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

Consultatory Meeting #2

Advanced Power and Energy Program
University of California, Irvine

Professor Scott Samuelsen (PI)
Dr. Kate Forrest (PM)

June 14, 2022

Meeting Agenda

- **Project Goal, Objectives, and Timeline**
- Consultatory Meeting #1 Summary
- Consultatory Meeting #2
  - Meeting Goals
  - Status of the Initiative
  - Feedback
  - Discussion Questions
  - Open Q&A
- Next Steps for the Second Year

Project Goal

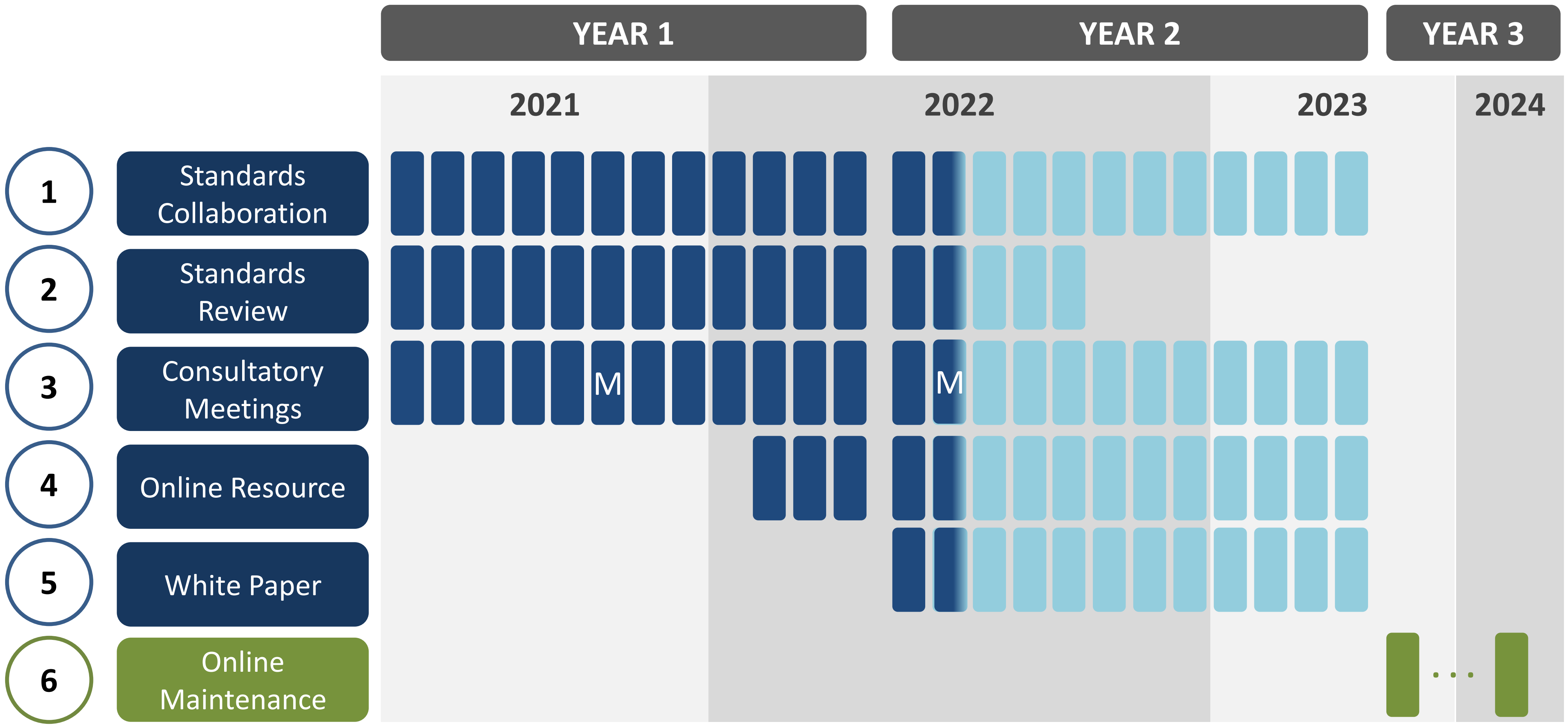
- UCI is conducting a two-year CARB contract to assess:
  - Status of charging/fueling standards for
    - Charging Battery Electric MHD Vehicles
    - Fueling Hydrogen Fuel Cell Electric MHD Vehicles
- Overall Goal
  - Help assure standards are evolving to proactively enable the zero-emission MHDV market
  - Identify specific government actions that may facilitate a timely evolution
- Project Began 1 May 2021
- Consultatory Group Meetings
  - Two a Year
  - This is meeting #2
  - Summarize UCI findings to date, obtain input and guidance

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 infrastructure 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

Project Timeline

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



Meeting Agenda

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Consultatory Meeting #1 Summary

October 19, 2021

- **Overview of Project Motivation, Goal, and Standards Scope**
- **Current MH-ZEV Market**
- **Current Standardization Efforts**
- **Potential Government Actions**

- **Consultatory Meeting #1 slides available online:** **https://www.apep.uci.edu/MHDV_Protocol_Comment.html**

Meeting Agenda

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Meeting Goals

- **Present initial findings on:**
  - **The status for standardizing and verification of protocols for fueling on-road 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, such as staffing, grants, sponsorship, membership, etc…**

- **Solicit feedback on the UCI assessment**

Meeting Agenda

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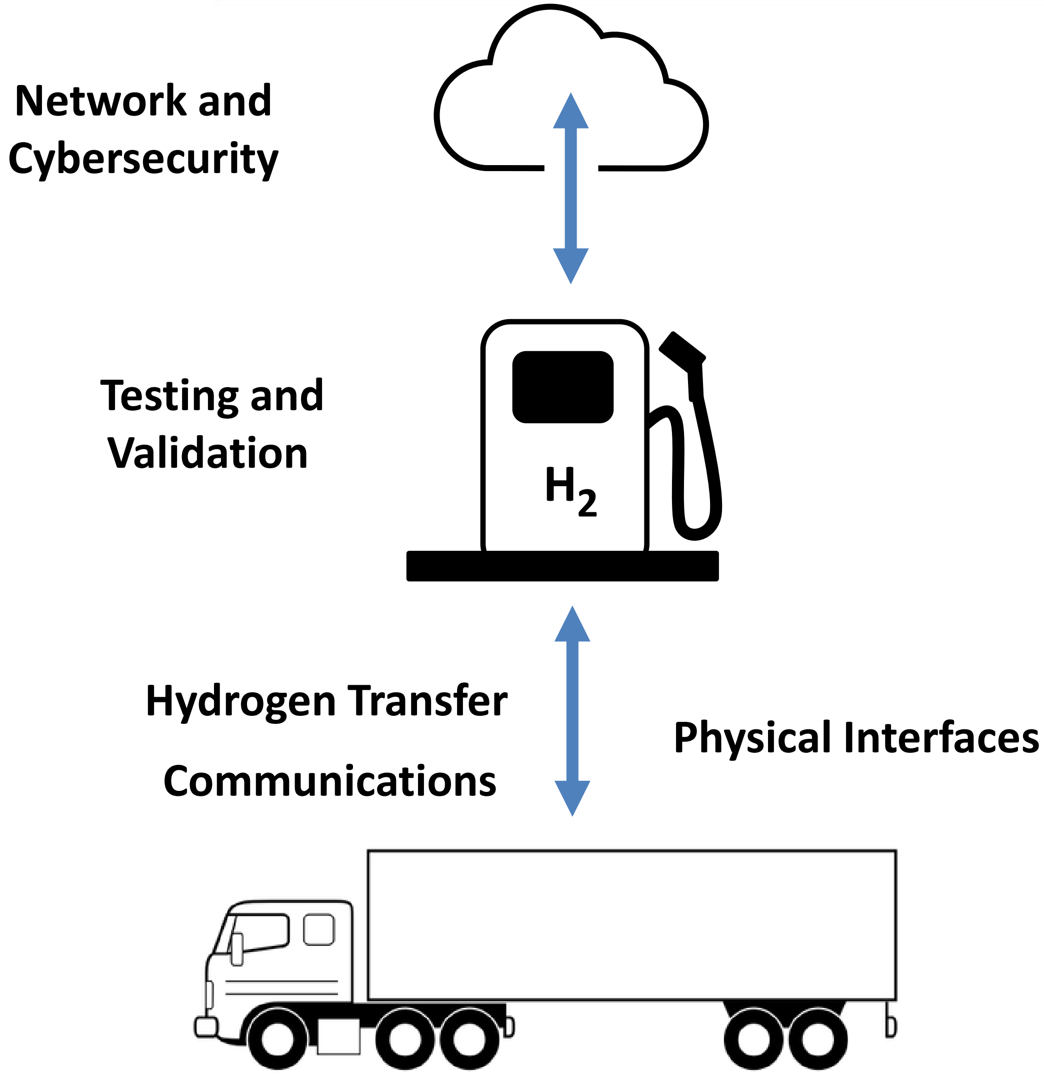
Status: Standards within Project Scope



Interim Report 1

Year 1 Topics	Year 2 Topics
Current Market	**Communications**
Hydrogen Transfer	**Testing and Validation**
Physical Interfaces	**Network and Cybersecurity**
Standardization Efforts	Industry Feedback
Current Standards Gaps	Policy Actions

Status: Interim Report 1

Medium- and Heavy-Duty Zero-Emission Vehicle Fueling and Charging Standardization Assessment

Interim Report 1

CARB Contract 20MSC006

Advanced Power and Energy Program (APEP)

University of California, Irvine 92627-3550

www.apep.uci.edu

March 2022

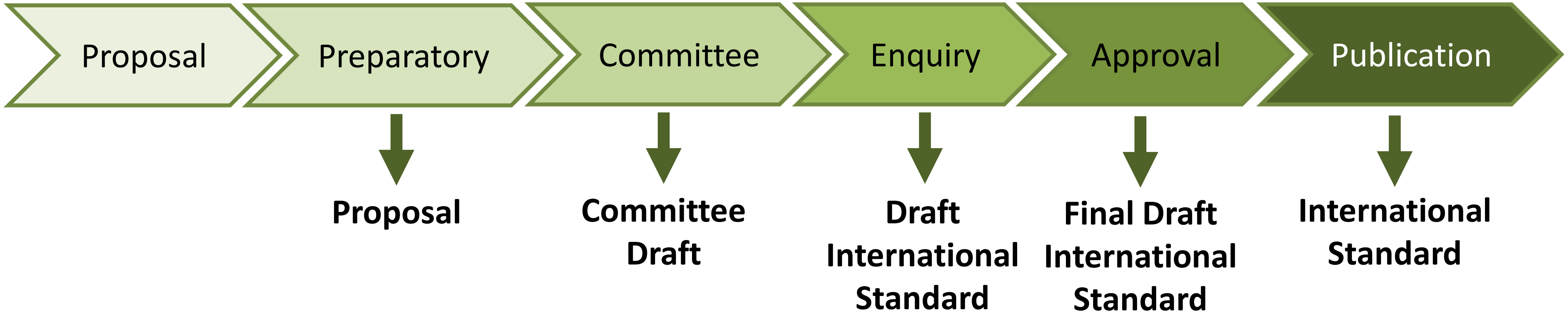
Table of Contents

Status: Standards Organizations Within Scope

- SAE (Society of Automotive Engineers) International
- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE)
- ASTM (American Society for Testing and Materials) International
- National Fire Protection Association (NFPA)
- National Institute of Standards and Technology (NIST)
- European Committee for Standardization (CEN)
- European Committee for Electrotechnical Standardization (CEN-CENELEC)
- CSA (Canadian Standards Association)
- Compressed Gas Association (CGA)
- Japan petroleum Energy Center (JPEC)

Status: Standards Document Types and Stages

ISO Stages and Documents



SAE Document Types

Status: 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

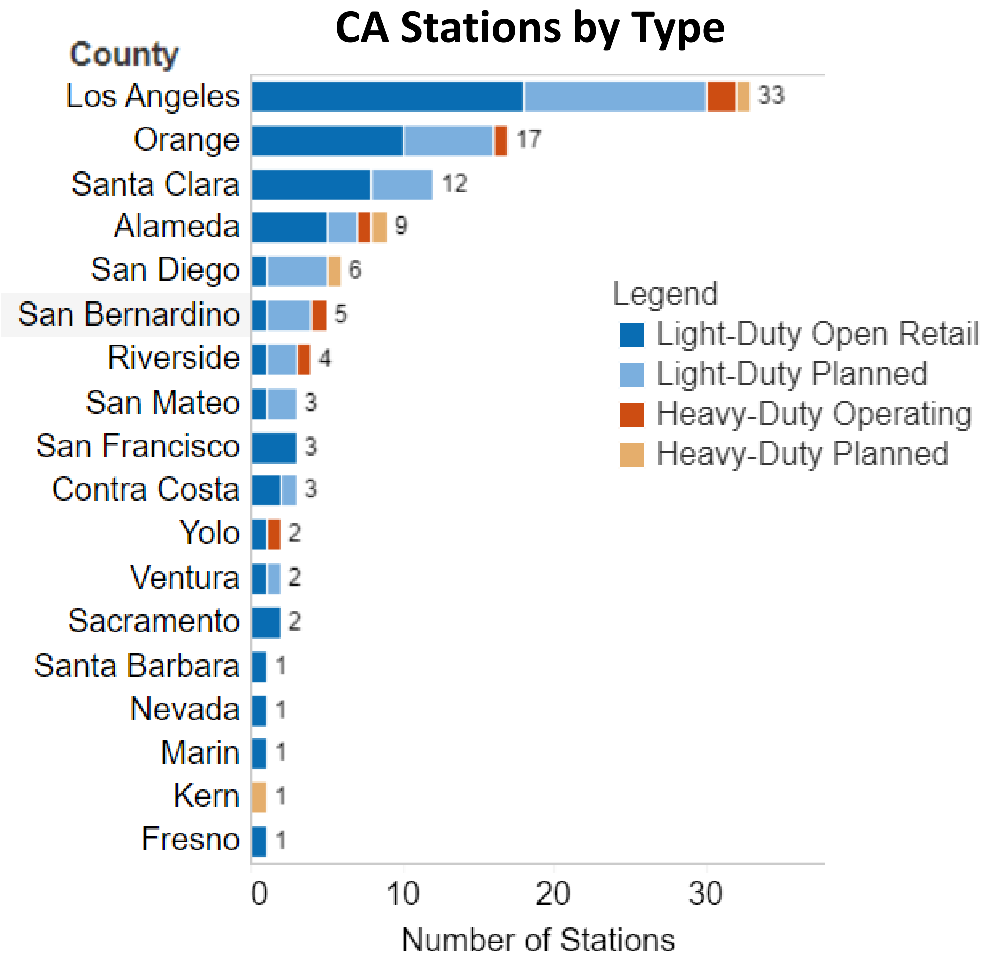
Equivalent ISO Standards

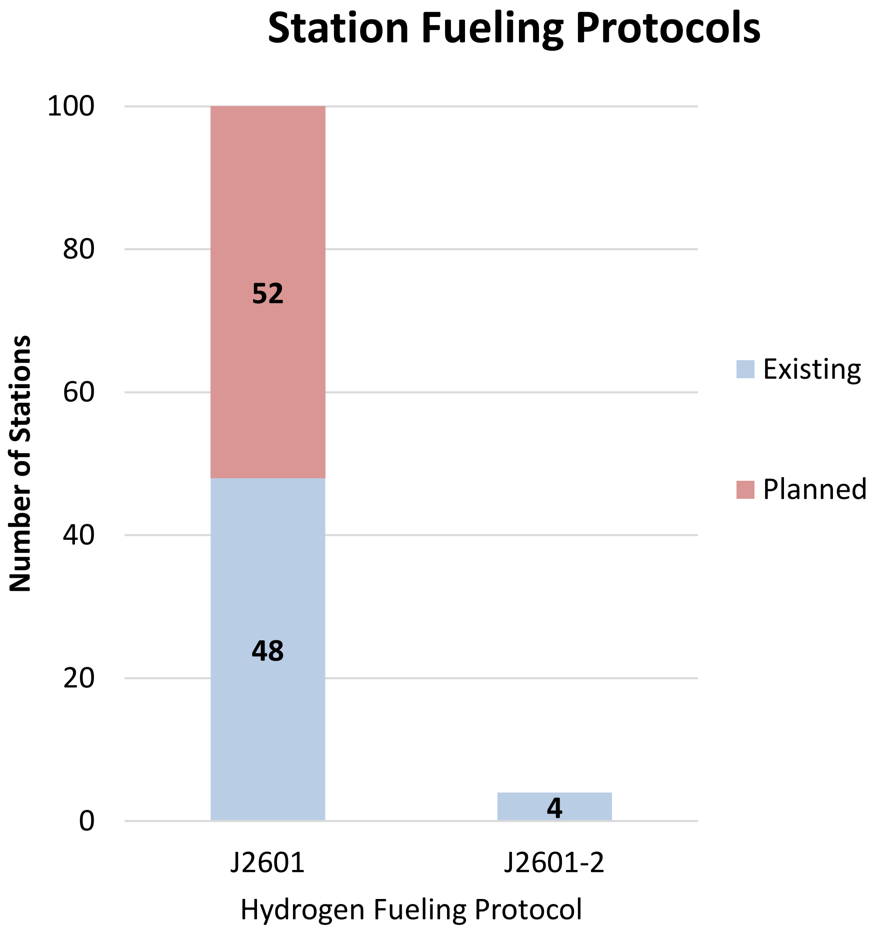
Standard	Description
ISO 17268	Hydrogen Fueling – Coupling
ISO 19880-1	Hydrogen Fueling for LDVs (H35, H70)
ISO 14687-2	H2 gas quality

Status: Existing Global Hydrogen Fueling Protocols

- SAE J2601 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 J2601-2 Fueling Protocol For Gaseous Hydrogen Powered Heavy Duty Vehicles
  - Heavy-duty, H35, guidance document
- SAE J2601-3 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 J2601
- JPEC-S 0003 Compressed hydrogen filling technical standard
  - Japanese Regulation, Based on SAE J2601, 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

Status: Current Infrastructure Deployment





Source: California Energy Commission (2022). Hydrogen Refueling Stations in California. Data last updated May 22, 2022

Data extracted from US DOE Alternative Fueling Station Locator April 27, 2022

Status: SAE J2601

- Parameters
  - <u>Tank rated pressure</u>
    - H35 or H70
  - <u>Hydrogen delivery temperature</u>
    - -40^{o}C (T40), -30^{o}C (T30), and -20^{o}C (T20)
  - Compressed hydrogen storage system (CHSS) capacity
  - <u>Vehicle-station communications</u>
    - Communications or Non-Communications
  - <u>Refueling gas flow rate calculation method</u>
    - Table-based fueling protocol
    - MC Formula

Status: SAE J2601

- **Table-based protocol**
  - Selected table based on measured initial conditions (vehicle and station)
  - Communication versus non-communication fill options
    - Determined by initial conditions as defined in SAE J2799
  - "Top-off" category under the H70 communications fills when a vehicle starts refueling at a low initial CHSS pressure (0.5 – 5 MPa) and ambient temperature above 0°C

- **MC formula**
  - Dynamic, analytical approach using a regression equation
    - Improved fueling performance
  - Communication versus non-communication fill options
    - As defined in SAE J2799 (2019)
    - Non-communication fill assumes "Worst Case" conditions

- **Maximum fueling rate for both: 3.6 kg/min (60 g/s)**

Status: SAE J2601-2

- Guidance document
  - Technical Information Report
  - Not a protocol—Defines three fueling rates for 350 Bar, 10 kg+

Option	A	B	C
Name	Fast Fueling	Normal Fueling	Slow Fueling
Fueling Rate (kg/min)	7.2	3.6	1.8

- Currently utilized for H35 Bus Refueling
  - Requires custom protocol that considers vehicle type being fueled
- Public versus Private Fleet Stations
  - Not suitable for future public stations

Status: Hydrogen Dispenser Nozzles

- H2 dispenser nozzles defined in SAE J2600 and ISO 17268
  - 5 Pressure Classes
    - H11, H25, H35, H50, H70
  - Nozzle designs
    - Vehicle can fuel with nozzle rated for pressure equal to or less than vehicle tank rating
  - Nozzle and Receptacle Temperature Range for H35 and H70
    - Ambient Temperature: -40°C to 65°C
    - Gas Process Temperature: -45°C to 85°C
  - "High Flow" Option
    - Heavy Duty Hydrogen Surface Vehicle (HDHSV) connection (ISO 17268:2012)
    - H35 Only
    - Fueling protocol: J2601-2 H35 Option A – 7.2 kg/min
- New, updated nozzle designs for H70 high flow protocols

Status: Current H2 Fueling Protocols/Guidance and Hardware

350 Bar

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="4">Fueling Rate (kg/min)</td></tr>
<tr><td>1.8</td><td colspan="2">3.6</td><td>7.2</td></tr>
<tr><td rowspan="5">CHSS (kg)</td><td>1.19-2.39</td><td colspan="3">J2601 Category A</td><td></td></tr>
<tr><td>2.39-4.18</td><td colspan="3">J2601 Category B</td><td></td></tr>
<tr><td>4.18-5.97</td><td colspan="3">J2601 Category C</td><td></td></tr>
<tr><td>5.97-10</td><td colspan="3"></td><td></td></tr>
<tr><td>10+</td><td>J2601-2 Slow Fueling Option C</td><td colspan="2">J2601-2 Normal Fueling Option B</td><td>J2601-2 Fast Fueling Option A</td></tr>
</table>

Connection Type
SAE J2600/ISO 17268
ISO 17268:2012 HDHSV
Future connection (ISO 17268)

700 Bar

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="5">Fueling Rate (kg/min)</td></tr>
<tr><td colspan="2"><=3.6</td><td>7.2</td><td>8</td><td>10</td></tr>
<tr><td rowspan="5">CHSS (kg)</td><td>2.00-4.00</td><td>J2601 Category A</td><td rowspan="4">JPEC-S-0003</td><td></td><td rowspan="5">DOE 2030 Goal</td><td rowspan="5">DOE Ultimate Goal</td></tr>
<tr><td>4.00-7.00</td><td>J2601 Category B</td><td></td></tr>
<tr><td>7.00-10.00</td><td>J2601 Category C</td><td></td></tr>
<tr><td>10-30</td><td rowspan="2">J2601 Category D</td><td></td></tr>
<tr><td>30+</td><td></td><td></td></tr>
</table>

CHSS = Compressed Hydrogen Storage System

Status: Proposed Standards and Updates

Name	Scope	Status
SAE J2601-1	H35 Category D (CHSS >5.97 kg)	WIP
SAE J2601-4	Ambient Temperature Fueling	WIP
ISO 19885-1	Design and development process for fueling protocols	**WIP:** CD
ISO 19885-2	High Flow Communications	**WIP:** Preparatory
ISO 19885-3	High Flow Protocols	**WIP:** Preparatory
ISO 17268 (Update)	High Flow Components	**Current version:** ISO 17268:2020 **WIP:** Preparatory

WIP = Work in Progress
TBA = To Be Announced
CD = Committee Draft

Status: 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 components (nozzle, breakaway coupling, hose) 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 (avg.)**

Current timeline for new standard publication: 3 years?

- **Does this align with commercial deployment of MH-FCEVs and hydrogen refueling stations?**

Status: Proposed Standards/WIP

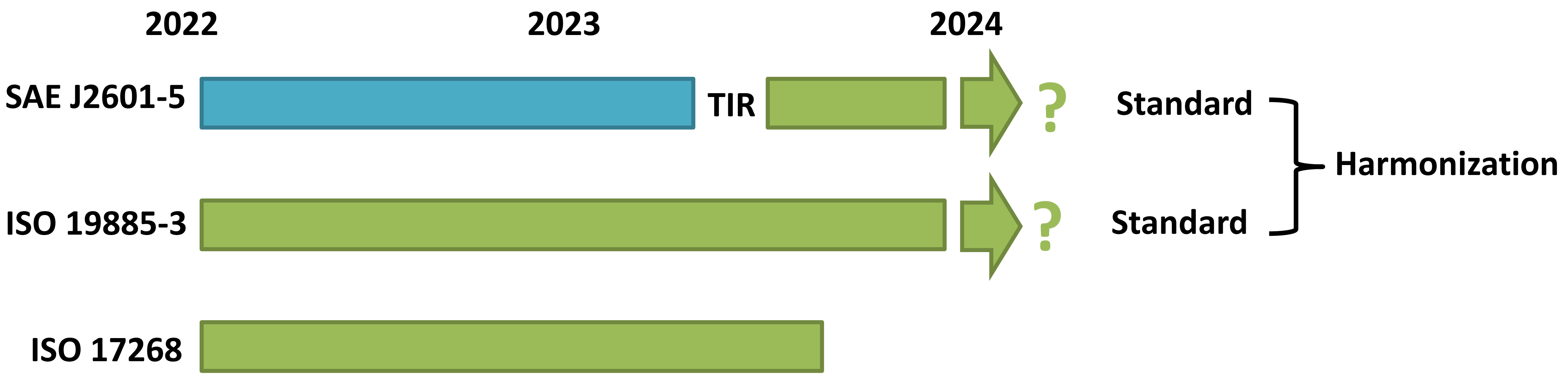
Name	Scope	Status
SAE J2601-1	H35 Category D (CHSS >5.97 kg)	WIP
SAE J2601-4	Ambient Temp Fueling	WIP
SAE J2601-5?	High Flow Protocols	--
ISO 19885-1	Design and development process for fueling protocols	**WIP:** CD
ISO 19885-2	High Flow Communications	**WIP:** Preparatory
ISO 19885-3	High Flow Protocols	**WIP:** Preparatory
ISO 17268 (Update)	High Flow Components	**Current version:** ISO 17268:2020 **WIP:** Preparatory

Potential Option

WIP = Work in Progress
TBA = To Be Announced
CD = Committee Draft

Status: Standards Pathways and Timelines

- **Precedent:** SAE J2601 TIR was previously required in PON-12-606
- **Current:** EnergIIZE references “J2601-5”



Status: Standards Pathways and Timelines

EnergIIZE
Attestation Form Screenshot

Appendix P – Hydrogen Project Attestation of Codes and Standards

Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles (EnergIIZE) aims to increase the market acceleration of infrastructure to support medium and heavy duty (MHD) zero emission vehicles (ZEVs). EnergIIZE incentivizes infrastructure projects to support hydrogen fuel cell vehicles which are compliant with all relevant safety codes and regulatory standards.
ZEV infrastructure deployment can be a complex endeavor involving an array of safety and regulatory codes in which infrastructure must comply. To help applicants navigate these requirements, EnergIIZE staff have create this inventory of relevant requirements. Applicants are encouraged to check relevant websites for the latest information; this list is intended for instructional purposes only and may not be comprehensive for your specific project.

To ensure EnergIIZE incentives safe, reliable technologies, we require all vendors to comply with the following codes listed below. This attestation form must be filled out by hydrogen infrastructure developers in order to be considered eligible for EnergIIZE incentives.

Company Information

Name of project point of contact (Last name, First name):	
Email address:	
Phone number:	
Vendor Company Name:	
Parent Company (if applicable):	
Project Site Address:	

Required Codes and Standards

All hydrogen projects must meet the requisite installation, construction, and safety standards, including but not limited to those listed below or the most up-to-date version of these standards:	
SAE Standards	• One or more of the following fueling protocols or an equivalently accepted industry standard o J2601 – 1 Category D (greater than 10 kg tank sizes) o J2601 – 2 HD fueling o J2601 – 4 Ambient Temperature refueling o J2601 – 5 MC Method for HD fueling o JPEC-S 0003 Japanese Bus fueling protocol • J2600 or an equivalently accepted industry

Source: EnergIIZE Workshop III - Hydrogen Application Process Overview, 2 June 2022

Status: H2 Fueling Protocols/Guidance and Hardware

350 Bar (H35)

CHSS (kg)		Fueling Rate (kg/min) 1.8	3.6	7.2
	1.19-2.39	J2601 Category A		
	2.39-4.18	J2601 Category B		
	4.18-5.97	J2601 Category C		
	5.97-10	Future J2601 Update (Category D)		
	10+	J2601-2 Slow Fueling Option C	J2601-2 Normal Fueling Option B	J2601-2 Fast Fueling Option A

Connection Type
SAE J2600/ISO 17268
ISO 17268:2012 HDHSV
Future connection (ISO 17268)

700 Bar (H70)

CHSS (kg)		Fueling Rate (kg/min) <=3.6		7.2	8	10
	2.00-4.00	J2601 Category A	JPEC-S-0003		DOE 2030 Goal	DOE Ultimate Goal
	4.00-7.00	J2601 Category B				
	7.00-10.00	J2601 Category C			Possible SAE TIR J2601-5	
	10-30	J2601 Category D				
	30+				ISO 19885-3*)	

SAE J2601 harmonized with EN 17127 and ISO 19880-1

*Target is parity with diesel (80 kg in 10-15 minutes)

Status: Current Gaps

- <u>Topic areas directly related to codes and standards</u>
  - Fueling protocols
  - Station certification, validation, and testing
  - Cybersecurity and tampering/misuse prevention

- <u>Topic areas adjacent to codes and standards</u>
  - Station design
  - Public fueling network buildout

Status: Current Gaps and MHDV Refueling Goals

Fueling Protocols

- **Need for faster refueling and increased end SOC**
  - <u>Type of Gap:</u> Standards, Technology
    - Limited by SAE J2601's overly conservative approach, current hardware
  - <u>MH-ZEV Gap Impact:</u> long fill times, difficulty achieving 100% SOC, restarts
  - <u>Recent Activities:</u>
    - Standards
      - ISO 17268 updates; ISO 19885-1, -2, -3
      - Proposed: update to J2601-2 or creation of J2601-5
    - Industry/Research
      - Development and testing of hardware (nozzle, breakaway, hose, etc.)
      - Testing and modeling of high flow refueling
  - <u>Goal:</u> Parity with diesel

Status: Current Gaps and MHDV Refueling Goals

Fueling Protocols

- **Reduced protocol complexity**
  - **Type of Gap: Standards**
    - SAE J2601 complex, SAE J2601-2 requires custom protocol, current high-fill (>10 kg) vehicles are being refueled using a variety of methods
  - **MH-ZEV Gap Impact:** Complex implementation
  - **Recent Activities:**
    - Standards
      - MC Formula introduced in 2016
      - ISO 19885-1: Design and development process for fuelling protocols
    - Research
      - Multiple activities: updated computer modeling and experimental testing results to inform a more optimized approach
  - **Goal:** Improve protocol designs to reduce complexity and improve performance/flexibility

Status: Current Gaps and MHDV Refueling Goals

Fueling Protocols

- H35 fueling protocol for larger (>6 kg) fill
  - Type of Gap: Standards
    - SAE J2601-2 is a guidance document that requires a custom protocol
  - MH-ZEV Gap Impact: Custom implementation, current document not suitable for public stations
  - Recent Activities:
    - Standards
      - Future update anticipated for J2601 (Category D)
  - Goal: Improve protocol designs to reduce complexity and improve performance/flexibility

Status: Current Gaps and MHDV Refueling Goals

Station Certification, Validation, and Testing

- Existing testing methods may not be suitable for high flow protocols
  - Type of Gap: Standards, Technology
    - MHDV components and protocols still in development
  - MH-ZEV Gap Impact: testing and certification challenges
  - Existing requirements:
    - Hydrogen fuel quality and dispensing accuracy
  - Recent Activities:
    - Research
      - Multiple activities: updated hardware and software to improve accuracy of existing systems, experimental testing, including flow meter testing for high flow refueling
  - Goal: Reliable and accurate accounting of hydrogen dispensed

Status: Current Gaps and MHDV Refueling Goals

Cybersecurity and Tampering/Misuse Prevention

- **Cyber and physical security**
  - **Type of Gap:** Standards, Technology
  - **MH-ZEV Gap Impact:** Risk of damage, fueling disruptions, and data breaches
  - **Recent Activities:**
    - Standards
      - Type certified, sealed, tamperproof
      - Intentional in-compatibility
    - Research
      - Risk assessments generally focus on physical security
      - U.S. DOE H2 Tools: modeling and planning tools, risk assessments, best practices

  - **Goals:** Maintain high level of safety at stations and improve security

Status: Current Gaps

- Topic areas directly related to codes and standards
  - Fueling protocols
  - Station certification, validation, and testing
  - Tampering/misuse prevention

- Topic areas adjacent to codes and standards
  - Station design
  - Public fueling network buildout
  - Other topics

Status: Topic Areas Adjacent to Codes and Standards

Station Design:

- **Need to consider range of applications when looking at MHDV fueling**
  - **Capacity, fueling protocols, station layout, ingress, egress, mix of vehicles fueling, etc.**

Source: CALSTART 2021 Taking Commercial Fleet Electrification To Scale: Financing Barriers and Solutions

Status: Topic Areas Adjacent to Codes and Standards

Station Design:

- Need to consider range of applications when looking at MHDV fueling
  - Capacity, fueling protocols, station layout , ingress, egress, mix of vehicles fueling, etc.
- Station deployment standardization can reduce planning time to construct and commission hydrogen refueling stations
- 350 bar versus 700 bar is often an economic decision
  - Future demand in the MHDV sectors for 350 bar?

Public fueling network buildout

- Public stations with standardized fueling can support fleets with or without on-site fueling

Status: 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)

Status: Topic Areas Adjacent to Codes and Standards

On-board hydrogen storage tank design/materials

- Temperature tolerances for end SOC

Back-to-back refueling

- Limited by equipment recovery times, can cause additional strain on station hardware

Broader training and planning for emergency services

- Local and regional variability in station permitting, hydrogen understanding, and emergency response training

Status: Initial Findings Summary (I/II)

- **New fueling standards are being developed for MHDV**
  - **i.e, greater than 10-30 kg**
  - **Protocols are in development with timeline to market of 1-3 years**
    - **ISO, SAE International, PRHYDE, JPEC, etc.**
  - **Harmonization is crucial**

Status: Initial Findings Summary (II/II)

- **Initial Consensus:**
  - A combination of station configurations are needed to meet MHDV needs
    - 350 and 700 bar
    - Varying capacity
    - Liquid versus gaseous hydrogen station storage (Depends on hydrogen supply, station size)
  - Fueling protocol needs to accommodate:
    - Range of on-board storage capacities (most current demos range from 15 kg to 60 kg)
    - Nominal versus high flow (3.6 kg/min versus 10 kg/min)
    - Optimized performance within safety limits
    - Cost effective flexible protocol that can minimize chilling, compression storage needs

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Discussion Questions (I/III)

1. What additional fueling infrastructure standards gaps and/or performance gaps need to be addressed to support large-scale deployment for MH-FCEVs?

Discussion Questions (II/III)

2. What specifications are appropriate to guide those applying for hydrogen refueling station grant awards?

  – Are there any ambiguity or issues with current funding solicitations?
  – Listing standards/certification/testing requirements?
  – Referencing a TIR (Technical Information Report) pre-standard
  – Guidance for Demonstrations

Additional Discussion Questions (III/III)

1. **Should public funding requirements vary for fleet (private) versus public hydrogen stations?**
   - **Codes and Standards**
   - **Preference for LDV and MHDV shared access**

2. **What are the current limitations holding back the widescale deployment of a MHDV hydrogen refueling network?**
   - **What actions can the state or federal government take to accelerate deployment?**

3. **Are there additional topics/issues that you would like to see in the second interim report?**

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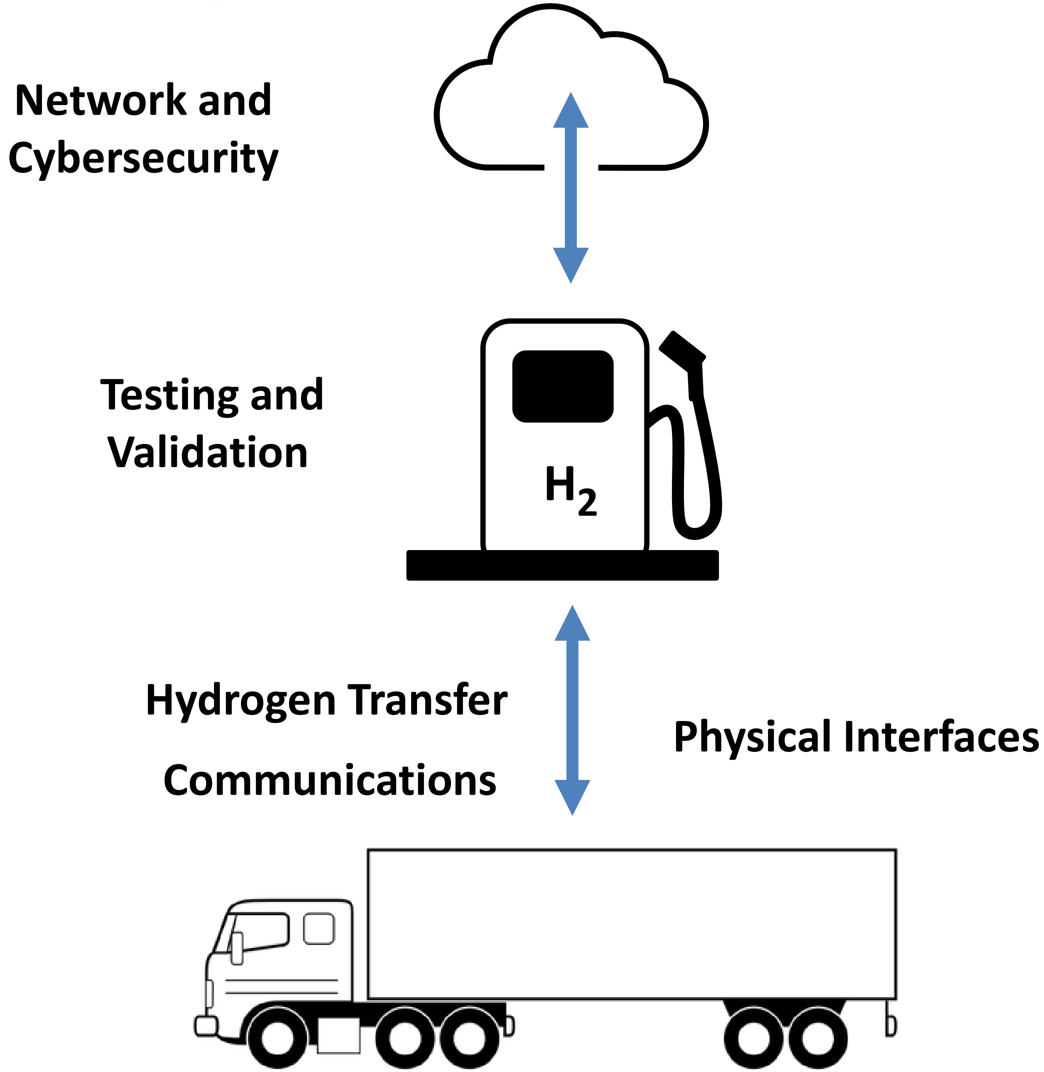
Next Steps



Interim Report 1	Interim Report 2
Year 1 Topics	**Year 2 Topics**
Current Market	**Communications**
Hydrogen Transfer	**Testing and Validation**
Physical Interfaces	**Network and Cybersecurity**
Standardization Efforts	Industry Feedback
Current Standards Gaps	Policy Actions

White Paper
Analysis of Findings
Policy Recommendations

Next Steps

- **Continue examining current standards and technologies development**
  - International efforts, Optimization within existing standards, Testing, Communications protocols
- **Engage key stakeholders and integrate stakeholder input**
  - Drive towards consensus
- **Further refining of policy actions and timeline**
  - Specificity, Timing

Interim Report 2

Consultatory Meetings, Online Comments, One-on-One Interviews

Interim Report 2, White Paper

Next Steps

- **Finalize list of *current* federal and state government actions related to supporting the standardization of MH-ZEV infrastructure deployment**

- **Finalize list of *possible* federal and state government actions related to supporting the standardization of MH-ZEV infrastructure deployment**

What actions should the state and/or federal government take to support standardization and accelerate the MH-ZEV infrastructure network buildout?

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  - **Discussion Questions**
  - **Open Q&A**
- **Next Steps for the Second Year**

Project Final Product – White Paper

- **White Paper Goals:**
  - Synthesize the background, research, interviews, and findings of the project
  - Identify standardization gaps, pinch points, and priority areas that are critical for the market success of MH-ZEVs within the State
  - Present policy recommendations and high-level guidance based on the assessments conducted
  - Propose additional assessments necessary to facilitate MH-ZEV adoption and protect investments in a zero-emission transportation future

- **Draft White Paper – January 2023**

Written Comments

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

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

Consultatory Meeting #2

Professor Scott Samuelsen (PI)
Dr. Kate Forrest (PM)

June 14, 2022

Combustion Fuel Cells Distributed Power

Advanced Power and Energy Program
University of California, Irvine