

BEST PRACTICES FOR PAYMENT SYSTEMS

at Public Electric Vehicle
Charging Stations



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List of Acronyms

ChargeX Consortium	National Charging Experience Consortium
CSO	charging station operator, also referred to as a charge point operator (CPO)
eMSP	e-mobility service provider
EV	electric vehicle
EVSE	electric vehicle supply equipment
NFC	near-field communication
PCI	payment card industry
QR	quick response
RFID	radio frequency identification
SIM	subscriber identity module
SMS	short message/messaging service

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1 Introduction

Failure to accept and process payment is a cause of public electric vehicle (EV) charging session failures. This document summarizes EV charging payment challenges and proposed solutions. Data are not available to rank the severity of payment issues; however, input from members of the National Charging Experience Consortium (ChargeX Consortium) suggests that payment issues present ongoing challenges. The input also indicates that credit card readers have been more prone to failure than other payment methods. The multiple EV charging payment options commonly provided for customers at public charging stations increase the complexity in solving the issue. This document considers the following forms of payment: credit card readers, radio frequency identification (RFID), near-field communication (NFC), apps, Plug & Charge, and phone call, text, or short message service (SMS).

1.1 EV Charging Payment Methods

There are multiple methods to pay for an EV charging session. The flexibility allows customers various options to address the needs of different customers and to offer backup options if a preferred method fails. Most methods depend on a network connection to authenticate payment and allow the charging session to start. All methods of payment can be impacted when a customer has an invalid credit or debit card or payment information stored in an account. Credit card, NFC, and RFID reader hardware are subject to durability, environmental, and vandalism impacts. The authors are unaware of an EV station that accepts cash payment.

1.1.1 Credit Card Readers

Credit card readers at public EV charging stations allow customers to pay for charging using credit and debit cards. A customer can generally insert, swipe, or tap a credit or debit card to pay. This method of payment is familiar, convenient, and accessible for many customers. The National Electric Vehicle Infrastructure Formula Program and other federal and state programs require card readers. Card readers for insert and swipe methods of payment are exposed to dirt, dust, rain, snow, and ice, as well as vandalism. Issues with payment can be due to an inoperable card reader, network connection issues, or an invalid or expired credit or debit card.

1.1.2 RFID

RFID is a wireless communication method that allows customers to pay for charging directly from their charging network account. They do this by holding a charging network membership card near an RFID reader,¹ transmitting account information via the card's embedded chip and antenna. RFID cards are also a form of prepaid card made available by fleet operators and charging station operators (CSOs). Most RFID cards follow the International Organization for Standardization (ISO) 14443 standard for communication with the reader. A card's unique identifier is shared with the electric vehicle supply equipment (EVSE) and sent to the charging network provider for authorization, which will be granted if it belongs to an authorized member of the network. Issues with RFID payment are generally due to a customer account storing an

¹ There are various implementations of payment hardware on EVSE—RFID may be incorporated into a credit card reader or it may be a stand-alone RFID reader.

invalid or expired credit or debit card, lack of funds for prepaid cards, or network connection issues.

1.1.3 NFC

NFC, a subset of RFID, is a wireless communication method that enables contactless payment via credit or debit card, smartphone apps (e.g., Apple Pay, Google Wallet, Samsung Pay), wearables, and other contactless payment cards. Credit card readers are typically NFC-enabled, or there can be a separate NFC device on the EVSE. NFC payment issues are generally due to a customer account storing an invalid or expired credit or debit card or network connection issues.

1.1.4 Apps

Charging station, roaming, and vehicle apps allow a customer to store their credit and/or debit card information for payment at a station. Issues with app payment are generally due to a customer account storing an invalid or expired credit or debit card or customer cellphone connection strength.

1.1.5 Plug & Charge

Plug & Charge automates communication and payment between the vehicle and charging station. An e-mobility service provider (eMSP) is an organization that provides EV charging roaming service and is a required part of the Plug & Charge ecosystem. The customer has credit and/or debit card information stored in their account, which is used to authorize and pay for a charging session. Issues with Plug & Charge payment are generally due to a customer account storing an invalid or expired credit or debit card or EVSE network issue. Issues with public key infrastructure security certificates may also contribute to failed authorizations. Additionally, inconsistent implementation of Plug & Charge may also prevent authorizations. Even if a customer's EV is capable of Plug & Charge, authorization will fail if the charger is not capable of this method of payment, or due to varied implementation of ISO 15118, the communication standard that defines Plug & Charge.

1.1.6 Phone Call, Text, or SMS

CSOs offer customer support and payment through a toll-free phone number or allow text/SMS for assistance with payment and remotely starting a charging session. This provides a payment option for customers without smartphones, preestablished membership accounts, or payment cards. It also provides a backup option if a customer encounters an issue with payment by other methods.

1.2 Methodology and Resources

A literature review found survey data stating that there are payment challenges for EV charging; however, no comprehensive documents were found detailing the issues. The approach for this report included input from ChargeX Consortium members through one-on-one meetings, which served as a starting point to identify issues and, in some instances, potential solutions. The ChargeX Consortium's Payment & User Interface Task Force members refined the issues list and provided proposed solutions. Ongoing meetings, reviews, edits, and comments from the task force refined the information included in this document. The content is separated into key topic sections, and a table within each section groups issues and proposed solutions.

Useful references include the two publications issued by the U.S. Payments Forum EV Open Payments Working Committee on the use of the correct merchant category code and terminal payment flow guide (U.S. Payments Forum 2024).

2 Network

All forms of payment rely on various forms of network connections to enable charging. Card, NFC, and RFID readers either have their own network connection or are tied into the EVSE network connection. This section focuses on card, NFC, and RFID reader network connections. However, it is also applicable to EVSE network connections necessary for app and Plug & Charge payment methods.

Table 1. Network Issues and Proposed Solutions

Issues	Proposed Solutions
<p>Network Strength</p> <p>Poor network connectivity of payment systems is a significant issue.^a</p> <p>The U.S. cellular network generally lacks robustness. The United States has a patchwork of overlapping cellular networks run by three major networks with spotty coverage outside of urban areas.</p> <p>EVSE located outside urban areas suffers from chronic connectivity issues.</p> <p>EVSE and mobile phone connectivity at stations located in underground garages is poor.</p> <p>Customer's phone shows good connectivity but data is not working.</p> <p>Payment system could be online but with high latency and low connectivity.^b</p>	<p>CSO and site hosts conduct site survey for cellular connectivity and analyze site factors that may cause signal interference or lessen reception. Signal strength should be tested at different days and times (including weekdays and weekends) and tested at each maintenance visit.</p> <p>Designate standard for minimum connectivity level inclusive of network speed.</p> <p>Use dedicated subscriber identity module (SIM) cards for the strongest signal at the station location; use a backup, multi-network (roaming) SIM card if the configuration allows for a second SIM.</p> <p>Use ethernet connection where possible for hardwire connection to a modem or router.^c</p> <ul style="list-style-type: none"> • Run ethernet cable through a separate conduit than power lines. • Include a cellular modem and SIM card as a backup network connection. • Not all locations will have ethernet as an option, and it adds significant expense. • Caution: CSOs may encounter scaling issues with having different connectivity systems at different sites. <p>Use Wi-Fi hot spots generated from a hardwired router as primary or backup network connection. Note that this requires coordination with site host to avoid data security and reliability issues of shared internet.</p>

Issues	Proposed Solutions
	<p>Use EVSE network to create a Wi-Fi hot spot to allow customers to connect their cellphones. The hot spot can provide a backup option for a customer having issues with their cellphone connection. A related option is a mobile Wi-Fi connection, in which a portable device uses a cellular network to create a hot spot.</p> <p>Enable external antenna on EVSE for payment system to increase signal reception. Antenna placement needs to be thought out and addressed early in the design of equipment.</p> <p>Select card readers that offer multiple connectivity options.</p>
<p>Network Hardware</p>	
<p>Degradation of connectivity devices leads to end of useful life of communications equipment (e.g., modem, router).</p> <p>Insufficient/inadequate communications equipment preventative maintenance.</p>	<p>Establish a network component health check during scheduled maintenance.</p>
<p>Network Integration</p>	
<p>Poor software integration of the credit card reader into the EVSE can affect overall reliability and customers' ability to use the EVSE with their intended payment method.</p>	<p>Integrate credit card reader into EVSE network connection, including network segregation via a security switch.^d</p>
<p>Data Plan</p>	
<p>Cellular data plan runs out of data.</p>	<p>Carefully select cellular data plan. Generally, select a plan that does not run out of data but instead incurs overage fees. Use data plans that are robust and do not encounter reduced network speeds.</p>

^a This refers to connectivity between the local card reader hardware (potentially through the EVSE modem to cloud pod security policies backend) and payment merchant gateway (credit card payments facilitator); this does not refer to merchant gateway cloud connection to CSO backend that releases charging to begin after payment is collected.

^b Unpublished research suggests ping time—how fast a response is received from an internet connection—is a better indication of payment transaction success than upload and download speeds.

^c There is a concern for leased locations about the ability to use ethernet long term.

^d It is suggested that retrofits of this solution are complex, and data security requirements could make this challenging.

3 Integration, Activation, and Installation

This section focuses on the integration and activation of the card reader payment system with the EVSE.

Table 2. Integration, Activation, and Installation Issues and Proposed Solutions

Issues	Proposed Solutions
Integration	
<p>EVSE and credit card system are not fully integrated. EVSE and payment system backends are not connected.</p> <p>Integration of credit card reader into EVSE has been challenging, largely due to software issues.</p> <p>Not all card readers are compatible with a specific EVSE's hardware and software.</p>	<p>Select card readers compatible with specific EVSE models and that have received payment card industry (PCI) certification or are PCI compliant.</p> <p>Subject third-party integration of card reader and EVSE to factory acceptance test and site acceptance test.</p> <p>The point-of-sale software should be tested with the EVSE prior to deployment.</p> <p>Card reader manufacturers and EVSE integrator need to align software update schedules and perform testing prior to deploying new card reader software versions. Coordinate updates with all parties, include release notes, and schedule for off-peak hours. Implement automatic update checks.</p> <p>Card readers integrated into EVSE outside of the United States need to be registered for U.S. systems prior to installation.</p>
Activation & Installation	
<p>Incomplete activation of payment system prior to installation.</p>	<p>Verify correct station location is assigned to card reader during activation of payment system. This will avoid confusion when troubleshooting and reduce repair times.</p> <p>During activation, make sure EVSE has correct terminal ID connected to the correct merchant ID provided by the acquirer.</p> <p>Perform active monitoring to ensure proper activation, installation, and ongoing operation.^a</p>
Payment Standards	
<p>Noncompliance with PCI standards—particularly for network segregation.</p>	<p>Comply with all PCI standards, including PCI data security standards.</p>

Issues	Proposed Solutions
	<p>Only use PCI-certified or PCI-compliant payment solutions.</p> <p>Use correct merchant category code: 5552 Electric Car Charging.</p> <p>Regularly audit and ensure compliance with PCI data security standards. This requires a recurrent certification once per year to stay aligned with the latest PCI requirements.</p>

^a This can be done via live monitoring or within the reconciliation process of transactions at the card reader level.

4 Robustness of Hardware

EV charging stations are generally not under a canopy, and card readers are subject to weather impacts and incursions of dust, water, and other foreign debris.

Table 3. Robustness of Hardware Issues and Proposed Solutions

Issues	Proposed Solutions
<p>Hardware Physical Parameters</p> <p>There has been limited scrutiny of robustness of hardware.</p> <p>Card readers are often outdoors and impacted by dirt, dust, rain, ice, high/low temperatures, and other climate impacts.</p> <p>Operational specifications are for -20°C to 70°C; if these temperatures are exceeded, it goes offline into safe mode.</p>	<p>Embed contactless/tap card reader into the EVSE.</p> <p>Use weather-resistant card readers designed for outdoor use.</p> <p>Increase ruggedness of card reader hardware.</p> <p>Card readers should meet International Electrotechnical Commission ingress protection rating of IP54 or IP66.</p> <p>Card readers should meet the National Electrical Manufacturers Association ratings of 4 or 4X.</p> <p>Use card readers that shut down with high temperatures and reactivate when a customer uses the card reader.</p> <p>Use card readers that send an alert to the backend in the event of a disconnection or malfunction.</p> <p>Conduct environmental tests for card reader hardware.</p>

Issues	Proposed Solutions
	Design card readers to work in direct sunlight. Similarly, design sites where EVSE faces away from direct sunlight.
Vandalism	
Card readers can be targets of vandalism and tampering, causing malfunctions or security issues.	<p>Embed contactless/tap card reader into the EVSE.</p> <p>Use tamper-evident seals, designs, surveillance cameras, or other security measures.</p> <p>Use impact protection IK-rated card readers for resistance to impact.</p> <p>Detect vandalism/tampering, send alert to backend, and disable/shut down.</p>
Hardware Integration	
Externally integrated product selected by CSO unlikely to go through validation that EVSE manufacturers use for other components.	The selection and EVSE integration of the card reader should consider methods and designs to reduce the potential for environmental damage.

5 Customer Experience

The varied methods of payment and timing for authentication can confuse customers and lead to payment challenges.

Table 4. Customer Experience Issues and Proposed Solutions

Issues	Proposed Solutions
User Interface	
The sequence of payment is not the same at each charging station.	Display clear, step-by-step instructions at the charging station.
Customers are confused by multiple payment options.	Display card reader prompts on the EVSE’s user interface.
Customers lack familiarity with different charging stations.	Standardize the order of operations on the user interface screen and in apps for payment for consistent customer experience. The U.S. Payments Forum published “Public Electric Vehicle Charging Terminal Payment Flow Guidelines,” inclusive of suggested payment prompts (U.S. Payments Forum 2023).
Card reader user prompts are difficult to read or are not obvious because the customer is looking at EVSE user interface instead of card reader.	Educate customers on the various payment methods for a charging session and provide easy-to-understand instructions for each method.

Issues	Proposed Solutions
Quick-Response (QR) Code	
<p>The QR label has degraded and is not readable.</p>	<p>Use more durable materials such as engraved stainless steel or photo-anodized aluminum rather than stickers.</p> <p>Static QR code should be displayed on card reader screen and EVSE screen, rather than stickers.</p>
Payment Declined	
<p>Customer credit or debit card declined.</p>	<p>Communicate that the credit or debit card is not approved on the user interface the customer is interacting with (kiosk screen, card reader, app, or vehicle screen).</p>
Receipts	
<p>Payment systems lack the means to produce receipts.</p>	<p>The National Institute of Standards and Technology Handbook 44 Section 3.40 provides a framework for receipts, allowing for digital receipts delivered via text, email, or as a web receipt.</p> <p>Printed receipts are not recommended due to increased maintenance.</p>
Fleet Cards	
<p>Fleet cards may require answering prompts on a screen prior to charging, and not all card readers provide this capability.</p> <p>Fleet cards are generally not tap/contactless enabled.</p>	<p>Select card readers capable of meeting the requirements for fleet card payment.</p> <p>Work with fleet card providers on methods to enable tap/contactless payment.</p>
Accessibility	
<p>Accessibility of card reader.</p>	<p>The location/height of credit card reader must be installed at or below 48 inches at an angle accessible and convenient for all users and compliant with the Americans with Disabilities Act. Note that this placement may be outside the typical line of sight for nondisabled customers, so also display card reader prompts on the EVSE user interface.</p>

6 Maintenance

Maintenance of payment hardware and systems may be overlooked and is an important component of improving payment reliability.

Table 5. Maintenance Issues and Proposed Solutions

Issues	Proposed Solutions
<p>Regular wear and tear, as well as vandalism, can cause card reader malfunction.</p> <p>Payment system is generally not included in the EVSE service and maintenance plan.</p>	<p>Plan and contract for timely support and repairs for the payment systems, including regular cleaning of swipe- and insert-style card readers.</p> <p>Train staff to identify and report issues.</p> <p>Test payment network strength with each maintenance visit.</p> <p>Maintain a small inventory of replacement parts.</p> <p>Partner with card reader suppliers that offer prompt support.</p>

7 Other

Several other issues were introduced by task force members, including issues with RFID and other more technical communication issues that involve payment issues.

Table 6. Other Issues and Proposed Solutions

Issues	Proposed Solutions
NFC	
<p>When paying with NFC token (e.g., Apple Pay) that is not set up properly, the payment is rejected but the reason(s) why are not clear.</p>	<p>Push notifications or email are needed to resolve issue.</p>
<p>There is not a single standard for RFID implementation.</p>	<p>Industry could agree on a single RFID standard.</p>
RFID	
<p>RFID tags can be issued that work on different frequencies. Most card readers support only one frequency.</p>	<p>Deploy RFID cards with the same frequency throughout the industry. Alternatively, install more expensive, dual-antenna RFID readers.</p>
<p>Roaming network impacts are experienced if the RFID card identifier does not indicate to a CSO which eMSP issued the card.</p>	<p>CSOs could use a hub for roaming that uses remote start to mitigate any RFID card issues.</p>
Plug & Charge	

Issues	Proposed Solutions
Payment and user account are correct and customer is using Plug & Charge but CSO cannot authenticate.	No proposed solutions; more research is needed.
Plug & Charge Transport Layer Security (TLS) loop failure where first vehicle fails for some reason and this customer then authenticates and pays via another method, and the EVSE does not offer TLS; therefore, the next car cannot ask for Plug & Charge.	No proposed solutions; more research is needed.

8 Conclusion

This document summarizes payment issues encountered by public EV charging infrastructure and proposes solutions based on input from both individual ChargeX Consortium members in one-on-one interviews and the ChargeX Consortium’s Payment & User Interface Task Force collaborating as a whole. Key takeaways include the following:

- Because all forms of payment require network connectivity, special attention should be given to charging station design to ensure a robust network connection. When relying on a cellular network connection, employ an external antenna, redundant SIM card, and carefully selected data plan. If using a local modem or router as a primary or backup connection, a wired connection with ethernet cable routed through dedicated conduit is superior to a Wi-Fi connection to a local modem or router. It is also important to have a robust agreement in place with the site host to ensure data security and connection speed are maintained. Regardless of the network connection method employed, it is important to test network connectivity during the charging station design stage and repeat testing during each maintenance visit. Finally, consider providing a Wi-Fi hot spot for customers to ensure their cellular phones have connectivity for app- and phone-based payment.
- Credit card reader integration with the EVSE is critical for reliable operation. Use PCI-compliant devices that are compatible with EVSE software. Test functionality after device integration with the EVSE and point-of-sale software, both prior to and upon installation. Plan for and coordinate card reader software update and verification processes. Use merchant category code 5552—Electric Car Charging.
- Selecting a ruggedized card reader designed for outdoor use is also critical for reliable operation. Test card readers to ensure robustness.
- Carefully design the EVSE user interface so that the customer understands how to use multiple payment options and so that information presented on the credit card reader and EVSE user interface is visible and consistent. Create a consistent user experience by following “Public Electric Vehicle Charging Terminal Payment Flow Guidelines” (U.S. Payments Forum 2023).
- Maintenance of payment systems is important for reliability and requires contracting to ensure qualified staff conduct timely inspection and maintenance.

Future work is needed to quantify the benefits of these proposed solutions to help industry prioritize solutions that realize the greatest improvement in payment system reliability.

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About the ChargeX Consortium

The National Charging Experience Consortium (ChargeX Consortium) is a collaborative effort between Argonne National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory, electric vehicle charging industry experts, consumer advocates, and other stakeholders. Funded by the Joint Office of Energy and Transportation, the ChargeX Consortium's mission is to work together to measure and significantly improve public charging reliability and usability by June 2025. For more information, visit chargex.inl.gov.

