U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# $H_2$ Infrastructure for the Transportation Sector – Key Needs and Priorities Workshop


## Ned Stetson, HFTO – $H_2$ Infrastructure Technologies Program Manager


Old Town Alexandria Westin Hotel

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# Acknowledgements to the Workshop Organizing Team

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# Workshop Objectives

Provide expert input to aid in the development of the DOE $H_2$ Infrastructure Technologies' ***RD&D plan for the next 5 to 10 years*** so that the program can help enable ***successful deployment of MD/HD vehicle and fueling infrastructure*** and support ***success of the selected $H_2$ Hubs***

- Identify key focus areas for the MD/HD Transportation Sector
- Identify key performance metrics that need to be met
- Identify key RD&D needs
- Prioritize focus areas, including consideration of deployment timelines

# $H_2$ Infrastructure Technologies Program Mission

- Our Program's mission is to support research, development and demonstration (RD&D) efforts for technologies with potential to enable successful deployment of hydrogen in applications to help meet the Administration's aggressive decarbonization goals
  - Efforts are supported primarily through cooperative agreements and grants selected through competitive Funding Opportunity Announcements (FOA) and SBIR processes, and through efforts at the national laboratories. The efforts cover approximately the TRL 2-6 space.
  - FOA and SBIR topics are developed with consideration of stakeholder feedback (e.g., through RFIs, workshops, conferences, one-on-one listening sessions), Congressional direction, and in accordance with the Program's multi-year plan
  - The Program is performance based, so targets or performance metrics are used to measure progress towards meeting the technology needs for the applications. Performance metrics are ideally developed in concert with expert stakeholders.
- Information from this workshop will feed into the Performance Metrics for the MD/HD Transportation efforts and the 5-10 year Program Plan

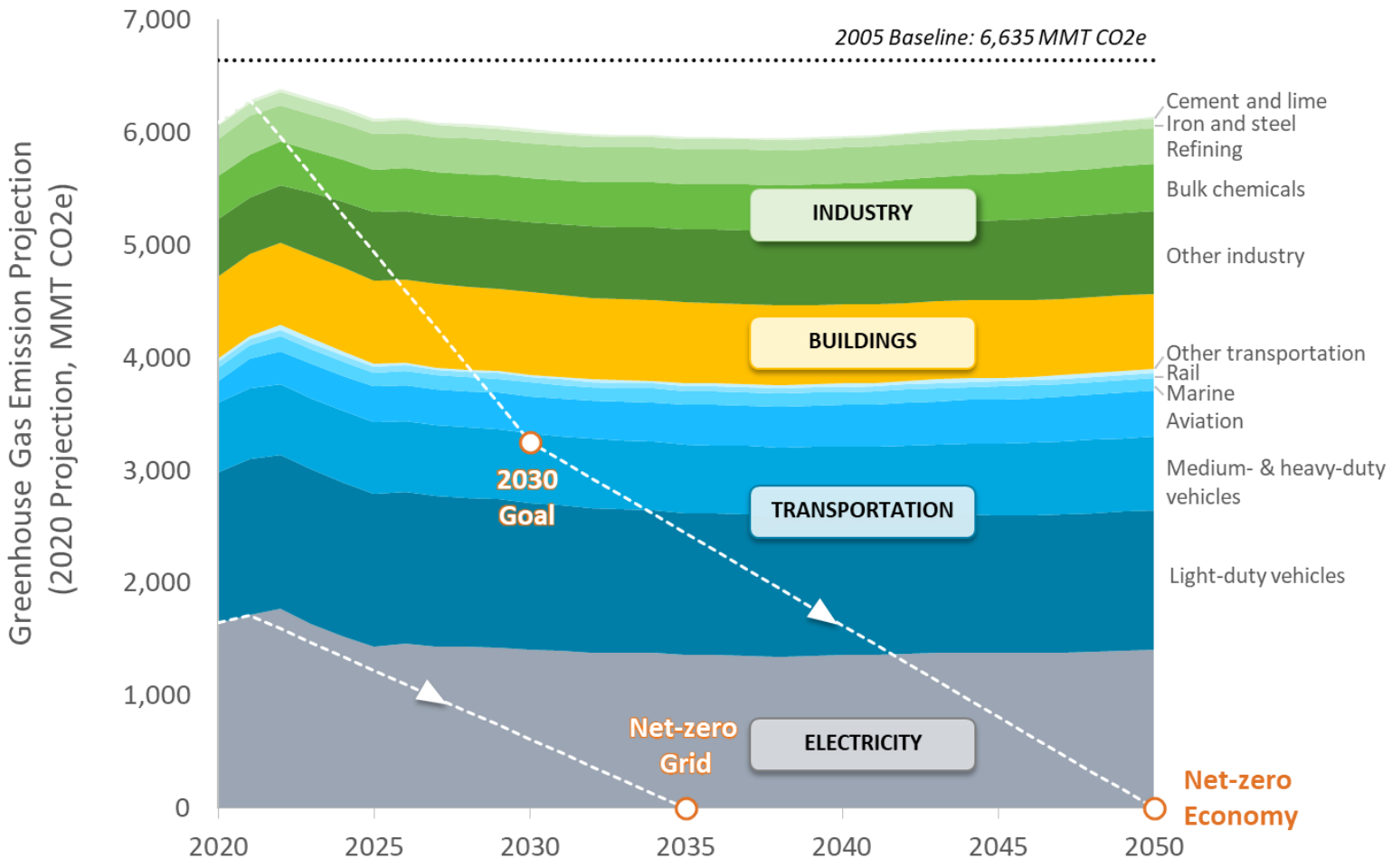
# U.S. Key Goals and $CO_2$ Emissions by Sector

## Administration Goals include:

- Net-zero emissions economy by 2050 and 50–52% reduction by 2030
- 100% carbon-pollution-free electric sector by 2035

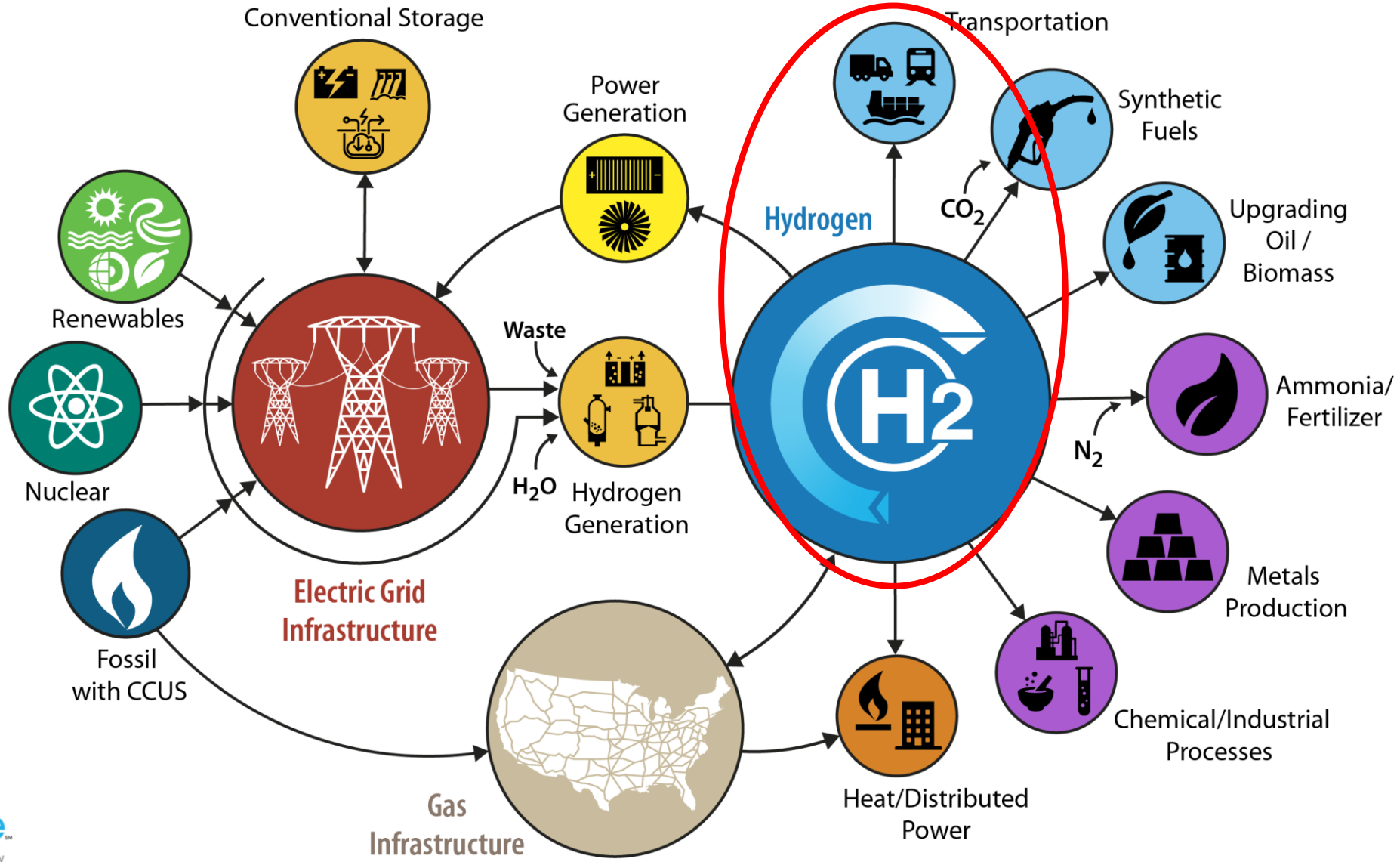
**Priorities: Ensure benefits to all Americans, focus on jobs, Justice40: 40% of benefits in disadvantaged communities**

EJ: Environmental Justice




**Source:** Annual Energy Outlook 2021, DOE National Clean Hydrogen Strategy and Roadmap

# Low-carbon $H_2$ Can Help Decarbonize Many Sectors of the Economy




H2@Scale
U.S. Department of Energy

# Background – FreedomCAR and Fuel Initiative/US DRIVE

- Focus was strictly on medium-sized, light-duty vehicles

**Table 2 Technical Targets: On-Board Hydrogen Storage Systems [f]**

| Storage Parameter | Units | 2010 | 2015 | Ultimate |
|---|---|---|---|---|
| System Gravimetric Capacity: | | | | |
| Usable, specific-energy from $H_2$ (net useful energy/max system mass) [a] | kWh/kg (kg $H_2$/kg system) | 1.5 (0.045) | 1.8 (0.055) | 2.5 (0.075) |
| System Volumetric Capacity: | | | | |
| Usable energy density from $H_2$ (net useful energy/max system volume) | kWh/L (kg $H_2$/L system) | 0.9 (0.028) | 1.3 (0.040) | 2.3 (0.070) |
| Storage system cost [b] | $/kWh net ($/kg $H_2$) | 10.00 400 | 9.00 333 | 8.00 267 |
| (& fuel cost) | $/gge at pump | 3-7 | 2-6 | 2-4 |
| Durability/Operability | | | | |
| • Operating ambient temperature [d] | ° C | -30/50 (sun) | -40/60 (sun) | -40/60 (sun) |
| • Min/max delivery temperature | ° C | -40/85 | -40/85 | -40/85 |
| • Operational cycle life (1/4 tank to full) [e] | Cycles | 1000 | 1500 | 1500 |
| • Min delivery pressure from storage system; FC= fuel cell, ICE= internal combustion engine | bar (abs) | 5FC/35 ICE | 5FC/35 ICE | 3FC/35 ICE |
| • Max delivery pressure from storage system[g] | bar (abs) | 12 | 12 | 12 |
| • Onboard Efficiency | % | | | 90% |
| • "Well" to Powerplant Efficiency | % | | | 60% |

# Background – FreedomCAR and Fuel Initiative/US DRIVE – part 2

## Table 2 Technical Targets: On-Board Hydrogen Storage Systems [f]

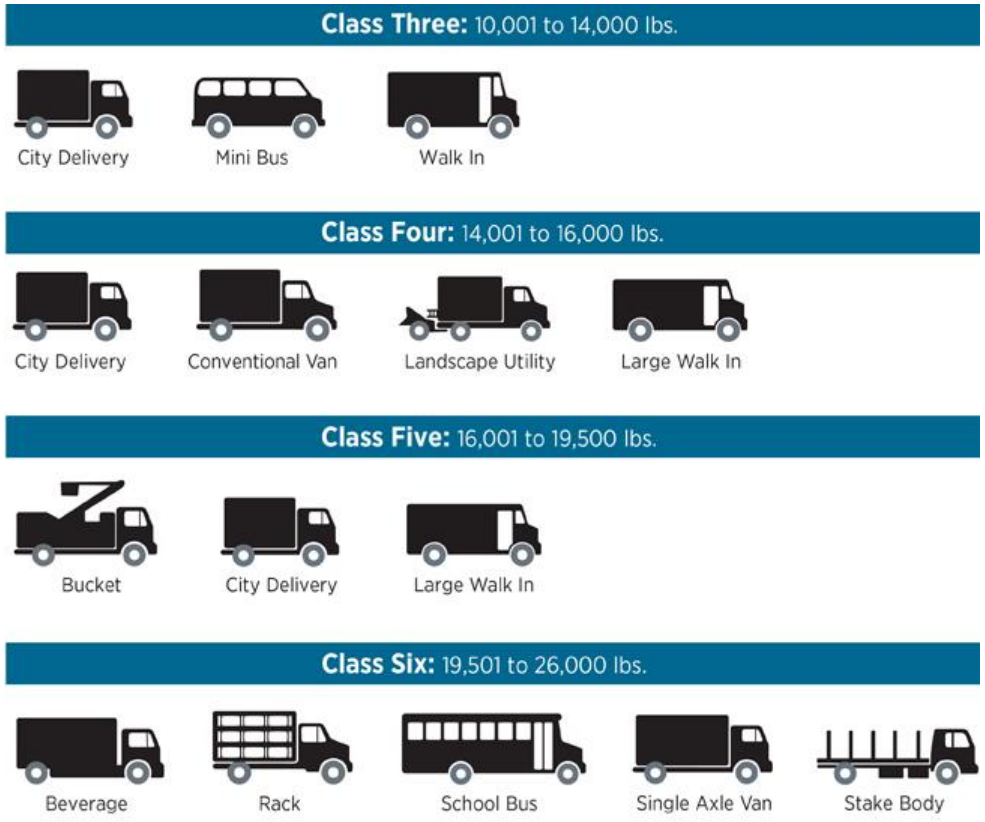
| Storage Parameter | Units | 2010 | 2015 | Ultimate |
|---|---|---|---|---|
| Charging/discharging Rates | | | | |
| • System fill time (for 5-kg H2) | min (kg $H_2$/min) | 4.2 min (1.2 kg/min) | 3.3 min (1.5 kg/min) | 2.5 min (2.0 kg/min) |
| • Minimum full flow rate | (g/s)/kW | 0.02 | 0.02 | 0.02 |
| • Start time to full flow (20ºC) h | s | 5 | 5 | 5 |
| • Start time to full flow (-20ºC) h | s | 15 | 15 | 15 |
| • Transient response 10%-90% and 90% -0%[i] | s | 0.75 | 0.75 | 0.75 |
| Fuel Purity ($H_2$ from storage)[j] | % $H_2$ | SAE J2719 and ISO/PDTS 14687-2 (99.97% dry basis) | | |
| Environmental Health & Safety | | | | |
| • Permeation & leakage [k] | Scc/h | Meets or exceeds applicable standards | | |
| • Toxicity | - | | | |
| • Safety | - | | | |
| • Loss of useable $H_2$ [l] | (g/h)/kg $H_2$ stored | **0.1** | **0.05** | **0.05** |

## Dispensed Hydrogen Cost Targets

| | Units | Early-market | Ultimate |
|---|---|---|---|
| $H_2$ Cost Target (produced, delivered, & dispensed) | \$/kg $H_2$ | 7 | 4 |

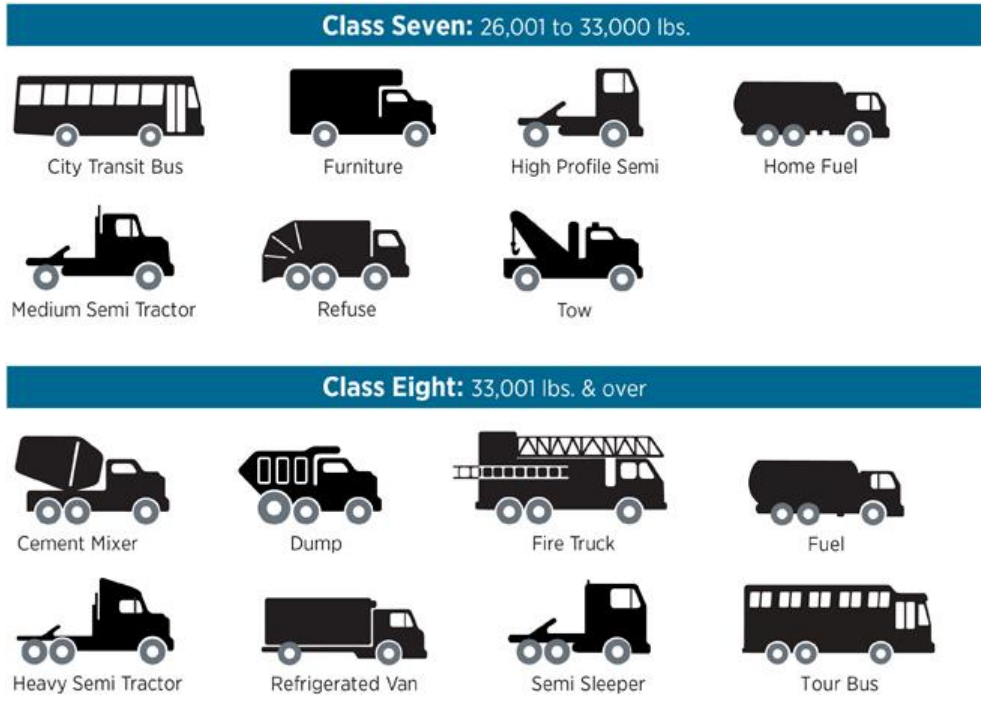
# New Reality – Variety of MD & HD Vehicle Classes and Vocations

## Medium Duty




https://afdc.energy.gov/data/10381

## Heavy Duty




- Federal Highway Administration classification
  - U.S. Census Bureau and Environmental Protection Agency also classify vehicles

# What Performance Metrics Should Be Developed?

| | MD/HD Trucks | | | Bus (350 bar) |
|---|---|---|---|---|
| **Onboard Capacity (kg $H_2$)** | **25** | **60** | **100** | **30** |
| Target range (miles) | 300+ | 300+ | 600+ | 300+ |
| Storage System mass (kg) | | | | |
| **Near-term** | 500 (5 wt%) | 1000 (6 wt%) | 1667 (6 wt.%) | 500 (6 wt.%) |
| **Ultimate** | 333 (7.5 Wt.%) | 750 (8 wt.%) | 1000 (10 wt.%) | 400 (7.5 wt.%) |
| Storage System volume (L, envelope) | | | | |
| **Near-term** | 833 (30 g/L) | 1700 (35 g/L) | 2850 (35 g/L) | 1667(18 g/L) |
| **Ultimate** | 700 (36 g/L) | 1580 (38 g/L) | 2630 (38 g/L) | 1400 (21.5 g/L) |
| Operational cycle life (minimum acceptable) | 5000 | 8000 | 8000 | 8000 |
| $H_2$ release rate (g/s/kW) | 0.02 | 0.02 | 0.02 | 0.02 |
| $H_2$ Delivery Pressures (bar) (fuel cell powered) | | | | |
| Minimum | 5 | 5 | 5 | 5 |
| Maximum | 12 | 12 | 12 | 12 |
| Ambient Operating Temp Range (°C) | $^{-}40$ - $^{+}85$ | $^{-}40$ - $^{+}85$ | $^{-}40$ - $^{+}85$ | $^{-}40$ – $^{+}85$ |

Strictly as examples!

# What Performance Metrics Should Be Developed?

| | MD/HD Trucks | | | Buses |
|---|---|---|---|---|
| **Onboard Capacity (kg $H_2$)** | **25** | **60** | **100** | **30** |
| Storage System Cost ($/kg $H_2$) | | | | |
| **Near-term** | *300 ($9/kWh)* | *300 ($9/kWh)* | *300 ($9/kWh)* | *250 ($7.5/kWh)* |
| **Ultimate** | *267 ($8/kWh)* | *267 ($8/kWh)* | *267 ($8/kWh)* | *225 ($6.75/kWh)* |
| Fuel Cost ($/kg $H_2$ dispensed) | | | | |
| **Near-term** | 7 | 7 | 7 | 7 |
| **Ultimate** | 4 | 4 | 4 | 4 |
| Fill time (minutes) | | | | |
| **Near-term** | 10 (2.5 kg/min) | 15 (4 kg/min) | 15 (6.7 kg/min) | 12 (2.5 kg/min) |
| **Ultimate** | 5 (5.0 kg/min) | 10 (6 kg/min) | 10 (10 kg/min) | 7.5 (4 kg/min) |

Strictly as examples!

**Challenge for the workshop participants:**

- What are the key vehicle types and duty cycles that the program should focus on?
- What key property or process should performance metrics be developed around?
- What are the key technology elements for which performance and cost improvements are needed to meet the targeted performance metrics?
- What is the prioritization of the RD&D needs, with consideration of deployment timelines, to enable successful deployment of the technology?

# Workshop Objectives

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# Breakout Sessions and Targeted Outcomes

- Day 1 – Two breakouts, with a whole group discussion in between
  - Breakout discussions divided between onboard and offboard applications
  - Targeted Outcome:
    - Identification of top vehicle classes/vocation for DOE focus with station configurations and needs to meet vehicle requirements
    - Identification of key performance metrics for onboard and offboard RD&D efforts
- Day 2 – Breakouts and whole group discussions are TBD
  - Targeted Outcome:
    - Identification of key RD&D needs to meet station and vehicle performance metrics;
    - Prioritization of RD&D activities, with consideration of deployment timelines and impact of the deployment

# Items That Will Not Be Discussed

- There are several current, active solicitations (FOAs, SBIR/STTR, Lab Calls, etc.) with similar or related topics, the DOE will not discuss anything related to any currently active solicitation

- 45V – Tax Credit for Clean Hydrogen Production: Comment period for the Notice of Public Rulemaking closed Feb. 26th. DOE will not comment on anything related to the proposed 45V regulations.

# Thank You for Your Participation

- **Your expert input is highly valued**
- Feedback from this workshop will help set the stage for the program's activities for the next 5 to 10 years, so **it is important to "get it right"**
- The goal is to **enable successful deployment of clean, low-carbon hydrogen that meets the needs of the MD/HD Transportation sector**

# Thank You

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