20] [21]. It is based on a simulated EV with help of hardware in the loop testing. The measurement method is not published currently.

1.2.3.3 OBC testing proposal (literature)

1.2.3.3.1 Experimental validation of onboard electric vehicle chargers to improve the efficiency of smart charging operation, K.Sevdari e.a., Sustainable Energy Technologies and Assessments, vol.60, 2023[22]

This article describes a large test campaign about EV charging by the Technical University of Denmark. It analysis the total losses between the domestic distribution board and the EV battery.

[19] https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/laden/ladeverluste-elektroauto-studie/

[20] https://solar.htw-berlin.de/forschungsgruppe/wallbox-inspektion/

[21] https://solar.htw-berlin.de/publikationen/qualitaetstest-fuer-wallboxen/

[22] https://doi.org/10.1016/j.seta.2023.103512

This is based on measuring the AC power with help of a power quality meter and the DC power by reading the available on-board data (OBDII).

As shown in the data, reactive power consumption is not a strong point for many automakers. In fact, some models when charging with a current below 10 A violate low-voltage network code by experiencing a PF smaller than 0.9.

It is concluded that OBDII is a fast, inclusive and reliable method for investigating electric vehicles (EVs).

It is also concluded that some EV models consume larger amounts of reactive power at lower currents or vice-versa.

1.2.4 Comparative and gaps analysis in EV charging infrastructure test standards

The Energy Star® programme published a detailed EVSE test method. The energy loss is based on the differential voltage combined with input current. This is a precisely defined method (and the only one) and carried out for several charging powers and also different ambient temperatures in case of mode 4 charging.

The PEP ecopassport® method (power consumption + internal resistance in case of AC charging) is very different from the Energy Star® method. Measuring resistance is much easier and only needs one measurement. The power consumption is just declared by the manufacturer. However, to measure the energy consumption for each function state implies anyway that a complete energetic measurement has to be performed, favouring the Energy Star® method.

The other identified initiatives have not published their measurement methods.

1.2.4.1 Gaps

prEN 50732 ‘Measuring systems for supply equipment’ is not published currently.

Stakeholder questions related to standards:

10) The PEP ecopassport method (power consumption + internal resistance) is very different from Energy Star method (differential voltage combined with input current). Is there a preference?

11) Is there an alternative method?

12) Call to ADAC , Fraunhofer ISE and HTW Berlin to share their measurement methods.

13) The PEP Ecopassport, MEErP and PEF are similar methods bot not identical. Has anyone remarks on favourable issues in them like the Life Time?

14) Other remarks?

1.3 Overview of existing legislation and Directives

1.3.1 EU Legislation and Directives

1.3.1.1 Ecodesign for Sustainable Products Regulation (ESPR)

To be completed in the final version when the Regulation becomes available.

Relevant items:

This aim of this study is to support future EVSE policy.

1.3.1.2 The ecodesign regulation for external power supplies ((EU) 2019/1782

So far, battery chargers without power supply function are excluded from the scope of the ecodesign requirements for external power supplies ((EU) 2019/1782).

Relevant items:

- The proposed scope of this study does not cover external battery chargers for light vehicles (category L). Given their potential important a future policy option to consider is to amend that regulation.

1.3.1.3 The ecodesign regulation for power transformers (EU) 2019/1783 amending Regulation (EU) 548/2014

So far, in Article 1 of (EU) 2019/1783 transformers specifically designed and intended to provide a DC power supply to electronic or rectifier loads are excluded from the scope.

Relevant items:

- The formulation of the exemption in (EU) 2019/1783 Article 1 is not technology neutral but simply based on the declared application.
- This exclusion from the scope constitutes a potential loophole for transformers installed to supply mode 4 EVSE from the Medium Voltage (MV) AC grid.
- Nevertheless, MV/LV transformer losses cannot be neglected, for example the transformer regulation allows for 675 Watt no-load losses when using a 400 kVA transformer.
- Despite this exemption from the scope, many EVSE mode 4 today simply use the same transformers as distribution transformers (stakeholders please confirm).
- Most likely the standby losses in mode 4 EVSE are inferior to the no-load losses of their distribution MV/LV transformers (< 675 Watt) ((EU) 548/2014).
- From a technical point of view 'rectifier' transformers could use different technical requirements which can be related to their short circuit impedance and therefore could be excluded based on this metric. Also, it does not mean that rectifier transformer cannot be made as efficient as their distribution grid counterparts, in contrary rectifier transformers could be constructed to be more efficient.

- Article 7 of in (EU) 2019/1783 requires a review for which a study is currently ongoing[23].

Conclusion:

Important losses related to the roll out of EVSE mode 4 are related to their MV/LV transformers but they can be exempted due to the Article 1.

This can be updated in the ongoing review of this regulation and therefore can be scoped out of this study.

Stakeholder questions related to existing Ecodesign Regulation:

15) Is the scope exemption of Article 1 of (EU) 2019/1783 for rectifier transformers used for mode 4 EVSE MV/LV supply transformers?

1.3.1.4 The Ecodesign regulation for Displays (EU) 2019/2021

This regulation is laying down ecodesign requirements for electronic displays.

Relevant items:

- In Article 1 the following is scoped out:
  - any electronic display with a screen area smaller than or equal to 100 square centimetres.
  - displays integrated or to be integrated into products listed into Article 2, point 3(a) and point 4 of Directive 2012/19/EU (WEEE). This means also that displays for 'large-scale fixed installations, except any equipment which is not specifically designed and installed as part of those installations' can be scoped out.

Conclusion:

Displays for mode 2 and 3 are covered by this regulation if they are larger than 100 square centimetres.

1.3.1.5 European regulation on deployment of alternative fuels infrastructure (EU) 2023/1804 (AFIR)

The regulation contains many aspirations concerning vehicle charging and the required infrastructure. This covers almost all types of vehicles:

- electrically power-assisted bicycles and L-category vehicles
- light-duty electric vehicles.

[23] https://eco-transformers-review.eu/

- heavy-duty electric vehicles
- electric vehicles in road, rail, maritime, inland navigation and other transport modes
- aircraft being stationary at airports.

Apart from requirements to enable charging infrastructure, it also encourages smart recharging .

Relevant Items:

- It contains significant number of useful definitions for this study, see previous section 1.1.1.3.2.
- Article 3 section (3) requires that:
    - Prices charged by operators of publicly accessible recharging points shall be reasonable, easily and **clearly comparable**, transparent and non-discriminatory.
- Article 5 section (4) requires that:
    - '… publicly accessible recharging points with a power output equal to or more than 50 kW**,** the ad hoc price charged by the operator shall be based on the price per kWh for the **electricity delivered..'.** '
- Standards are under development for metering DC power of EVSE mode 4 to support Article 5, see sections 1.2.2.5 and 1.2.2.6.

Interpretation and consequences of 'delivered energy' (Art. 5 (4)) and 'clearly comparable ' (Art. 3 (3)):

EVSE mode 4 (DC fast charging) can have significant losses (6-10%) within their AC/DC power electronic converter and also the recharging cable. This differs from EVSE mode 2/3 AC recharging stations that rely on On-board Chargers (OBC) with its losses within their car. Therefore, the word electricity **'delivered'** from Article 5 (4) has significant impact because according to our interpretation the **losses** of the EVSE mode 4 **are in principle not delivered but lost before being delivered**. In practice this means that at EVSE mode 4 or DC fast charging stations the metering must be done at the DC socket outlet. Meters and standards are developed for this purpose, see section 1.2.2.6 and 1.2.2.7. AC is always measured at the grid Point of Connection (PoC) thus EVSE mode 3 have their losses metered.

Moreover, if the metered electricity at one station would include losses versus another station exclude losses, then a **clear comparison** in line with Article 3 (3) won't be possible. **Due to their losses, it is an issue for EVSE mode 4 DC fast charging stations** because metering differences between stations could be typically 6 - 8 %. Thus, here again, in order to apply Article 3 (3) in practice a clear comparison would require metering of EVSE mode 4 is done at the DC socket side and/or **using a metering standard**, see section 1.2.2.6.

Conclusion:

Because **mode 4 EVSE charge station operators (>50 kW)** have most often their supplied AC power metered and the supplied DC to the vehicle (Art. 3 (3) and Art. 5 (4) of AFIR), they **in practice measure their EVSE losses**.

1.3.1.6 Measuring Instruments Directive (MID) 2014/32/EU

The Measuring Instruments Directive (MID) harmonizes legal metrology across all member states. Its key principle is that any meter with MID approval can be used in all EU countries. For electricity meters, the relevant MID approval is MI-003 (active electrical energy meters).

Nothing is prescribed for EVSE currently. This may appear in the upcoming new edition.

1.3.1.7 Vehicle type approval Regulation (EU) 2017/1151 (WLTP)

This contains the Worldwide harmonized Light vehicles Test Procedure (WLTP) to determine the range. This includes a specification for the outside temperature of 23 degrees, which can be easily ensured in a laboratory. The basis of the WLTP is the driving cycle, WLTC (C for Cycle), meaning the speed curve that must be followed on a dynamometer in laboratory conditions. This means that several values are collected during a single measurement: first, the actual usable capacity [kWh] of the traction battery and second, the current energy consumption [kWh/100 km]. This allows to calculate the combined range according to WLTP [km]. An AC power supply has to be used and thus the losses of the On Board Charger (OBC) in standard conditions are included. Meaning that DC charging will result in a lower energy consumption.

Relevant items:

- The WLTP includes on board charger (OBC) losses in standard conditions.
- When the WLTP energy consumption [kWh/km] is multiplied with the WLTP range (km) the energy [kWh] will be above the useful capacity [kWh] of the vehicle and the difference is due to the OBC losses. Nevertheless, one should be careful by trying to reverse calculating OBC losses from WLTP data because not all manufacturers provide the 'useful capacity' metric and useful capacity depends on the software settings of the Battery Management System related to the safe operational area of the cells and minimum lifetime.
- Up to our knowledge manufacturers can choose freely the operational power setpoint of the charger, meaning they can choose the most efficient one and thus charging at a lower or higher setpoint could result in higher losses.
- In order to improve the efficiency of the OBC an policy options is to update the WLTP and requiring data at different loads (25%, 50%, 75%, 100%) in combination by setting a minimum requirement in the Emission regulations (see 1.3.1.8)
- In addition, or alternatively, an "information requirement" could compel manufacturers to declare the efficiency level or the OBC at different loads, and have this indicated in the vehicle user manual or similar freely available documentation (including indication on screen during the charging).

Conclusions:

See also the subsequent related regulation in section 1.3.1.8.

1.3.1.8 Emission performance standards for new passenger cars and new light commercial vehicles Regulation (EU) 2023/851(Euro 7)

The Euro 7 regulation will cover the emissions of cars and vans but there are also other rules contained in the regulation concerning brakes, tyres and battery life. There are no limits on energy consumption or On Board Charger (OBC) losses.

Relevant items:

- There are no limits on energy consumption or OBC losses.

Conclusion:

Would one consider such a policy to impose maximum **On Board Charger (OBC) losses** and/or report losses, then it would be straightforward to amend this regulation. However, it **can be scoped out of this study**.

1.3.1.9 European Battery Regulation (EU) 2023/1542

These new EU rules on batteries aim to make batteries sustainable throughout their entire life cycle – from the sourcing of materials to their collection, recycling and repurposing.

Relevant item:

- In (9) It **defines 'light means of transport' (LMT)** means wheeled vehicles that have an electric motor of less than 750 watts, on which travellers are seated when the vehicle is moving and that can be powered by the electric motor alone or by a combination of motor and human power.

  Note: The LMT definition covers both category L vehicles, such as speed-pedelecs, but also Electrically Power Assisted Cycles(EPAC), scooters, etc.

- In (41) it deals with the interoperability of chargers for specific categories of batteries including LMT battery chargers and **requires the Commission to assess how to introduce harmonised standards for common LMT chargers**.
- Article 11 is dedicated to Removability and replaceability of portable batteries and LMT batteries and:
  - Allows the Commission to adopt delegated acts.
  - Requires that LMT batteries, as well as individual battery cells included in the battery pack, are readily removable and replaceable by an independent professional at any time during the lifetime of the product.
  - Requires the Commission to publish guidelines to facilitate the harmonised application of this Article, but at there are not yet available at the time of writing this report.

Conclusion:

For mode 1 chargers it has already been decided that the Commission will investigate the technical feasibility of harmonised standards for "common chargers" in the context of the Battery Regulation. Therefore, **mode 1 chargers can be left out of this study**.

1.3.1.10 Energy Performance of Buildings Directive (EPBD) (EU/2024/1275)

The EPBD remains a Directive setting out minimum requirements and national implementation in Member States needed.

Relevant items:

The revised Directive further **requires** Member States to simplify, streamline and accelerate the procedure for **the installation of recharging stations, and remove barriers to the installation of recharging points in multi-apartment buildings**.

Therefore, it also defines '**pre-cabling'** which means all measures that are necessary to enable the installation of recharging points, including data transmission, cables, cable routes and, where necessary, electricity meters.

Infrastructure for sustainable mobility is addressed in **Article 14** and requires **Member States to ensure:**

- For new non-residential buildings with more than 5 car parking spaces including non-residential buildings undergoing major renovation it requires:
    - the installation of at least one recharging point for every 5 car parking spaces
    - the installation of pre-cabling and ducting for at least 50 % of car parking spaces
- For all non-residential buildings with more than 20 car parking spaces, Member States shall, by 1 January 2027 it requires:
    - the installation of at least one recharging point for every 10 car parking spaces or of ducting for at least 50 % of the car parking spaces
- For buildings owned or occupied by public bodies, it requires:
    - pre-cabling for at least 50 % of car parking spaces by 1 January 2033
- For new residential buildings and residential buildings undergoing major renovation with more than three car parking spaces it requires:
    - the installation of pre-cabling for at least 50 % of car parking spaces
    - The installation of at least one recharging point
- Measures to simplify, streamline and accelerate the procedure for the installation of recharging points in new and existing, residential and non-residential buildings, especially of co-owners' associations, and remove regulatory barriers, including permitting and approval procedures.
- To remove barriers to the installation of recharging points in residential buildings with parking spaces, in particular the need to obtain consent from the landlord or co-owners for a private recharging point for own use. A request by tenants or co-owners to be allowed to install recharging infrastructure in a parking space may be refused only if there are serious and legitimate grounds for doing so.
- To assess administrative barriers regarding the application for the installation of a recharging point in a building with multiple residential building units at a tenants' or a co-owners' association.
- To ensure the availability of technical assistance for building owners and tenants wishing to install recharging points.
- To ensure the coherence of policies for buildings, active and green mobility, climate, energy, biodiversity and urban planning.

Of potential importance is also Article 16 on data exchange.

Conclusion:

The reviewed EPBD will be an **important driver to support the installation of recharging points**.

Within Task 7, this reviewed EPBD will be looked at and will be an incentive to install suitable recharging points in building.

1.3.1.11 Renewable Energy Directive (EU) 2023/2413 amending (EU) 2018/1999)

The Renewable Energy Directive (RED) is the legal framework for the development of clean energy across all sectors of the EU economy, supporting cooperation between EU countries towards this goal. Also, this is only a Directive and national implementations are needed.

Relevant items:

- Requires in Art. 20a that in addition to Regulation (EU) 2019/943 and Directive (EU) 2019/944 on the Energy Market, **Member States shall ensure** that the national regulatory framework allow **electric vehicles to participate in the electricity markets, including congestion management and the provision of flexibility and balancing services**, including through aggregation. To that end, Member States shall, in close cooperation with all market participants and regulatory authorities, establish technical requirements for participation in the electricity markets, on the basis of the technical characteristics of those systems.
- Requires in Art. 25 that economic operators that **supply renewable electricity** to electric vehicles **through public recharging points shall receive credits**. Member States may include private recharging points in that mechanism.

Conclusion:

To be considered in Task 7 when discussing policy options, **there are clear policy incentives for digitally connected and smart recharging points**.

1.3.1.12 The Directive on common rules for the internal market for electricity (EU/2019/944) (EMD)

This Directive establishes common rules for the generation, transmission, distribution, energy storage and supply of electricity, together with consumer protection provisions, with a view to creating truly integrated competitive, consumer-centred, flexible, fair and transparent electricity markets in the Union.

Relevant items:

- Article 7 deals with the support of 'direct lines' and requires all producers and electricity supply undertakings established within their territory to supply their own premises, subsidiaries, and customers through a direct line, without being subject to disproportionate administrative procedures or costs. Thus, this article provides some support for onsite electricity production for EV recharging with a direct line and off grid.
- Article 10 deals with basic contractual rights and requires that suppliers shall provide final customers with transparent information on applicable prices and tariffs and on standard terms and conditions, in respect of access to and use of electricity services, most importantly:
    - Final customers shall be provided with a summary of the key contractual conditions in a prominent manner and in concise and simple language.
    - Suppliers shall **provide final customers with a final closure account after any switch of supplier no later than six weeks** after such a switch has taken place.
- Article 18 deals with billing and sets minimum billing requirements for which reference is made to Annex 1. Apart from the price data it also **requires the disclosure of used energy sources**.
- Article 20 outlines the functionalities of smart metering systems to which the AFIR is referring. It covers reliable data, remote reading, time-based tariffs, consumer access, privacy and security.

Conclusion:

To be seen in Task 7 if this matters for any policy measure.

1.3.1.13 *The Electromagnetic Compatibility Directive (EMCD) 2014/30/EU*

All electric devices or installations influence each other when interconnected and this is important matter for reliable charging of electric vehicles as well.

The purpose of electromagnetic compatibility (EMC) is to keep all those side effects under reasonable control. EMC designates all the existing and future techniques and technologies for reducing disturbance and enhancing immunity.

As mentioned before EMC is addressed by standard EN IEC 61851-21-2.

Relevant items:

It defines:

- ‘equipment’ means any apparatus or fixed installation.
- ‘apparatus’ means any finished appliance or combination thereof made available on the market as a single functional unit, intended for the end-user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance.
- ‘fixed installation’ means a particular combination of several types of apparatus and, where applicable, other devices, which are assembled, installed and intended to be used permanently at a predefined location

It is worth noting that EMCD considers equipment and discriminates apparatus versus fixed installations and set different requirements.

Conclusion:

This important EVSE aspect is addressed by standard EN IEC 61851-21-2.

1.3.1.14 *The Low Voltage Directive (LVD) 2014/35/EU*

The European Low Voltage Directive defines essential safety requirements for electrical products within the European Union. The LVD ensures that electrical products meet safety standards, minimizing the risk of electric shocks or other dangerous situations. It applies to electrical appliances with rated voltages between 50 and 1000 V_{AC} and 75 to 1500 V_{DC}.

Relevance:

The LVD aims to protect people, animals, and property by ensuring safe design, proper insulation, and appropriate mechanical strength. Manufacturers, importers, dealers, and distributors must comply with LVD requirements to introduce electrical equipment into the European market. This holds for EVSE.

1.3.1.15 *Articles 5 and 114 of the Treaty for the functioning of the European Union (TFEU)*

Relevant Items:

- Article 5 deals with **the principle of subsidiarity** and states that the Union shall act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States.
- Article 114 **enables the EU** to adopt regulation which has as their object **the establishment and functioning of the internal market**.

Conclusion:

Typical **installation requirements are likely to remain local policy while products can be harmonized** to support the functioning of the internal market. This is relevant when considering policy options in Task 7.

1.3.1.16 CE Regulation (EC) No 765/2008 and the 'Blue Guide' on the implementation of EU products rules (2016/C 272/01)

This regulation sets the requirements for accreditation and market surveillance relating to the marketing of products within the European Economic Area (EEA).

Relevant items:

It should be noted that new ESPR (see 1.3.1.1) and Energy Labelling Regulation (EU) 2017/1379 are in principle 'product policy' and apply when products are brought for the first time on the EEA market.

According to the blue guide a manufacturer is responsible for the conformity assessment of the product and is subject to a series of obligations including traceability requirements and they must also cooperate with the competent national authorities in charge of market surveillance if a product presents a risk of being non-compliant.

According to the definitions of the blue guide a manufacturer may design and manufacture the product themselves, but as an alternative, they may also have it "designed, manufactured, assembled, packed, processed or labelled" with a view to placing it on the market under their own name or trademark, and thus presenting themselves as a manufacturer. Consequently, someone who packed and/or processed the recharging point with new functionality and who must demonstrate conformity with any new EU regulation could become a de facto manufacturer because of the new EU regulation's requirements.

In addition, an important issue to consider is that the **prospective policy measures would apply to products when placed on the market for the first time but mode 3 and mode 4 recharging points can also come on the market as components or sub-assemblies** and assembled by the installer onsite.

Conclusion:

For mode 3 and 4 recharge points there could be a loophole when proposing Ecodesign requirements when they are brought on the market as components. This is an item to be considered in Task 7.

1.3.1.17 Upcoming Right to Repair Directive (R2RD)

On April 23, 2024, the European Parliament adopted the Right to Repair Directive (R2RD)[24]. **This Directive will be published soon**, and this section will be updated accordingly. Once the directive is formally approved by Council and published in the EU Official Journal, member states will have 24 months to transpose it into national law.

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24 https://www.europarl.europa.eu/news/en/press-room/20240419IPR20590/right-to-repair-making-repair-easier-and-more-appealing-to-consumers#:~:text=On%20Tuesday%2C%20Parliament%20adopted%20the,a%20product's%20lifecycle%20through%20repair.

Relevant item:

The purpose is to **introduce obligations for manufacturers to repair goods** and **encourage consumers to extend a product's lifecycle through repair.**

1.3.1.18 Unfair Practices Directive (EU) 2024/825 amending Directives 2005/29/EC and 2011/83/EU

The purpose of this Directive is to empowering consumers for the green transition through better protection against unfair practices and through better information.

Directive 2005/29/EC concerns unfair business-to-consumer commercial practices.

Directive 2011/83/EU is a directive on consumer rights concern consumer rights and deals for example with the right of withdrawal for online sales.

Relevant items:

- Article 2 of 2005/29/EC **amended definitions** for: **'environmental claim', 'generic environmental claim', 'sustainability label', 'certification scheme', 'recognized excellent environmental performance**', 'software update'.
- Amendments to Directive 2011/83/EU related to definitions on:
  - **commercial guarantee of durability** means a producer's commercial guarantee of durability as referred to in Article 17 of Directive (EU) 2019/771, under which the producer is directly liable to the consumer during the entire period of the commercial guarantee of durability for repair or replacement of the goods in accordance with Article 14 of Directive (EU) 2019/771, whenever the goods do not maintain their durability;
  - **reparability score** means a score expressing the capacity of a good to be repaired, based on harmonised requirements established at Union level;
  - **software update** means a free update, including a security update, that is necessary to keep goods with digital elements, digital content and digital services in conformity in accordance with Directives (EU) 2019/770 and (EU) 2019/771.
- By 27 September 2025 the Commission shall publish **a harmonized notice and label for green claims**.

Conclusion:

The Commission will make available a repairability scope and a harmonized notice and label for green claims within the context of this Directive.

1.3.1.19 The Waste of Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU

The WEEE Directive set collection, recycling and recovery targets for all types of electrical goods.

Relevant items:

- In Article 2 the following is scoped out:
  - large-scale fixed installations, except any equipment which is not specifically designed and installed as part of those installations.

Conclusion:

EVSE mode 4 can be scoped out of the WEEE. This is not the case for mode 2 and 3 EVSE.

1.3.1.20 Other Directives/Regulations that apply to EV charging infrastructure

Apart from the previous listed European Directives/Regulations that are directly relevant for the study also those apply:

- Directive on the Restriction of Hazardous Substance (RoHS) (EU) 2011/65/EU (For EVSE this at least implies that lead-free solder must be used for the electronics).
- Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (EC) 1907/2006.

1.3.2 Beyond Europe

Connected to the recharging point are vehicles and it is important to note that they need to be compatible with vehicles. Vehicles are also able for cross-border traffic, and this is made possible by UNECE car Regulation.

1.3.2.1 United States of America

National Electric Vehicle Infrastructure Standards and Requirements

This is a rule by the Federal Highway Administration on 28-2-2023[25]. As summary:

- Charger-to-EV Communication: Chargers must conform to ISO 15118-3 and must have hardware capable of implementing both ISO 15118-2 and ISO 15118-20. One year after publication of this document, charger software must conform to ISO 15118-2 and be capable of Plug and Charge. Conformance testing for charger software and hardware should follow ISO 15118-4 and ISO 15118-5, respectively.
- Charger-to-Charger-Network Communication: Chargers must conform to Open Charge Point Protocol (OCPP) 1.6J or higher. One year after publication of this document, chargers must conform to OCPP 2.0.1.
- Charging-Network-to-Charging-Network Communication: One year after publication of this document, charging networks must be capable of communicating with other charging networks in accordance with Open Charge Point Interface (OCPI)

1.3.3 Member state Legislation

Recharging points are part of the electrical installation. Electrical installations in buildings are defined by the international standard IEC 60364 series. Therefore, electrical installation rules at EU member state level are in general according to these international and European standards, however there may exist deviations and/or additional requirements at member state level. The above-mentioned standards are primarily concerned with safety aspects of the electrical installation, but member states can also differ on the socket outlets that can be installed and/or used. Hereafter we are summarizing for most relevant aspects identified for the study.

[25] 2023-03500.pdf (govinfo.gov)

1.3.3.1 Local regulation for mode 2 recharging

Mode 2 chargers depend on socket outlets.

For domestic sockets they are different according to the member states (CEE 7 sockets), see standard IECEE CEE-7 and section 1.6 about connectors.

Of more general or higher power use are the industrial or so-called CEE 17 sockets or EN 60309 sockets and plugs. Most cars come with a mobile connector and often this already provides a 7.4 kW charge point simply by using a CEE-connector 32A with 2 poles (2P+PE)[26]. Thus, the cheapest solution to provide a charge point is to install CEE-connector 32 A sockets. However, a barrier is that some member states installation rules do not allow or support to install such an industrial socket.

Example of barrier by local regulation to install a powerful mode 2 recharge point:

Belgium by 'Koninklijk besluit AREI[27]' in section 7.22 on power supply of electrical vehicles:

- Art. 7.22.3 says that ' It is prohibited to connect a charging system to a fixed electrical installation by means of a socket'.
- Art. 2.11.2. deals with certification of electrical installations by recognized certification bodies. In Belgium it is never the installer that can do this approval and thus certification of a recharging point involves additional cost for a certification.
- Art. 4.2.2.3 b on rooms designated for children (BA2) requires that 'low-voltage sockets are designed in such a way that they are de-energized or are completely covered by a screen when the socket is pulled out'.
- Art. 5.3.3.4 on special provisions for wall sockets above 16A/500VAC or 32A, must be NBN certified sockets with regards to interrupting the current or have a mechanical or electrical lock that makes it impossible to insert or remove the live socket.
- Art. 5.3.5.2 b on special requirements for domestic sockets, refers to Art. 4.2.2.3 & 4.2.3.3 but grants some exception for:
    - sockets mounted in switch or distribution boards;
    - socket with a rated voltage of 400 V in alternating current, which are exclusively intended for the power supply of mobile appliances with a fixed location.
- Notes:
    - Art. 7.22.3 seems to apply to 'any vehicle' thus also to EU vehicle category L1(speed pedelecs, ...), however there are no wall chargers available for these vehicles and so-far they can only be charged from a socket (mode 1)?
    - Industrial CEE sockets can be installed (3 phase) in residential installations if mounted in a switchboard, for example a cabinet that includes the mode 2 charger socket.
    - Although a 'mode 2 EVSE being installed within a cabinet' might be a convenient solution for rental property and/or car parks of multi-family buildings, Art. 7.22.3 seems not to allow for this?

[26] https://shop.tesla.com/nl_be/product/blauwe-adapter---16a_32a?sku=1104948-10-B

[27] https://economie.fgov.be/nl/publicaties/algemeen-reglement-op-de

France Décret n° 2017-26[28] du 12 janvier 2017 relatif aux infrastructures de recharge pour véhicules électriques:

- Article 22 says that recharging points for electric vehicles should be installed by an authorized professional in accordance with article R. 4544-9 of the labour code with an exception for recharging points equal or below 3.7 kW.
- Article 23 also put's the responsibility of installing the protection devices with the installer, thus indirectly it requires a mode 3 EVSE.

In Germany installing such an **industrial CEE socket (32A) in a residential house is not an issue** up to our knowledge and thus Mode 2 EVSE with CEE 32 A are commonly used.

Relevant items:

Mode 2 EVSE with industrial sockets are a simple and cost effective, however there might be local regulations hampering the use of this. Therefore, member states are invited to provide their local regulations on this.

Stakeholder questions related to existing local Regulation related to mode 2:

16) Apart from the two cases(BE, F) mentioned before are there any other countries that have regulation that would hamper the use of mode 2 for charge current supply above 16 A?

1.3.3.2 Local regulation for mode 3 and 4 EVSE recharging

It should be noted that some countries have or had local regulations for public charging that are redundant with the new AFIR, for example:

France Décret n° 2017-26 :

- Article 19 which refers for technical characteristics of public recharging points to Article L. 112-1 du code de la consommation. In principle the new AFIR is in part redundant with this French regulation.

And the related French ministerial decision 'Décision n° 22.00.570.001.1 du 1er mars 2022' about metering for mode 4 EVSE, to be noted that:

- Meters will have to be certified according to that decision.
- It is worth noting that allows for a software to calculate charging cable losses.

Note: we assume that in France EVSE mode 4 metering is requested by law on the delivered energy and thus without the losses, however we could not track it back.

[28] https://www.legifrance.gouv.fr/

Stakeholder questions related to existing local Regulation related to mode 2:

17) Up to our knowledge there are no significant installation regulations within Member States that would hinder the installation of identical products, if so please report?

1.3.4 Relevant examples of legislation outside the EU

No relevant examples were found.

1.4 Preliminary conclusion of Task 1

1.4.1 Scope

For the product scope it is most appropriate to use the definitions from standard IEC 61851-1. The scope is the EV supply equipment' (EVSE) for Mode 2 and 3 charging.

EVSE is defined in IEC 61851-1 as 'conductors, including the phase, neutral and protective earth conductors, the EV couplers, attachment plugs, and all other accessories, devices, power outlets or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the EV and allowing communication between them if required'.

- **EVSE for mode 2**:
  Mode 2 charging cable that can be connected to domestic (IEC 60083) and industrial (IEC 60309) sockets. It delivers 3,7 up to 22 kW depending on the socket. It contains electrical protection devices & communication devices.
- **EVSE for mode 3**:
  It is an 'AC EV charging station' according to IEC 61851-1 definition (all equipment for supplying AC current to EVs, installed in a cabinet(s) and with special control functions). It can has 1 or 2 charging outputs, that can be sockets or cables. Each of them is indicated as '**charging point**' in this study. It has electrical protection devices and 1 or 2 controllers It delivers 3,7 up to 22 kW. If there are sockets, then the cable is assumed to belong to the EV, not to the EVSE. Options: EMC filter, communication devices, metering, illumination and display.

Several arguments are given to exclude mode 1. Mode 1 charging is discouraged for light duty electric vehicles in favour of mode 2 charging. For light means of transport charging with help of mode 1, separate regulation is under development. Another approach would be to update the Ecodesign requirements for external power supplies.

For EVSE mode 4 the study team has doubts be included in the scope, due to double regulation with AFIR, difficult comparability of data due to differences in EMC design and because it are products sold business to business. As a consequence the study team also excludes EVSE with mixed mode.

Wireless charging is excluded from the product scope since not being generally on the market (see task 2). The same holds for catenary charging. This product is less developed currently and mostly used in a commercial environment.

In later tasks other market or application product categories can be defined, such as target market in Task 2 (e.g. company cars) or charging profile in Task 3 (e.g. fast charging, ..). Nevertheless, these categories are avoided for later policy making because they can be circumvented as long as they are sold for 'other' purposes.

Since EVSE mode 3 devices have options (see also secondary performance parameters), these must be stated explicitly when they are assessed for Ecodesign calculations.

1.4.2 Primary performance parameter

Concerning the primary performance parameter there seems to be agreement in the found literature.

The primary performance parameter (functional unit) of an EVSE is: **to put at disposition 1 kWh to an EV according to the reference case including the reference lifetime at a charging point**.

Note:

- The reference scenario and lifetime for each EVSE type is defined in Task 3.
- An EVSE can have 1 or 2 charging points (i.e. sockets or cables). The energy is attributed to a charging point.

1.4.3 Secondary product performance parameters and/or functions

First, the most important secondary performance parameter for the end user is likely the maximum power output which can be defined according to AFIR as:

- 'power output' which means the theoretical maximum power, expressed in kW, that a recharging point, station or pool, or a shore-side electricity supply installation can provide to vehicles or vessels connected to that recharging point, station, pool or installation (AFIR definition).

Second, are the 4 modes defined in IEC 61851-1.

Finally, the study team also identified the following performance parameters to identify further subcategories to consider:

- 'bi-directional recharging' function
- 'connector' [type see Figure 1-3] (source: IEC 61851-1)
- 'digitally-connected recharging point'
- 'high-power recharging point' (>22 kW)
- 'payment service'
- 'publicly accessible alternative fuels infrastructure'
- 'smart recharging'
- DC/Single phase AC/Three Phase AC [DC/ 230 VAC/ 3x400 VAC]
- Number of charging points per EVSE
- Fixed cable attached to the EVSE
- Display included

- Signage lighting included
- ‘recharging point, station or pool dedicated to light-duty vehicles’ or ‘recharging point, station or pool dedicated to heavy-duty vehicles’ or ‘shore-side electricity supply’ [LD /HD /OPS C] (own definition)

1.4.4 Test standards

The test standards needed for this ecodesign preparatory study should take into consideration:

- Energy consumption and power loss
- Function state of the EVSE
- EMC filter
- Reactive power

The Energy Star® programme published a detailed EVSE test method. The energy loss is based on the differential voltage combined with input current. This is a precisely defined method (and the only one) and carried out for several charging powers.

The PEP ecopassport® method (power consumption + internal resistance in case of AC charging) is very different from the Energy Star® method. Measuring resistance is much easier and only needs one measurement. The power consumption is just declared by the manufacturer. However, to measure the energy consumption for each function state implies anyway that a complete energetic measurement has to be performed, favouring the Energy Star® method.

The other identified initiatives have not published their measurement methods.

The prEN 50732 ‘Measuring systems for supply equipment’ is not published currently.

1.4.5 Legislation

The Energy Performance of Buildings Directive (EPBD) (EU/2024/1275) will be an important driver to support the installation of recharging stations.

The CE Regulation (EC) No 765/2008 and the ‘Blue Guide’ on the implementation of EU products rules (2016/C 272/01) may create a loophole when proposing Ecodesign requirements for mode 3 and 4 recharge stations if they are brought on the market as components. This is an item to be considered in Task 7.

There are clear policy incentives for digitally connected and smart recharging stations. These are defined in:

- Renewable Energy Directive (EU) 2023/2413
- European regulation on deployment of alternative fuels infrastructure (EU) 2023/1804 (AFIR)
- The Directive on common rules for the internal market for electricity (EU/2019/944) (EMD)

Since smart charging can lead to charging at reduced power (and even temporarily charging other vehicles by an EV battery) it influences the charging efficiency. In the ADAC EVSE test (section 1.2.3.1) this was covered by adding charging at half power of the maximum EVSE charging power. This is an issue for the reference scenario (task 3).

For mode 1 chargers it has already been decided that the Commission will investigate the technical feasibility of harmonised standards for "common chargers" in the context of the Battery Regulation (EU) 2023/1542.

Based on articles 5 and 114 of the Treaty for the functioning of the European Union (TFEU), Typical installation requirements are likely to remain local policy while products can be harmonized to support the functioning of the internal market. This is relevant when considering policy options in Task 7.

Important losses related to the roll out of EVSE mode 4 are related to their MV/LV transformers but they can be exempted due to the Article 1 of the ecodesign regulation for power transformers (EU) 2019/1783.

EVSE mode 4 can be scoped out of the WEEE Directive 2012/19/EU being ‘large-scale fixed installations, except any equipment which is not specifically designed and installed as part of those installations’.

1.5 References

No references in this chapter (only footnotes are used).

1.6 Annex Connector and socket types

The EV charging stations are connected to the EVs with help of sockets and connectors if conductive charging is used. Many types exist and they can be known under different names. In the tables below a comprehensive overview is compiled. Mostly the plug is shown, but sometimes socket variants exist. They are given in that case.

Table 1-2: Plugs and sockets used in Europe for EV charging (pictures from wikimedia.org and own drawings)

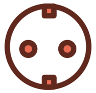
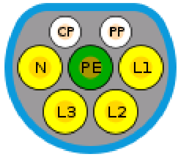
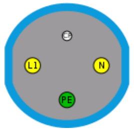
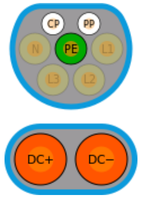
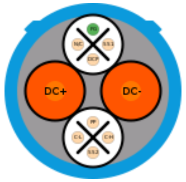
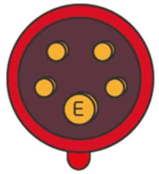
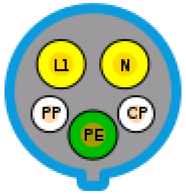
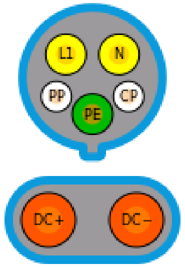
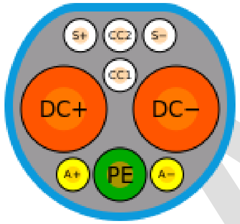
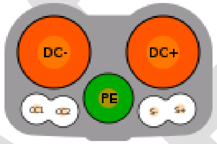
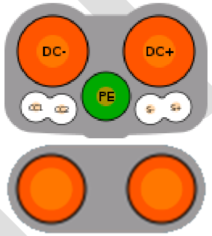
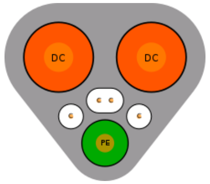
Region	Europe	,,	Europe, USA, China	France	Italy, France	Europe	Japan, Europe	Worldwide	Worldwide	Worldwide
Name	Standard national plug	Reinforced *socket* for EV	Type 2	Type 2S *socket*	Type 3A	CCS Combo 2	CHAdeMo	1 phase industrial socket	3 phase industrial socket	NACS
IEC 62196	—	—	Type 2	,,	Type 3A	FF	AA	—	—	—
Others	IEC 60083 Type E, F, G, J, K, L; IECEE CEE7	NA	SAE J3068, GB/T 20234.2	,,	—	—	—	IEC 60309; IECEE CEE17	IEC 60309; IECEE CEE16	—
Nickname	Schuko [type F]	NA	Mennekes	—	Scame					Tesla
Shape				idem						
Current	AC, 1 phase	AC, 1 phase	AC, 3 phase	,,	AC, 1 phase	DC	DC	AC, 1 phase	AC, 3 phase	AC, 1 phase & DC
Max. voltage (V)	230	230	400	,,	230	1000	1000	230	400	410
Max. current (A)	16	16 (continuously)	32	,,	16	200; 500	400	16; 32; 63; 125	16; 32; 63; 125	330
Available power (kW)	3,7	3,7	22; 43	,,	3,7	175; 360	50; 400	3,7; 7,4; 14; 29	11; 22; 44; 87	22 (AC); 135 (DC)
Charge mode (IEC 61851-1)	Mode 1, 2	Mode 1, 2	Mode 3	,,	Mode 3	Mode 4	Mode 4	Mode 2	Mode 2	Mode 3, 4
Communication	NA	NA	PWM, PLC	,,	PWM	PLC	CAN	NA	NA	CAN
Remark		Reinforced, may have RCCB	The Chinese version has a different wire configuration	With child protection (shutters) and cable locking		Tesla has a version with notches : only compatible with Tesla charging stations				

Table 1-3: Plugs and sockets used outside Europe, specific for EV charging (the ones shown in previous table are not copied; pictures from wikimedia.org or own drawing)

Region	North America, Japan	North America	China	Japan, China	Japan, China	Worldwide
Name	Type 1	CCS Combo 1	GB/T 20234.3	ChaoJi	Ultra-ChaoJi	MCS
IEC 62196	Type 1	EE	—	—	—	—
Others	SAE J3068 AC$_6$ / J1772	SAE J3068 AC$_6$DC$_8$	GB/T 20234.3-2015	CHAdeMO 3.0	—	—
Nickname	Yazaki; J-plug		—	—	—	—
Shape						
Current	AC, 1 phase	AC, 1 phase; DC	DC	DC	DC	DC
Max. voltage (V)	600 (AC)	600 (AC); 1000 (DC)	1000	1500	1500	1250
Max. current (A)	60	500 (DC)	250	600	1200	3000
Available power (kW)	19	360	250	900	1800	700; 3750
Charge mode (IEC 61851-1)	Mode 3	Mode 3, 4	Mode 4	Mode 4	Mode 4	Mode 4
Communication	PWM, LIN	PWM, LIN	CAN	CAN, ethernet	CAN, ethernet	PLC
Remark					In development	Under test

1.7 Annex Standards

This annex gives an overview of related standards to recharging stations.

1.7.1 EVSE design

IEC 61851 series ‘Electric vehicle conductive charging system

This series of standards is about the requirements for design and operation of recharging stations and consists of many parts. They contain test methods for safety and functionality. However, no test methods for energy loss or efficiency determination are included. Part 3-1 (DC charging up to 120 V_{dc} defines a consumption limit of 0,5 W for all luminous elements together.

- Part 1 (2017): General requirements
- Part 1-1 (2023): Specific requirements for electric vehicle conductive charging system using type 4 vehicle coupler
- Part 3-1 (2023): DC EV supply equipment where protection relies on double or reinforced insulation - General rules and requirements for stationary equipment
- Part 3-2 (2023): DC EV supply equipment where protection relies on double or reinforced insulation - Particular requirements for portable and mobile equipment
- Part 21-1 (2017): Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply
- Part 21-2 (2018): Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems
- Part 23 (2023): DC electric vehicle supply equipment
- Part 25 (2020): DC EV supply equipment where protection relies on electrical separation

Part 1 contains tests in chapter 12. They are safety and functionality related. Measuring losses and efficiency is not included.

Part 23 discerns for DC charging stations different so-called systems:

- System A (annex AA): uses dedicated CAN communication circuit. The vehicle connector must have two separate communication connections for this. It is connector type AA defined in IEC 62196-3. In fact this is the CHAdeMO connector. The charging voltage is limited to 500 V_{dc}. System A is originally defined in JIS/TSD0007.
- System B (annex BB): it is the Chinese charging method with connector GB/T 20234.3 (or type BB in IEC 62196-3). This system is explicitly excluded for Europe.
- System C (annex CC): it is the combined charging system. It allows connector types CC up to FF (IEC 62196-3). EE corresponds to CCS type 1 or SAE J1772 and FF to CCS type 2. They allow 500 V_{dc} except FF that allows 1000 V_{dc}. The communication happens with help of the Control Pilot line and is powerline communication.

IEC 62196 Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles

This standard series cover the mechanical, electrical and performance requirements for dedicated plugs, socket outlets, vehicle connectors and vehicle inlets for interfacing between such dedicated charging equipment and the electric vehicle. It consist of the following parts:

Part 1: General requirements

Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories

Part 3: Dimensional compatibility requirements for DC and AC/DC pin and contact-tube vehicle couplers

Part 4: Dimensional compatibility and interchangeability requirements for DC pin and contact-tube accessories for Class II or Class III applications

The standards describe the design of the sockets and connectors, including the mechanical strength and resistance against foreseen operating conditions. They contain corresponding test methods. Part 4 is a technical specification (TS) for power supply up to 120 V_{AC} and 60 A.

There are no test methods for energy loss or efficiency determination.

1.7.1.1 IEC 62752 (Ed.2, 2024) In-Cable Control and Protection Device for mode 2 charging of electric road vehicles (IC-CPD)

The essential purpose of this standard[29] is the safe and reliable access of electric vehicles to a supply system with help of mode 2 charging, including the situation where it cannot be guaranteed that the installation is equipped with RCDs, for example charging the electric vehicle at an unknown installation, a dedicated protection is used for the connected electric vehicle. The IC-CPD:

- provides a control pilot function in accordance with IEC 61851-1:2017, Annex A;
- checks supply conditions and prevents charging in the event of supply faults under specified conditions;
- can have a switched protective conductor;
- is only valid for AC current.

The standard contains construction requirements and tests about safety, reliability and endurance. No energy consumption or efficiency is measured.

The intention of this document

is to describe the relevant requirements for an in-cable control and protection device (IC-CPD)

to be used for mode 2 charging.

[29] https://webstore.iec.ch/preview/info_iec62752%7Bed2.0%7Db.pdf

1.7.1.2 IEC 62893 series Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV

This standard series specify the construction, dimensions and test requirements for cables with extruded insulation and sheath having a voltage rating of up to and including 0,6/1 kV_{AC} or up to and including 1500 V_{DC} for flexible applications under harsh conditions for the power supply between the electricity supply point of the charging station and the electric vehicle (EV). The EV charging cable is intended to supply power and, if needed, communication (for details see the IEC 62196 series and IEC 61851-1). The charging cables are applicable for charging modes 1 to 4 of IEC 61851-1. Ordinary duty cables with rated voltage 300/500 V are only permitted for charging mode 1 of IEC 61851-1. Maximum conductor temperature for the cables in this part of IEC 62893 is 90 ºC. The particular types of cables are specified in IEC 62893-3 (modes 1 to 3 for AC charging) and in IEC 62893-4(-1+2) (mode 4 for DC charging). The test methods specified are given in IEC 62893-2, IEC 60245-2, IEC 60332-1-2, IEC 62821-1 Annex B, and in the relevant parts of IEC 60811. The tests in part 2[30] are resistance tests against environmental conditions.

1.7.1.3 ISO 17409:2020 Electrically propelled road vehicles - Conductive power transfer - Safety requirements

This standard specifies electric safety requirements for conductive connection of electrically propelled road vehicles to external electric circuits. External electric circuits include external electric power supplies and external electric loads. This document provides requirements for the charging modes 2, 3, 4, as defined in IEC 61851-1, and reverse power transfer. For mode 4, this document provides requirements regarding the connection to an isolated DC EV charging station according to IEC 61851-23.

1.7.1.4 China GB/T 18487.1

This standard is close to the IEC 61851 series, but not identical. It has no test method for energy losses neither. However, it defines catenary charging of vehicles. The catenary can be placed in the charging room (, so-called Case D connection.) or in the vehicle (Case E connection).

1.7.1.5 China GB/T 20234 series

This is the Chinese equivalent of the IEC 62196 series. They define the couplers. Although the Type 2 connector is defined in GB/T 20234.2, the wire lay-out is different from the IEC version.

1.7.2 Communication with EV

1.7.2.1 IEC 61851-1:2017 'Electric vehicle conductive charging system

- Part 1 (2017): General requirements
- Part 3-4 (2023): DC EV supply equipment where protection relies on double or reinforced insulation - General definitions and requirements for CANopen communication

[30] https://webstore.iec.ch/preview/info_iec62893-2%7Bed1.0%7Den.pdf

- Part 3-5 (2023): DC EV supply equipment where protection relies on double or reinforced insulation - Pre-defined communication parameters and general application objects
- Part 3-6 (2023): DC EV supply equipment where protection relies on double or reinforced insulation - Voltage converter unit communication
- Part 3-7 (2023): DC EV supply equipment where protection relies on double or reinforced insulation - Battery system communication
- Part 24 (2023): Digital communication between a DC EV supply equipment and an electric vehicle for control of DC charging

The basic way to control the charging process between the EV and EVSE and to allow simple smart charging is the control pilot Pulse Width Modulation (PWM) signal. It is defined in ‘Part 1: General requirements’. The duty cycle of the signal is controlled by the EVSE and indicates the charging amperage limits. The voltage level of the signal is controlled by the EV and indicates the state of the vehicle (no vehicle connected, vehicle connected but not ready to charge, …). A duty cycle of 5% triggers the high-level communication for charge control via ISO 15118 or DIN Spec 70121.

For DC charging two digital communication architectures are used:

- one, based on CAN using a dedicated data communication circuit; CAN protocol is given in ISO 11898-1
- the other, based on Homeplug Green PHY™1 over the control pilot line
- The digital communication for the d.c EV charging station of system C is defined in the following standards: DIN SPEC 70121, ISO/IEC 15118-1, ISO/IEC 15118-2 and ISO/IEC 15118-3

The charger output voltage and current are communicated in the protocol (charger charge state) as well as the battery charging voltage and current (battery charge state1).

1.7.2.2 ISO 15118 series ‘Road vehicles -- Vehicle to grid communication interface’

This standard series defines the communication interface for EV charging. It provides a number of use cases including smart charging, secure communication as well as Plug and Charge functionality (see Figure 1-7 for the logo). The protocols are defined in part 2 and 20 (2nd generation network, including bi-directional charging).

Without secure communication between the charging stations and the EVs, malicious parties can hijack and alter messages and interfere with billing information. To avoid this, the Plug & Charge mechanism deploys multiple cryptographic tools to secure communication and guarantee the confidentiality, authenticity, and integrity of the exchanged data.

The Plug & Charge mechanism allows EVs to identify themselves automatically to the charging station and get approval to access to electrical energy required to recharge the EV battery. The advanced smart charging capability lets the EV send information about the requested amount of energy and anticipated departure time. This allows the EVSE to generate an accurate charging profile to be used during the transaction.

Figure 1-7: Plug and Charge logo from ISO 15118 (source: Wikimedia)

1.7.2.3 DIN spec 70121

This standard is a predecessor of the ISO 15118 series. It is high level communication but most of the features of the ISO one like secured communication, smart charging and Plug and Charge mechanism are lacking. It is meant as a temporary solution.

1.7.3 Communication between EVSE and the operator

This communication type is also called front-end communication. Communication from between operators and service providers is similarly called back-end communication. That is not in the scope of this section. See also the annex in Eurelectric's position paper on protocols[31] and the next section on interoperability.

1.7.3.1 Open Charge Point Protocol (OCPP)

OCPP[32] is an often used standard[33] for communication between a (Re-)Charging Station (CS) and a Charging Station Management System (CSMS) and is designed to accommodate any type of charging technique. The protocol started in 2009 as an initiative from the E-Laad foundation (now ElaadNL) in the Netherlands with the release of OCPP version 1.5.

Most charging stations today have implemented OCPP 1.6 and are being extended with OCPP 2.0.1. OCPP 1.6 supports charging session authorization, billing, grid management, charge station operation, reservation and basic smart charging functionality. Version 2.0.1 added improvements for security, ISO 15118, smart charging and extensibility of the protocol.

A draft OCPP version 2.1 specification is expected to be released in 2024. This release will add some relevant functionality to the protocol such as ISO 15118-20 support, bi-directional power transfer (BPT) and grid support functionality. This will make it possible to support V2G systems as Distributed Energy Resources (DER).

The development roadmap in Figure 1-8 shows the functionality provided by the different OCPP versions.

Due to this standard homegrown protocols in recharging stations have been out-phased, avoiding a buyers lock-in and therefore supports a long lifetime of the equipment.

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31 https://cdn.eurelectric.org/media/4562/20200709_eurelectric_ev_charging_interoperability-2020-030-0465-01-e-h-4C8220FC.pdf

32 https://www.openchargealliance.org/

33 Certified companies - Open Charge Alliance shows a list with certified products.

The smart charging functionality has a direct influence on the charge profile at the EVSE and therefore influences the charging efficiency.

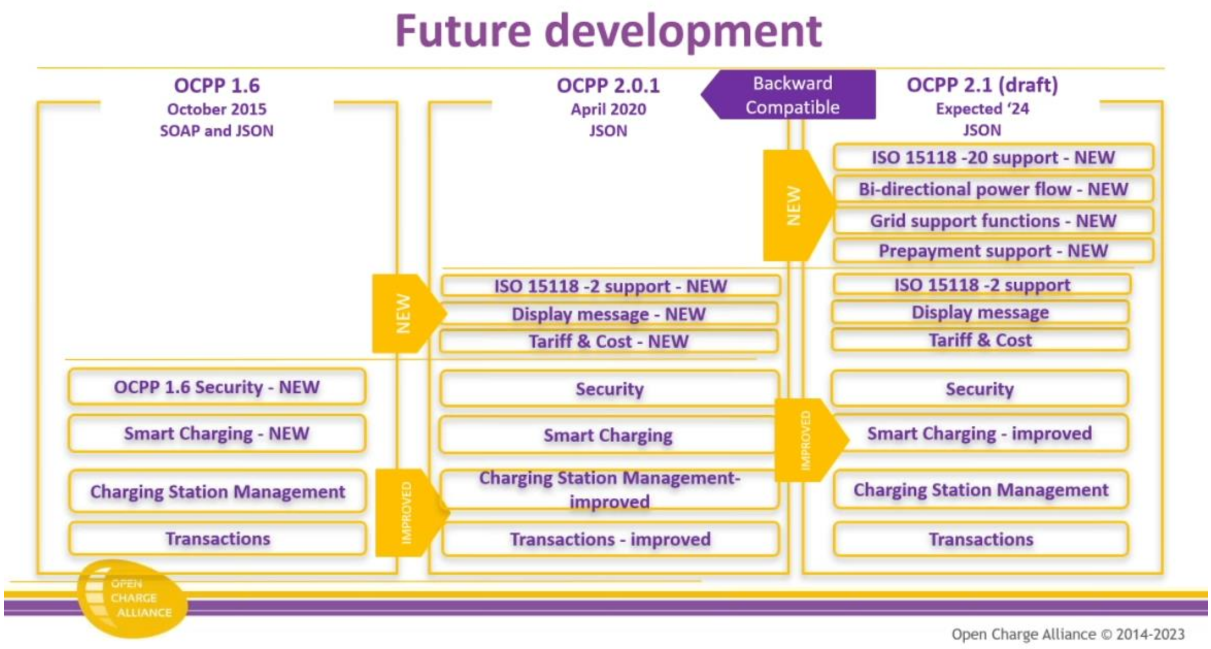

Figure 1-8: OCPP development roadmap (OCA symposium, 28 march 2023, Arnhem)

1.7.3.2 IEC 63110 series 'Protocol for management of electric vehicles charging and discharging infrastructures'

This standard series lays down the interoperability between different EV charging networks. It defines common communication protocols for EV charging infrastructure. These protocols allow different charging networks to communicate seamlessly, regardless of the manufacturer or operator. The standard enables roaming services, allowing EV users to charge their vehicles at any compatible charging point, regardless of the network provider. This promotes convenience and accessibility. By standardizing data formats and communication methods, IEC 63110 ensures that charging networks can exchange essential information such as pricing, availability, and authentication securely. Interoperability simplifies the process of connecting to charging stations. EVs equipped with IEC 63110-compliant systems can plug-and-play across various networks without compatibility issues.

This standard has the same scope as OCPP. It delivers the same functions, has a similar architecture but is not exactly the same. Both standards rival with each other.

1.7.4 Communication between EVSE and home energy management

1.7.4.1.1 EEBUS

EEBUS is a standardized digital infrastructure that facilitates seamless intelligent communication between various devices in the energy domain. Specifically, it enables communication between household appliances, electric vehicles (EVs), heat pumps, energy producers, storage systems, energy management systems (EMS), and external control signals (such as those from grid operators)1. In the context of EVs, EEBUS ensures efficient communication between the Electric Vehicle Supply Equipment (EVSE) and the EV itself. It uses the necessary Power Line Communication (PLC) based on ISO 15118 Part 22. EEBUS allows the EVSE to coordinate with other energy-consuming devices (like heat pumps) and energy producers (such as photovoltaic systems) to optimize cost, sustainability, and grid stability during EV charging[34].

1.7.4.1.2 HomePlug

HomePlug is a competing standard with EEBUS. It also communicates via PLC to the EV. It defines a common communication protocol for EVSEs, that is supported by various EV manufacturers.

1.7.4.1.3 Sunspec

SunSpec publishes free, open interoperability specifications and information models that software developers, hardware manufacturers, and integrators use to achieve plug-and-play interoperability between Distributed Energy Resource (DER) components and smart grid applications. Many PV inverters and batteries support the Sunspec protocol. It also supports bi-directional vehicle-to-grid (V2G) communication.

1.7.5 Generic standards on interoperability

According to **ISO/IEC 2382-01** on 'Information Technology Vocabulary, Fundamental Terms', **interoperability** is defined as follows: 'The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units'.

Despite this ISO/IEC 2382-01 definition there are several other definitions of interoperability in formal standards[35]. For example, within standard (IEC 63105) interoperability is defined as 'ability of systems or systems components to transmit, receive, interpret, and/or react to data and/or power and function in a specified manner'.

Also, ETSI[36] defined, several **levels of interoperability** in an **ETSI** white paper[37] which can be applied to a multitude of topics and applications:

- **Technical Interoperability** is usually associated with hardware/software components, systems and platforms that enable machine-to-machine communication to take place. This kind of interoperability is often centred on (communication) protocols and the infrastructure needed for those protocols to operate.
- **Syntactical Interoperability** is usually associated with data formats (e.g. XML[38], MODBUS[39]). Accordingly, the messages transferred by communication protocols need to have a well-defined syntax and encoding, even if it is only in the form of bit-tables. Today, many protocols specify data or content using high-level transfer syntaxes such as HTML, XML or ASN.
- **Semantic Interoperability** is usually associated with the meaning of content and concerns the human rather than machine interpretation of the content (e.g. Smart

[34] https://www.eebus.org/wp-content/uploads/2023/04/20190715-EEBUS_Whitepaper_E-Mobility_UseCases-v1.01.pdf
[35] http://www.internet-of-things-research.eu/pdf/IERC_Position_Paper_IoT_Semantic_Interoperability_Final.pdf
[36] https://www.etsi.org/
[37] http://www.etsi.org/images/files/ETSIWhitePapers/IOP%20whitepaper%20Edition%203%20final.pdf
[38] https://www.w3.org/TR/xml/
[39] http://modbus.org/about_us.php

Appliances REFerence (SAREF) ontology[40], MODBUS[41], Zigbee stack and certified products, etc.). Interoperability at this level means that there is a common understanding of the meaning of the content (information) being exchanged.

- **Organizational Interoperability**, as the name implies, is the ability of organizations to effectively communicate and transfer (meaningful) data (information) even though they may be using a variety of different information systems over widely different infrastructures, possibly across different geographic regions and cultures. Organizational interoperability depends on successful technical, syntactical, and semantic interoperability.

1.7.6 Standards on lifetime, repairability and material content

Specific aspects of circular economy are addressed in the **recent standard series EN 4555x** Reparability and upgradability are addressed in **EN 45554** on 'General methods for the **assessment of the ability to repair, reuse and upgrade** energy related products'. This is a generic standard which in essence only contains definitions and therefore the type of Ecodesign criteria which can be set for products. In an informative annex there is an extended description on how to report and assess methods for repair, re-use and upgrade. This informative annex is mostly related to hardware (repair tools, spare parts, etc.) but does not contain specific methods for software.

The standard IEC 62474 on **'Material Declaration for Products of and for the Electrotechnical Industry' has a database**. The main document describes the material declaration requirements. There are six types of information provided in IEC 62474 DB are represented by the six hyperlinked text fields on: Declarable substance groups and declarable substances (DSL), Reference Substances (RSL), Material classes (MCL), Exemption Lists, Supplementary Lists and Information and an XML schema for materials declaration.

1.7.7 Payment systems for electricity meters

1.7.7.1 IEC 62055 series 'Electricity metering - Payment systems'

The IEC 62055 series provides a comprehensive framework for designing, implementing, and maintaining payment systems in the context of electricity metering. It covers payment systems, including customer information systems, point-of-sale systems, coin holders, payment counters, and the associated interfaces between these entities[42].

[40] https://sites.google.com/site/smartappliancesproject/ontologies/reference-ontology
[41] http://modbus.org/about_us.php
[42] IEC 62055 Electricity Measurement - Payment Systems (eurolab.net)

2 Markets

The objective of Task 2 is to present an economic and market analysis of EV recharging points. The aims of this task therefore are:

- to place the EV recharging points within the context of EU industry and trade policy (subtask 2.1);
- to provide market size and cost inputs for the EU-wide environmental impact assessment of the product group (subtask 2.2);
- to provide insight into the latest market trends to help assess the impact of potential Ecodesign measures with regard to market structures and ongoing trends in product design (subtask 2.3, also relevant for the impact analyses in Task 3); and finally,
- to provide a practical data set of prices and rates to be used for Life Cycle Cost (LCC) calculations (subtask 2.4).

2.1 Generic economic data

In the MEErP, generic economic data refers to data that is available in official EU statistics (e.g. PRODCOM) and the aim is to identify and report: EU Production; Extra-EU Trade; Intra-EU Trade and EU sales and trade= production + import - export. The information required for this subtask should be derived from official EU statistics in order to be consistent with the official data used in EU industrial and trade policy. Therefore, general data for product sales based on the respective PRODCOM code are usually used as a first source for this task. However, in the case of EV recharging points, no such code exists yet (code 27.90.41.80 "Accumulator chargers" refers to smaller consumer batteries[43]). As PRODCOM data is often unreliable and/or does not always fit the product scope of Task 1 one-to-one and/or is not broken down by different product categories, PRODCOM data is usually only a first starting point and further analysis is needed.

2.1.1 Approach to subtask 2

PRODCOM data is publicly available and is a direct source of market information. PRODCOM data does not provide direct information on the total number of installed EV recharging points used in the EU28 Member States. The data may also not take into account those imported into or exported from the EU.

2.1.1.1 EV recharging points related PRODCOM categories

As already stated in Task 1, there is no specific category in the NACE2 classification that deals with EV recharging points. Only category 27904180 addresses chargers, although these are not those for charging vehicles.

2.1.2 Results of the PRODCOM analysis

The PRODCOM categories 271240[44] and 279044[45] are nevertheless analysed in more detail for the available years 2013 to 2022 in order to investigate whether the

[43] https://ec.europa.eu/eurostat/web/prodcom/information-data

[44] *Boards, panels, consoles, desks, cabinets and other bases for apparatus for electric control or the distribution of electricity (excluding those equipped with their apparatus)*

[45] *Appliance cords, extension cords, and other electrical cord sets, for a voltage <= 1 kV, with insulated wire and connectors*

aforementioned categories show a corresponding change with the increase in demand for EV recharging points.

Figure 1 shows the development of production volumes for the two mentioned categories in euros and units for the corresponding period. The data shows a stagnation or a slight increase in production value. Data for the production quantity for 279044 is just available since 2016. While the production quantity for 271240 (boards, panels,..) stayed rather on a constant level, the production quantity for 279044 (Appliance cords,..) showed an increase until 2019 followed by a reduction.

Figure 1 shows the evolution of the volume of production for the two categories mentioned, in euros and in units. The data reveal a stagnation or a slight increase in the production value. Production quantity data for 279044 are only available since 2016. While the production quantity for 271240 (plates, panels, ...) remained fairly constant, the production quantity for 279044 (cables for appliances, ...) showed an increase until 2019 and then a decrease.

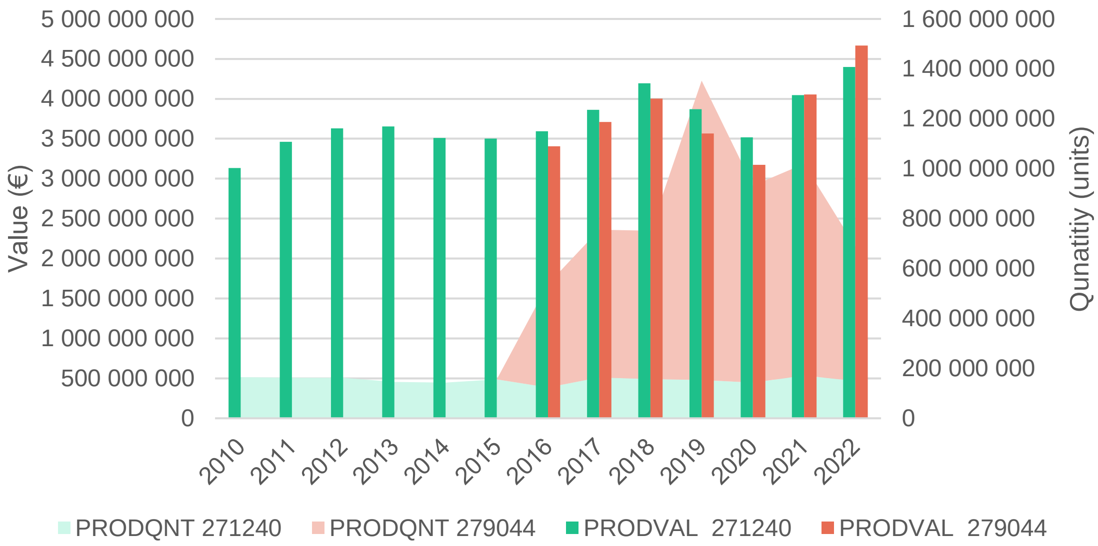

Figure 2-1: EU production in PRODCOM categories 279044 and 271240[46]

In addition to production, the following Figure 2-2 and Figure 2-3 show the development of exports and imports in the two categories considered. For imports and exports, data for 279044 are again only available from 2016 onwards. In addition, there are no data on the volume of exports and imports for 271240.

[46] https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_11418878/default/table?lang=en

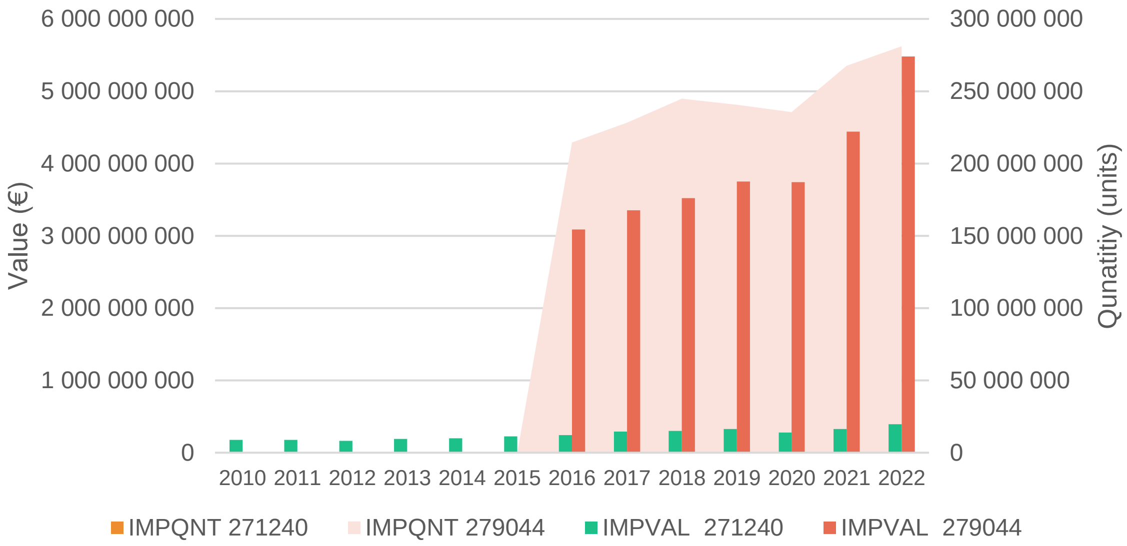

Figure 2-2: EU import in PRODCOM category 279044 and 271240[47]

While a slight increase in the value of imports and exports has been observed for category 271240 since 2010, this increase has been stronger for category 279044, with imports value increasing slightly more than exports value. The quantity of exports has remained relatively constant since 2016.

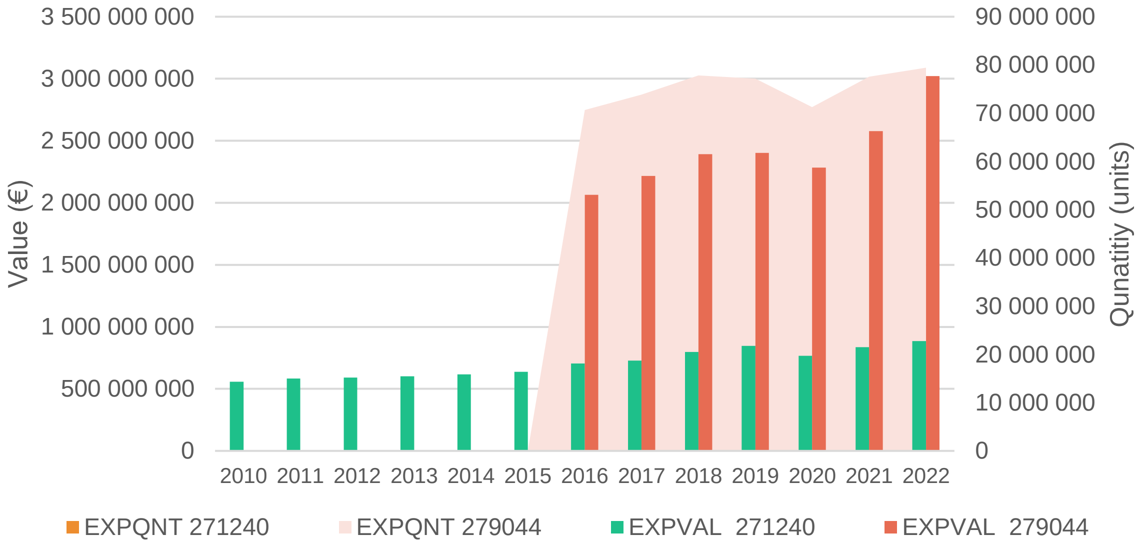

Figure 2-3: EU export in PRODCOM categories 279044 and 271240[48]

However, as several products are summarised in these PRODCOM categories, no specific values for EV recharging points can actually be derived from this data. As the market for EV recharging points is still comparatively young, it is not surprising that no explicit statistics are available. In order to assess the significance of the market nevertheless, other sources will be used.

[47] https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_11418878/default/table?lang=en

[48] https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_11418878/default/table?lang=en

Stakeholder questions related to definitions and scoping:

18) Do you have any suggestions for other relevant prodcom data?

2.2 Market and stock data

Task 2.2 will compile market and stock data in physical units for the EU-27, for the product categories defined in Task 1.1 and for today combined with a forecast for presumable entry into force of measures for 2030-2040-2050. Therefore the following parameters are to be identified:

- installed base ('stock') and penetration rate;
- annual sales growth rate (% or physical units);
- average product life (in years), in service, and a rough indication of the spread (e.g., standard deviation);
- total sales/ real EU-consumption, (also in euros, when available);
- replacement sales (derived);
- new sales (derived).

2.2.1 General objective of subtask 2.2 and discussion of useful data sources

EV recharging points as a product varies greatly depending on the area of application. They are particularly widespread in road transport, especially when it comes to charging EVs in private or public areas. While public charging points are generally used by several people and are therefore visited more frequently, private charging stations are only accessible to a select group of people[49]. Accordingly, they differ greatly depending on the target group in terms of features (e.g. authentication, payment options, etc.) or charging power (≤ 3.7 kW to > 300 kW). However, EV recharging points are also used outside of road transport, such as for shore power supply on ships or the power supply of aircraft on the ground. In order to be able to determine the stock of EV recharging points in the EU with sufficient reliability, the areas of application mentioned have to be considered separately.

Public charging points are currently well monitored by the European Alternative Fuels Observatory (EAFO). In addition, the AFIR provides a legal framework that sets specific aims (in connection with the ramp-up of electric vehicles) for the expansion of publicly accessible charging points.

Private recharging points are not addressed in the AFIR. However, the Energy Performance of Buildings Directive (EPBD) contains aims for different types of buildings. The EPBD thereby identifies two main categories of buildings: non-residential (e.g. office, retail buildings) and residential. In order to provide a holistic estimation of the current and future stock of EV recharging points, both private and public recharging points must be considered. The following considerations and analyses are based, as far as possible, on the two pieces of legislation mentioned and their preceding impact assessments and accompying studies [50].

[49] For more information see Task 3 - Users

[50] https://op.europa.eu/en/publication-detail/-/publication/ef0b9a03-728e-11ec-9136-01aa75ed71a1/language-en & https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

2.2.2 Public recharging points

Since 2012, the stock of public recharging points in the EU has grown from ~10,000 to more than 130,000 in 2019 (based on the old counting methodology until 2019, only considering public recharging points).

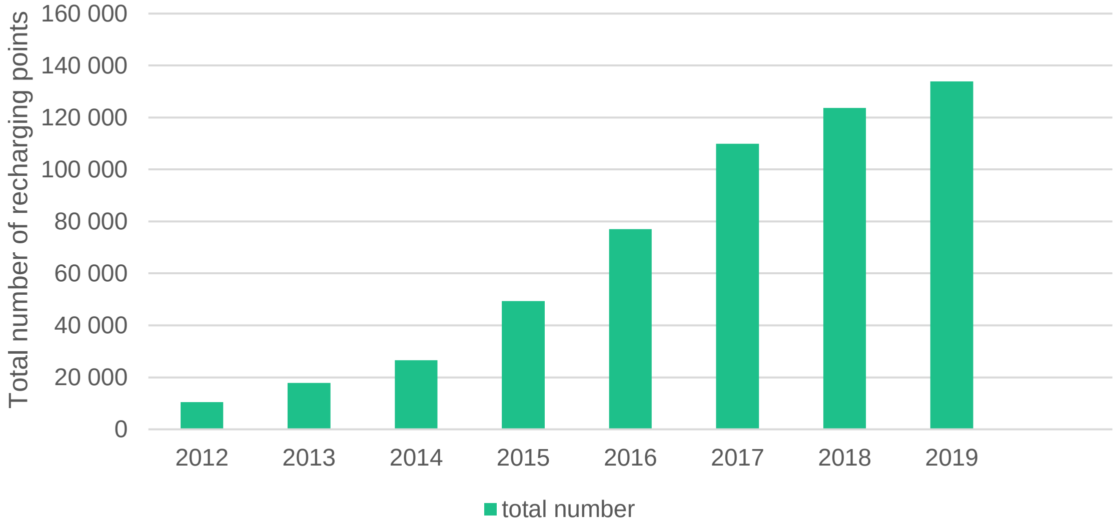

Figure 2-4: Total number of recharging points until 2019 based on the old counting methodology until 2019 (source: EAFO[51])

The number of recharging points since 2019 is shown in Figure 2-5 (according to AFIR classification) and it becomes obvious that the amount of recharging points in the EU has surpassed the number of 500,000 in Q1 2023. The year-to-year growth rate for the DC recharging points is hereby slightly higher than the one for the AC.

[51] https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/infrastructure

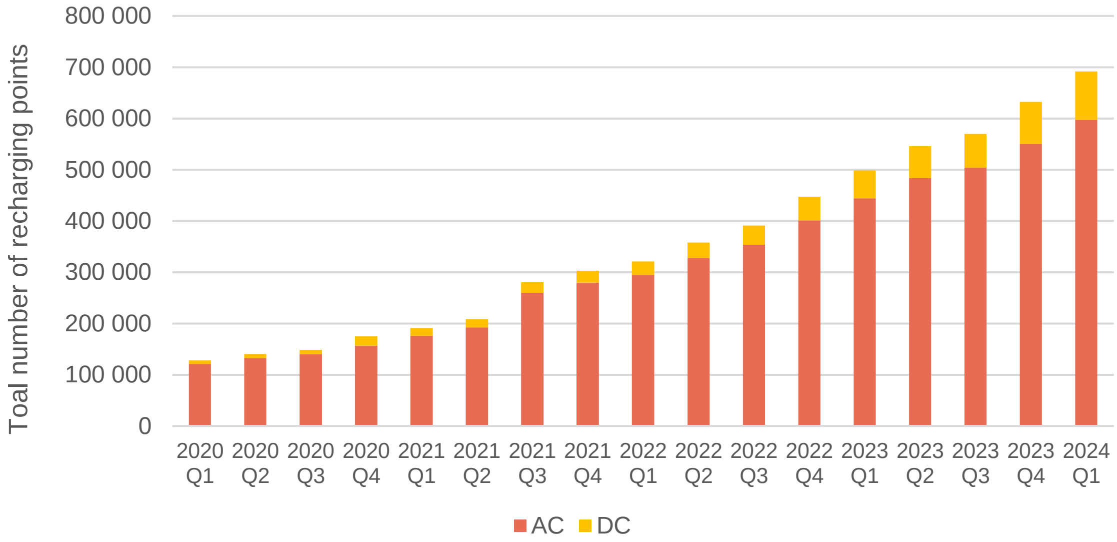

Figure 2-5: Current development of total numbers of recharging points since 2019 according to the AFIR classification (source: EAFO[52])

Looking at the stocks by country, it is clear that around 60% of the total is installed in 3 countries (the Netherlands, France and Germany), as can be seen from the map below showing the location of public recharging points.

[52] https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/infrastructure

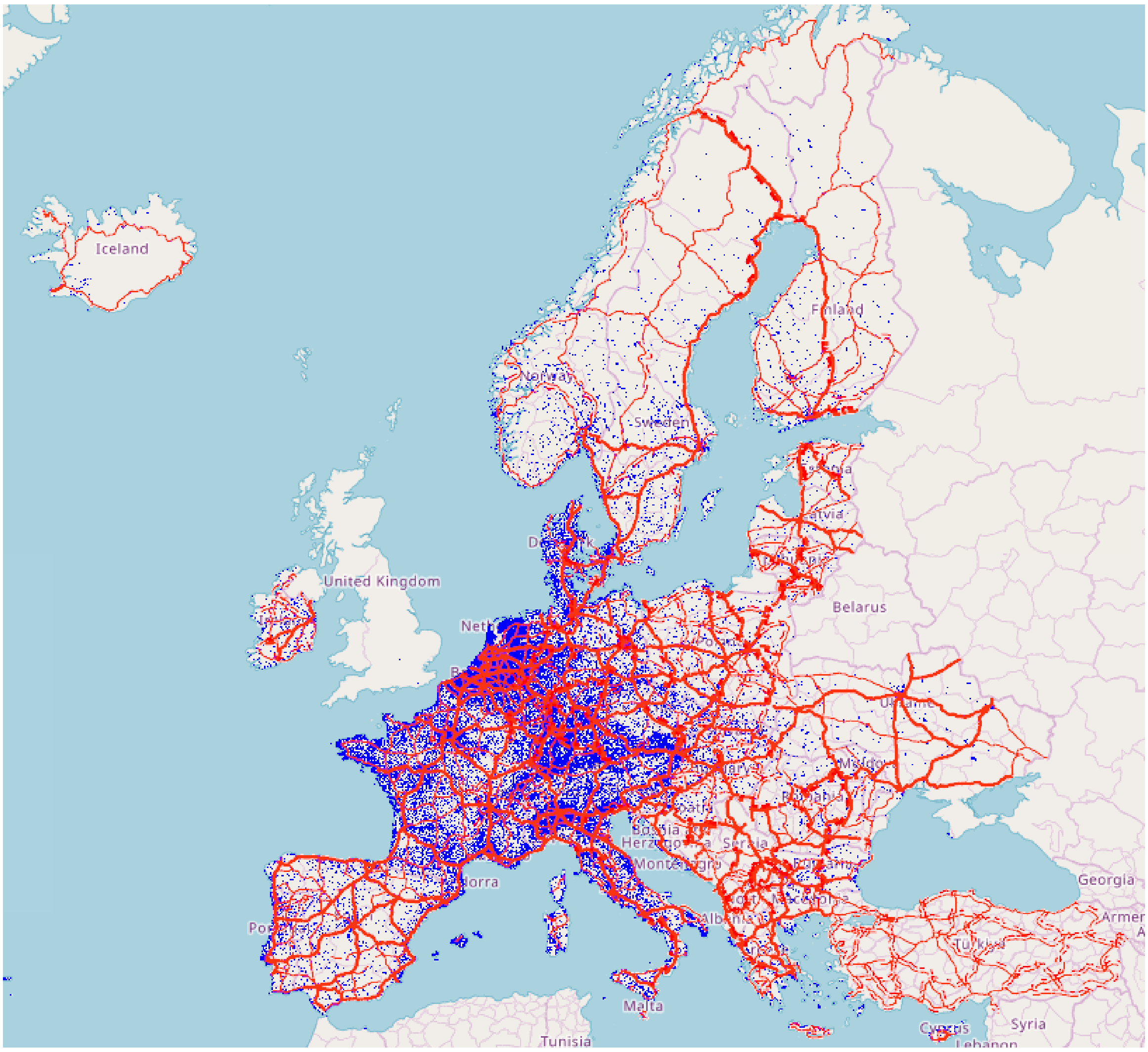

Figure 2-6: Distribution of public recharging points in Europe[53]

Figure 2-7 shows a more detailed overview of the installed recharging points by country. Although these total numbers seem to be quite high, it becomes clear that this is just the beginning of the EV infrastructure rollout.

[53] https://ec.europa.eu/transport/infrastructure/tentec/tentecportal/map/maps.html?layer=11,12,13,14,15

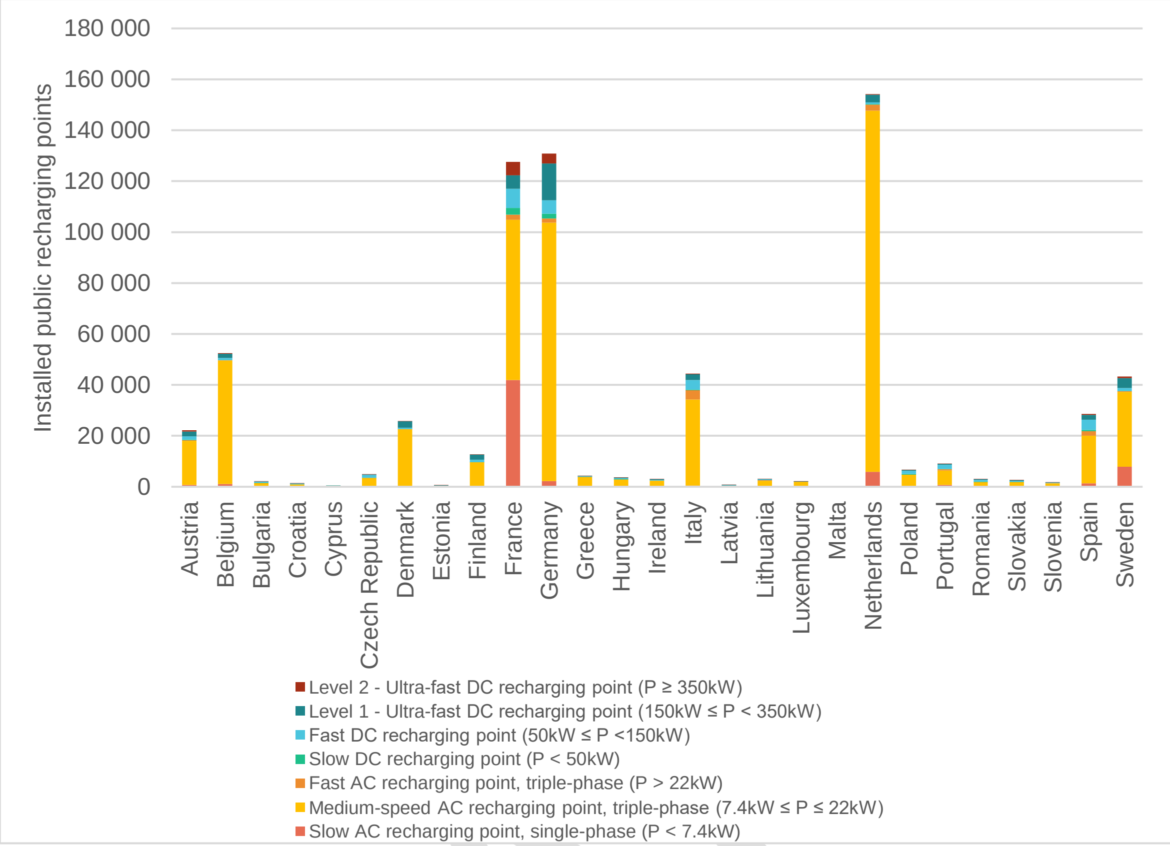

Figure 2-7: Total number of AC and DC recharging points in 2022 according to the AFIR categorization (source: EAFO[54])

The AFIR links the future targets for public recharging points to the number of vehicles in each country (among other criteria). Based on the power output per EV envisaged in the AFIR, the required number of charging points needed in the respective countries can be estimated. However, it should be noted that AFIR itself does not mandate a certain number of recharging points in individual Member States. Furthermore, compliance with the targets also depends on the aggregated power output.

Figure 2-8 indicates that even if many public recharging points are already installed, and most countries already meet the required numbers set for 2024, there is still a lot of effort needed to meet future demand. It becomes obvious that the number of recharging points has still massively to grow to match the required amount for 2030. For example, Germany has already installed more than 100,000 recharging points. But, would have to install tenfold this number is required. Also, there are no numbers given for Spain, France, or Italy; the situation might be comparable to that of Germany, considering the current number of recharging points and the size of the national automotive and truck market.

[54] https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/target-tracker

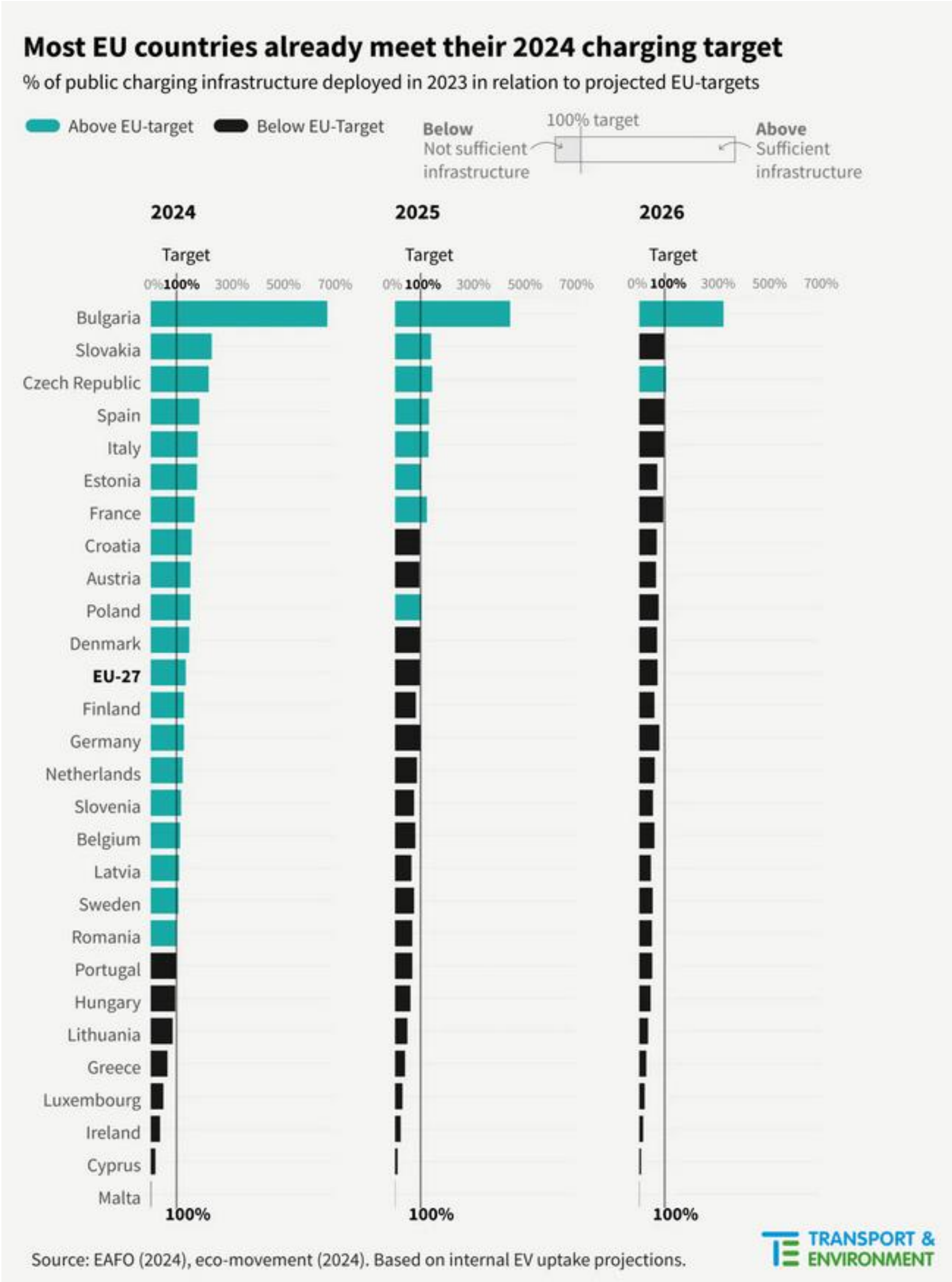

Figure 2-8: NIR charging infrastructure targets for 2030 and current progress (source: T&E[55])

The future stock of recharging points is, therefore, very closely linked to the development of electromobility. The number of recharging points depends on the level of power, i.e. the factor of public recharging points to EVs. While the Support study for the Impact Assessment (IA) of the AFIR[56] originally envisaged 1kW per BEV and 0.66 kW per PHEV, these values were raised to 1.3 and 0.8 kW. It should be noted that these figures are the minimum level of infrastructure that needs to be put in place in the EU. Depending on the market penetration of EVs, the ratio may therefore be higher. Other stakeholders see an even higher ratio of e.g. 3 kW per BEV or 2 kW per PHEV. However, the difficulty in setting

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[55] https://www.transportenvironment.org/articles/most-eu-countries-on-track-to-meet-charging-targets

[56] https://op.europa.eu/en/publication-detail/-/publication/ef0b9a03-728e-11ec-9136-01aa75ed71a1/language-en

such target values is the balance between the availability of charging points and their utilisation.

In addition, the number of future recharging points depends on the average energy consumption per vehicle, the proportion of private charging and the charging power. All of this means that different stakeholders have different expectations regarding the future expansion of the public charging infrastructure.

In addition to the scenario on which the AFIR is based (here still with 1 kW or 0.66 kW), the assumptions of ACEA[57] and T&E[58] are compared below.

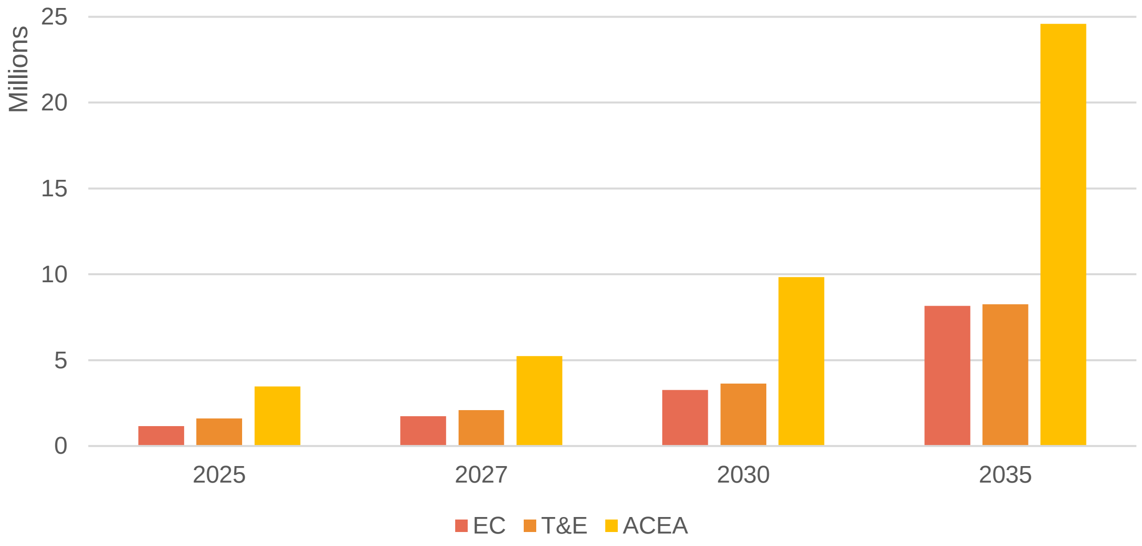

Figure 2-9: Uptake of public recharging point depending on different scenarios[59]

The comparison shows that although there are sometimes widely differing assumptions regarding the future demand for public recharging points, a strong increase is expected. The two assumptions of EC and T&E are quite close to each other[60] and, according to the assumptions made there, it is expected that the threshold of 5 million public recharging points will be exceeded between 2030 and 2035. However, as previously mentioned, the resulting number of recharging points depends on the average power output of the recharging points, which is constantly increasing and was still around 14 kW at the time of the studies shown. In the meantime, however, it has increased and could be more than 40 kW today. The actual number of recharging points required is therefore likely to be lower than shown in the figure above.

In order to determine the publicly installed charging capacity, this was calculated on the basis of the AFIR. In the IA, a ratio of 1 kW per BEV and 0.66 kW per PHEV was assumed. However, this value was increased by the co-legislator to 1.3 and 0.8 kW. Respectively, a corresponding calculation was added to take this current status into account. Likewise, in the figure above, an alternative assumption from ACEA[61] with a ratio of 3 kW per BEV and 2 kW per PHEV is also depicted.

[57] https://www.ACEA.auto/files/ACEA_Position_Paper-Alternative_Fuels_Infrastructure_Regulation.pdf
[58] https://www.transportenvironment.org/articles/charging-for-phase-out
[59] https://www.transportenvironment.org/articles/charging-for-phase-out
[60] whereby the values based on the AFIR will be slightly higher again under the new assumptions of 1.3 kW instead of 1.0 kW for BEVs and 0.85 kW instead of 0.66 kW for PHEVs.
[61] https://www.ACEA.auto/files/ACEA_Position_Paper-Alternative_Fuels_Infrastructure_Regulation.pdf

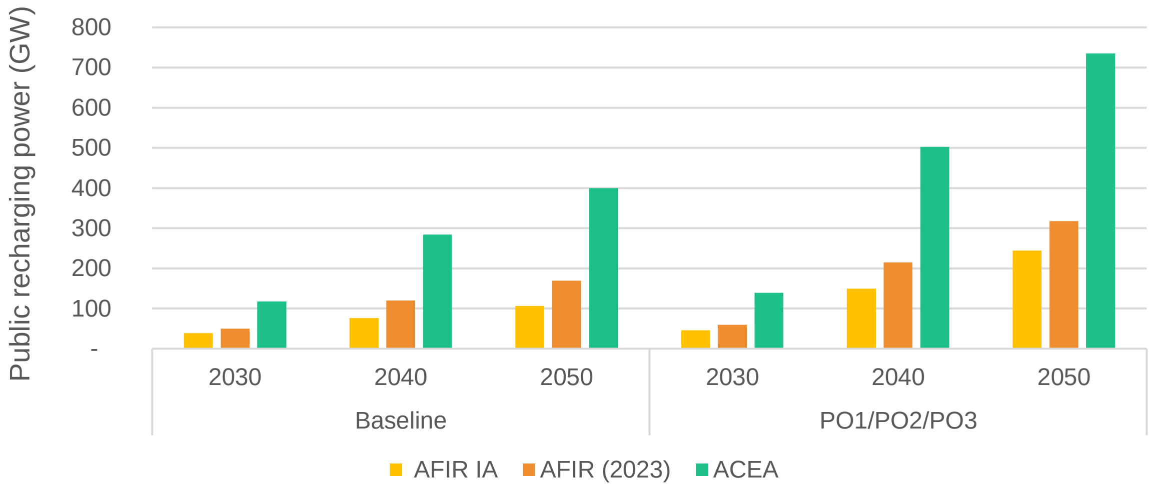

Figure 2-10: Estimated Installed public charging power under different assumptions

The following figure compares the stock and recharging points based on different policy options (POs[62]) analysed in the AFIR IA. These differ in this point only marginally in total. The biggest difference is in comparison to the baseline scenario, whose assumptions for the diffusion of EVs compared to the POs are not based on the MIX scenario[63] but on the more conservative REF[64] scenario, which assumes a lower number of EVs. Accordingly, fewer recharging points are needed. The diagram also shows that, based on the assumptions made there, the majority of recharging points result from demand from passenger cars and not from heavy-duty vehicles (HDVs).

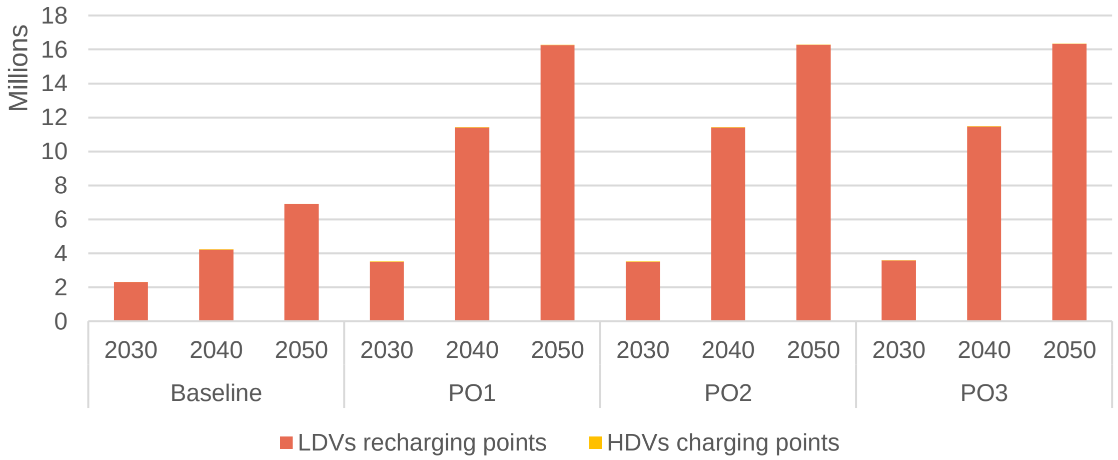

Figure 2-11: Estimated stock of recharging points based on AFIR IA[65]

For the purposes of Task 2, we will consider the ‘product life’ as ‘the expected lifetime of new products' which are placed on the market or put into service for the first time. These new products or recharging point sales can be either at a new location or a new replacement for an outdated recharging point. It is important to bear in mind, however, that this market

[62] For further details please see: https://op.europa.eu/en/publication-detail/-/publication/ef0b9a03-728e-11ec-9136-01aa75ed71a1/language-en

[63] https://energy.ec.europa.eu/data-and-analysis/energy-modelling/policy-scenarios-delivering-european-green-deal_en

[64] https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

[65] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0631

is still very young, and data is sometimes incomplete or unavailable (as could already be observed in the PRODCOM analysis). This also applies to data on sales of charging points. However, what is very well documented, at least in the public sector, and can also be determined for private charging points, is the data on stocks. As the market is still in its infancy, it is relatively easy to estimate sales on the basis of current stocks. Since historical data is still missing, the product lifetime is usually estimated at 10 years. By using this lifetime, the recharging point's sales can be calculated from the recharging points' stock. In line with the distribution of the stocks shown in Figure 2-11 the greatest difference is also evident here between the baseline and the PO scenarios, while the latter again show only minor deviations.

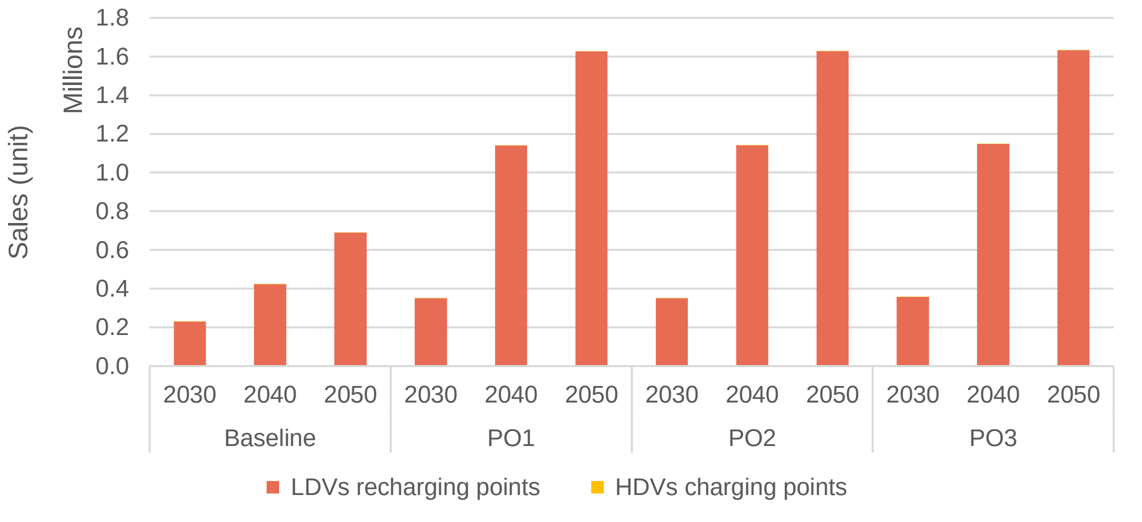

Figure 2-12: Estimated sales of recharging points (own calculation based on[66])

Stakeholder questions related to definitions and scoping:

19) What is a reasonable lifetime for mode 2, mode 3 and mode 4 recharging points?

20) Do you agree with the statement in the diagram that the pure number of public recharging points for HDV should be very low compared to those for LDV?

2.2.3 Private recharging points

The aforementioned data only referred to public recharging points, which have a smaller share of the total stock compared to residential recharging points with an estimated total of 5.7 million in 2023 and another 0.8 million recharging points at workplaces (see Figure 2-13). These numbers are, according to ChargeUp Europe, expected to increase to 27.5 million residential and 5.4 million workplace recharging points in 2030.

[66] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0631

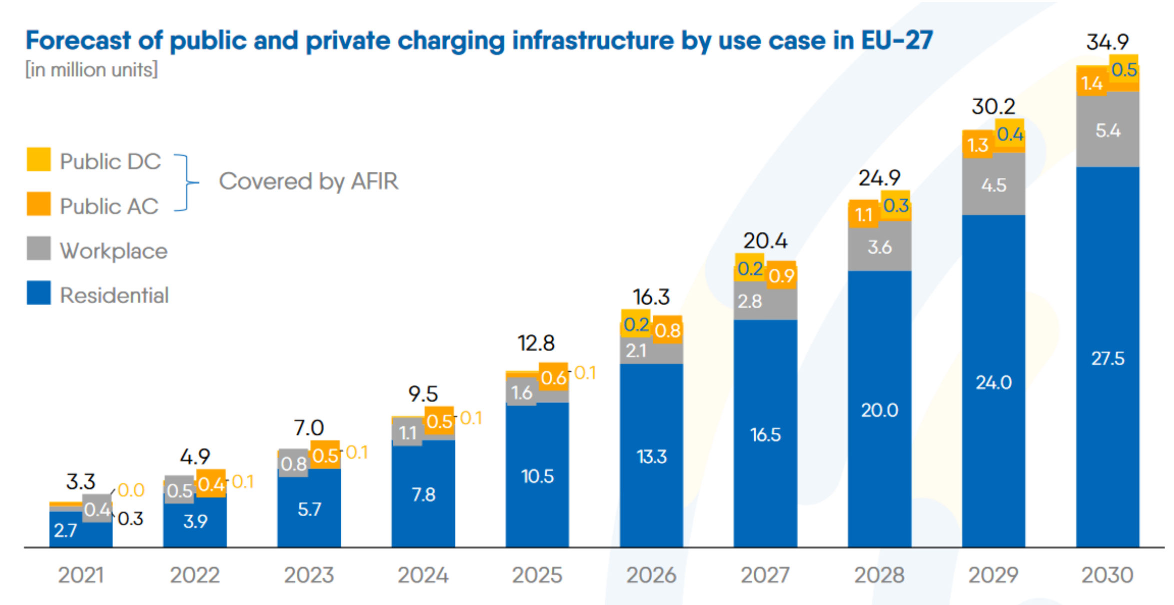

Figure 2-13: Developing of public and private charging infrastructure (source: ChargeUp Europe[67])

Private charging is usually used in single-family homes or multi-family homes and at workplaces and is therefore only available to a defined user group. Charging at home is usually the most convenient and cheapest option for EV users. A slow AC recharging point (up to 7 kW) is furthermore considered appropriate for home charging as the EV is parked at home for 8 or more hours. However, the main obstacle is the availability of a private parking space where the recharging point can be installed. For this reason, charging is also often done at the workplace (see also Task 3). The recharging points at these locations are usually slightly faster than residential charging (up to 22 kW)[68].

The ability to charge at home, therefore, depends heavily on the living situation, which can vary greatly from one EU country to another (see Figure 2-14). For instance, countries like Belgium, Bulgaria, Ireland, Spain, Poland, and Romania have a high percentage of multi-family homes in their residential housing inventory. On the other hand, nations such as Denmark, France, Latvia, Luxembourg, the Netherlands, and Slovenia have a lower percentage of these types of dwellings.

[67] https://www.chargeupeurope.eu/2023-state-of-the-industry
[68] https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

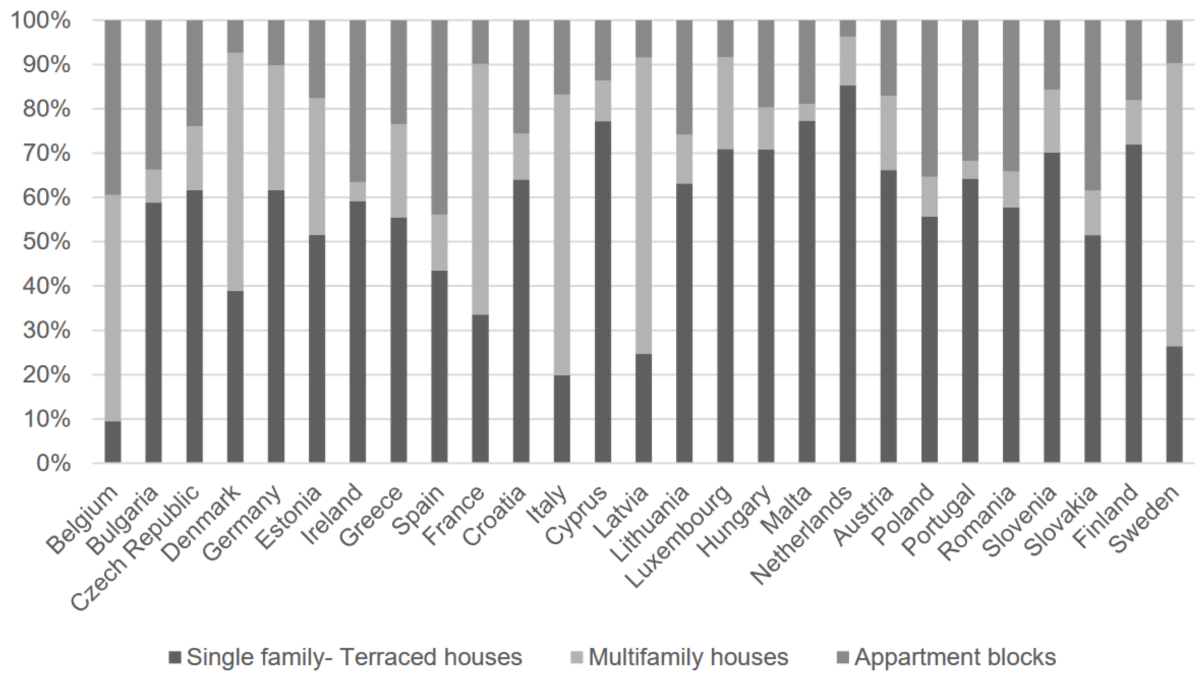

Figure 2-14: Share of different types of residential houses by country in Europe [69]

Since the total number of recharging points in buildings that fall within the scope of the EPBD is not known, and as Member States have no reporting obligations, the total number must be estimated. In order to determine the current number of charging stations for private households, the same method is used as in an accompanying study to the EBPD[70] and a fixed ratio per electric vehicle was assumed. Transport & Environment (2020) estimates that there is currently an average of 0.8 private recharging points per EV. Based on the total number of EVs (BEV+PHEV), the number of charging stations at private homes can be derived using the latest data from the European Alternative Fuels Observatory (EAFO). In 2023, 7.7 million EVs were stated there in Europe. Assuming that 80%[71] of EV owners have a recharging point at home, this means that there were an estimated total of 6.16 million recharging points in Europe in 2023.

To determine the number of recharging points at the workplace, a similar approach is used as in the accompanying study[72]. According to Transport & Environment[73], 60 % of all energy is charged at home and 15 % at work. Therefore, it can be assumed that there are four times more recharging points at home than at work. This results in an estimate of 1.54 million recharging points at the workplace, which are mostly private.

In order to also compute the estimated number of private recharging points for Vans (N1s), the data for 2023 from the EAFO is used. In 2023, there were around 314,000 N1s in Europe. As with cars (M1s), it is assumed that there will be around one private recharging station per N1. The IA for the EBPD assumes that around 51% of private charging will take place at work and 49% at home. In total, this means that there are around 160,000 recharging points for N1 at the workplace and 154,000 in private households. Across all private charging options considered, this leads to a total of just over 8 million recharging points in the private sector, as shown in Table 2-1.

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69 https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

70 https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

71 https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

72 https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

73 Transport & Environment, How many charge points will Europe and its Member States need in 2020s?

Table 2-1: Number of private recharging points for home charging and workplace in 2023

EV type	Location	Number of private recharging points (in million)
Cars	Home	6.16
Cars	Workplace	1.54
Vans	Home	0.15
Vans	Workplace	0.16
Total		8.01

The future stock of private recharging points was calculated, same as for the public recharging points, based on the two scenarios: the EU Reference Scenario and the EU MIX Scenario. According to these scenarios, the number of electric vehicles is expected to increase to between 44 and 51 million by 2030 and to between 151 and 250 million by 2050, depending on the scenario chosen. It is also assumed that the distribution of recharging locations will change over time and that the role of residential charging will steadily decline, which is likely to be around 50% by 2050. Accordingly, the role of workplace charging will increase significantly and public charging will also gain shares in the future (see Table 2-2.).

Table 2-2: Distribution of charging locations over time[74]

Location	2020	2025	2030	2050
Residential	76%	69%	61%	52%
Workplace (priv.)	19%	25%	32%	41%
Public	5%	6%	7%	8%

The number of electric vehicles projected from the EU scenarios allows, in combination with the charging location, to estimate the number of recharging points required (see Figure 2-15).

In 2021, the estimated total number of recharging points in buildings was 5.7 million, with 4.4 million in residential buildings and 1.3 million in non-residential buildings. By 2030, the total number of recharging points is expected to increase to between 46 and 54 million, with about 32 to 38 million in residential buildings and 14 to 16 million in non-residential buildings. By 2050, the projected number of recharging points is expected to rise to between 157 and 261 million, with between 99 and 163 million in residential buildings and between 58 and 98 million in non-residential buildings.

[74] 74 https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

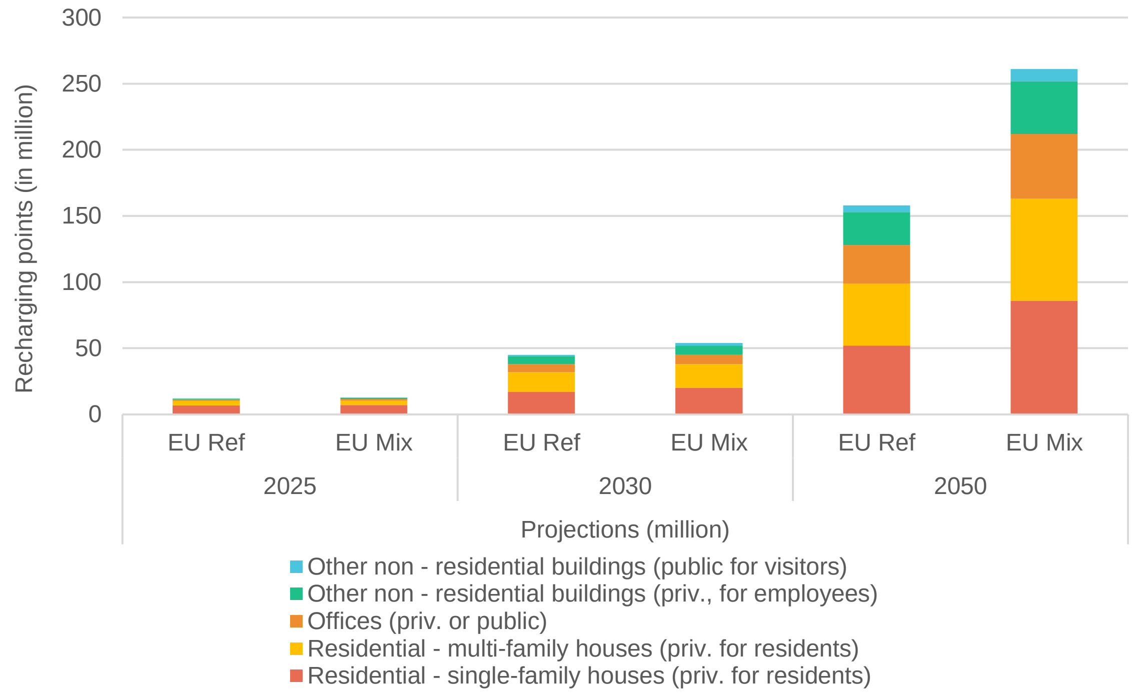


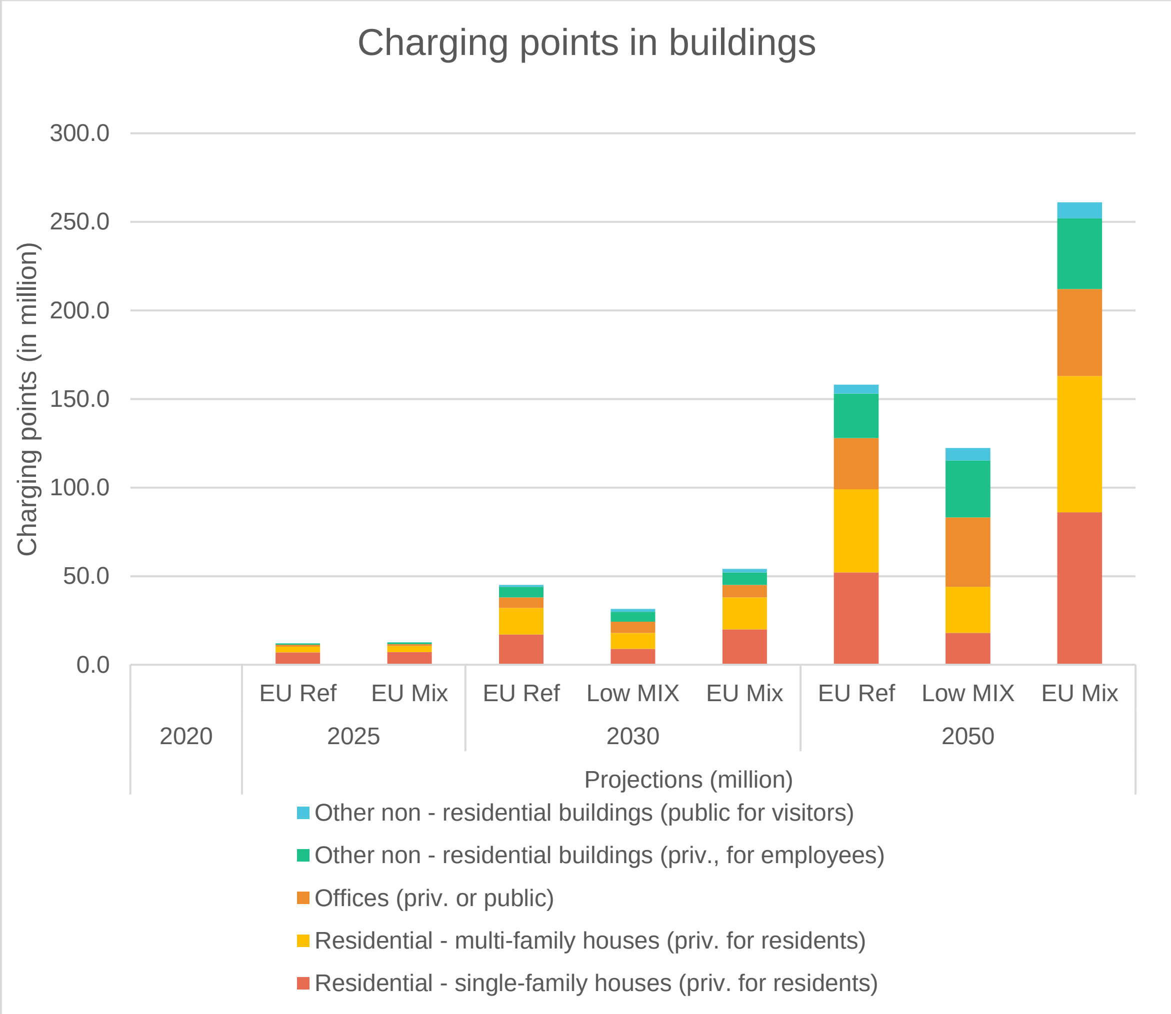
Figure 2-15: Estimated number of recharging points in buildings [75]

It should be pointed out again at this point that this is a calculation based on the building stock and that some of the buildings are both private and publicly accessible. The projected values for residential recharging points in 2030 are 32 and 38 million, which at least for this timescale aligns with the range specified by ChargeUp Europe in Figure 2-13.

However, the values from the previous figure appear to be very high, at least for 2050, and would indicate that there will be roughly one private recharging point for every electric vehicle. Due to the strong diffusion of EVs and the rather optimistic assumptions on the expansion of private recharging points, this scenario would rather represent a "high" scenario.

In order to analyse the effect of a less optimistic roll-out of private recharging points, a further scenario was introduced. The new scenario is also based on the EV diffusion of the MIX scenario (more realistic than REF from today's perspective). It is assumed that 10% of all single-family homes will be equipped with a private charging point in 2030 and 20% in 2050. Electric car owners will therefore rely more heavily on public charging stations and/or mode 2 charging. 25% of all MFHs will have their own private car parks and it is assumed that a charging station will be installed in every second MFH by 2030. In 2050, it is assumed that there will be 1.5 charging points per apartment block. These figures are slightly higher for apartment buildings (50 % and one charging point in 2030 and 50 % and two charging points in 2050). The number of charging points for non-residential buildings is therefore almost as high as in the mix scenario. The results of this alternative scenario is depicted in the following figure.

[75] https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en



315 *Figure 2-16: Estimated number of recharging points in buildings including a low mix* [76]

The following Figure 2-17 shows the sales derived from the stock. This is again divided into three scenarios, REF and MIX high and MIX low, which assume a different ramp-up of EVs.

[76] https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

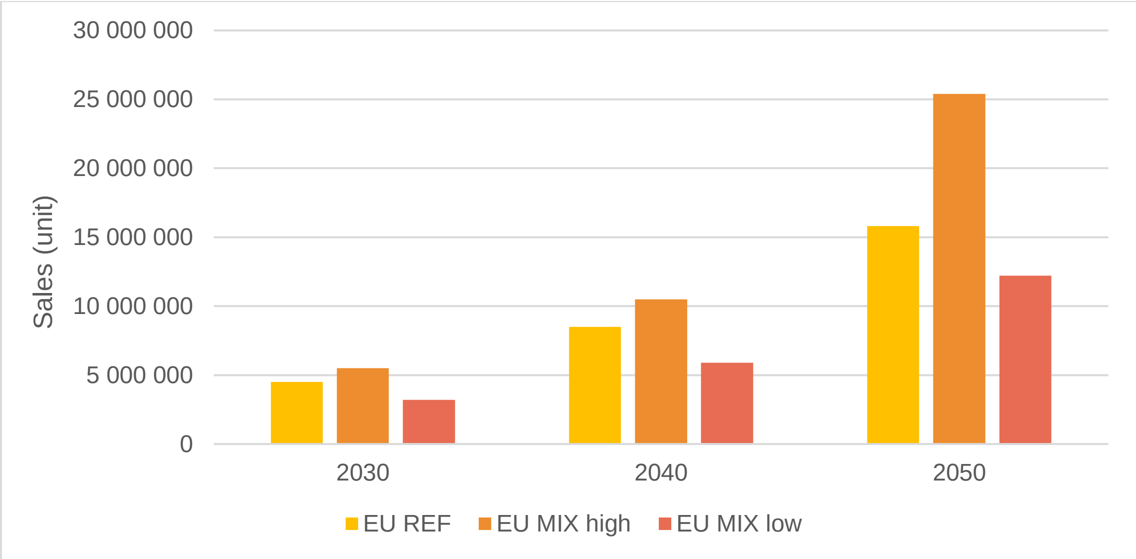


Figure 2-17: Estimated sales of private recharging points (own calculation based on[77])

Stakeholder questions related to definitions and scoping:

21) Do you consider the number of recharging points shown in 2-15 also as too high with a ratio of 1:1?

22) Are the assumptions made for the EU mix low scenario reasonable out of your perspective?

2.2.4 Total stock

After the data for public and private recharging points was identified in the previous chapters 2.2.2 and 2.2.3 the expected future stock will be derived in this chapter, differentiated according to Mode 2, Mode 3 and Mode 4 recharging points.

In order to make a statement about the individual modes based on the demand for recharging points in the private sector, assumptions must first be made about in which type of building and at what time such recharging points are likely to be found. The assumptions shown in Table 2-3 below were made for this purpose. While individual assumptions on the role of recharging point types in certain building types can still be found for the year 2030[78], no sources can be found for the following decades. Correspondingly, individual assumptions were made. Due to the available charging time, it is assumed that Mode 3 charging will be sufficient for residential buildings and large parts of offices in the future. Nevertheless, there are probably also users, especially in the latter, who only have a short time available and for whom Mode 4 recharging points will be provided. This is likely to play an even greater role for users of destination recharging points, so Mode 4 recharging points are likely to be predominantly found there in the future.

[77] https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

[78] https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en https://www.acea.auto/files/Research-Whitepaper-A-European-EV-Charging-Infrastructure-Masterplan.pdf

Table 2-3: Assumptions on the predominant use of recharging points in different building types

Building type	2020	2025		2030			2050		
		EU Ref	EU Mix	EU Ref	Mix Low	Mix high	EU Ref	Mix Low	Mix high
Residential - single-family houses (priv. for residents)	AC	AC	AC	AC	AC	AC	AC	AC	AC
Residential - multi-family houses (priv. for residents)	AC	AC	AC	AC	AC	AC	AC	AC	AC
Offices (priv. or public)	AC	AC	AC	AC	AC	AC	AC	25% DC	50% DC
Other non - residential buildings (priv., for employees)	AC	AC	AC	AC	AC	AC	AC	25% DC	50% DC
Other non - residential buildings (public for visitors)	AC	AC	AC	AC	AC	AC	10% DC	25% DC	DC

Using the assumptions made and in conjunction with the data in Figure 2-15, the stock of Mode 3 and Mode 4 recharging points can be estimated. The results are shown in the following Table 2-4.

Table 2-4: Estimated stock of Mode 3 and Mode 4 recharging points resulting from private use

	Projections (million)							
	2025		2030			2050		
	EU Ref	EU Mix	EU Ref	Mix low	Mix high	EU Ref	Mix low	Mix high
Mode 3	12.2	12.8	45.0	31.5	54.0	157.5	102.8	207.5
Mode 4	0.0	0.0	0.0	0.0	0.0	0.5	19.6	53.5

For the estimation of the public chargers, assumptions also had to be made as to how the recharging points determined are likely to be distributed among the individual modes in the future. In this case, too, a distinction was made between the REF and MIX scenarios. Assumptions for the future distribution of recharging points between Mode 3 and Mode 4 can be found in literature (e.g.[79]). However, reliable assumptions that go beyond 2030 were not available, which is why an estimate was also made here. In the scenarios, an increase in Mode 4 recharging points can be expected, although this development is likely to be faster in the Mix scenario due to the greater demand on the one hand and cost reductions probably resulting from economies of scale on the other. In the case of the MIX low scenario, the assumptions regarding the expansion of Mode 4 chargers are slightly more optimistic than in the case of the Mix high scenario.

[79] https://www.acea.auto/files/Research-Whitepaper-A-European-EV-Charging-Infrastructure-Masterplan.pdf

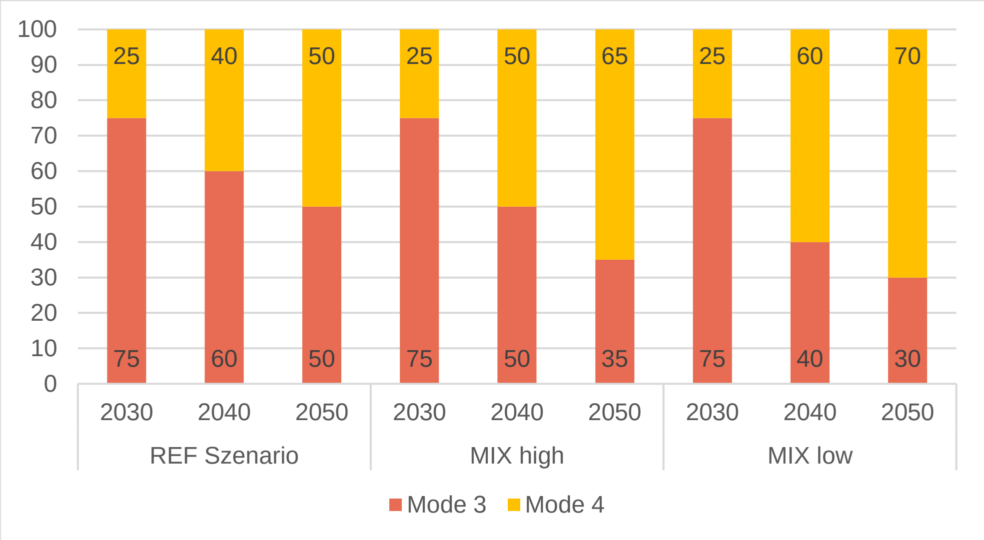


Figure 2-18: Estimated share of modes for public recharging points

Mode 2 recharging points have not yet been considered[80]. So far, these have been supplied as standard with every electric car. Their stock and sales are, therefore, proportional to the number of EVs in the respective scenarios. Mode 2 recharging points have not yet been taken into account. Up to now, these have usually been supplied with every electric car. For the Mix high scenario, it is assumed that this will also be the case in the future and that the Mode 2 cable could take on a similar role to the spare tyre for "emergency charging". Their stock and sales are therefore proportional to the number of electric cars in the respective scenarios.

For the Mix Low scenario, on the other hand, it is assumed that not every car will be supplied with a Mode 2 charger. In addition, those who own a Mode 3 charger will not buy an additional Mode 2 charger. Of the remaining electric car owners, 1/3 will buy a Mode 2 in 2030 and ¼ in 2050, while the rest of EV owners will limit themselves to public charging.

Using the data from Figure 2-11 and the distribution assumed in Figure 2-18, the stock and public recharging point can thus be determined. This is shown in the following Table.

Table 2-5: Estimated stock of Mode 2, Mode 3 and Mode 4 recharging points resulting from public use

	REF			MIX low			MIX high		
Mode	2030	2040	2050	2030	2040	2050	2030	2040	2050
2	44	110	150	14	42	58	51	180	250
3	1.7	2.5	3.5	2.6	4.6	4.9	2.6	5.7	5.7
4	0.6	1.7	3.5	0.9	6.9	11.4	0.9	5.7	10.6

The total stock shown in Figure 2-19 is the sum of the recharging points from the public and private areas, again differentiated according to the two scenarios.

[80] Mode 2 recharging points might be more fitting to private chargers, but due to their direct association with EVs, they are considered here.

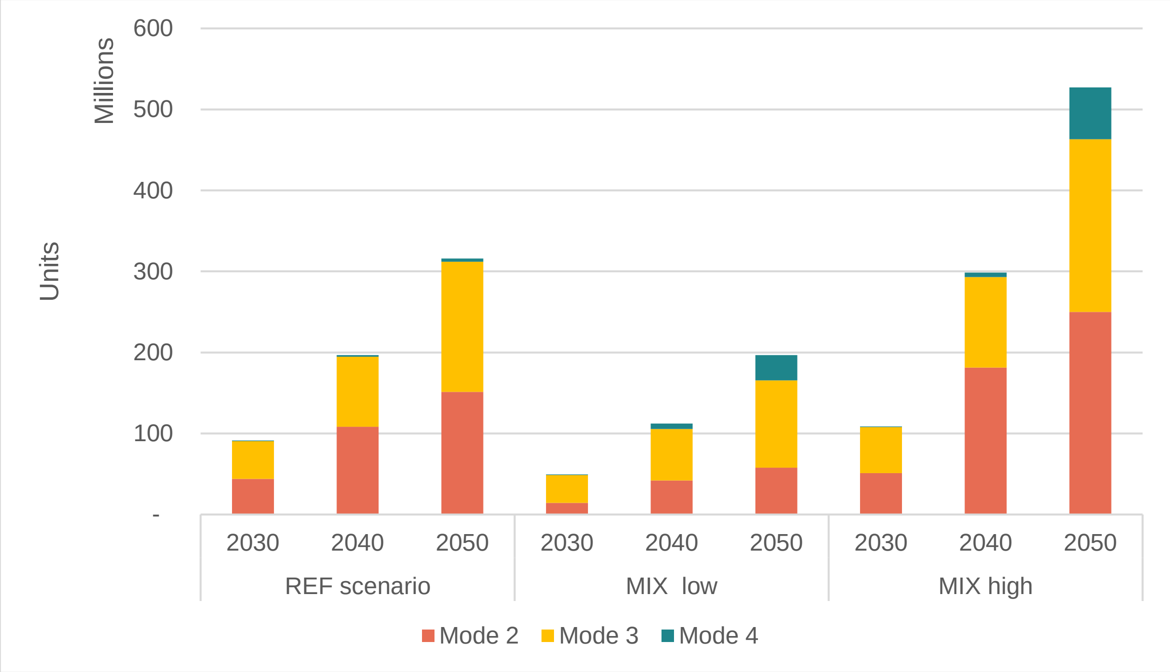


Figure 2-19: Estimated total stock of different recharging points

Figure 2-19 illustrates the effect associated with the ramp-up of EVs by comparing the scenarios. In addition, the future need for Mode 2 recharging points becomes clear, provided they continue to be delivered with every EV. These sometimes make up around half of the stock. In second place are the Mode 3 recharging points, which are also likely to account for a large proportion of future demand. Mode 4 recharging points appear to be relatively small compared to the other two modes, but their estimated demand in the Mix high scenario in 2050 is over 60 million units. It is also striking that the proportion of recharging points from the private area is significantly higher than that from the public area.

Stakeholder questions related to definitions and scoping:

23) Do you agree with the assumptions on the predominant use of recharging points in different building types (table 2-3) and the assumed estimated share of modes for public recharging points (figure 2-18)?

24) Are the assumptions made for the future role of mode 2 chargers in line with your expectations?

2.2.5 Non-road recharging points markets

2.2.5.1 Sea transport

In addition to road-based recharging points, the AFIR also covers charging options for aircraft on the ground and for ships using shore power. Both cases are explicitly related to the TEN-T network and limited to those harbours or airports that have a sufficiently high frequency of use. The need to cover these requirements was also determined as part of the IA for the AFIR.

With regard to the onshore power supply (OPS) in ports. Depending on any expansion and the scenario, the resulting energy demand in 2030 can be estimated at 1,000 to 4,000 MWh.

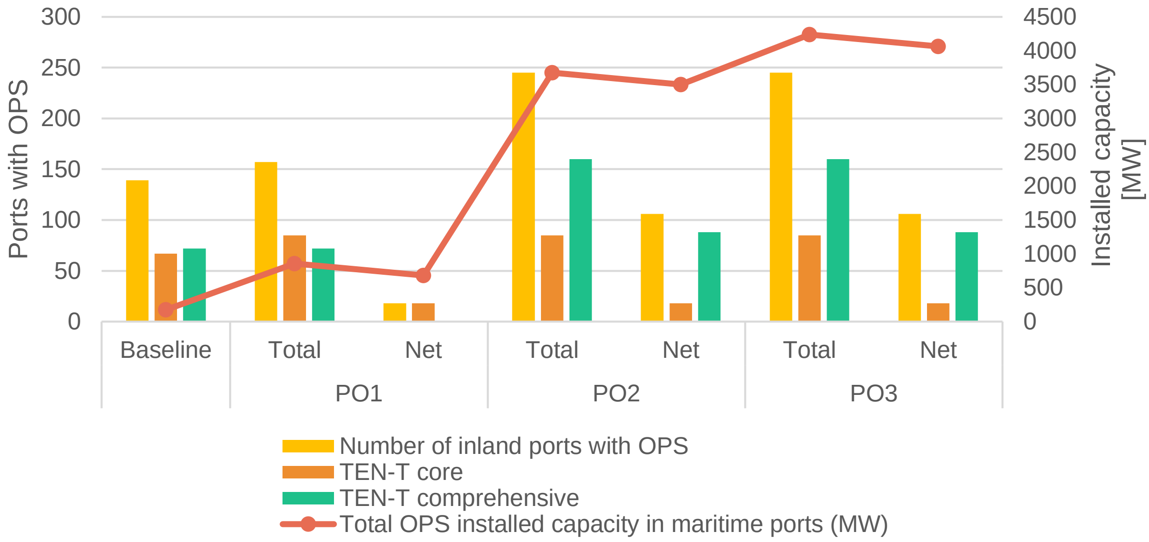


Figure 2-20: Expected OPS deployment in 2030 in maritime ports[81]

2.2.5.2 Air transport

As regards the electricity supply at airports, it can be deduced that between 4,000 and 5,000 recharging points will need to be installed at passenger gates and between 6,000 and 10,000 recharging points at the outfield positions in 2030.

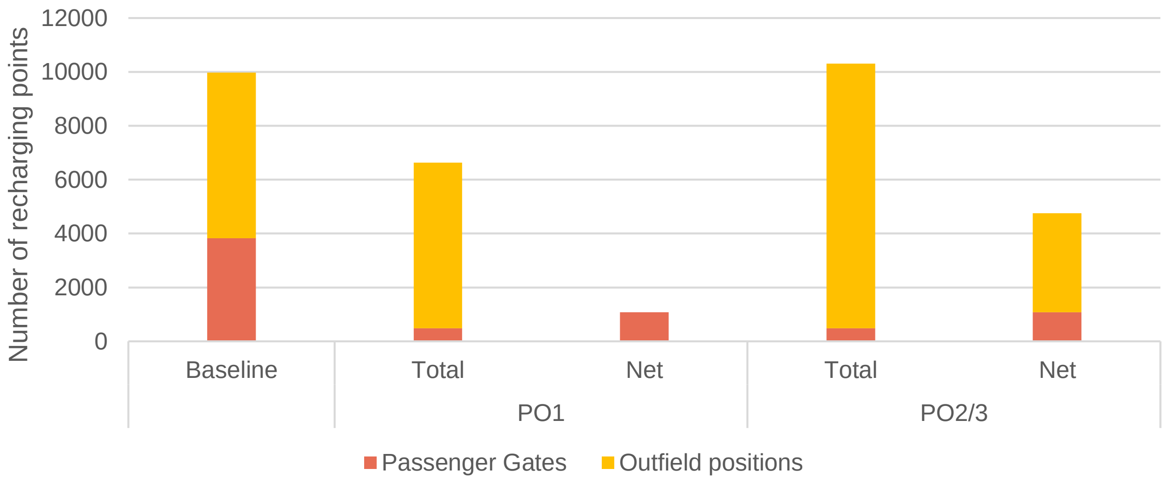


Figure 2-21: Expected recharging points deployed at airports[82]

2.2.6 Green Public Procurement (GPP)

In the EU, public purchasing represents 15% of its GDP[83]. The leverage provided by Green Public Procurement (GPP) would be correspondingly large. In line with the proposal in the SPI Task 8 "Report on the Outline of the Methodology", this effect of public procurement is

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[81] https://op.europa.eu/en/publication-detail/-/publication/ef0b9a03-728e-11ec-9136-01aa75ed71a1/language-en

[82] https://op.europa.eu/en/publication-detail/-/publication/ef0b9a03-728e-11ec-9136-01aa75ed71a1/language-en

[83] https://www.sei.org/wp-content/uploads/2023/02/green-public-procurement-eu.pdf

also estimated here. The data in Figure 2-15 is used to roughly estimate this effect. As the public procurement is only applicable to public buildings, residential buildings are not included. For the proportion of recharging points procured for offices, it is assumed that the public sector's share of offices is approx. 27.5%[84]. For other non-residential buildings (private), the share is likely to be lower and is estimated at 5% (e.g. for equipping road maintenance depots). In contrast, the share of other non-residential buildings (public) is likely to be significantly higher and is estimated at 75%. In total, this results in the following estimated demand from the public sector for the private sector.

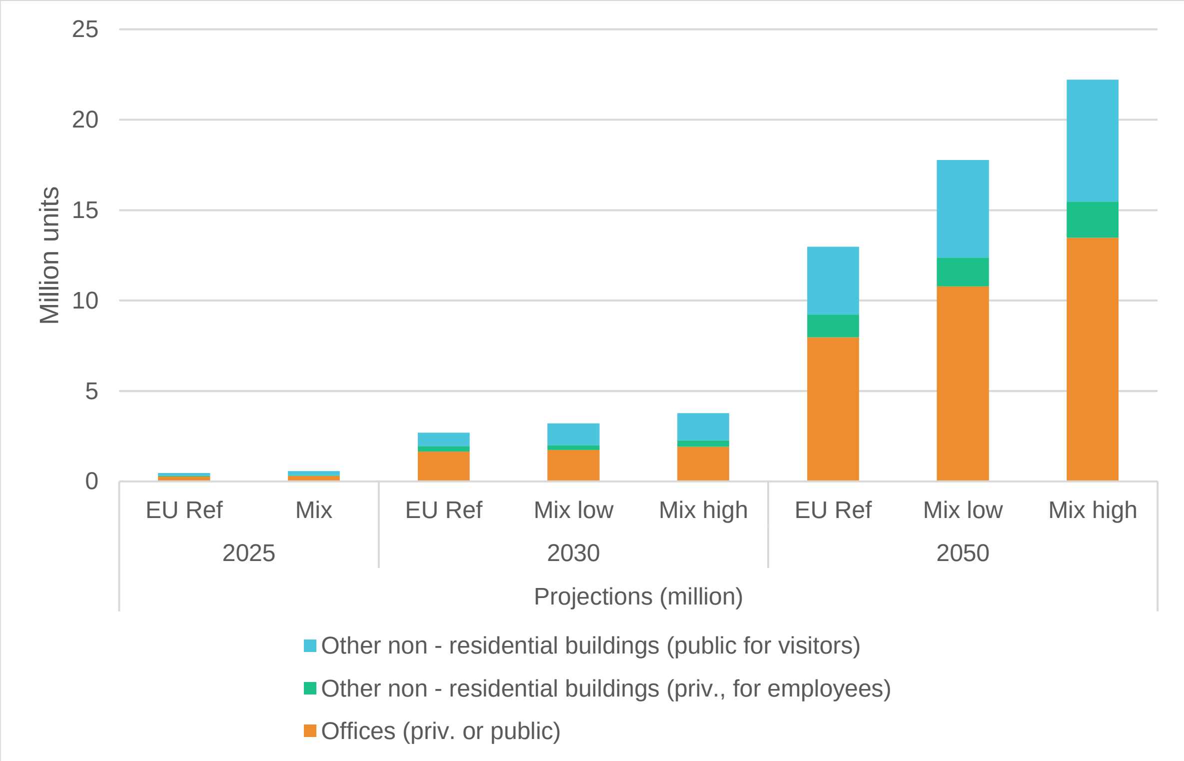

Figure 2-22: Estimated public procurement for recharging points (own calculation based on [85])

Based on the assumptions made, public procurement could be responsible for 20 to 25% of the recharging points for the building types mentioned or for 5-9% of all building types. This emphasises that GPP could have a major influence on procurement in these product groups.

2.3 Market trends

2.3.1 General objective of subtask 2.3 and approach

The purpose of this task is to identify market trends such as:

- general market trends (growth/ decline, if applicable per segment), trends in product-design and product-features;
- market channels and production structure; identification of the major players (associations, large companies, share SMEs, employment);

[84] Estimated number based on assumptions for Germany https://www.aire-mag.com/sites/default/files/2021-03/Digitalisierung%20der%20%C3%96ffentlichen%20Hand%20%E2%80%93%20Droht%20uns%20ein%20Nachfrageeinbruch.pdf

[85] https://op.europa.eu/et/publication-detail/-/publication/329402d1-79d1-11ed-9887-01aa75ed71a1/language-en

- trends in product design/ features, illustrated by recent consumer association tests (valuable, but not necessarily fully representative of the diversity of products put on the market).

2.3.2 General market trends

As the market is a comparatively new one, it is constantly changing and new trends are emerging. Nevertheless, important trends can be observed with regard to the general market. Also, knowing that there are many other trends in EV charging, such as Automatic Connection Devices, battery swapping or charging via catenary wire, we will focus in this proposal on the following six important trends: Steadily increasing charging power, Mega Watt Charging Systems for trucks, smart charging & (Aggregated bidirectional charging) V2G, wireless charging, PV-AC charging as well as Plug and Charge.

2.3.2.1 Steadily increasing DC charging power

In particular, when looking at the growth of DC recharging points, it is clear that there is a trend towards installing fast recharging points with a higher kW capacity to reduce the charging time.

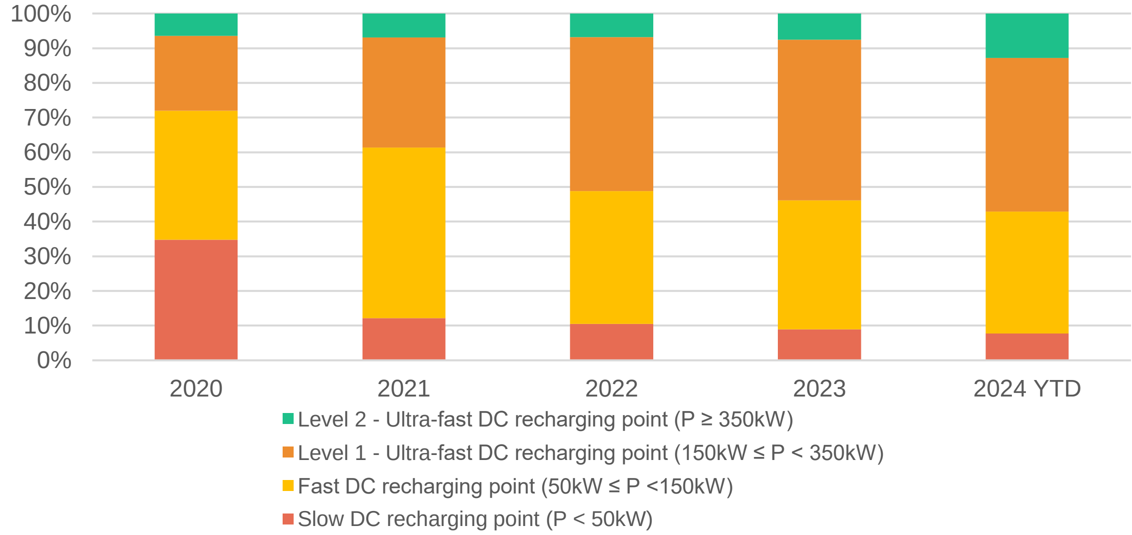

Figure 2-23: Share of DC recharging points (source: EAFO[86])

Figure 2-23 indicates this steady growth of power for newly installed public DC recharging points. However, this trend is not surprising and might further continue; one must look at it from a systemic perspective: An increasing DC charging power means that also the battery of the EV must be capable of charging at this rate and up to now, only a few EVs are equipped with an 800V or 900V onboard power supply. Furthermore, restrictions on the side of the grid to deliver the required power also have to be considered.

[86] https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/infrastructure

2.3.2.2 Megawatt charging for trucks

Driving and rest periods for truck and bus drivers are defined in Regulation (EC) No. 561/2006[87]. Especially in long-haul traffic, the maximum allowed driving time of 4.5 hours is frequently fully used. Vehicles must then be recharged within the mandatory break of 45 minutes. This requires charging power that is not covered by today's Combined Charging System (CCS) standard. Therefore, the Megawatt Charging System (MCS), which has up to 3.75 MW, is currently under development[88]. According to ACEA a major part of public truck recharging points in 2030 are supposed to be megawatt-charging systems. They assume that a total number of 35,000 MCS chargers would be needed to match their requirements[89]. Other calculations result in a demand of significantly less than 10,000 MCS recharging points in 2030[90].

According to the AFIR, by 2030 a total of around 2,800 charging points with a total charging capacity of at least 7.5 GW should be set up across Europe along the almost 110,000 kilometres of the TEN-T corridors.

	Network - km		Truck charge locations			Charge power in MW		
	Core	Comp.	2025	2027	2030	2025	2027	2030
Österreich	1.097	730	6	17	52	10,9	62	156
Belgien	805	1.038	6	18	48	10,1	53	129
Bulgarien	1.508	1.340	8	27	78	16,4	90	224
Kroatien	1.153	780	6	18	55	11,6	66	164
Zypern	157	336	2	5	13	2,7	13	32
Czech Rep.	1.015	1.134	6	20	57	12,0	64	157
Dänemark	813	849	5	16	45	9,5	51	126
Deutschland	6.369	5.027	32	104	314	65,9	369	918
Estonia	375	975	4	14	33	6,9	32	77
Finnland	1.040	4.572	17	55	127	26,7	113	264
Frankreich	5.555	8.960	41	137	366	76,9	386	940
Griechenland	1.760	3.079	14	46	121	25,4	126	305
Ungarn	1.102	1.607	8	26	70	14,7	75	183
Irland	504	1.715	7	22	52	10,9	48	114
Italien	4.319	6.416	31	101	273	57,3	292	712
Lettland	719	1.012	5	17	45	9,5	48	118
Litauen	609	1.450	6	20	50	10,5	50	119
Luxemburg	70	20	1	2	4	0,8	5	12
Malta	16	111	1	2	4	0,8	4	8
Niederlande	670	1.417	7	21	52	10,9	53	126
Polen	3.700	4.398	23	75	212	44,5	235	578
Portugal	946	2.015	9	29	73	15,3	74	177
Rumänien	2.575	2.268	14	45	132	27,7	153	379
Slowakei	834	747	5	15	43	9,0	50	123
Slowenien	446	157	2	6	19	4,0	24	60
Spanien	5.774	6.365	34	113	321	67,4	360	887
Schweden	3.010	3.435	18	60	170	35,7	190	467
EU-27	**46.939**	**61.958**	**304**	**1.012**	**2.805**	**589**	**3.059**	**7.494**

Figure 2-24: AFIR requirements for public truck charging infrastructure by country[91]

[87] https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=celex%3A32006R0561

[88] https://www.charin.global/technology/mcs

[89] https://www.ACEA.auto/news/afir-eu-negotiators-must-urgently-set-ambitious-charging-and-refuelling-infrastructure-targets/

[90] https://www.mdpi.com/2032-6653/13/9/162

[91] https://hochleistungsladen-lkw.de/hola-wAssets/docs/publikationen/HoLa_LessonsLearnt.pdf

It is estimated that an initial public fast-charging network with at least 1,000 MCS charging points should be established by 2030. With rapid market penetration of trucks in long-distance transport and longer idle times of 45 minutes, 2,000 MCS charging points are more likely to be needed by 2030[92].

Figure 2-25 shows an exemplary charging network for Europe. However, the demand for MCS recharging points depends on various parameters, such as whether additional CCS infrastructure is available that is used for public overnight charging.

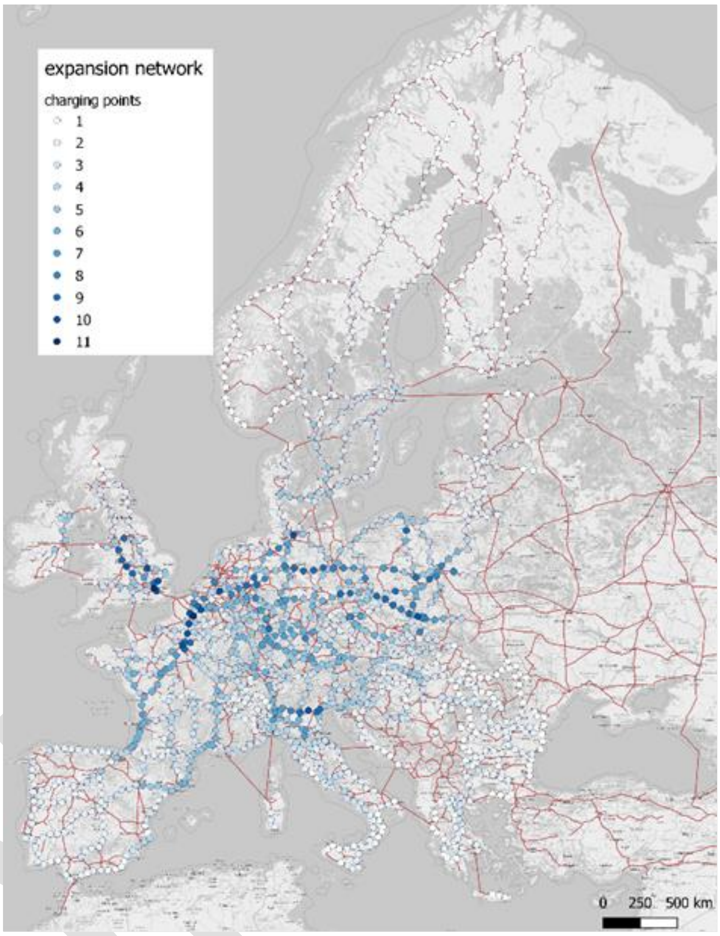

Figure 2-25: Exemplary megawatt charging network with almost 5,000 recharging points for trucks, 2030. (source: WEVJ[93])

Megawatt charging can also be used for ships and aircraft in the future. Due to the limited potential for electrification, comparatively small numbers of recharging points are assumed, and no explicit modelling will be carried out.

2.3.2.3 Smart recharging and V2G

'Smart recharging' means, according to the AFIR, a recharging operation in which the intensity of electricity delivered to the battery is adjusted in real-time, based on information received through electronic communication, taking into account the electricity price, power outage and/or carbon intensity. However, depending on the degree of grid integration, four levels can be defined from V1G (Controlled charging) to V2G (Aggregated bidirectional charging). The more the recharging point interacts with the grid and the more intelligently controlled it is, the more technical requirements, such as ISO 15118-20:2022, have to be

[92] https://hochleistungsladen-lkw.de/hola-wAssets/docs/publikationen/HoLa_LessonsLearnt.pdf
[93] https://www.mdpi.com/2032-6653/13/9/162

fulfilled.[94] Besides technical components, the communication and interoperability between hardware and software plays an essential role. The Open Charge Point Protocol (OCPP) is a communication standard that enables interoperability between the mostly public EV recharging station and the central back-end management system. The following Figure 2-26 provides an overview of the different levels of grid integration.

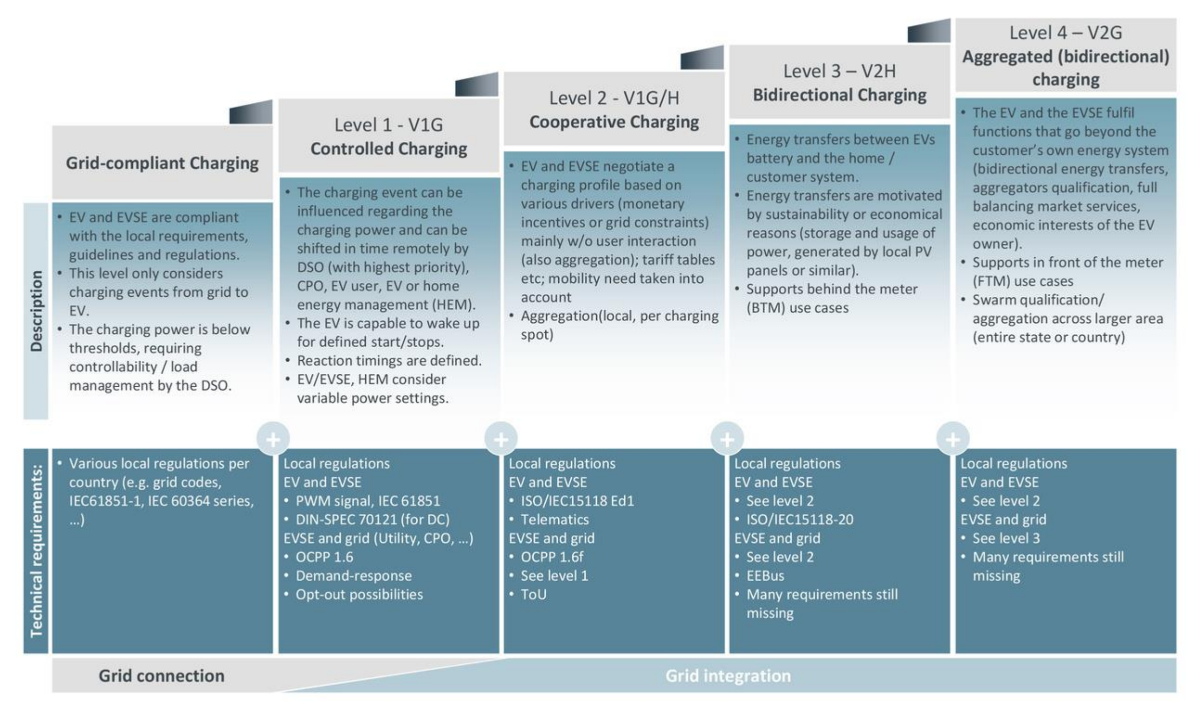

Figure 2-26: Grid Integration Levels (source: CharIn[95])

The future number of recharging points that will be V2G-ready in the future is therefore, also directly related to the sale of Vehicle-to-Everything (V2X)-ready electric vehicles. Individual market studies assume that sales of such vehicles will increase by 70% between 2025 and 2030 and should then reach almost 4 million EVs, as shown in Figure 2-27.

[94] https://www.charin.global/technology/v2g/
[95] https://www.charin.global/technology/v2g/

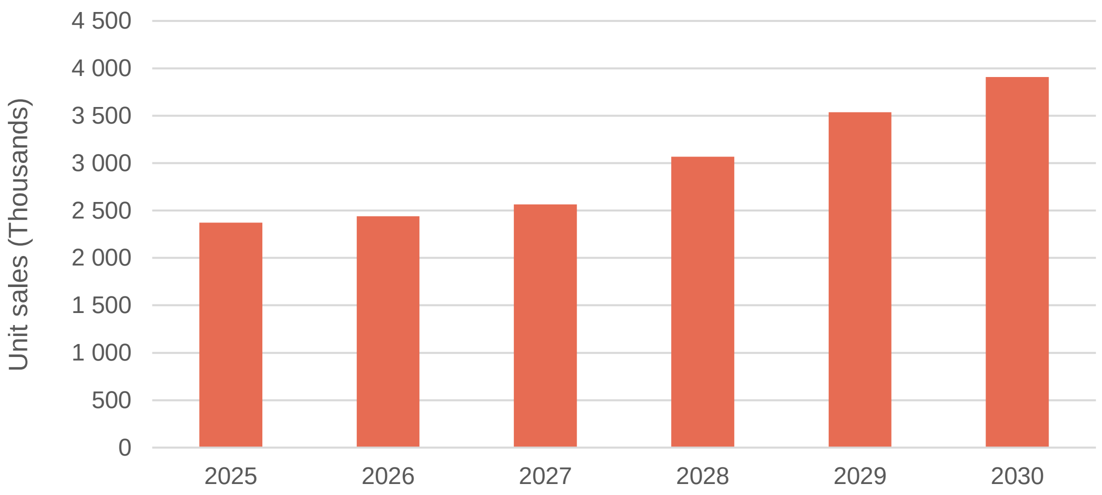

Figure 2-27: Sales of vehicles with V2X capability in EU[96]

2.3.2.4 Wireless charging

Wireless Electric Vehicle charging enables the charging of electric cars without the use of direct cable connections to the vehicle's system. This method of charging does not require a connector. Unlike other standard recharging points, they do not feature a plug. The fundamental concept behind both electric car charging and wireless charger systems is similar to that of a transformer. Wireless charging offers two offers 2 types of charging: dynamic charging while the vehicle is in motion (e.g. on the highway) and static charging when the vehicle is stationary (as in a garage or parking lot). The wireless charging can thereby happen by different technologies: Inductive Power Transfer is the most used technology for wireless charging, while Resonant Inductive Power Transfer is an advanced technology of it, or Permanent Magnet Gears can be used[97].

The costs for these charging opportunities are named by a producer of these products to cost “automakers several hundred dollars per car, and consumers at least $2,500 to start — both figures he sees falling over the next five years”[98].

However, wireless charging is not yet on the market, and the assumed uptake depicted in Figure 2-28 first has to be proved by time.

[96] Frost & Sullivan (2023). V2X Growth Opportunities in North America and Europe’s Passenger Vehicle Markets

[97] Frost & Sullivan. (2022, August 10). Global Wireless EV Charging Growth Opportunities.

[98] https://www.bloomberg.com/news/articles/2024-02-20/wireless-charging-for-electric-cars-is-inching-closer-to-reality

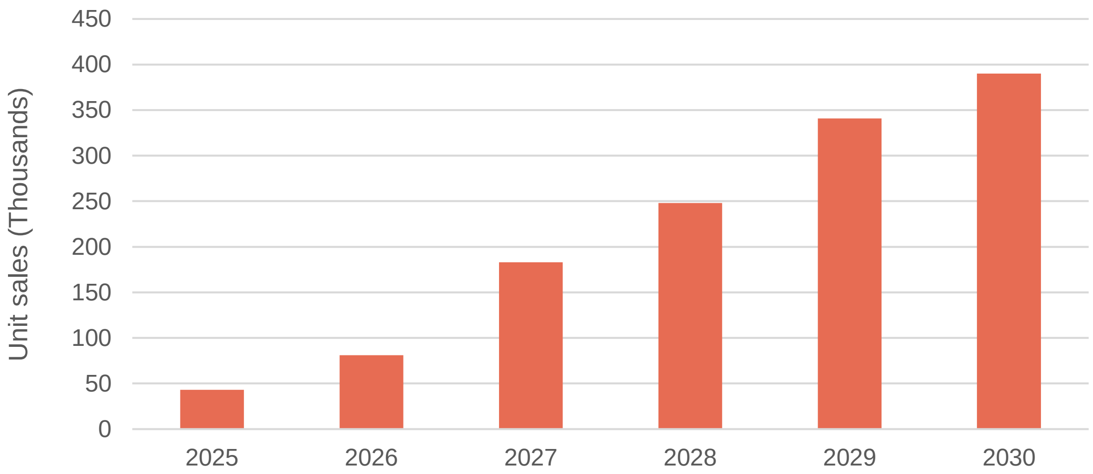

Figure 2-28: Sales of wireless recharging points in the EU[99]

2.3.2.5 Plug and Charge

Plug and Charge (P&C) allows an EV to be simply connected to a public recharging station and the charging process to start automatically without any further authentication steps. Therefore, the charging process starts automatically as soon as the vehicle is connected to the recharging station. Plug and Charge is also based on the ISO 15118. According to a survey from CUE, already 25% of the interviewed CPOs have already started with the implementation of P&C while 67% plans to start within the next 3 years[100]. So, Plug and Charge is already becoming reality. However, it still needs tight communication between the EV (OEM), MSP and CPO; unfortunately, not all have agreed on a common P&C standard yet. Currently some CPOs use a simplified solutions that identify the vehicles only based on the MAC-address of the vehicle (Autocharge), which could raises issues concerning the IT security and data privacy.

2.3.2.6 PV AC- Recharging points

A PV AC-Recharging point can utilise electricity from the photovoltaic system that is not currently needed in the house (PV surplus) to charge the battery of the electric car directly. An energy management system (EMS) is required to recognise and allocate the solar power. Some AC recharging points have the energy manager fully or partially integrated, others use the existing system of the solar installation in the house. Still other AC recharging points need to be retrofitted with additional electronics. The energy management system recognises the surplus at the home's power connection and controls the AC recharging points accordingly. This is a particular challenge on days with changeable weather or when electricity consumption in the house fluctuates greatly. This is because switching the charging process on and off too frequently is interpreted by some electric cars as a "fault" and the charging process is cancelled. The PV-AC-Recharging points enable automatic switching to one or three phases. The minimum charging current for electric cars is usually 6 A, which corresponds to an output of 1.4 kilowatts. With three phases, this corresponds to 4.2 kW. Without this phase switching of the AC recharging points, the electric car would only charge when the PV surplus delivers an impressive 4.2 kW. This value is often not

[99] Frost & Sullivan. (2022, August 10). Global Wireless EV Charging Growth Opportunities. https://store.frost.com/wip/PCFA-01-00-00-00
[100] https://www.chargeupeurope.eu/state-of-the-industry-report

reached on cloudy days. For single-phase charging, on the other hand, it is sufficient if the solar system supplies 1.4 kW.[101]

Stakeholder questions related to definitions and scoping:

25) Have any megatrends not been addressed?

2.3.3 Market channels and production structure; identification of the major players

2.3.3.1 Public recharging points

This involvement of many different actors from different industries which are all interconnected, imposes a general challenge for the EV charging ecosystem. The EV charging ecosystem consists of many different players, all of which are interconnected. The grid operator supplies electricity to the Charge Point Operator (CPO). The Mobility Service Provider (MSP) has contracts with one or more CPOs. The end customer, in turn, can either charge directly at a CPO (ad hoc charging or he has a contract with the MSP and can thus charge at the affiliated CPO's charging network or at another network via roaming. However, Figure 2-29 shows the close relationship and interconnectedness between all actors, especially with regard to data communication.

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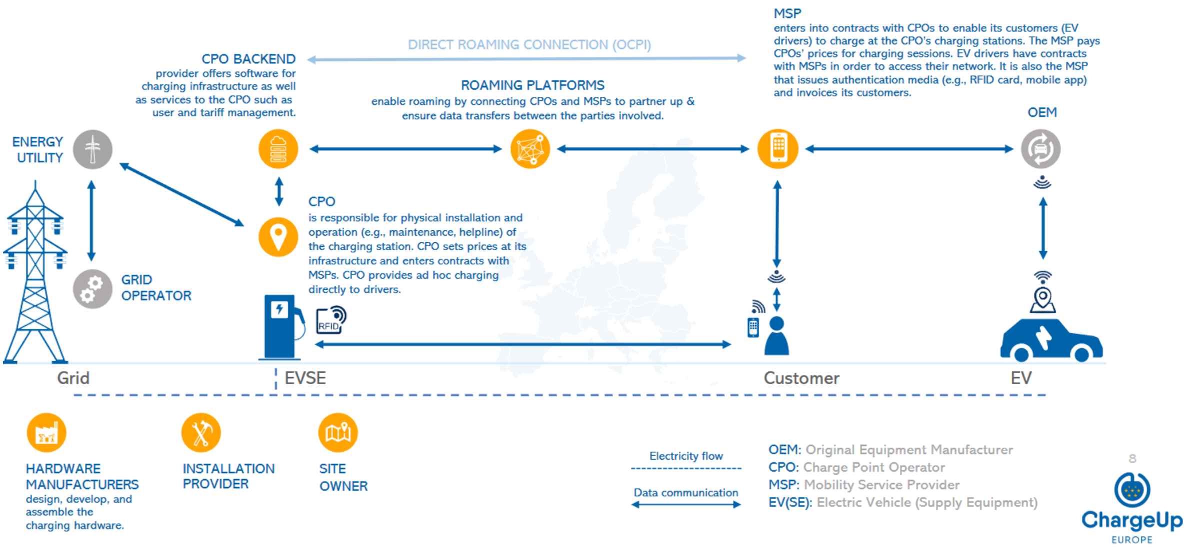

Figure 2-29: Actors within the EV recharging ecosystem (source: ChargeUp Europe[102])

In the case of private recharging points, the mode 3 recharging station is often bought in combination with an EV. Thus, the recommendation of the car dealer or the OEM plays a crucial role during the decision process. However, for the public EV recharging points the picture is a bit different. The CPO and his strategy often determines the layout of a recharging station. Thereby it has to be considered that the CPO may also come from different business areas: Dedicated CPOs (e.g. Ionity, Allego,..), energy providers (e.g. Enel X or EnBW..), oil and gas providers (e.g. Total Energies, Aral Pulse,..) or even OEMs (e.g.

[101] https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/laden/wallbox-photovoltaik-anlagen-test/

[102] https://www.chargeupeurope.eu/state-of-the-industry-report

Tesla, Daimler,..). However, the choice of EV recharging points is also depending on the available grid power and thus Distribution System Operators and Transmission System Operators have to be involved. Finally, if the recharging station shall allow roaming or Plug and Charge the MSP has to be involved and the EV recharging points have to be equipped with the appropriate components.

When looking at the operators of recharging stations only in terms of their overall installed charging capacity, as indicated in Figure 2-30 (left side), Tesla seems to dominate. However, the picture becomes relative when looking at the total number of installed recharging points.

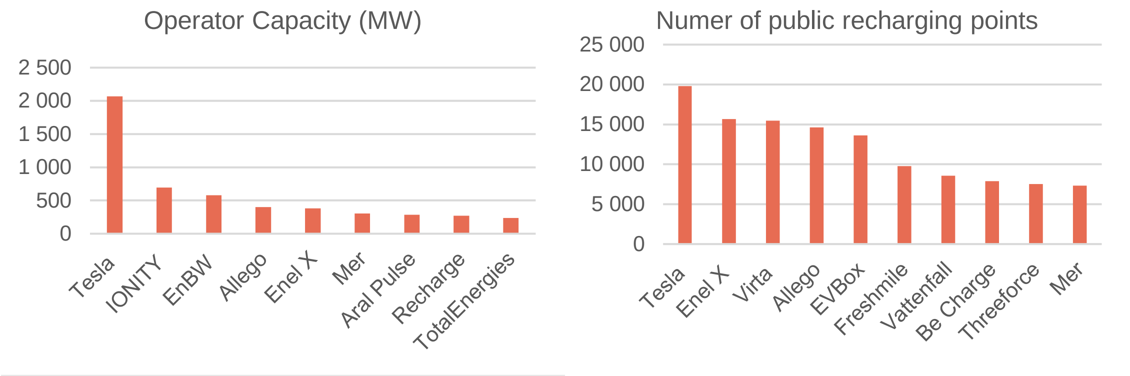

Figure 2-30: Operator capacity and total number of public recharging points (source: gridX[103])

The reason for this ratio between the number of recharging points and total capacity becomes obvious when looking at the typically installed power of the recharging points depicted in Figure 2-31. Enel X or Virta have a high number of recharging points, but these are equipped with a low charging power, and thus the resulting overall capacity is comparatively small. While Tesla has a high number of recharging points and builds a mix between slow and fast recharging points.

[103] https://de.gridx.ai/resources/ev-charging-infrastructure-report-europe-2023

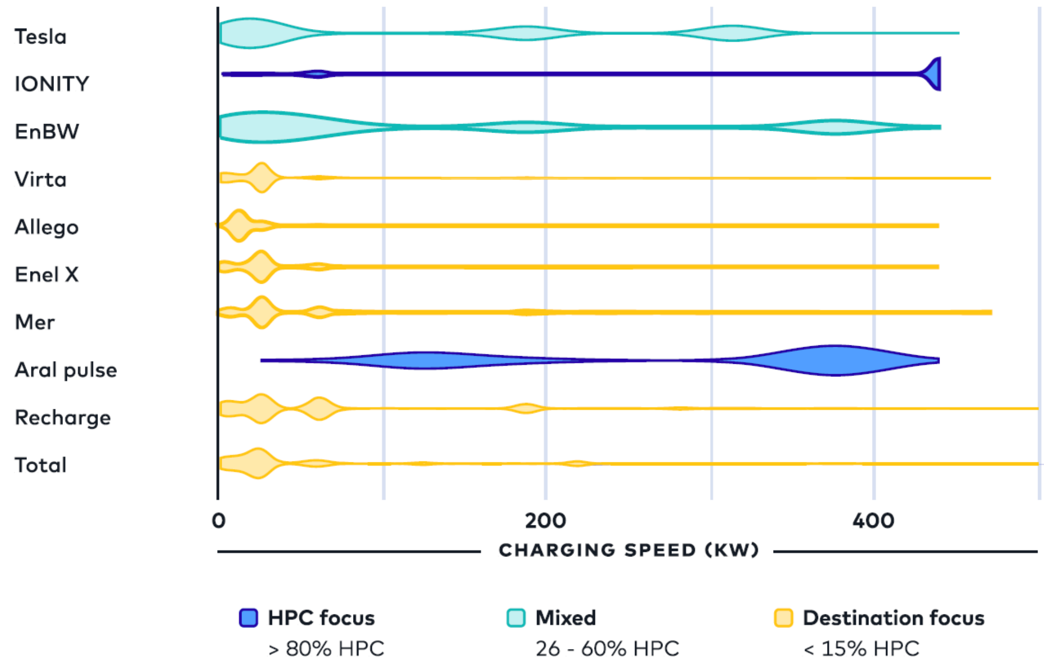

Figure 2-31: Charging power by operators (source: gridX[104])

Thus, the decision for the layout of a recharging station is depending on the interest of different stakeholders, while usually (perhaps apart from the home recharging point) more than one are involved in this decision process. However, the market for purchasing public recharging points is predominantly a B2B market, with manufacturers (SME and large companies) of Mode 3 or Mode 4 charging points supplying CPOs, energy providers, oil and gas providers or even OEMs.

2.3.3.2 *Private recharging points*

Compared to public recharging points, the B2C market plays a much greater role in private recharging points where those points are sold directly to individual users. Many companies (including SMEs) are represented here and supply end customers, usually with Mode 3 recharging points. OEMs also have a special role to play here, as they also sell their own Mode 3 recharging points and usually offer these as accessories when purchasing an EV. Table 2-6 shows that most of the larger European OEMs have such a recharging point on offer. Although the average age of a car in the EU is around 12 years, which would exceed the service life of a recharging point, the actual holding period is often shorter. In such cases, the question then arises as to the continued use of the recharging point if a vehicle from another manufacturer is purchased. Although the compatibility should be given, end customers could still opt for a new recharging point from the manufacturer. In addition to OEMs that offer Mode 3 recharging points, there are many other SMEs and larger companies. Table 2-7 and Table 2-8 show a selection without claiming to be exhaustive[105]. Mobile Mode 4 recharging points are also used in private areas and in special applications such as car workshops[55] or for construction machinery[56]. Typically, however, the market for private recharging points is strongly characterised by Mode 3 recharging points.

[104] https://de.gridx.ai/resources/ev-charging-infrastructure-report-europe-2023

[105] And some of these companies also offer Mode 3 or 4 chargers for public recharging.

Stakeholder questions related to definitions and scoping:

26) Detailed data on the market shares of AC recharging points are not available. Do you have this information or do you know a relevant source/publication?

27) Do you think that the end customer will also buy a new charging station when purchasing a new vehicle, even though the old one is still functional and would also be compatible with the new vehicle?

2.3.4 Trends in product design/ features

Trends in product design or equipment features are generally very specific to AC and DC recharging points and are also determined by the AFIR in the form of interfaces for payment or interaction.

In order to assess the extent to which the recharging points differ in terms of their features, a database of 139 AC recharging points and 34 DC recharging points was first analysed. This was followed by a detailed analysis of selected recharging points.

The majority of AC recharging points are capable of solar-optimised charging and dynamic load management. The ability to charge bidirectionally, on the other hand, is still the exception rather than the rule. Communication mainly takes place via WLAN or GSM or a connection via LAN is usually also possible. In contrast, only a third of the AC recharging points analysed have a display, as shown in Figure 2-32.

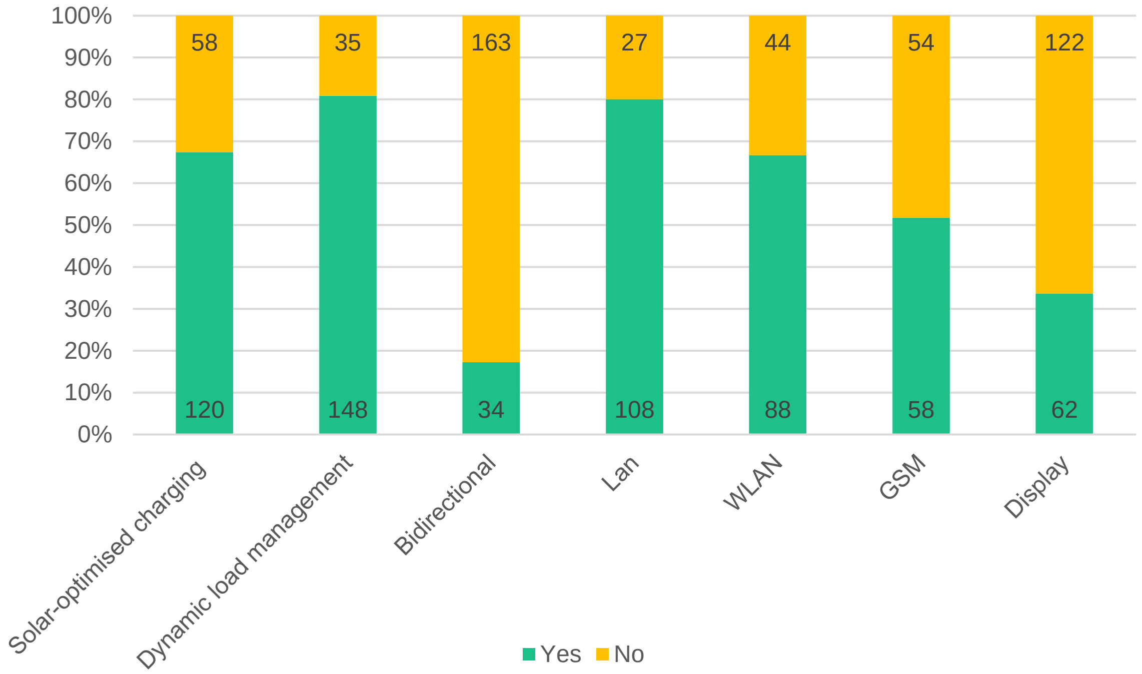

Figure 2-32: Proportion of AC recharging points with a certain characteristic (own illustration based on[106])

[106] https://www.pv-magazine.de/marktuebersichten/marktuebersicht-elektroauto-ladeloesungen/produktdatenbank-elektroauto-ladeloesungen-wallboxen-und-ladesaeulen-2023/

The DC recharging points are fewer in number than the AC recharging points, so no representativeness can be derived here either, but a vague statement can be made about the availability on the market. Compared to the AC recharging points, it can be seen that the DC recharging points are more often in a position to operate dynamic load management. Likewise, almost half of the DC recharging points analysed are capable of bidirectional charging, Figure 2-33. They are also generally more comprehensively equipped in terms of communication and enable almost all options from conventional LAN connection to WLAN and GSM. In most cases, they also have a display, which is necessary due to the requirements of the AFIR and the intended user group.

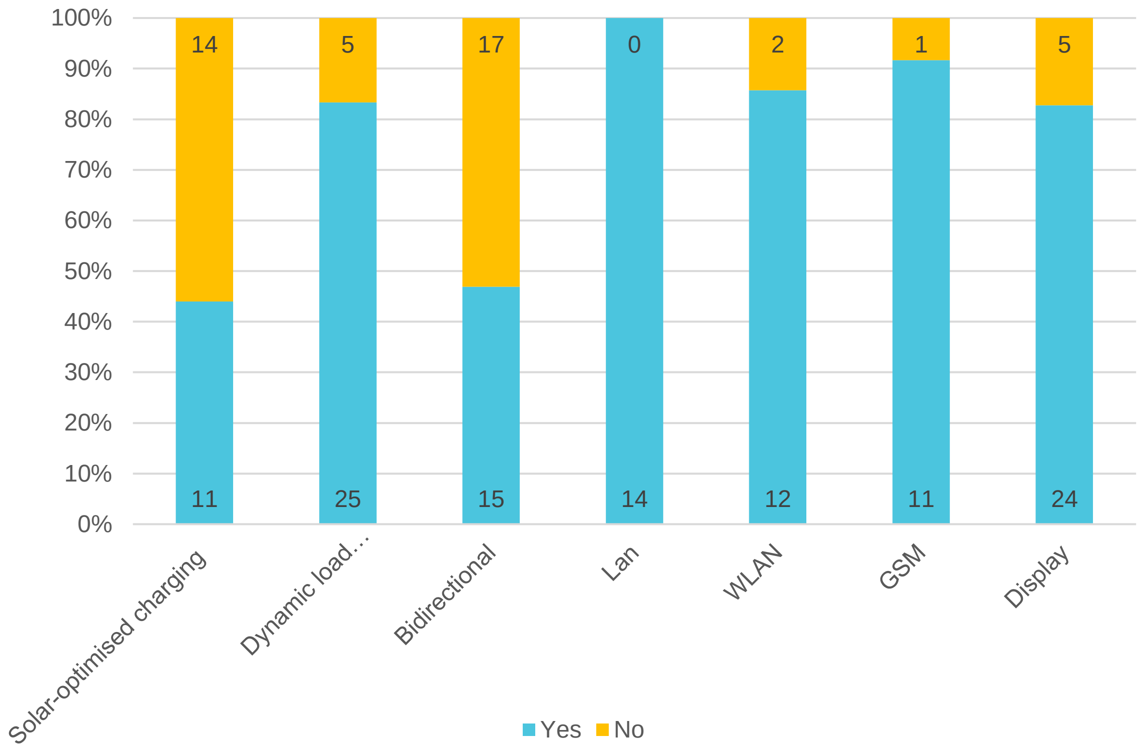

Figure 2-33: Proportion of DC recharging points with a certain characteristic (own illustration based on [107])

The AC recharging points usually offered by OEMs when purchasing a car sometimes differ greatly in terms of both cost and features. The price varies from €500 to €1000. The cable length ranges from 4.5m to 7.5m. However, a display is the exception rather than the rule and can only be found on one recharging point, Table 2-6. The app or web interface varies from none to a possible connection via Bluetooth, WLAN, GSM or Ethernet. The standby consumption is also a major difference, which will be discussed again later.

Table 2-6: Price and performance of selected AC recharging points from OEMs (without any claim to completeness)[108]

	Av. Price (incl. VAT)	max. Power (kW)	Cable length	App/Web-Interface	Display	Authorisation	Energy demand in Standby (kWh)	Costs per year (0.3€ / kWh)
Hyundai Wallbox Pulsar Plus	911	11	5	Bluetooth/WLAN	No	App free	35.9	10.77

[107] https://www.pv-magazine.de/marktuebersichten/marktuebersicht-elektroauto-ladeloesungen/produktdatenbank-elektroauto-ladeloesungen-wallboxen-und-ladesaeulen-2023/
[108] https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/laden/wallboxen/

Mercedes-Benz Wallbox	990	22	6	Ethernet/WLAN / Mobile	No	App, RFID, free	25.4	7.62
Peugeot ePro Full Wallbox	899	22	-	Bluetooth/Ethernet/WLAN/ Mobile	Yes	App, RFID, free	49.9	14.98
BMW Wallbox Gen. 3	599	22	5	Bluetooth	No	free	18.4	5.52
Ford Connected Wallbox	689	11	7.5	Bluetooth/WLAN	No	App	27.2	8.15
Tesla Gen 3 Wall Connector	500	22	7.3	WLAN	No	free, Tesla specific	13.1	3.94
Volvo Garo Wallbox	999	11	4.5	Ethernet/WLAN	No	free	42.9	12.88
Volkswagen ID. Charger	569	11	4.5	None	No	free	7	2.1

PV AC recharging points as depicted in Table 2-7, have a higher purchase price compared to “normal” AC recharging points. They are mostly equipped with WLAN and Ethernet access, and authorisation is usually done via app, PIN, or RFID (free access is also possible). The AC recharging point from Fronius, Myenergi and openWB has an integrated switching function, while an additional set is available for the recharging point from KEBA, which includes an energy meter and automatic phase switching. The models from Charge Amps, SMA and Smartfox can also do this in combination with the in-house energy manager.

Table 2-7: Prices and performance of selected PV AC-Recharging point (without any claim to completeness)[109]

	Av. Price (incl. VAT)	max. Power	Cable length	App/Web-Interface	Display	Authorisation
Fronius Wattpilot Home 11 J 2.0	938	11	-	-	No	App, RFID, free
Entratek Power Dot Fix	1259	22	7	Ethernet/WLAN/ Mobile	No	App, RFID, free
KEBA KeContact P30 PV-Edition	1019	11	6	Ethernet/WLAN	Yes	free
Myenergi Zappi V2.1	1397	22	6.5	Ethernet/WLAN	Yes	PIN, free
openWB Series2 Standard+	1614	11	5	Ethernet/WLAN	Yes	PIN, free
Charge Amps Halo	1199	11	7.5	Ethernet/WLAN	No	App, RFID

[109] https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/laden/wallbox-photovoltaik-anlagen-test/

SMA EV Charger 22	1699	22	5	Ethernet/WLAN	No	App, free
Smartfox Pro Charger	1239	11	5	-	No	free

Bidirectional charging enables the EV not only to draw energy from the power grid, but also to feed energy back into the power grid or the household grid. This enables a variety of other applications, such as improving grid stability, increasing energy efficiency and reducing electricity system costs and can generate benefits for the user. Even if the number of EV models that are currently in the pipeline for this purpose is still manageable, there are already corresponding recharging points that are in the pipeline or will be launched on the market in the near future, such the ones in Table 2-8.

Table 2-8: EV Recharging points offering bidirectional charging (without any claim to completeness) [110]

Company	**Model**	**Power (DC)**	**Price (ca.)**	**Application**
Wallbox	Quasar	7.4 kW	4 250.00 €	
Wallbox	Quasar 2	11.5 kW	5 350.00 €	
Kostal	BDL Wallbox	11 kW	3 500.00 €	
ionix	AVA	25 kW	n.a.	V2G
evtec	sospeso&charge	10 kW (16 A)	12 200.00 €	
Alpitronic	HYC 50	50 kW	23 500.00 €	
Ambibox	Ambicharge	11 kW	4 200.00 €	
Ambibox	Ambicharge	22 kW	n.a.	
Enercharge	DCW20/DCW40	20/40 kW	n.a.	
Volvo	BiDi-Charger		n.a.	
E3/DC	E3/DC S10 M		n.a.	
E3/DC	Edison DC Connect	10 kW	n.a.	V2H
eaton	Green Motion DC	22 kW	n.a.	V2G
BorgWarner	DCVC125-480-V2G	125 kW	n.a.	V2G
BorgWarner	DCVC60-480-V2G	60 kW	n.a.	V2G
dcbel	dcbel r16	15.2 kW	6 900.00 €	V2H, V2G-ready
Enteligent	Hybrid DC Bi-Directional Fast EV Charger	12.5/25 kW	n.a.	V2G, V2H, V2BESS
AME	V2G 3p10kW V2X Charger	10 kW	n.a.	V2G
Ford	Charge Station Pro	19 kW	n.a.	V2H
Nuvve	RES-HD60-V2G	60 kW	n.a.	V2G
Nuvve	RES-HD125-V2G	125 kW	n.a.	V2G

[110] https://nationale-leitstelle.de/wp-content/uploads/2024/03/Bidirektionales-Laden_final_240306.pdf

Silla	Duke 44	2x 22 kW	n.a.	V2H, V2G, V2V
SolarEdge	SolarEdge Ladestation	24 kW	n.a.	
Endphase	Bidirektionale Wallbox		n.a.	
Enovates	Single Wallbox	7.4 kW / 22 kW	n.a.	V2G
Mobilize	Powerbox	22 kW		

2.4 Consumer expenditure base data

2.4.1 General objective of subtask 2.4 and approach

Subtask 2.4 gives an overview of average production costs and consumer prices, incl. VAT (for consumer prices; street price)/ excl. VAT (for B2B products), as well as an estimation of repair and maintenance as well as installation and disposal costs.

Due to their recent larger-scale market introduction, there is still little experience with maintenance as well as disposal expenses. Hence, only estimations can be made based on isolated sources.

For each of the categories defined in Task 1 this task will define:

- Average EU consumer prices, incl. VAT (for consumer prices; street price)/ excl. VAT (for B2B products), in euros;
- consumer prices of consumables;
- repair and maintenance costs (euro/product life);
- installation costs (for installed appliances only);
- disposal tariffs/ taxes (euro/product).

For electricity, fossil fuel, water, interest, inflation and discount rates, this task will use values from the MEErP methodology, including the average annual price increases mentioned there. Also an approach will be elaborated for regional differentiation of consumer prices that can be used in a sensitivity analysis in Task 7.

2.4.2 Consumer prices for AC recharging points

Mode 2 recharging points are part of the basic equipment of a drive train and are usually supplied as standard. The prices for these comparatively simple recharging points on market portals are generally between €150 and €300. In terms of mode 3 recharging points, consumer prices have dropped over the past few years (after a slight increase in 2022). The average price (incl. VAT) now is approximately ~770 € per mode 3 recharging point and there is none anymore with an average price above 1000 € (see Figure 2-34).

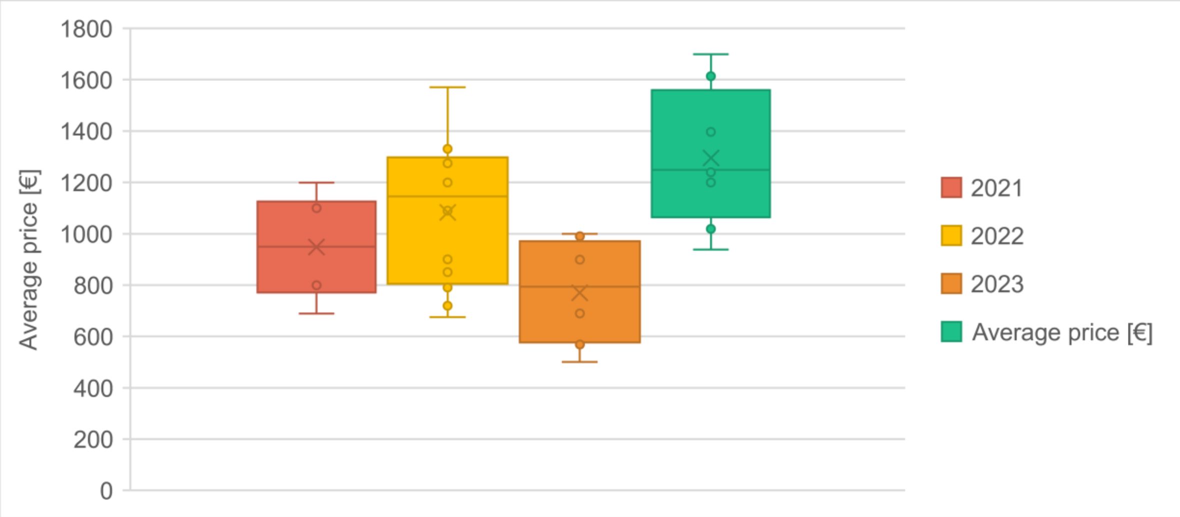

Figure 2-34: Average sales prices for 26 mode 3 recharging stations in Germany from 2021 to 2023 (calculated on information from ADAC [111], excluding installation, including VAT)

Even if you can observe the tendency of falling prices, this, of course, depends on the individual AC recharging point. It also turns out that AC recharging points with additional functions, such as phase switching, cost even more for PV.

In order to be able to make a better statement on the price distribution independently of the AC recharging points considered here, the database for AC and DC recharging points, which was already analysed at the beginning of the chapter with regard to equipment features, has now been evaluated with regard to prices. However, only those recharging points for which prices were explicitly stated were analysed.

[111] https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/tests/wallboxen/

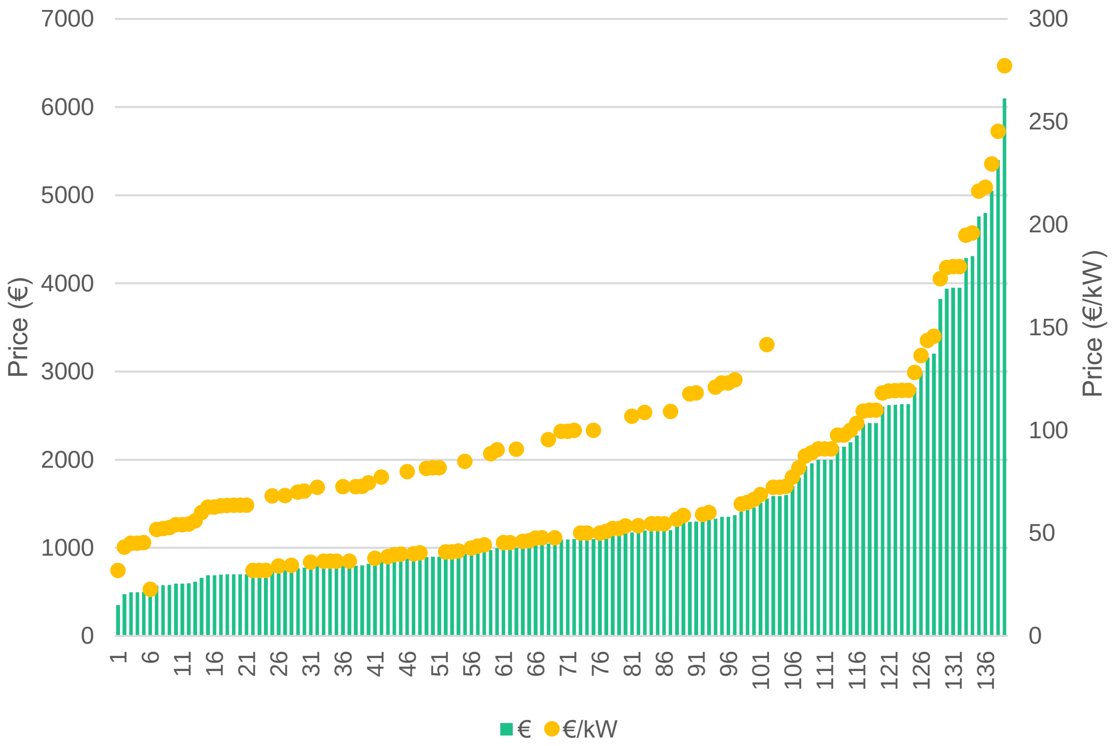

Figure 2-35: Price and power of different AC recharging points (calculated on information from[112])

The evaluation for AC recharging points shows that there is quite a wide range of prices, from €350 to over €6000. The graph also shows the correlation between the prices and the available maximum charging power. While the most expensive 11 kW recharging point is around €1500, all other recharging points are 22 kW, see Figure 2-35.

2.4.3 Consumer prices for DC recharging points

For the analysis of the prices for DC recharging points, not so many models were available. Nonetheless, it is clear that the costs are significantly higher than those of AC recharging points, and there is also a clear correlation between price and charging power. While the cheapest model only has 11 kW and costs around €3500, DC recharging points with over 150 kW cost 20 times as much, Figure 2-36. Again, it should be emphasised that these results are not representative and are only intended as a point of orientation.*

[112] https://www.pv-magazine.de/marktuebersichten/marktuebersicht-elektroauto-ladeloesungen/produktdatenbank-elektroauto-ladeloesungen-wallboxen-und-ladesaeulen-2023/

Figure 2-36: Price and power of different DC recharging points (calculated on information from[113])

2.4.4 Standby losses and energy costs

Standby consumption differs significantly between the AC recharging points. The AC recharging point with the highest standby losses has a yearly energy consumption of 50 kWh per year, see Figure 2-37. For an EV with a battery of 50 kWh, this is practically a full charge of "wasted" electricity. The best-performing recharging point only has 7 kWh losses over the year. To put these figures into context, it should be noted that 30 to 50 kWh is about as much energy as a computer, Wi-Fi router, TV, or satellite receiver consumes in standby mode per year.

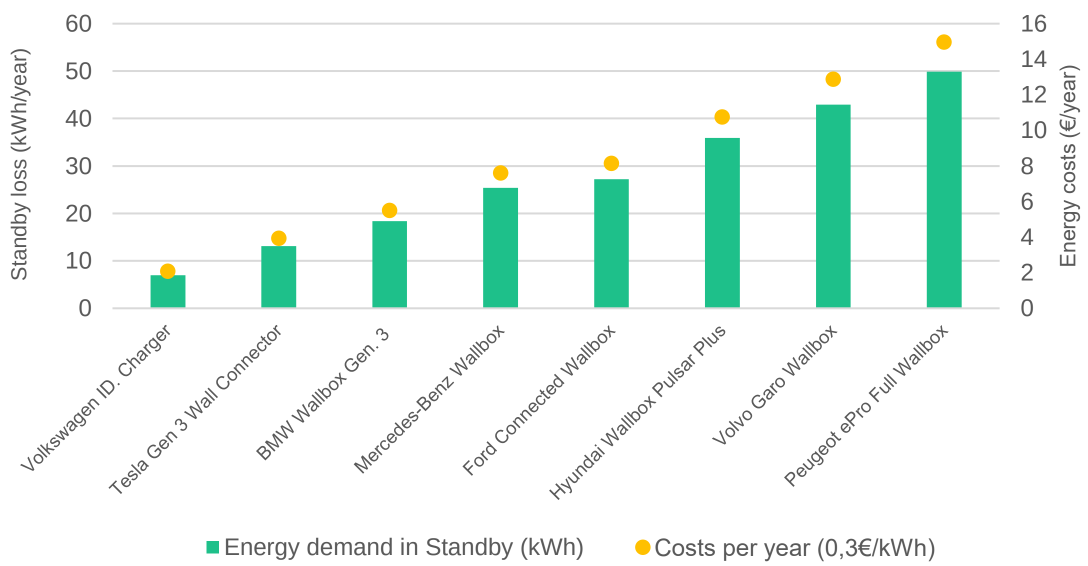

Figure 2-37: Standby energy consumption (in kWh per year)[114]

[113] https://www.pv-magazine.de/marktuebersichten/marktuebersicht-elektroauto-ladeloesungen/produktdatenbank-elektroauto-ladeloesungen-wallboxen-und-ladesaeulen-2023/
[114] https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/laden/wallboxen/

2.4.5 Installation and O&M costs

The total costs for the equipment and installation of EV recharging points varies especially when looking at DC recharging points. However, considering that we are at the very beginning of the market development, it can be assumed that the prices for EV recharging points will further decrease in the future. Within the IA for the AFIR, assumptions are made for the current and future costs of different EV recharging points. The costs are given for the CAPEX and the installation (Network upgrade costs are not included) of the recharging point, as shown in Table 2-9.

Table 2-9: CAPEX and installation costs for different types of recharging points in €

Recharging point type	Capex	Installation	Total
Slow recharging points			
public HH (7KW AC)	667	833	1,500
public spaces (22KW AC)	3,280	3,000	6,280
Rapid recharging points			
public spaces (50KW DC)	28,125	16,875	45,000
public spaces (150KW DC)	70,000	20,000	90,000
Ultra-Rapid fast recharging points			
public spaces (350 KW DC)	170,000	60,000	230,000

The given CAPEX thereby seem to fit into the ranges for the prices of AC and DC recharging points depicted before in Figure 2-35 and Figure 2-36. In addition to the aforementioned costs, assumptions were also made regarding their future development. Table 2-10 shows the investment costs as sum of CAPEX and installation costs until the year 2050.

Table 2-10: Investment costs for various recharging points up to the year 2050 in euros

Investment costs (EUR/point)	2020	2025	2030	2040	2050
Slow recharging points					
public HH (7KW AC)	1,500	1,340	1,253	(1,171)	(1,139)
public spaces (22KW AC)	6,280	5,423	4,974	4,561	4,403
Rapid recharging points					
public spaces (50KW DC)	45,000	37,728	34,019	30,687	29,422
public spaces (150KW DC)	90,000	72,510	63,757	56,016	53,114
Ultra-rapid recharging points					
public spaces (350 KW DC)	230,000	186,614	164,836	145,532	138,282

In addition, the IA also made assumptions about the operation and maintenance costs associated with maintaining the infrastructure, Table 2-11. These are usually stated as a percentage of the original investment. A statement is also made on the costs associated with extending the lifetime of recharging points that have been installed for more than 15 years.

Table 2-11: Operation and maintenance costs for various EV recharging points

O&M costs (% investment costs/point, p.a.)	2020-2050
Slow recharging points	
private HH off-street charging (7KW AC)	1%

public HH on-street charging (7KW AC)	1.60%
public spaces (22KW AC)	1.20%
Rapid recharging points	
public spaces (50KW DC)	1.20%
public spaces (150KW DC)	1.20%
Ultra-rapid recharging points	
public spaces (350 KW DC)	1.20%
Lifetime extension for recharging points with > 15 years lifetime (% investment cost)	25%

The "European EV Charging Infrastructure Masterplan"[115] also gives assumptions for different costs depending on the recharging point type for the year 2030. The CAPEX (incl. hardware, installation, planning and engineering and administration) per kW charging power thereby lies between 125 €/kW for an AC 11 kW recharging point and 400 €/kW for a DC 150 kW recharging station. Thus, the CAPEX for a DC 500+ kW recharging station might be approximately 104,000 € and can reach 260,000 € for DC 1 MW recharging points (see Figure 2-38).

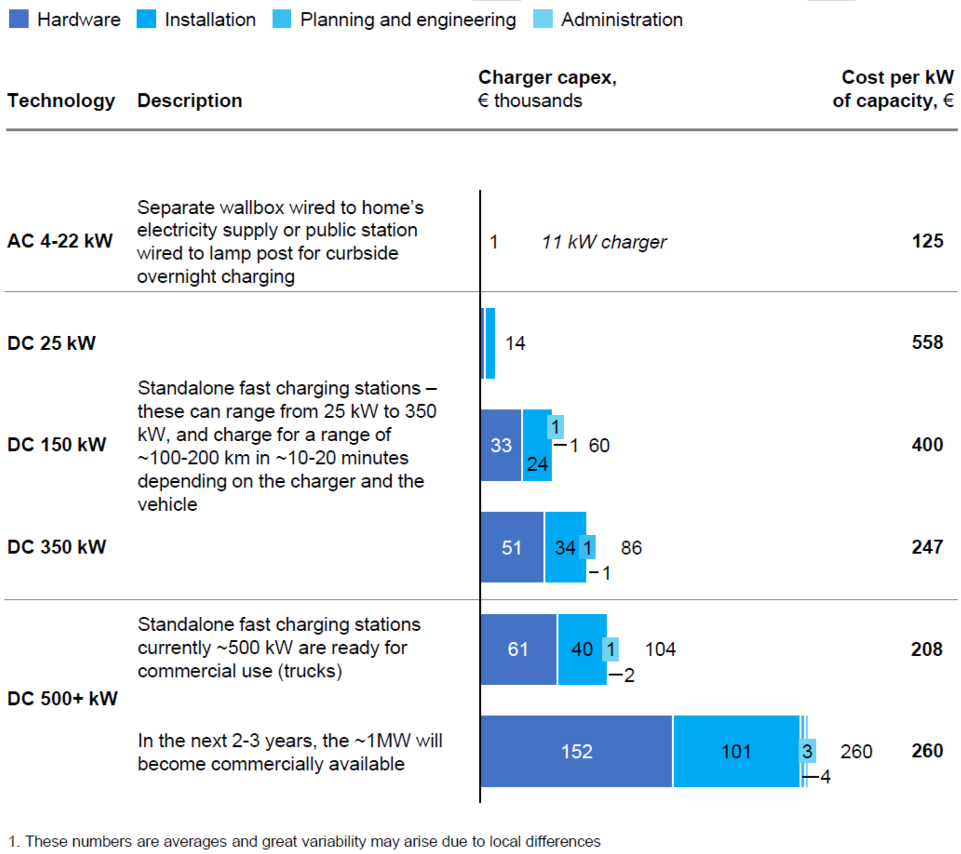

Figure 2-38: CAPEX for different EV recharging point types in 2030 excl. grid investments (source: ACEA[116])

[115] https://www.ACEA.auto/files/Research-Whitepaper-A-European-EV-Charging-Infrastructure-Masterplan.pdf

[116] https://www.ACEA.auto/files/Research-Whitepaper-A-European-EV-Charging-Infrastructure-Masterplan.pdf

Besides the purchase prices, energy costs will also play a crucial role when determining the LCC of an EV recharging point. First, calculations regarding the impact of energy costs were already conducted within Task 3.

2.4.6 Consumer energy costs

The consumer energy costs were calculated based on the assumptions made in the IA of the AFIR. The following Figure 2-39 was calculated under the given assumptions in the IA regarding the diffusion of EVs. The average km/year was accordingly assumed to be 13141 km/year. While the electric energy per km in 2030 was also assumed for 2040 and 2050 (0,148 kWh/km for BEV and 0,192 kWh/km for PHEV). Furthermore, the utility factor for PHEV was also taken as 52% (also knowing from today's perspective that this is a rather optimistic value). Following these input values from the IA, the Energy demand, as depicted in Figure 2-39, was calculated.

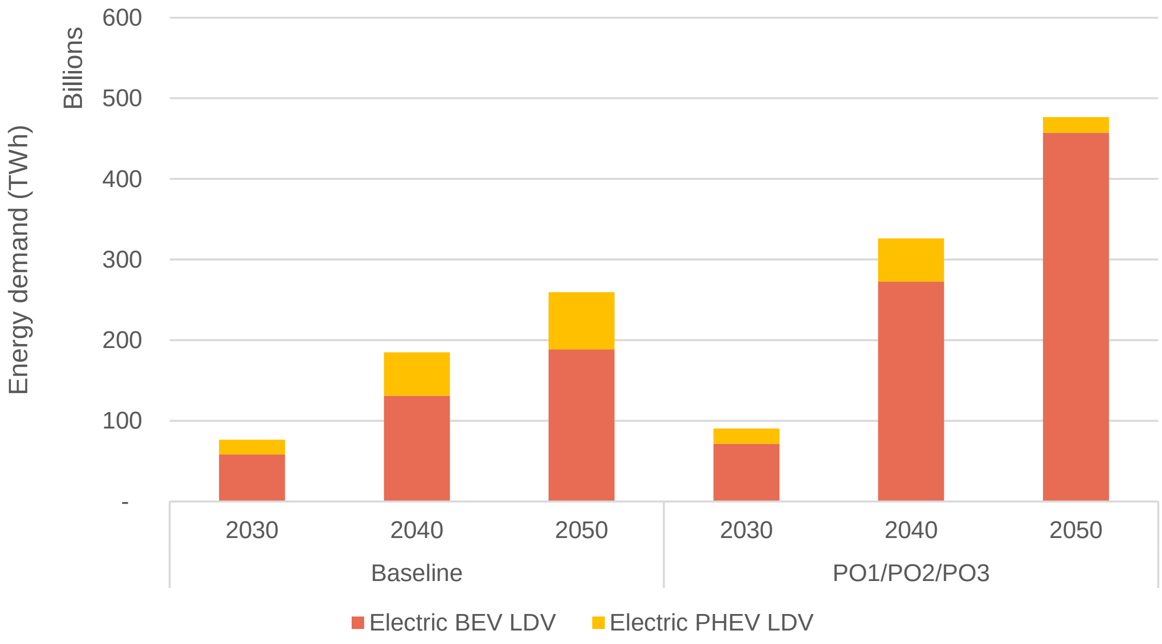

Figure 2-39: Energy demand for recharging EVs in Europe (based on [117])

Using an energy price of 0.3 € as an approximation, the consumer costs are calculated and depicted in the following Figure 2-40.

[117] https://op.europa.eu/en/publication-detail/-/publication/ef0b9a03-728e-11ec-9136-01aa75ed71a1/language-en

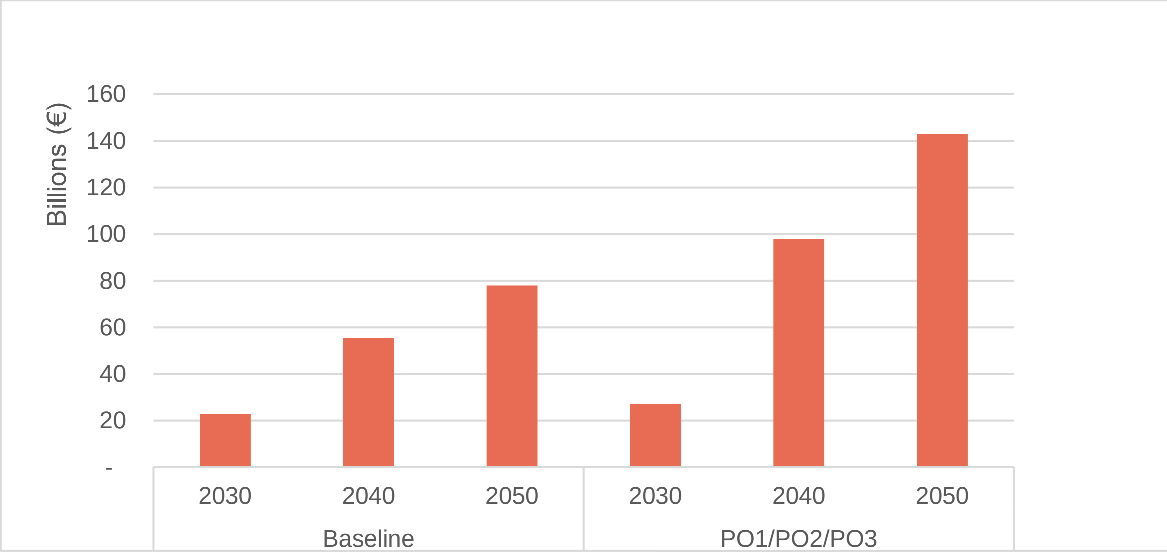

Figure 2-40: Consumer energy costs per year (in € with 0.3 € per kWh)

Stakeholder questions related to definitions and scoping:

28) Do the assumed costs and prices match your experience and expectations?

29) Do you have any further information on costs and/or prices that should be included?

2.5 Preliminary conclusion

General objective of subtask 2.5:

This task makes recommendations with regard to a refined product scope from an economical/ commercial perspective (e.g. exclude niche markets) and identifies barriers and opportunities for Ecodesign from the economic/ commercial perspective.

Conclusions:

The product group of recharging points for EVs is a comparatively young one. This is reflected in the fact that, for example, there is not yet a defined PRODCOM classification, nor does the retrospective data situation go back very far. Nevertheless, the stock of public recharging points has grown from around 10,000 in 2012 to almost 700,000 (597,000 AC and 94,000 DC) in 2024.

The market is directly correlated with the market growth of EVs. In 2050, it is estimated that between 6.9 and 16.3 million public recharging points will be installed. Even if this alone represents a large market, the number of private recharging points is significantly higher and could be between 120 and 260 million recharging points in 2050. The proportion of Mode 3 recharging points is significantly higher than that for Mode 4. What is also striking here is the large proportion of Mode 2 chargers that are often supplied as standard with EVs, and if this remains the case in the future, their stock will grow to around 250 million in 2050. The product classes above should, therefore, be considered in line with Article 15(2)(a) of the Ecodesign Directive 2009/125/EC for further consideration.

Other areas of application in which recharging points are required include onshore power supply (OPS) in harbours or the electricity supply of aircraft at the gate or in the outfield position. The stock for the latter is likely to be around 10,000 recharging points in 2030, while around 250 harbours are likely to be equipped with one or more OPS. Both applications can, therefore, be regarded as niche markets that are wide below 1% of the market of charging points for road transport. However, also small in numbers, the energy consumption, especially of the single OPS, can be quite high.

The impact of a GPP was also estimated. The results show that GPP could play a relevant role in this product group.

The evolving EV market has significant growing trends, including increasing DC charging power, the development of MCS for heavy-duty vehicles, advancements in smart charging and V2G technology, and the adoption of wireless charging and Plug and Charge solutions. These trends highlight the industry's focus on enhancing charging infrastructure efficiency and integration with the grid.

It should also be mentioned that the market channels for this product group are very complex, as different players from different sectors (energy, automotive, etc.) are active in this ecosystem. While the sales of Mode 3 recharging points are predominantly a B2C market, Mode 4 recharging points sales are a B2B market from suppliers of the recharging points to CPOs or workplaces/offices/other buildings. The costs for the individual recharging points vary accordingly. One major challenge represents the definition of the service life of the products, for which no historical data is yet available.

Stakeholder questions related to definitions and scoping:

30) Do you agree on these preliminary conclusions?

3 Users

3.1 Preliminaries

3.1.1 Aim

Users affect the environmental impact of EV chargers especially during the use phase. In line with the MEErP methodology their influence on the life-cycle performance of EV chargers is analysed within this Task 3 across five subtasks. These subtasks cover the direct energy consumption (Subtask 3.1) as well as indirect energy consumption effects (Subtask 3.2) of the EV chargers during the use phase, user influence on end-of-life behaviour (Subtask 3.3), the relevance of local infrastructure (Subtask 3.4) and a set of conclusions (Subtask 3.5) for the following steps within this preparatory study.

3.1.2 Context

Charging behaviour can be distinguished based on different characteristics. Following the Alternative Fuels Infrastructure Regulation (AFIR) (EU, 2023b), the morphological box in Figure 3-1 shows different dimensions.

The AFIR distinguishes private and public charging points, although only public charging points are part of the regulation. It is common to further distinguish charging locations based on their accessibility (e.g. AAAA Association P.E.P. (2018)). In this analysis, we distinguish

- private use only - typically at a private parking location,
- accessibility for selected and known users - the most common type is often referred to as charging at work,
- time restricted charging - for example charging at supermarkets within opening hours, also known as semi-public charging, and
- fully accessible charging infrastructure - also known as public charging infrastructure.

From a technical perspective, charging can be distinguished in alternating current (AC) and direct current (DC). AC is typically used for normal power charging up to 22 kW, while DC charging is used for high power charging. However, from a technical perspective normal power charging up to 22 kW could also be done with DC. Charging at sockets with up to 3.7 kW is a special case that is explicitly excluded in AFIR. The AFIR further distinguishes high power charging up to 50 kW, up to 150 kW, up to 350 kW, and more than 350 kW (EU, 2023b).

Regarding the energy transmission, recharging stations with cables - including wallboxes - are most often used. However, there are also options for wireless charging, battery swapping, and electric road systems mentioned in the AFIR. The latter ones are systems in which energy can be transferred to the vehicles while travelling, for example overhead lines or contact strips in the ground.

In terms of applications, the AFIR names:

- L-category vehicles - such as electric bicycles and electric mopeds -,
- light-duty vehicles - either as passenger vehicles (up to 8 passengers and one driver, M1) or as freight vehicles (≤3.5 t, N1) -, and
- heavy-duty vehicles - either as passenger vehicles (more than 8 passengers and one driver, M2, M3) or as freight vehicles (> 3.5t, N2, N3) (EU, 2018, 2023b).

Trains, vessels, and aircrafts are also mentioned in the AFIR, especially regarding stationary electricity supply through fixed or mobile interfaces.

To support the electricity grid, the AFIR and the Renewable Energy Directive (RED) names smart charging and bi-directional charging as options (EU, 2023a, 2023b). Smart charging - a recharging operation in which the intensity of electricity delivered to the battery can be adjusted dynamically - is mandatory for public charging infrastructure, as defined in AFIR (EU, 2023b). RED requires the member states to ensure that new and replaced non-publicly accessible normal power recharging points shall be prepared for smart charging. (EU, 2023a). Today, owners of battery electric vehicles often also possess a photovoltaic system and possibly even a battery buffer. In 2017, 48% of electric vehicle owners surveyed in Germany also owned a photovoltaic system. About one fourth of the photovoltaic systems were coupled with a battery storage (Scherrer et al., 2019). The national average for owning a solar system was 5% (Scherrer et al., 2019). Therefore photovoltaic systems - or, more generally, locally produced renewable energy - and battery buffers are also included in the morphological box.

Finally, charging systems are equipped with different feature components. For newly built public charging points, one of the following options for payment need to be available, according to the AFIR:

- payment card reader
- devices with a contactless functionality that is at least able to read payment cards
- for charging points with less than 50 kW, devices using an internet connection and allowing for secure payment transactions, such as those generating a specific Quick Response code.

From 2027 onwards, at least a single payment terminal needs to be installed for each recharging location with charging points with at least 50 kW power (EU, 2023b). To integrate charging points into backend systems and the make them controllable, a digital connection - WiFi or LTE - is needed. Finally, a radio frequency identification system (RFID) can be used to identify users with charging cards.

Type	Private charging points			Public charging points		
Accessibility	Private use (e.g. home)	Selected users (e.g. work)		Time-restricted (e.g. shops)	Fully accessible (e.g. at roads)	
Current	Alternating Current (AC)			Direct Current (DC)		
Charging power	Socket ≤ 3.7 kW	Normal power 3.7 < P ≤ 22 kW	High power 22 < P ≤ 50 kW	High power 50 < P ≤ 150 kW	High power 150 < P ≤ 350 kW	High power > 350 kW
Energy transmission	Modular recharging station	Wireless		Battery swapping	Electric road system	
Applications	E-Bikes (L)	Light-duty (M1, N1)	Heavy-duty (M2, M3, N2, N3)	Trains	Vessels	Aircrafts
Interoperability with grid	Smart charging	Bi-directional charging		Battery buffered	Locally produced renewable energy	
Features	Display	RFID reader	Digitally connected (WiFi, LTE)	Payment card reader	QR-Code	...

Figure 3-1: Morphological box on charging characteristics

Additionally, a distinction can also be made according to the charging mode, as shown in Task 1:

- Mode 1 - Standard socket outlet - domestic installation
- Mode 2 - Standard socket outlet with an AC EV supply equipment – domestic and industrial plugs
- Mode 3 - AC EV equipment permanently connected to an AC supply network
- Mode 4 - DC EV supply equipment

However, from a user's perspective, there is no difference between Mode 2 and Mode 3, as the mobile EV supply equipment can be used like a permanently installed charging infrastructure. Some charging infrastructure providers even sell the same charging equipment for permanent installation (Mode 3) and for flexible installation (Mode 2). It is likely, that Mode 2 charging equipment is normally used like Mode 3 equipment, but can be taken with the vehicle in rare cases - for example for holiday trips when no charging infrastructure is available at a hotel or a camping ground. However, often other plugs - for example according to the CEE7 (a standard for alternating-current plugs and sockets) - are available in underground garages or at camping grounds. Therefore, in daily use the Mode 2 charging equipment should be treated as Mode 3 equipment.

To handle the broad variety of chargers for different applications, the following charging situations - following AAAA Association P.E.P. (2018) - for light-duty vehicles are distinguished from the users' perspective:

- Charging with up to 3.7 kW at domestic sockets (Mode 1[118], Mode 2)

[118] Mode 1 charging does not contain any communication between the vehicle and the charging infrastructure. The vehicle is directly connected to the power outlet (1 phase or 3 phases). For safety reasons, this is typically not used for light-duty vehicles anymore, but rather for microcars or bicycles.

- Charging with up to 22 kW at private locations (Mode 2, Mode 3)
- Charging with up to 22 kW at restricted (semi-public) locations (Mode 3)
- Charging with up to 22 kW at fully accessible (public) locations (Mode 3)
- Charging with more than 22 kW at restricted (semi-public) locations (Mode 4)
- Charging with more than 22 kW at fully accessible (public) locations (Mode 4)

Given the early stage of heavy-duty vehicle charging, the analysis does not distinguish between different power levels in the range of 50 to 350 kW. Therefore, heavy-duty vehicles, the following charging situations are distinguished:

- Charging with up to 50 kW at private locations (Mode 4, Mode 3 up to 44 kW technically possible)
- Charging with more than 50 kW and less than 350 kW at private locations (Mode 4)
- Charging with more than 350 kW at private locations (Mode 4)
- Charging with up to 50 kW at restricted (semi-public) locations (Mode 4, Mode 3 up to 44 kW technically possible)
- Charging with more than 50 kW and less than 350 kW at restricted (semi-public) locations (Mode 4)
- Charging with more than 350 kW at restricted (semi-public) locations (Mode 4)
- Charging with up to 50 kW at fully accessible (public) locations (Mode 4, Mode 3 up to 44 kW technically possible)
- Charging with more than 50 kW and less than 350 kW at fully accessible (public) locations (Mode 4)
- Charging with more than 350 kW at fully accessible (public) locations (Mode 4)

Open question to stakeholders:

31) Do you agree that Mode 2 and Mode 3 will be used similarly in practice?

3.2 System aspects in the use phase affecting direct energy consumption

Subtask 3.1 aims at reporting on the direct impact of charging infrastructure on the environment and on resources during the use phase. Direct impact refers to impact, which is directly related to the function of the charging infrastructure: the transmission of energy to a vehicle. Different approach levels are shortly presented according to MEErP, in order to select the best one for the analysis of charging infrastructure: first, a strict product approach will be pursued which is then broadened to an extended product approach. After that, a technical system approach will follow, leading to an analysis from a functional system perspective.

- **Strict product approach**: In the strict product approach, only the charging infrastructure is considered. Herein, the system boundary just contains the EVSE hardware. Nominal operating conditions would apply as defined in traditional standards. As there is no standard available, the strict product approach follows suggestion by the Ecopassport Programme and the Energy Star Program. As a product category rule, the Ecopassport Programme aims to support the harmonisation of the life cycle analysis of charging infrastructure. The Energy Star Program defines minimum standards for charging infrastructure that is marked with the corresponding label.

- **Extended product approach:** In the extended product approach, the influence of usage and real-life deviations from the test standard will be considered. Herein, the actual utilisation of charging infrastructure will be reviewed. Compared to the strict product approach, the variation in use will be shown.
- **Technical system approach:** Charging infrastructure connects electric vehicles to the electricity grid. Therefore, the charging infrastructure also influences the efficiency of the electricity grid and the vehicles itself. For example, AC charging infrastructure requires an AC/DC converter in the vehicle that will lead to additional losses. However, as losses in the grid and the vehicle are part of the indirect energy consumption effects in subtask 3.2 (chapter 3.3), the technical system approach will be skipped.
- **Functional approach:** In the functional approach the basic function of charging infrastructure, the transmission of energy to a vehicle, is maintained, yet other ways to fulfil that function and thus other transmission technologies are reviewed.

Moreover, when following the strict or extended product approach, the MEErP proposes three large groups of products the can be distinguished (see Figure 3-2):

- products that are using energy during the use phase, hereafter referred to as 'direct ErP'.
- products that - in the use phase - do not use energy but have a significant impact on the energy consumption of products that are using energy, hereafter referred to as 'indirect ErP'.
- the combination of both

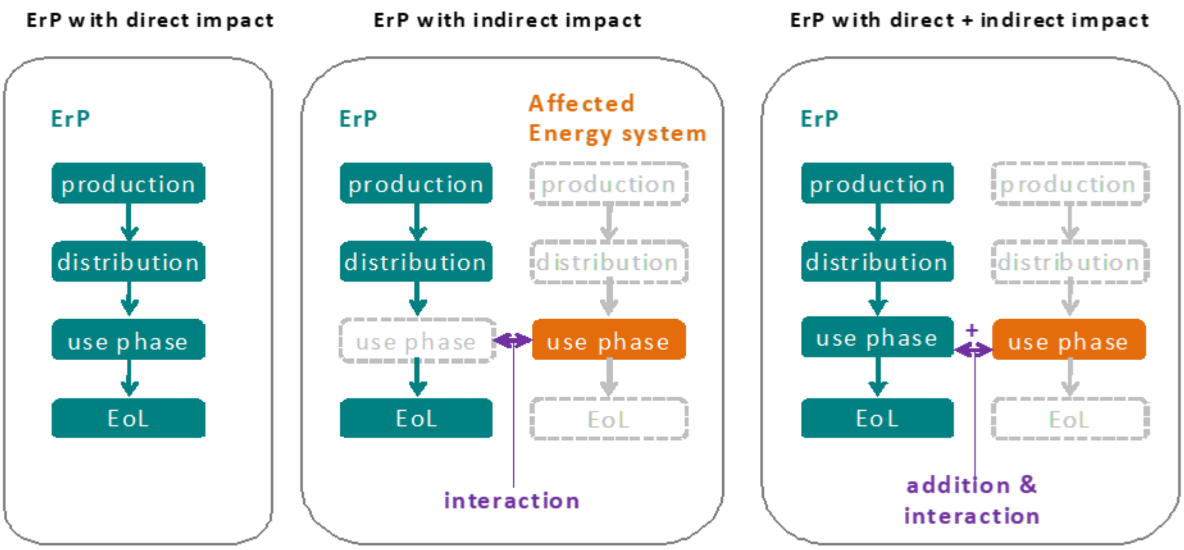

Figure 3-2 Diagram illustrating how the system boundaries can be extended (Source: MEErP, 2011)

Figure 3-3 shows the EVSE from a system perspective. Main losses arise when converting AC to DC. For example, when recharging with a mode 3 EVSE then most of the losses are

Indirect within the vehicle On Board Charger (OBC) and only minor parts are direct losses within the EVSE (ADAC, 2022). When recharging with mode 4 EVSE then most of the losses are direct losses, because in mode 4 the converter for the current control is included in the EVSE.

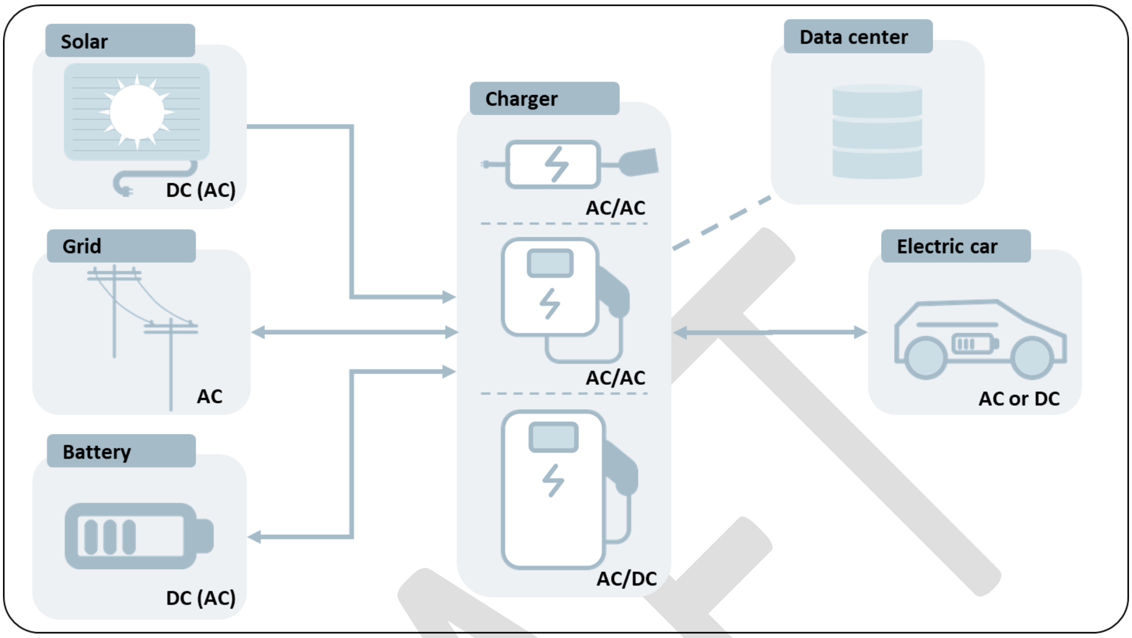

Figure 3-3: Charging infrastructure from a system perspective

3.2.1 Strict product approach: energy efficiency of charging infrastructure

From a strict product perspective, charging infrastructure causes two types of energy consumption:

- **Heat dissipation / losses**, when charging a vehicle due to resistance and efficiency of the energy transmission (conversion losses for DC-DC voltage conversion and AC-DC conversion)
- **Intrinsic electricity consumption** of the charging infrastructure, related to additional functions of the charging infrastructure (e.g. screen, communication interface)

As charging infrastructure is quite a new product, there are no existing standards that define the efficiency of charging infrastructure. However, the Ecopassport Programme - a privately defined product category rule - and the Energy Star Program - a voluntary product label - give guidance on the calculation of the energy efficiency of charging infrastructure for (light-duty) vehicles.

3.2.1.1 Calculation of the heat dissipation, according to the Ecopassport Programme

According to the Ecopassport Programme (AAAA Association P.E.P., 2018), the heat dissipation for alternating current products can be calculated as follows:

$$E_{HD} = R * I^2 * t * X$$

E_{HD}: Energy losses associated with heat dissipation

R: Resistance of the connections that transmit the current to the vehicle

I: Current[119]

$$I = \begin{cases} 1 * I_n, & in\ single\ phase\ AC \\ 3 * I_n\ , & in\ three - phase\ AC \end{cases}$$

with I_n as normal intensity

t: Charge time of a single charging event

X: Number of charging events during the use phase

For direct current products, the heat dissipation can be calculated as follows:

$$E_{HD} = (1 - eff) * Q_d$$

E_{HD}: Energy losses associated with heat dissipation

eff: Converter yield; efficiency

Q_d: Average quantity of energy supplied for a given charging point during the use phase

3.2.1.2 Calculation of the intrinsic electricity consumption according to the Ecopassport Programme

The electricity consumption can be defined, based of different operation modes (AAAA Association P.E.P., 2018):

$$E_i = \left(P_{active} * \%t_{active} + P_{as} * \%t_{as} + P_{ps} * \%t_{ps} + P_{off} * \%t_{off}\right) * usage$$

E_i: Electricity consumption

P_{active}: Operating power (vehicle connected and charging)

$\%t_{active}$: Share of time in active mode (vehicle connected and charging)

P_{as}: Active standby Power (vehicle connected and charging completed)

$\%t_{as}$: Share of time in active standby (vehicle connected and charging completed)

P_{ps}: Passive standby mode (vehicle not connected)

$\%t_{ps}$: Share of time in active standby (vehicle not connected)

[119] The Ecopassport Programme uses “Intensity” for current.

P_{off}: Power off (socket not connected and no current passing through it)

$\%t_{off}$: Share of time in off mode (socket not connected and with no current passing through it)

$usage$: Total duration of use phase

3.2.1.3 Usage definition according to Ecopassport Programme

In the following, the main parameters for the product focussed calculation according to the Ecopassport Programme in the reference use scenario (AAAA Association P.E.P., 2018) are shown. Table 3-1 contains more general parameters, while Table 3-2 contains to assumed utilisation.

It is evident that some parameters, for example the underlying power levels, are outdated. Especially charging at high power with a constant power of 50 kW over one hour is unusual today. Today’s vehicles reach a higher peak power, typically more than 100 kW (Wassiliadis et al., 2021). At the same time, the peak power is not maintained over the entire charging process, but decreases as the state of charging increases. Typically, there is a plateau - depending on the vehicle up to approximately 20 to 40% state of charge - and afterwards the charging power is reduced. At the same time, the charging behaviour depends on the battery temperature. If the battery is too cold (or too warm), the charging power is also reduced (Wassiliadis et al., 2021). **Therefore, DC charging infrastructure needs to support a wide range of different charging powers at different currents and different voltages (400 V versus 800 V). Up to now, this is not covered in the efficiency analysis of the charging infrastructure.**

With regard to the assumed utilisation in Table 3-2, it is obvious that one specific case is defined for the test procedure. In reality, however, utilisation rates vary heavily depending on the specific charging behaviour.

	Unit	Domestic wall socket AC	Private / semi-public AC	Public AC	Private / semi-public DC	Public DC
T Charge time single event	h	7.32 (by 3.7 kW)	7.32 (by 3.7 kW) 3.87 (by 7 kW) 2.46 (by 11 kW) 1.24 (by 22 kW)	3 (by 22 kW)	1 (by 22 kW)	1 (by 50 kW)
$usage$ Reference service life	yr	10	10	10	10	10
Charging events per week		2	2	14	28	70
X Charging events in use phase		1,040	1,040	7,300	14,600	36,500
Average daily travel	km	43	43			
Charging at private stations		90% (38.7 km/day)	90% (38.7 km/day)			
Average vehicle consumption	kWh/km	20	20			
Q_d Energy supplied over life-time	kWh	28,251	28,251	481,800	321,200	1,825,000

Table 3-1: Framework parameters for usage definition according to AAAA Association P.E.P. (2018) (1/2)

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	Domestic wall socket AC	Private / semi-public AC	Public AC	Private / semi-public DC	Public DC
Average time plugged in	- not provided -	12 h/charge			
$\%t_{active}$ Share of time in active mode	- not provided -	8.7% (3.7 kW) 4.6% (7 kW) 2.9% (11 kW) 1.5% (22 kW)	25%	17%	42%
$\%t_{as}$ Share of time in active standby	- not provided -	5.6% (3.7 kW) 9.7% (7 kW) 11.4% (11 kW) 12.8% (22 kW)	0%	0%	0%
$\%t_{ps} + \%t_{off}$ Share of time in passive standby and off mode	- not provided -	85.7% h (3.7 kW) 85.7% (7 kW) 85.7% (11 kW) 85.7% (22 kW)	75%	83%	58%

230 *Table 3-2: Framework parameters for usage definition according to AAAA Association P.E.P. (2018) (2/2)*

Users

3.2.1.4 Calculation and suggested maximum values of power consumption according to Energy Star Program

The Energy Star Program (Energy Star, 2021) considers four types of charging infrastructure:

- **Level 1 electric vehicle supply equipment:** A galvanically connected EVSE with a single-phase input voltage nominally 120 volts AC and maximum output current less than or equal to 16 amperes AC.
- **Level 2 electric vehicle supply equipment:** A galvanically connected EVSE with a single-phase input voltage range from 208 to 240 volts AC and maximum output current less than or equal to 80 amperes AC.
- **Dual Input Level 1 and Level 2 electric vehicle supply equipment**
- **DC-output electric vehicle supply equipment with output power less than or equal to 350 kW:** A method that uses dedicated direct current (DC) electric vehicle/plug-in hybrid electric vehicle (EV/PHEV) supply equipment to provide energy from an appropriate off-board charger to the EV/PHEV in either private or public locations.

While the first three are treated almost equally, the DC-infrastructure follows different calculations approaches.

In the Energy Star Program (Energy Star, 2021), the maximum allowed power is defined depending on the operating mode, analogous to the Ecopassport Programme. The different operating modes can be associated to different states of definition J1772 of the Society of Automotive Engineers. An overview is given in Table 3-3.

Mode	Related Interface State (SAE J1772)	Description
No Vehicle Mode	State A	No Vehicle Mode is associated with State A, or where the EVSE is not connected to the EV. The EVSE is connected to external power.
Partial On Mode	State B1 or State B2	Partial On Mode is associated with State B1 or State B2 where the vehicle is connected but is not ready to accept energy. Sub-state B1 is where the EVSE is not ready to supply energy and sub-state B2 is where the EVSE is ready to supply energy.
Idle Mode	State C	Idle Mode is associated with State C, where the vehicle is connected and ready to accept energy and the EVSE is capable of promptly providing current to the EV but is not doing so.
Operation Mode	State C	Operation Mode is associated with State C, where the EVSE is providing the primary function, or providing current to a

		connected load (i.e., the relay is closed and the vehicle is drawing current)

Table 3-3: Operational Modes and Power States (Energy Star, 2021)

Calculations for Level 1 and Level 2 electric vehicle supply equipment

In the "No Vehicle Mode" - associated with SAE J1772 State A -, the power for Level 1 and Level 2 electric vehicle supply equipment shall be less than or equal to the following equation:

$$P_{No\,Vehicle\,Max} = 4 + P_{Wake} + P_{AUX}$$

$P_{No\,Vehicle\,Max}$: Maximum No Vehicle Mode Power Requirement [W]

P_{Wake}: No Vehicle Mode power allowance for the network connection with wake capability [W]

P_{AUX}: No Vehicle Mode power allowance for the sum of auxiliary features [W]

In the "Partial On Mode" - associated with SAE J1772 State B1 or B2 -, the power for Level 1 and Level 2 electric vehicle charging supply equipment shall be less than or equal to the following equation:

$$P_{Partial\,On\,Max} = 4 + P_{Wake} + P_{AUX}$$

$P_{Partial\,On\,Max}$: Maximum Partial On Mode Power Requirement [W]

P_{Wake}: Partial On Mode power allowance for the network connection with wake capability [W]

P_{AUX}: Partial On Mode power allowance for the sum of auxiliary features [W]

In the "Idle Mode" - associated with SAE J1772 State C -, the power for Level 1 and Level 2 electric vehicle supply equipment shall be less than or equal to the following equation:

$$P_{Idle\,Max} = (0.4 * \mathrm{Max}\,Current) + 4 + P_{Wake} + P_{AUX}$$

$P_{Idle\,Max}$: Maximum Idle Mode Power Requirement [W]

$\mathrm{Max}\,Current$: Nameplate Maximum Output Current, in amperes

P_{Wake}: Idle Mode power allowance for the network connection with wake capability [W]

P_{AUX}: Idle Mode power allowance for the sum of auxiliary features [W]

For the network connection and its related power, Energy Star (2021) distinguishes three different options:

- Wi-Fi or Ethernet Interface with Wake Capability
- Cellular with Wake Capability
- Other LAN (local area network) Interface with wake Capability

Users

The power allowances are defined, as follows:

$$P_{Wake,WiFi} = {}^{1.0}/_{n}$$

$$P_{Wake,Cellular} = {}^{2.0}/_{n}$$

$$P_{Wake,LAN} = {}^{1.0}/_{n}$$

$P_{Wake,WiFi}$: Power allowance for Wi-Fi or Ethernet Interface with Wake Capability [W]

$P_{Wake,Cellular}$: Power allowance for Cellular with Wake Capability [W]

$P_{Wake,LAN}$: Power allowance for other LAN (local area network) Interface with Wake Capability [W]

n: Number of outputs

If a charging infrastructure supports more than one network connection, only the one used during testing will be claimed.

The power allowances for auxiliary features can be calculated as follows:

$$P_{AUX} = P_{Display} + P_{Speaker} + P_{PLC} + P_{credit\ card} + P_{RFID} + P_{RGM} + P_{Occupancy\ Sensing}$$

P_{AUX}: Power allowance for the sum of auxiliary features [W]

$P_{Display}$: Power allowance for in-use High Resolution Display [W]

$P_{Speaker}$: Power allowance for in-use speaker [W]. Maximum: 1 W

P_{PLC}: Power allowance for in-use power line communication board [W]. Maximum: 1 W per port

$P_{credit\ card}$: Power allowance for in-use credit card reader. Maximum: 5 W

P_{RFID}: Power allowance for in-use radio frequency identification card system [W]. Maximum: 1.5 W

P_{RGM}: Power allowance for in-use revenue grade meter [W]. Maximum: 1 W

$P_{Occupancy\ Sensing}$: Power allowance for in-use occupancy sensing (camera, proximity sensor etc.) [W]. Maximum: 1.5 W

For a high resolution display, Energy Star (2021) allows the following power demand:

$$P_{Display} = \frac{4.0 * 10^{-5} * l * A + 119 * \tanh(0.0008 * (A - 200.0) + 0.11) + 6.0}{n}$$

$P_{Display}$: Power allowance for in-use High Resolution Display [W]

A: Screen area [in²]

l: Maximum Measured Luminance of the Display [cd/m²]

n: Number of outputs

For example, a single-output charging infrastructure with a maximum measured luminance of 300 cd/m² and a 5*5 inches screen would be allowed for a maximum of 2.7 W.

Calculations for DC-output electric vehicle supply equipment

In the “No Vehicle Mode” - associated with SAE J1772 State A -, the power for DC-output electric vehicle supply equipment shall be less than or equal to the following equation:

$$P_{No\ Vehicle\ Max} = (35.6 * \ln(Max\ Power)) - 54.3 + P_{Display} + P_{BMS}$$

$P_{No\ Vehicle\ Max}$: Maximum No Vehicle Mode Power Requirement [W]

$Max\ Power$: Nameplate maximum output power [kW]

$P_{Display}$: Power allowance for in-use High Resolution Display [W]

P_{BMS}: Power allowance for a battery management system in electric vehicle supply equipment with integrated battery pack that cannot be disabled during testing [W]

In the “Partial On Mode” - associated with SAE J1772 State B1 or B2 -, the power for DC-output electric vehicle supply equipment shall be less than or equal to the following equation:

$$P_{Partial\ On\ Max} = (35.6 * \ln(Max\ Power)) - 54.3 + P_{Display} + P_{BMS}$$

$P_{Partial\ On\ Max}$: Maximum Partial On Mode Power Requirement [W]

$Max\ Power$: Nameplate maximum output power [kW]

$P_{Display}$: Power allowance for in-use High Resolution Display [W]

P_{BMS}: Power allowance for a battery management system in electric vehicle supply equipment with integrated battery pack that cannot be disabled during testing [W]

$P_{Display}$ is calculated similar to the calculations for Level 1 and Level 2 electric vehicle supply equipment. For P_{BMS}, 15 W are defined as a maximum allowance.

In “Operation Mode”, the average loading-adjusted efficiency of DC-output electric vehicle supply equipment shall be calculated as follows:

$$Eff_{avg} = 0.02 * Eff_{25\%} + 0.11 * Eff_{50\%} + 0.09 * Eff_{75\%} + 0.78 * Eff_{100\%}$$

Eff_{avg}: Average loading-adjusted efficiency of DC-output electric vehicle supply equipment

$Eff_{25\%}$: Efficiency at 25% loading condition

$Eff_{50\%}$: Efficiency at 50% loading condition

$Eff_{75\%}$: Efficiency at 75% loading condition

$Eff_{100\%}$: Efficiency at 100% loading condition

Each efficiency at loading condition i shall be calculated as follows:

$$Eff_i = 0.15 * Eff_{i,20F} + 0.75 * Eff_{i,68F} + 0.1 * Eff_{i,104F}$$

Eff_i: Efficiency at loading condition i

$Eff_{i,20F}$: Recorded efficiency at loading condition i at 20° F

$Eff_{i,68F}$: Recorded efficiency at loading condition i at 68° F

$Eff_{i,104F}$: Recorded efficiency at loading condition i at 104° F

For DC-output electric vehicle supply equipment with output power less than or equal to 65 kW, the average loading-adjusted efficiency shall be greater than or equal to 0.93. For higher output power, the average loading-adjusted efficiency shall be reported.

Open question to stakeholders:

32) Does Energy Star miss relevant aspects?

3.2.2 Extended product approach: usage of charging infrastructure

In the previous section, a methodology to calculate the energy demand of charging infrastructure was presented. Both, the Ecopassport Programme and the Energy Star Program, necessarily make simplifications and define general parameters, especially regarding the real-life usage of charging infrastructure.

The aim of the extended approach is to point out where real-life may deviate from the assumed parameters. The focus is particularly on the actual use of charging infrastructure. Possible future developments are discussed, when appropriate.

The analysis is twofold: First, results for light-duty vehicles are presented as today’s main users of charging infrastructure. Afterwards, some shorter sections on heavy-duty vehicles are included. When discussing relevant parameters, a plausible range is given at the end of the respective subsection.

3.2.2.1 Charging habits of light-duty vehicle drivers

Today, the normal procedure for refuelling a car is to fuel at a gas station after the car has driven 500-1000 km on a full tank of gasoline. The actual time it takes to refuel a car depends on the size of the tank and the speed of the pump. A modern pump can deliver 30-50 litres gasoline per minute meaning that the typical tank size between 45 and 65 litres can be refuelled in a few minutes on average. In future with a high share of electric cars the “refuelling habits” will change dramatically. This applies in particular to the duration, frequency and location of the recharging process. These factors are reflected in the utilization of the different charging options.

The latest Consumer Monitor from the European Alternative Fuels Observatory (Vanhaverbeke et al., 2023) gives an overview where people charge their electric car. Based on responses from 1,378 battery electric vehicles drivers in ten EU countries (Austria, Belgium, Denmark, France, Germany, Hungary, Italy, Netherlands, Slovenia, Spain) Figure 3-4 shows that private recharging stations or wallboxes (Mode 3) are by far the most often used charging locations. 48% of all respondents claimed that they use such a recharging infrastructure daily or at least weekly. One third of all participants never use a private recharging station or a wallbox at home. Charging at a household socket (Mode 2) at home is also often used - daily or weekly - by 28% of all electric vehicle owners in the survey[120]. However, half of all participants never use a socket at home. A recharging stations or a wallbox at work (Mode 3) is used by 40% of all respondents. Half of them (20%) use this infrastructure daily or at least weekly. Public slow recharging infrastructure (Mode 3) - on street or public parking - is used daily or weekly by one fifth of all electric vehicle owners in the survey. However, another 59% use this infrastructure sometimes (monthly). The same applies to semi-public recharging stations, for example at restaurants or stores. Public fast charging (Mode 4) is used least frequently on a daily or at least weekly basis (10% of all respondents). At the same time, 68% of all respondents use public fast rechargers sometimes (monthly), probably for long-distance journey. Figure 3-4 shows an overview on the frequency of recharging at different locations.

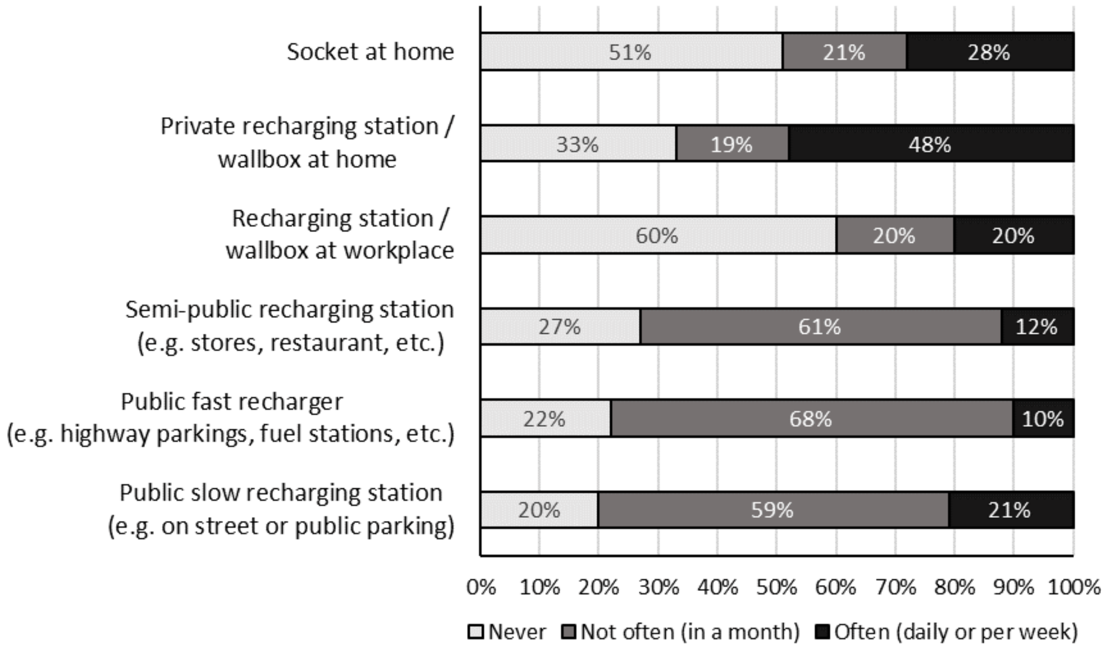

Figure 3-4: Recharging location and frequency used by EU BEV drivers. Own illustration with data from Vanhaverbeke et al. (2023)

[120] The survey does not contain any information on charging at sockets at work. It is known that some companies allow their employees to use their mobile charging equipment (Mode 2) at work as an interim solution. As the total charging demand does not change, the actual use of the charging infrastructure (frequency, duration) is not affected by the location.

Users

Similar results are shown in BDEW (2022). The survey among 2,964 electric vehicle users in Germany show that 74% of all respondents charge at home (Mode 2, Mode 3), 14% use public fast charging for everyday charging (Mode 4), while 54% use public fast charging (Mode 4) on the road. An overview is given in Table 3-4.

Used charging location	Share of respondents (N = 2,964)
Home	74%
Work	26%
Customer parking	31%
Public (normal power)	34%
Public (high power)	14%
On the road (high power)	54%

Table 3-4: Used charging locations according to BDEW (2022)

For privately owned light-duty vehicles, different studies show that most of the charging events - typically more than half of all charging events - take place at private charging points (Mode 2, Mode 3). The share varies between owners of single-family houses and multi-family houses. Less than one quarter of all charging events happens at public slow charging points (Mode 3). Public fast charging (Mode 4) and slow charging (Mode 3) at work both account for approximately 10% of all charging events (Preuß et al., 2021). An overview for different European countries from different studies is given in Figure 3-5. In the context of the Alternative Fuels Infrastructure Regulation (EU, 2023b), it is assumed that "around 40% of all recharging events for battery electric vehicles will take place at publicly accessible recharging points towards 2030" (EC, 2021a, p. 162), given an increasing share of users in urban areas without private parking.

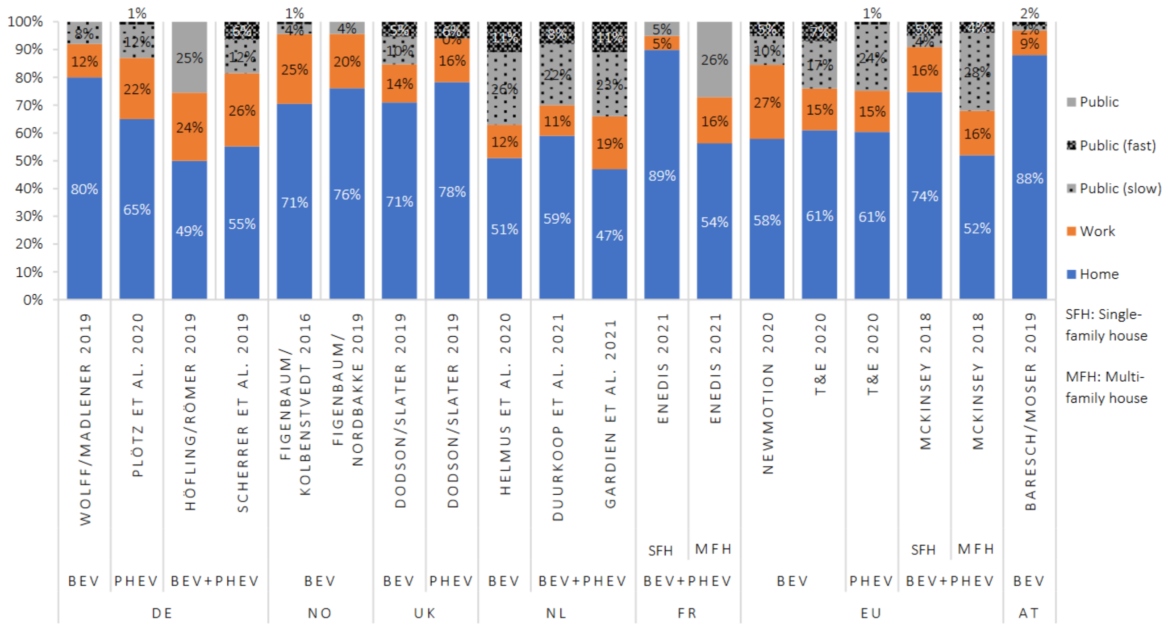

Figure 3-5: Overview of published shares of charging modes for different European countries (Preuß et al., 2021).

3.2.2.2 Charging events per week for light-duty vehicles infrastructure

In order to determine the utilisation of individual charging devices, the frequency of charging events is relevant. As shown in Figure 3-6, most electric vehicle drivers charge once or twice a week. Only 10% of all respondents claimed that they charge daily (BDEW, 2022). Since private charging with up to 22 kW is the dominating charging application (c.f. 3.2.2.1), one might assume that this charging behaviour is identical to the charging behaviour at private charging infrastructure with up to 22 kW (Mode 2, Mode 3). For the base case, it is assumed that 2 charging events will happen per week at private infrastructure with up to 22 kW. This is in line with AAAA Association P.E.P. (2018). Based on data of the ADAC database on electric vehicles, it can be concluded that less than 25% of all available models - often luxury vehicles - can charge at 22 kW AC (ADAC, 2023). Therefore, it is assumed that charging typically happens at 11 kW. In a "high" scenario, 3 charging events are assumed, while the "low" scenario contains charging once a week. Please note that the number of charging events at private work chargers might be higher. For example, ChargeUp Europe (2022) **suggests four time more charging at work AC charging infrastructure than at residential locations. Please note that controlled charging or vehicle-to-grid may incentivise more charging events at private locations.**

For domestic sockets (Mode 2), the charging behaviour is probably similar to the previously described charging at private charging points up to 22 kW. However, one might argue that vehicles are plugged in more often - at least for drivers with a high daily mileage -, due du lower charging power. Therefore, 4 charging events are suggest for the "high" scenario.

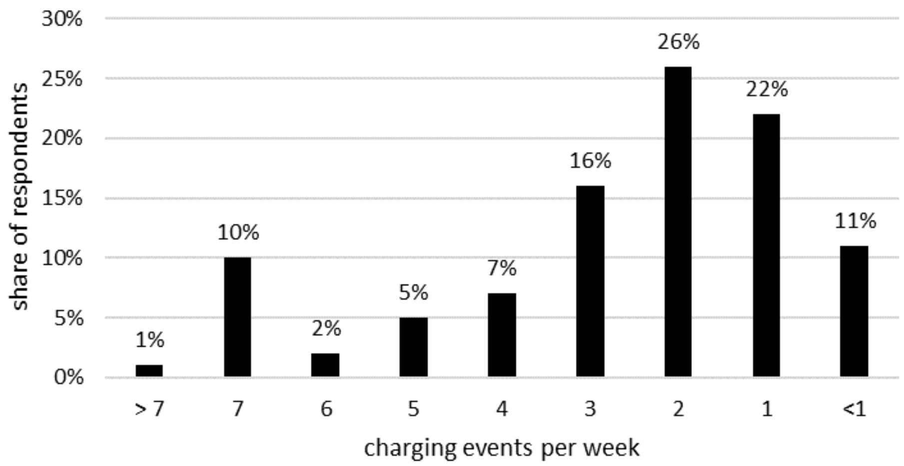

Figure 3-6: Charging events per week per user. Own illustration with survey data (N=2,964) from BDEW (2022)

For publicly accessible AC charging points (Mode 3), ChargeUp Europe (2022) reports 0.47 charging events per day. Numbers derived from publicly funded German charging locations are slightly higher with 1.2 charging events per day (median value), as shown in Figure 3-7b[121]. The Ecopassport Programme assumes two charging events per day at public normal charging infrastructure (AAAA Association P.E.P., 2018). All in all, 2 events per day seems plausible as an average value, given future growth of the EV fleet. This equals 14 events per week. In a “low” scenario, one charging event per day - or seven charging events per week - seems plausible. In an optimistic case, it is assumed that 4 charging events per day, as indicated by the whisker, can be reached.

For public high power charging (Mode 4), ChargeUp Europe (2022) reports 1.6 charging events per day for charging points with less than 100 kW power and up to 3 charging events per day on average with higher power. This is in line with data from publicly funded charging infrastructure in Germany, as shown in Figure 3-7a. Highly occupied charging points may even reach up to 9 charging events. The Ecopassport Programme suggest ten charging events per day (AAAA Association P.E.P., 2018). Given the fact that we are still in an early market phase and based on Figure 3-7a, two charging events are suggested as “low” scenario, four as base case, and nine as “high” scenario.

[121] For simplicity in data analysis, charging point and charging columns are treated similar in this analysis. One may argue that some charging columns have two charging points, which leads to a lower utilisation.

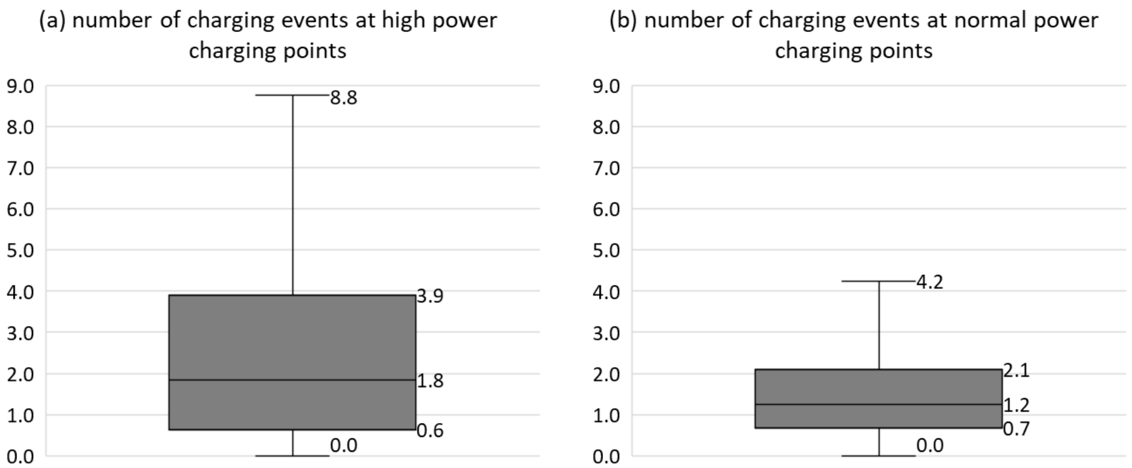

Figure 3-7: Boxplots for daily charging events at (a) high power (N=2,208) and (b) normal power (N=7,446) charging locations in Germany from July 2022 to June 2023. Own calculations with data from NLL (2024).

Table 3-5 sums up the expected charging events per week for the most important charging situations.

	Medium	Low	High
Domestic socket	2	1	4
≤ 22 kW, private	2	1	3
≤ 22 kW, restricted	14	7	28
≤ 22 kW, fully accessible	14	7	28
> 22 kW, restricted	28	14	63
> 22 kW, fully accessible	28	14	63

Table 3-5: Summary of expected charging events per charging point per week

Open questions to stakeholders:

33) Which changes are expected when having controlled charging and vehicle-to-grid?

- AC private: More charging events, as user plug-in more often?
- AC public: Same amount of charging events, but probably longer?
- DC: No changes?

34) Do you expect any deviation between the temporal utilisation at restricted infrastructure (for example at shops) in comparison with fully accessible infrastructure?

3.2.2.3 Temporal utilisation of charging infrastructure for light-duty vehicles

The temporal utilisation of a charging infrastructure shall be defined as the share of time when a vehicle is connected to the charging infrastructure, i.e. the share of time where the infrastructure is not available for other users. According to the ENERGY STAR program requirements for electric vehicle supply equipment, four modes can be distinguished (Energy Star, 2021). An overview is given in Table 3-3. The temporal utilisation not only contains the "operation mode", but also the "partial on mode" and the "idle mode" where a vehicle is connected but does not charge. This might be especially relevant for slow normal charging infrastructure (≤ 22 kW).

The temporal utilization of charging infrastructure is influenced by two parameters: (1) How often do vehicles plug in at the charging infrastructure (c.f. 3.2.2.2) and (2) how long are vehicles typically plugged in?

For charging with up to 22 kW at private locations (Mode 2, Mode 3), one might assume that each charging point is primarily used by one or two vehicles. This is also true for multi-family houses, assuming that each parking lot is dedicated to one owner and has its own charging infrastructure. Given the weekly charging behaviour in Figure 3-6, one might assume one to three charging events per vehicle. This is in line with the Ecopassport Programme that assumes two charging events per week and an average plug-in time of 12 hours (AAAA Association P.E.P., 2018). These assumptions fit quite well for overnight charging. The preparatory study for the Ecodesign and Energy Labelling Working Plan (EC, 2021b) suggests 60% of temporal utilisation, probably assuming users to connect their vehicle every evening. However, this is not in line with the observed user behaviour. Therefore, the temporal utilisation is about 14%. If assuming only charging at one day, the utilisation reduces to 7%, for three days of charging it increases to 21%. Please note that controlled charging and vehicle-to-grid will be an incentive to connect the vehicle more often in the future. The same applies to private charging locations for selected users, for example at work, where multiple users share one charging point. In this case, charging behaviour can be expected to be similar to that at public normal charging points.

For charging at domestic household sockets (Mode 2) one might consider one to four charging events per week, based on the user behaviour in Figure 3-6. This is in line with the Ecopassport Programme that assumes two charging events per week and an average charging time of 7.3 hours at 3.7 kW (AAAA Association P.E.P., 2018). However, typically the power installation at domestic sockets in old and not renewed houses is equipped for a permanent power of 2.3 kW (230 V, 10 A) (ADAC, 2024). With less obsolete electrical installation, it is possible to charge with up to 3.7 kW (230 V, 16 A) permanently, as suggested by the Ecopassport Programme (AAAA Association P.E.P., 2018). Therefore, in the base case, it is assumed that there are two charging events per week, lasting 11.7 hours per charging event. This means a temporal utilisation of 14% in the base case. In the "high" case, the number of charging events per week doubles, and also does the utilisation. In the "low" case, a modern electrical installation with up to 3.7 kW and one charging events per week is assumed, resulting in 4% temporal utilisation. Please note that in these cases it is assumed that the vehicle is only plugged in, if it is really charging.

For public charging, the calculation is slightly more complicated, since multiple vehicles share a common infrastructure. The utilisation is mainly defined by the distribution of charging demand throughout the day. Potential over- or under-dimensioning of the public infrastructure can also influence the utilisation. Over-dimensioning generally leads to lower utilisation. Under-dimensioning is likely to result in increased utilisation and a shift to off-peak times. Figure 3-8 shows an exemplary profile in Germany for one week in August 2022, based on data from NLL (2024). It is clearly evident that charging events happen mostly during daytime between 06:00 and 18:00. However, while high power charging (> 22 kW) is almost not existent in night-time hours - and therefore the temporal utilisation is limited - there are still vehicles pugged in at normal charging infrastructure (≤ 22 kW). Additionally, there is an above-average charging demand at Saturdays and a below-average charging demand at Sundays, especially at high power charging infrastructure.

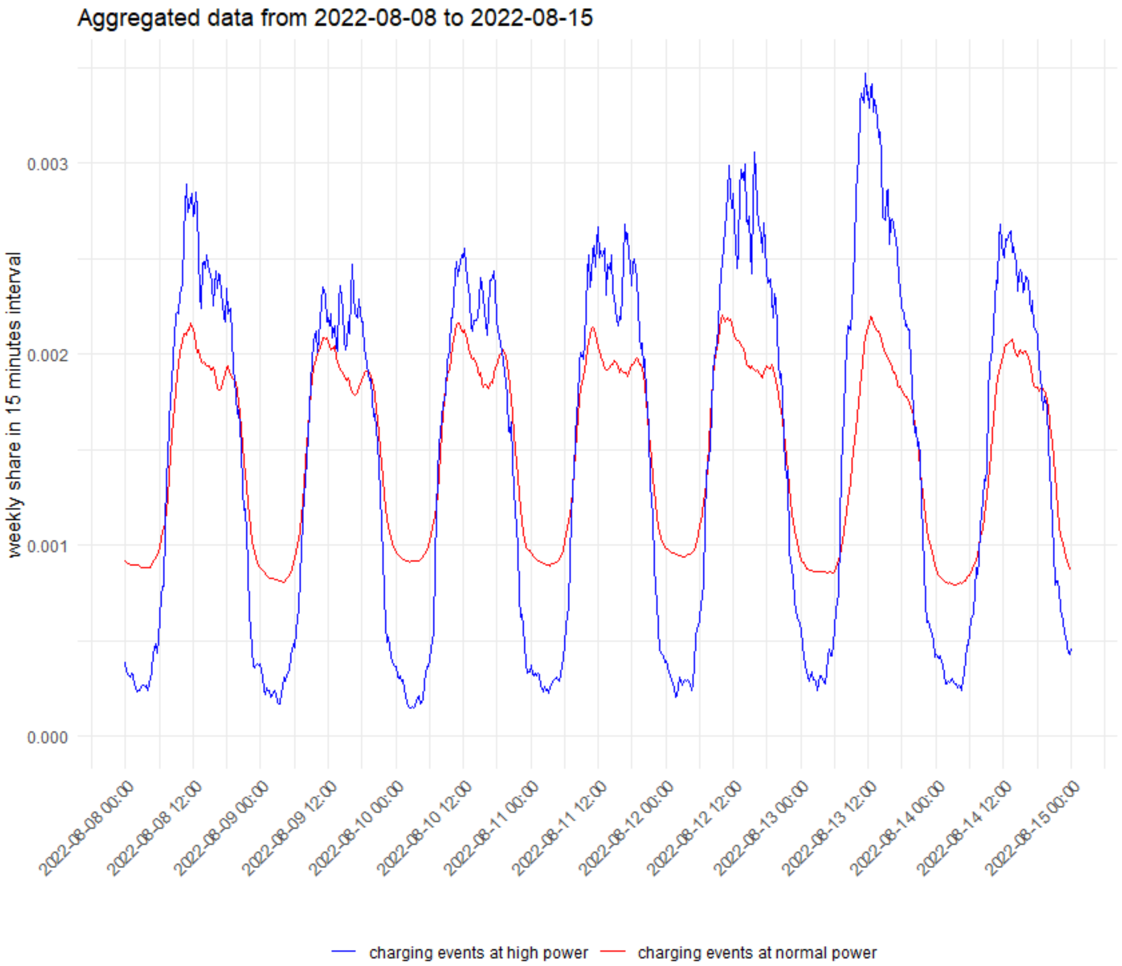

Figure 3-8: Distribution of charging events from 2022-08-08 to 2022-08-15 (Mo-So) at publicly funded charging infrastructure in Germany. Own calculations with data from NLL (2024)

Based on data from 22,200 public charging stations in Germany from 2019 until the beginning of 2022, Hecht et al. (2022) showed that 90% of all charging points at normal power are occupied less than 25% of the day. With regard to high power charging points, the occupation is even lower, typically below 10%. Additional information are given in Figure 3-9.

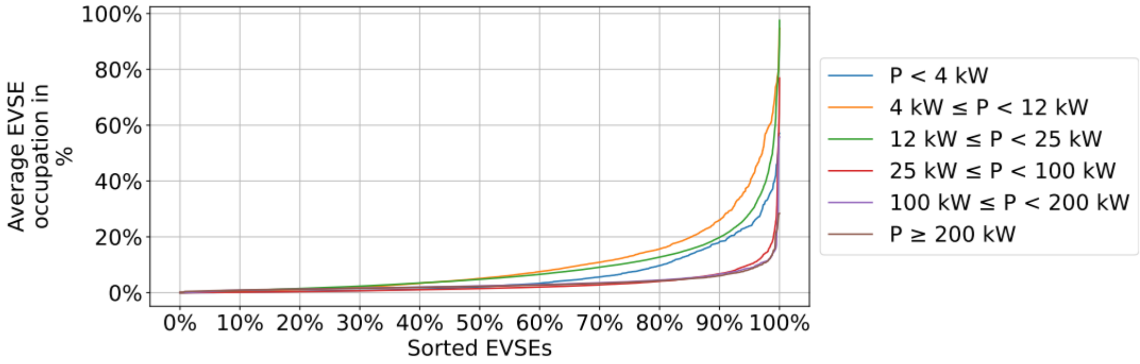

Figure 3-9: Average occupation per public electric vehicle supply equipment unit (EVSE, single charging point) categorized by the power level (Hecht et al., 2022)

Additional analysis of publicly funded public charging locations in Germany from July 2022 to June 2023[122] show an average temporal utilisation of 6% for high power charging points (> 22 kW) (Mode 4). An overview is given in Figure 3-10a. Industry data from FASTNED claims that charging points were occupied 13% of the day in Q1 2023 on average. The best stations even reached a temporal utilisation of 38% (Fastned, 2023). Numbers from Norway, as a more mature market, show an average temporal utilization of 18% for public high power charging points with at least 150 kW at gas stations (Brickenstein et al., 2023). As a rule of thumb, Strategy& assumes - in accordance with different charging point operators - a maximum utilization of 25%. At higher utilisation rates, user dissatisfaction is to be expected due to waiting times (Brickenstein et al., 2023). The Ecopassport Programme suggests 10 charging events per day per, lasting one hour (AAAA Association P.E.P., 2018). This equals a temporal utilisation of 42%. However, increasing charging power (Ecopassport Programme calculated with 50 kW) favours shorter charging times and therefore probably lower temporal utilisation. Given the ongoing ramp-up and early market phase of public charging infrastructure, one might assume 6% - today's median value - as lower value for the utilisation of high power charging infrastructure. As a base case value, a doubling of the utilisation to 12% seems realistic, given that this is the upper quartile at publicly funded charging locations in Germany. As an optimistic value, 25% - according to the rule of thumb mentioned above - is plausible. Please note that this is still an average value and some highly trafficked charging points may achieve higher values.

For normal charging power (≤ 22 kW) (Mode 2, Mode 3), the analysis of publicly funded German charging locations show a temporal utilisation of 17%, as shown in Figure 3-10b. However, it also visible that the spread is higher than for high power charging. In Norway, the average temporal utilization at normal charging points is below 10%. **However, when focussing on charging points in larger main cities, the average is 18%** (Brickenstein et al., 2023)**. The Ecopassport Programme assumes two charging events per day, lasting 3 hours each** (AAAA Association P.E.P., 2018)**.** This results in a temporal utilisation of 25%. Today, many charging point operators charge blocking fees if charging points are blocked for a longer period of time - typically more than four hours. This leads to comparatively few vehicles being plugged in overnight (c.f. Figure 3-8). However, this could change in the future if controlled charging or even vehicle-to-grid becomes possible. As an average value, 18% temporal utilisation seems plausible. This is in line with the findings from Germany and from Norway. As a lower value, 9% - the lower quartile at publicly funded charging locations in Germany and half of the average value, is suggested. Taking into

[122] For simplicity in data analysis, charging point and charging columns are treated similar in this analysis. One may argue that some charging columns have two charging points, which leads to a lower utilisation.

account the possibility of charging overnight - especially in combination with controlled charging -, 50% utilisation seems a good upper value.

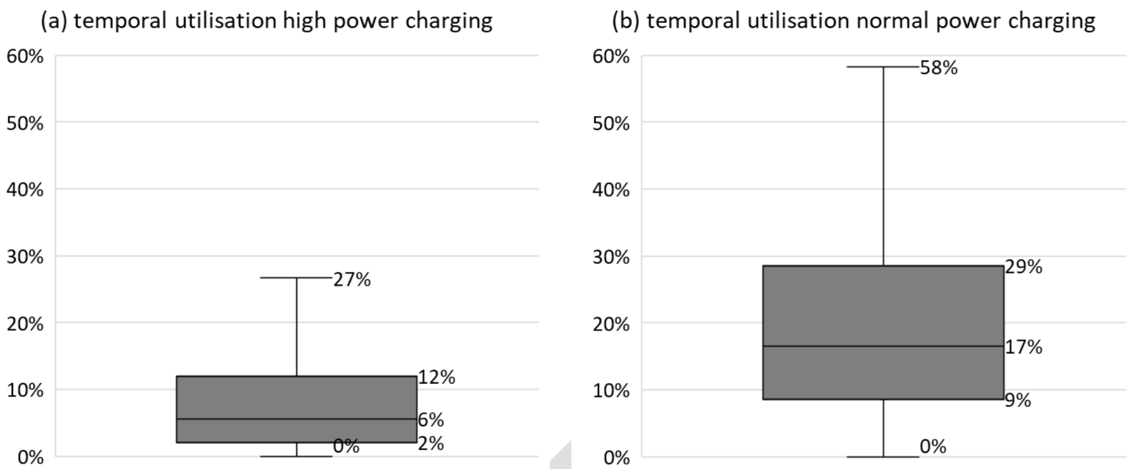

Figure 3-10: Boxplots for temporal utilisation of publicly funded (a) high power (N=2,208) and (b) normal power (N=7,446) charging locations in Germany from July 2022 to June 2023. Own calculations with data from NLL (2024).

Table 3-6 sums up the assumed temporal utilisation of different charging infrastructure types. Please note that for restricted infrastructure, for example at shops, the values are identical to fully accessible infrastructure. Please also note that controlled charging and vehicle-to-grid are not considered in the utilisation at this point and may further increase the share of utilization, especially for normal power charging infrastructure. A first estimate for private charging points with up to 22 kW is given in brackets.

	Medium utilisation	Low utilisation	High utilisation
Domestic socket	14%	4%	28%
≤ 22 kW, private	14%	7%	21% (60%)
≤ 22 kW, restricted	18%	9%	50%
≤ 22 kW, fully accessible	18%	9%	50%
> 22 kW, restricted	12%	6%	25%
> 22 kW, fully accessible	12%	6%	25%

Table 3-6: Summary of expected temporal utilisation of charging infrastructure

Open questions to stakeholders:

35) Do you expect any deviation between the temporal utilisation at restricted infrastructure (for example at shops) in comparison with fully accessible infrastructure?

Users

36) Will the utilisation at private infrastructure for commercial use (for example at work or for fleet operators) be within the given range?

37) How might controlled charging and vehicle-to-grid change the utilisation?

38) Do you expect major changes or any trends regarding the charging behavior within the next years?

3.2.2.4 *Energy demand and charging duration of light-duty vehicles*

In the following, the average energy demand per charging event of light-duty vehicles, as well as the actual charging time shall be analysed. Please note that the actual charging time differs from the previously described utilisation, as the utilisation includes also time when the vehicle is connected but not charging.

For charging up to 22 kW the recharged energy can be calculated as follows:

$$e_{CE}\ [kWh] = mileage_{\ recharged}\ [km] * consumption_{vehicle}\ [\frac{kWh}{km}]$$

Correspondingly, the charging duration can be calculated[123]:

$$d_{CE}\ [h] = \frac{e_{CE}\ [kWh]}{p\ [kW]}$$

For charging up to 22 kW at private locations (Mode 2, Mode 3) the Ecopassport Programme assumes an average daily mileage of 43 km, of which 90% (38.7 km) are recharged at private or semi-public locations (AAAA Association P.E.P., 2018). Resulting in 16,000 km, this is higher than the European average yearly mileage of 11,298 km in 2019. However, it should be mentioned that the annual mileage of passenger cars varies widely between different member states. For example, in Germany vehicles travel 13,602 km per year while vehicles in Italy travel 8,891 km per year (ADEME et al., 2023). The Ecopassport mileage is based on data from electric vehicle owners in France. Assuming - rather conservative - 20 kWh/100km[124] (AAAA Association P.E.P., 2018), a vehicle needs to recharge 7.74 kWh/day or 54.18 kWh/week[125]. Assuming 11 kW charging power - the typical AC charging power of today's vehicles that can be reached throughout the whole charging process - and 54.18 kWh/week results in 4.93 hours of charging. To determine the highest possible charging duration and energy demand, a consumption of 32.2 kWh/100km (EV-Database, 2024) is assumed. The charging power remains at 11 kW. This results in 87.23 kWh and 7.93 hours per week. The lowest energy demand and charging time is defined by a consumption of 13.9 kWh/100km and 22 kW charging power. This results in 37.66 kWh and 1.71 hours per week.

For domestic household sockets (Mode 2), the energy demand per week is similar to the case with up to 22 kW at private locations. However, typically the power installation at domestic sockets is equipped for a permanent power of 2.3 kW (230 V, 10 A) (ADAC, 2024).

[123] Please note that there is a small simplification, as the charging power also needs to include charging losses.

[124] According to real-world data from EV-Database (2024), the average value is 18.8 kWh/100km, ranging from 13.9 kWh/100km to 32.2 kWh/100km.

[125] Please note that ChargeUp Europe (2022) reports 100 kWh/week at residential locations and 400 kWh/week at workplace locations, based on a membership survey. However, those number probably refer to charging infrastructure commercially operated, for example in multi-family houses, not to fully private locations.

With obsolete electrical installation, as are all those in buildings constructed or renovated along the last 30 years, it is also possible to charge with up to 3.7 kW (230 V, 16 A), as suggested by the Ecopassport Programme (AAAA Association P.E.P., 2018). In some countries even 7.4 kW in monophase are possible, by using a suitable IEC 60309 socket (32A "blue" socket). However, 3.7 kW is only assumed as the lower bound in the low scenario.

For public charging up to 22 kW (Mode 2, Mode 3), AAAA Association P.E.P. (2018) suggests two charging events per day, lasting three hours at 22 kW. This equals 42 hours and 924 kWh per week. However, this seems quite high compared to real-world data. ChargeUp Europe (2022) reports 0.47 charging sessions per day with an average energy consumption of 12.6 kWh. This results in 41.45 kWh per week. As shown in Figure 3-11, the sales-weighted battery size in the individual segments has converged in recent years. A significant increase in energy consumption per charging process is therefore currently not expected. In the base case, 19 kWh of charging per charging event are suggest, based on the data from publicly funded German charging points in Figure 3-12b. Taking into account 14 charging events per week (c.f. 3.2.2.2), 266 kWh per week are recharged at one charging point per week. As a "low" scenario, 16 kWh per charging event and seven charging events per week are assumed, resulting in 112 kWh. Finally, as a "high" scenario, 26 kWh per charging event - taking into account possible growing battery size - and 28 charging events per week result in 728 kWh. Analogue to normal private charging, 11 kW charging power is assumed in the base case and in the "high" scenario. 22 kW are assumed in the "low" scenario. The resulting charging durations are shown in Table 3-7.

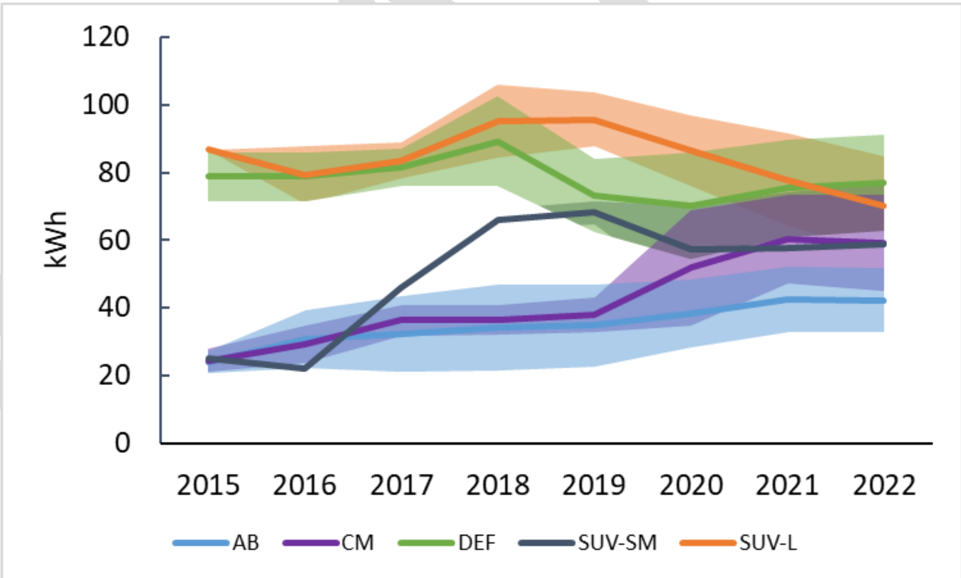

Figure 3-11: European sales-weighted average battery size by vehicle segment from 2015 to 2022. Own illustration, based on Link et al. (2024)

For public high power charging (> 22 kW) (Mode 4), ChargeUp Europe (2022) reports 18.8 to 22.8 kWh per charging event on average, depending on the charging power. This is in line with the results from the German charging infrastructure sample, shown in Figure 3-12a (lower quartile: 19.9 kWh, median: 25.3 kWh, upper quartile: 29.3 kWh). Again taking into account the early market phase and a possible underutilization of the charging infrastructure, the upper quartile is taken as base case. As "low" scenario, the median value is considered. Finally, the upper whisker (42.5 kWh) serves as "high" scenario. Taking into account 28, 14, and 63 charging events (c.f. 3.2.2.2), the scenarios result in 820 kWh for the base case, 607 kWh in the "low" scenario, and 2,678 kWh in the "high" scenario. For comparison, the AAAA Association P.E.P. (2018) assumes 3,500 kWh per week. Today, most vehicles need approximately 30 minutes to recharge from 10% battery state of charge to 80% state of charge. This describes the typical high power charging event and is also in line with the analysis of the NLL (2024) data for Germany and the analysis from Hecht et al. (2022). Therefore, 30 minutes per charging event are assumed, resulting in the weekly charging duration shown Table 3-7.

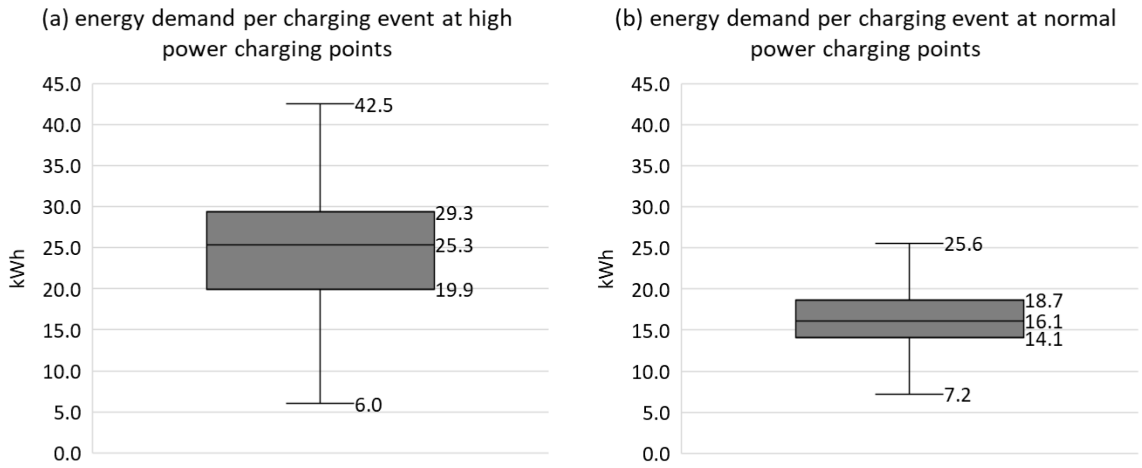

Figure 3-12: Boxplots for energy demand per charging event at publicly funded (a) high power (N=2,208) and (b) normal power (N=7,446) charging infrastructure in Germany from July 2022 to June 2023. Own calculations with data from NLL (2024).

	Energy demand [kWh/week]			Charging duration [h/week]		
	Medium	Low	High	Medium	Low	High
Domestic socket	54.18	37.66	87.23	23.56	10.18	37.93
≤ 22 kW, private	54.18	37.66	87.23	4.93	1.71	7.93
≤ 22 kW, restricted	266	112	728	24.18	5.09	66.18
≤ 22 kW, fully accessible	266	112	728	24.18	5.09	66.18
> 22 kW, restricted	820	607	2,678	14	7	28
> 22 kW, fully accessible	820	607	2,678	14	7	28

Table 3-7: Expected energy demand and charging duration at charging locations

Open questions to stakeholders:

39) Do you expect increasing energy demand per charging event in the future?

40) Do you expect any deviation between the temporal utilisation at restricted infrastructure (for example at shops) in comparison with fully accessible infrastructure?

41) What do you expect regarding 22 kW AC charging? Today, only a minority of the vehicles can charge with up to 22 kW. However, bigger batteries may support the diffusion of 22 kW charging.

42) Do you expect declining charging duration per charging event in the future for fast charging?

3.2.2.5 Partial on mode and idle mode of charging infrastructure for light-duty vehicles

As shown in Table 3-3, there are situations when a vehicle is plugged in, but no energy is delivered. There are different reasons, for example the vehicle is already fully charged. These situations are referred to as “partial on mode” - the vehicle is connected but not ready to accept energy - and “idle mode” - the vehicle is connected and ready to accept energy and the infrastructure is capable of providing energy, but not doing so -. In the following, the corresponding time will be referred to as “idle time”.

In principle, the idle time can be calculated as the difference between the time the infrastructure is used, shown in subchapter 3.2.2.3, and the actual charging time, shown in subchapter 3.2.2.4.

Charging at the domestic socket (Mode 2) represents a special case. As a basic assumption, we assumed no idle time for those charging equipment. Please note that the numbers of subchapter 3.2.2.3 and 3.2.2.4 do not fit perfectly to each other, since there are different approaches to calculate the charging demand.

For normal charging up to 22 kW at private locations (Mode 2, Mode 3), it is assumed that the charging infrastructure is occupied 14 % (24 hours per week) in the base case. At the same time, a charging duration of 4.93 hours per week (3%) is assumed. Therefore, the idle time accounts for 11% (19 hours per week). This is below the assumption of EC (2021b) that initially assumed 40%, probably still thinking that vehicles will be plugged in all day. Doing the same calculation for the “low” scenario and for the “high” scenario results in 6% idle time (10.29 hours per week) and 17% idle time (28.07 hours per week).

For normal charging at fully accessible locations, idle times of 4% (base case), 6% (“low scenario”, and 11% (“high” scenario) can be calculated. This is again lower than the value in EC (2021b) that assumed 20%. However, blocking fees are a plausible reason why vehicles are no longer plugged in than necessary.

For public high power charging (Mode 4), we derive 6% (base case), 2% (“low” scenario), and 9% (“high” scenario) idle time. This is slightly lower than assumed in EC (2021b) that assumed 10% idle time.

	Medium idle time	Low idle time	High idle time
Domestic socket	0%	0%	0%
≤ 22 kW, private	11%	6%	17%
≤ 22 kW, restricted	4%	6%	11%
≤ 22 kW, fully accessible	4%	6%	11%

Users

> 22 kW, restricted	6%	2%	9%
> 22 kW, fully accessible	6%	2%	9%

Table 3-8: Expected share of idle time of the charging infrastructure

Open questions to stakeholders:

43) Do we need to redefine the case of charging at domestic sockets, so that the numbers in 3.2.2.3 and in 3.2.2.4 fit to each other?

44) Do you expect any deviation between the temporal utilisation at restricted infrastructure (for example at shops) in comparison with fully accessible infrastructure?

45) Will the utilisation at private infrastructure for commercial use (for example at work or for fleet operators) be within the given range?

46) How might controlled charging and vehicle-to-grid change the utilisation?

3.2.2.6 Charging habits of heavy-duty vehicle drivers

Today, diesel trucks typically carry up to 1,500 litres of diesel, allowing operational ranges of more than 4,000 kilometres without refuelling. Additionally, the vehicles can be refuelled at a suitable infrastructure within 15 minutes. However, very few vehicles actually need a range of several thousand kilometres. Figure 3-13 shows the distribution of daily driving ranges of German trucks. The figure is divided into rigid trucks with a mean daily mileage of 256 km and tractor-trailer trucks with a mean daily mileage of 448 km (Speth & Plötz, 2024). Similar results for a European truck fleet can be found in Basma et al. (2021). The consumption is roughly 1 kWh/km to 1.1 kWh/km on average- maybe slightly higher in early years (Speth & Plötz, 2024).

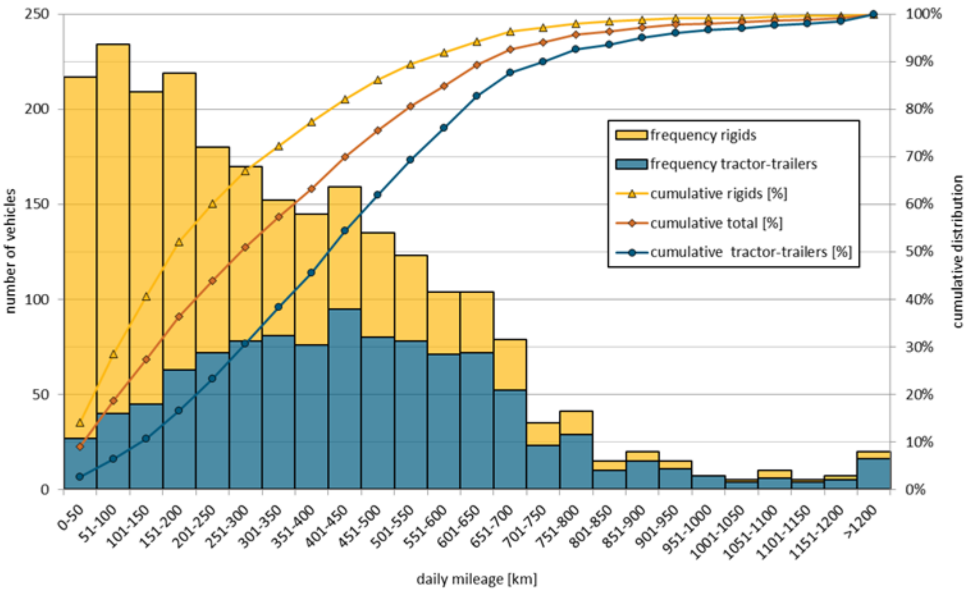

Figure 3-13: Distribution of daily km travelled of German heavy-duty vehicles (N=2,410). Speth and Plötz (2024) with data from WVI et al. (2012).

As there are almost no electric heavy-duty vehicles on the road today, there is not much information on the charging behaviour of battery electric vehicles. Given the daily mileage and the anticipated range development of battery electric vehicles (today: up to 400 km, 2030: 350 to 1,000 km) (NOW, 2023), it is likely that battery electric trucks will need to recharge on a daily basis. The International Council on Clean Transportation (ICCT) assumes that half of the vehicles will charge only once a day at overnight charging infrastructure. Other vehicles, with higher mileage, will need a second charging event to fulfil their daily driving (Ragon et al., 2022). In principle, the legally defined driving breaks of 45 minutes after 4.5 hours of driving - approximately 300 to 350 km - can be used for this purpose (EU, 2006). The Megawatt Charging System (MCS), currently under development, will provide the technical framework to recharge a truck in less than 45 minutes (CharIN, 2023).

Figure 3-14 shows a simulated battery electric heavy-duty vehicle fleet and its charging behaviour throughout the day. For the vehicles, a range of approximately 500 km is assumed. It is evident that most charging can be done with a charging power of less than 44 kW, typically overnight at the depots. 44 kW can in principle be done with alternating current. Higher power is mainly needed for intermediate charging in the midday-hours. While charging with up to 350 kW is still often used in the depots, megawatt charging with significantly more than 350 kW will be needed at public charging locations, mainly for long-haul trucks (Speth & Plötz, 2024). The maximum charging power will increase, industry estimates assume up to 1,500 kW by 2030 (NOW, 2023).

Users

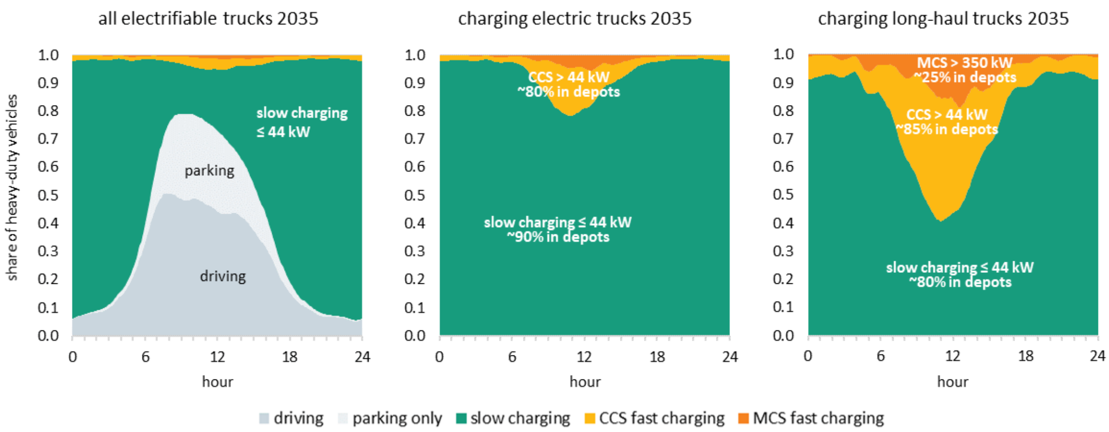

Figure 3-14: Simulated driving and charging behaviour of battery electric heavy-duty vehicles in 2035. Left panel: All feasible HDVs, middle panel: only charging HDVs, right panel: only charging long-haul (>500 km per day) HDVs. (Speth & Plötz, 2024)

3.2.2.7 Temporal utilisation of charging infrastructure for heavy-duty vehicles

As there is almost no charging infrastructure for heavy-duty vehicles today, it is hard to obtain a real-world utilisation.

A first estimate for high-power charging (Mode 4) can be made, using queuing theory (Speth et al., 2022). The following assumptions can be made:

- High-power charging will be used as intermediate charging in midday hours, especially when talking about charging with more than 350 kW (“megawatt charging”) (Speth & Plötz, 2024).
- Approximately 6 to 10% of all charging events will happen in the most trafficked hour of the day, given today’s traffic volume throughout the day.
- The duration of charging will be around 30 to 60 minutes, given expected battery technology and the mandatory 45 minutes break after 4.5 hours of driving (EU, 2006).
- Drivers will only accept short waiting periods. As an assumption, 5 minutes on average seems plausible. This means that the waste majority of all drivers won’t wait at all, but some will wait longer than 5 minutes (Speth et al., 2022).

Given those assumptions and assuming a queuing system as defined in Speth et al. (2022), the daily charging events can be calculated. The results are shown in Table 3-9. The more charging points a charging location will have, the more the number of possible charging events per hour will be at the theoretical optimum (2 charging events per point at 30 minutes charging and 1 charging event per point at 60 minutes charging), as it is more likely to find a free charging point at a huge location than on a small location.

Charging points	Hourly charging events in peak hour		Daily charging events (6%)		Daily charging events (10%)	
	30 min charging	60 min charging	30 min charging	60 min charging	30 min charging	60 min charging
2	1.97	0.75	33	12	20	8

10	16.85	7.78	281	130	169	78

Table 3-9: Charging events at high power charging locations for heavy-duty vehicles, based on queuing theory and an assumed peak traffic in the worst hour of 6% or 10% of daily traffic.

For high power charging with more than 350 kW, the lowest utilisation will be reached for a small charging location (e.g. 2 charging points), 60 minutes of charging, and a low peak traffic (e.g. 10%). Given eight charging events per day - four charging events per charging point -, the temporal utilisation will be 17%. The highest utilisation will be reached for huge charging locations (e.g. 10 charging points), 30 min of charging, and a low peak traffic (e.g. 6%). For a base scenario, on might assume the average of 38% utilisation. Please note that those values are highly uncertain, as the actual distribution of charging events throughout the day is unknown today. It is possible that chargers will be less occupied, for comfort reasons. On top of that an optimally dimensioned charging infrastructure is calculated. One might also assume that the utilisation at private and restricted areas is similar, as the infrastructure is still used in a commercial context and dimensioning is done for the traffic that actually needs to be served. Therefore, no different values for different charging locations are given.

For high power charging with more than 50 kW up to 350 kW (Mode 4), a charging duration of 60 min is more likely, given the expected energy demand of approximately 350 kWh after 4.5 hours of driving. Therefore, low utilisation might be similar to the low utilisation for charging infrastructure > 350 kW. However, the high utilisation is reached for huge charging locations (e.g. 10 charging points), 60 min of charging, and a low peak traffic (e.g. 6%). Again the medium utilisation is assumed as average between both parameters and it is not distinguished between different charging locations.

Charging power below 50 kW power (Mode 4, Mode 3 up to 44 kW possible) will be used for overnight charging. Therefore, one charging event per day seems plausible in the base case. For one-shift service, a minimum rest period of approximately 14 hours seems reasonable, as the maximum driving time is limited to 10 hours (EU, 2006). This results in 58% temporal utilisation. For two-shift service, the rest period is therefore at least 4 hours. Therefore, in the “low” scenario, only one charging event with 4 hours is assumed. In the “high” scenario, one could assume two charging events, one with 14 hours and one with 4 hours. Again, we assume no difference between private and public charging points.

	Medium utilisation	Low utilisation	High utilisation
≤ 50 kW	58%	17%	75%
≤ 350 kW	36%	17%	54%
> 350 kW	38%	17%	59%

Table 3-10: Summary of expected temporal utilisation of charging infrastructure for heavy-duty vehicles.

3.2.2.8 Energy demand and charging duration of heavy-duty vehicles

Manufacturers announced vehicle ranges of 350 to 1,000 km by 2030 (NOW, 2023). As shown in Figure 3-13, the average daily mileage is smaller (256 km rigid trucks and 448 km tractor-trailer trucks). Since the consumption is about 1.0 and 1.1. kWh/km (Speth & Plötz, 2024), the mileage can be directly transferred to energy. One might assume the energy demand of 4.5 hours of driving - the legally binding maximum driving time per stint (EU, 2006) - as a proxy for the energy demand per charging event, approximately 350 km or 350 kWh. Considering technical improvement and the announcements of the manufacturers, one might argue that in the “high” scenario vehicles will manage to drive two stints with one charge (750 km, 750 kWh).

For charging up to 50 kW (Mode 4, Mode 3 up to 44 kW possible), these assumptions lead to a daily energy demand of 350 kWh in the base case scenario. In a “low” scenario, only one charging events of 4 hours is expected. One might assume half of the energy demand. In the “high” case, one long charging event and one short charging event are assumed, leading to 525 kWh energy demand. The charging duration is taken from 3.2.2.7.

For charging up to 350 kW (Mode 4), four charging events per charging point were assumed in the “low” scenario in 3.2.2.7, each lasting one hour. For the “high” scenario, 13 charging events were assumed, again each lasting one hour. For the base scenario, an average value was taken, resulting in 8.5 charging events per day, lasting one hour. Assuming 350 kWh per charging event, the energy demand can be calculated, as shown in Table 3-11.

For charging with more than 350 kW (Mode 4), 4 charging events per charging point per day were calculated in the “low” scenario and 28 charging events per charging point per day were calculated in the “high” scenario. For the base scenario, the average value, 16 charging events, were taken. The actual charging time can be considered to be 30 minutes. Again, the energy demand can be calculated by multiplying the amount of charging events with 350 kWh per charging event.

	Energy demand [kWh/day]			Charging duration [h/day]		
	Medium	Low	High	Medium	Low	High
≤ 50 kW	350	175	525	14	4	18
≤ 350 kW	2,975	1,400	4,550	8.5	4	13
> 350 kW	5,600	1,400	9,800	8	2	14

Table 3-11: Expected energy demand and charging duration at charging locations for heavy-duty vehicles

3.2.2.9 Partial on mode and idle mode of charging infrastructure for heavy-duty vehicles

Similar to high power charging infrastructure for light-duty vehicles, one might argue that there will be almost no partial on mode or idle mode for charging with more than 50 kW. Idle time could only arise, if vehicles manage to charge within 30 minutes, but the driver is not allowed to remove the vehicle, due to the mandatory break of 45 minutes. However, even in this case, the vehicle could be disconnected from the charging infrastructure.

For charging below 50 kW, it is assumed that the charging infrastructure will be connected to a charging management system, so that there will be also almost no idle time. One might argue that the charging event is controlled, so that the charging power is kept to a minimum, while using as much of the available time as possible.

A more detailed analysis is beyond the scope of this preparatory study, given the high uncertainty regarding framework parameters of public charging.

Open question to stakeholders:

47) Given the early stage of charging infrastructure for heavy-duty vehicles, do you have remarks on the presented assumptions or any initial data from real-world usage?

3.2.3 Technical system approach: charging infrastructure as connection between electricity grid and vehicles

As already mentioned, charging infrastructure connects electric vehicles to the electricity grid. Therefore, the charging infrastructure also influences the efficiency of the electricity grid and the vehicles itself. However, as losses in the grid and the vehicle are part of the indirect energy consumption effects in subtask 3.2 (chapter 3.3), the technical system approach is skipped at this point.

3.2.4 Functional system approach: alternatives for charging

Charging infrastructure connects electric vehicles to the electricity grid. Up to now, the focus was on conductive chargers (plugs). However, there are alternatives to transfer electrical energy to vehicles.

Battery swapping for light-duty vehicles: If battery swapping is used, the vehicle battery is automatically removed from the vehicle and replaced with a charged battery. There is one commercial provider for battery swapping in Europa - Nio. The battery swap stations can exchange a battery in three minutes (NIO, 2024). However, light-duty vehicle manufacturers would need to agree on common standards to enable a large-scale application of battery swapping. However, such a standard is not yet available in Europe. From a technical point of view, the actual charging infrastructure - or more accurate the plug - is still needed to charge the batteries in the battery swap station, even though it can be designed differently.

Inductive charging for light-duty vehicles: Inductive charging is another option to transfer electricity to a battery electric vehicle. Resonant electromagnetic induction is used to transmit electricity to the car. In contrast to charging infrastructure that relies on plugs, inductive charging can - in principle - be used statically while parking and dynamically while driving (Aydin et al., 2022). Although scientific publications show increasing efficiency- up to 98% - there is no commercially available system on the market today (Aydin et al., 2022).

Battery swapping for heavy-duty vehicles: Similar to light-duty vehicles, battery swapping can be applied to heavy-duty vehicles. First batteries swap stations are installed in China (Cui et al., 2023). However, similar to battery swapping for light-duty vehicles, there is a lack of standards so that interoperability between different manufacturers is an issue. For Europe, no products are commercially available.

Inductive charging for heavy-duty vehicles: Similar to inductive charging for light-duty vehicles, there is no application ready on the market.

Electric road systems for heavy-duty vehicles: The AFIR (EU, 2023b) mentions electric road systems as a possible options to charge vehicle while driving. Electric road systems include overhead lines for catenary vehicles, conductor rails, and dynamic inductive charging. Although there are demonstration projects for overhead lines, for example in

Germany and Sweden, there are no vehicles commercially available today (Speth & Funke, 2021). Main issues are the need for standardization and the necessary coordinated infrastructure installation directly at the roads (Speth & Funke, 2021).

Given the novelty and the uncertain perspectives of those technologies, a functional system approach is not purposeful today. In the following, the focus will be on conductive chargers with a plug.

3.3 System aspects use phase with indirect energy consumption effect

The aim of this subtask is to report on any indirect consumption effects during the use phase that impact the environment and resources. From a system perspective, the charging infrastructure connects primarily the electricity grid to an electric vehicle. To be more precise, the charging infrastructure connects the vehicle to the local electricity grid, which can also be the local grid of an industry location or the electricity grid of a household. The local grid can also be equipped with a solar system or battery buffers. Last but not least, the charging infrastructure often communicates with different data centres, to enable billing, but also to manage the charging events. An overview is given in Figure 3-3. In the following, the integration into the energy system, as well as into the data backbone, will be investigated.

3.3.1 Integration into the energy system: solar power, V2G, and V2C

User data show that users of battery electric vehicles more often have their own photovoltaic system than the average. A 2019 survey showed that almost half of electric car drivers owned also a photovoltaic system, while the average for all households was just under 4% (Scherrer et al., 2019). The data also show a general willingness to use load management. To use electricity from photovoltaic systems directly, direct current mode 3 recharging stations are announced, thus avoiding conversion losses. However, deeper integration also leads to higher variation in charging power and thus less optimal efficiency. Vehicles will probably be longer connected to the charging infrastructure. Today, the majority of installed photovoltaic rooftop systems have less than 10 kW peak power (Fraunhofer ISE, 2023). This means that charging events purely powered by solar energy will last longer than expected in subchapter 3.2.2.4. At the same time, however, the power grid can be relieved and solar power can be better integrated. Logistics sites also often have large solar systems. A first survey among 71 logistics companies show that 58% of them have solar systems (VSL, 2024).

With regard to the energy system, bidirectional charging is often discussed as a possibility for load management. Typically, the following cases are distinguished (Gschwendtner et al., 2021):

- Vehicle-to-Grid (V2G): The vehicle provides services to distribution or transmission grids. The vehicle can be either charged or discharged.
- Vehicle-to-Customer (V2C): The vehicle provides energy to a (commercial) building (V2B) or to the drivers' home (residential building) (V2H). Typically, the energy flow is behind the meter of the corresponding building.

However, the standardization of the charging equipment and the protocols is identified as a relevant issue for a future market diffusion (Gschwendtner et al., 2021). From a user's perspective V2G or V2C requires plugging in the vehicle more often to have the best possible flexibility (Gschwendtner et al., 2023). Therefore, we suggest to assume daily plugging-in at private infrastructure for bidirectional applications.

Open question to stakeholders:

48) Do we need to consider different specifications for bidirectional charging, apart from the time the vehicle is connected to the infrastructure? Given the early stage of bidirectional charging, do you have assumptions regarding the scope of utilisation?

3.3.2 Impact of electric vehicle charging infrastructure the power quality

Charging infrastructure can influence the power quality, e.g. reactive power, power factor, and harmonics. Charging stations contain electric converters with power semiconductor elements, to transform supply voltage and current. As the semiconductor elements are nonlinear, the charging stations represent a nonlinear load and therefore consumes a distorted current from the power grid that contains harmonic components (Stanko et al., 2023).

Open question to stakeholders:

49) Do we need to consider the power quality and/or the power factor?

3.3.3 Conversion losses of chargers in vehicles

Conversion losses are mainly related to AC charging infrastructure, as the vehicle itself stores the energy on DC batteries. The on-board-charger converts the alternating current to direct current. This results in losses in the order of 10%, as shown in Sevdari et al. (2023). However, the efficiency is highly influenced by the current, as shown in Figure 3-15. Losses may reach 30% or more for low current charging in poorly designed chargers in cars.

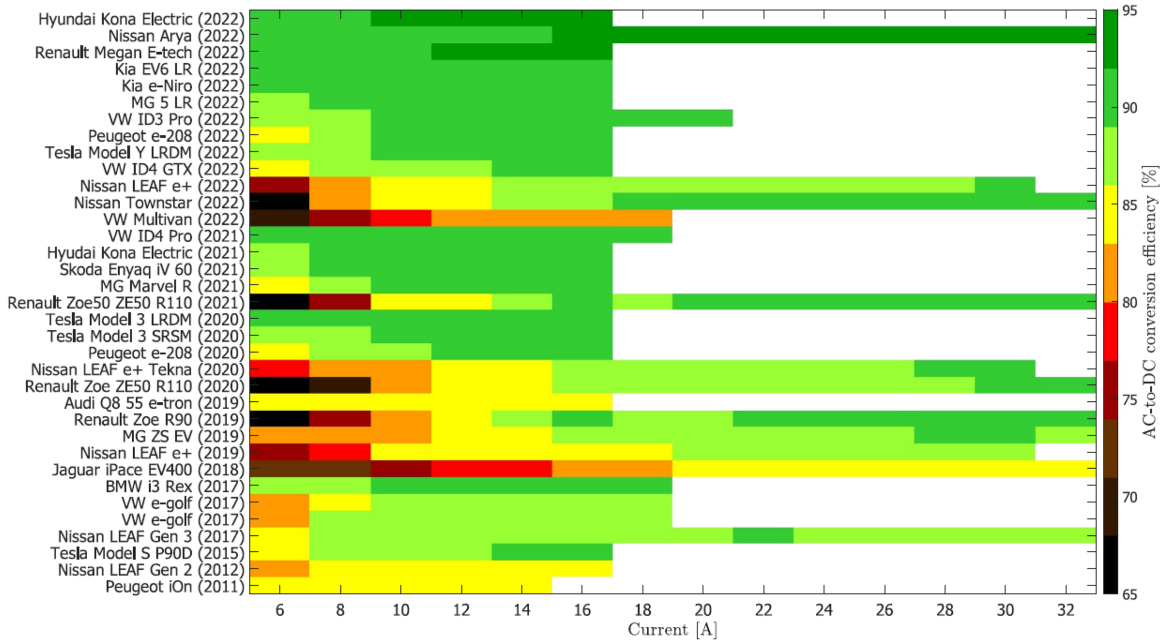

Figure 3-15: Electric vehicle on-board-charger characteristics - AC-to-DC conversion efficiency. (Sevdari et al., 2023)

The following losses were identified by ADAC (2022):

- Domestic socket (2.3 kW):
  - 5% - 10% on-board-charger
  - 5% - 15% 12V on-board power supply (auxiliary systems)
  - <3% high-voltage cable, high-voltage battery, battery conditioning
- Wallbox (11 kW)
  - 5% - 10% on-board-charger
  - <1% 12V on-board power supply (auxiliary systems)
  - <3% high-voltage cable, high-voltage battery, battery conditioning

Open questions to stakeholders:

50) For mode 2 and 3 EVSE: Are there improvement options related to the EVSE itself that can reduce indirect energy losses?

51) For mode 4 EVSE: Do you expect relevant losses for DC charging on the vehicle side?

3.3.4 Backend and data centre

To control and bill public charging, a backend is necessary. Private charging points are also increasingly equipped with a data connection, for example to remotely control the charging process. While the network connection hardware is part of the charging infrastructure, the necessary data warehouse and the backend are not part of the investigated infrastructure.

As a first estimate, one might argue that the energy consumption for billing is similar to the energy consumption of credit card transactions. In the reporting period 2022, VISA Inc. carried out 193 billion transactions and reported an energy consumption of 747,000 GJ (VISA, 2022). This equals less than 1.1 Wh per transaction. Probably, the energy demand per transaction for charging infrastructure will be higher, as additional services - for example online occupancy status - are provided.

Open question to stakeholders:

52) Do you have any additional information on the backend energy demand for charging infrastructure?

53) Do you have numbers on the system losses of the described charging infrastructures?

3.4 End-of-life behaviour

The aim of this subtask is to identify, retrieve and analyse data and to report on consumer behaviour regarding end-of-life aspects. As charging infrastructure for battery electric cars is a quite new product, the analysis will contain assumptions and estimates, rather than actual data.

3.4.1 Product use & stock life

The service life of charging infrastructure is a key parameter for its ecological assessment. Given the novelty of the technology, hardly any charging points have yet reached the end of their service life. The Ecopassport Programme suggests 10 years of use (AAAA Association P.E.P., 2018). Other sources assume a longer lifespan of up to 20 years, but mention possible replacements, for example for the coil or the transformer (Danlec, 2024). Similar to the Ecodesign preparatory study for Building Automation and Control Systems (van Tichelen et al., 2023), one might assume 15 years, at least for Mode 3 chargers. In summary, 10 years of use are suggested as a base case, up to 15 years in an optimistic case.

Open questions to stakeholders:

54) Are there any other numbers, regarding the expected life time? Do we need to consider a range of possible life times? Do we need to differentiate between different types of charging modes, i.e. AC/DC, mobile cables, wall cables, etc?

55) At the moment, vehicles and charging infrastructure are sometimes offered as a bundle. What do you expect will happen with charging infrastructure after the leasing contract?

56) What are reasons for a shortened lifetime?

3.4.2 Repair & Maintenance

Publicly and commercially used charging points must be regularly inspected. For example, in Germany an annual inspection is foreseen, based on BGHM (2012) and VDE (2015). However, the actual maintenance interval is highly dependent on the actual environmental conditions, typically between one and four years. The maintenance interval is determined on the basis of an initial risk assessment after installation. If such an assessment is missing, at least one inspection per year is required.

Fixed installed charging stations in public areas are inspected, taking into account age, condition, environmental influences, usage, and results of previous inspections. An electrical specialist conducts visual inspections, continuity measurements, insulation and grounding resistance tests, and tests of protective switches (TÜV Süd, 2022).

Additionally, vandalism is a critical topic for charging infrastructure. On the one hand, anti-EV beliefs are a reason for demolishing charging infrastructure, on the other hand copper from the cables can be sold (Malone, 2024). This is one reason why AC charging stations are often not equipped with a permanent cable.

Open questions to stakeholders:

57) Are there any different regulations for the maintenance of charging infrastructure, possibly on EU level?

58) Is there any additional maintenance that needs to be carried out regularly in practice?

59) To which extent will charging infrastructure be repaired (work hours, costs)?

60) Are there any reliable numbers on demolition of charging infrastructure?

61) Can you provide annual costs for operation and maintenance?

3.4.3 Upgrade

Open questions to stakeholders:

62) Given the rapid technical development with regard to peak power and additional payment functions, is there any chance to upgrade existing charging infrastructure?

63) If so, which parts / functions of the infrastructure can be upgraded at which costs?

3.4.4 Collection rates, by fraction (consumer perspective)

Directive 2012/19/EU (EU, 2012) defines the handling of electrical and electronic equipment waste. As a directive, the national legislation of EU member states has to implement a corresponding law. For Germany, the foundation for the waste electrical equipment register defined that charging infrastructure falls under the corresponding German law. This means that charging infrastructure must not be disposed as household waste. Instead, it can be handed in at appropriate collection points and retailers are obliged to take back old chargers for free. Similar regulations are in force for other, but not all, EU countries (EAR, 2019; Go4Recycling, 2024). In summary, one might argue that old charging infrastructure will be almost completely collected at the end of its lifespan.

3.4.5 Estimated second hand use, fraction of total and estimated second product life

Having a look at classified ad portals, like eBay, Marktplaats, or Gumtree, used AC charging infrastructure is offered. Especially Mode 2 chargers - mobile chargers - are offered, probably since they do not need to be uninstalled. Reasons for sale are, among others:

- Users bought electric vehicle and charging infrastructure as a bundle, but had already a charging infrastructure
- Missing functions, like controlled charging, integration of solar power, integration into smart home system, or separated billing for company car owners

From today's perspective, it can be assumed that charging infrastructure will reach its expected lifespan, as used chargers can be resold.

Open question to stakeholders:

64) Are there any reliable numbers for the share of used charging infrastructure?

3.5 Local infra-structure

3.5.1 Energy: reliability, availability and nature

From a user's perspective, technical reliability is a key parameter of charging infrastructure (BDEW, 2022). However, information on the typical downtime of charging infrastructure are hard to obtain.

Open question to stakeholders:

65) Can you provide numbers of the average downtime of (public) charging infrastructure?

66) How does the downtime influence the maintenance costs?

3.5.2 Telecommunication

For newly built public charging points, one of the following options for payment need to be available, according to the AFIR:

- payment card reader
- devices with a contactless functionality that is at least able to read payment cards
- for charging points with less than 50 kW, devices using an internet connection and allowing for secure payment transactions, such as those generating a specific Quick Response code.

From 2027 onwards, at least a single payment terminal needs to be installed for each recharging location with charging points with at least 50 kW power (EU, 2023b). Today, by far the most users pay via mobile app or identification card of their preferred mobility service provider, as a survey among eight charge point operators show (ChargeUp Europe, 2023). Ad hoc charging, probably via an app or a website, is used in less than 10% of all charging events. Payment terminals are only used in 0 to 30% of all charging events, depending on the charge point operator. Another survey among users (N=1,329) show that on quarter of all users ask for additional payment options. 30% would even accept slightly higher charging fees, if additional payment would be offered (BDEW, 2022). Therefore, one might expect that payment card readers will be needed for almost all public charging points in the future and have to be considered in the energy consumption of the infrastructure.

Plug&Charge is another trend regarding future charging payment. A digital mobility service provider contract certificate is installed directly at the vehicle and the vehicle identifies itself, as soon as it is plugged in. The charging session can start without any additional identification. However, this requires cooperation between charge point operators, vehicle manufacturers, and mobility service providers. Data from ChargeUp Europe (2023) shows that one quarter of their members already started the implementation of Plug&Charge, another 67% plan to do so within the next three years. Plug&Charge is already available at different charge point operators, for example Tesla, Fastned, and EnBW. Up to now, it is typically restricted to their own customers.

Additional services are also relevant for privately used infrastructure. Some charging systems can be connected to a photovoltaic system so that the vehicle can store a possible surplus of energy. To do so, the charging system needs to be connected to either the inverter of the photovoltaic system, a smart meter system, or flow sensors.

Intelligent charging systems can be controlled either via LAN, WLAN, Bluetooth, or cellular network. They enable (remote) steering of the charging process, statistics on the charging events based on integrated electricity meters, and potentially load management. It is also possible to charge at different rates, for example to be able to bill an employer for company cars.

Finally, private charging systems may also be equipped with an authorization system, for example via RFID card reader or a key system.

Open questions to stakeholders:

67) Do we need to consider any other additional services, not included up to now?

3.5.3 Physical environment

The number of vehicles per inhabitant in Europe is constantly rising, reaching 560 vehicles per 1,000 inhabitants in 2020 (ACEA, 2022). Many households own more than one vehicle. For example, in France 37% of all households own two cars or more. Austria reports 26%, Denmark and Latvia 18% (ACEA, 2022). Therefore one might assume that approximately one third of all private charging points will be used by two cars in the future.

Taking into account that the available power per household varies in different countries, as well as in different housing situations, grid connection might be a relevant topic. As shown in 3.2.2.3 and 3.2.2.4, the anticipated AC charging power of 11 kW is not necessary to fully charge the vehicles, but private charging infrastructure shows idle time. For multi-family houses, simulation shows that five battery electric vehicles could share one 11 kW charger (Kühnbach et al., 2024). However, the authors assume that shared chargers in multi-family houses are less likely, and rather assume a load management system. Therefore we assume one charging point per vehicle / per parking space and consider additional hardware to enable load management (power balancing function).

After April 2024, operators of recharging points need to ensure that newly equipped charging points need to be smart (EU, 2023b). That means they need to have a communication module and need to be able to adjust the intensity of electricity in real-time. Additionally, a smart meter integration is helpful. Therefore it is assumed that all publicly used infrastructure will be equipped with the corresponding hardware. For private infrastructure, we also assume that smart charging will gain attention and therefore consider the hardware in the calculation. This is in line with EU (2023a), which mandates members states to ensure that new and replaced non–publicly accessible normal power recharging points installed in their territory can support smart recharging functionalities

In line with EU (2023b), we assume a fixed cable for DC charging infrastructure. For AC charging infrastructure, we assume no fixed cable, as they are often subject to vandalism and therefore rather unusual (c.f. 3.4.2)

Finally, we assume a screen for public charging infrastructure, but not for private charging infrastructure.

With regard to public charging infrastructure, electric vehicle drivers ask for roofing of charging locations, a friendlier environment (cleanliness, seating options, lightning etc.), longer cables (BDEW, 2022) and the cable itself for AC charging points[126] . Consequently, newly designed DC charging locations are often equipped with (solar) roofs, toilets, recreation areas, light, and sometimes snack vending machines (EnBW, 2024; Fastned, 2023).

3.6 Recommendations

Based on the analysis in this task, several recommendations can be made. The focus of the recommendations is on the product scope from the perspective of consumer behaviour, pointing out barriers and opportunities for Ecodesign.

[126] As in the past a variety of connectors existed, charging points have been equipped since long without the cable, to let the vehicle owner use its own adapter. However, now that only Type-2 is used, users ask to have the cable instead of having to spend time to plug their own one with the inconvenience of realoading a dirty one or even just wet.

Users

- Charging infrastructure is a young technology compared to other products in the Ecodesign scope. Given this novelty, usage numbers come with high uncertainty and technological changes are likely. This may complicate a upcoming Ecodesign regulation. **To deal with novelty, updates should be considered from the very beginning.**
- **New functions, such as V2G or V2C**, will change the requirements for the charging infrastructure - and also some framework parameters -, but will have a positive impact on indirect energy consumption.
- As charging behaviour widely vary between different users and use cases, an **extended product approach** is indicated.
- Charging infrastructure for **heavy-duty vehicles** is not addressed in any existing efficiency scope. However, given the large amount of energy, and the different user profile compared to charging infrastructure for light-duty vehicles, it should be considered as a separate type of infrastructure in a potential Ecodesign regulation.
- The basic function of a charging infrastructure is to connect electric vehicles to the electricity grid. From a functional system perspective, inductive charging or battery swapping can also be used to recharge a vehicle. However, given the novelty of those technologies and the lacking market introduction, the focus should be on **plug-based charging infrastructure**.

Open questions to stakeholders:

68) Did we miss central recommendations?

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4 Technologies [2nd study phase]

Will be added in 2nd phase of the preparatory study.

5 Environment & Economy [2nd study phase]

Will be added in 2nd phase of the preparatory study.

6 Options [2nd study phase]

Will be added in 2nd phase of the preparatory study.

7 Scenarios [2nd study phase]

Will be added in 2nd phase of the preparatory study.

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