INL/MIS-25-82972-Revision-0

ChargeX Consortium Presentation at OCPP Plugfest

January 2025

Casey W Quinn, Dhananjay Anand

Changing the World's Energy Future

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ChargeX Consortium

Plugfest Presentation

CHARGEX consortium

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January 28, 2025

INL/MIS-25-82972

Any Driver, Any EV, Any Charger

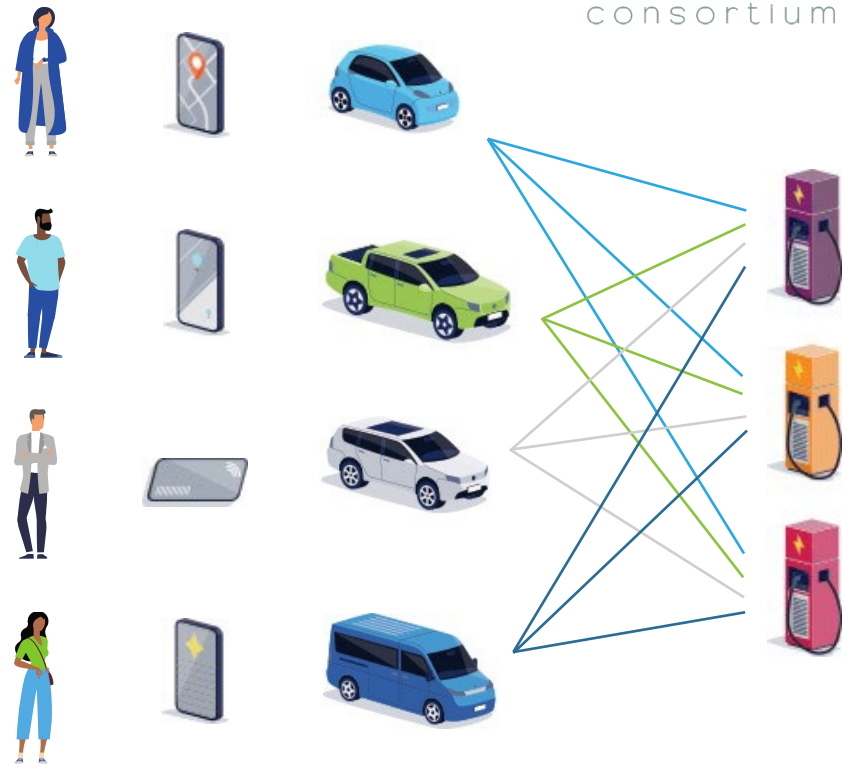
CHARGEX consortium

Mission

Bring together EV charging industry members, national laboratories, consumer advocates, and other stakeholders to measure and significantly improve public charging reliability and usability in North America **by June 2025**

Scope

Focus on complex issues that require multi-stakeholder collaboration and national lab support to solve and simplify



FIRST TIME,
EVERY TIME

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Executive Summary

- ChargeX Consortium will have aided industry to improve the driver EV public charging experience
- Research priorities were directed by industry participants
- Collaborated, shaped and standardized steps and processes of EV charging with 90+ company participants since 2023
- Accomplished handover efforts to industry for implementation
- Widened the consortium's scope to include VGI tasks to elevate the charging experience

Participants (90 as of 12/31/2024)

Charger Manufacturers and Suppliers	ABB e-Mobility, Amphenol, Autel, Bosch, BTC Power, ChargeTronix, Dover Fueling Solutions, Eaton, Evalucon, Heliox, IoTecha, Qualcomm, Siemens, SK Signet,Tritium, Wallbox
Customer-Facing Charging Station Operators	Apple Green Electric, Blink Charging, bp pulse, ChargePoint, Electrify America, EVgo, FLO, Francis Energy, HeyCharge, KIGT, Koulomb, Lynkwell, NovaCHARGE, NYPA, Rove, SWTCH, Xeal Energy
Charging Network and Software Providers	ampcontrol, AMPECO, ampUp, ChargeMate, Driivz, EV Connect, Noodoe, PIONIX, Switch
Auto Manufacturers	American Honda, BMW of North America, Ford Motor Company, General Motors, Lucid, Mercedes-Benz North America, Rivian, Stellantis, Subaru of America, Tesla, Toyota Motor North America, VinFast Auto, Volvo Car USA
3rd-Party Roaming Hubs and eMSPs	AeonCharge, Bluedot, ChargeHub, Emobi, Hubject
Field Services and Analytics Firms	Atlas Public Policy, ChargerHelp!, Energetics, EVSession, Field Advantage, ReliON, Uptime Charger, WattsUp
Consumer Advocates	Cool the Earth, Consumer Reports, EVinfo, J.D. Power, Plug In America
Fleets	Hertz
Payment Industry Stakeholders	Nayax, Payter, WEX
Standards Organizations and Technology Alliances	CharIN North America, COVESA, NEMA, Open Charge Alliance, SAE Sustainable Mobility Solutions
Research Organizations and Universities	American Center for Mobility, EPRI, Transportation Energy Institute, University of California, Davis; University of Washington
State Agencies	California Air Resources Board, California Energy Commission, Caltrans

Scope of Work

Defining the Charging Experience

- Define KPIs
- Develop and verify implementation instructions

Reliability/Usability Triage

Create fixes for:

- Payment and user interface
- Communication
- Hardware

Solutions for Scaling Reliability

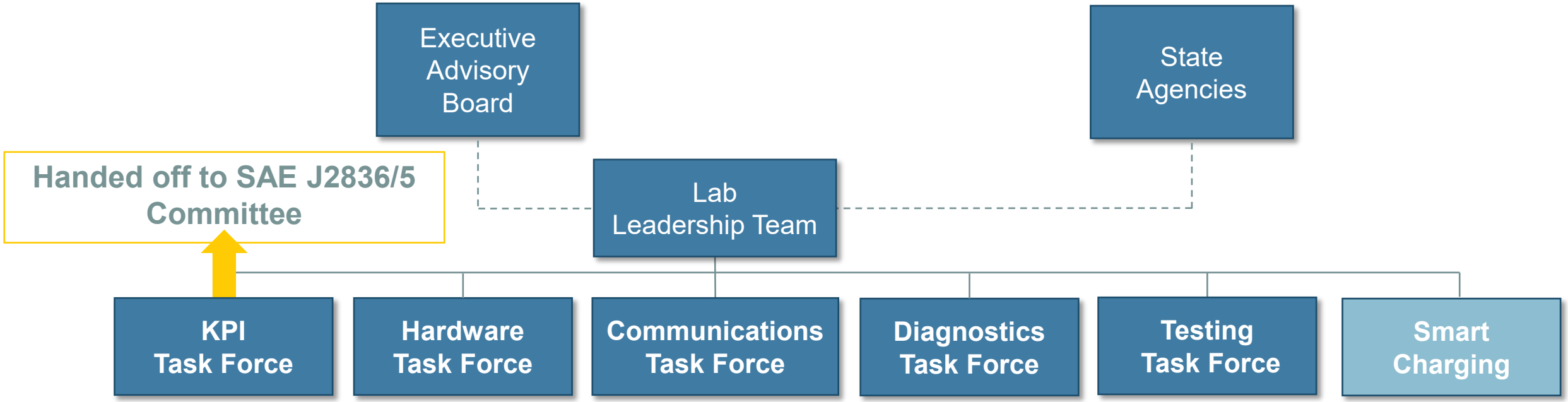
Improve:

- Diagnostics
- Interoperability testing methods

Outcomes

- Labs produce recommended practices, prototype tools
- Industry adopts practices and tools, improves standards

Structured Industry Engagement



Payment & UI Task Force - Discontinued Sept 30, 2024

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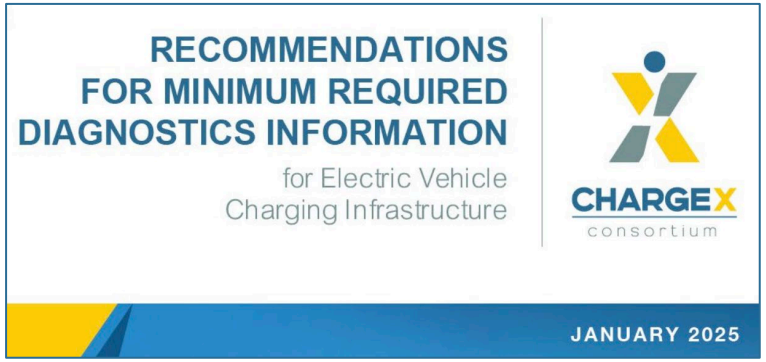
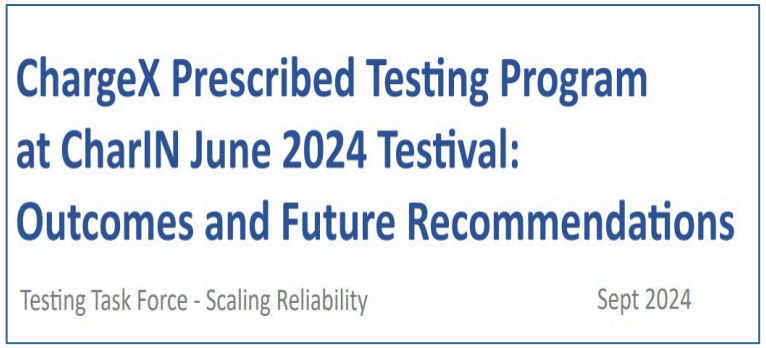
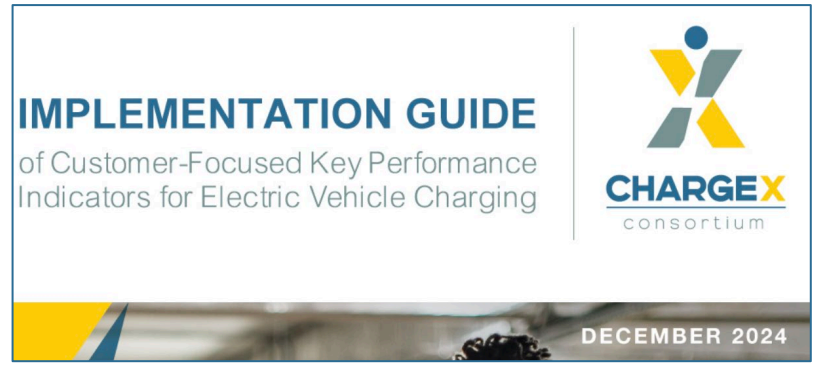
Publications Tied to OCPP

All reports available at: https://inl.gov/chargex/







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Ensuring Managed Charging is Reliable

New VGI projects:

- Communications TF
  - Ensure reliable AC communication while charging via pilot wake
- Outside of ChargeX Task Forces

  VGI 1. Map V1G state machine and **sequence diagrams** for L2 managed charging

  VGI 2. **Define performance metrics** for public L2 managed charging

  VGI 3. **Analyze the reliability** of managed and scheduled charging use cases

  VGI 4. **Benchmark pilot wake** capabilities of current U.S. EV makes/models

VGI 1 – Sequence Diagrams

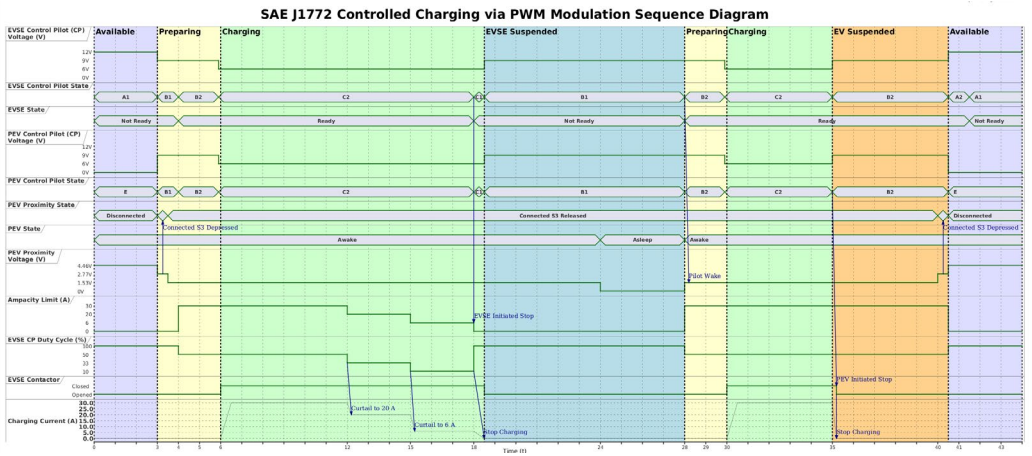
Goal: Develop state-machine and sequence diagrams for EV, EVSE, CSMS, and Electric Utilities spanning LIN-CP, ISO 15118, OCPP and grid protocols.

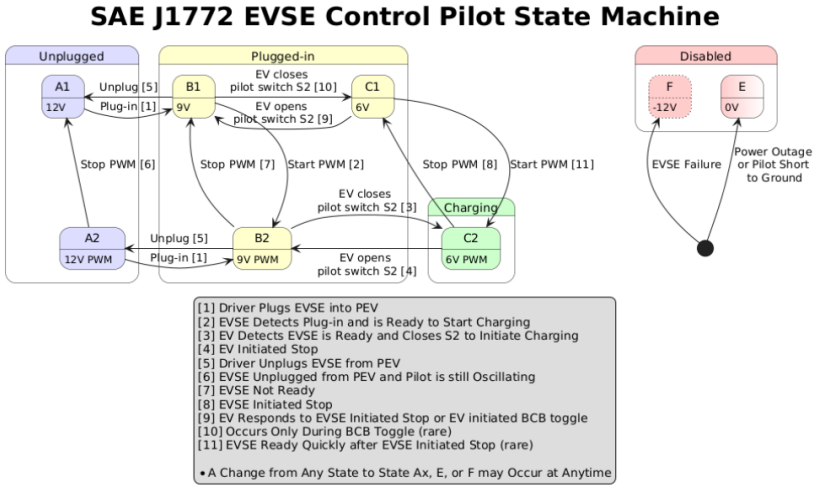
Progress:

- Controlled charging (PWM control, no HLC)
  - PWM control sequence draft is complete – ready for review
  - EVSE Pilot State Machine draft is complete – ready for review
- Scheduled Charging (ISO15118 enabled EV and EVSE)
  - Draft sequence diagram in process.

Next Steps:

- Complete scheduled-charging sequence diagram
- Manage industry feedback – execute consensus revisions





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VGI 2– Performance Metrics

Goal: Establish key performance indicators (KPIs) for AC Level 2 managed charging that measure its performance and effectiveness from the perspective of different stakeholders

Progress:

- ChargeX will focus on performance metrics at the hardware level to complement aggregate-level performance metrics being developed by a multi-year research effort called EVs@Scale
- Began outreach to industry to identify groups starting to implement VGI leveraging EVSE control (e.g., utility, EV driver, CSO, EV OEM, aggregator)

Next Steps:

- Publish report by June 2025 that defines the performance metrics and provides insights into data requirements for calculating the metrics

VGI 3 – Reliability Analysis

Goal: Leverage previously studied objective functions to understand reliability considerations for two specific managed charging use cases.

Progress:

- Identified objective functions developed as part of EVs@Scale and corresponding inputs and outputs for each strategy
- Chose the objective functions relevant to this analysis (highlighted in the top table)

Next Steps:

•Identify a "current" communication architecture for each objective function which reflects the current implementation capabilities.

•Identify a "future" communication architecture for each objective function which reflects a more capable / ideal implementation of the managed charging strategy.

•Perform Process Failure Mode and Effect analysis of the "current" and "future" implementation using sequence diagrams created as part of VGI Task 1.

•Perform gap analysis to identify the major obstacles for future implementations.

Strategy Name	Objective Function: EV Charging…
Distribution Transformer	scheduled to reduce coincident charge/overloads, this includes first come first served and equal split, and their variations
Day-ahead Pricing	scheduled to minimize costs per PJM LMP (Locational marginal price)
TOU (Time-Of-Use) Random	randomly distributed within dwell during lowest TOU
Random Start	randomly distributed within dwell
Feeder Peak Avoidance	distributed within dwell to limit feeder peak
Demand Response	curtailed based on non-transportation loads
TOU Immediate	begins immediately at start of TOU within dwell
Volt/VAR	provides reactive power support
Volt/Watt	power adjusted to support local voltage quality
BTM Depot DER	schedule to avoid transformer upgrade with PV/ESS
Renewables/Emissions	scheduled to coincide w/ renewables/low-emissions

Legend	
	Will be considered as part of this analysis
	Not part of this analysis

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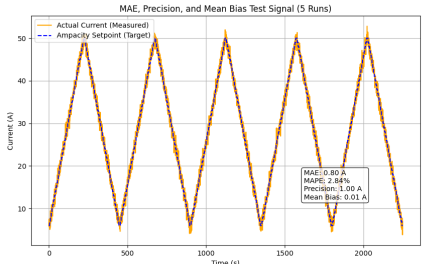
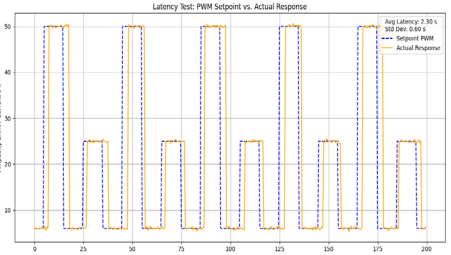
VGI 4 – EV Benchmarking

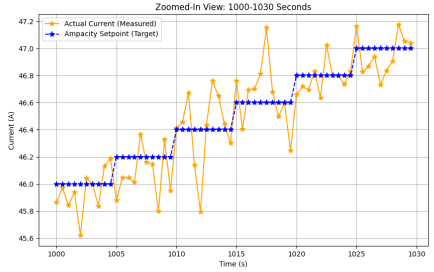
Goal: Benchmark 80% of US available PEV makes to understand charge control capabilities via SAE J1772 PWM modulation

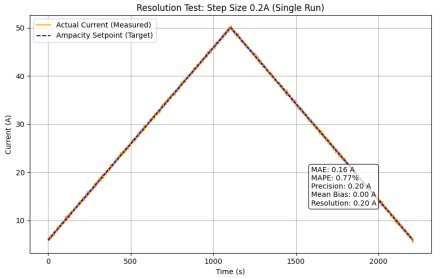
Progress:

- Draft charge control benchmarking test plan is developed.
  - Charge control accuracy and precision, latency, and resolution.
  - PWM-based charge control response: PJM RegD response score.
  - EV Pilot Wake response – timeout tests.



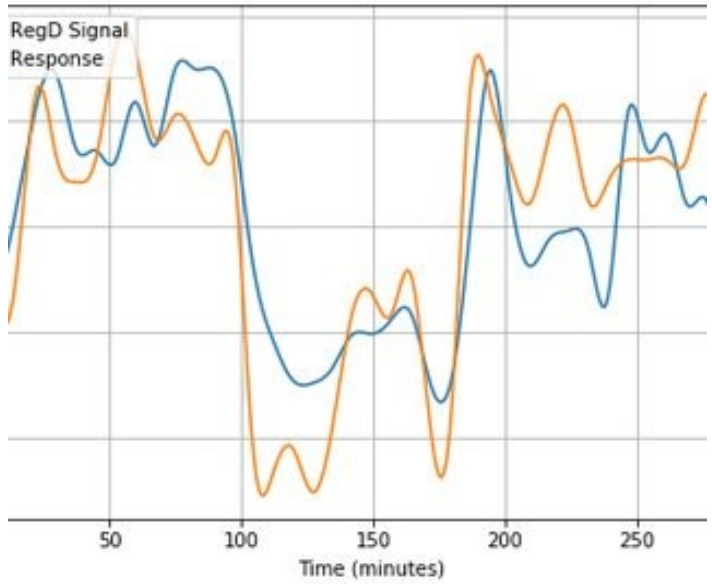






Next Steps:

- Validate test plan with R&D EV assets.
- Execute scheduling and benchmarking
- Deliver internal test results and industry summary



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VGI Communications Task Force - Pilot Wake

Goals: Accelerate smart charge management (SCM) based on open standards by:

- Ensuring reliable AC communications while charging via pilot wake
- Demonstrating scheduled AC charging via ISO 15118 – should we consider adding OCPP?

Progress:

- Searching for demonstration partners
  - Several EV OEMs who have implemented AC 15118-2 have not fully implemented the optional charge management features

Next Steps:

- Bring topic into the Communications Taskforce meetings to gather input and discussion
- Identify one EV and one EVSE partner for demonstration
- Engage with industry to determine barriers for scheduled charging implementation

OCPP plays a key role in effective public L2 managed charging.

Here are some use cases that we would like your technical input on.

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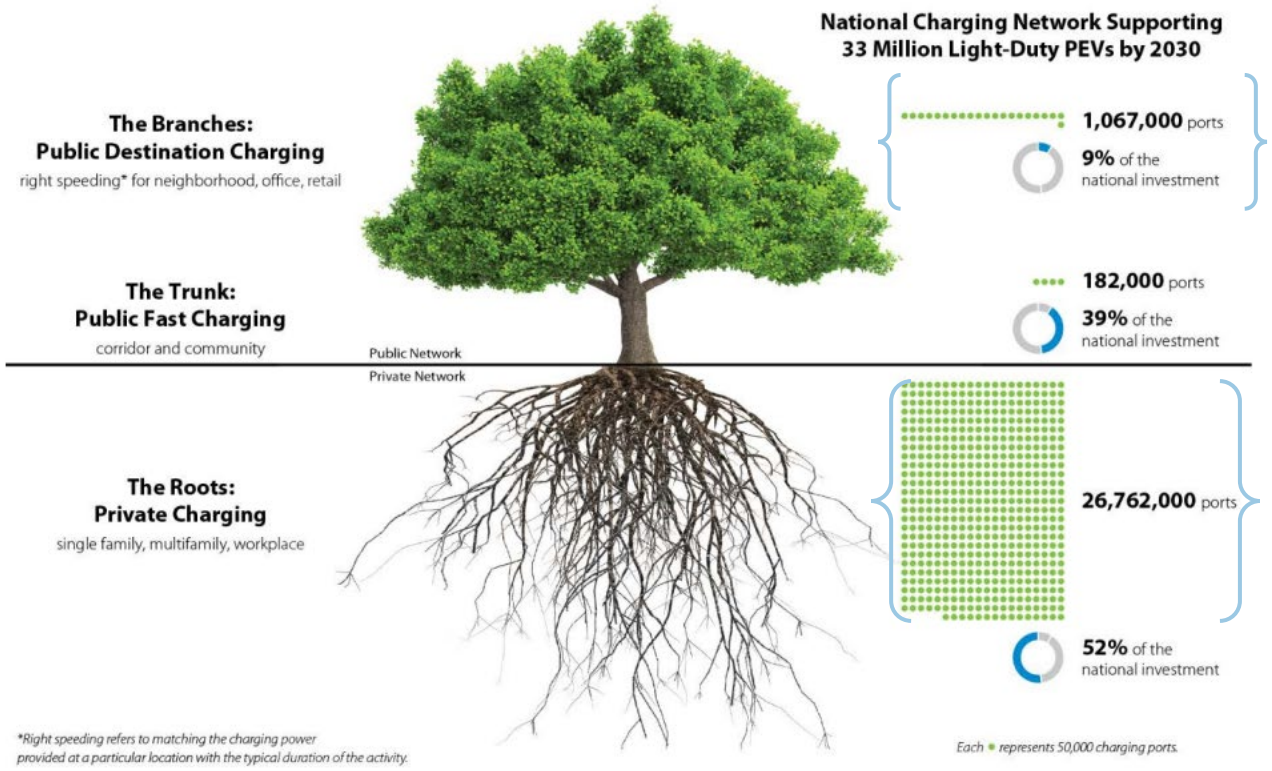
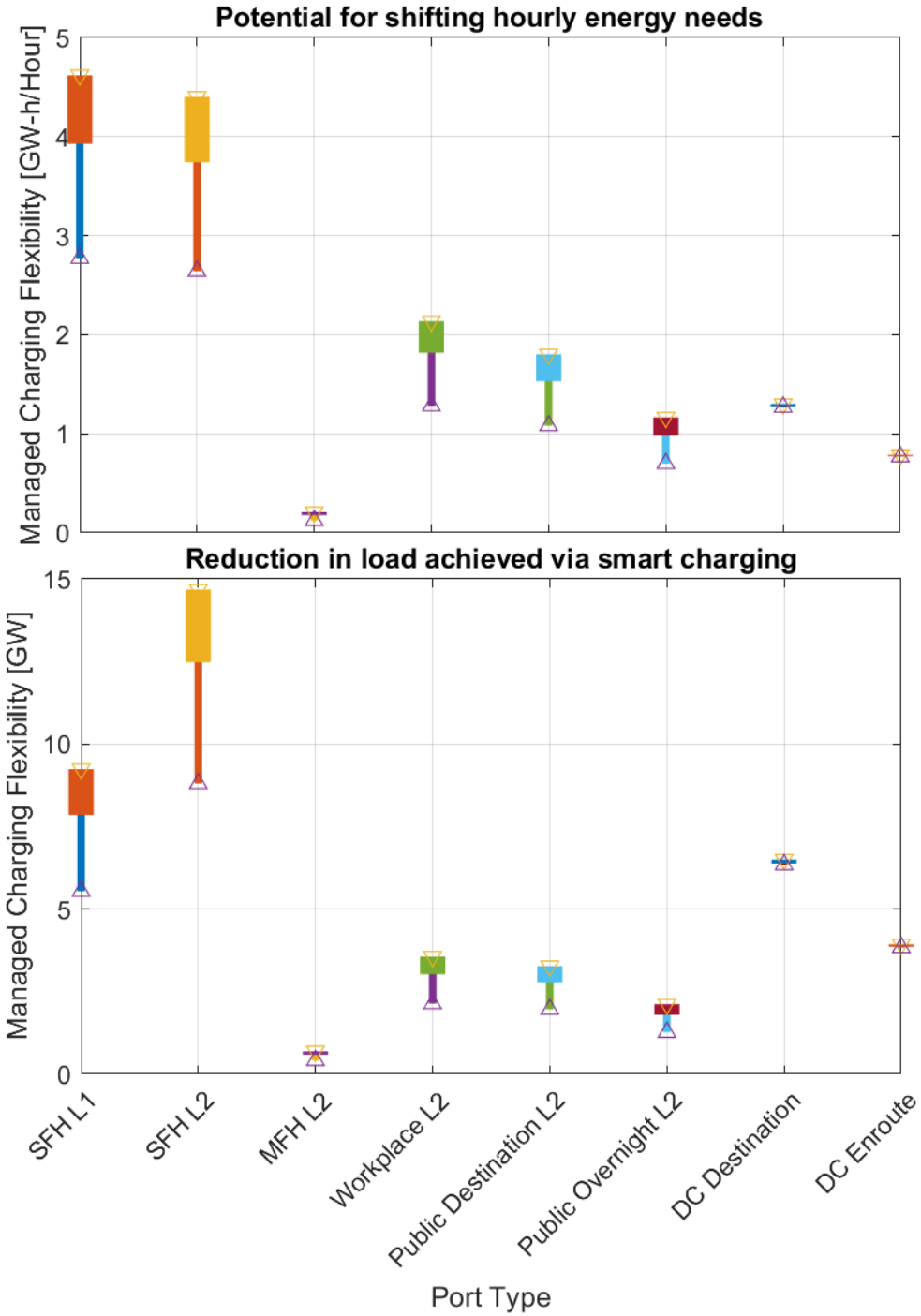
L2 charging flexibility is valuable



The 2030 National Charging Network: Estimating US Light-Duty Demand for Electric Vehicle Charging Infrastructure. No. NREL/TP-5400-85654.



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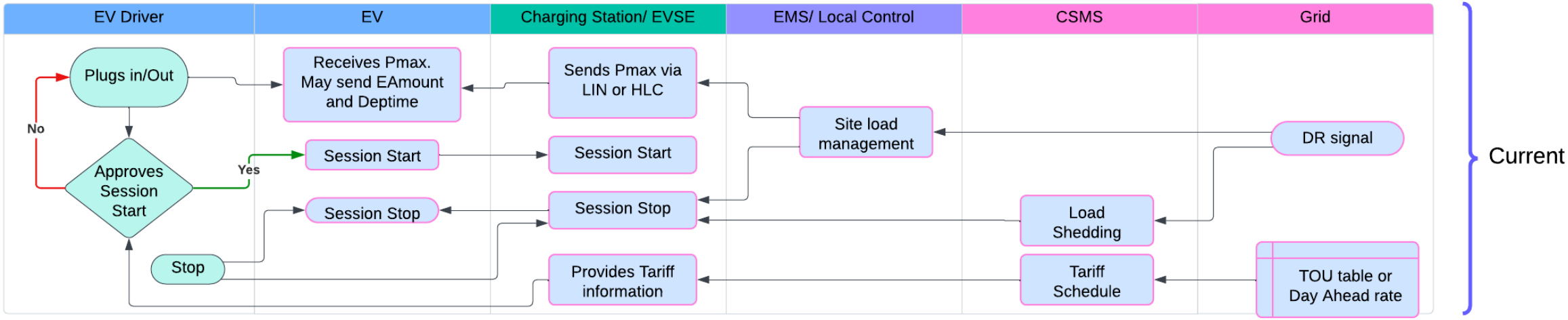
Current practice

Minimal driver engagement – site load management handles DR

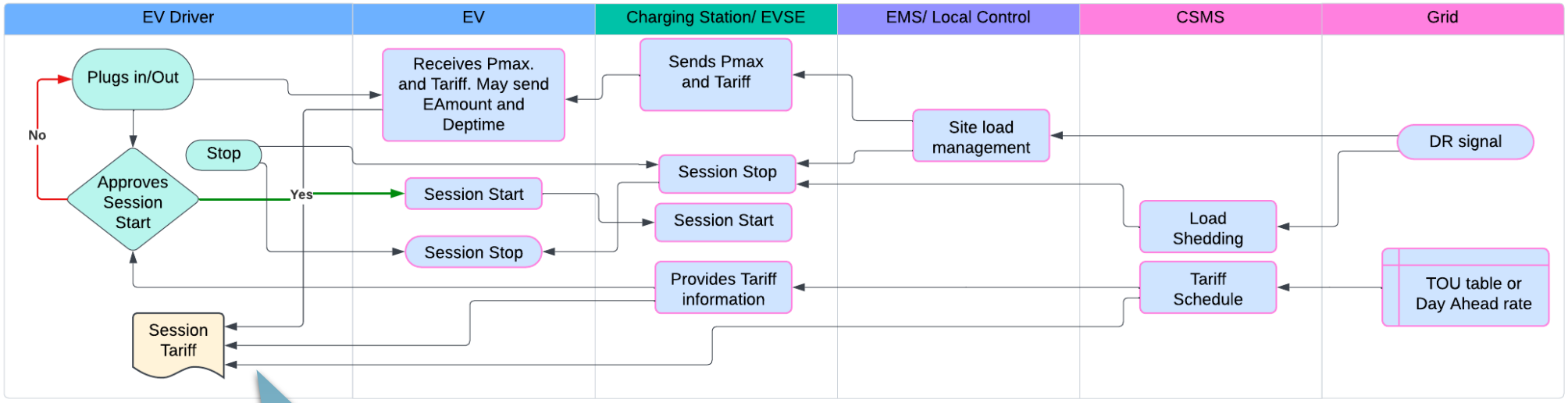


Currently, managed charging schemes used in large L2 charging stations have minimal driver engagement and limit the level of control the driver has on the charging profile.

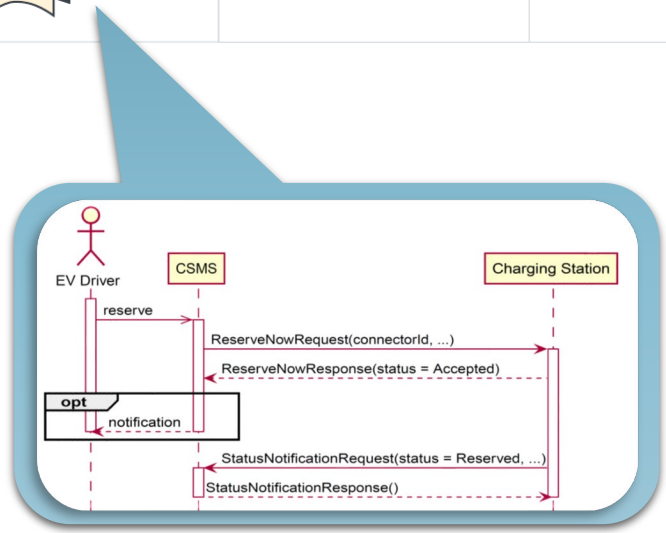
We think there are ways to achieve managed charging goals while improving the experience for the driver.

Improving price transparency

Transmit day-ahead LMP to driver (charging load shaped by market elasticity)



Day ahead prices, mostly static TOU tables



1) How is the Time of Use price communicated to the driver – can this be done before they arrive at a port?
2) Can tariff information be added to the reservation exchange?

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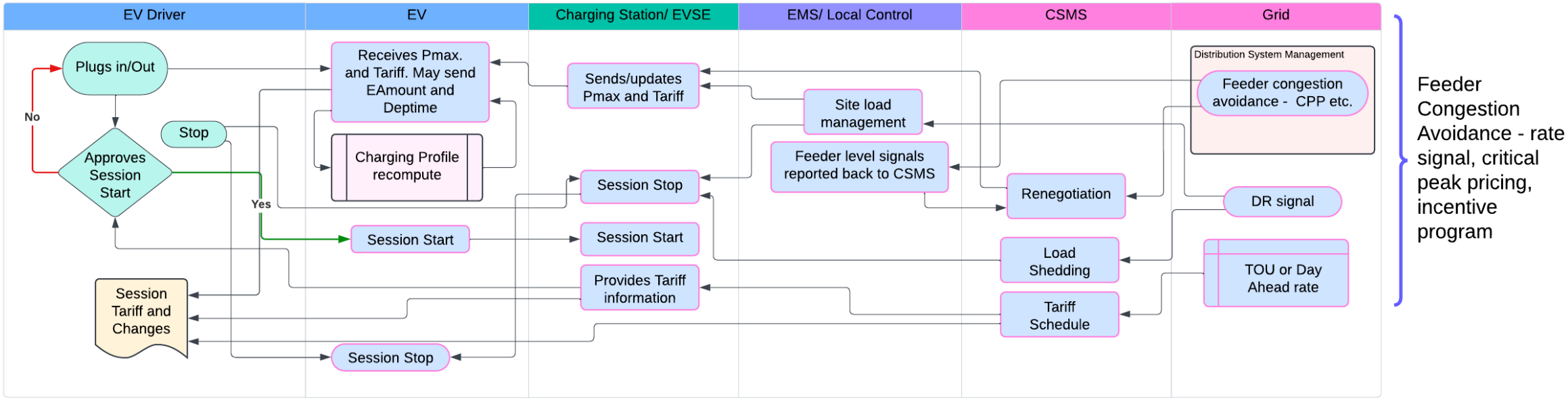
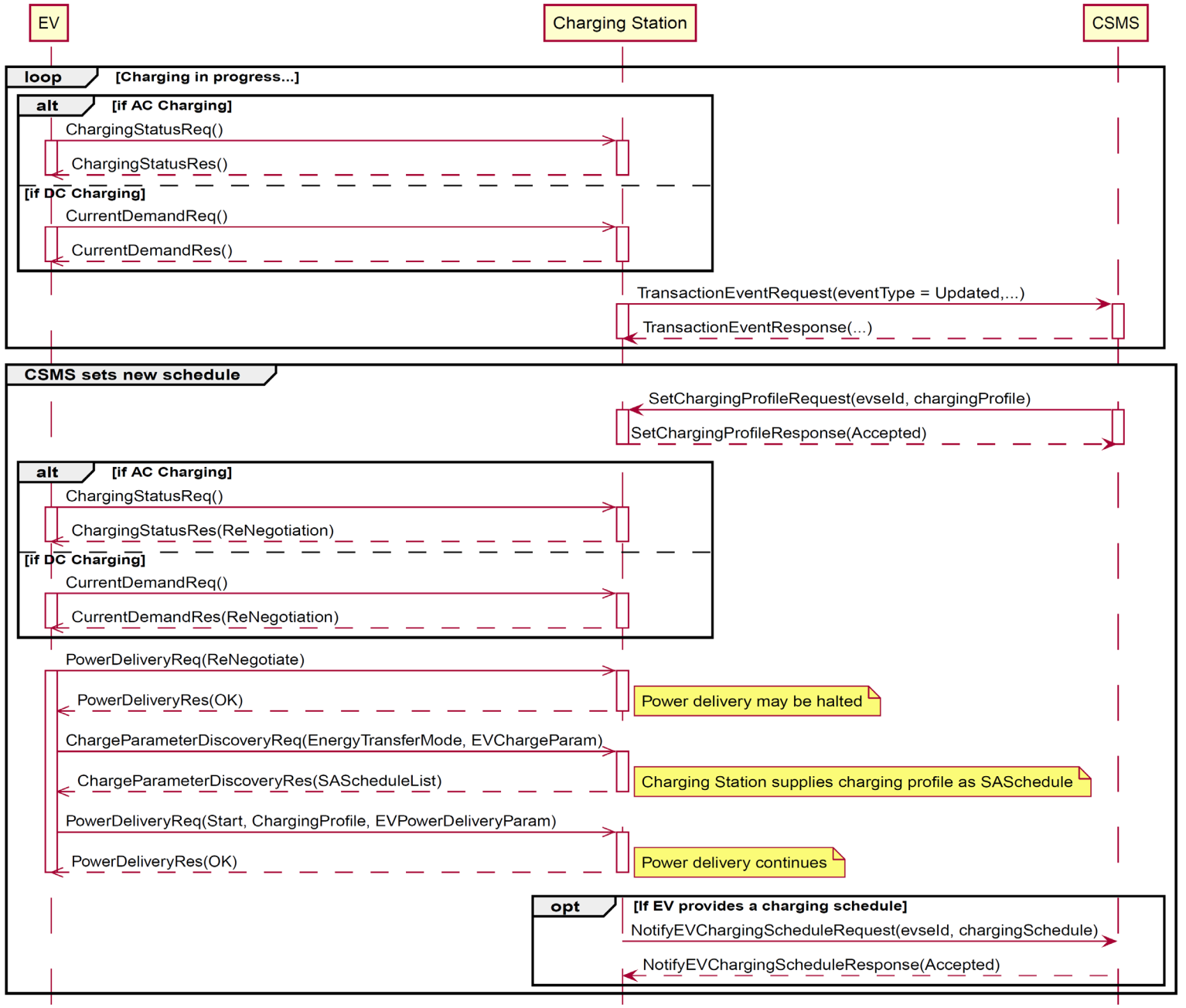
Real time price – midsession rescheduling

Feeder congestion avoidance through TOU tariffs (tariffs update at plug in and may change during session, user chooses to deferral/pause/slow/stop etc.)



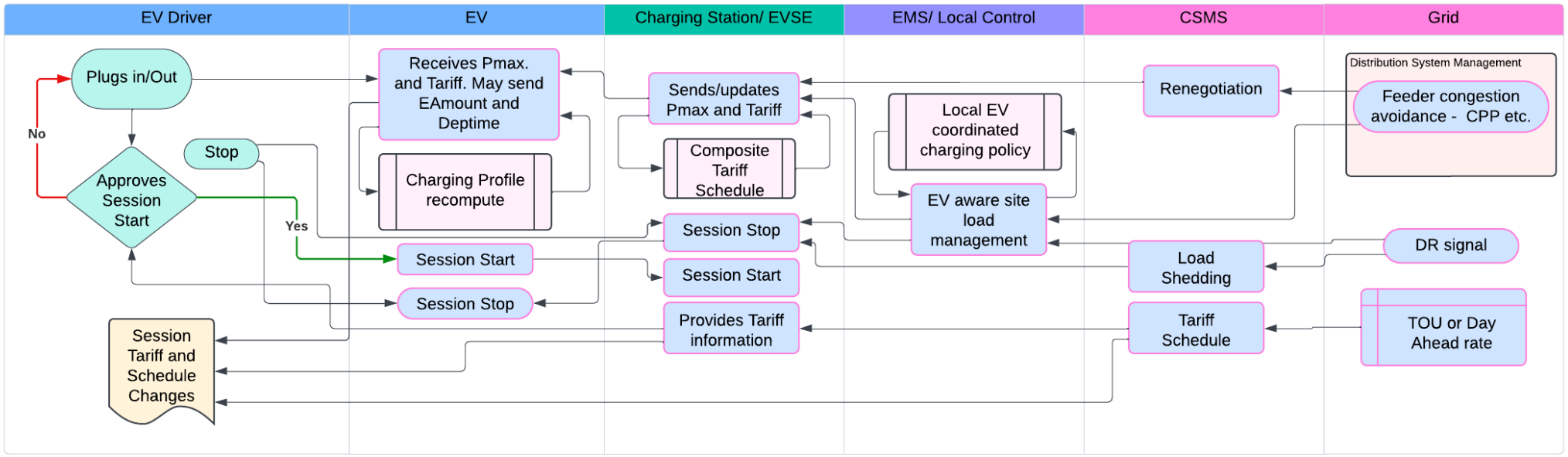
Once the vehicle is charging and there is a feeder congestion event that generates a new tariff structure.
How should the driver be notified? CSMS initiated renegotiation?
Is case K15 in the 2.0.1 sufficient?

K15


EV
Charging Station
CSMS
loop
[Charging in progress...]
alt
[if AC Charging]
ChargingStatusReq()
ChargingStatusRes()
[if DC Charging]
CurrentDemandReq()
CurrentDemandRes()
TransactionEventRequest(eventType = Updated,...)
TransactionEventResponse(...)
CSMS sets new schedule
SetChargingProfileRequest(evseId, chargingProfile)
SetChargingProfileResponse(Accepted)
alt
[if AC Charging]
ChargingStatusReq()
ChargingStatusRes(ReNegotiation)
[if DC Charging]
CurrentDemandReq()
CurrentDemandRes(ReNegotiation)
PowerDeliveryReq(ReNegotiate)
PowerDeliveryRes(OK)
Power delivery may be halted
ChargeParameterDiscoveryReq(EnergyTransferMode, EVChargeParam)
ChargeParameterDiscoveryRes(SAScheduleList)
Charging Station supplies charging profile as SASchedule
PowerDeliveryReq(Start, ChargingProfile, EVPowerDeliveryParam)
PowerDeliveryRes(OK)
Power delivery continues
opt
[If EV provides a charging schedule]
NotifyEVChargingScheduleRequest(evseId, chargingSchedule)
NotifyEVChargingScheduleResponse(Accepted)

Site control – hierarchy and integrity

User authorizes EV and CSMS to coordinate schedules as needed to keep session cost stable or predictable.
CSMS updates charging rates for customers in response to TOU tariffs using its business logic (random, first come first served, EV specific policies)



Site level control of schedule. Includes EV specific policies such as TOU random, first come first serve, etc.

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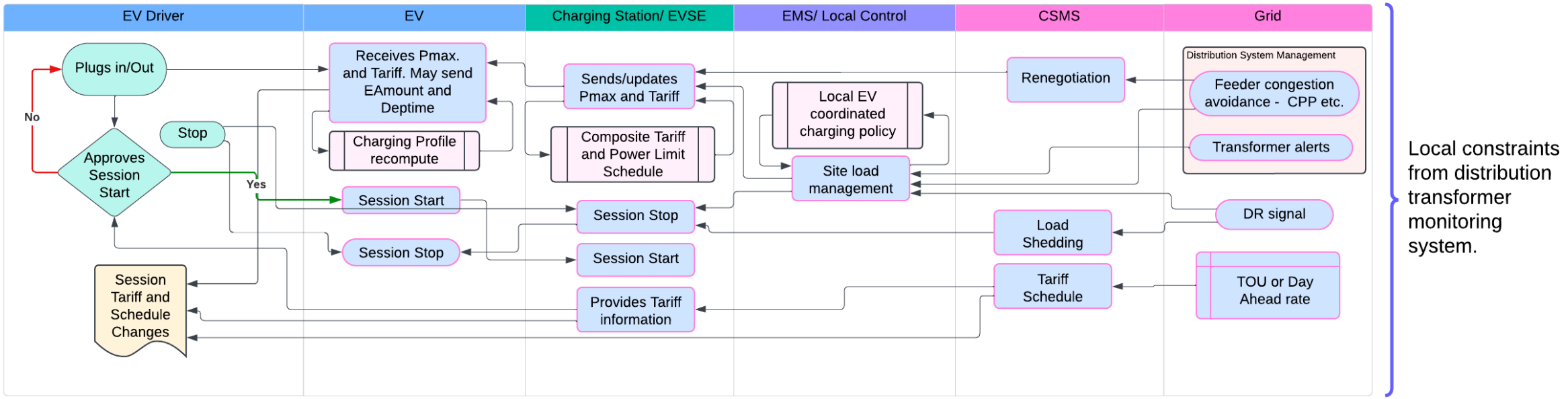
Peak load and transformer load mitigation

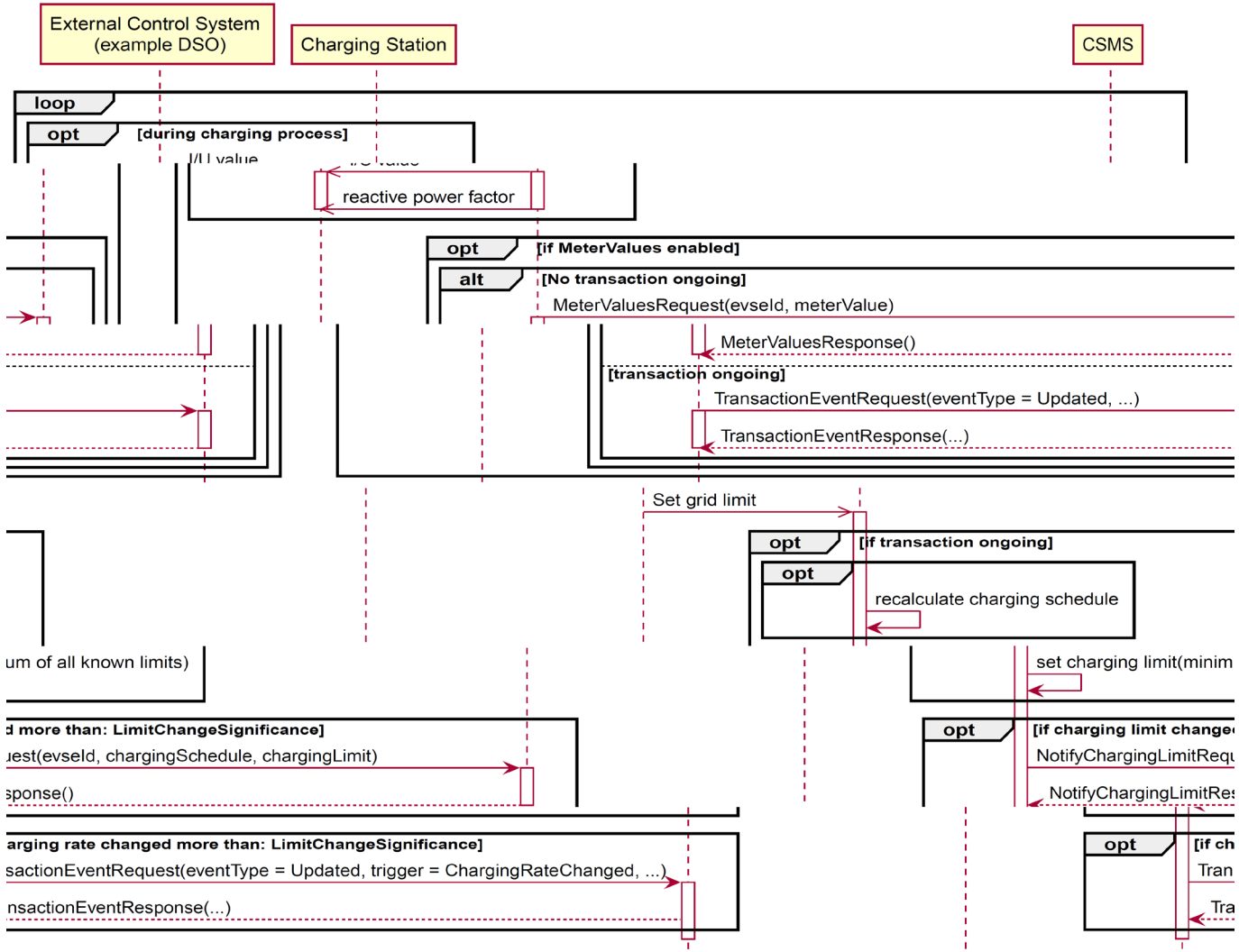
Maximum charging rate set for each EV to meet distribution transformer constraint (transformer constraints are first communicated to site host EMS and the EMS needs pathways to communicate to the CSMS, EV and EV driver)



How best to handle a transformer constraint at a site?

Start by having a model of the transformer load and providing a model-based estimate of charging power limit at the start of charging session so the driver has knowledge, then if the constraint requires further reduction of load, then use Case K11 from OCPP spec to make a change to the charging rate. How is the driver notified in this case?

K11



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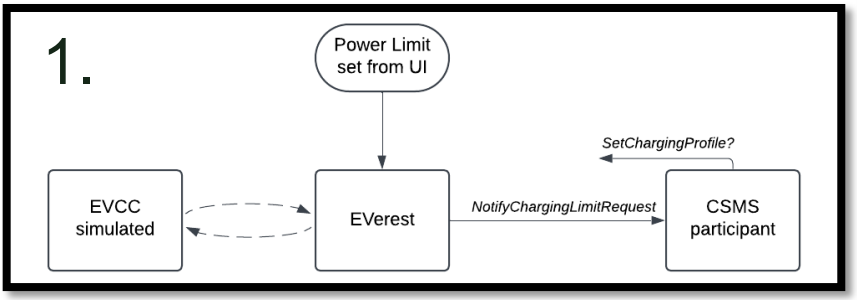
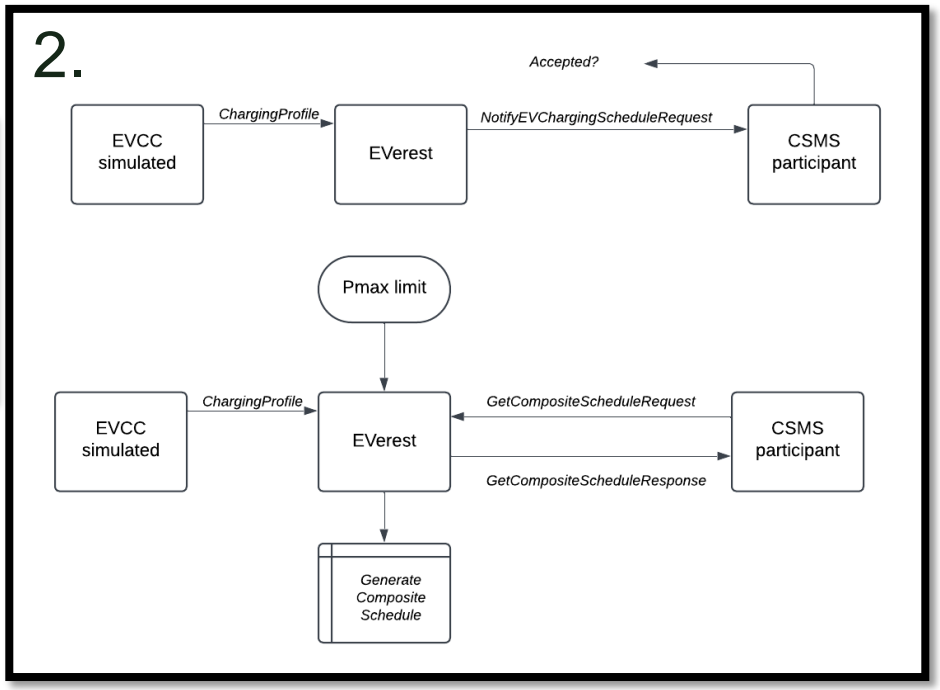
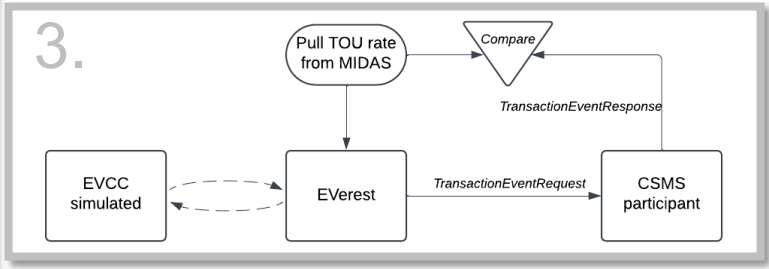
EVerest Test cases

1. External power limit - *NotifyChargingLimitRequest*
2. Transparency of charging rate -*NotifyEVChargingScheduleRequest* *GetCompositeScheduleRequest*
3. Tariff update - *TransactionEventRequest*







Thank you

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Project Updates

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Defining the Charging Experience

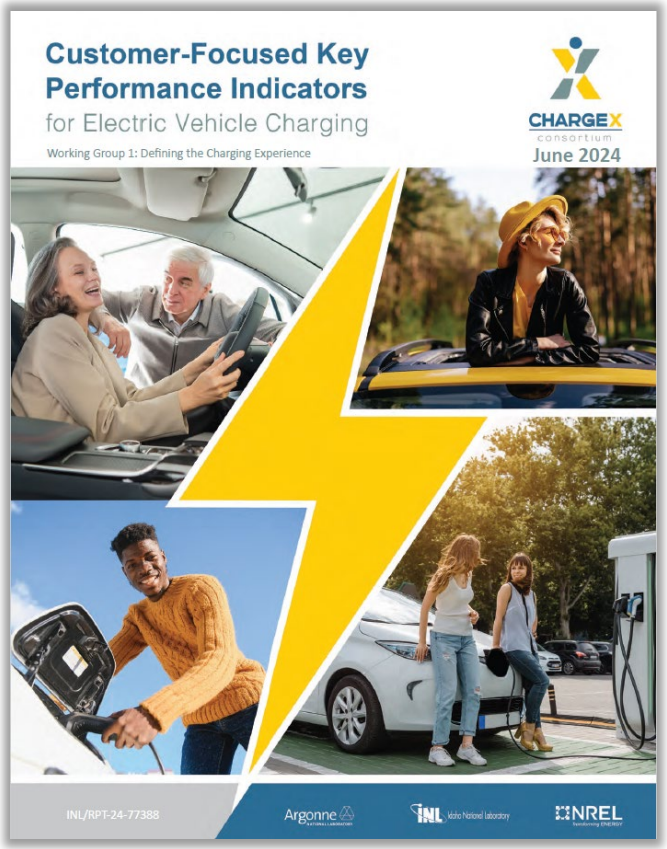
Goal: Establish customer-focused key performance indicators (KPIs) to provide industry with standard methods to measure the customer charging experience

Progress:

- Handed off to SAE. Reopened J2836/5 to add KPI definitions
- Collaborated with major CSO to pilot and validate KPI implementation guide
- Published KPI Implementation Guide

Next steps:

- Finalize KPI implementation code and publish to public-facing Github site (target Q1 CY25)



Improving Payment System Reliability

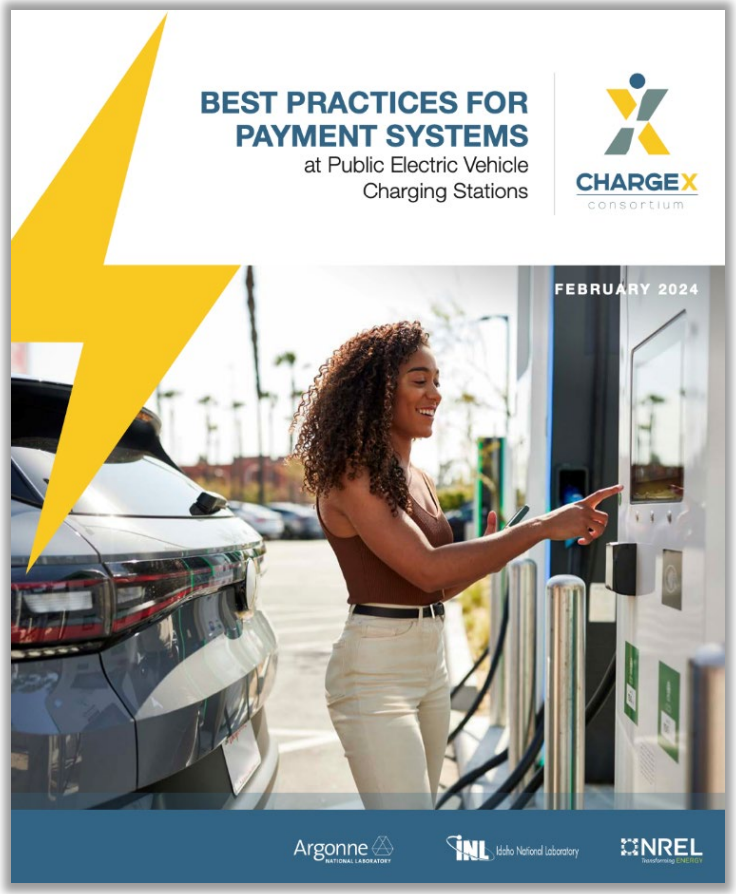
Goal: document problems and recommend solutions for wide range of payment system issues seen in the field

Progress:

- Published a best-practices report documenting problems and recommending solutions for wide range of payment system issues seen in the field

Next Steps:

- Project complete



Increasing Charge Start Success with Seamless Retry

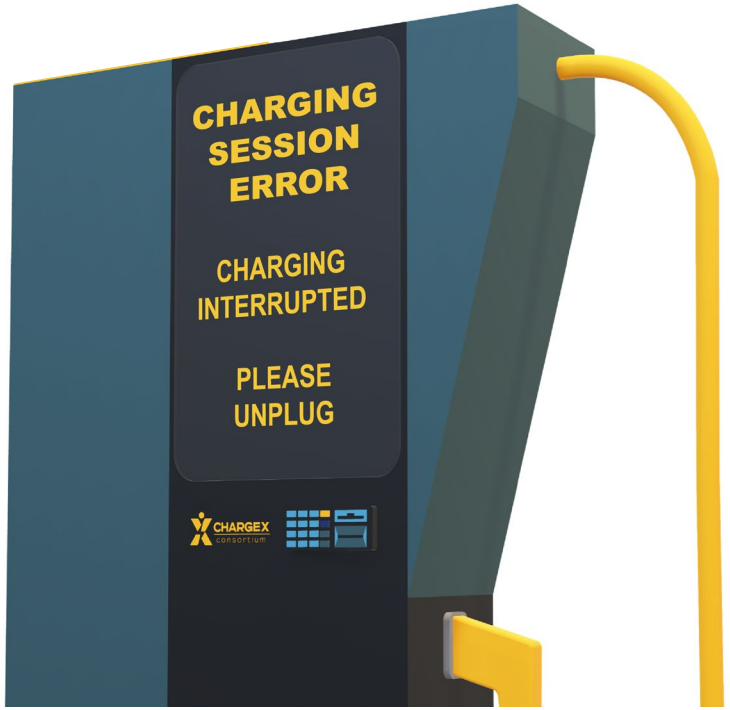
Goal: institute process to automatically retry session initialization after failure to prevent customer from needing to unplug and replug if issues arise during session startup

Progress:

- Published Seamless Retry Best Practices Report

Next Steps:

- Develop Seamless Retry 2.0 (target Q2 CY25)
  - Improve error handling and recovery of EV/EVSE communications and fallback mechanisms
  - Start by gathering input and developing best practices with the industry task force



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Streamlining Timeouts

Goal: identify timeout issues in EV-EVSE communications and document industry best practices

Progress:

- Identified root causes of timeout issues in EV-EVSE communication and drafted recommended-practice report
- Main timeout issues only persist with legacy equipment
  - Still relevant for ongoing development but not pushing to SDOs
- Smaller portion relevant to push to SDOs

Next Steps:

- Publish recommended-practice report (target Q1 CY25)

Improving EV/EVSE Information Exchange

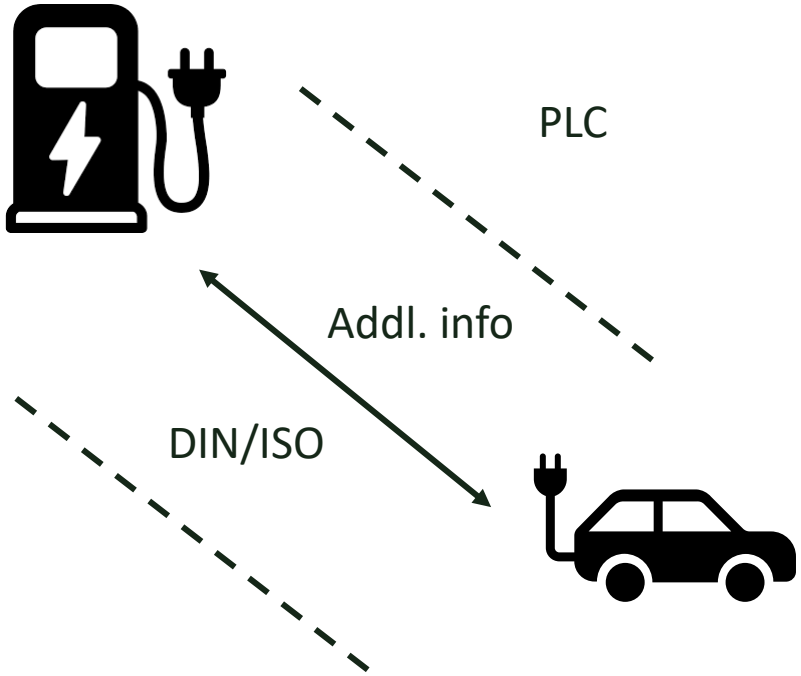
Goal: support the creation and adoption of ISO 15118-202 to enable flexible exchange of additional signals between EV/EVSE

Progress:

- Identified scope for implementation: co-identification, adapter detection, ongoing current/power limits, error codes
- Successfully demonstrated initial national-lab implementation of ISO 15118-202 in EVerest framework at Nov 2024 CharIN Testival

Next Steps:

- Finalize implementation in EVerest and share lessons learned formally with ISO 15118-202 working group (target Q1 CY25)
- Partner with industry for testing and demonstration



ISO 15118-202 standard defines extended SECC discovery protocol (eSDP) and event notification protocol (ENP) for additional information exchange, such as power delivery

Quantifying and Reducing Time to Start Charge Sessions

Goal: Quantify current performance and identify methods to reduce charge session start time

Progress:

- Identified several sources of communications log files to analyze to quantify session start time

Next Steps:

- Collect industry feedback on time to charge and possible improvements (target Q1 CY25)

Ensuring Adapters are Reliable and Safe

Goal: ensure performance standards (J3400/1), conformance standards (UL 2252), and industry practices catch all major failure modes

Progress:

- Adapter FMEA results provided to UL2252 and J3400/1; participating in the consensus process
- Developed reference inlet; tested thermal performance of inlets, connectors and adapters

Next steps:

- Compile, share results of thermal testing (target Q1 CY25)
- Conduct pin-cap and side-load testing ((target Q2 CY25)
- Develop evaluation approach for DC arc detection/mitigation
- Continue SAE and UL engagement on safety and reliability

Thermal evaluation of J3400 connector and reference inlet

Minimum Required Error Codes

Goal: Institute common set of error codes and supporting diagnostic information across industry to accelerate problem resolution

Progress:

- Published charger-focused Minimum Required Error Codes (MRECs) and implementation instructions on developer-friendly website (inl.gov/chargex/mrec)
- EVgo demonstrated subset of MRECs at CharIN North America Testival in Nov 2023 and MRECs were a part of the prescribed testing at the Nov 2024 Testival
- Supported MREC implementation in EVerest for OCPP 1.6J and 2.0.1

Next Steps:

- Develop MRECs for OCPI 2.2.1 and 3.0, focusing on VGI applications
- Standardize MRECs in SAE J2953/3 (target Q2 CY25)

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Diagnostic Information Sharing

Goal: Develop, verify, and publish Minimum Required Diagnostic Information (MRDI) for diagnosing the root cause of faults communicated by MRECs

Progress:

- Minimum Required Diagnostic Information (MRDI) parameters finalized with the Diagnostic Taskforce
- Published MRDI report

Next Steps:

- Recruit auto OEM and CSO partners to demonstrate diagnostic information sharing
- Integrate MRDI with eSDP (extended SECC discovery protocol) and ENP (event notification protocol) in ISO 15118-202 (target Q2 CY25)

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Interoperability Test Cases

Goal: Develop comprehensive set of interoperability test cases to accelerate EV and charger product development

Progress:

- Completed report on current testing practice
- Completed EV-EVSE Interoperability Test Plan (EEITP) ver1
- Executed Prescribed Testing Program (PTP) at June 2024 CharIN Testival, published outcomes report
- Executed PTP at November 2024 CharIN Testival

Next Steps:

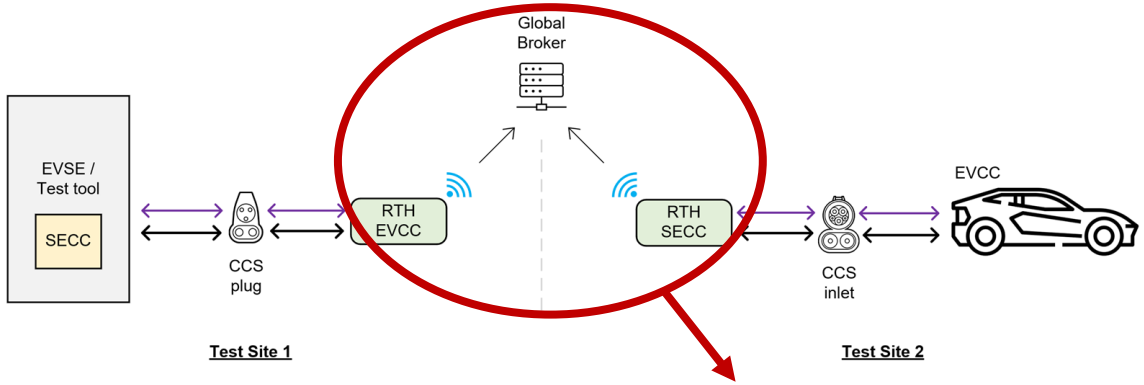
- Publish Nov 2024 CharIN Testival PTP outcomes report
- Hand off PTP administration to industry for incorporation into future industry testing event (target Q1 CY25)
- Develop EEITP ver2, hand off to industry (target Q2 CY25)

Creating Remote Test Harness (RTH)

Goal: Develop first-of-a-kind testing system to conduct remote interoperability testing with EVs and EVSE at separate locations

Progress:

- Completed system design specification and feasibility testing
- Finished test plan
- RTH-to-RTH Proof of Concept built and functional
- Completed proof-of-concept live/video demonstration



Next Steps:

- Build RTH using commercial-off-the-shelf controller
- Complete RTH minimum viable product and technology transfer for industry implementation (target Q3 CY25)

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