



BUILD THE FUTURE



EVALUATION REPORT

BuildZero Test Event 2026



This report builds on the findings report of the 2025 test event. Descriptions of the test setup, methodology, and background information have been retained where necessary, as they remain relevant to the 2026 edition. The substantive changes in this report are limited to the results of the 2026 tests, the corresponding analyses, and the conclusions drawn from those results.

Contributors

Editorial

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Thanks to ENI, BMWt, ElaadNL and all participating manufacturers from vehicles, charging stations and battery systems.

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Event overview

After two successful BuildZero Test Events in 2024 and 2025, ENI, BMWT and ElaadNL hosted the third edition from the 20th to the 22nd of May 2026 at the ElaadNL Testlab in Arnhem. The event continued its focus on improving the interoperability of charging solutions for electric construction machinery.

Over the course of three days, 12 combinations of vehicles and charging stations from various manufacturers were tested. 11 combinations charged successfully, while one combination did not. Testing was carried out by engineers from the participating manufacturers, supported by technical specialists from ElaadNL. The test setup replicated real-world construction site conditions, with a focus on communication protocols, smart charging functionality and overall charging behaviour.

This report highlights the key findings and lessons learned from the third BuildZero Test Event.

Equipment

Heavy Duty Construction vehicles

One excavator, one wheel loader and one tractor from the following manufacturers participated:

- Holland- Utrecht (Fendt)
- Staad
- SMT Netherlands (Volvo)

DC charging stations

Three DC CCS2 charging stations with output powers ranging from 240 kW to 480kW were provided by the following manufacturers who participated in the BuildZero Test Event:

- Venema E-Mobility Charge Systems
- Autel Energy
- Van Der Sijs EV Charging Systems

Battery charging system

Battery systems feature integrated packs with both CCS2 output (for charging a vehicle) and CCS2 input (to recharge the battery itself).

Depending on the mode, a battery system functions either as a charger or as a vehicle. Each test follows the appropriate protocol and results are recorded accordingly.

The following manufacturer of battery systems participated during the event:

- Atlas Copco

EMS and BESS

Also three Battery Energy Storage Systems (BESS) were available on-site. These systems were supplied by three different manufacturers and ranged in power from 100 kW to 300 kW. Each BESS was connected to a different sub-distribution board within the ElaadNL electrical installation.

ElaadNL has developed a standardized communication protocol that enables Energy Management Systems (EMS) to communicate with different energy assets in a uniform manner. For the BuildZero event, this protocol was implemented through a physical gateway installed inside each of the three BESS units. This allowed ElaadNL to use a single EMS to control all three BESS installations for peak shaving purposes throughout the event. The BESS units were connected at different locations within the electrical installation. One BESS was installed on the same sub-distribution board as all DC chargers used during the interoperability tests, while the other two BESS units were connected at the main grid connection.

The systems were configured to perform peak shaving at these connection points, thereby reducing the power drawn from the grid during periods of high charging demand, see Figure 1. In practice, this emulated the conditions of a construction site with a limited grid connection. Because one of the BESS units was installed locally at the charging infrastructure, the available power at the simulated construction site could be increased without increasing the capacity of the main grid connection.

The BuildZero event also represented the first real-world deployment of ElaadNL's standardized asset communication protocol. During the event, several software limitations were identified and resolved, preventing the BESS units from operating optimally at all times. Nevertheless, the demonstration successfully captured several instances where the combined power consumption of the DC fast chargers exceeded the power imported through the main grid connection, demonstrating that the BESS installations effectively absorbed the demand peaks through peak shaving.

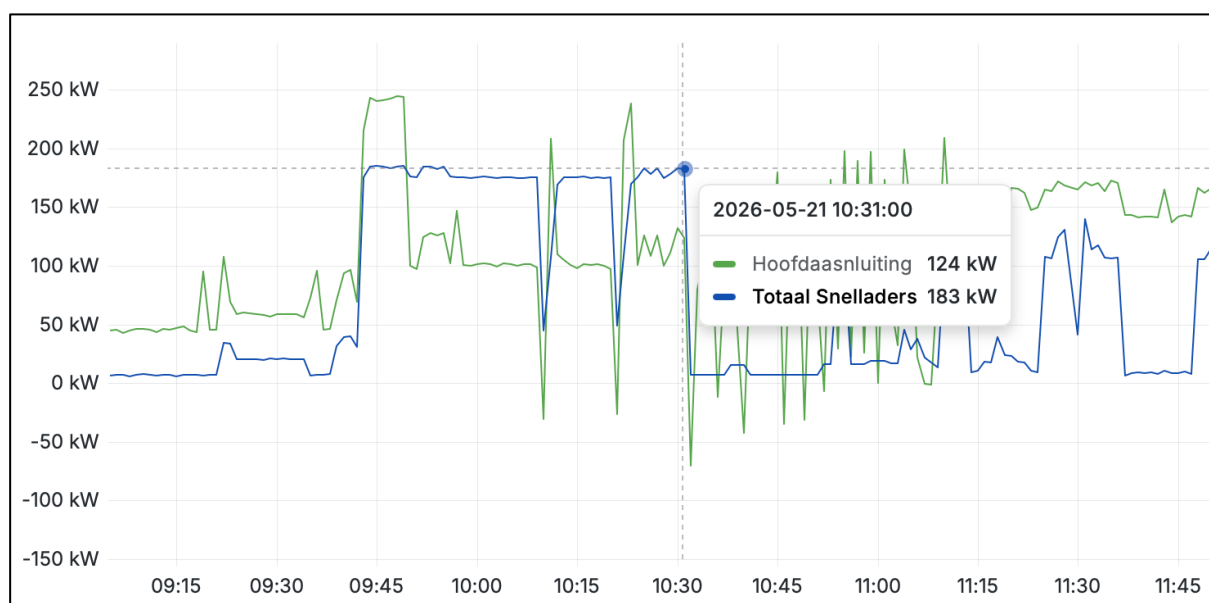


Figure 1: Thanks to the EMS and 3 BESS, the EVSEs could draw more power, even if the power provided by the grid is limited.

Test system ElaadNL

ElaadNL also used its 360kW EV/EVSE test system, which could serve both as a vehicle or charging station, and act as a Man in the Middle to record the communication between a vehicle and charging station. Furthermore, the AC emulator could be used to emulate a power outage.

Test Protocol

Interoperability

Various charging protocols are used within EV charging infrastructure. Following the first two test events, ElaadNL advised manufacturers to prioritize ISO 15118-2. This improves interoperability by ensuring consistent protocol use. During this test event, we evaluated that recommendation in practice.

Regular charging test protocol

The test verifies what the default charging protocol between a charger and a vehicle is. During this test the reliability of the plug connections between the charger and vehicle is also determined.

Start a charging session by connecting the CCS plug and authorizing charging. Then verify the following:

1. Does the combination of charger and vehicle result in a successful charging session, in which power is transferred to the vehicle.
2. What is the time between authorization and actual power flow?
3. Is the cable locked during the whole charging session, and unlocked when the charging session is stopped?
4. What is the default charging protocol used during the charging session. (DIN 70121, ISO 15118-2 or ISO 15118-20)
5. What are the current and voltage limits and target current communicated via the charging protocol during power flow?
6. What is the measured maximum power and current during the charging session?
7. Is it visible whether the EV or EVSE is limiting the charging power?
8. Are there any visible errors when a charging session is stopped?

Smart charging

Smart charging is essential at construction sites to efficiently manage limited power resources, prevent overloading the electrical installation, and prioritize charging based on operational needs. Therefore, it is crucial that combinations of chargers and vehicles support smart charging. We recommend testing the following charging profiles to evaluate the capability of charging at different power levels.

The charging profiles should be initiated by the charger. This can preferably be done using OCPP messages. ElaadNL provides a TxDefaultProfile that can be sent to the charger before the charging session starts. If no OCPP connection is available with a working back-end, the fluctuating charging profile can be executed manually by using the software of the charger.

Fluctuating charging profile

To evaluate whether the charger vehicle combination can charge at different charging powers a fluctuating charging profile has been tested, this profile can be seen in 2.

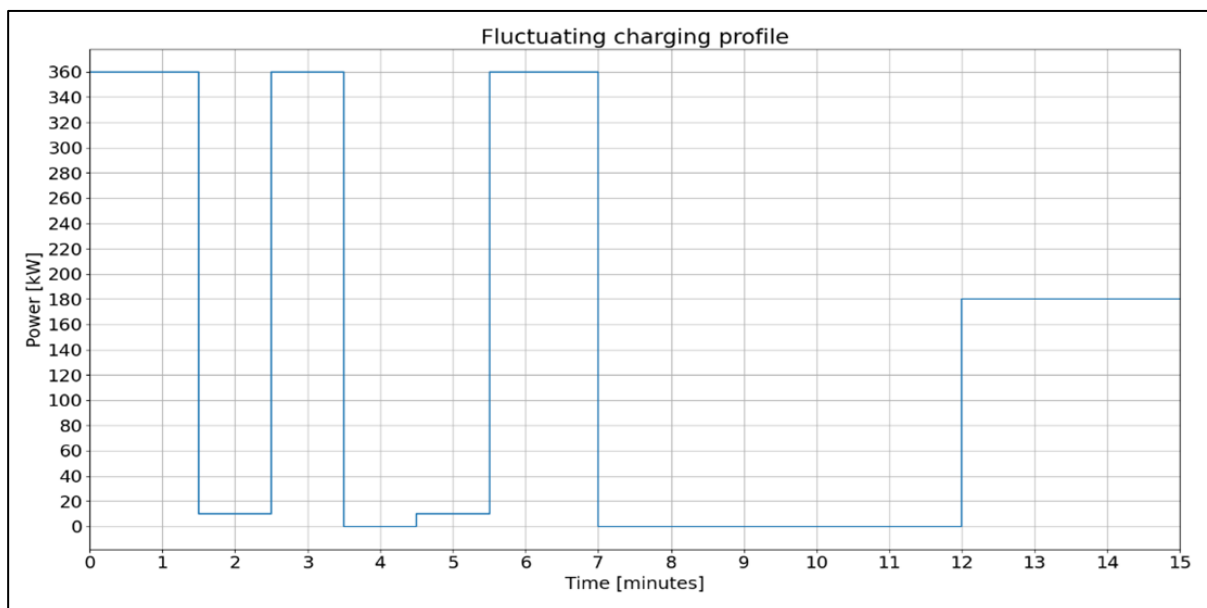


figure 2: Fluctuating charging profile

Delaying or pausing a charging session

The pause profile tests whether EV and EVSE can handle short interruptions in the charging session, which could be initiated by a balancing system or when other vehicles have higher priority in charging. The profile can be found below, in 3: Delayed and paused charging profile.

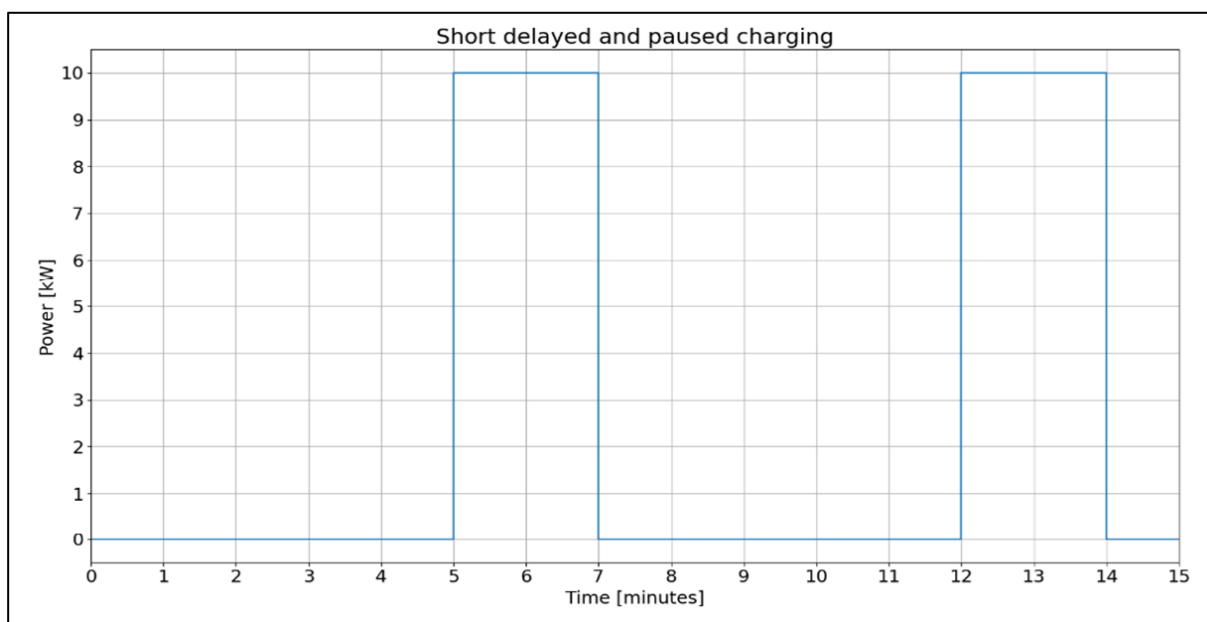


figure 3: Delayed and paused charging profile

Vehicle charging safety

Emergency button

In this test we evaluate the the behaviour of a vehicle-charger combination when the emergency button is pressed. During a charging session, the emergency button is pressed, and the time until the current drops to 0A and the time until the cable is unlocked are recorded.

The OEM roundtable has previously already advised to only place an emergency button for charging on the EVSE, not the EV. This advice remains valid.

Power outage

This test evaluates how the charger and vehicle perform in an unstable grid environment where power outages are common, such as on construction sites. It is important that, after a temporary power loss, the charging process automatically resumes. The ideal outcome is that the charger continues charging (even if at a reduced current), ensuring that the vehicle will be sufficiently charged for the next working day.

To conduct this test, the charger should be connected to a grid emulated by the Keysight ACE (AC Emulator). During a charging session, the power will be removed for 2 minutes, after which the power is restored. The charging session should continue.

Test results

Interoperability test

Regular charging

A total of 12 vehicle-charger combinations were tested. 11 combinations successfully delivered power during the first test round. Most combinations charged without software modifications. One combination required minor adjustments to parameters during testing. These adjustments resulted in a successful charging session in the test round. One combination failed to charge successfully.

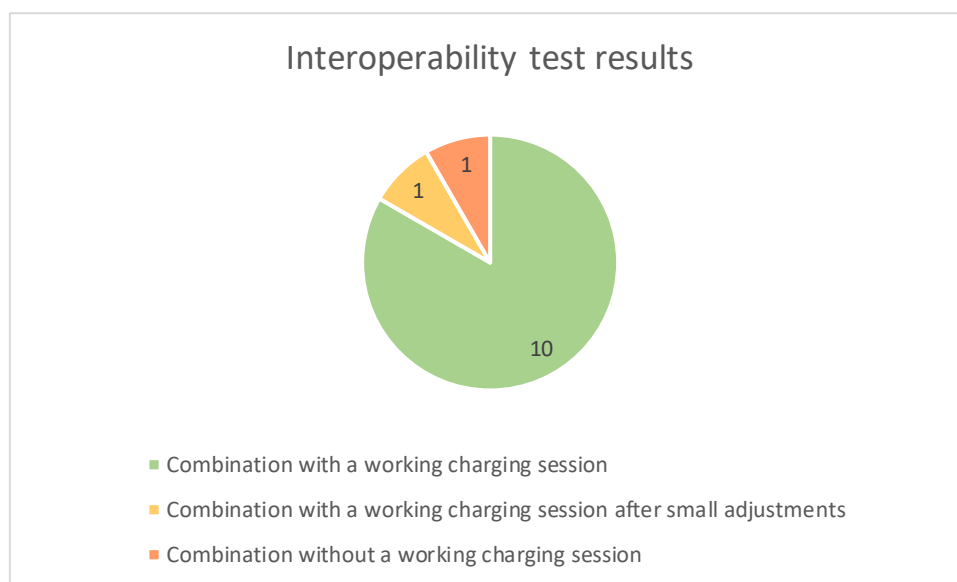


figure 4: Tested combination

The default charging protocol

- During 7 out of the 11 working combinations, the used protocol was recorded. Of those 7 combinations, 5 charged using the ISO 15118-2 communication protocol, and 2 charged using the DIN 70121 protocol. From this the following can be deducted: 3 out of 4 EVs (or BESS with CCS inlet) prioritize ISO 15118-2 over DIN 70121 2 EVSEs (or BESS with CCS out) support both ISO 15118-2 and DIN 70121, 1 EVSE supports at least ISO 15118-2 (DIN 70121 not confirmed) and for 1 EVSE the charging protocol has not been recorded.

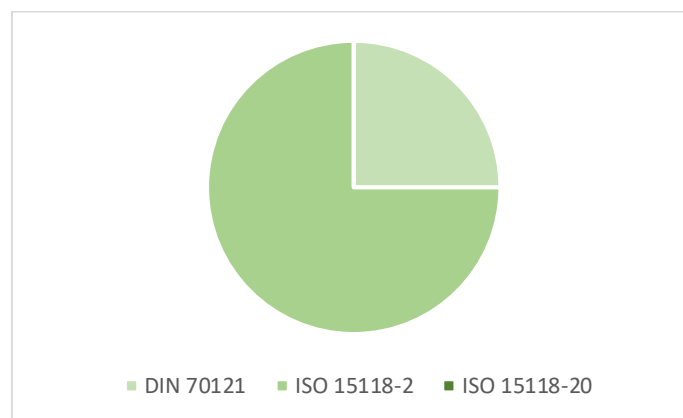


figure 5: Highest priority charging protocols of the tested vehicles/BESS with CCS inlet

Locking mechanism

All combinations that could charge resulted in a locked connector during charging. The connections also unlocked when the charging session was stopped.

Time between authentication and power flow

During 6 out of the 11 working combinations, the time between authentication and power flow was measured. All results were below 2 minutes, as expected.

Communicated limits and target, and measured current and power

For 7 combinations the EVTargetCurrent and real current and power was recorded. Also the limits by the EVs and EVSEs are known. From this the following could be deducted:

- The measured maximum current never exceeded the current limits set by the EV or EVSE.
- One combination resulted in the EVTargetCurrent not adapting to the Power limit of both EV and EVSE. For this combination the maximum measured power also exceeded the maximum power communicated by the EV. This power was manually limited to 20 kW so it was not exceeding the real power limit of the system, however it is still strange that the measured power exceeded this value.

Transparency of limiting actor of the charging speed

For 7 out of the 11 working combinations, it was clear to the customer which device (EV or EVSE) was limiting the charging speed. For 1 combination, the engineers found it to be not clear enough, for the other 3 combinations no test results have been filled in.

Stopping a charging session

The behaviour when stopping a charging session was monitored for errors for 8 EV-EVSE combinations. For example, an error message on the screen or a blinking red light. No errors have been observed when stopping a charging session.

Smart Charging

Fluctuating charging profile

The fluctuating charging profile was tested with 5 charger-vehicle combinations, with 3 different chargers and 4 different vehicles. 2 other combinations stated that the vehicle or charger did not support smart charging, and the other 4 combinations could not be tested with smart charging due to time constraints.

During the tests, the following results were found:

- 2 Of the chargers could execute the profile after it was sent through OCPP, for 1 charger the profile had to be executed manually;
- For 3 combinations it was verified that the EVSEMaximumPowerLimit followed the profile;
- For 1 combination it was verified that the EVSEMaximumCurrentLimit followed the profile;
- For 1 combination it was verified that the EVTargetCurrent followed the profile.

During the tests, one remarkable problem was found when pausing a charging session: the vehicle terminates the session because the target current of 0A is not met, since a value between 0.6A and 2A is still measured and communicated by the charger. When this value was overwritten, pausing the charging session did work.

Delayed and paused charging

Delayed and paused charging was tested for 2 vehicle-charger combinations, of which both succeeded.

Vehicle charging safety

Emergency button

During the test event this has not been tested due to time constraints. Also, for one vehicle and one charging station it was noted that an emergency button was not present.

Power outage

During the test event this has not been tested due to time constraints.

Evaluation

Interoperability test

Regular charging

The main goal of the BuildZero test event is to identify charging issues between vehicles and chargers. Between the first two events, no significant change in charging errors was observed. This third event, the percentage of charging errors between EV and EVSE combinations was 8%, which is a decrease with respect to the 17% and 18% of errors during the first and second test event. It should be noted that the total amount of tests executed and reported during this third event was lower than during the previous events. As a result, the probability of encountering interoperability issues was lower, and the reduced number of observed errors may therefore be partially caused by the smaller sample size.

The default charging protocol

During the third BuildZero test event, 3 out of 4 EVs communicated ISO 15118-2 as the protocol with the highest priority. Thus, no significant change is observed with respect to the previous event, where 4 out of 5 EVs had ISO 15118-2 as the highest priority.

Locking mechanism

Similar to the second BuildZero test event, the locking mechanisms functioned reliably during testing. All plugs connected securely and initiated communication successfully. Plugs remained securely locked during charging, and unlocked after charging ended. However, the same remark as the previous report remains: construction sites present harsher conditions. Debris such as dust, sand and mud can easily enter charging connectors, affecting performance.

Communicated limits and target, and measured current and power

During analysis of the reported limits and targets communicated by the EV and EVSE, and the measured current and power, all but one combination behaved as expected. The one that did not behave as expected showed conflicting limits and measurements. Since this could result in a situation where the current or power exceeds a limit, this could cause a dangerous situation.

Transparency of limiting actor of the charging speed

Smart charging is already often applied to AC charging, however it can also be applied to building sites where power is limited. In this case, it is important for the user to be able to understand which device is currently limiting the delivered power, to provide transparency about why the charging power is lower than expected. The results show that this is not always clear enough yet.

Smart Charging

Due to time constraints, only a few smart charging tests have been performed. The tests that have been performed showed similar results compared to the previous events: of the combinations that were tested with smart charging, most were able to complete the smart charging profiles.

For a possible next event, it is desired to encourage smart charging testing more, and to record the communication during the smart charging profile using a sniffer. This way, errors can be found more easily.

Vehicle charging safety

Emergency button

Due to time constraints this test has not been performed. However, ElaadNL advises to perform this test after the test event, to check whether the power delivery stops as expected, and the connector unlocks. During the previous event, charging did not stop immediately in 29% of the cases. Power should be cut off as quickly as possible. A correctly applied Emergency-stop button is important in emergency situations, such as fire or electrical shocks. It is also important to consider the accessibility of the button.

The OEM roundtable has previously already advised to only place an emergency button for charging on the EVSE, not the EV. This advice remains valid.

Power outage

After a power outage, it is desired that the charging station continues to charge the vehicle. Especially at a building site, where the power delivery might be dependent on a BESS instead of the grid. This test has not been performed due to time constraints, but it is advised to perform this test at OEM's their own testing facilities, or at a later moment in the ElaadNL Testlab.

This behaviour should only occur when the connector stays locked in the EV, or if the EVSE checks if the same vehicle is connected after the power outage, to prevent misuse of the charging session by plugging the cable in another vehicle during the outage.

Conclusion and recommendations

The third BuildZero Test Event expanded on the first two by testing new combinations. During the event, the test results of 12 combinations of vehicles and chargers were gathered. The presence of engineers from both vehicle and charger manufacturers enabled fast and effective troubleshooting during the event, also proving the effectiveness of these kinds of test events. The main conclusions will be discussed in this section, followed by a general recommendation.

Relevance of testing is still present

The results gathered are similar to the results of the previous test event, revealing the importance of testing. Although most tests went well, there is still room for improvement:

Interoperability

The results show that most EV-EVSE combinations are interoperable, though still not all combinations were able to start charging immediately. Interoperability therefore remains an important test and focus point for the future.

During this event, for the first time, charging parameters such as current and voltage limits were gathered. An interesting interoperability issue which was found was the conflict of communicated limits and targets, which could cause situations where more power is delivered than expected or desired.

Protocols

Not all vehicles prioritized the more modern ISO 15118-2 protocol, some vehicles still prefer the older DIN 70121 protocol. The ISO protocol offers additional features such as the ability to pause or delay charging sessions, which is particularly useful for smart charging at sites with limited grid capacity, such as construction sites.

Recommendations

The results and conclusions found during the third BuildZero test event confirm the importance of pre-deployment testing for identifying and solving compatibility issues. Further individual testing, or future test events, will help accelerate the seamless deployment of electrified building equipment.

Furthermore, some tests mentioned in the test protocol have not been performed (or not performed a lot) such as the emergency button test, power outage test, and smart charging tests. These tests are recommended to be conducted later. This can be done either separately, or at the ElaadNL Testlab.

Lastly, other tests are recommended to be completed in the future at the ElaadNL Testlab. Such as charging with the newest ISO 15118-20 protocol (including TLS1.3), double gun charging and MCS charging.