



BUILD THE FUTURE

EVALUATION REPORT

BuildZero Test Event 2025



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

This report summarizes the key insights from the second BuildZero Test Event. From 19 to 21 May 2025, ENI, BMWt and ElaadNL hosted a second BuildZero Test Event at the ElaadNL Testlab in Arnhem, focused on charging mobile electric construction equipment.

During the three-day event, 28 combinations of vehicles, battery systems and charging stations from various manufacturers were tested. Of these, 27 combinations charged successfully, one failed. Tests were carried out by manufacturer engineers, supported by technical specialists from ElaadNL. The test setup simulated real-world construction sites and focused on communication protocols, smart charging and general charging behaviour.

The programme also featured a knowledge-sharing session in addition to the technical tests.

Equipment

Heavy Duty Construction vehicles

Three excavators and one wheel loader from the following manufacturers participated:

- Sany
- Hitachi
- Suncar
- Staad

DC charging stations

Three DC CCS2 charging stations with output powers ranging from 40 kW to 350kW were provided by these manufacturers who participated in the BuildZero Test Event:

- ABB
- Autel
- Ecotap

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 manufacturers of battery systems participated during the event:

- Hivolt
- Fusion Energy

Test system ElaadNL

ElaadNL also used its 350kW EV/EVSE test system, which served as a testbench for both vehicles and charging stations.

Test Protocol

Interoperability

Various charging protocols are used within EV charging infrastructure. Following the first test event, 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.

Default charging 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 connector establish a reliable connection with the vehicle each time it is plugged in? Does communication start immediately, or is reconnection required?
2. Does the combination of charger and vehicle result in a successful charging session, in which power is transferred to the vehicle.
3. What is the default charging protocol used during the charging session. (DIN 70121, ISO 15118-2 or ISO 15118-20)
4. Is the cable locked during the whole charging session. This can be tested by trying to pull out the connector when charging.

Smart charging

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

Fluctuating charging profile

To evaluate whether the charger vehicle combination is able to charge at different charging powers a fluctuating charging profile will be tested, this profile can be seen in figure 1. The profile only goes to 80kW, although most chargers could deliver more power. The limit of 80kW was chosen because of the limited availability of AC power delivered by the local grid at ElaadNL facilities.

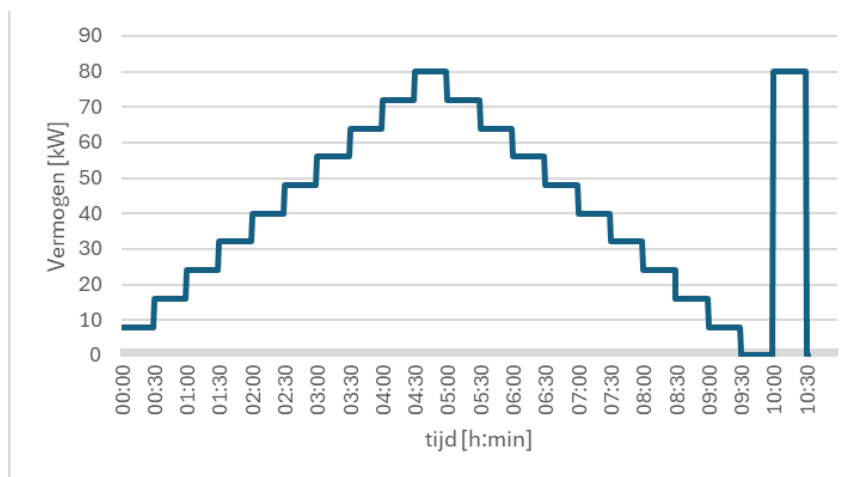


figure 1: Fluctuating charging profile

The fluctuating profile 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.

Pausing a charging session

Paused profiles 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 figure 2: Paused charging profile. Again, this can best be done via an OCPP TXDefaultProfile provided by ElaadNL.

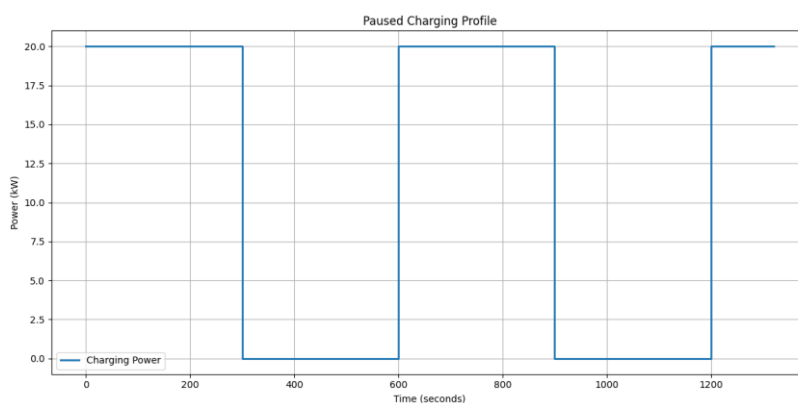


figure 2: Paused charging profile

Stopping a charging session

Charging session should be stoppable in three regular ways:

- By the vehicle
- By the charging station
- Via an OCPP command by the back office

To test this, a charging session must be started at 40kW. Then the session should be stopped using one of the above-named ways. Preferably once using DIN 70121 and once using ISO 15118-2(0) protocol while charging. Ideally, power is reduced to near zero before the contractor opens.

Vehicle charging safety

Emergency buttons

Emergency stop buttons on vehicles and charging stations are essential, because it instantly cuts off the power in case of a fire, electric shock or when equipment is damaged. Tests must confirm immediate power cut-off upon activation. When an emergency stop is performed, power should be cut immediately. Even a few extra seconds of current flow can worsen an arc fault, increase fire risk, or prolong electrocution. The test should be executed in both ways; by pushing the E-stop button on the vehicle and by pushing the E-stop button on the charger. To limit emergency stop tests, this test only has to be performed on one communication protocol.

Test results

Interoperability tests

Working charging session

A total of 28 vehicle-charger, vehicle-battery or battery-charger combinations were tested. 23 combinations successfully delivered power during the first test round. Most combinations charged without software modifications. Some required minor adjustments during testing. These adjustments resulted in a successful charging session in the test round. Five combinations could not charge during their first test round. However, after making adjustments in the software of the equipment, four of those five combinations were able to set up a working charging session when they tested together in a second test round. One combination failed to charge successfully.

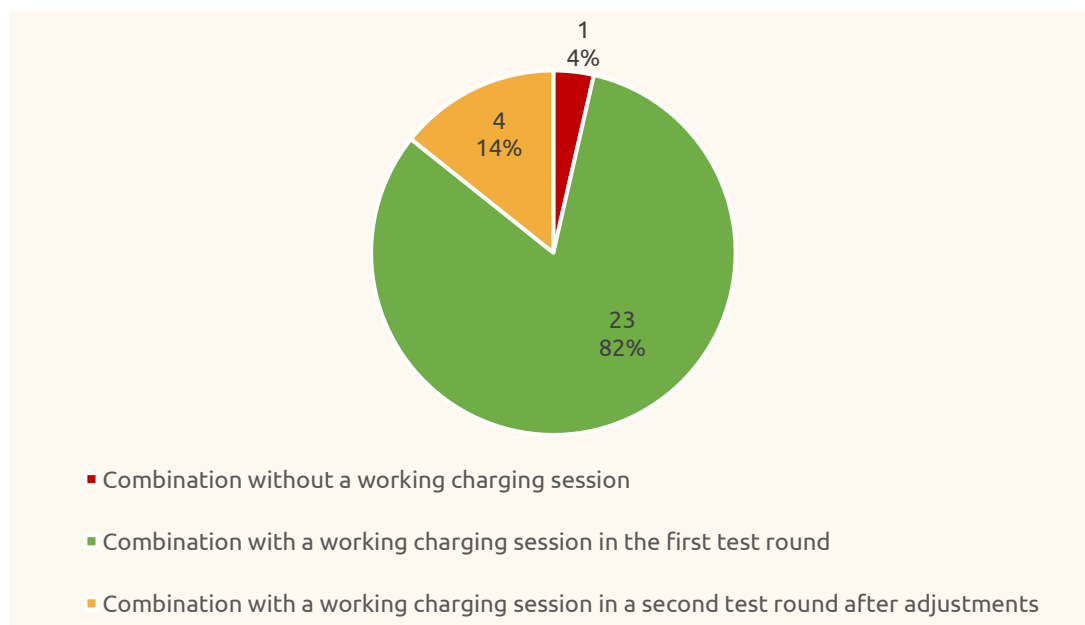


figure 3: Tested combination

The default charging protocol

Of the 27 tested working combinations, 22 had the ISO 15118-2 protocol as their default protocol and five had the DIN 70121 as their default protocol, as can be seen in figure 4. Figure 5 shows that five out of six tested vehicles (four vehicles, two battery systems) had the ISO 15118-2 as their default protocol. One vehicle had DIN 70121 as default protocol; therefore, this vehicle completed five charging sessions with the DIN protocol.

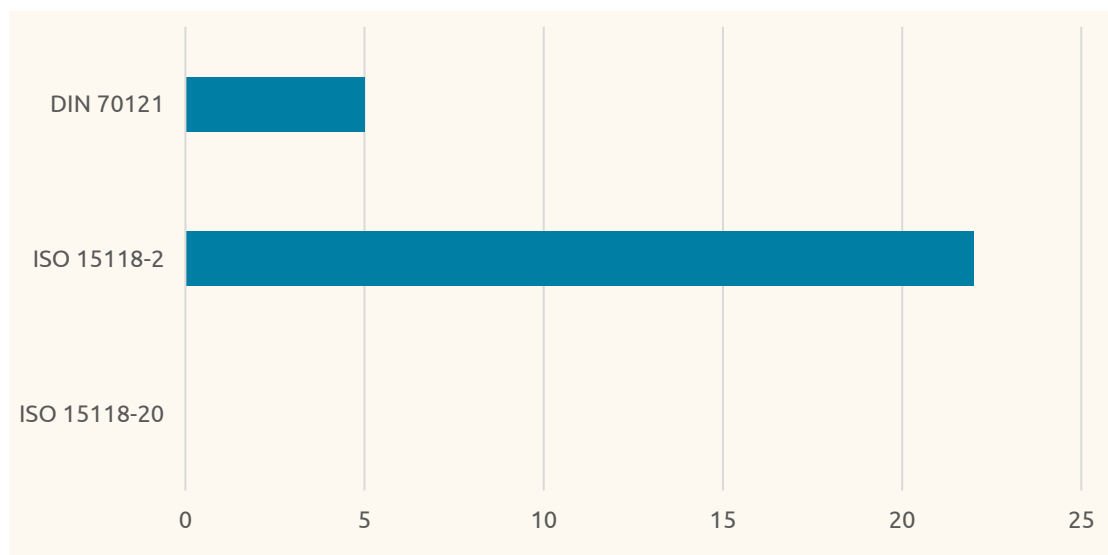


figure 4: Default charging protocols of the tested combinations

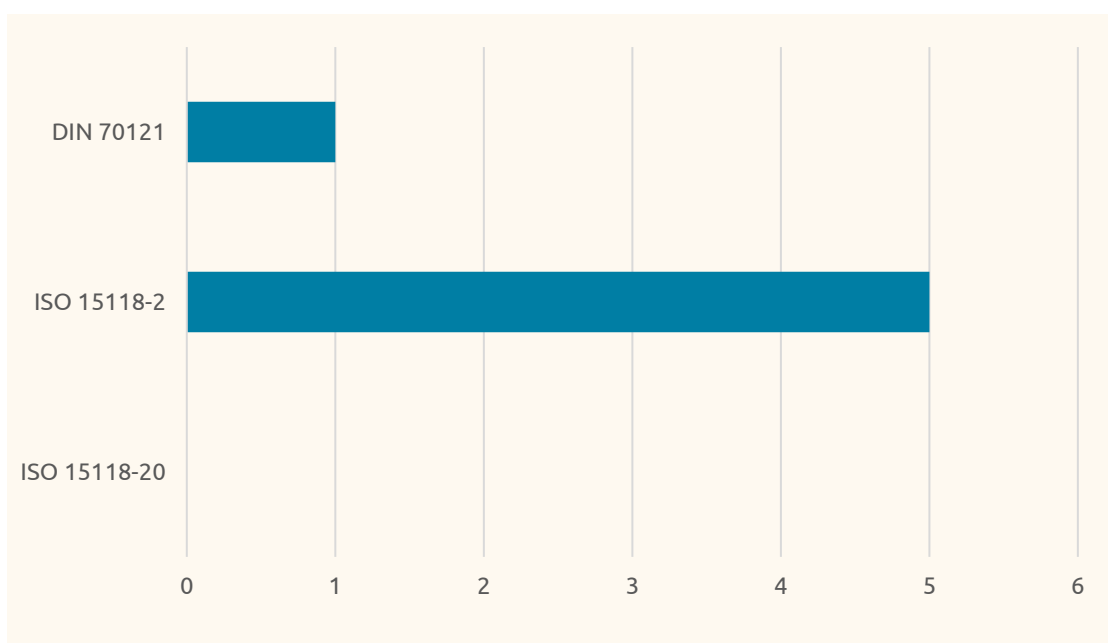


figure 5: Highest charging protocol priority of the vehicles

Locking mechanism

All combinations established a reliable and secure connection. The connections also stayed locked during charging.

Smart Charging

Fluctuating charging profile

The fluctuating charging profile was tested in 13 sessions. The test was done 11 times using ISO 15118-2 protocol and two times using DIN protocol. One ISO test failed. The results can be found in figure 6.

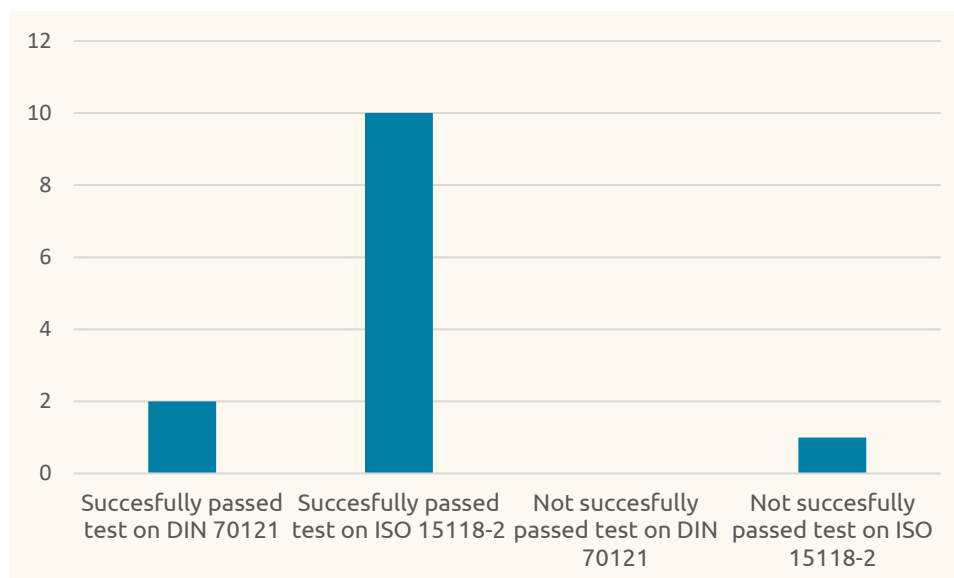


figure 6: Resulted fluctuating charging profile

Paused charging

Paused charging was tested 11 times: nine passed, two failed. Although sessions paused successfully, some failed to resume, which is mandatory for pausing sessions for smart charging. The results can be found in figure 7.

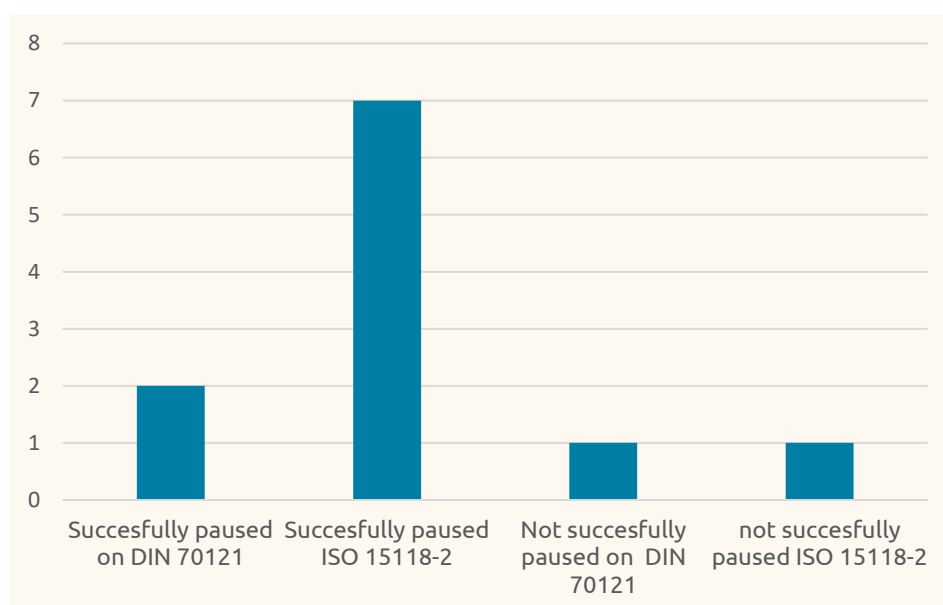


figure 7: Results paused charging test

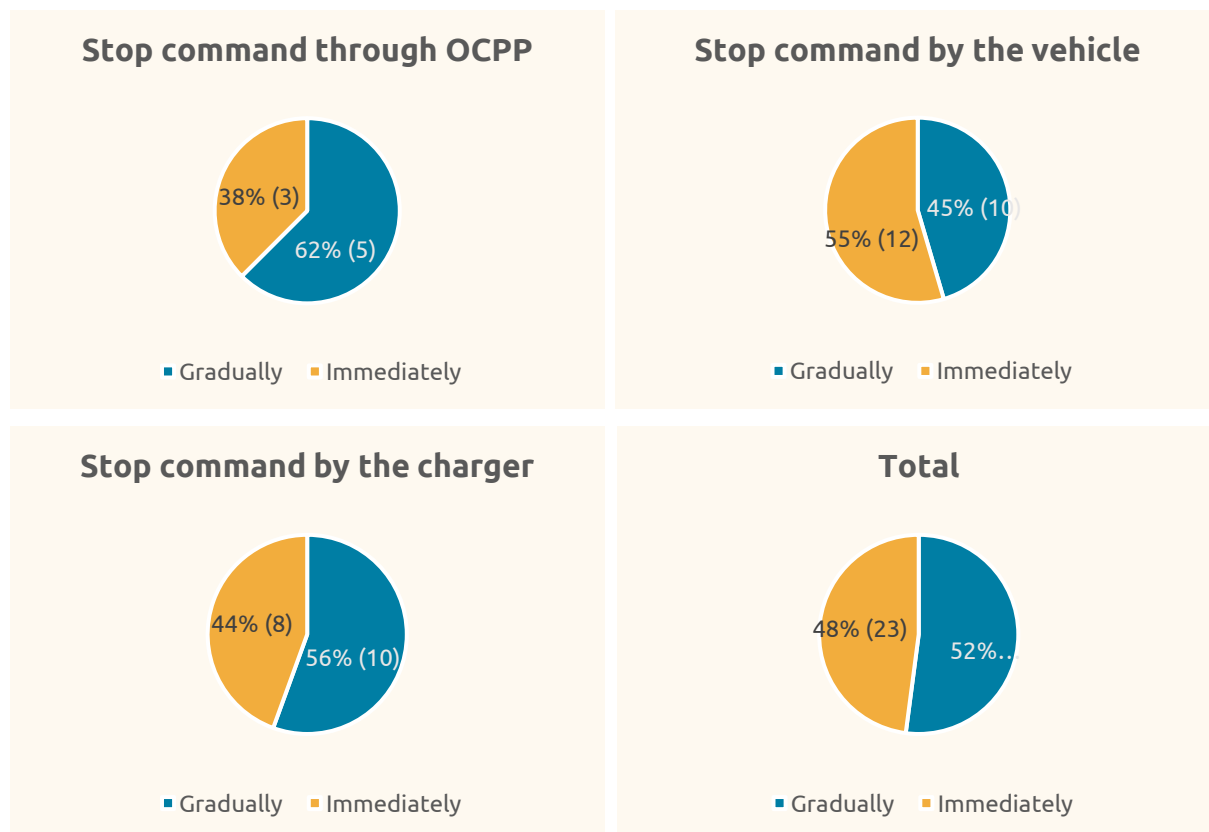
The two times the test failed the charging session did start and the session did pause, however when the charging should have continued again, it did not.

Out of the nine times a charging session passed the paused charging test, in three sessions, charging current dropped to 1 Ampere instead of 0 Ampere. Therefore, the power of the charging stations will not go completely to 0 Watt.

Stopping a charging session

Stopping a session was tested 48 times, 22 times it was initiated by the vehicle, 8 times by an OCPP command and 18 times by the charger.

Approximately half of the times the current from the charger stopped immediately and the other half it stopped gradually, meaning the current gradually went to 0.

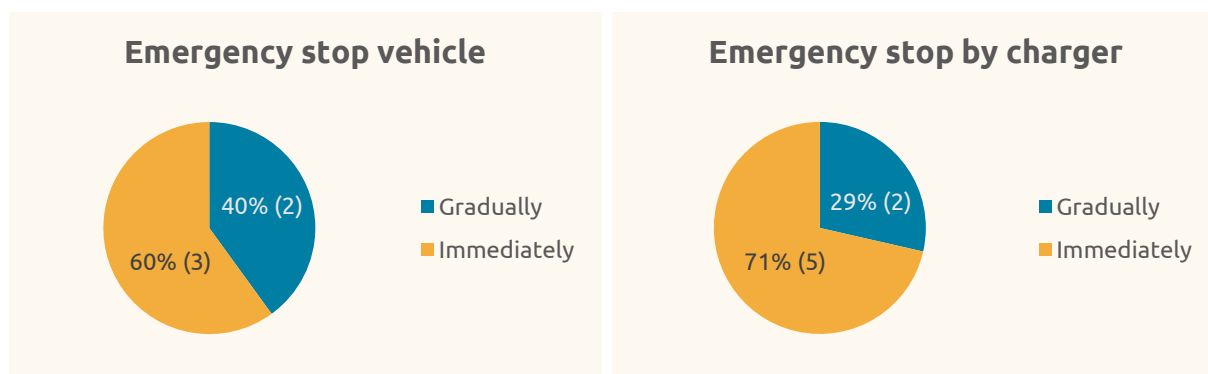


Vehicle charging safety

Emergency buttons

Out of the 27 combinations, only five tested the emergency stop initiated by pressing the E-stop on the vehicle. Seven combinations tested the emergency stop initiated by pressing the E-stop on the charger.

In 40% of vehicle E-stop tests, charging did not stop immediately; for chargers, 29% failed to cut power instantly.



Evaluation

Interoperability test

Working charging session

The main goal of the BuildZero test events is to identify charging issues in zero-emission construction equipment before deployment. When issues occurred during the test events, engineers from charging station, battery system and construction vehicle manufacturers, were able to resolve the issues by making adjustments to the implementation of the charging protocol. This was necessary for at least 18% of the tested combinations. 14% of those were resolved during the event.

In comparison to the first BuildZero Test Event, 50% more combinations were tested (28 vs 18 combinations). During the first event issues occurred in 17% of tested combinations, for the second event this was 18%.

If the charger and vehicle had not been tested together during the test event, issues could have occurred at the construction site, and the vehicle might not have charged. Testing them together allowed potential issues to be identified and resolved before deployment, ensuring reliable charging on-site. Engineer presence enabled fast issue analysis and resolution.

One combination failed to charge successfully. During this test, logfiles of the charging sessions were made and the problem will be analysed by the manufacturer. A retest will be conducted at ElaadNL to evaluate whether the solution was effective.

The default charging protocol

Out of the 27 tested combinations, 22 combinations communicated using ISO 15118-2 protocol, 5 used DIN 70121 protocol, and none used ISO 15118-20 protocol.

When a charger plugs into a vehicle, the charger tells the vehicle which protocols it can use. The vehicle proposes a default protocol (ISO 15118-2(0) or DIN 70121); if supported by the charger, it is applied. It is important to program the correct protocol as the preferred option in the vehicle/asset to avoid charging sessions using DIN when ISO is also supported.

Since four out of five vehicles used ISO 15118-2 protocol as the default protocol most of the sessions used the ISO protocol. The 5 sessions that were done using DIN protocol, were with the one vehicle that had DIN as its default protocol.

During the first BuildZero test event all vehicles used DIN 70121 as default protocol, therefore, all sessions were done with the DIN protocol. In the second event, 81% of the charging sessions were done with the ISO 15118-2 protocol. This marks significant progress since the first event.

The DIN 70121 is an older, simplified protocol that covers only DC charging use cases, primarily to allow early CCS rollouts before ISO 15118-2 implementations were mature.

The ISO 15118-2 protocol is a newer protocol and also offers more features. A short explanation of the differences between the protocols can be found in appendix A. The most important feature for construction vehicles is the paused and delayed charging feature of the ISO protocol. This feature will be highly beneficial on busy sites or charging plazas where grid capacity is limited and scheduling of charging is needed.

Locking mechanism

Locking mechanisms functioned reliably throughout the test event. All plugs connected securely and initiated communication successfully. Plugs remained securely locked during charging. However, construction sites present harsher conditions. Debris such as dust, sand and mud can easily enter charging connectors, affecting performance.

Smart Charging

Fluctuating charging profile

The fluctuating charging profile test was only done in 48% of the combinations, due to the fact that not all charging stations could recreate the fluctuating charging profile, because it could not be connected to a working back-office or adjusting the charging speed manually was not available. Another limiting factor was time constraints during test rounds.

A general conclusion about the best performed protocol cannot be made, because the ISO-protocol was tested in more combinations and failed once, while the DIN-protocol did not fail while being used in less combinations.

Out of all tested combinations, 12 combinations were able to perform smart charging with a fluctuating profile. For 14 combinations, the ability to charge at different speeds was not tested, and one combination was not able to handle this profile. Testing this profile reduces the risk of field errors during smart charging.

Paused charging

The paused charging test was only done on 40% of the combinations. The reason that this test was not done in 100% of the combinations, is because not all chargers could be connected to a back office or controlled manually. Another reason is the lack of time within the test round.

Again, a significant conclusion about the difference between ISO and DIN cannot be made because of the low number of combinations tested.

One thing that stood out was the fact that not all combinations lowered their output power to 0 kW when asked. In those cases, around 500 W of power was still delivered to the vehicle.

Stopping a charging session

No issues were found when trying to stop a charging session. However not every combination stopped in the same manner. Just over half of the times the charging session was stopped it was done in a controlled manner, in which the charging current gradually dropped to 0 Ampere and then the session was terminated. In the other half of tested combinations, the current dropped rapidly to 0 Ampere and the charging session was terminated. This could potentially have negative influence on the electrical components in the charger or vehicle. However, this influence was not tested.

Charging safety

Emergency buttons

The E(mergency)-stop of the vehicle was only tested on 19% of the combinations and the E-stop of the charger was only tested on 25% of the combinations. In follow-up test events, the E-stop tests should be conducted more frequently because a correctly applied E-stop button is important in emergency situations, such as fire or electrical shocks.

What stood out in this test was that not all charging sessions were ended immediately. When the E-stop was pressed on the vehicle, 40% stopped with delay. When the E-stop was pressed on the charger, charging did not stop immediately in 29% of the cases. This could lead to dangerous situations in emergencies, so the power should be cut off as quickly as possible.

Three out of four vehicles had an E-stop button, all three were accessible from inside the vehicle. One of those three was accessible from the outside. No formal regulations currently exist for this. However, the pre-market OEM roundtable hosted by ENI and ElaadNL will consider these results when drafting recommendations for E-stop placement on vehicles.

Equipment properties

Connector location

During the test event, it became clear that the location of the charging ports on the vehicles was not standardized. Connector placement varied: half left, half right.

Charging indication

LED indicators varied across vehicles and chargers.

Two vehicles did not have a led indicator on the outside of the vehicle. One used blinking blue when it was in handshake mode and the LED turned yellow when it was charging. The other vehicle used blinking blue when it was charging. The chargers and battery systems all used the blue LED light to indicate that it was charging a vehicle, and red, yellow and green for various other messages.

As stated in the first BuildZero Test Event report, ElaadNL recommends standardizing the following LED colors:

- Green: ready to charge
- Blue: charging
- Red: error

OCPP

OCPP (Open Charge Point Protocol) is an open standard that enables communication between charging stations and backend systems. It ensures interoperability, allowing chargers from different manufacturers to connect to the same platform. OCPP is essential for smart charging on construction sites, enabling remote monitoring, load balancing and dynamic control of multiple chargers. This way, limited grid capacity can be used more efficiently, preventing overloads while ensuring that all machines and vehicles get the energy they need.

All three chargers and two battery systems supported OCPP 1.6 JSON; one also supported OCPP 2.0.1.

OCPP 2.0.1 improves on 1.6 by adding stronger security, more advanced smart charging control, and support for new use cases like plug & charge.

Conclusion and recommendations

The second BuildZero Test Event expanded on the first by testing more combinations. During the event, 28 combinations of vehicles, chargers, and battery systems were tested. Of these, 23 established a working session in the first round, while 4 more were successful after minor software adjustments. One combination failed to establish a charging session. These results confirm the importance of pre-deployment testing for identifying and resolving compatibility issues. The presence of engineers from both vehicle and charger manufacturers enabled fast and effective troubleshooting during the event.

ISO 15118-2 gains ground as preferred protocol

A key improvement over the first test event was the increased use of the ISO 15118-2 protocol. In total, 81 percent of the working sessions used ISO, while only DIN 70121 was used in the first event. 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.

Smart charging: positive steps, more needed

Smart charging profiles were successfully tested in 12 combinations. In other cases, testing was limited by technical constraints or time. Despite partial coverage, the results show progress towards flexible and efficient charging. Smart charging should be the central focus of the next BuildZero event.

No standard in LED colour indication.

There was no uniformity found in the way LED colours were being used to indicate the charging status. Elaad recommends the following standard:

- Green: available
- Blue: charging
- Red: error

In recent history, this has been the most widely used, ensuring uniformity and clarity for the end user. Standardization will be addressed during the pre-market OEM roundtable, hosted by ENI and ElaadNL

Emergency stop access needs clear standardization

No standard exists for emergency stop functionality on vehicles. Three of the four vehicles had an emergency stop; only one was accessible from both inside and outside. Recommendations will follow from the pre-market OEM roundtable hosted by ENI and ElaadNL.

Appendix A

Feature	DIN 70121	ISO 15118-2(0)
Fluctuating charging profiles	Supported	Supported
Pausing a charging session	Not formally supported. Sessions can be paused by setting current to 0 A, but remain active. This keeps inverters engaged and results in reactive power draw. Additionally, some stations may still deliver power at 0 A.	Fully supported. Sessions can be paused or delayed without drawing reactive power from the grid.
Plug & Charge	Not supported	Supported
Vehicle-to-Grid (V2G)	Not supported	Only supported in ISO 15118-20