Medium- and Heavy-Duty Zero-Emission Vehicle Standardization Assessment: Hydrogen Fueling

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Advanced Power and Energy Program
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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 Hydrogen Fueling Standards
  - Existing Standards and Market
  - Standards in Development
  - Current Demonstrations and Commercial Deployments
- Government Roles
  - Current Government Initiatives
  - Examples of Potential State Actions
  - Short Term Approach to Standardization
- Next Steps
- Comments and Discussion

Meeting Goals

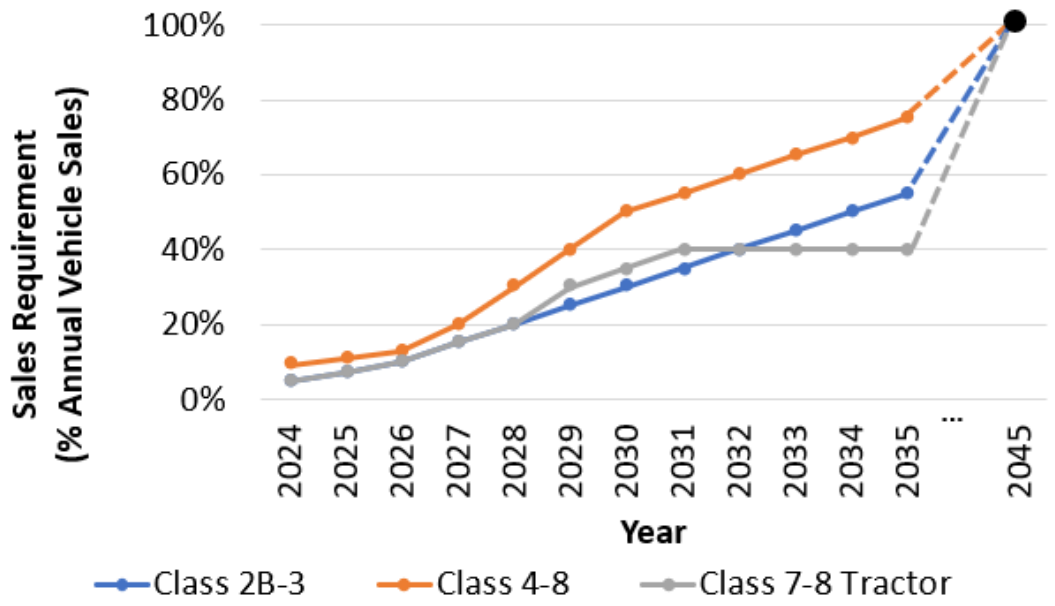
- **Present initial findings on:**
  - **The status for standardizing ~~charging MHD battery electric vehicles and~~ fueling MHD hydrogen fuel cell electric vehicles**
    Early insights into market-driven consensus
  - **Active initiatives in the development of standards**
  - **State actions (if any)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



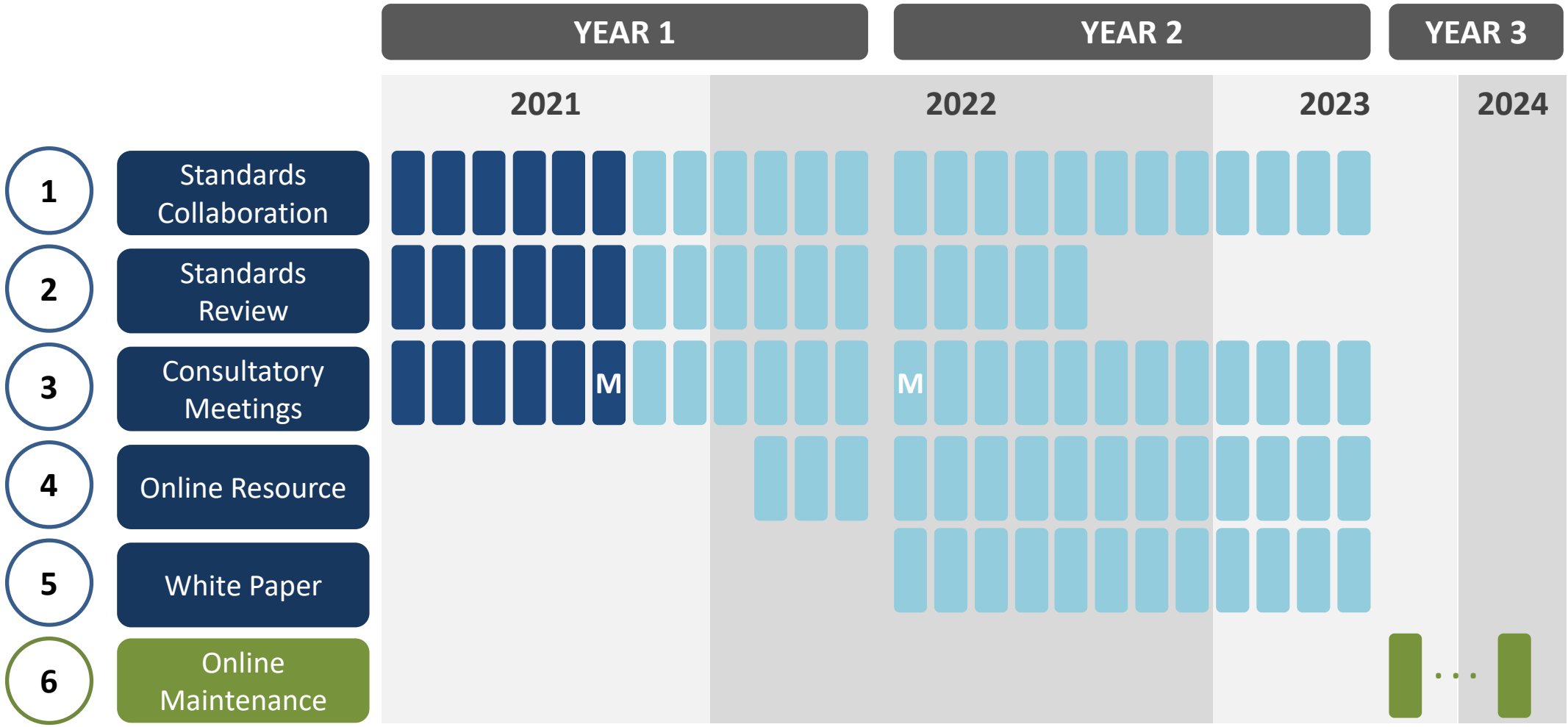
Successful adoption requires a rapid roll-out of reliable and interoperable fueling infrastructure

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

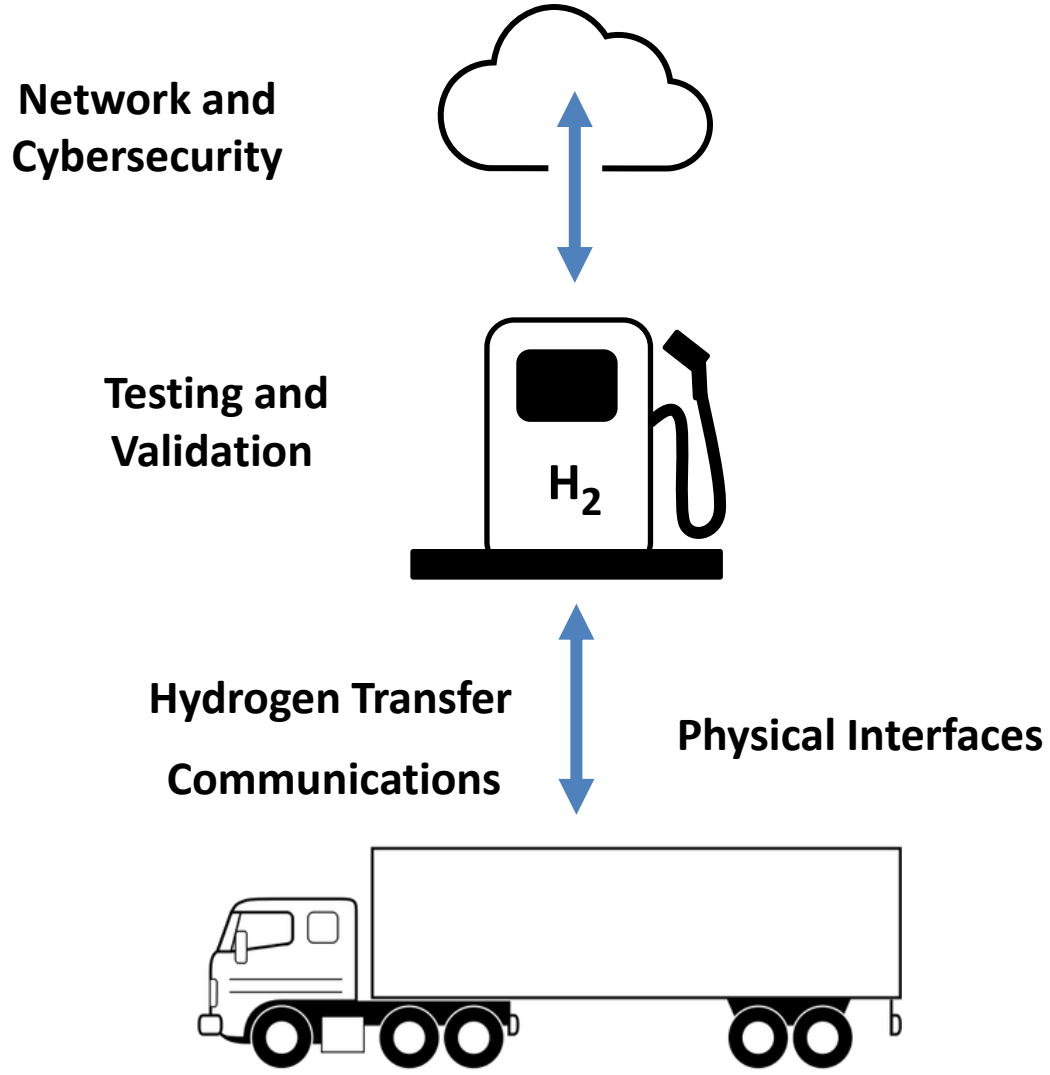
Schedule

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



Fuel Cell Electric MHDV Hydrogen Fueling Infrastructure Standards

Standards within Project Scope



Existing Global Hydrogen Fueling Protocols

- SAE 2601 Fueling Protocols For Light Duty Gaseous Hydrogen Surface Vehicles
  - H35 and H70
  - Table Look-up (Static)
    - Communications versus non-communications fill
  - MC Formula (Dynamic)
  - Category D for compressed hydrogen storage systems > 10 kg, H70
- SAE 2601-2 Fueling Protocol For Gaseous Hydrogen Powered Heavy Duty Vehicles
  - Heavy-duty, H35, guidance document
- SAE 2601-3 Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks
  - Industrial heavy-duty vehicles (e.g. forklifts)
- ISO 19880-1 Gaseous Hydrogen - Fuelling Stations
  - Harmonized with SAE 2601
- JPEC-S 0003 Compressed hydrogen filling technical standard
  - Japanese Regulation, Based on SAE 2601, includes greater tank size fill
- EN 17127 Outdoor hydrogen refuelling points dispensing gaseous hydrogen & incorporating filling protocols
  - European Standard, Based on ISO 19880-1, adds H50

Existing LDV/HDV Hydrogen Standards in the U.S.

SAE Hydrogen Standards

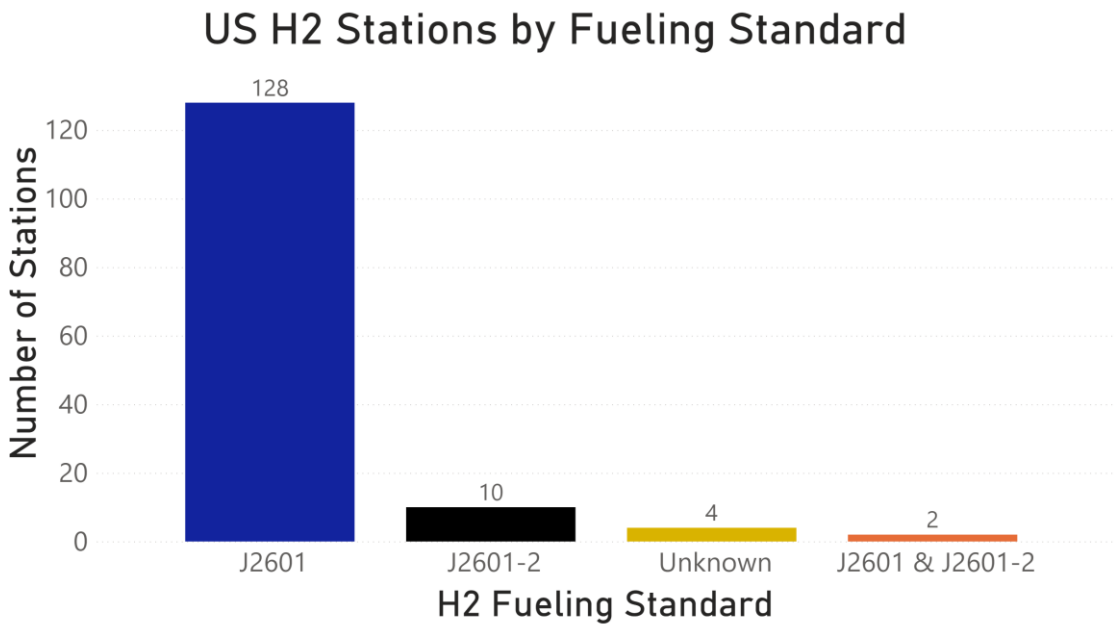
Standard	Description
SAE J2600	Hydrogen Fueling – Coupling
SAE J2601	Hydrogen Fueling for LDVs (H35, H70)
SAE J2601-2	Hydrogen Fueling for HDVs (H35)
SAE J2601-3	Hydrogen Fueling for Industrial Vehicles
SAE J2719	H2 gas quality
SAE J2799	FCEV to Station Communications

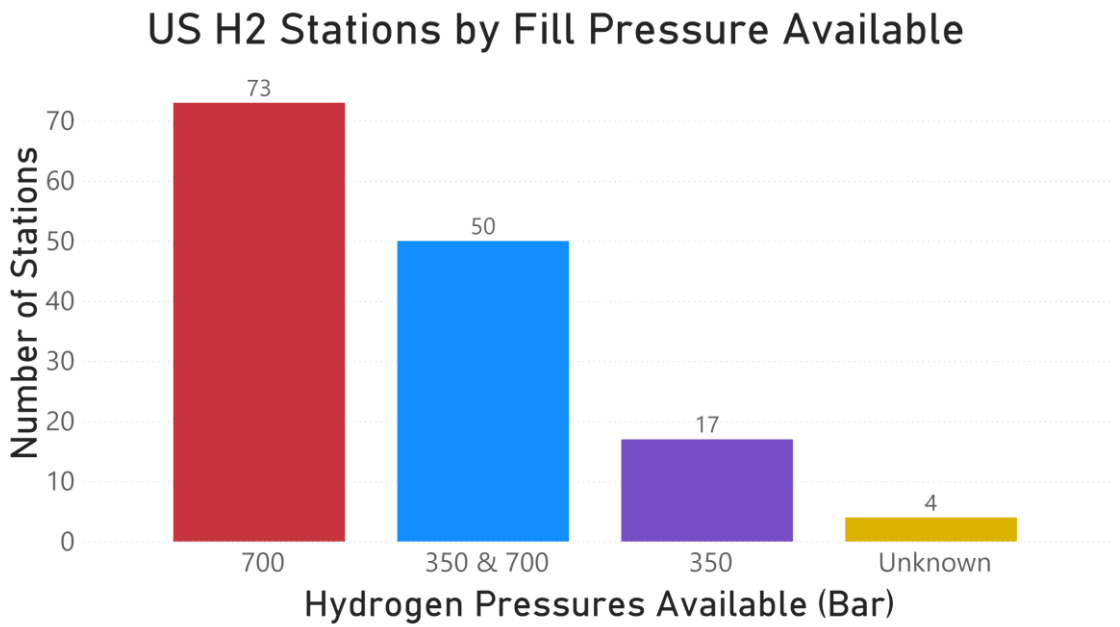
Equivalent ISO Standards

Standard	Description
ISO 17268	Hydrogen Fueling – Coupling
ISO 19880-1	Hydrogen Fueling for LDVs (H35, H70)
ISO 14687-2	H2 gas quality

Current Market

- **H2 fueling stations are predominantly for LDVs, then buses**
- **Several demonstrations within the MHD truck sector (major focus on Class 8)**





Data extracted from US DOE Alternative Fueling Station Locator Oct 6th, 2021, includes about 141 public, private, & planned stations.

Current MHDV Deployment

10 New Flyer H2 Buses Serving OCTA
1,750 kg/day Hydrogen Refueling Station
Photo: OCTA

16 H2 Buses Serving Sunline Transit
(11 El Dorado National, 5 New Flyer)
900 kg/day Hydrogen Refueling Station
Photo: Sunline

21 H2 Buses Serving AC Transit
1,050 kg/day Hydrogen Refueling Station
Photo: CaFCP

Current/Planned MHDV Deployments

Zero- and Near Zero-Emission Freight Facilities Project
10 Class 8 Fuel Cell Vehicles
1500 kg/day capacity, 700 bar Hydrogen Refueling Station
Photo: CA Climate Investments

Hyundai to deliver 30 Class 8 fuel cell trucks
for NorCAL ZERO project in 2023
Photo: Hyundai

Current Standardization Efforts

(1) PRHYDE - Protocol For heavy-duty hydrogen refueling

(2) ISO/TC 197 Under Development and Updates within Scope

(3) National Laboratory Testing

Current Standardization Efforts

PRHYDE-Protocol for heavy-duty hydrogen refueling

- **European effort to investigate MHD refueling protocols**
- **Goals:**
  - **Collect information on:**
    - Anticipated MHDV hydrogen on-board storage requirements;
    - Scope of existing MHDV fueling protocols, and if applicable identify any gaps;
    - Anticipated requirements for future fueling protocols; and
    - Existing refueling hardware, and if applicable, identify development gaps
  - **Define future refueling protocol with high performance**
- **Major findings related to current effort:**
  - **Current high-fill vehicles (>30 kg) are being refueled using a variety of methods**
    - e.g., J2601-2, JPEC-S 0003, custom average pressure ramp rate (APRR)-based protocol
  - **Current solutions with existing hardware are not optimized for performance**
    - Improvement limited by approach, hardware
  - **Advanced communications can lead to a more relaxed pre-cooling temperature and improved end SoC**
  - **Presents preliminary future fueling protocol requirements**

Current Standardization Efforts

ISO/TC 197 Under Development/Updates within Scope

Standard/Project under Development	Description
ISO/AWI TR 15916	Basic considerations for the safety of hydrogen systems
ISO/AWI 17268	Gaseous hydrogen land vehicle refueling connection devices
ISO/AWI 19880-5, -6, -8, -9	Gaseous hydrogen — Fueling stations
ISO/AWI 19885-1,-2,-3	Gaseous hydrogen — Fueling protocols for hydrogen-fueled vehicles

Goal: Develop a high-flow nozzle and fueling protocol to meet higher refueling rate target for HDVs

- **Broad stakeholder involvement in standards development aimed at achieving consensus**
- **Target flow rate of ~10 kg/min**
- **Current timeline for standard development – by 2023 – is in line with commercial deployment of several Class 8 fuel cell truck models**

ISO Standard → Harmonize with SAE

Current Standardization Efforts

National Renewable Energy Laboratory

- **Goals**
  - **Collect experimental data on high flow refueling to inform fueling protocols**
  - **Apply experimental data to develop a model of high flow refueling**
  - **Assess automation and ergonomics**

- **Laboratory and field testing of components, measuring of fueling behavior (T,P)**
  - **Validation of modeling efforts**
  - **Timeline for data/model: 2022**

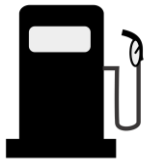
Early insights into market-driven Consensus and Gaps

- Existing J2601 protocol is conservative
- 350 bar versus 700 bar is often an economic decision
- Currently, variety of approaches for refueling large-storage FCEVs (>30 kg H2)
- New deployments will benefit from backwards compatibility, future proofing
- While new high flow technologies and protocols are being developed, there is on-going optimization of existing technologies/protocols for demonstrations
  - To what degree should demonstrations work together to optimize and disseminate protocol developments?
  - Is there a need for interim protocol(s)?
- Need to consider different vocations when looking at MHD fueling
  - Current refueling protocols may be sufficient for some applications
  - High flow refueling most important for intensive Class 8 duty cycles
- Intentional incompatibility of high flow nozzle and LDV refueling

Strawman for MHD Hydrogen Fueling Evolution

Current

Dispenser Pressure
(350 and 700 Bar)



Nozzle
(SAE J2600)

Fueling Protocol
(SAE J2601, SAE J2601-2)

kg/min

Vehicle Types
(Buses, Early Commercial Medium-Duty, Early Demonstration HDV)

Short Term (1-3 Years)

Dispenser Pressure
(350 and 700 Bar)

Nozzle
(SAE J2600)

Fueling Protocol
(SAE J2601/ JPEC-S 0003/Interim Fueling Protocol)

kg/min

Vehicle Types
(Buses, Demonstration/Early Commercial MHDV)

Roadmap to High Flow Deployment?

Long Term (3+ Years)

Dispenser Pressure
(350 and 700 Bar)

Nozzle
(ISO 17268, Harmonized SAE Std)

Fueling Protocol
(ISO 19885-3, Harmonized SAE Std)

kg/min

Vehicle Types
(All MHDV)

Government Roles

Current State Initiatives for MHD FCEV and Infrastructure

- **INFRASTRUCTURE FUNDING**
  - **Grant Funds**, e.g. GFO-20-603 Block Grant for Medium-Duty and Heavy-Duty Zero-Emission Vehicle Refueling Infrastructure Incentive Projects
  - **Low Carbon Fuel Standard (LCFS)**
  - **Rebates**
- **VEHICLE FUNDING**
  - **California Comeback Plan** (Vehicles & Infrastructure) – $3.9 billion
  - **Hybrid and Zero-Emission Truck & Bus Voucher Incentive Project (HVIP)**
  - **Carl Moyer Memorial Air Quality Standards Attainment Program**
  - **Volkswagen Environmental Mitigation Trust for California**
- **PLANNING/TESTING**
  - **CEC GFO-20-601** Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure
  - **Heavy Electric Vehicle Infrastructure Projection tool (HEVI-Pro)**
  - **Hydrogen Tools** (Safety and Station Design)
  - **Funding for national laboratory testing programs**

Potential Short-Term (1-3 Year) Government Actions

1. **Guidance: State or Federal Guidance on Hydrogen Fueling 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) Government 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?
            - Hardware, communications
    - Timeline for rulemaking and market compliance
        - Is there a market consensus on standards?
        - Timeline for mature MHD technologies and standards

Project Next Steps

- **Continue examining current standards and technologies development**
  - **International efforts, Optimization within existing standards, Testing, Communications protocols**
- **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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