# *Medium- and Heavy-Duty Zero-Emission Vehicle Standardization Assessment: Battery Electric Charging*

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# Introduction

- UCI is conducting a two-year CARB contract to assess:
  - Status of standards for
    - Charging Battery Electric MHD Vehicles
    - Fueling Hydrogen Fuel Cell Electric MHD Vehicles
- Overall Goal
  - Assure standards are evolving to proactively enable the zero-emission MHDV market
  - Identify any government actions that may facilitate an orderly and timely evolution
- Project Began 1 May 2021
- Consultatory Group Meetings
  - Two a Year
  - This is meeting #1
  - Summarize UCI findings to date, obtain input and guidance

# Contract

- **California Air Resources Board**
- **Start Date:  1 May 2021**
- **Duration:  2 years**
- **Goal:**

  **Assess role of policy mechanisms to guide medium and heavy-duty battery electric vehicle charging and fuel cell electric vehicle hydrogen fueling standards to:**

  - **Streamline medium and heavy-duty transformation**
  - **Reduce market uncertainty and complexity**
  - **Protect State investments, and**
  - **Accelerate deployment**

# Meeting Agenda

- Meeting Goals
- Project Overview
- MHDV Battery Electric Charging Infrastructure Standards
  - Existing Standards and Deployment
  - Standards in Development
  - Current Demonstrations and Commercial Deployments
- State Roles
  - Current State Initiatives
  - Examples of Potential State Actions
  - Short Term Approach to Standardization
- Next Steps
- Comments and Discussion

# Meeting Goals

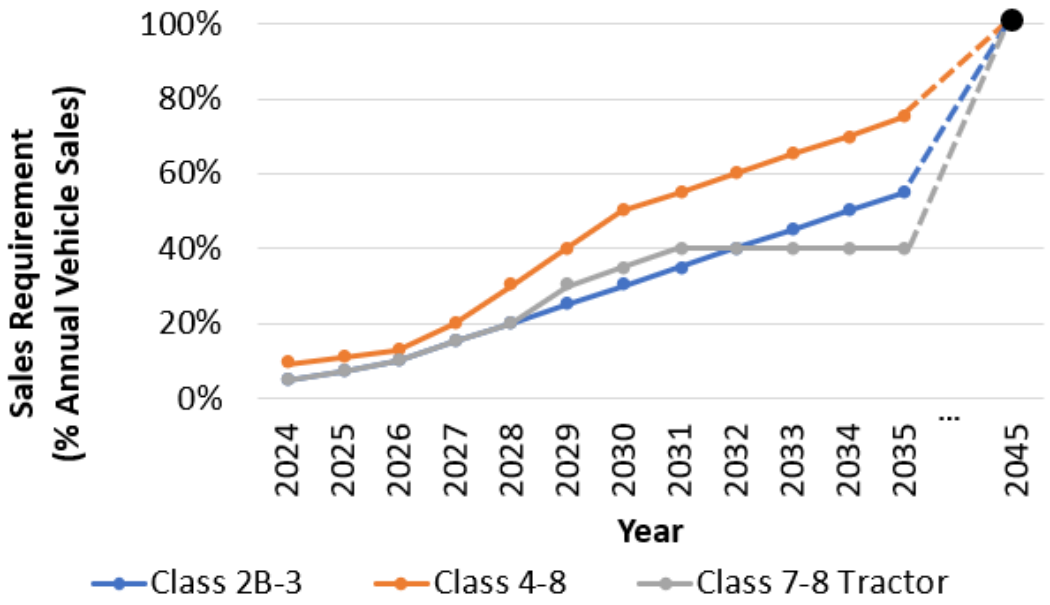
- **Present initial findings on:**
  - **The status for standardizing charging MHD battery electric vehicles ~~and fueling hydrogen fuel cell electric vehicles~~**
  - **Early insights into market-driven consensus**
  - **Active initiatives in the development of standards**
  - **State actions (if any) that might be useful to facilitate the process**

- **Solicit feedback on the UCI assessment**

# Project Overview

# Motivation and Background

- **California emissions reduction goals for the medium- and heavy-duty vehicle (MHDV) sectors:**
  - Innovative Clean Transit regulation mandates 100 percent zero-emission public bus fleets by 2040
  - Advanced Clean Trucks regulation mandates increasing sales of zero-emission MHDVs thru 2035
  - Executive Order (E.O.) N-79-20 directs that all MHDV be zero-emission by 2045, where feasible




**Successful adoption requires a rapid roll-out of reliable and interoperable charging infrastructure**

# Motivation and Background

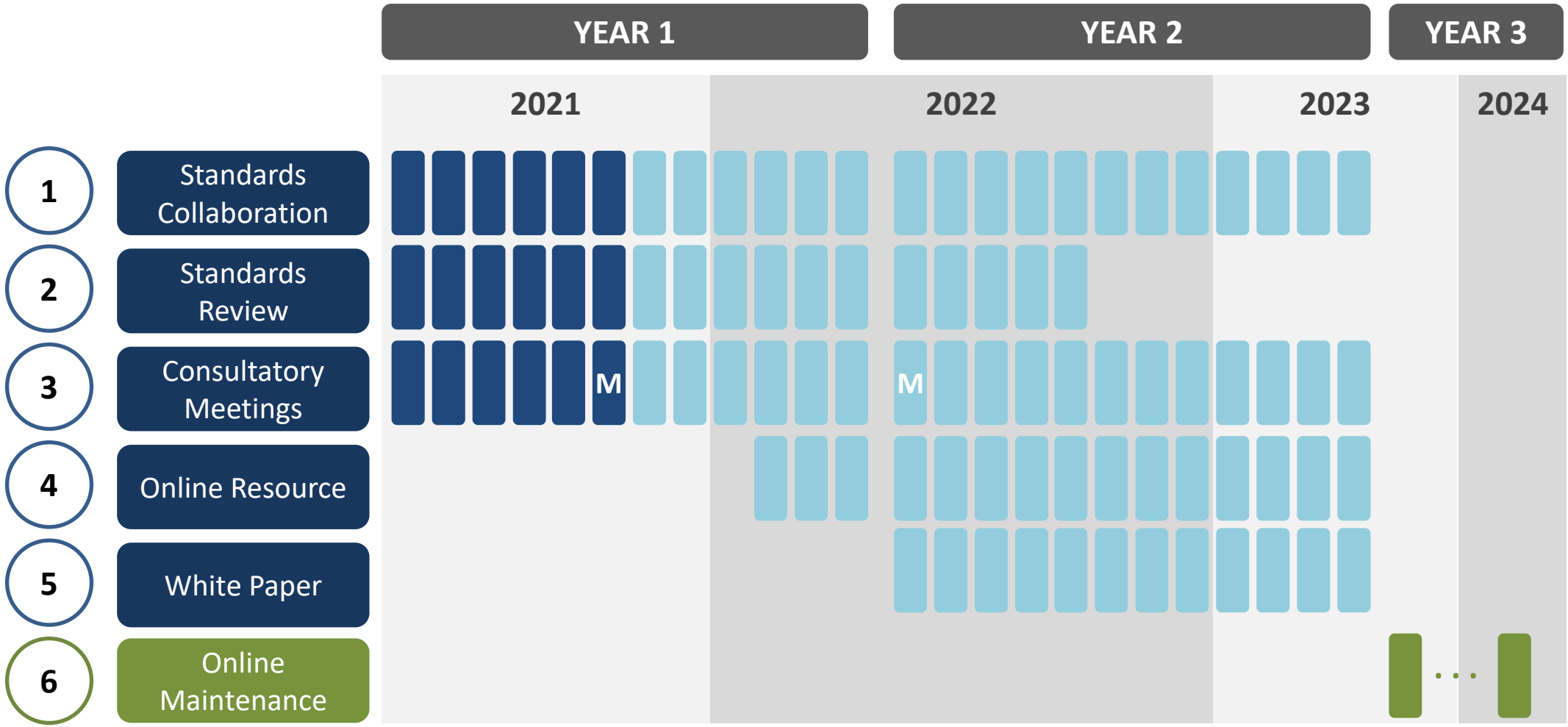
- **2021 Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment**
  - An additional 157,000 chargers are needed to support 180,000 MHDs anticipated for 2030
  - **"Prioritize standardized charger connectors and, for networked charging, prioritize hardware capable of standardized communications protocols"**
    - Lack of standardization reduces consumer confidence and ease of use
    - Risks stranded assets as market evolves

# Project Objectives

| | |
|---|---|
| Standards Organizations Collaboration | Collaborate with and utilize standards organizations to monitor developments, track activity, and inform the analyses conducted in other tasks. |
| Standards Review | Assess the status of standardization and associated activities within the context of State goals. |
| Consultatory Group Meetings | Convene a program consultatory group to create a public forum for key stakeholders to facilitate relationships and discussion on MH-ZEV standardization |
| Online Informational Resource | Publish an informational resource online for standardization processes, for government and stakeholders to understand the role and status of standardization |
| White Paper | Provide a White Paper on standardization status, outlook, and priorities, as well as policy recommendations |

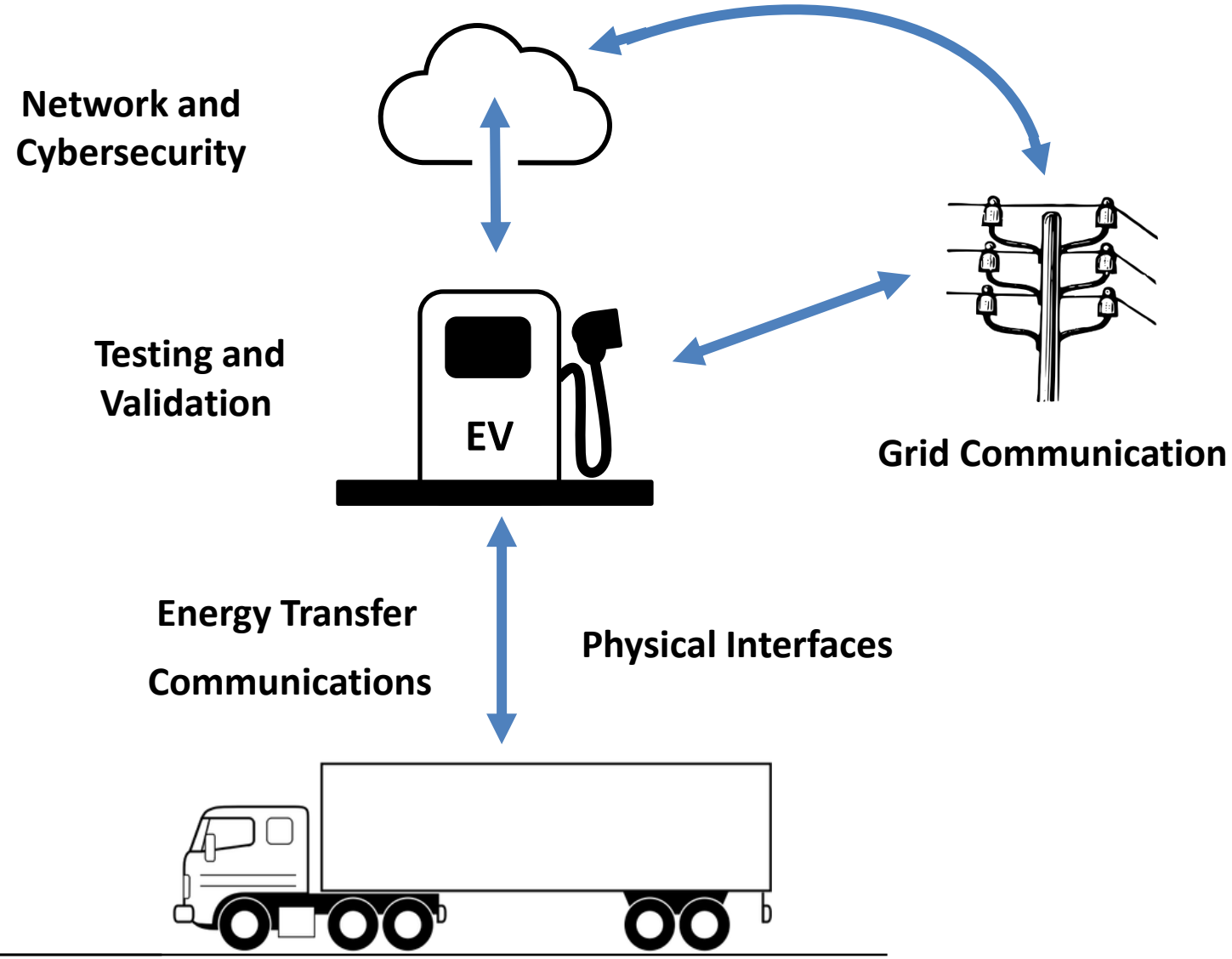
# Schedule

**2 Years + 1 Year online maintenance:  1 May 2021 to 30 April 2024**



# Battery Electric MHDV Charging Infrastructure Standards

# Standards within Project Scope



# Medium- and Heavy-Duty Charging Connectors

## Diverse Global EVSE Connector Market

| Connector | CHAdeMO | GB/T | Mennekes (IEC 62196) | NA Mennekes (J3068) | J1772 | CCS1 | CCS2 | Tesla | In Development: MCS | In Development: ChaoJi |
|---|---|---|---|---|---|---|---|---|---|---|
| AC/DC | DC | AC/DC | AC | AC | AC | AC/DC | AC/DC | DC | DC | DC |
| Power | 6 – 400 kW | 14 kW, 187.5 kW | Up to 33- 43 kW | Up to 133-166 kW | Up to 19.2 kW | Up to 350-500 kW | Up to 350-500 kW | 250 kW, 350 kW Planned | Up to 3.75 MW | 50-900 kW |
| Voltage | 1000V | 250/440VAC, 750VDC | 400/480V 3/1ϕ | 480/600V | 120V 1ϕ, 208-240V 3ϕ | IP: 920V Planned: 1000V | IP: 920V Planned: 1000V | 1000V | 1250 V | 1500 V |
| Max Current | 400A | 16/32A AC (Rated: 63A), 250A DC | IP: 70/63A 1/3ϕ Rated: 300 A | IP: 160A 3ϕ Rated: 300A | 80A | IP: 380 A Rated: 500A | IP: 380 A Rated: 500A | 250A | 3,000 A | 600 A |
| V2X | * | | | * | | | | | * | * |
| Markets | Japan | China | Europe | North America | North America, Japan | North America | Europe | North America | North America, Europe | China and Japan |

# Overview of Charging Protocols in U.S. Market

| | | Light-Duty | Buses | Class 3-5 Trucks | Class 6-7 Trucks | Class 8 Trucks |
|---|---|---|---|---|---|---|
| PRESENT | AC – J1772 | ✓ | | ✓ | ✓ | |
| | AC – J3068 | | ✓ | ✓ | ✓ | ✓ |
| | AC/DC – Tesla | ✓ | | | | * |
| | AC/DC – CCS 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | DC – CHAdeMO | ✓ | ✓ | | | |
| | DC – J3105 | | ✓ | | | |
| | DC – J2954 | R | | | | |
| FUTURE | J2954/2 | | * | * | * | * |
| | MCS | | | | * | * |

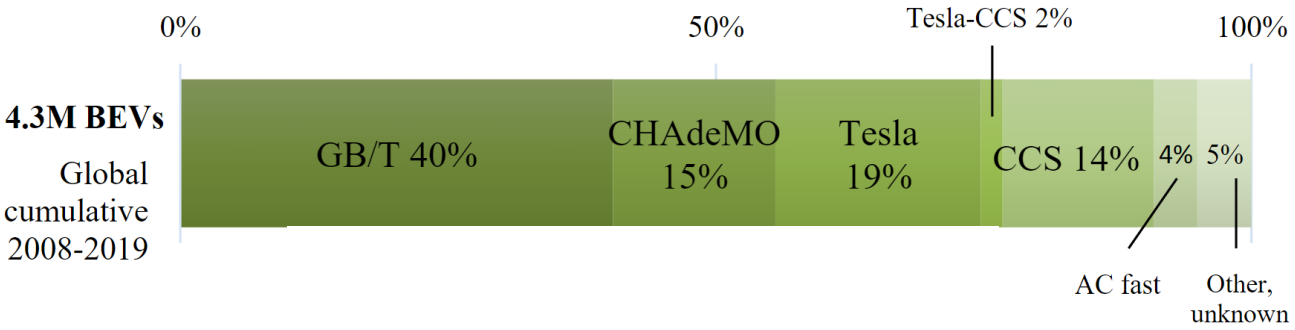
**LEGEND**

- ✓ Available
- ✓ Phasing Out
- R Recently Released
- * In development/ proposed

# Current EVSE Market

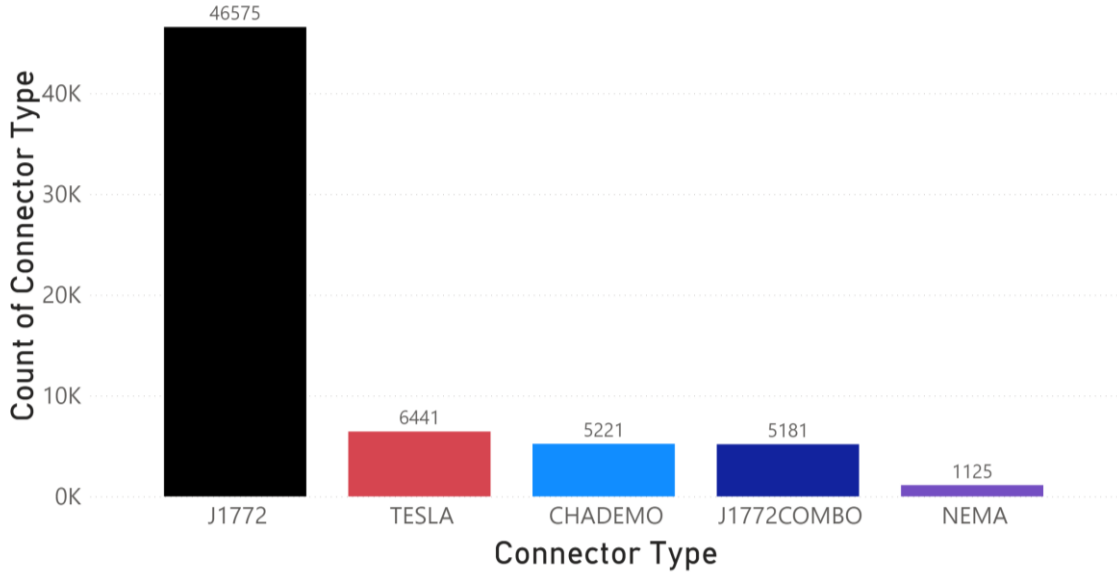
- **EVSE connector types driven by light-duty market**
- **Within the U.S., LDV DC market is a mixture of CCS, CHAdeMO, and Tesla**

**Global Market Share of all BEV Fast Charging Inlet Technologies**




**Tomoko Blech. (2020, September 11). Project ChaoJi: the background and challenges of harmonizing DC charging standards. EVS33. https://doi.org/10.5281/zenodo.4023281**

**U.S. Market Share of EVSE Stations by Connector Type***

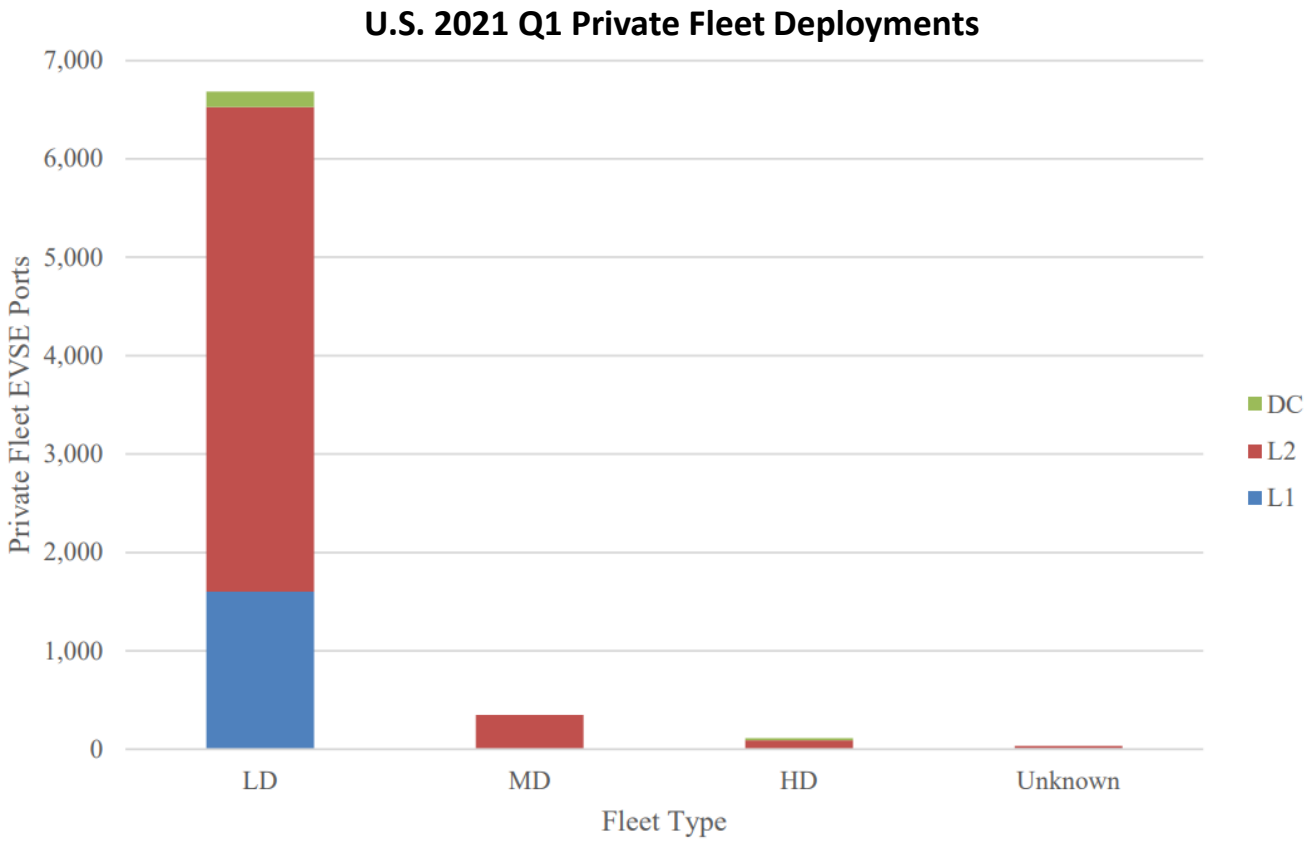



**Data Extracted from US DOE Alternative Fueling Station Locator Oct 6th, 2021**

* Some stations offer more than one connector type and are counted multiple times

# Current EVSE Market

- **Currently private fleet-based MHD deployments mostly level 2, small fraction DC**




**Brown, Schayowitz, and Klotz (2021) NREL/TP-5400-80684**

# Current Market

**As of 2020, California transit agencies have purchased 654 zero-emission buses**


**10 New Flyer Xcelsior CHARGE Buses Ordered by OCTA**

Photo: OCTA

**20 BYD Electric Buses In Use at UCI**

Photo: UCI



**Proterra Electric Buses Previously in Use by Foothill Transit**

Photo: NREL

# Current Market

**Frito Lay Operates about 270 Class 5 Smith Newton Delivery Vans**

Photo: NREL


**IKEA Operates ~50 Lightning eMotors Electric Class 4 Trucks and Workhorse C1000 Trucks**

Photo: IKEA


**SF Goodwill Operates 11 Class 6 Battery Electric Trucks**

Photo: SF Goodwill

# Current/Planned Market


Photo: Arrival

**UPS rolling out last-mile delivery vans from Arrival**

Target: 10,000 by 2024, option for 10,000 more

**Anheuser-Busch Deployed 21 BYD Class 8 Trucks**

Targets: Cut Fleet GHG Emissions 25% by 2025


Photo: BYD


Photo: CNBC

**Amazon rolling out last-mile delivery vans from Rivian**

Targets: 10,000 vans by 2022, 100,000 vans by 2030

# Current Standardization Efforts

**(1) Megawatt Charging System**

**(2) ChaoJi**

**(3) SAE**

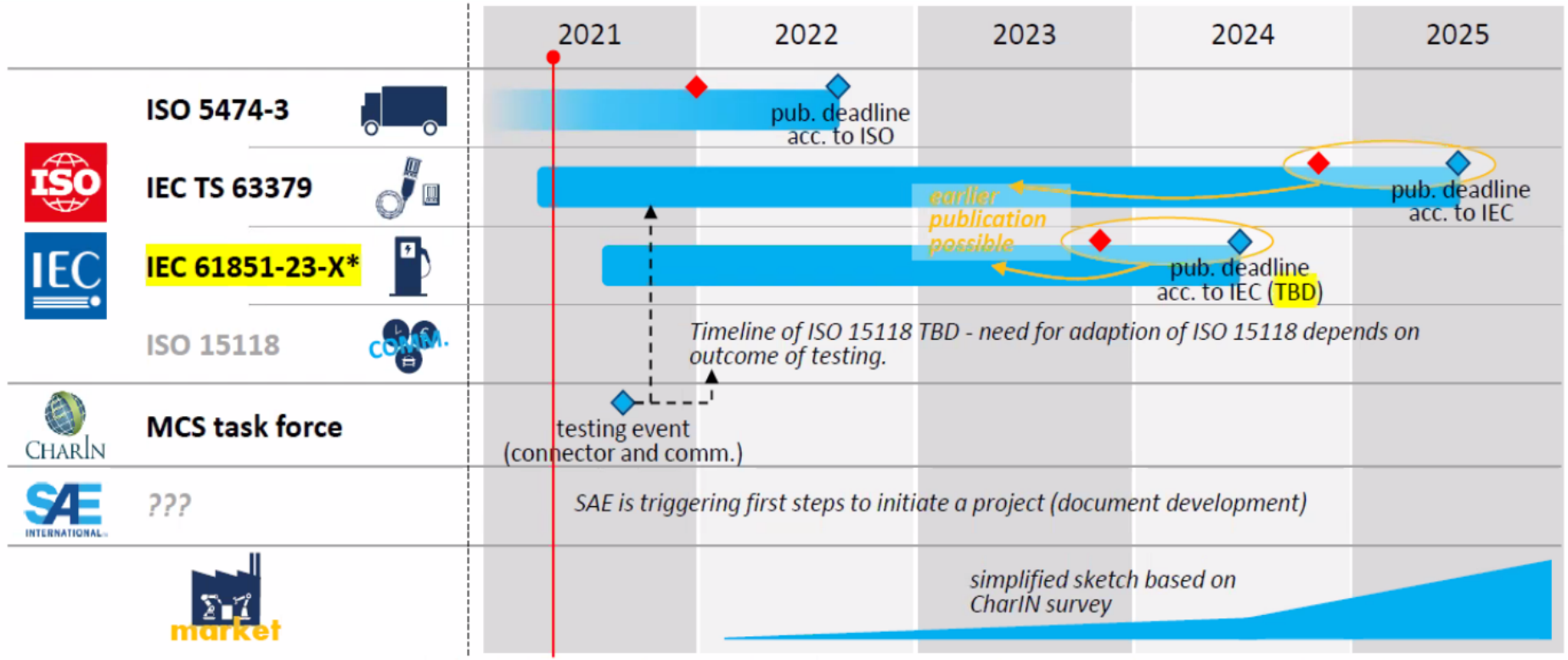
# Megawatt Charging System (MCS)

- **CharIN developing a new DCFC standard rated for up to 3.75 MW (1250VDC, 3000A)**
  - **Intended to serve the needs of various vehicle types, similar to CCS**
    - Use of current infrastructure in place for CCS to serve lower power classes for the MCS
  - **Use of PLC communications and ISO/IEC 15118**
  - **Based on CCS architecture**
- **Proposed Market**
  - **North American and European Class 6, 7, and 8 commercial vehicles**
    - Specifically, those used for long haul transport and those with rigorous duty cycles
- **Deployment Status**
  - **Demonstrations and Testing**
    - Current Testing: Air Cooled - up to 350A, Liquid Cooled - up to 3000A
    - Continuing discussion of details of the standard - iterative changes to be implemented
  - **Complete the requirements and specification document including the plug geometry by 2022**
- **Future Applications/Expected Market**
  - **Automated charging**
  - **V2X compatible**
  - **Expand market from commercial vehicles to buses, off road with ability to accept >1MW charge rate**

# Megawatt Charging System

## MCS STANDARDIZATION ROADMAP

Timeline and key milestones of international groups involved in MCS standardization.

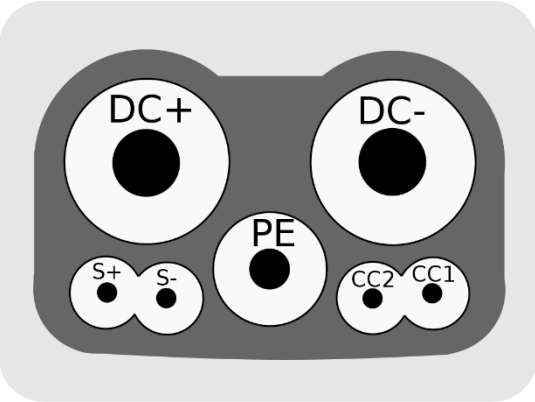



* Project and number to be confirmed, application documents are just about to be sent to IEC (from German DKE side)

◆ End of commenting phase for DIS/ CDV roughly 8 months before pubication. DIS/ CDV is the last stage that allows for technical changes.

# ChaoJi

- **CHAdeMO 3.0, Collaboration between Chinese Electric Council (CEC) and CHAdeMO (Japan) to make a harmonized standard for EV charging**
  - **Electrically compatible via adapters with GB/T 20234.3 and CHAdeMO 2.0, combo inlets compatible with Type 1, 2, CCS1, and CCS2 are also of interest**
  - **Rated Power: 350-400 kW available now, 900 kW (600A, 1.5kVDC) expected by 2021, possible expansion to 1.8 MW with additional pins**
- **Proposed Market**
  - **China and Japan**
- **Deployment Status**
  - **Proposed Timeline (Pre-COVID):**
    - Draft Protocol Finalized Q1 2020, with the final specification completed Q1 2021
  - **Demonstrations in China and Japan taking place**
- **Future Applications/Expected Market**
  - **CHAdeMO and supporting EVSE are manufactured worldwide, totaling over 25,000 different stations in 2017, similar global reach envisioned for ChaoJi**
  - **CHAdeMO sees the DCFC market converging to a single standard**




**ChaoJi Vehicle Connector Layout**
Source: White Paper of ChaoJi EV Charging Technology - State Grid Corporation of China and China Electricity Council

# MCS and ChaoJi Comparison

- **Similarities**
  - **Offers MW, or close to MW level, powered charging and a bridge to a universal standard**

- **Differences**
  - **MCS proposed use case is Class 6-8 vehicles, while ChaoJi is intended to be a universal interface for all classes of vehicles**
    - CHAdeMO has mentioned the addition of more pins to double the power output to 1.8 MW for special cases
  - **MCS proposals have suggested up to 3.75 MW**
    - ~4X that of standard ChaoJi connector

# SAE Standards Development

- **J2954/2 Wireless Power Transfer & Alignment for Heavy Duty Applications**
  - **Under development**
- **Updates to existing standards**
  - **e.g. J3105, J1939**
- **Future work**
  - **Megawatt Charging System**

# Early insights into market-driven Consensus and Gaps

- **CCS can meet the charging needs of early markets for battery electric trucks and buses**
- **Class 8 is a key market for higher charging rates (e.g. MCS)**
- **New deployments will benefit from backwards compatibility, future proofing**
- **Vehicle-to-grid use cases beyond school buses is unclear, keep technologies V2G-ready**
- **While performance is standardized, components are not**
- **Even with standardization, there's a need for interoperability testing among companies and products**

# Government Roles

# Current State Initiatives for MHD BEV and Infrastructure

- **INFRASTRUCTURE FUNDING**
  - ***(Light-Duty)*** **California Electric Vehicle Infrastructure Project (CALeVIP)** – $149 million
  - ***(Announced)*** **EnergIIZE Commercial Vehicles** – $50 million
  - **Low Carbon Fuel Standard (LCFS)**
  - **Loan Programs,** e.g. Electric Vehicle Charging Station Financing Program
- **VEHICLE FUNDING**
  - **California Comeback Plan** (Vehicles & Infrastructure) – $3.9 billion
  - **Hybrid and Zero-Emission Truck & Bus Voucher Incentive Project (HVIP)**–$25 million for FY20-21
  - **Carl Moyer Memorial Air Quality Standards Attainment Program**
  - **Volkswagen Environmental Mitigation Trust for California**
- **INTEROPERABILITY TESTING**
  - **CEC GFO-20-610** Vehicle-Grid Innovation Lab (ViGIL) – up to $2 million
  - **CEC RFP-21-601** Vehicle Interoperability Testing Symposium (VOLTS) – $900,000 to 1 million
  - Support for national laboratory testing programs
- **PLANNING**
  - **CEC GFO-20-601** Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure
  - **Heavy Electric Vehicle Infrastructure Projection tool (HEVI-LOAD)**

# Potential Short-Term (1-3 Year) State Actions

## (1) Guidance: State or Federal Guidance on Charging Protocols

- Recommended Standards/Protocols
- List of Vetted Vendors
- Best Practices

## (2) Procurement Requirements

- Required or recommended standards
- Compatibility requirements
- Technical Informational Reports
- List of vetted vendors
- Best practices

# Potential Long-Term (5-10 Year) State Actions

## (1) Procurement Requirements

- Required or recommended standards
- Compatibility requirements
- Technical Informational Reports
- List of vetted vendors
- Best practices

## (2) Rulemaking

- Standards Required for Zero-Emission Fueling Infrastructure
  - What would be an appropriate scope?
    - Connector, communications
- Timeline for rulemaking and market compliance
  - Is there a growing market consensus on standards?
  - Timeline for mature MHD technologies and standards

# Project Next Steps

- **Continue examining current standards and technologies development**
  - International efforts, Testing, Communication protocols (e.g. ISO 15118)
- **Further exploration of policy mechanisms**
  - Specificity, Timing
- **Engage key stakeholders and integrate stakeholder input**
  - Drive towards consensus

# Comments and Discussion

# Written Comments

http://www.apep.uci.edu/**MHDV**_Protocol_Comment.html

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