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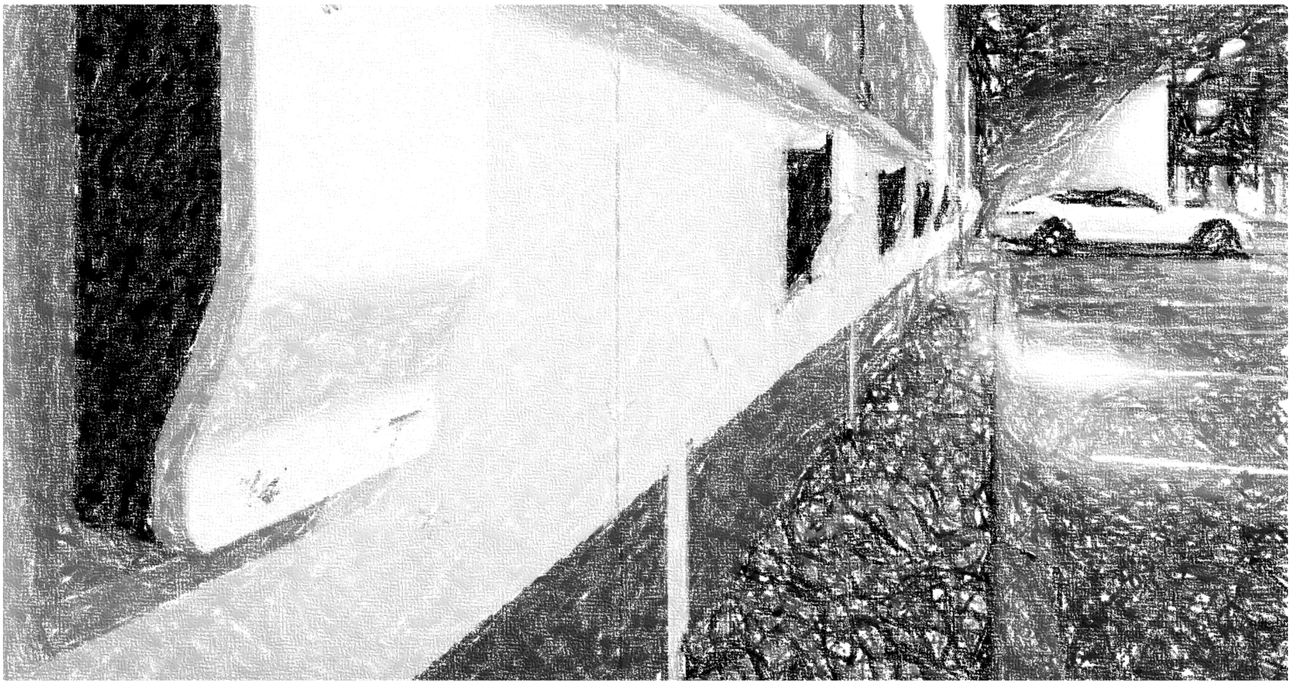

Unit Process Inventory Data for Residential Electric Vehicle Charger Life Cycle Assessment

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Cover illustration: ”Residential wallbox installations in the garage of a multihousehold building”. A digitally created sketch, originating from a photo published in the open media archive of Schneider Electric Sweden.

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Acronyms and Abbreviations

A	Ampere
AC	Alternating current
ACEA	Association des Constructeurs Européens d'Automobiles
BMS	Battery management system
DC	Direct current
EAFO	European alternative fuels observatory
EPD	Environmental product declaration
EU	European union
EV	Electric vehicle
EVCS	Electric vehicle charging station
EVSE	Electric vehicle supply equipment
GHG	Greenhouse gas
GWh	Gigawatt hour
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization of Standards
kg	Kilogram
kt	Kilotonne (metric)
kW	Kilowatt
kWh	Kilowatt hour
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
OBC	Onboard Charger
OCPD	Overcurrent Protection Device
OEM	Original Equipment Manufacturer
PEP	Product Environmental Profile
RCD	Residual Current Device
SAE	Society of Automotive Engineers
SPD	Surge Protection Device
t	Tonne (metric)
UVPD	Undervoltage Protection Device
V	Volt

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Context

This technical report has been written as joint deliverable from two projects, one named *“Environmental Assessment of Electromobility Charging Systems”*, funded by the Swedish Electromobility Centre, and one named *“Techno-environmental assessment of stationary EV charging solutions”*, funded by the Area of Advance Energy at Chalmers University of Technology.

Prevalent literature often excludes the infrastructure required for actualizing a transition to electric vehicles (EVs), namely electric vehicle supply equipment (EVSE) in transportation system assessments. This knowledge gap also extends into the domain of life cycle assessment of EVSEs. The existing body of work is limited in number and deviates notably from the charging equipment’s practicalities and representativeness. A reason is a lack of unit process inventory data that is detailed, compatible, consistent, and compliant with market trends, normative specifications and guidelines embodied in international standards and sometimes even mandated by regulations governing EVSE installation and utility interfacing. This report attempts to fill this gap and advance the body of knowledge on residential EV charging by compiling unit process data and developing a model coherent model file.

1 Introduction

1.1 Background

Road transport decarbonization is critical to achieving climate action goals and a core constituent of regional and national sustainable transport policy frameworks (European Union [EU], 2021). The effectiveness of such frameworks and the underlying greenhouse gas (GHG) mitigation pathways hinges on the “three-legged stool” of improving vehicle efficiency, decreasing fuel carbon intensity, and reducing travel demand (Lewis et al., 2018). However, there is a growing gap between GHG abatement targets and projected emissions (European Academies' Science Advisory Council, 2019). Meanwhile, passenger car and road freight transport demand is expected to grow by at least 30% in the next two decades (Raposo, 2019), which may further widen this gap (European Automobile Manufacturers Association [ACEA], 2020). This disconnect between long-term road transport GHG targets and the state-of-play has prompted the EU to intensify its pursuit of a fossil-free transport system, and new initiatives aim for a net-zero GHG road transport sector by 2050 (European Council [EC], 2021). However, this cannot be delivered by a status quo and a paradigm shift towards electrifying the road transportation, and mass market adoption of battery electric vehicles, is therefore vital.

Emission benefits of zero emission vehicles cited in regulatory (European Alternative Fuels Observatory [EAFO], 2017) and stakeholder assessments (ACEA, 2021) are predicated upon the co-existence of infrastructure, i.e., EVSE, often also referred to as EV chargers. Excluding the infrastructure decouples the influence of mobility (travel demand, energy consumption etc.) on macro-economic policy decisions and investments. Furthermore, it can be argued that any environmental life cycle assessment of electromobility precluding the infrastructure is incomplete.

There is a large amount of literature on the LCA of EVs (Ayodele & Mustapa, 2020; Bauer et al., 2015; Bicer & Dincer, 2018; Ellingsen et al., 2016; Hawkins et al., 2012; Nordelöf et al., 2014). There have also been efforts to develop standardized sets of LCA of EV guidelines (Del Duce et al., 2013; Patterson, 2018). A common theme across most of these studies and recommendations is a lack of attention and inclusion of the infrastructure, in absolute terms and/or relative to the vehicle. One likely reason is the fact that existing studies rely on widely used databases such as Ecoinvent, which do not present the use case specificities of EVSEs.

Access to charging, especially residential charging, is a key enabler of EV adoption. Convenience, secure and reliable access, cost-effectiveness, user’s flexibility and control over charging times, and availing utility incentives are some of the attributable factors (Hall, 2017; International Energy Agency [IEA], 2022; Needell et al., 2023). Several studies indicate that home charging will be the most preferred charging location in the coming decades (European Federation for Transport and Environment, 2021; McKinsey&Company, 2018), meeting 60%–90% of the total charging demand (Wood et al., 2018; Zink et al., 2020). The electricity supplied during this charging, unless entirely provided by renewables, could potentially be the dominating contribution to the overall life cycle environmental impacts of EVs (Hawkins, 2013; Nordelöf et al., 2014; Temporelli et al., 2020; Wu et al., 2020). These observations indicate the value and utility of compiling inventory data for EVSEs, given the limitations found in existing literature.

1.2 Report objectives, relevance and structure

This report explains technical, operational and installation requirements of residential EV charging infrastructure, and proposes representative unit process data for LCA. The presented datasets are constructed based upon international standards, manufacturer recommendations, environmental product declarations (EPDs) and installation guidelines to ensure that the studied product/system is representative of its practical use. The intended application is to serve as the foundation for life cycle assessment studies of a typical residential EVSE, or similar charging equipment.

In addition to this introductory chapter, the report is organized as follows. Chapter 2 presents the basic aspects of EV charging and introduces the reader to the relevant nomenclature and classification used in practice. International standards and practices for EV charging installations are synthesized. Chapter 3 elaborates the methodological approach adopted in this report in building the unit process inventory data. Information outlined in the international standards is expanded and supplemented with manufacturer recommendations and electric utility compliance requirements. Subsystems, parts, and components of the charging infrastructure are then systematically identified followed by an overview of the data collection steps—from raw material composition to final assembly. Chapter 4 delves into each of these individual parts/components/subsystems and their functions. Composition data, corresponding Ecoinvent flows and activities, as well as suitable strategies implemented to address the intermediary transforming and final assembly process are tabulated and detailed in Chapter 4.

2 Technical and Operational Fundamentals

The purpose of this chapter is to summarize the definitions formalized in international standards, and several regional electromobility policy frameworks within the EU, that are used in this report.

2.1 Terminology

An introductory overview of EV charging, charging types and what constitutes a charging infrastructure most pertinent to this report alongside the terms utilized in this report shortly follows.

- **EV charging modes and levels:** Several regional and international standards adopt a set of normative specifications and requirements and delineate the principles, technologies, and related self-contained aspects of EV charging. Common terms are *modes* and *levels,* which are further explained in section 2.2.
- **EV Supply Equipment (EVSE):** EVSEs, also called charging points, are comprised of devices outside of the vehicle, that together provide electric power from the grid to the EV's battery (National Electronics Manufacturer Association, n.d.). In everyday language EVSEs are simply often referred to as "chargers". Hardware components included within the scope of the EVSE term are typically protection, monitoring, and metering devices, along with cables, connectors, and wall- or freestanding boxes for the housing of components.

  In summary, the EVSE is working as an intermediary between the local grid connection and the vehicle, making sure the energy is transferred safely and efficiently. The EVSE refers to the entire spectrum from slow to fast charging points. Parts included in EVSEs can differ depending on the mode and level, as well as requirements in the specific region. This report presents an LCI of an EVSE for residential AC charging.

  From now on in this report, the term EVSE is used synonymously and interchangeably with *charging point* and refers to the infrastructure needed to charge one vehicle, from grid to connection into the EV.
- **EV Charging Station (EVCS):** This term is similar to EVSE, but in addition to what is included in the EVSE, it also accounts for location, services, and infrastructure where EVs are charged (EAFO, n.d.). All EVCS contain at least one EVSE, but not all EVSEs are part of an EVCS (Setec Power, n.d.). As the EVSEs considered in this report use slow AC charging, and are usually installed in a residential setting, EVCSs are not studied.
- **Wallbox:** A type of housing which is wall-mounted and connected to the grid via a fixed installation. It usually contains several of the parts that are needed for an EVSE, such as devices for circuit protection, measuring and monitoring. It is included in the type of EVSEs studied in this report (mode 3, explained in section 2.2.2).
- **Connector (plug):** An EV connector or charge plug refers to the physical interface between an EVSE and the EV.
- **Grid interfacing and peripherals:** List of devices, components and parts additionally required for installing a wallbox or similar as the stipulated by the manufacturer, international standards, or local regulations. Details in section 4.3-4.5.

2.2 Classification of EVSE and different types of charging

This chapter presents different types of conductive EV charging and gives an introduction to the classification of EVSE charging modes and levels.

2.2.1 AC and DC charging

The power delivered to the EV from the EVSE can be supplied as alternating current (AC) or direct current (DC). The typical residential EVSE uses *AC charging*, and that is what is studied in this report. *AC* and *DC charging* is carried out in different ways, and a simplified illustration can be seen in **Figure 1**.

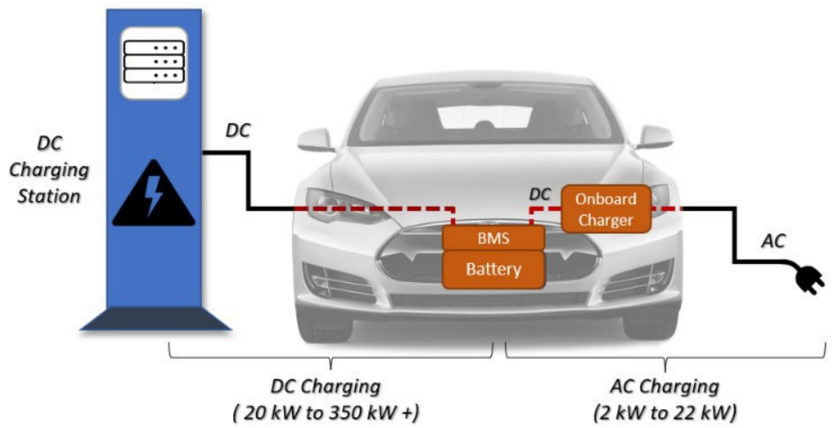

Figure 1: *Onboard and offboard charging systems of electric vehicle. Replicated (unaltered, in accordance with CC BY-NC-ND 4.0) from Review of Electric Vehicle Charging Technologies, Standards, Architectures, and Converter Configurations, by Acharige, S. S., et al., (2023), IEEE Access. (https://doi.org/10.1109/ACCESS.2023.3267164).*

During AC charging, the battery is in fact fed DC but this current is shaped and controlled inside the vehicle, after delivery from an external AC source. An *on-board charger* (OBC) converts the incoming AC into DC, and delivers it to the battery (Acharige et al., 2023). In the context of AC charging, the EVSE is therefore not actually a “charger” in its true meaning, even if it is commonly referred to with this term. Instead, in the case of AC charging, the EVSE constitutes a combination of devices that provides connection to the grid, as well as safety and control functions. AC charging is conducted at lower power levels than DC charging and therefore it takes longer time to provide the same amount of charge. For this reason, it is sometimes referred to as slow charging. Typical power levels for AC charging ranges from around 2 kW up to 22 kW, depending on the EVSE, grid connection and vehicle.

When using DC charging, the current is formed and controlled outside of the vehicle in an *off-board charger*, which is in that case is included in the EVSE (Acharige et al., 2023). The DC is delivered directly to the battery, and DC chargers range from around 20 kW and upwards, into the MW scale. DC charging is often referred to as fast charging, and is usually only available in commercial settings, i.e. “fast charging stations”.

As this report focuses on EVSEs designed for AC charging, an overview of the complete charging process, including the on-board power electronics interface is presented in **Figure 2**. It shows a typical configuration of an OBC, operating in conjunction with an AC EVSE (Acharige et al., 2023). The AC power is delivered from the EVSE to the OBC, where the rectifier converts the AC into DC. Thereafter, the current is converted into a suitable voltage level by the DC/DC converter, before being fed into the EV battery, via protection circuits. The protection circuits communicate with the Battery Management System (BMS) and the power control unit to assure safe and effective charging. Although AC charging infrastructure cannot function without an OBC, it is usually not included when referring to the EVSE, as it is located inside the EV. Data for the OBC will therefore not be included in this report.

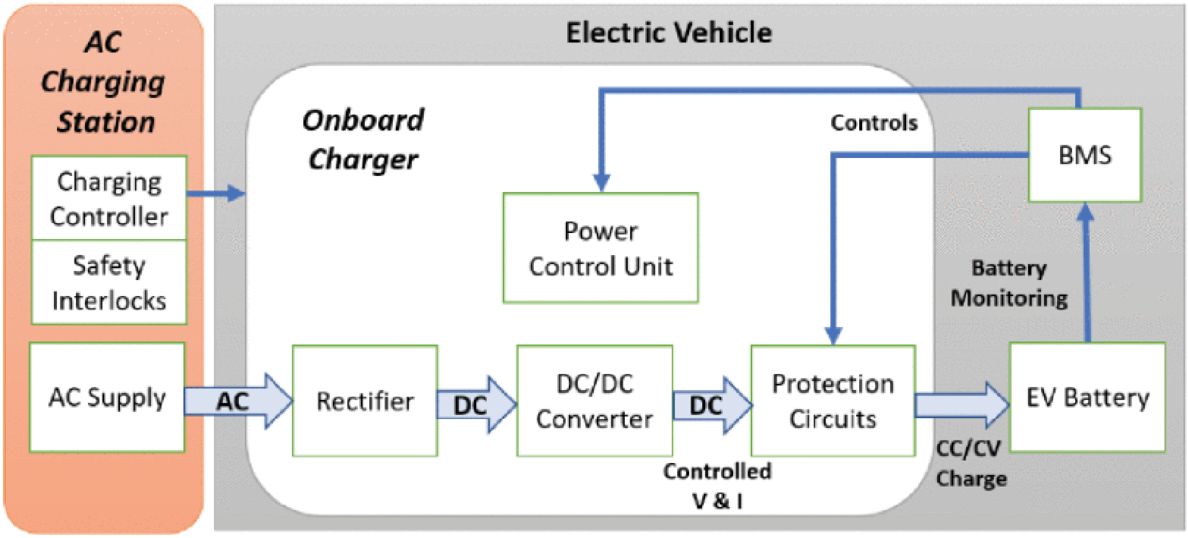

Figure 2*: Configuration of conventional onboard EV. Replicated (unaltered, in accordance with CC BY-NC-ND 4.0) from Review of Electric Vehicle Charging Technologies, Standards, Architectures, and Converter Configurations, by Acharige, S. S., et al., (2023), IEEE Access. (https://doi.org/10.1109/ACCESS.2023.3267164).*

2.2.2 Charging modes, charging levels and connector types

"Charging modes" and "charging levels" are two different ways to categorize EVSEs. Charging modes are based on the standard IEC 61851 (IEC, 2020) and charging levels are based on the standard SAE J1772 (SAE International, 2017). The categorization into modes is mainly based on the characteristics of the charging infrastructure, i.e. the physical interface between EV and EVSE, including the level of control and safety features, while the definition of charging levels is primarily based on power delivery capabilities.

There are 4 types of charging modes, as defined in the standard IEC 61851 (IEC, 2017). Mode 1 to 3 refers to AC charging and mode 4 to DC charging. The definition of the modes are as follows:

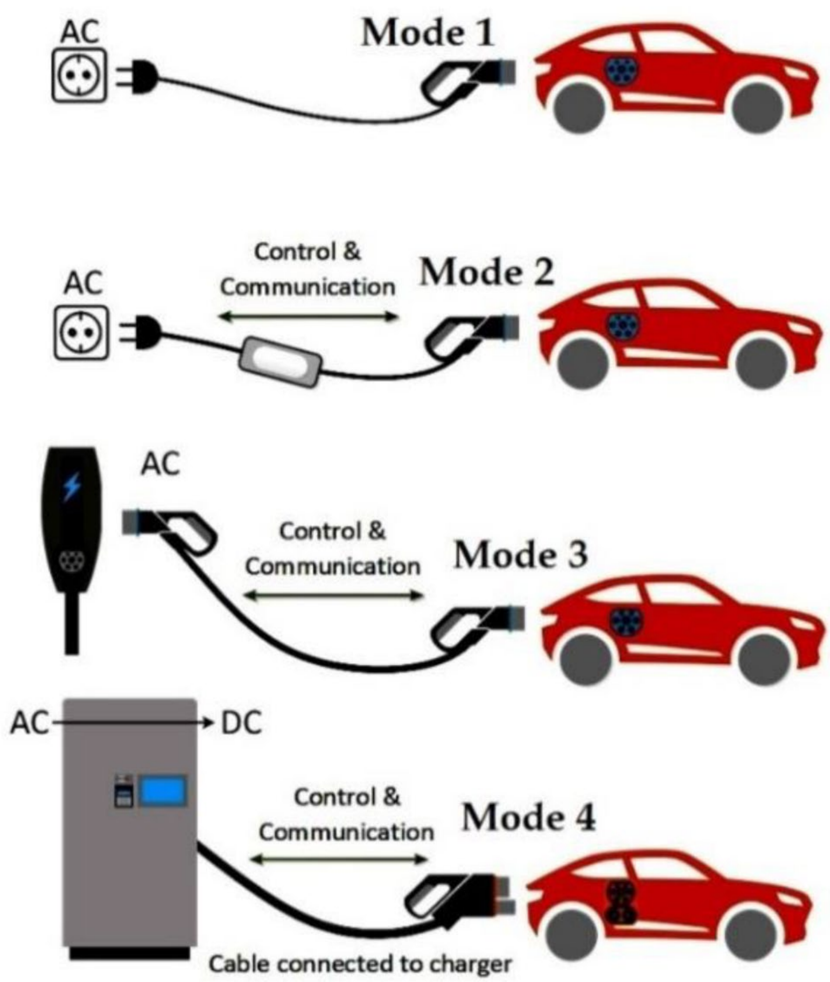

Figure 3*: Illustration of different charging modes. Reproduced from Skouras et al. (2020).*

- **Mode 1:** *Standard socket outlet, non-dedicated circuit*
  In charging mode 1, the EV is directly connected to a standard household socket, either 1-phase or 3-phase. Apart from protective earthing, no protection, safety, or control measures are required. Mode 1 is generally not recommended, and even prohibited in certain regions.
- **Mode 2:** *Standard socket outlet, non-dedicated circuit*, *cable-incorporated protection.*
  In charging mode 2, the EV is connected to the AC supply via a standard household socket, either 1-phase or 3-phase, just as in mode 1. In this mode, in addition to protective earthing, a "control pilot function" and additional safety features should be in place between the socket outlet and the EV. These requirements are usually housed in the charging cable, using a so-called *in cable-control box* or *in-cable control and protecting device.*
- **Mode 3:** *Dedicated EV charging system, dedicated outlet.*
  Charging mode 3 requires the EVSE to be permanently connected to the AC supply, via a dedicated circuit, either 1-phase or 3-phase. Usually a wallbox, or similar housing equipment, is used for household safety and control features. In addition to the requirements in mode 2, mode 3 also needs to enable two-way communication

between the EVSE and EV. This is the charging mode for the EVSEs studied in this report.

- **Mode 4:** *Dedicated EV charging system, dedicated outlet, offboard DC charging.* Charging mode 4 regulates DC charging, i.e. where DC is delivered from the EVSE to the EV, and the charger is located outside of the vehicle (off-board charger). The equipment for mode 4 charging needs to fulfill high safety, control, and communication standards.

Charging levels are formalized by the Society of Automotive Engineers (SAE), and the functionalities and requirements for each level are described in the standard SAE J1772 (SAE International, 2017). The standard is designed for North America, and some parts are not applicable to other parts of the world. For example, in the EU the voltage output from households is generally different from that in the US (Khalid et al., 2021). In the descriptions below, voltage levels are given both for the US and for the EU. There are three different levels – Level 1 and 2 apply for on-board chargers, and Level 3 for off-board chargers (Acharige et al., 2023).

- **Level 1** charging is classified as using 1-phase 120 V in the US and 230 V in the EU (Khalid et al., 2021). Charging takes place using a cable connected to the power grid by a standard socket outlet. Charging a 16-50 kWh EV battery using level 1 charging generally takes around 11-36 hours, due to the low charging speed with a maximum of 1.9 kW (Acharige et al., 2023) .
- **Level 2** charging can operate on either a 1-phase or 3-phase system with voltages up to 240 V in the US and up to 400 V in the EU (Khalid et al., 2021; SAE International, 2017). Maximum power level is 19.2 kW, and the charging time is around 2-3 hours for an EV battery with the capacity of 30-50 kWh (Acharige et al., 2023). Dedicated EV supply equipment is needed for this level of charging, to handle the higher power levels and meet safety requirements. The EVSEs studied in this report falls into this level.
- **Level 3** charging, more commonly called DC fast charging, places the charger outside of the EV, i.e. an off-board charger. This charger is in turn fed by a 3-phase supply, using 480 V or higher (Khalid et al., 2021). DC fast charging can provide power up to around 350 kW, and a usual charging time is around 0.2-0.5 hours (Acharige et al., 2023).

In addition to modes and levels, *the type of connector* used in EV charging also differs, both in terms of the pin placement, with differences between regions, and in terms of the type of current fed into the EV. North America and Japan generally follows connector standards from SAE, whereas the EU follows connector standards from IEC. **Figure 4** shows the different types of connectors used for AC charging over the world, and **Figure 5** shows the corresponding connectors for DC charging.

Specifications	Japan	USA	Europe		China		ALL Markets	
Charger type								
	Type 1 (SAE J1772)		Type 2 (Mennekes)		Type 2 (GB/T)		Tesla	
	Level 1	Level 2	Mode 1	Mode 2-3	Mode 2	Mode 3	Mobile connection	Wall connection
Maximum Capacity	1.9 kW	19.2 kW	4 kW	22 kW	7 kW	27.7 kW	7.7 kW	11.5 kW
Input voltage	120 V Single phase	240 V Split phase	250 V Single phase	480 V Three phase	250 V Single phase	400 V Three phase	120/240 V Single phase	208/250V single phase
Current rating	16 A	80 A	16 A	32 A	16 A	32 A	16/32 A	48 A
Standards	SAE J1772-2017 IEC 62196-2, IEC 61851-22/23		IEC 62196-2 IEC 61851-22/23		GB/T 20234-2 IEC 62196-2		IEC 62196-2	

Figure 4: *Specification of different AC charging connectors. Replicated table (unaltered, in accordance with CC BY-NC-ND 4.0) from Review of Electric Vehicle Charging Technologies, Standards, Architectures, and Converter Configurations, by Acharige, S. S., et al., (2023), IEEE Access.*

Specifications	Japan	USA	Europe	China	ALL Markets	
Charger type						
	CHAdeMO	CCS - Combo 1	CCS - Combo 2	GB/T	Tesla Supercharger	CHAdeMO
Capacity	50 - 400 kW	150 - 350 kW	350 kW	60 - 237 kW	250 - 350 kW	50 - 400 kW
Input voltage	50 - 1000 V	200 - 1000 V	200 - 1000 V	250 – 950 V	300 - 480 V	50 - 1000 V
Maximum Current	400 A	500 A	500 A	250 – 400 A	800 A	400 A
Standards	IEC 61851-23/4 IEC 62196-3 JEVS G105	SAE J1772 IEC 61851-23/24 IEC 62196-3	IEC 61851-23/24 IEC 62196-3 DIN EN 62196-3	GB/T 20234-3 IEC 62196-3	IEC 62196-3	IEC 61851-23/4 IEC 62196-3 JEVS G105

Figure 5: *Specification of different DC charging connectors. Replicated table (unaltered, in accordance with CC BY-NC-ND 4.0) from Review of Electric Vehicle Charging Technologies, Standards, Architectures, and Converter Configurations, by Acharige, S. S., et al., (2023), IEEE Access.*

2.3 Governing standards

Standards are essential for ensuring the safety, reliability, and interoperability of the EV infrastructure. They enable EV and EVSE manufacturers and charging infrastructure providers to develop products that promote a harmonized set of performance, operationality, reliability, and design criteria and can be used in different regions of the world. Major standardization initiatives have been undertaken by international and regional organizations such as the International Electrotechnical Commission (IEC), Underwriters Laboratory, International Organization of Standards (ISO) and the Society of Automotive Engineers (SAE). Some of the governing standards have been used in this report as a guide for which parts and subcomponents to include in a typical EVSE setup.

This subsection summarizes some of the most widely adopted standards that are also directly related to the report:

- **IEC 61851**: Defines the general and functional requirements for electric vehicle conductive charging systems, communication between the EV and the charging station, isolation requirements, electromagnetic interference/compatibility, safety and protection (IEC, 2017).
- **IEC 62196:** Defines electrical, mechanical, thermal, and performative criteria of EV charging dedicated plugs, cables, socket-outlets, vehicle connectors/inlets, and cable assemblies used in conductive charging systems (IEC, 2022).
- **IEC 60364:** Provides guidelines and requirements for the design, erection, inspection, and maintenance of electrical installations, including wiring, switchgear, and other equipment used in buildings and public premises. Planners, designers, installers, and maintenance personnel rely on this standard to ensure that electrical installations meet the necessary safety requirements and can be used in multi-use facilities and buildings such as residential units, apartment complex and commercial establishments (IEC, 2005).
- **SAE J1772:** This is the North American standard for EV conductive charging systems. It includes specifications for the charging connector, communication protocol, and safety features (SAE International, 2017).
- **GB/T 20234:** This is the Chinese standard for EV conductive charging systems. It includes specifications for the safety and reliability of EV charging systems, including the connectors, cables, and control devices used as well as testing procedures (National Standards of the People's Republic of China, 2015).

3 Methodological Considerations

In this chapter, the approach to data collection is described, followed by recommendations for which Ecoinvent flows that best represent explicit materials. Lastly the representativeness of the data is discussed.

3.1 Approach and scope

International standards, OEM guidelines and installation requirements are the starting point for identifying all the parts, devices, and equipment that are essential for the complete charging infrastructure (IEC, 2020; Iskra, 2022; Rajendran, 2021). The requirements differ from country to country for some of the protection devices. In these cases the Swedish standards for electrical installations, which is highly based on EU standards such as the IEC 61851, has been consulted (Svensk Elstandard, 2023). Representative parts needed to get a complete EVSE installation are then selected, and for each of them corresponding EPDs or product environmental profile (PEP) are utilized for evaluating their material composition. Packaging materials are excluded.

Qualified assumptions are then made to link each material input to a matching flow in the Ecoinvent database (version 3.9.1 with the cut-off system model). Next, due to the lack of detailed production and assembly data for subcomponents and larger assemblies, aggregate information reported in the annual sustainability report of a facility — Mitsubishi Electric Corporation, which manufactures a range of parts and equipment used in EVSEs — is used to proxy the product assembly energy (electricity, natural gas, crude oil), water, chemical substance inputs and discharges (see section 4.6).

In **Table 1** different parts identified for the charging infrastructure are presented, including wallboxes, safety protection, metering devices, and charging cables. Wallboxes often already contain a few – or sometimes all – of the additional components needed. The table shows which of the parts are already included in the different wallbox options studied in this report.

Table 1. *Itemized list of parts and equipment for residential EV charging.*

Item			**Section in report**
Wallbox - 2 variants			4.2
Ensto wall-mounted 7.4 kW			4.2.1
EVlink wall-mounted 7.4 kW			4.2.2
	Already included in EVSE?		
	Ensto	**EVlink**	
Circuit Protection			4.3
Residual Current Device – RCD	Yes	Yes	4.3.1
Overcurrent Protection Device – OCPD	Yes	Yes	4.3.2
Undervoltage Protection Device – UVPD	No	Yes	4.3.3
Surge Protection Device – SPD	No	No	4.3.4
Metering and Monitoring			4.4
Smart Meter/Energy meter	No	Yes	4.4.1
Load Management Controller[1]	No	No	4.4.2
Cable			
Charging cable and connector(s)	Yes	No	4.5

[1]Two different types are studied, one for use in only one EVSE, and one for use with multiple EVSEs

3.2 Ecoinvent flow mapping assumptions

Though an EPD provides material composition details, instances where a particular material is categorized too broadly (e.g. “steel”), vague (e.g. “copper alloys”), or incomplete (e.g. “various” ,“other”) are very common. All such instances require an interpretation in the selection of a suitable database flow to model the specific material input. In addition to this, several different processes (or “activities”) can provide the same type of flow. As result, a lot of very detailed information is needed in order to build an LCA model which closely captures the conditions set a by any specific manufacturer and its resolution of upstream material acquisition, primary and secondary suppliers, transshipment activities and semi-processing steps. In this work, to reconcile the inevitable variations of the real-world circumstances, simplifying assumptions are made and the data tables include a combination of raw material inputs and intermediate material transformation activities that convert raw materials into semi- or finished products, to roughly capture the typical production processes required.

The category “various” (also called “other/miscellaneous”), has generally been grouped in the same material category as those marked as “electronic cards” in the EPDs. This was done to prevent an underestimation of the impact from electronic components, and because of a lack of another fitting category.

All the Ecoinvent mapping assumptions are presented in **Table 2**. These are homogenous and uniformly applied based on material.

***Table 2**. EPD to Ecoinvent mapping assumptions for select materials or assembled products.*

Material listed in EPD	*Ecoinvent material/product input*	*Ecoinvent material transformation*[1]
Metals		
Aluminium	Aluminium, wrought alloy	1. Sheet rolling, aluminium 2. Metal working, average for aluminium product manufacturing
Brass, Copper alloys	Brass[2]	Brass casting
Copper	Copper, cathode	Wire drawing, copper
Ferrite	Ferrite	
Iron Cast iron	Cast iron	Casting removed by milling[3]
Other metals	Aluminium, wrought alloy	1. Sheet rolling, aluminium 2. Metal working, average for aluminium product manufacturing
Silver	Silver	-
Stainless steel, Ferrous alloys	Chromium 18/8 steel	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing
Steel	Steel, low-alloyed[4]	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing
Zinc	Zinc	

Continued on next page.

Table 2. *Continued.*

Plastics		
ABS	Acrylonitrile-butadiene-styrene copolymer	Injection molding[5]
Bulk and sheet molding compounds (BMC/SMC)	Epoxy resin	Injection molding[5]
Elastomer	Styrene-acrylonitrile copolymer	
EPDM	Synthetic rubber	
Epoxy resin	Epoxy resin, liquid	
Glass fiber	Glass fiber	Injection molding[5]
Glass fiber reinforced plastics (GFRP), Polyamide (PA), Polyamid 6.6 with 30% glass fibers (PA6.6 GF30%)	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding[5]
PA Resin	Phenolic resin	
Polyacetal (POM)	Nylon 6	Injection molding[5]
Polycarbonate (PC)	Polycarbonate	Injection molding[5]
Polyethylene (PE)	Polyethylene, low density, granulate	Injection molding[5]
Polyethylene terephthalate (PET), PBT	Polyethylene terephthalate, granulate, amorphous	Injection molding[5]
Polyphenylene sulfide (PPS)	Polyphenylene sulfide	Injection molding[5]
Polypropylene (PP), Other plastics	Polypropylene, granulate	Injection molding[5]
Polyurethane	Polyurethane, flexible foam	Injection molding[5]
Polyvinyl chloride (PVC)	Polyvinylchloride, bulk polymerized	Injection molding[5]
Thermoplastic polyurethane (TPU)	Polyurethane, flexible foam, flame retardant	Extrusion, plastic pipes
Other		
LCD Screen	Liquid crystal display, unmounted	Liquid crystal display, minor components, auxiliaries, and assembly effort
Electric cable/wires	Cable, unspecified	
Electronic cards, Electronic circuits and components, PCBA, PCBA-TI, Other electronic components, Various	Printed wiring board, surface mounted, unspecified, Pb free	

1. If more than one, implies all transformation activities are needed

2. Common in electrical equipment (Callcut, 2000)

3. ABB (2023)

4. Own assumption

5. Most dominant molding process (Packaging Europe, 2022)

3.3 Data and model representativeness

Regarding the representativeness of the data and model, several factors are to be considered, such as geographical, technological, and temporal applicability.

The Swedish electrical installation standards – *Elinstallationsreglerna* – were consulted for the selection of components needed for a complete installation of an EVSE (Svensk Elstandard, 2023). The standards covering EVSEs are mainly based on the international standards such as IEC 61851 (2020). The standards by IEC are largely adopted by the EU, and therefore the components in this report are deemed representative for EVSEs in the EU (European Committee for Electrotechnical Standardization, 2024). In addition, the IEC standards are supposed to be applicable globally, so the listed components are likely representative outside of EU as well (IEC, 2024).

All components studied for data collection are produced by European companies: Schneider Electric (French), ABB (Swedish-Swiss), Ensto (Finnish), and Harting Technology group (German). Most of the components studied were produced by Schneider Electric, which has factories all over the world (Schneider Electric, 2020c). The data is deemed to be applicable globally, even if it may be especially representative of the European market. The data for the electrical equipment assembly process was based on the sustainability reports of Mitsubishi Electric Corporation (2021, 2023a) a global manufacturing company based in Japan. The data for their global industrial operations in the report is considered, collected from the years 2019-2023.

For the data to be representative of the current situation as possible, all the data is collected from products that are currently, or have very recently been, for sale on the global market. Prospectively, it is challenging to determine how long the data can be considered relevant and representative. Given the relative novelty of the technology, limited data on the lifetime statistics have been gathered so far, making predictions difficult. Once the EVSE is installed, it could potentially be used for up to 20+ years, but this depends on how the technology develops.

3.3.1 Alternative technical scopes for EVSE use

The EVSEs covered in this report are designed to be used in a residential setting, charging only one EV at the time, likely in a single-family household. As elaborated in Chapter 1, the most common place to charge an EV is at home. However, there are several different ways in which the EVSEs covered in this report could be used:

- In residential buildings with multiple apartments. where charging points may be private (individual garage) or shared between residents (multiple EVSEs located in the common parking place).
- In public spaces, where parking may be the primary intent, and charging is a bonus, such as car parks, parking spaces by a supermarket or a workplace.

Some adjustments might be necessary for the EVSE data to better match and represent wallbox solutions for these above-mentioned alternate applications, such as another type of load balancing than what is described in this report, as well as implemented payment and identification possibilities. It might also be a good idea to assume EVSEs that can provide a higher power level in public spaces, especially if they have more than one charging port (socket outlet).

The EVSEs in this report have one charging port each. It is not uncommon for EVSEs to have two charging ports, meaning it is possible to charge two EVs at the same time. Double charging ports are likely more prevalent when the EVSE is used in public spaces rather than for single households. The infrastructure in EVSEs with two charging ports does not differ substantially from the ones shown in this report but will need a few additional elements.

Another way that EVSEs can differ is in the way the “housing” of components is designed, especially for those in mode 3. The EVSEs in this study have most components housed in a so-called wallbox, which is just as it sounds, a box mounted on the wall. These are usually installed inside a garage or similar. There are also other common ways to install these housing compartments, such as on a pedestal (typical at outdoor parking spaces), and floor standing (usually higher power level EVSEs).

4 Complete Charging Infrastructure

In this chapter, a brief generalized description of an EVSE is first provided. Then, the compiled inventory including the recommended Ecoinvent flows, and transformation activities are presented for the devices necessary to complete the two EVSE variants. The assembly and final product manufacturing related inputs and discharges are separately discussed and summarized in section 4.6.

4.1 Generalized description of an EVSE

In this section, a short general description is given for a general EVSE for residential charging. It must be noted that this descriptive overview is intended to familiarize the reader with the basics of an EVSE, and not explicitly linked to any specific PEP/EPDs analyzed in this report. For a more detailed discussion about the same, interested readers are encouraged to refer to major EVSE manufacturers (Ensto, 2021), engineering and design service providers (Festo, 2021), 3rd party testing and certification organizations (Underwriters Laboratory [UL], 2022), or city/local/regional EVSE procurement guidelines (Vattenfall, 2022).

A conventional ~7 kW residential EVSE consists of wallbox, circuit protection, devices for metering and monitoring, and cable with connector(s). All devices have previously been listed in **Table 1**, in section 3.1.

- A **wallbox** houses some, or all, of the other devices belonging to an EVSE. The fixed installation and the charging cable are connected to the wallbox.
- **Circuit protection devices** are designed to protect the electrical circuits, the components inside, as well as surrounding people and equipment from any damage that could be caused by electric faults such as excessive current, voltage spikes and voltage surges. The studied circuit protection devices are residual current devices (RCDs), overcurrent protection devices (OCPDs), undervoltage protection devices (UVPDs), and surge protection devices (SPDs).
- **Meter and monitoring devices** are devices that manage monitoring, measuring, control and communication of the EVSE. The studied devices in this report are **smart meter** and **load management controller** (two types).
- **Charging cable** and **connector(s**) enable the connection between the EVSE and the EV**.** The connector attaches to the vehicle inlet of the EV. If the cable is not permanently fixed to the EVSE, a connector is needed to attach to an outlet on the EVSE as well (sometimes called a plug in this case).

4.1.1 EVSE power levels

Both EVSE options included in this study are single-phase AC units, with one charging outlet and a maximum capacity of 7.4 kW. For the EVSE to be able to deliver this maximum power to the EV, the current delivered to the EVSE would need be around 32 Ampere (A) (for a 230 V circuit, which is the standard in Europe). Most household circuits in Europe cannot supply current of 32 A. Instead, a typical maximum current is 16 A. Consequently, both EVSE options can be regarded as over-specified in relation to the most typical use case. Still, in order to be valid for this more common household scenario, it was assumed in this study that the power level will not be over 3.7 kW, with the household current being the limiting factor.

A residential EVSE could also have a higher charging power level than 7.4 kW, up to around 22 kW, but for that level of power the supply current would need to be around 95 A, which is not common for a household output. Charging levels higher than 7.4 kW are more common for public EVSEs. The maximum charging level of an EV battery is also dependent on the capacity of the OBC, for AC charging. The most common maximal power capabilities of an OBC are around 6.6-11 kW (Khaligh & D'Antonio, 2019).

4.2 Wallboxes

Two types of wallboxes, Ensto and EVlink, are presented. Both have similar specifications (single phase, one charging outlet, same maximum capacity), but Ensto has a fixed charging cable included while EVlink has some other additional components included.

4.2.1 Wallbox Ensto

In **Table 3**, data for the first EV wallbox – Ensto – is presented, including recommended Ecoinvent flows. For information regarding assembly input, see section 4.6.

Table 3. *Specification, reference composition and Ecoinvent flows: Ensto wallbox.*

Ensto wallbox 7.4 kW (Ensto, 2022)				
Technical name **Description** **Weight [kg]**	Ensto One Home EVH321B-HCR00 Wallbox with a maximum charging rate of 7.4 kW. Charging mode 3 (level 2). 1 charging point, single phase, with cable (5 m 32 A) and connector (Type 2) included. 6.0			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
PC	Polycarbonate	Injection molding	28.1%	1.69E+00
Electric cables/wires	Electric connector, peripheral component interconnect buss	-	26.5%	1.60E+00
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	19.2%	1.16E+00
PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	8.1%	4.86E-01
Copper alloy	Brass	Brass casting	5.6%	3.39E-01
Other plastics	Polypropylene, granulate	Injection molding	4.5%	2.70E-01
Electronic cards and other electronic components	Printed wiring board, surface mounted, unspecified, Pb free	-	4.5%	2.27E-01
PET	Polyethylene terephthalate, granulate, amorphous	Injection molding	1.0%	6.17E-02
PBT	Polyethylene terephthalate, granulate, amorphous	Injection molding	0.9%	5.40E-02
PP	Polypropylene, granulate	Injection molding	0.8%	4.63E-02
Other metals	Aluminium, wrought alloy	1. Sheet rolling, aluminium 2. Metal working, average for aluminium product manufacturing	0.4%	2.31E-02
Total			100 %	5.99E+00

4.2.2 Wallbox EVlink Pro AC

In **Table 4**, data for the second EV wallbox – EVlink – is presented, including recommended Ecoinvent flows. For information regarding assembly input, see section 4.6.

***Table 4**. Specification, reference composition and Ecoinvent flows: EVlink wallbox.*

EVlink wallbox 7.4 kW (Schneider Electric, 2019)				
Technical name	EVlink Pro AC EVB3S07N4EAM			
Description	Wallbox with a maximum charging rate of 7.4 kW. Charging mode 3 (level 2). 1 charging point, single phase, no cable included			
Weight [kg]	7.2			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
PC Polycarbonate	Polycarbonate	Injection molding	50.5%	3.63E+00
PA Polyamide	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	12.3%	8.85E-01
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	14.5%	1.04E+00
Electronic components	Printed wiring board, surface mounted, unspecified, Pb free	-	10.0%	8.67E-01
Copper	Copper, cathode	Wire drawing, copper	6.3%	4.51E-01
Various[1]	Printed wiring board, surface mounted, unspecified, Pb free	-	1.0%	7.26E-02
Brass	Brass	Brass casting	1.0%	6.94E-02
Stainless steel	Chromium 18/8 steel	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing	1.0%	6.94E-02
PE Polyethylene	Polyethylene, low density, granulate	Injection molding	0.8%	6.07E-02
Ferrous alloys	Chromium 18/8 steel	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing	0.4%	2.60E-02
Aluminium	Aluminium, wrought alloy	1. Sheet rolling, aluminium 2. Metal working, average for aluminium product manufacturing	0.1%	8.67E-03
PVC	Polyvinylchloride, bulk polymerized	Injection molding	0.1%	8.67E-03
Total			100 %	7,19E+00

1. Calculated as the residual after deduction of the stated packaging mass from the combined values for paper and cardboard reported under the category named "various" in the EPD.

4.3 Circuit protection devices

In the context of EV charging, circuit protection devices encompass a wide range of functions aimed at ensuring safe, reliable, and secure charging as well as protect the vehicle, equipment, and personnel from any electrical, mechanical, thermal, and weather-related faults. In this report, four such devices are included in the inventory, and depending on the type of EVSE, one or more of these devices are required for the complete charging infrastructure installation. Commonly occurring faults include leakage currents, grounding faults, or currents and voltages being outside the safe operating limits.

A combination of electrical, magnetic, mechanical, and electronic components constitutes these devices. They typically contain contacts made of mostly metal, a trip or triggering mechanism that responds to abnormal conditions (voltage, current, temperature, lightning, transient spikes, grounding etc.), a sensing mechanism that continuously compares the reference with the actual parameter (peak currents and voltages for example), a reset or recoil mechanism to restore the device back to its initial condition (normally open or close), once the operating conditions are back to normal.

4.3.1 Residual Current Device (RCD)

An RCD for EV charging, also known as an earth leakage protection system, residual current circuit breaker, or ground fault circuit interrupter, is a safety mechanism that protects against electric shocks and electrocution during the charging process.

An RCD is an important safety feature. It works by constantly monitoring the electric current flowing through the charging cable and detecting any imbalances in the flow of electricity. If there is an imbalance, it indicates that some of the current is leaking out of the charging cable and into the surrounding environment, potentially posing a safety risk. In response to this imbalance, the RCD will automatically shut off the power supply to the charging cable, preventing any further electrical flow until the issue is resolved. This helps ensure the safety of the user of the EVSE or the vehicle, as well as any bystanders who may be in the vicinity. An RCD typically contains a current transformer for sensing current, differential amplifier for current comparison, solenoid which is activated upon detecting an imbalance housed in an enclosure.

There are two main types of RCDs used in electrical installations, Type A and Type B, and they differ principally based on the type of residual current they are designed to detect:

- Type A RCDs are designed to detect and trip in the presence of alternating residual currents, which are predictably caused by AC voltage sources. They are often used in residential and workplace charging to protect against electrical shock hazards caused by faults in appliances and equipment.
- Type B RCDs are designed to detect and trip in the presence of both alternating and direct residual currents. Type B RCDs also have a higher sensitivity compared to Type A RCDs, and they can detect smaller current imbalances. This makes them more suitable for applications where very low current leakage must be detected as in the case with slow AC charging. Type B RCDs are also used to provide additional protection against electrical shock hazards caused by DC faults.

In **Table 5**, data for a representative RCD is presented, including recommended Ecoinvent flows. For information regarding assembly data, see section 4.6.

Table 5. *Specification, reference composition and Ecoinvent flows: RCD.*

Residual Current Device (RCD) (Schneider Electric, 2020a)				
Technical name	Acti9 iID B-SI RCCB - A9Z65463			
Description	Type B RCD, with a sensitivity of 30mA			
Weight [kg]	0.388			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	37.6%	1.46E-01
Copper	Copper, cathode	Wire drawing, copper	23.5%	9.13E-02
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	23.5%	9.13E-02
Electronic components	Printed wiring board, surface mounted, unspecified, Pb free	-	4.1%	1.61E-02
PPS	Polyphenylene sulfide	Injection molding	3.5%	1.36E-02
PBT	Polyethylene terephthalate, granulate, amorphous	Injection molding	2.9%	1.15E-02
Stainless steel	Steel, chromium steel 18/8	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing	1.9%	7.22E-03
PC	Polycarbonate	Injection molding	1.4%	5.52E-03
PET	Polyethylene terephthalate, granulate, amorphous	Injection molding	1.1%	4.25E-03
POM polyacetal	Nylon 6	Injection molding	0.2%	8.49E-04
Silver	Silver	-	0.1%	4.25E-04
Various	Printed wiring board, surface mounted, unspecified, Pb free	-	0.1%	4.25E-04
Total			100%	3.89E-01

4.3.2 Overcurrent Protection Device (OCPD)

Overcurrent protection helps prevent damage to the charging equipment, the vehicle's battery, and other electrical components in case of a fault or malfunction caused by short circuit, over loading or ground fault, by limiting the current flowing through the charging system (Keller, 2010). OCPDs are also useful for controlling and limiting the amount of power that is supplied to the EV as charging occurs within safe operable voltage and current levels. Options for overcurrent protection include, for example:

- Fuses: A wire or filament that melts when current exceeds the threshold (Nurse et al.). They are simple and cost-effective but must be replaced after they blow.
- Circuit breakers: Circuit breakers are like fuses, but they can be reset after they trip. They use an electromechanical, magnetic, or electronic mechanism to disconnect the circuit when the current exceeds a certain level.

- Electronic trip units: Electronic trip units are used in more advanced over current protection systems, together with circuit breakers. They use electronic sensors to measure current and can be programmed to provide more precise protection based on specific current thresholds.
- Overcurrent relays: Overcurrent relays are another type of advanced protection system that use current transformers and electronic sensors to detect overcurrent conditions. They are generally used in conjunction with circuit breakers or other protective devices. They can be used to protect against sudden inrush, short-circuit and overload conditions.

In **Table 6**, data for a representative OCPD is presented, including recommended Ecoinvent flows. For information regarding assembly data, see section 4.6.

Table 6. *Specification, reference composition and Ecoinvent flows: OCPD.*

Overcurrent protection device (OCPD) (ABB, 2022)				
Technical name	SACE Tmax XT2 with electronic release			
Description	Low voltage circuit breaker			
Weight [kg]	1.25			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
BMC/SMC	Epoxy resin, liquid	Injection molding	41.7%	5.19E-01
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	25.9%	3.22E-01
Copper	Copper, cathode	Wire drawing, copper	14.3%	1,78E-01
PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	4.4%	5,47E-02
Brass	Brass	Brass casting	2.5%	3,11E-02
Copper alloys	Brass	Brass casting	2.3%	2,86E-02
PC	Polycarbonate	Injection molding	2.3%	2,86E-02
PBT	Polyethylene terephthalate, granulate, amorphous	Injection molding	2.1%	2.61E-02
Printed Circuit Board	Printed wiring board, surface mounted, unspecified, Pb free	-	1.8%	2,24E-02
Stainless steel	Steel, chromium steel 18/8	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing	0.9%	1,12E-02
PET	Polyethylene terephthalate, granulate, amorphous	Injection molding	0.8%	9.95E-03
Precious metal	Silver	-	0.7%	8,71E-03
ABS	Acrylonitrile-butadiene-styrene copolymer	Injection molding	0.3%	3,73E-03
Total			100%	1,25E+00

4.3.3 Undervoltage Protection Device (UVPD)

A UVPD is a safety feature that is commonly used in EVSEs to protect against too low voltage levels. It is designed to prevent operation if the input voltage falls below a certain threshold. A UVPD works by monitoring the input voltage by using a voltage detector or a comparator circuit that compares the input voltage to a reference voltage. If the input voltage falls below the reference voltage, the UVPD circuit will disable the charging system until the voltage returns to an acceptable level. UVPD is an important safety feature because it helps prevent damage to the charging system and the vehicle's battery.

Table 7 presents data representative for an UVPD, including recommended Ecoinvent flows. Conversely, this data was collected from an EPD for an overvoltage protection device (OVPD), as no EPD for the UVPD could be found. The webpage presenting the UVPD linked to the EPD of the OVPD (Schneider Electric, n.d.-b), i.e. it can be claimed that the data is valid also for the UVPD. For information regarding assembly data, see section 4.6.

***Table** 7:Specification, reference composition and Ecoinvent flows: UVPD*

Undervoltage protection device (UVPD) (Schneider Electric, n.d.-b), represented by overvoltage protection device (OVPD) (Schneider Electric, 2020d)				
Technical name	Auxiliaries iMSU - A9A26500			
Description	This part is an overvoltage protection device, working as a representative part for the corresponding UVPD, as there are no EPD published for that specific component (Schneider Electric, n.d.-b).			
Weight [kg]	0.08			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	39.3%	3.04E-02
Copper	Copper, cathode	Wire drawing, copper	17.2%	1.33E-02
Electronic components	Printed wiring board, surface mounted, unspecified, Pb free	-	15.0%	1.16E-02
Ferrous alloys	Chromium 18/8 steel	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing	7.7%	5.99E-03
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	5.8%	4.47E-03
Brass	Brass	Brass casting	5.0%	3.90E-03
PC	Polycarbonate	Injection molding	3.7%	2.85E-03
PBT	Polyethylene terephthalate, granulate, amorphous	Injection molding	3.3%	2.57E-03
PPS	Polyphenylene sulfide	Injection molding	1.8%	1.43E-03
Stainless steel	Chromium 18/8 steel	1. Sheet rolling, chromium steel 2. Metal working, average for chromium steel product manufacturing	0.7%	5.70E-04
Silver	Silver	-	0.1%	9.50E-05
Total			100%	7.71E-02

4.3.4 Surge Protection Device (SPD)

For this compilation of circuit protection devices, the Swedish electric standard (Svensk Elstandard, 2023) was used as the reference literature. It states that an "*överspänningsskydd*" is a necessity when installing an EVSE. However, even though this Swedish term can be directly translated into "over voltage protection device", i.e. an OVPD as presented in the previous section in connection to the EPD representative for an UVPD, another and seemingly more common translation is surge protection device (SPD). The glossary within the standard itself translated the term to SPD. Therefore, for this work, only the SPD was deemed to be a mandatory component.

SPDs help protect the charging infrastructure, including the charging station and associated electrical components, from damage caused by voltage surges and transient spikes. Many jurisdictional standards and regulations mandate their inclusion within EV charging installations. These devices help to extend the lifespan of the charging infrastructure, reduce maintenance costs, ensure the safe and reliable operation of the EV, avoid costly non-compliance fines, and facilitate safe and efficient EV charging. There are several variants and SPD options such as:

- Type 1 SPD: These are designed to protect against direct lightning strikes and other high-energy surges that can occur in outdoor environments. They are typically installed on the incoming power line to the charging station and provide high-level protection against transient surges.
- Type 2 SPD: These are designed to protect against lower-level surges that may occur in indoor or outdoor environments. They are typically installed at the service entrance or subpanel and provide intermediate-level protection against transient surges.
- Type 3 SPD: These are designed to protect against low-level surges that may occur within the charging station or in other electrical equipment connected to the charging system. They are typically installed at the device level and provide low-level protection against transient surges.
- Combination SPD: These combine two or more types of SPDs (e.g., Type 1 and Type 2) in a single device. They provide multiple levels of protection against transient surges and are often used in locations where high levels of surge protection are required.
- Modular SPD: These are designed to be installed in a modular fashion, allowing for easy expansion and modification of the surge protection system. They are often used in larger charging stations or in locations where the electrical system is subject to frequent changes.
- Active SPD: These use electronic components to actively monitor the electrical system and provide surge protection as needed. They are often used in high-tech charging systems or in locations where advanced surge protection capabilities are required.

In **Table 8**, data for a representative SPD is presented, including recommended Ecoinvent flows. For information regarding assembly data, see section 4.6.

***Table 8**. Specification, reference composition and Ecoinvent flows: SPD.*

Surge Protection Device (SPD) (Schneider Electric, 2016)				
Technical name	iPRD40r 3P+N -A9L40601			
Description	Type 2 SPD, modular Made for 3P + N installations[1]			
Weight [kg]	0.41			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	32.56%	1,33E-01
PBT Polybutylene Teraphtalate	polyethylene terephthalate, granulate, amorphous	Injection molding	31.40%	1,29E-01
Electronic cards	Printed wiring board, surface mounted, unspecified, Pb free		19.77%	8,09E-02
PC Polycarbonate	Polycarbonate	Injection molding	8.14%	3,33E-02
Brass	Brass	Brass casting	3.49%	1,43E-02
Copper	Copper, cathode	Wire drawing, copper	3.49%	1,43E-02
PA Polyamide	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	1.16%	4,76E-03
Total			100%	4,09E-01

1. Overspecified for the EVSEs in this report, but it was chosen as no EPD for 1-phase SPD was found.

4.4 Measuring and monitoring

In this section, two types of components used for measuring and monitoring are presented, energy meter and load management.

4.4.1 Energy meter

An energy meter, sometimes called smart meter, is a device with the primary function to measure energy consumption, in this case when charging the vehicle. It is not a requirement to include this in the EVSE, but it is recommended, and it can play an important role in more advanced charging setups, for example, in vehicle-to-grid solutions.

A separate EV energy meter may also be desirable under certain circumstances for billing, and for load management, utility incentives and installation readiness reasons. For example, a new EV owner interested in installing a residential EVSE may opt for a separate EV meter for billing validation, familiarization with the technology and adjustment of their charging behavior. A separate EV meter is also suited for cases where the existing electrical wiring system must be upgraded and retrofitted to install the home charging station. Lastly utilities could also use the separate EV meter installation status as an eligibility criterion for enrolling in their EV incentive programs.

In **Table 9**, data for a representative energy meter is presented, including recommended Ecoinvent flows. For information regarding assembly data, see section 4.6.

Table 9*. Specification, reference composition and Ecoinvent flows: Energy meter.*

Energy Meter (Schneider Electric, 2015)				
Technical name	Acti iEM3100 - A9MEM3100			
Description	Energy meter with poles 1P+N, 3P and 3P+N			
Weight [kg]	0.37			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
PC	Polycarbonate	Injection molding	35.5%	1.31E-01
PET	Polyethylene terephthalate, granulate, amorphous	Injection molding	20.6%	7.65E-02
Electronic cards	Printed wiring board, surface mounted, unspecified, Pb free		19.0%	7.04E-02
Copper	Copper, cathode	Wire drawing, copper	10.8%	4.02E-02
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	10.7%	3.97E-02
LCD Screen	Liquid crystal display, unmounted	Liquid crystal display, minor components, auxiliaries and assembly effort	2.2%	8.21E-03
Elastomer	Styrene-acrylonitrile copolymer	-	0.7%	2.59E-03
PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	0.1%	4.32E-04
PUR	Polyurethane, flexible foam	Injection molding	0.1%	4.32E-04
Total			100%	3.70E-01

4.4.2 Load management controller

A *load management controller* or *load shredder* can help manage the electricity load of an EVSE in relation to other devices on the same circuits, and make sure there is no overloading. It can manage the flow of electricity to the EV (depending on the power usage in the rest of the circuit), monitor the battery charge level, and provide data on energy usage and costs.

There are different types of load management controllers. For a residential EVSE as described in this report, the load only needs to be balanced between one charging point, and the rest of the household, whereas if one has several EVSEs (commercial use or in the case of a multi-household residential association), a more powerful load management controller is needed. Load management controllers are often classified as being static or dynamic. Static load management has a set maximum charging level that does not change over time, whereas dynamic load management is more complex, using real-time monitoring which adapts the power according to other factors, such as cost and strain on the grid (Mennekes, 2024).

In **Table 10** data for a representative load management controller for residential use is presented, including recommended Ecoinvent flows. For information regarding assembly data, see section 4.6.

***Table 10**: Specification, reference composition and Ecoinvent flows: Load management controller for residential use.*

Load management controller for residential use (Schneider Electric, n.d.-a)				
Technical name	EVlink Home anti tripping system 3P - EVA1HPC3			
Description	Load management controller for residential use with poles 3P + N[1]			
Weight [kg]	0.48			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
Ferrous alloys	Chromium 18/8 steel	1. Sheet rolling 2. Metal working, average for chromium steel product	12.20%	1.15E-01
Electronic components	Printed wiring board, surface mounted, unspecified, Pb free	-	9.30%	8.74E-02
ABS	Acrylonitrile-butadiene-styrene copolymer	Injection molding	9.20%	8.65E-02
Copper	Copper, cathode	Wire drawing, copper	8.90%	8.37E-02
PE Polyethylene	Polyethylene, low density, granulate	Injection molding	7.50%	1.78E-03
PVC	Polyvinylchloride, bulk polymerized	Injection molding	5.80%	5.45E-02
PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	5.70%	5.36E-02
PC	Polycarbonate	Injection molding	0.20%	1.88E-03
Total			100%	4.84E-01

1. Overspecified for the EVSEs in this report, but it was chosen as no EPD for 1-phase load management was found.

***Table 11**. Specification, reference composition and Ecoinvent flows: Load management controller for multiple EVSEs*

Load management controller for multiple EVSEs (Schneider Electric, 2020b)				
Technical name	EV charge controller, EcoStruxure EV Charging Expert, 5 charging stations, dynamic charge management			
Description	A load management controller to be used when several EVSEs are combined, such as in a parking garage. Uses dynamic charge management.			
Weight [kg]	0.94			
Material according to EPD	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
Steel	Steel, low-alloyed	1. Sheet rolling, steel 2. Metal working, average for steel product manufacturing	63.1%	5.93E-01
Aluminium	Aluminium, wrought alloy	1. Sheet rolling, aluminium 2. Metal working, average aluminium product	18.1%	1.70E-01
Electronic components	Printed wiring board, surface mounted, unspecified, Pb free	-	17.9%	1.68E-01
PE	Polyethylene, low density, granulate	Injection molding	0.5%	4.79E-03
PC	Polycarbonate	Injection molding	0.4%	3.59E-03
Total			100%	9.38E-01

In **Table 11** data for a representative load management controller for commercial use, called EV charge controller, is presented, including recommended Ecoinvent flows. This component should not be included when modelling a residential EVSE as described earlier in this report. Instead, the EV charge controller should be included when modelling several EVSEs in use at the same time, such as in a parking garage. In this case, it would replace the residential load management controller (presented in **Table 10**).

In addition to the EV charge controller, a fleet with multiple EVSEs might need more additional components, such as an external modem, a more powerful energy meter (replacing the one listed in this report) and a switch (Schneider Electric, 2024). For larger fleets, such as parking garages with several floors, several more switches, as well as additional communication devices, are likely needed.

4.5 Charging cable and connectors

In this section, the charging cable needed to transfer power from the EVSE to the EV is presented in more detail.

The purpose of an EV charging cable is to connect the electric vehicle to a charging station, allowing the vehicle's battery to be charged with electricity. The cable must be capable of transmitting the required amount of electrical power to charge the battery, which can range from a few kilowatts for a home charging station to several hundred kilowatts for a fast-charging station. Charging cables are designed with safety in mind, to protect against electric shock, short circuits, and other hazards. The cables typically include features like insulation, grounding, shielding, and jacketing, which improve their durability to withstand the rigors of daily use such as weather, temperature changes, and overall stressors—physical, electrical, mechanical.

EV charging cables are typically manufactured using a combination of materials and processes to ensure their durability, reliability, and safety. Here is an overview of the general steps involved in the manufacturing of EV charging cables:

- Conductor Stranding: The first step in the manufacturing process is to strand the copper or aluminium conductors that will transfer the electric power to the vehicle. This process involves twisting multiple thin wires together to form a single, thicker conductor.
- Insulation Extrusion: Once the conductors are stranded, they are coated with insulation material. The most common insulation materials for EV charging cables are thermoplastic elastomers (TPE) or cross-linked polyethylene. These materials are extruded onto the conductor using a process called insulation extrusion, which involves melting the insulation material and then extruding it over the conductor.
- Shielding: After the insulation has been applied, a layer of shielding is often added to protect the cable from electromagnetic interference. The shielding can be made of materials like copper or aluminium foil, or it can be braided with fine wires.
- Jacketing: The final step in the manufacturing process is to add a protective jacket over the cable. The jacket is typically made of a durable, weather-resistant material like polyvinylchloride (PVC) or TPE. It protects the cable from environmental factors like heat, cold, moisture, and sunlight.

Connectors are the parts enabling the connection between the cable and other components. The end of the charging cable that goes into the vehicle needs to have a connector that fits the model of the vehicle. The end of the cable going into the wallbox or charging station can be connected either through a fixed installation, or via another connector.

One of the wallboxes in this report – Ensto – already has a charging cable included, with a length of 5 m. It has a fixed installation in the wallbox end, and a type 2 connector in the vehicle end. For the sake of comparability, the cable length for the other wallbox – EVlink – is assumed to be 5 m as well, but being equipped with connectors at both ends.

The component chosen to represent the cable needed to complement the EVlink wallbox is a charging cable from Harting Technology group with the specification *Charging cable Mode3 Typ2 32A 1ph 5m* (n.d.-a). This specific cable is a fitting example of what is needed to make the EVlink unit complete, as it is 5 meters long and has connectors at each end, while also complying with the specified charging power of 7.4 kW and the rated current of 32 A.

4.5.1 Mass calculations

The charging cable datasheet specifies the materials used for its various parts, and a total weight, but as opposed to other components, does not mention how much mass is allocated to each material. Calculations are therefore performed to estimate the mass.

The cable contains four copper wires. Three with a cross-sectional area of 6 mm^2 and one with a cross-sectional area of 0.5 mm^2 (Harting Technology Group, n.d.-a). By calculating the total volume of these wires, and using the density of copper, a mass could be determined. In the same way, the mass of the remaining parts of the cable could be estimated, as the total cable diameter is specified in the datasheet – 12.8 mm. The rest of the cable was assumed to be thermoplastic polyurethane (TPU), which is in accordance with the information given in the datasheet. The total volume of the cable was calculated, the volume for copper wires subtracted, and then the density was used to calculate the total mass of TPU.

The rest of the mass specified for the Harting charging cable was assumed to be allocated to the contactors. In the datasheet it is specified that the material of the hood/housing is polyamide (PA), and the pin contacts are made from copper alloy, with silver plating. Three contact pins, formulated for a cross-sectional area of 6 mm^2 per wire, are needed per side. Two smaller contact pins for communication were neglected for the overall mass estimate. On the infrastructure side, the contactor pins are of male variant, and on the vehicle side the contractor pins are of female variant. In order to calculate the amount of silver plated on the contact pins, representative subparts from the same supplier were chosen (Harting Technology Group, n.d.-b, n.d.-c). In these documents, the pins are illustrated along with values for their dimensions, and a total weight is stated. Using the illustrations, a plated area could be approximated. The thickness of the silver plating is not given in the data for this specific component, but was assumed to be the same as for a similar component – 3 μm (Harting Technology Group, 2007).

The calculated weight of the silver was subtracted from the weight of the contact pin, and the rest was assumed to be copper alloy. Finally, when the mass of copper wire, TPU, silver plating and copper alloy were all calculated, the rest of the total mass was assumed to be PA, used in the contactors. The calculated mass is presented in **Table 12**.

Table 12: *Specification, reference composition and Ecoinvent flows: Charging cable with connectors.*

Charging cable with connectors (Harting Technology Group, n.d.-a)				
Technical name	Charging cable Mode3 Typ2 32A 1ph 5m			
Description	EV charging cable, with two type 2 connectors, one for vehicle part, and one for infrastructure side. The length of the cable is 5 m. It has 1 phase, and a max current of 32A.			
Weight [kg]	2.4 kg			
Material according to datasheet	***Recommended material flow in Ecoinvent***	***Recommended transformation flows in Ecoinvent***	***Weight [%]***	***Weight [kg]***
Hood/housing: PA	Glass fiber reinforced plastic, polyamide, injection molded	Injection molding	37.4%	8.98E-01
Wire: copper	Copper, cathode	Wire drawing, copper	34.5%	8.27E-01
Cable: TPU	Polyurethane, flexible foam, flame retardant	Extrusion, plastic pipes	27.7%	6.64E-01
Contact pins: copper alloy	Brass	Casting, brass	0.47%	1.1E-02
Contact pins plating: silver	Silver	-	0.004%	1.06E-04
Total			100%	2.40E+00

4.6 Electrical equipment production

In sections 4.2-4.5, composition data and the intermediate material transformations were discussed and tabulated. These transformed materials may have to undergo one or more of further transformations and component manufacturing steps, as well as be assembled, packaged, and made ready for shipment to the installation site as finished parts or products. As discussed earlier, in section 3.2*,* there is an absence of information on primary and secondary supplier activities, and the number of production steps necessary to take bring raw materials into components readymade for installation. This has prompted a few additional assumptions to be made, in order to complete the inventory modeling.

For this purpose, publicly available environmental reports from Mitsubishi Electric Corporation (2021, 2023a) are utilized as proxy indicators of assembly and processing inputs. Mitsubishi is a global manufacturer of electrical and electronic products for home, building, energy, automotive, rolling stock and information and communication systems that manufactures the type and range of parts covered in this report for residential EV charging infrastructure installations (Mitsubishi Electric Corporation, 2023b). The corporation's sustainability report for fiscal years 2021 and 2023 (Mitsubishi Electric Corporation, 2021, 2023a) comply with Japanese laws for emission reporting and provide aggregate estimates of a variety of material balance, energy, emissions, waste and water indicators assessed in accordance with the Global Reporting Initiative standards (2018). Five-year average estimates (2019-2023) are then normalized and reported on a per kg of product basis.

Data from four different tables in two reports by – *manufacturing input*, *manufacturing output*, *reducing greenhouse gases emitted in the value chain,* and *amount of water intake/drainage/reuse* – were used to estimate flows related to the electrical equipment assembly process. One of the outputs reported by Mitsubishi Electric Corporation (2021, 2023a) was "regulated chemicals, air emissions." As no corresponding flow was identified in the Ecoinvent database, the top ten reported and estimated releases of substances from the Pollutant Release and Transfer Register (PRTR) in Japan were chosen as a proxy (Ministry of the Environment, 2018). Adapted versions of these tables, containing all the raw data used for the calculations, along with summary explanations for how the data was used for these calculations, can be found in appendix A.

Table 13 presents the normalized inputs, outputs, and emissions, expressed per kg of product, recommended to be used in the LCA modelling as a proxy for the assembly process and all final manufacturing steps for all EVSE parts presented earlier in presented tables 2-12.

***Table 13a**: Normalized inputs, adapted from Mitsubishi Electric Corporation (2021, pp. 79, 81; 2023a, pp. 86, 88) to be used as a proxy for the electric equipment assembly process.*

Flows	*Normalized values*	*Unit*	*Recommended E3.91 provider*
Inputs			
Electronic equipment for assembly	*1.10E+00*	*kg / kg product*	*Upcount of all incoming mass per kg*
Electricity	7.99E-01	kWh/kg product	market for medium voltage…
Natural gas[1]	2.08E-02	m3 / kg product	market group for natural gas
LPG	1.63E+00	g / kg product	market for LPG
Oil	1.46E+00	kg / kg product	market for heavy fuel oil
Chemicals	2.60E+00	g / kg product	50 % market for chemical, organic 50% market for chemical, inorganic
Water	1.02E+00	kg / kg product	market for tap water

[1]*Combination of "city gas" and "other greenhouse gases". Partly recalculated from mass to volume.*

Table 13b: *Normalized outputs, adapted from Mitsubishi Electric Corporation (2021, pp. 79, 81; 2023a, pp. 86, 88) and the Ministry of the Environment (2018) in Japan to be used as a proxy for the electric equipment assembly process.*

Flows	***Normalized values***	***Unit***	***Recommended E3.91 provider***
Outputs			
CO_2, air emission	1.15E-01	kg / kg product	Elementary flow
VOC, air emission	3.69E-01	g / kg product	Elementary flow
Toluene, air emission[1]	9.76E-02	g / kg product	Elementary flow
Xylene, air emission[1]	7.15E-02	g / kg product	Elementary flow
Ethyl benzene, air emission[1]	3.46E-02	g / kg product	Elementary flow
Hydrocarbons, air emission[1]	3.06E-02	g / kg product	Elementary flow
Isohexane, air emission[1]	1.76E-02	g / kg product	Elementary flow
Dichloromethane, air emission[1]	1.23E-02	g / kg product	Elementary flow
Alkylbenzene, air emission[1]	1.17E-02	g / kg product	Elementary flow
Dichlorobenzene, air emission[1]	9.03E-03	g / kg product	Elementary flow
Chlorodifluoromethane, air emission[1]	8.76E-03	g / kg product	Elementary flow
Regulated chemicals, water emission	3.20E-03	g / kg product	Elementary flow
NO_x, air emission	1.91E-02	g / kg product	Elementary flow
SO_x, air emission	3.14E-04	g / kg product	Elementary flow
BOD, water emission	3.73E-02	g / kg product	Elementary flow
COD, water emission	4.01E-02	g / kg product	Elementary flow
Scrap, going to recycling	6.69E-02	kg / kg product	Cut off /optional collection
Non-hazardous waste, to treatment	3.13E-02	kg / kg product	market for treatment of inert waste
Hazardous waste, to treatment	3.29E-03	kg / kg product	market for hazardous waste, for incineration
Electronic equipment, assembled	*1.00E+00*	*kg / kg product*	*Mass data from tables 3-12*

[1]Assumed to be a fraction of "regulated chemicals, air emissions"

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Appendix A

In **Tables A to E,** the data from Mitsubishi Electric Corporation (2021, 2023a) and the Ministry of the Environment (2018) in Japan that was used to establish inputs and outputs for the assembly process, and all final manufacturing steps, are presented. The resulting flows are found in **Table F**, and the corresponding normalized values are presented in **Table 13** in the report. Following is a summary of how the tables in this appendix has been used to estimate the flows in **Table 13**:

- The input ***chemicals*** is the sum of both the two categories for inputs classified *controlled chemical substances* and *volatile organic compounds* in **Table A**.
- The input ***natural gas*** is the sum of *city gas* and *other greenhouse gases* in **Table A**, with the latter recalculated from mass to volume.
- The percentages of the different substances in **Table C** are used to distribute the mass of *regulated chemicals* in **Table A**.
- In order to ensure a mass balance, the input ***electronic equipment for assembly*** is calculated from the sum of the following flows in **Table B:**
    - *Weight of all products sold.*
    - *Amount recycled.*
    - *Non-hazardous waste* minus *amount recycled.* (in order to not count recycled material twice)
    - *Hazardous waste*
- The total ***water input*** is represented by the *water consumption (water intake minus drainage volume)* from **Table D**.

All data presented in table A-E are reported "as is", except some water data values (see tables' footnotes for water usage), but values not used at all for the compilation in Table F have been left out here. For example, the manufacturing input in the original Mitsubishi table includes input of materials summarizing weight of all products sold with the weight of the packaging materials and "waste emissions". This value is not included in table A below, as packaging materials intentionally have been left out, and the mass input is calculated from the summary of products sold, wastes and recycled materials in order to establish mass balance for the unit process.

***Table A**: Manufacturing input, representative for electric equipment assembly process. Adapted from Mitsubishi Electric Corporation (2021, p. 79; 2023a, p. 86), where the each year corresponds to a fiscal year period, i.e. from 1st of April the previous year and up to 30th of March for the year stated:*

Category	***Base Unit***	***2019***	***2020***	***2021***	***2022***	***2023***
Electricity total	GWh	1.87E+03	1.81E+03	1.74E+03	1.91E+03	1.89E+03
City gas[1]	m^3	3.99E+07	3.72E+07	3.49E+07	3.80E+07	3.58E+07
LPG	t	3.67E+03	3.62E+03	3.73E+03	3.99E+03	3.78E+03
Oil (crude oil equivalent)[2]	kl	3.92E+03	3.81E+03	2.81E+03	-	-
Other greenhouse gases[1]	t	8.24E+03	7.61E+03	6.72E+03	8.22 E+03	9.27 E+03
Controlled chemical substances (amounts handled)[3]	t	4.23E+03	3.73E+03	2.61E+03	3.15E+03	4.24E+03
Volatile organic Compounds[3]	t	2.78E+03	2.66E+03	2.02E+03	2.12E+03	2.44E+03
Water usage intake[4]	m^3	1.09E+07	1.11E+07	1.03E+07	1.07E+07	1.09E+07

1. Modelled as natural gas

2. Values for 2022 and 2023 includes transports and are therefore not included in the calculations

3. Modelled together as "chemicals" – 50% inorganic and 50% organic

4. The values for 2021-2023 have been adjusted, as they were reported one order of magnitude too large. This was discovered when comparing the reported "water consumption" with calculated values of water consumption using "water usage intake" and "discharge of water into water."

***Table B:** Manufacturing output, representative for electric equipment assembly process. Adapted from Mitsubishi Electric Corporation (2021, pp. 79, 81; 2023a, pp. 86, 88), where the each year corresponds to a fiscal year period, i.e. from 1st of April the previous year and up to 30th of March for the year stated:*

Category	*Base Unit*	*2019*	*2020*	*2021*	*2022*	*2023*
Products						
Weight of all products sold[1]	kt	2.39E+03	2.30E+03	2.11E+03	2.25E+03	2.50E+03
Emissions (from manufacturing)						
Controlled chemical substances, air emission[2]	t	8.81E+02	7.91E+02	8.14E+02	3.89E+02	5.15E+02
Volatile organic compounds, air emission	t	9.99E+02	9.46E+02	7.92E+02	6.45E+02	8.82E+02
NO_x, air emission	t	-	8.30E+01	2.50E+01	2.80E+01	4.00E+01
SO_x, air emission	t	-	1.00E+00	1.00E+00	6.00E-01	3.00E-01
Controlled chemical substances, water emission	t	8.00E+00	8.00E+00	8.00E+00	7.20E+00	5.70E+00
BOD, water emission	t	-	9.80E+01	1.01E+02	6.50E+01	8.10E+01
COD, water emission	t	-	1.31E+02	1.09E+02	5.70E+01	7.30E+01
Water, discharge into water	m^3	8.58E+06	8.64E+06	8.07E+06	8.39E+06	8.47E+06
Waste						
Non-hazardous waste	t	2.06E+05	1.98E+05	1.82E+05	2.63E+05	2.86E+05
Hazardous waste	t	7.22E+03	1.26E+04	5.45E+03	6.11E+03	6.64E+03
Amount recycled	t	1.73E+05	1.59E+05	1.47E+05	7.00E+04	2.23E+05

1. Shipping weight of products

*2. In Japan, these substances are subject to Japan's PRTR law. Statistics for the PRTR emissions are used as a proxy in the modelling (Ministry of the Environment, 2018), see **Table C**.*

Table C: Top ten substances of reported releases and estimated releases from Pollutant Release and Transfer Register (PRTR) according to the Ministry of the Environment (2018) in Japan.

PRTR chemicals	***Base Unit***	***Reported releases***	***Estimated releases***	***Total***	***Share of total***
Toluene	t/year	5.25E+04	4.09E+04	9.33E+04	33%
Xylene	t/year	2.81E+04	4.03E+04	6.83E+04	24%
Ethylbenzene	t/year	1.49E+04	1.82E+04	3.30E+04	12%
Polyoxyethylene alkyl ether (C=12-15)[1]	t/year	8.90E+01	2.08E+04	2.09E+04	7%
n-Hexane	t/year	1.02E+04	6.62E+03	1.68E+04	6%
Dichloromethane (alias: methylene dichloride)	t/year	9.88E+03	1.84E+03	1.17E+04	4%
Linear alkylbenzene sulfonate (C=10-14)	t/year	1.30E+01	1.12E+04	1.12E+04	4%
Dichlorobenzene	t/year	9.60E+01	8.54E+03	8.63E+03	3%
D-D / Dichloropropane[1]	t/year	4.00E+00	8.44E+03	8.44E+03	3%
Chlorodifluoromethane (alias HCFC-22)	t/year	1.83E+02	8.19E+03	8.37E+03	3%

[1]Modelled as hydrocarbons in Ecoinvent

Table D: Amount of water intake/drainage/reuse, representative for electric equipment assembly process. Adapted from Mitsubishi Electric Corporation (2021, p. 81; 2023a, p. 88), where the each year corresponds to a fiscal year period, i.e. from 1st of April the previous year and up to 30th of March for the year stated:

Category	***Base Unit***	***2019***	***2020***	***2021***	***2022***	***2023***
Water consumption (water intake minus drainage volume)[1]	10000 m^3	2.32E+02	2.42E+02	2.25E+02	2.36E+02	2.41E+02

[1]The values for 2021-2023 have been adjusted, as they were reported with one order of magnitude too large. This was discovered when comparing the reported "water consumption" with calculated values of water consumption using "water usage intake" and "discharge of water into water."

Table E: Greenhouse gas emissions, representative for electric equipment assembly process. Adapted from Mitsubishi Electric Corporation (2021, p. 81; 2023a, p. 88), where the each year corresponds to a fiscal year period, i.e. from 1st of April the previous year and up to 30th of March for the year stated:

Category	***Base Unit***	***2019***	***2020***	***2021***	***2022***	***2023***
Scope 1						
Greenhouse gas emissions (CO_2-equivalent) total[1]	kt-CO_2	2.78E+02	2.65E+02	2.42E+02	2.76E+02	2.72E+02

[1]Direct emissions from fuel use and industrial processes at the company (Scope 1). CO2, SF6, HFCs and PFCs emissions associated with the use of city gas, heavy oil, etc., and with product manufacturing.

Table F-a: Input flows, representative for electric equipment assembly process, resulting from average values in Table A, B and D. Corresponding to Table 13a.

Flows	***From table***	***Unit***	***Average values***
Inputs			
Electronic equipment for assembly[1]	B	*t*	2.54E+06
Electricity	A	GWh	1.85E+03
Natural gas[2]	A	m^3	4.81E+07
LPG	A	t	3.76E+03
Oil[3]	A	kt	3.37E+03
Chemicals[4]	A	t	6.00E+03
Water[5]	D (or A+B)	kt	2.35E+03

*[1]Sum of "Scrap, going to recycling", Non-hazardous waste, to treatment", "Hazardous waste, to treatment", and "Electronic equipment, assembled", see **Table F-b**.*

[2]Combination of city gas and other greenhouse gases, both assumed to be natural gas. Greenhouse gases are recalculated from mass to volume, by using density of natural gas at 15°C and 1013 mbar.

[3]Recalculated from kL to kT, by using a median density for heavy fuel oil, as reported by Alfa Laval (2018).

*[4]Combination of "controlled chemical substances" and "volatile organic compounds" in **Table A**. Modelled as 50% organic chemicals and 50% inorganic chemicals.*

*[5]Value is taken from **Table D**, which is the same value gotten from subtracting "water discharged into water" in Table B from "water usage" in **Table A**.*

Table F-b: Output flows, representative for electric equipment assembly process, resulting from average values in Table B-E. Corresponding to 13b.

Flows	***From table***	***Unit***	***Average values***
Outputs			
CO_2, air emission	E	kt-CO_2	2.67E+02
VOC, air emission	B	t	8.53E+02
Toluene, air emission[1]	B + C	t	2.25E+02
Xylene, air emission[1]	B + C	t	1.65E+02
Ethyl benzene, air emission[1]	B + C	t	7.98E+01
Hydrocarbons, air emission[1]	B + C	t	7.08E+01
Isohexane, air emission[1]	B + C	t	4.05E+01
Dichloromethane, air emission[1]	B + C	t	2.83E+01
Alkylbenzene, air emission[1]	B + C	t	2.70E+01
Dichlorobenzene, air emission[1]	B + C	t	2.09E+01
Chlorodifluoromethane, air emission[1]	B + C	t	2.04E+01
Regulated chemicals, water emission	B	t	7.38E+00
NO_x, air emission	B	t	4.40E+01
SO_x, air emission	B	t	7.25E-01
BOD, water emission	B	t	8.63E+01
COD, water emission	B	t	9.25E+01
Scrap, going to recycling	B	t	1.55E+05
Non-hazardous waste, to treatment[2]	B	t	7.23E+04
Hazardous waste, to treatment	B	t	7.60E+03
Electronic equipment, assembled[3]	B	t	2.31E+06

[1]*Calculated by taking their share of total in Table C and multiply by the average of "controlled chemical substances, air emission" in* ***Table B.***

[2]*Calculated by subtracting "Amount recycled" from "Non-hazardous waste" in* ***Table B.*** *In order to achieve a reasonable mass balance, it was assumed that the amount recycled was a fraction of the non-hazardous waste.*

[3]*From "weight of all products sold" in Table B.*

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