



EV-111

# Security threat analysis for EV charging infrastructure

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The European Network for Cyber Security (ENCS) is a non-profit membership organization that brings together critical infrastructure stake owners and security experts to deploy secure European critical energy grids and infrastructure.

## Version History

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April 2016	EV-101-2016 v1.0	EV Charging Systems Security Threats
24 December 2019	EV-101-2019 v1.0	Security risk assessment for electric vehicle charging infrastructure
25 February 2025	EV-111 2025v1.0	Threat analysis for EV charging infrastructure, including context analysis to build profiles.

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# 1 Introduction

This document provides a threat analysis for electrical vehicle charging infrastructure. It analyzes information assets, access control policies, and threats to derive security objectives for the infrastructure and its operational environment.

Cyber-attacks on the electric vehicle charging infrastructure are not just a financial and reputational risk to the Charge Point Operators (CPOs) that manage the infrastructure. They are also becoming a large societal risk.

Electric vehicle charging is quickly becoming an essential service to our society. As we are transitioning to electric vehicles, more and more people will rely on charging for their mobility. If the charging infrastructure is not working, people cannot use their cars. So, cyber-attacks on the infrastructure can lead to major societal damage.

Moreover, the EV charging infrastructure could be used to attack the power grid. Large CPOs remotely control hundreds of thousands of charging stations throughout Europe. If attackers gain control of a CPO's infrastructure, they could switch the power of the connected charging stations on and off. The switching could also cause grid imbalances in the supply and demand for electricity. If these imbalances are large enough, they could lead to severe power outages.

Making sure the EV charging infrastructure is secure is, hence, critical. This document analyzes the threats to these systems and defines security objectives to counter these threats. Objectives are defined for both the EV charging infrastructure itself and for the environment in which it operates.

The threat analysis outlines the threats to the EV charging infrastructure. This document is not a risk assessment. It does not assess the impact or likelihood of the threats nor evaluate the risk on whether it is acceptable or not. This document can help CPOs to assess their risk, according to their own processes and risk appetite.

## 1.1 Relation to other documents

This document is part of a larger series on EV charging infrastructure security:

- *EV-211: Security requirements from IEC 62443 for EV charging infrastructure* [1] gives security requirements for the EV charging infrastructure as a system, selected from the IEC 62443-3-3 standard. The requirements can be used to procure EV charging services from a CPO.
- *EV-311: Security requirements from IEC 62443 for procuring EV charging stations* [2] contains security requirements that CPOs can use when they procure EV charging stations. The requirements are chosen so that a charging

station meeting them can be easily integrated into a system meeting the security requirements in this document.

- *EV-312: Implementing IEC 62443-4-2 requirements in OCPP 2.0.1* [3] provides guidance on how the requirements in this EV-311 can be implemented in the OCPP 2.0.1 protocol.

*EV-313: Coverage of EN 18031 requirements by the IEC 62443 requirements for EV charging stations* [4] shows how the requirements in the harmonized standard EN 18031 for the Radio Equipment Directive are covered by the requirements in EV-311.

## 2 System description

To determine the security threats to the EV charging infrastructure, we should first understand how the system works: what its intended use is, in what environment it will be used, and what information assets are processed by it.

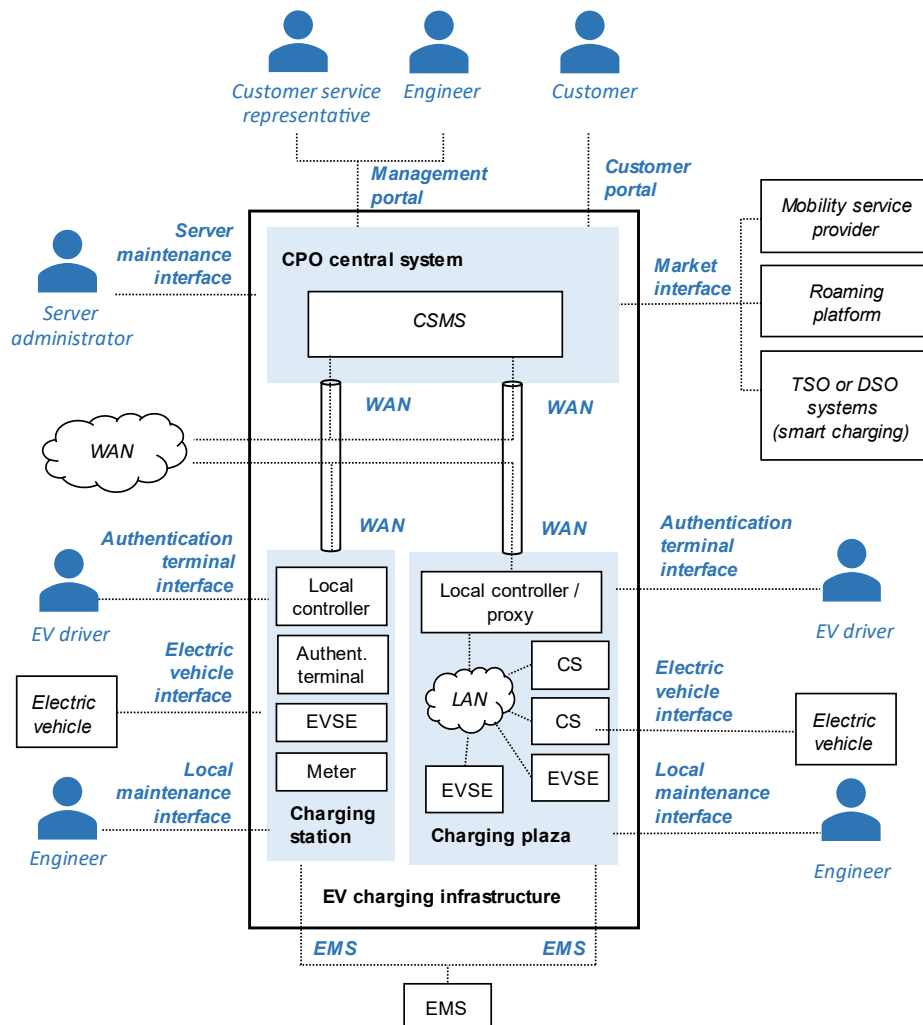


Figure 1: Reference architecture for the EV charging station, showing its users and interfaces.

### 2.1 Intended use of the system

The EV charging infrastructure consists of the systems used by a Charge Point Operator (CPO) to operate and maintain their charging stations and plazas. This includes the charging stations themselves, and the central systems such as the charging station management system (CSMS).



### 2.1.1 Components in the system

The CPO central system manages the different charging stations through the charging station management system (CSMS). It contains the servers and workstations used to maintain the CPOs charging stations remotely.

The central system allows to exchange information with mobility service providers and roaming platforms to allow EV drivers to use charging stations operated by different CPOs.

In some cases, the central system also connects to the systems of a Transmission System Operator (TSO) or Distribution System Operator (DSO) to allow smart charging. The rate of charging is then adjusted based on the capacity of the electricity grid.

Through the customer portal, customers can retrieve their transaction data and contact customer services, who can access the CPO central system through the management portal, like engineers, to solve issues for the customers. The customer portal is not in scope of this document. However, it should be developed following secure development guidelines.

The charging stations can be standalone devices or be in a group forming a charging plaza. The charging stations usually include a local controller and authentication terminal for EV drivers to authenticate to the device, the electric vehicle supply equipment (EVSE) to supply electrical power to the EV vehicles, and a meter, to measure how much power is supplied. The charging station can also be locally maintained by engineers.

### 2.1.2 Users of the system

The CPO central system is maintained by employees or contractors of the charge point operator. This threat analysis distinguishes between three different groups:

- **Customer service representatives** working for instance at the helpdesk of the CPO. They assist customers with simple problems with the charging stations and have limited access to them.
- **Engineers** that maintain the charging stations. They can make changes to the charging station configuration and update the firmware.
- **Server administrators** that maintain the CPO central system. They are responsible for both the server infrastructure, such as operating systems, virtualization platforms, databases, and CSMS applications.

The charging stations can be accessed by electric vehicle drivers to start and stop charging. Electric vehicles also communicate with the charging station to, for instance, control the charging speed and for stop charging when the vehicle's battery is full. Engineers can also perform maintenance of the charging stations locally.

## 2.2 Intended operational environment

The intended operational environment of the EV charging infrastructure is shown in the reference architecture in Figure 1.

### 2.2.1 Interfaces

The EV charging infrastructure is connected to the operational environment on the following interfaces.

#### 2.2.1.1 Management portal

Customer service representatives and engineers can access the CPO central system through the management portal to get information on charging stations and change their state or configuration. The management portal is usually a web portal accessed over the internet.

#### 2.2.1.2 Customer portal

Customers can access their customer and billing information through the customer portal. The customer portal can be a web portal on the internet or a smartphone app.

#### 2.2.1.3 Market interface

The central systems are connected to the market parties, such as mobility service providers, roaming platforms, and DSO and TSO systems, over the market interface. The connections are usually over the internet, sometimes through a VPN. Typically, web services are used, for instance using the OCPI, OCHP, OSCP, and OICP protocols [5].

#### 2.2.1.4 Server maintenance interfaces

Server administrators use the server maintenance interface to perform maintenance on the CPO central system servers. The interface is usually accessed over the internet, sometimes through a VPN. Administrators can use any protocol used to administer servers, such as remote desktop protocols or SSH.

#### 2.2.1.5 WAN interface

The charging station is connected to the CPO central system over a wide-area network (WAN). The CPO central system collects meter values and transaction data. The other way around, the CPO central system may send charging profiles, set tariffs, or install configurations and updates on the charging station.

The WAN is usually a wireless mobile network, such as a GPRS or LTE network. Network segregation measures such as private APNs are commonly used.

The CSMS often manages the charging stations through the Open Charge Point Protocol (OCPP). This protocol allows to change the settings, perform firmware updates, and collect logs. The reference architecture assumes that all remote maintenance is done through the CSMS central system.

#### **2.2.1.6 Authentication terminal interface**

Users authenticate to the charging station through the authentication terminal interface. Some of the most common methods include RFID cards, bank cards, and authentication through an application. In the near future, ISO 15118's Plug & Charge will allow authorization by means of certificates [6].

The authentication method used depends on the mobility service provider and often cannot be freely chosen by the CPO. So, only high-level security requirements are included for the terminal. The payment terminal should be secured according to relevant standards depending on the payment method it accepts. For example, for credit cards, it should follow the PCI DSS [7].

#### **2.2.1.7 Electrical vehicle interface**

The electric vehicle connects to the charging station on the electric vehicle interface, which is the power connection that will charge the car. In Europe, the main EV plug standards are IEC 62196 Type 2 [8] for AC chargers, and CCS Combo 2 [9] for DC chargers.

The vehicle can communicate with the charging station to control charging. For AC charging, this is usually done through simple electrical signals. For DC charging, digital communication over protocols such as DIN SPEC 70121 [10] or ISO 15118 is used. In the future, AC charging will also use digital communication. According to ISO 15118, through the electrical vehicle interface, EV and charging station are able to communicate to:

- Start and end the charging process
- Update and install certificates
- Perform identification and authorization for charging
- Set charging targets and schedules
- Share charging and booking information

#### **2.2.1.8 Local maintenance interface**

Besides over the WAN through the CPO central system, engineers may also locally configure and maintain the equipment through the local maintenance interface. This interface can be an Ethernet, serial, or USB port. Engineers connect an engineering laptop to the local maintenance interface and can configure the equipment using specialized management software or a web interface.

### 2.2.1.9 EMS interface

An energy management system (EMS) can be used for load balancing by connecting to the charging plazas or charging stations through the EMS interface. The EMS might set charging control limits to prevent overloading connections or due to weather conditions. The communication between the EMS and the charging station can be done through IEEE 2030.5 protocol [5]. This interface is found only in certain charging stations, depending on the brand, model, and deployment (e.g., stand-alone or within a charging plaza).

## 2.2.2 Physical locations

The CPO central system can be located in the data centers of the CPO or in a cloud system.

Charging stations can be placed in public parking spaces, in parking garages, or at homes. A charge point operator can operate hundreds of thousands of charging stations spread over a large area. So, it is not realistic to physically protect them with cameras or alarm systems. Engineers only visit charging stations when there are problems or there is scheduled maintenance.

## 2.3 Information assets

As the primary function of the infrastructure is to enable EV charging, the core information assets are charging transaction information and information to authorize charging. In some cases, the infrastructure will also process charging profiles for smart charging. To allow the infrastructure to be managed, maintenance and security assets are also needed.

### 2.3.1 Charging transaction information

The main purpose of a charging infrastructure is to charge electric vehicles and process usage information per customer in the CSMS for billing. Therefore, important information assets for the charging infrastructure are those needed for charging transactions:

- Transaction data from EV drivers, such as the ID of the EV driver
- Meter values
- Tariffs

If the integrity of the transaction information is compromised, this could lead to financial damage to the CPO as transactions are not processed correctly. It may also cause problems with charging. A charging station could for instance stop charging before the EV's battery is full. Or it could lock the power plug because it thinks a transaction is not completed. Switching charging on or off at many charging stations could lead to instability in the power grid.

The confidentiality of the transaction information is also important, as it contains personal data. The transactions show for instance where someone's car has been. If such information would leak, it would likely be an incident under the GDPR.

A compromise of availability could also lead to economic losses for CPOs and customers. If, for instance, the charging stations cannot connect to the central systems, this could mean that EV charging customers cannot charge their vehicles, delaying their trip. But if charging is allowed, it could lead to delays in payment to the CPO or some transactions not being properly registered.

### 2.3.2 Authorization information

Credit and debit card information or other information for transaction authorization (such as RFID data or PIN codes) is also critical. If its integrity is compromised, attackers may charge without paying. If the confidentiality of transaction authorization information, such as credit card information, is compromised, attackers could steal money from the CPO's customers. If the availability of processing authorization information is compromised, customers may not be able to charge their EVs or CPOs may not be able to charge customers for the transactions, leading to financial damage.

### 2.3.3 Smart charging information

If the charging station is used for smart charging, the CSMS may send charging profiles to the charging station to set the maximum charging speed. A compromise of the integrity of the profiles could worsen grid congestion, possibly requiring TSOs or DSOs to disconnect customers, which could have a financial impact.

Load profiles are not highly confidential, as they contain, for instance, load limit and time duration data, but no sensitive data is included. Nonetheless, they do give information about congestion in the grid, that attackers may use to plan attacks on it.

If smart charging is not available, TSOs and DSOs will need to resolve congestion issues in the grid in another ways. They may be required to forcibly disconnect some users, leading to economic damage.

### 2.3.4 Maintenance assets

The information assets needed for maintenance are the firmware and the stored configuration, including the communication settings. Additionally, engineers may need the operational logs of the device to analyze and fix problems with the device. If the integrity of the configuration or firmware is compromised, attackers may use it to get to the other information assets. If the confidentiality of maintenance information is compromised, attackers may use the information to prepare attacks.

### 2.3.5 Security assets

For security, key information assets are the security logs and the keys and passwords. These include the passwords used by engineers to log in and the keys used for authentication and communication security on the WAN. A compromise of the integrity or confidentiality of these assets can again lead to a compromise of the other assets.

## 3 Threats

Based on the system description we can determine the possible threats. On external interfaces, there are threats of unauthorized access, exploits of software vulnerabilities, and attacks on communication. There are physical threats to the location and supply chain threats to the equipment used. For each normal user group, there are insider threats. And there are threats of what attackers may do to the critical assets after they have gained access.

### 3.1 Threat actors

The threat analysis considers both external and internal threat actors. Possible external threat actors are:

- Criminals
- Nation-state actors
- Terrorists

Criminals can try to make money from the EV charging infrastructure through fraud. Individual EV drivers may try to find ways to charge without paying. Criminal groups may try to offer tools or methods to charge more cheaply. The risk of fraud seems to have been low until now. There are publicly known vulnerabilities in some payment systems. However, the financial damages of these vulnerabilities have apparently not been high enough to force CPOs to fix them.

Criminals may also try to make money through ransomware. They could for instance try to make it impossible to charge at the charging stations of a CPO, causing serious financial and reputational damage. They could also threaten to release confidential information about customers.

Nation-state actors and terrorists may try to use the EV charging infrastructure to disrupt the electricity grid. By switching the power for many charging stations on or off at the same time, they can cause problems in balancing electricity demand and supply. Such balancing problems could lead to major power outages. If smart charging is used in the future to counter grid congestion, attacking it may also cause damage to transformers and power lines [11] [12].

It is difficult to know the capabilities and goals of nation-states. However, there are signs that some are developing cyber-attacks to cause power outages. There have been targeted cyber-attacks on grid operators in Ukraine in 2015 and 2016 [13]. Most EU member states have appointed electricity companies as operators of essential services under the NIS directive so that they are required to take appropriate security measures. However, attackers do not have to limit themselves to operators of essential services. Major CPOs may already be big enough to cause balancing issues.

## 3.2 Unauthorized access threats to the CPO central system

Unauthorized access threats to the CPO central system concern an attacker getting access to the central system as one of the user groups (see Figure 1 in Section 2) using the normal access method on an interface. They may, for instance, compromise a key or password and then log in. Threats are considered per interface (see Figure 1), as usually different measures are taken on each interface.

<b>T-UA1 Unauthorized access as a charging station on the WAN</b>	An attacker gains access to the WAN network and then gains unauthorized access to the CSMS as a charging station. With this access, they may stop charging, and tamper with transactions and meter values.
<b>T-UA2 Unauthorized access as an engineer or customer service representative on the management portal</b>	An attacker gains access to the management portal interface and then gains unauthorized access to the CSMS as an engineer or customer service representative. With this access, they may stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware on all connected charging stations.
<b>T-UA3 Unauthorized access as a server administrator on the server maintenance interface</b>	An attacker gains access to the server maintenance interface and then gains unauthorized access to the CSMS as a server administrator. With this access they may change the server software and configuration, and in this way take full control of the CSMS. With such control, they can stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware on all connected charging stations.
<b>T-UA4 Unauthorized access as a DSO system, roaming platform or mobility service provider on the market interface</b>	An attacker gains access to the market interface and then gains unauthorized access to the CSMS. With this access, they may stop charging, tamper with transactions and meter values, and set incorrect tariffs or charging profiles.



<b>T-UA5 Unauthorized access as a customer on the customer portal</b>	An attacker gains access to the customer portal and then gains unauthorized access to the CSMS. With this access, they may stop charging, tamper with transactions and meter values, and set incorrect tariffs or charging profiles.
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### 3.3 Unauthorized access threats to the charging station

Unauthorized access threats to the charging station concern an attacker getting access to the charging station as one of the user groups (see Figure 1 in Section 2) using the normal access method on an interface. They may, for instance, compromise a key or password and then log in. Threats are considered per interface (see Figure 1), as usually different measures are taken on each interface.

The interface to the EMS is considered part of the physical threats in Section 3.6, as it is usually not possible to directly access the interface on the EV charging station or plaza without physical tampering.

<b>T-UA6 Unauthorized access as the CSMS</b>	An attacker gains access to the WAN network and then gains unauthorized access to the charging station as the CSMS. With this access, they may stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware.
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<b>T-UA7 Unauthorized access as an EV driver on the authentication terminal interface</b>	An attacker gains access to the authentication terminal interface and then gains unauthorized access to the charging station as an EV driver. With this access, they may commit fraud and charge their vehicle without cost.
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<b>T-UA8 Unauthorized access as an electric vehicle in the electric vehicle interface</b>	An attacker gains access to the electric vehicle interface and then gains unauthorized access to the charging station as an electric vehicle. With this access, they may commit fraud.  <i>Remark:</i> Committing fraud is only possible if it is possible to pay through EV charging interface (“plug & charge”).
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<b>T-UA9 Unauthorized access as an engineer on the local maintenance interface</b>	An attacker gains access to the local maintenance interface and then gains unauthorized access to the charging station as an engineer. With this access, they may change the configuration or firmware.
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### 3.4 Exploits of software vulnerability

Exploits of software vulnerabilities concern an attacker exploiting a vulnerability in the EV charging infrastructure to gain access to it. Using a software vulnerability, attackers may gain privileged access to the system, even when users on an interface normally have restricted access, as is for instance the case on the market interface.

<b>T-EX1 Exploit of a software vulnerability on the CPO central system on the WAN</b>	An attacker gains access to the WAN interface and then exploits a software vulnerability to gain access to the CPO central system. With this access, they may stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware on all connected charging stations.
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<b>T-EX2 Exploit of a software vulnerability on the internet-facing interfaces</b>	An attacker gains access to the management portal, customer portal, and market interface and then exploits a software vulnerability to gain access to the CPO central system. With this access, they may stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware on all connected charging stations.
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<b>T-EX3 Exploit of a software vulnerability on the server maintenance interface</b>	An attacker gains access to the server maintenance interface and then exploits a software vulnerability to gain access to the CPO central system. With this access, they may take full control of the CSMS. With such control, they can stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware on all connected charging stations.
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<b>T-EX4 Exploit of a software vulnerability on the</b>	An attacker gains access to the WAN interface and then exploits a software vulnerability to gain access to
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**charging station on the WAN**

the charging station. With this access, they may take full control of the charging station, and then stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware.

**T-EX5 Exploit of a software vulnerability on local interfaces on the charging station**

An attacker gains access to the authentication terminal, electric vehicle, local maintenance, or EMS interface on the charging station and then exploits a software vulnerability to gain access to it. With this access, they may take full control of the charging station, stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware.

### 3.5 Communication threats

Communication threats concern compromising the confidentiality, integrity, or availability of the communication on an interface. Separate threats are considered on different interfaces (see Figure 1 in Section 2), as they are protected by different measures.

Attacks on local networks in the field, such as the charging plaza LAN or the network between the EMS and the charging stations or plaza, are not considered here. They are seen as physical threats to the system and treated in Section 3.6.

**T-CM1 Data modification on WAN**

An attacker gains access to the WAN network and then modifies information sent between the charging station and the CSMS. In this way, they may stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware.

**T-CM2 Data disclosure on WAN**

An attacker gains access to the WAN network and then eavesdrops on information sent between the charging station and the CSMS. In this way, they may gain confidential information sent between the charging station and CSMS, such as meter values or the configuration of the charge point operator's system.

**T-CM3 Network denial-of-service attack on the WAN**

An attacker gains access to the WAN interface and disrupts the normal operation of the charging station,

for instance by sending malformed messages or flooding the device with data. In this way, they may stop charging, prevent transaction data, meter readings, and logs from being sent to the CSMS, or prevent charging profiles, configurations, and firmware updates from being sent to the charging station.

**T-CM4 Data modification on the internet facing interfaces**

An attacker modifies information sent or received on the management portal, customer portal, or market interface. In this way, they may stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware.

**T-CM5 Data disclosure on internet facing interfaces**

An attacker eavesdrops on information sent or received on the management portal, customer portal, or market interfaces. In this way, they may gain confidential information, such as credit and debit card information, charging station keys or passwords, or personal information from customers.

**T-CM6 Network denial-of-service attack on the internet-facing interfaces**

An attacker disrupts normal communication on the management portal, customer portal, or market portal, for instance by sending malformed messages or flooding the servers with data. In this way, they may prevent transactions from being completed normally, charging profiles from being changed for smart charging by DSOs systems, or configuration changes and firmware updates from being done by engineers and customer service providers.

**T-CM7 Data modification on the server maintenance interface**

An attacker gains access to the server maintenance interface and then modifies information sent between the server administrator and the CPO central system. In this way, they may change the central system configuration or software.

**T-CM8 Data disclosure on the server maintenance interface**

An attacker gains access to the server maintenance interface and then eavesdrops on information sent between the server administrator and the CPO central system. In this way, they may gain confidential

information, such as the configuration of the charge point operator's system.

**T-CM9 Network denial-of-service attack on the server maintenance interface**

An attacker gains access to the management portal or market interfaces and disrupts the normal operation of the central system, for instance by sending malformed messages or flooding the servers with data. In this way, they may prevent server administrators from performing maintenance on the system, for instance, to recover after an incident.

### 3.6 Physical threats

Physical threats concern an attacker gaining access to the system using physical means. They may try to break into the charging station and then access local interfaces, such as the local maintenance interface, tamper with the hardware, for instance by changing data stored on a hard disk or in flash memory, or tamper with the networks, for instance by putting additional devices in them.

They may also try to break into the data centers for the central systems and gain access to the servers.

Of particular concern is the threat of an attacker breaking into one charging station and using their access to get to other charging stations. Such an attack would allow an attacker to compromise more than one charging station at the same time, leading to a higher impact.

We only consider physical threats that may lead to a compromise of the information assets in Section 2.3. Direct physical sabotage of the charging station itself is not considered.

**T-PH1 Unauthorized physical access to the central system centers**

An attacker gains physical access to the data center where the CPO central system is hosted and uses the physical access to gain logical access. Attackers may log in on one of the ports or physically tamper with the hardware. With this access, they may take full control of the CSMS. With such control, they can stop charging, tamper with transactions and meter values, set incorrect tariffs or charging profiles, or change the configuration or firmware on all connected charging stations.

**T-PH2 Unauthorized physical access to a charging station**

An attacker gains physical access to a charging station and uses the physical access to gain logical access to the EV charging station. Attackers may log in on one of the ports or physically tamper with the hardware. With this access, they may commit fraud or change the configuration or firmware.

**T-PH3 Unauthorized access to a charging plaza LAN or local controller**

An attacker gains physical access to the LAN or local controller of a charging plaza. They use the access to gain logical access to the charging plaza. Attackers may tap into one of the network cables, connect to a router or switch, log in on one of the ports of the controller, or physically tamper with the hardware. With this access, they may stop charging in the plaza, commit fraud, or change the configuration or firmware.

**T-PH4 Unauthorized access as the EMS on the EMS interface**

An attacker gains access to the EMS interface, for instance by physically breaking into the interface or the connection between the EMS and the charging station, or by compromising the EMS. The attacker then uses the interface access to gain logical access to the EV charging station or plaza. With this access, they may stop charging or reduce the rate of charging.

**T-PH5 Unauthorized access to the EV charging infrastructure from a compromised field location**

An attacker gains physical access to a charging station or charging plaza and uses it as an entry point into the EV charging infrastructure to perform further attacks on the CPO central system or other charging stations or plazas.

### 3.7 Supply chain threats

Supply chain threats concern attacks on the EV charging infrastructure through suppliers. Attackers may compromise the hardware or software used in the infrastructure before it is installed, for instance to put backdoors in it.

The threat of sensitive information leaking through suppliers is not considered here. It can only be countered by organizational measures, not by any technical measures in the EV charging infrastructure.

Threats through staff at suppliers working on the EV charging infrastructure (remotely or locally) are considered part of the insider threats (Section 3.8).

<p><b>T-SC1 Unauthorized software, firmware, or hardware modification at suppliers</b></p>	<p>An attacker modifies software, firmware, or hardware at the supplier. This way, attackers may for instance install backdoors or logic bombs in the EV charging infrastructure that would allow them to stop charging, tamper with transactions and meter values, or set incorrect tariffs or charging profiles.</p>
<p><b>T-SC2 Unauthorized software, firmware or hardware modification between the supplier and installation</b></p>	<p>An attacker modifies software, firmware, or hardware after it leaves the supplier and before it is installed in the EV charging infrastructure. This way, attackers may, for instance, install backdoors or logic bombs in the charging station that would allow them to stop charging, tamper with transactions and meter values, or set incorrect tariffs or charging profiles.</p> <p><i>Remark:</i> Attackers could, for instance, modify software or firmware in transit from the supplier to the CPO or stored on a server or laptop. They could modify the hardware in storage or during transport.</p>

### 3.8 Insider threats

Insider threats concern threats to the EV charging infrastructure by authorized human users. Different threats are considered for the two user groups: engineers and server administrators (see Figure 1 in Section 2).

<p><b>T-IN1 Harmful actions by engineers</b></p>	<p>An engineer with authorized access, incidentally or on purpose, performs actions that are harmful to the EV charging infrastructure. They may, for instance, make incorrect changes to the configuration or install the wrong firmware.</p>
<p><b>T-IN2 Harmful actions by server administrators</b></p>	<p>A server administrator with authorized access, incidentally or on purpose, performs actions that are harmful to the EV charging infrastructure. They may, for instance, make incorrect changes to the configuration or install the wrong firmware.</p>

**T-IN3 Harmful actions by former employees or contractors**

An employee or contractor no longer working for the organization performs actions that are harmful to the EV charging infrastructure. They may, for instance, make incorrect changes to the configuration, or install the wrong firmware.

### 3.9 Post-exploitation threats

The following threats concern steps attackers can take to compromise the EV charging infrastructure information assets after they have gained access to the system. They are considered separately, as they may be combined with any threat that gives an attacker access.

**T-PE1 Loss of configurations**

The configuration of the charging station is deleted or becomes corrupted through mistakes by engineers or intentional actions from an attacker who has gained access.

**T-PE2 Software or firmware corruption**

The software or firmware installed in the EV charging infrastructure is corrupted, for instance by placing a backdoor or logic bomb in it, or simply making it unusable.



## 4 Zoning model

To mitigate the threats, the EV charging infrastructure will be divided into three zones: the CPO central system, charging stations, and charging plazas. Different objectives will be defined for each zone. To define the access control objectives, we also identify the users of each zone.

### 4.1 Security zones

In the reference architecture, the EV charging infrastructure is divided into three zones:

- The **CPO central system** consists of all servers that are used to manage and maintain the charging stations remotely.
- The **charging station** consists of all the equipment physically inside the charging station. This can include a local controller, the authentication terminal, the electric vehicle supply equipment (EVSE), and a meter.
- The **charging plaza** consists of all EV charging equipment in a charging plaza connected to the central system through one local controller or proxy. This can include multiple charging stations, EVSE, and a local area network (LAN).

The zoning model allows to set different objectives for the different types of systems in each zone. The CPO central system is a modern IT application, often running in the cloud. The charging station is an embedded system, usually placed in public locations without supervision. The charging plaza consists of multiple embedded systems, connected over a local network in a somewhat supervised location. Different security measures can and should be taken for each type of system.

### 4.2 Access control policy

To determine what access control measures have to be taken in each zone, we need to know the users of the zone. Table 1 and Table 2 list the users that are authorized to access the CPO central system and the charging station respectively, and the access they require. The last column gives the interfaces on which they access the system (see the reference architecture in Figure 1).

*Table 1 User groups on the CPO central system.*

User	Required access	Interface
Charging station	<ul style="list-style-type: none"> <li>• Send transaction data and meter values for billing</li> <li>• Optional: Get charging profiles</li> </ul>	WAN

Engineers	<ul style="list-style-type: none"> <li>• Remote maintenance to charging stations through the central system</li> </ul>	Management portal
Customer service representative	<ul style="list-style-type: none"> <li>• Fix customer problems with charging stations</li> </ul>	Management portal
Customers	<ul style="list-style-type: none"> <li>• See transaction information</li> </ul>	Customer portal
Market parties (mobility service provider, roaming platform, TSO, or DSO)	<ul style="list-style-type: none"> <li>• Exchange transaction data</li> <li>• Enable EV drivers to use charging stations from different CPOs</li> <li>• Provide smart charging schedules</li> </ul>	Market interface
Server administrator	<ul style="list-style-type: none"> <li>• Maintain applications</li> <li>• Maintain network and server infrastructure</li> </ul>	Server maintenance interface

The access control model assumes that engineers do not access charging stations directly over the WAN. They always work through the central maintenance system.

*Table 2 User groups on the charging station.*

<b>User</b>	<b>Required access</b>	<b>Interface</b>
Charging Station Management System (CSMS)	<ul style="list-style-type: none"> <li>• Collect transaction data and meter values for billing</li> <li>• Set tariffs</li> <li>• Configure the charging station</li> <li>• Restore the charging station from a backed-up configuration</li> <li>• Update the firmware</li> <li>• Monitor operational logs</li> <li>• Optional: Send charging profiles</li> </ul>	WAN
Engineer	<ul style="list-style-type: none"> <li>• Configure the charging station</li> <li>• Restore the charging station from a backed-up configuration</li> </ul>	Local maintenance

- Update the firmware
- Analyze the operational logs

EV driver	<ul style="list-style-type: none"> <li>• Authenticate for charging</li> <li>• <i>Optional:</i> Pay for the charging</li> </ul>	Authentication terminal
Electric vehicle	<ul style="list-style-type: none"> <li>• Control the charging</li> <li>• <i>Optional:</i> authenticate for charging</li> </ul>	Electric vehicle
Other charging station	<ul style="list-style-type: none"> <li>• Load balancing within a charging plaza</li> </ul>	LAN
Local EMS	<ul style="list-style-type: none"> <li>• Energy management within the local context (e.g., building)</li> </ul>	LAN

## 5 Security objectives for EV charging infrastructure

We can now define security objectives to mitigate the threats. The zoning model described in Section 4 allows to set objectives based on how scalable threats are:

- For threats that can affect many charging stations through the central systems or the WAN network, the security objectives provide protection against intentional violation using sophisticated means with moderate resources, domain-specific skills, and moderate motivation.
- For local threats where the impact is limited to one charging station or a small number of charging stations, such as physical attacks, the security objectives provide protection against intentional violation using simple means with low resources, generic skills, and low motivation.

Less strict objectives are set for local threats because providing protection against sophisticated attackers would be costly. Charging stations would have to be designed to be much more physically hardened than they are now, and they should be monitored for physical intrusions. The impact of local attacks is usually not large enough to justify such measures.

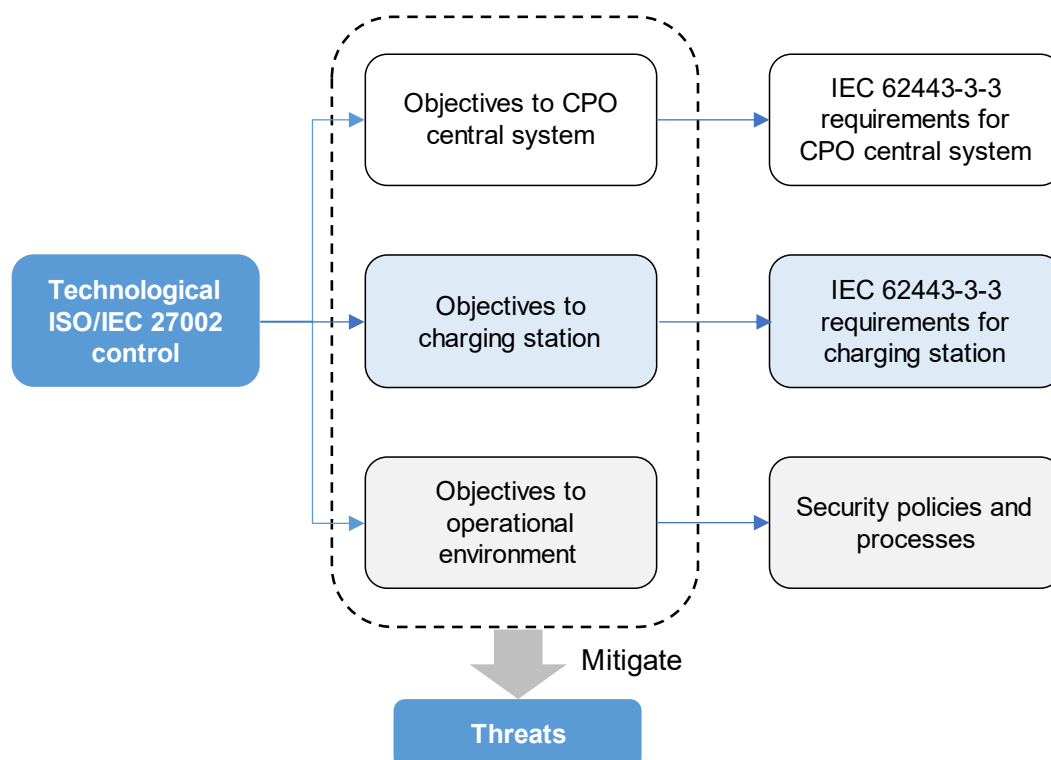


Figure 2: Relation of the security objectives to the ISO/IEC 27001 and IEC 62443 standards.

The objectives are derived from the controls in ISO/IEC 27002:2022 [14]. For the organizational and people controls, the controls themselves are used as objectives. The physical and technological controls are refined into more detailed objectives for the central system, charging station, and operational environment, as shown in Figure 2, as the aim of this document is in the end to define technical security requirements for EV charging infrastructures in [1].

The objectives of the operational environment are additional organizational and technical measures that the charge point operator should take to securely operate the EV charging infrastructure. These should be addressed in the internal security policies and processes of the operator.

## 5.1 Organizational controls

The charge point operator should implement at least the following organizational objectives from ISO/IEC 27002:2022 in the operational environment to mitigate the threats:

<b>Operational environment</b>	<p><b>5-SO1 Access control processes:</b> The CPO has implemented access control processes covering the following controls from ISO/IEC 27002:2022:</p> <ul style="list-style-type: none"> <li>• 5.4 Management responsibilities</li> <li>• 5.9 Inventory of assets and other information</li> <li>• 5.15 Access control</li> <li>• 5.16 Identity management</li> <li>• 5.18 Access rights</li> </ul>
	<p><b>5-SO2 Supplier management:</b> The CPO has implemented processes to manage the security of its suppliers, covering the following controls from ISO/IEC 27002:</p> <ul style="list-style-type: none"> <li>• 5.19 Information security in supplier agreements</li> <li>• 5.20 Addressing information security within supplier agreements</li> <li>• 5.21 Managing information security in the ICT supply chain</li> <li>• 5.24 Information security incident management planning and preparation</li> </ul>
	<p><b>5-SO3 Security event and incident handling:</b> The CPO has implemented security event and incident handling processes covering the following controls from ISO/IEC 27002:2022:</p> <ul style="list-style-type: none"> <li>• 5.25 Assessment and decision on information security events</li> </ul>

	<ul style="list-style-type: none"> <li>• 5.26 Response to information security incidents</li> </ul>
	<p><b>5-SO4 Business continuity:</b> The CPO has implemented business continuity policies and processes covering the following controls from ISO/IEC 27002:2022</p> <ul style="list-style-type: none"> <li>• 5.30 ICT readiness for business continuity</li> </ul>
	<p><b>5-SO5 Protecting personal information:</b> The CPO has implemented process to protect the privacy and personal information of its customers and employees covering the following controls from ISO/IEC 27002:2022:</p> <ul style="list-style-type: none"> <li>• 5.34 Privacy and protection of PII</li> </ul>

## 5.2 People controls

The charge point operator should implement at least the following people controls from ISO/IEC 27002:2022 in the operational environment to mitigate the threats:

Operational environment	<p><b>6-SO1 Personnel security:</b> The CPO has implemented personnel security processes covering the following controls from ISO/IEC 27002:2022:</p> <ul style="list-style-type: none"> <li>• 6.1 Screening</li> <li>• 6.2 Terms and conditions of employment</li> <li>• 6.3 Information security awareness, education, and training</li> <li>• 6.4 Disciplinary process</li> <li>• 6.5 Responsibilities after termination or change of employment</li> </ul>
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## 5.3 Physical controls

The charge point operator should ensure that the data center housing the central system is protected following physical security standards for modern data centers. This includes implementing at least the following controls from ISO/IEC 27002:2002:

Operational environment	<p><b>7-SO1 Physical security:</b> The CPO has implemented a physical security policy covering the following controls from ISO/IEC 27002:2022:</p> <ul style="list-style-type: none"> <li>• 7.1 Physical security perimeters</li> <li>• 7.2 Physical entry</li> </ul>
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	<ul style="list-style-type: none"> <li>• 7.3 Securing offices, rooms, and facilities</li> <li>• 7.4 Physical security monitoring</li> <li>• 7.8 Equipment siting and protection</li> <li>• 7.12 Cabling security</li> </ul>
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Describing appropriate physical security measures for data centers would go too far for this document. Guidelines and best practices can be found, for example, in the EUCS document for cloud services, published by ENISA [15] or in the CSA CCM [16]. If the CPO is using a cloud platform, it is important to understand the physical security measures applied by the cloud provider (e.g., [17], [18]).

For the charging stations and plazas, the strategy is to limit the impact of a physical break-in to one location (see objective **8.22-SO3** in Section 5.4). By restricting network communications, it can be made very difficult for physical attackers in one charging station to reach other charging stations or central systems.

But is still useful to have physical protection against intentional violation using simple means with low resources, generic skills, and low motivation to discourage fraud and vandalism. Hence, the following objectives should be met by the charging stations and plazas, and their operational environment.

Note that for physical controls, objectives for the charging stations and charging plazas differ. However, for the technological controls defined in the section 5.4, objectives for charging stations and charging plazas are the same.

#### 7.4 Physical security monitoring

<b>Charging station</b>	<p><b>7.4-SO1 Physical access detection on charging stations:</b> The charging station sends an alert to the CSMS when any part of its casing is opened.</p> <p><i>Implementation guidance:</i> Alerts for opening the casing are included in the OCPP 2.0 (Appendix 1) standard and the security extension to OCPP 1.6.</p>
<b>Charging plaza</b>	<p><b>7.4-SO2 Physical access detection on charging stations:</b> The cabinets housing the charging plaza equipment (see objective 7.4-SO1) send an alert to the CSMS when they are opened.</p>
<b>Operational environment</b>	<p><b>7.4-SO3 Physical access monitoring:</b> The charge point operator monitors physical security events on the charging stations and plazas and responds to them.</p>

	<p><i>Implementation guidance:</i> Operators should at least respond to access control events generated according to objective 7.4-SO1, and to reports from users or passers-by on physical damage to charging stations.</p> <p>In most cases, an engineer will need to go to the charging station to inspect it. The operator should define a policy on what checks an operator must perform to ensure that the charging station configuration and firmware have not been modified.</p>
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### 7.8 Equipment siting and protection

<b>Charging station</b>	<p><b>7.8-SO1 Tamper resistance on charging stations:</b> The charging station has a casing that protects against physical manipulation so that attackers without specialist tools cannot reach its internal components without leaving visible traces.</p>
<b>Charging plaza</b>	<p><b>7.8-SO2 Tamper protection for charging plaza equipment:</b> The local controller or proxy, and the networking equipment for a charging plaza will be placed in a locked cabinet. The cabinet protects against physical manipulation so that attackers without specialist tools cannot reach its internal components without leaving visible traces.</p>

### 7.12 Cabling security

<b>Charging station</b>	<p><b>7.12-SO1 Cabling security for EMS connection:</b> Network cables connecting a charging station to an EMS are protected against tampering. Attackers without specialist tools cannot physically connect to the EMS interface without leaving visible traces.</p>
<b>Charging plaza</b>	<p><b>7.12-SO2 Cabling security for charging plazas:</b> The network cables of the charging plaza local area network and the connection to an EMS are protected against tampering. Attackers without specialist tools cannot physically connect to the corresponding interfaces without leaving visible traces.</p>

## 5.4 Technological controls

While for the organizational, people, and physical controls we just use the controls from ISO/IEC 27002:2022, the technological controls are further specified in more detailed



objectives for the CPO central system, charging station, and the operational environment (see Figure 2).

### 8.3 Information access restriction

<b>CPO central system</b>	<p><b>8.3-SO1 Least privileges on the WAN interface:</b> The CPO central system enforces access control on the WAN, so that charging stations and plazas can only access the functions they need.</p>
	<p><b>8.3-SO2 Role separation on the market interface:</b> The CPO central system enforces access control on the market interface with separate roles for mobility service providers, roaming platforms, and DSO systems so that they can only access the functions they need for their role.</p>
	<p><b>8.3-SO3 Centrally managed, role-based access control for customer service representatives, engineers, and server administrators:</b> The CPO central system enforces role-based access control for customer service representatives, engineers, and server administrators with individual user accounts managed on a central server.</p>
	<p><b>8.3-SO4 Restrictions on switching commands:</b> The CPO central system does not allow engineers and customer representatives to switch charging on or off on many charging stations at the same time, for instance by limiting the number of switching commands per user per hour.</p>
	<p><b>8.3-SO5 Individual accounts for customers:</b> The CPO central system supports individual accounts for customers and enforces access control so that they can only access the functions they need.</p>
<b>Charging station or plaza</b>	<p><b>8.3-SO6 Least privileges on the WAN, authentication terminal, electric vehicle, local maintenance, LAN, and EMS interfaces:</b> The charging station or plaza enforces access control on the WAN, authentication terminal, electric vehicle, local maintenance, LAN, and EMS interfaces so that user groups with access to the interface can only access the functions they need.</p>

### 8.5 Secure authentication

<b>CPO central</b>	<p><b>8.5-SO1 Mutual authentication for the charging stations, mobility service provider, roaming platform and DSO systems:</b> The CPO central system enforces mutual authentication with the charging stations, mobility</p>
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	<p>service provider, roaming platform, and DSO system. Devices on each side uniquely identify themselves and allow the other side to authenticate them. They only provide access after having authenticated the other side's identity.</p> <p><b>8.5-SO2 Authentication with individual passwords for customers, customer service representatives, engineers, and server administrators:</b> The CPO central system enforces mutual authentication for customers, customer representatives, engineers, and server administrators. These users use individual credentials. The login procedure is protected against known attacks.</p> <p><b>8.5-SO3 Multifactor authentication for server administrators on the server maintenance interface:</b> The CPO central system enforces multifactor authentication for server administrators on the server maintenance interface with a login procedure that is protected against known attacks.</p> <p><i>Remark:</i> The multifactor authentication could for instance be implemented by using a remote access VPN for server administrators with multifactor authentication configured for the user authentication.</p>
<p>Charging station or plaza</p>	<p><b>8.5-SO4 Role-based authentication for engineers:</b> Engineers identify to the charging station with information that allows the zone to determine its role. The zone authenticates the user's role and assigns them access rights based on the role.</p> <p><i>Remark:</i> Engineers may use shared passwords on the local maintenance interface, although it is recommended to use unique passwords per charging station or centrally managed accounts with individual passwords for the engineers.</p> <p><b>8.5-SO5 Unique authentication for the CSMS and electric vehicles:</b> The CSMS and electric vehicles uniquely identify themselves to the zone. The zone authenticates their identity and assigns them access rights based on their role.</p> <p><b>8.5-SO6 Authentication for EV drivers on the authentication terminal:</b> The charging station enforces authentication for EV drivers on the authentication terminal using a mechanism chosen by the mobility service provider.</p>

### 8.7 Protection against malware

CPO central system	<p><b>8.7-SO1 Active malware protection in the CPO central system:</b> Hosts in the CPO central systems are actively protected against malware, for instance through anti-virus software or endpoint protection software.</p>
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### 8.8 Management of technical vulnerabilities

CPO central system	<p><b>8.8-SO1 Hardening over the local maintenance or server maintenance interface:</b> Server administrators can harden hosts in the CPO central system over the server maintenance interface or from engineering workstations. They can disable unneeded functions to reduce the likelihood of vulnerabilities and enable security functions available on the hardware and software platforms to reduce their possible impact.</p>
Charging station or plaza	<p><b>8.8-SO2 Hardened by default:</b> The charging stations and charging plaza devices are delivered by the manufacturer in a hardened configuration. Unneeded functions are disabled to reduce the likelihood of vulnerabilities. Security functions on the hardware and software platforms are enabled to reduce the possible impact of vulnerabilities. The device does not contain publicly known vulnerabilities that can be exploited on the device.</p>
Operational environment	<p><b>8.8-SO3 Vulnerability management process:</b> The charge point operator manages vulnerabilities in the system by:</p> <ul style="list-style-type: none"> <li>• disabling unused ports, services, user accounts, and functions to reduce the likelihood of vulnerabilities</li> <li>• monitoring vulnerabilities in the system's software and firmware, assessing the risks of the vulnerabilities, and mitigating the high-risk vulnerabilities, for instance by applying security updates</li> <li>• limiting the impact of vulnerabilities by enabling the security features on the hardware and software platforms used</li> </ul> <p><i>Implementation guidance:</i> A clear policy should be defined for when vulnerabilities must be patched, based on their severity. The CVSS score could be used as a severity measure but must usually be complemented with information about the location of the vulnerability in the system.</p>

### 8.9 Configuration management

<b>CPO central system</b>	<p><b>8.9-SO1 Managing network and security configurations over the server maintenance interface:</b> The CPO central system allows server administrators to manage and monitor the network and security configurations of the CPO central system from the server maintenance interface.</p> <p><i>Remark:</i> Changes to configurations are logged according to objective 8.15-SO1.</p>
<b>Charging station or plaza</b>	<p><b>8.9-SO2 Automated configuration management:</b> The charging station can be restored from a backed-up configuration automatically by the CPO central system.</p>
	<p><b>8.9-SO3 Secure configuration by default:</b> The charging stations and charging plaza devices are delivered by the manufacturer with a secure configuration. Unneeded functions are disabled to reduce the likelihood of vulnerabilities. All default network and security configurations are secure. Each factory default password is either set to a unique value during production or is required be changed by the user on first use.</p>

### 8.10 Information deletion

<b>CPO Central system</b>	<p><b>8.10-SO1 Personal information deletion:</b> The CPO central system can securely erase sensitive information when no longer required to comply with privacy regulations such as the GDPR.</p>
<b>Charging station or plaza</b>	<p><b>8.10-SO2 Personal information deletion:</b> The charging station can securely erase sensitive information when no longer required to comply with privacy regulations such as the GDPR.</p>

Operational environment	<p><b>8.10-SO3 Personal information deletion process:</b> The charge point operator has a process to remove sensitive information stored in the charging stations when no longer required.</p> <p><i>Remark:</i> The CPO can define a period for data retention subject to regulations and internal policies.</p>
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### 8.11 Data masking

CPO Central system	<p><b>8.11-SO1 Data masking:</b> The CPO central system has the capability of performing data masking, pseudonymization, or anonymization on the sensitive data stored in the system.</p>
Operational environment	<p><b>8.11-SO2 Data masking policy:</b> The charge point operator has a policy to ensure that sensitive data stored in charging stations is protected by hiding techniques such as data masking, pseudonymization, or anonymization.</p>

### 8.13 Information backup

CPO Central system	<p><b>8.13-SO1: Automated backups for the CPO central system:</b> The CPO central system supports making automated backups of the configurations and data.</p>
Operational environment	<p><b>8.13-SO2 Backup process for charging stations configurations:</b> The charge point operator has a process to back up the charging station and plaza configurations on the CPO central system. Older versions of the configurations are kept so that it is possible to revert to them in case of issues.</p> <p><b>8.13-SO3 Backup process for the CPO central system:</b> The charge point operator has an automated process to back up the data and configurations on the CPO central systems (including the charging station and plaza configurations stored there according to 8.13-SO2).</p>

### 8.15 Logging

<b>CPO central system</b>	<p><b>8.15-SO1 Integration with SIEM system:</b> The servers in the CPO central system log all relevant security events, such as access control events, and changes to the configuration and software. The servers can store the logs locally for forensic analysis. They can send them to a Security Information and Event Management (SIEM) system in a commonly supported format so that they can be analyzed to detect incidents.</p>
<b>Charging station or plaza</b>	<p><b>8.15-SO2 Collecting security events from the charging station through the CPO central system:</b> The charging station logs all relevant security events locally and sends selected events to the CPO central system so that they can be analyzed to detect incidents.</p> <p><i>Remark:</i> The CPO central system can then forward the security logs to a SIEM system according to 8.15-SO1.</p>

### 8.16 Monitoring activities

<b>Operational environment</b>	<p><b>8.16-SO1: Security monitoring and incident response:</b> The charge point operator monitors and responds to security events on the CPO central system and the charging stations and plazas. They gather security logs from the devices centrally, for instance, in a SIEM. They establish procedures, use cases, and rules to find incidents in the logs. And they establish a process for responding to the incidents and minimizing the impact.</p> <p><i>Implementation guidance:</i> Monitoring should try to detect at least:</p> <ul style="list-style-type: none"> <li>• unauthorized access attempts</li> <li>• unauthorized local access to charging stations</li> <li>• unauthorized changes to security settings (e.g., keys or credentials, authentication settings)</li> <li>• unauthorized installed firmware or software</li> <li>• possible signs of attacks (e.g., physical tamper events, invalid certificates)</li> </ul>
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### 8.17 Clock synchronization

<b>CPO Central system</b>	<b>8.17-SO1 Clock synchronization for the CPO central system:</b> The CPO central system synchronizes time with a central source to have reliable timestamps for security events.
<b>Charging station or plaza</b>	<b>8.17-SO2 Clock synchronization for the charging station:</b> The charging station or plaza synchronizes time with a central source to have reliable timestamps for security events.

### 8.19 Installation of software on operational systems

<b>CPO central system</b>	<b>8.19-SO1 Software updates over the server maintenance interface:</b> Server administrators can update the software and firmware in the CPO central system over the server management interface or from engineering software. Hosts in the CPO central system check the authenticity of firmware or software before installation through digital signatures.
<b>Charging station or plaza</b>	<p><b>8.19-SO2 Automated firmware management for local controllers:</b> The software and firmware on the local controller in the charging station or plaza can be updated through remote access from the CPO central system. The local controller can check the authenticity of firmware before installation through digital signatures.</p> <p><i>Remark:</i> The local controller is the part that communicates with the CPO central system over the WAN. It is not required that other components of the charging station or plaza that are not reachable over the WAN can be remotely updated. It is however recommended to support remote updates for them to allow vulnerabilities in them to be patched more efficiently.</p>

### 8.20 Network security

<b>CPO central system</b>	<b>8.20-SO1 Cryptographic protection of communication confidentiality and integrity on the WAN, management portal, market interface, and server maintenance interface:</b> The CPO central system protects the integrity and confidentiality of communication on the WAN, management portal, market interface, and server maintenance interface using
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	cryptographic measures. The measures allow to verify the source of messages and protect against replay and man-in-the-middle attacks.
<b>Charging station or plaza</b>	<p><b>8.20-SO2 Cryptographic protection of communication confidentiality and integrity on the WAN interface:</b> The charging station protects the integrity and confidentiality of communication on the WAN interfaces using cryptographic measures. The measures allow to verify the source of messages and protect against replay and man-in-the-middle attacks.</p> <p><i>Remark:</i> If wireless communication is used on the local charging station interfaces, such as the authentication terminal, the local maintenance interface, or the EMC interface, the communication shall be protected cryptographically.</p>
	<p><b>8.20-SO3 Resilience of charging functions against denial-of-service attacks on the WAN:</b> The charging station shields charging functions from denial-of-service attacks on the WAN interface, so that these functions keep working if the device is flooded with data or malformed messages</p>

### 8.21 Security of network services

<b>Operational environment</b>	<p><b>8.21-SO1 Resilience against denial-of-service attacks on the WAN:</b> The wide-area network (WAN) is resilient against accidental disruptions and against intentional denial-of-service attacks using simple means with low resources, generic skills, and low motivation. The required service level is agreed with the telecom provider and is regularly monitored. The telecom provider monitors the network and can respond in case of an incident to minimize the impact of attacks.</p>
	<p><b>8.21-SO2 Resilience against denial-of-service attacks on the internet facing interfaces:</b> The internet connections for the management portal and market interfaces are resilient against accidental disruptions and against intentional denial-of-service attacks using simple means with low resources, generic skills, and low motivation. The required service level is agreed with the telecom provider and is regularly monitored. The telecom provider monitors the network and can respond in case of an incident to minimize the impact of attacks.</p>



## 8.22 Segregation of networks

<b>CPO central system</b>	<p><b>8.22-SO1 Logical network segregation on the WAN, management portal, market interface, and server maintenance interface:</b> The CPO central system is segregated from other zones on the WAN, management portal, market interface, and server maintenance interface. Only normal incoming and outgoing connections are allowed through the network perimeter. The communication load can be controlled at the perimeter.</p> <p><i>Implementation guidance:</i> When the CPO central system is hosted in the cloud, further guidance is given by cloud providers on network segmentation [19], [20].</p>
<b>Charging station or plaza</b>	<p><b>8.22-SO2 Logical network segregation on the charging station WAN:</b> The charging station is segregated from other zones on the WAN interface. Only normal incoming and outgoing connections are allowed through the network perimeter. The communication load can be controlled at the perimeter.</p>
<b>Operational environment</b>	<p><b>8.22-SO3 No communication between charging stations on the WAN:</b> There is no direct communication between charging stations on the WAN interface. The charging stations can only communicate with the CPO central system.</p> <p><i>Implementation guidance:</i> The restriction on communication can be enforced in the architecture of the telecom network.</p> <p>The firewall at the central systems should only allow through network services needed for normal communication to the charging stations. The services exposed to the charging stations should be tested for vulnerabilities, assuming that a charging station can be compromised.</p> <p>Charging stations may communicate with each other over a LAN in the same charging plaza. Such communication may be needed for local load balancing. However, it should be restricted to local IPs and needed protocols and ports.</p> <p>It is recommended to use a private APN to shield the charging stations from attacks from the internet.</p>

## 8.24 Use of cryptography

<p style="text-align: center;">CPO central system</p>	<p><b>8.24-SO1 Key and password management over the server maintenance interface:</b> Server administrators can manage all passwords and keys used on the CPO central system server efficiently over the server maintenance interface.</p> <p>When the central system generates passwords or keys it should ensure that they are long and complex enough to be resistant against brute-force attacks.</p>
<p style="text-align: center;">Charging station or plaza</p>	<p><b>8.24-SO2 Automated key and password management over the WAN:</b> All passwords and keys used in the charging station can be updated automatically through remote access from the CPO central system.</p> <p>When the charging station generates passwords or keys it should ensure that they are long and complex enough to be resistant against brute-force attacks</p>
<p style="text-align: center;">Operational environment</p>	<p><b>8.24-SO3 Key and password management process:</b> The charge point operator manages the keys and passwords of the devices so that they are properly protected and can be updated when needed.</p>

## 6 Rationale for the security objectives

This section explains how the security threats in Section 3 are mitigated by the security objectives in Section 5.

### 6.1 Protection from unauthorized access threats to the CPO central system

Unauthorized access threats are mitigated by preventing attackers from getting access through authentication, and by limiting access by authorizations, as shown in Table 3.

*Table 3: Security objectives to mitigate unauthorized access threats.*

Threat	Authentication	Authorization
<b>T-UA1</b> Unauthorized access as a charging station on the WAN	<b>8.5-SO1</b> Mutual authentication for the charging stations, mobility service provider, roaming platform, and DSO systems	<b>8.3-SO1</b> Least privileges on the WAN interface
<b>T-UA2</b> Unauthorized access as an engineer or customer service representative on the management portal	<b>8.5-SO2</b> Authentication with individual passwords for customers, customer service representatives, engineers, and server administrators	<b>8.3-SO3</b> Centrally managed, role-based access control for customer service representatives, engineers, and server administrators  <b>8.3-SO4</b> Restrictions on switching commands
<b>T-UA3</b> Unauthorized access as a server administrator on the server maintenance interface	<b>8.5-SO2</b> Authentication with individual passwords for customers, customer service representatives, engineers, and server administrators	<b>8.3-SO3</b> Centrally managed, role-based access control for customer service representatives, engineers, and server administrators

	<b>8.5-SO3</b> Multifactor authentication for server administrators on the server maintenance interface	
<b>T-UA4</b> Unauthorized access as a DSO system, roaming platform or mobility service provider on the market interface	<b>8.5-SO1</b> Mutual authentication for the charging stations, mobility service provider, roaming platform and DSO systems	<b>8.3-SO2</b> Role separation on the market interface
<b>T-UA5</b> Unauthorized access as a customer on the customer portal	<b>8.5-SO2</b> Authentication with individual passwords for customers, customer service representatives, engineers, and server administrators	<b>8.3-SO5</b> Individual accounts for customers

To protect against unauthorized access, the goal is to provide protection against sophisticated threats by using strong authentication and applying the least privileges on each interface. To ensure that these measures provide the required level of security, the following supporting objectives are required:

- **Key and password management:** to reduce the risk of the authentication measures being bypassed by stolen keys or passwords, these must be updated regularly or after incidents. Server administrators should be able to manage the passwords and keys over the server maintenance interface (**8.24-SO1**). The key and password management process (**8.24-SO3**) makes sure there is a structured process to update them.
- **Account management:** accounts of the engineers should be managed to ensure (**5.16, 5.18**), for instance, that when an engineer changes jobs their access is revoked. To allow this process to work efficiently, the accounts of customer service representatives, engineers, and administrators in the CPO central system are managed centrally (**8.3-SO3**).
- **Hardening:** the servers in the central systems should be hardened by disabling unused services so that there are no network services exposed without access control. The server administrator should be able to perform the hardening over the server maintenance interface (**8.8-SO1**). The vulnerability management process (**8.8-SO3**) ensures hardening is performed structurally.
- **Monitoring:** attempts to bypass the access control mechanisms should be monitored. The logging objective (**8.15-SO1**) allows failed and successful login

attempts to be logged and gathered in a SIEM system. Clock synchronization allows to make a reliable timeline of alerts (**8.17-SO1**). Processes should be established to detect and respond to these alerts (**8.16-SO1**).

Additional measures are taken for engineers, customer service representatives, and server administrators. These user groups are considered the highest risk, as they have privileged access to the system. For engineers and customer service representatives, restrictions are placed on how many charging stations they can control at the same time (**8.3-SO4**). In this way, incidents in which many charging stations are switched on or off at the same time can be prevented. For server administrators, multifactor authentication (**8.5-SO3**) is required to further reduce the chances of someone gaining unauthorized access.

## 6.2 Protection from unauthorized access threats to the charging station

The measures to prevent unauthorized access to the charging station are similar to the ones for the CPO central system. Authentication should prevent attackers from getting access. Authorization should limit the impact if they do get access.

A simple access control model can be used because each user group accesses a different interface:

- For authentication, authentication (**8.5-SO4**, **8.5-SO5**, **8.5-SO6**) is used on all interfaces except the EMS and for other charging stations. Having engineers authenticate by role allows to keep account management simple. Charging stations cannot always rely on centralized authentication, as the connection to the central system may sometimes be lost. So, it would be technically challenging to use individual accounts. For EMS and other charging stations, protection against unauthorized access is provided through tamper detection (**7.12-SO1**, **7.4-SO2**).
- For authorization, the least privileges are applied on each interface (**8.3-SO6**). Active access rights management is not required (and is sometimes not possible for the protocols used). It is not needed to set up new users on an interface or change their access rights, as only one user group is using each interface.

The authentication mechanism for EV drivers on the authentication terminal (**8.5-SO5**) is specified by the mobility service provider. A strong authentication mechanism is advisable, as the interface is used for financial transactions. However, interoperability is usually the deciding factor, as EV drivers want to be able to charge at different CPOs.

To ensure that the authentication and authorization measures can provide security against sophisticated attackers, the following supporting objectives are required:

- **Key and password management:** the charging station should be delivered with secure keys and passwords and no default keys (**8.24-SO3**). Keys and credentials used for authentication should be regularly updated, to reduce the impact of them being compromised. Automated management over the WAN (**8.24-SO2**) makes it possible to update the keys efficiently. The key and password management process (**8.24-SO3**) makes sure there is a process to update them.
- **Hardening:** the charging station should be hardened by disabling unused services so that there are no network services exposed without protection. Charging stations should be delivered and installed in a hardened configuration (**8.8-SO2**). The vulnerability management process (**8.8-SO3**) hardening is monitored and improved if needed.
- **Monitoring:** attempts to bypass the access control mechanisms should be monitored. The logging objective (**8.15-SO2**) allows failed and successful login attempts to be logged and collected by the central system. Clock synchronization allows making a reliable timeline of alerts (**8.17-SO2**). Processes should be established to detect and respond to these alerts (**8.16-SO1**).

## 6.3 Protection from exploits of software vulnerabilities

For all software exploits threats, hardening is used to prevent vulnerabilities. Patching is used to fix vulnerabilities on the CPO central system and the WAN interface on the charging station.

### 6.3.1 Protection for the CPO central system (T-EX1, T-EX2, T-EX3)

As the internet facing interfaces and server maintenance interface may be directly exposed to external attackers, protection against software exploits should be provided through hardening, patching, and malware protection.

Hardening should reduce the risk of exploits by disabling unused services and enabling security features. The vulnerability management process (**8.8-SO3**) should ensure that unused services are disabled to reduce the attack surface and hence the likelihood of vulnerabilities being exposed. It should also ensure that security features on the hardware and software platform are enabled to reduce the impact of vulnerabilities. The central system should allow server administrators to perform the hardening (**8.8-SO1**).

If vulnerabilities are still found on the internet facing interfaces, they should be fixed through patching. Server administrators should be able to perform patching through the server maintenance interface (**8.19-SO1**). The vulnerability management process (**8.8-SO3**) ensures there is a structured process for patching.

Malware protection (**8.7-SO1**) should be used to detect and remove any payloads that get through the hardening and patching measures.

### 6.3.2 Protection for the charging station (T-EX4, T-EX5)

Protection against software exploits against the charging station is provided through secure configuration, hardening, and patching.

Hardening is effective on the charging station because the functionality needed on each interface is usually simple. Charging stations should be delivered and installed with unneeded network services and functionality disabled and with security functions of the hardware and software platform enabled (**8.8-SO2, 8.9-SO3**). The vulnerability management process (**8.8-SO3**) should monitor that the charging station stays hardened throughout its lifecycle.

Hardening the interfaces should provide security against at least protection against intentional violation using simple means with low resources, generic skills, and low motivation. On most interfaces, this is considered sufficient protection, as they can only be accessed locally. So, the impact of an attack will be limited.

On the WAN interface, additional security should be provided through patching. Efficient patching is made possible on the charging station through automated firmware management (**8.19-SO2**). Updates are, however, only required for the local controller in the charging station, the part that communicates with the CPO central system. For other parts, it may be only possible to perform firmware updates locally. Vulnerabilities on other interfaces may hence be difficult to patch. The vulnerability management process (**8.8-SO3**) ensures there is a process to perform security updates.

## 6.4 Protection from communication threats

The confidentiality and integrity of information on all untrusted networks are protected through cryptographic measures, both for the CPO central system (**8.20-SO1**) and for the charging station (**8.20-SO2**).

Communication is not required to be cryptographically protected on the local interfaces on the charging station (authentication terminal, electric vehicle, local maintenance, and EMS). An attacker would usually have to be physically present at these interfaces to compromise the communication. Communication on the charging plaza LAN and the connection to the EMS should be protected through tamper detection measures (**7.12-SO1** and **7.12-SO2**).

The availability of communication is protected by network segregation and resilience of the underlying network. Network segregation through firewalls is used on all interfaces of the CPO central system (**8.22-SO1**) and the WAN interface of the charging station (**8.22-SO2**), so that they are protected against denial-of-service attacks. Additionally, it is

assumed that the networks connected to the WAN, management portal, and market interfaces are sufficiently resilient (**8.21-SO1**, **8.21-SO2**), and that the charging functions can continue even when network communication is unavailable (**8.20-SO3**).

## 6.5 Protection from physical threats

Physical threats to the CPO central system are countered through data center security. For charging stations and plazas, tamper detection is provided against fraud, while the impact is limited through network segregation.

### 6.5.1 Physical threats to the CPO central systems (T-PH1)

Physical threats to the CPO central systems are countered by protecting the data center in which it is hosted using the physical security controls (**7.1**, **7.2**, **7.3**, **7.4**, **7.8**, **7.12**), see Section 5.3. If properly implemented, these controls should provide protection against intentional violation using sophisticated means with moderate resources, IACS-specific skills, and moderate motivation.

### 6.5.2 Physical threats to the charging station (T-PH2, T-PH3, T-PH4, T-PH5)

For the charging station, tamper detection allows to detect fraud. The impact of a physical compromise is limited through network measures.

Tamper protection should be provided first passively through the casing of the charging station or the cabinets in which charging plaza equipment is placed (**7.8-SO1**, **7.8-SO2**). Cables to the EMS or within the charging station LAN should also be protected (**7.12-SO1**, **7.12-SO2**). Active detection should be provided by creating alarms for physical access to the casing or cabinets (**7.4-SO1**, **7.4-SO2**). For detection to be effective the CPO must of course also have a process to react to the alarms (**7.4-SO3**).

Together the active and passive measures should counter the main physical threats (**T-PH2**, **T-PH3**, **T-PH4**) and provide protection against intentional violation using simple means with low resources, generic skills, and low motivation.

This security level is acceptable as long as the threats only affect the charging stations that are physically attacked. To ensure that the rest of the EV charging infrastructure is not affected (**T-PH5**), network segregation is used to limit the impact (**8.22-SO3**).

## 6.6 Protection from supply chain threats

To prevent the firmware or software from being modified at the supplier (**T-SC1**), the developers and manufacturers of the EV charging infrastructure must protect their assets (**5.25**).



To prevent the firmware or software from being modified between the supplier and installation (**T-SC2**), the server software updates on the central systems and the automated firmware updates on the charging station are protected with a digital signature (**8.19-SO1**, **8.19-SO2**).

Network segregation between the central system and the outside (**8.22-SO1**) and between the charging station and the central system (**8.22-SO2**) makes it difficult for an attacker to reach the backdoor, even if they succeed in putting it into the firmware.

## 6.7 Protection from insider threats

Protection against insider threats is provided through access control, people control, and monitoring.

The risks of insider threats can be significantly reduced by separating roles through role-based access control for representatives, engineers, and server administrators (**8.3-SO3**). The largest group of insiders would be customer representatives. These only need limited access. They should for instance not be allowed to update the firmware or change security settings on a charging station. Engineers must have some more access, but they should not be allowed to change the central system software or settings. Switching commands should be limited to both user groups (**8.3-SO4**) to make sure that they cannot cause problems in the power grid. With these measures, only a small group of server administrators need privileged access to the central system. An account management process (**5.16**, **5.18**) is required to keep the access rights up to date when engineers and operators change roles or organizations.

People controls (**6.1**, **6.2**, **6.3**, **6.4**), such as screening and training, are important to prevent users from misusing or abusing the privileges they have.

For former employees and contractors (**T-IN3**), CPOs need to revoke access to the EV charging infrastructure. For the CPO central system, they can do this through the centralized access control (**8.3-SO3**) following the access control processes (**5.15**, **5.16**, **5.18**). For the EV charging station, accounts for local access are role-based and passwords might be shared among employees, so that it might not be feasible to change passwords when an employee leaves. Instead, physical access should be monitored to detect unauthorized access (**7.1**, **7.2-SO1**, **7.2-SO2**, **7.2-SO3**, **7.4-SO1**, **7.4-SO2**, **7.4-SO3**).

Monitoring and incident response processes should be used to detect misuse or abuse and respond to it (**8.16-SO1**). Some unusual behavior by engineers, representatives, and server administrators may be detected with monitoring. If there is an incident the security logs should allow to find out the cause, so that corrective measures can be taken.

To technically support the monitoring and incident response process, security events are logged locally and gathered in a SIEM system (**8.15-SO1**, **8.15-SO2**). Clocks are

synchronized to allow making a timeline of an incident (**8.17-SO1**, **8.17-SO2**). Engineers and administrators log in with individual user accounts (**8.5-SO2**, **8.5-SO3**), so that actions can be traced to them. Requiring centralized access control on the local maintenance interface is not considered feasible yet. So, additional organizational requirements may be needed to monitor who has accessed it.

## 6.8 Protection from post exploitation threats

Protection against the post exploitation threats is provided through backups, monitoring, firmware, and software signing, and network segregation.

### 6.8.1 Protection against loss of configuration (T-PE1)

The main measure to protect against loss of configurations (**T-PE1**) in the central system is to make backups of this system (**8.13-SO1**) following a backup process (**8.13-SO3**) and then restore the working configuration through server configuration management (**8.9-SO1**).

For the charging station to restore the configuration, it must be possible to restore a working configuration via automated configuration management (**8.9-SO2**). These technological controls must be enabled by a backup process (**8.13-SO2**)

### 6.8.2 Protection against software or firmware corruption (T-PE2)

To protect against software or firmware corruption (**T-PE2**), changes to the firmware are logged and can be sent to the SIEM system (**8.15-SO1**, **8.15-SO2** with **8.17-SO1**, **8.17-SO2** for clock synchronization), so that operators can detect unauthorized modifications (**8.16-SO1**). The software and firmware are moreover digitally signed (**8.19-SO1**, **8.19-SO2**).

If an attacker installs a backdoor, it would be hard to reach because of the network segregation between the central systems and the outside (**8.22-SO1**) and between the central system and the charging station (**8.22-SO2**).

## Glossary

AC	Alternating Current
APN	Access Point Name
CPO	Charge Point Operator
CSMS	Charging Station Management System
CVSS	Common Vulnerability Scoring System
DC	Direct Current
DSO	Distribution System Operator
EMS	Energy Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GDPR	General Data Protection Regulation
GPRS	General Packet Radio Service
IACS	Industrial Automation and Control System
LAN	Local Area Network
LTE	Long-Term Evolution
SIEM	Security Incident and Event Management
SSH	Secure Shell Protocol
TLS	Transport Layer Security
TSO	Transmission System Operator
VPN	Virtual Private Network
WAN	Wide Area Network

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