Heavy-duty Hydrogen Fueling Station Corridors

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**Project Goal**

Assess infrastructure costs and needs to meet hydrogen fueling demand for transportation in the Medium- and Heavy-duty vehicle (M/HDV) sectors in order to support development of hydrogen refueling corridors in the United States

**Objectives**

- Identify datasets and develop methodologies to analyze freight demand, infrastructure needs, and load and operation requirements
  - Forecast national freight demand with origin/destination information
  - Identify strategic locations for refueling deployments
  - Calibrate models for comprehensive and accurate infrastructure analysis
  - Propose a nationwide hydrogen M/HDV infrastructure expansion at minimum cost
Overview

Timeline and Budget

• Project Start Date: 10/22
• Project End Date: 09/23
• NREL’s Project Budget: $300K
  • Total DOE Share: 100%
• FY 2023: $300K

Barriers and Targets

• Project closes the information/knowledge gap barrier
  • for strategic M/HD vehicle infrastructure deployment with respect to location, volume, and station type (e.g., gaseous or liquid)
  • for most economic pathway for M/HD hydrogen vehicles adoption
• Project targets to support DOE’s freight vehicles infrastructure planning efforts and accelerate zero-emission vehicles adoption in the United States

Partners

• NREL’s project lead: Mark Chung, NREL
• Co-PI(s): N/A
• Partner organization(s) and role(s)
  • LBNL: EV demand/adoption, infrastructure analysis and deployment, demand-side datasets
NREL’s **SERA** and LBNL’s **HEVI-LOAD** models combine forces to solve ZEV infrastructure needs

- **Goal**: Assess the near- and long-term infrastructure needs by M/HD zero-emission vehicles (ZEV) over national freight corridors using HEVI-LOAD.
- HEVI-LOAD is a software tool that can project the charging M/HD infrastructure type, quantity and optimal deployment locations
- In this project, HEVI-LOAD is augmented to provide infrastructure assessment over the national freight corridors

- **Project part of** *Medium- and Heavy-Duty Electric Vehicle Load, Operations, and Deployment (HEVI-LOAD) Augmentation for National-Scale Infrastructure Assessment* project
• In 2020, M/HD vehicles emitted ~413 MMT CO2e
  • based on 317,245 million vehicle miles traveled
• Depending on the source of electricity and hydrogen production path, M/HD vehicle emissions could be nearly zero
• Major metrics for assessment
  • Split ratio of hydrogen fuel cell vs. battery electric vehicle for future scenarios
  • Hydrogen refueling parameters
    • Storage and dispensing capacity
    • Maximum fueling rate
    • Maximum allowable pressures
    • Type of supply
    • Footprint

Note: Numbers have been rounded
Potential Impact

1. Facilitate development and early adoption of hydrogen fueling corridors nationally
2. Calculate levelized cost of dispensed hydrogen under a few scenarios which could be used by industry in planning of station and/or fleet deployment
3. Accelerating decarbonization of the M/HDV hydrogen fleet
4. Inform other similar transportation studies, regionally, or internationally
Approach

Assessments of freight traffic along major corridors and assumptions on refueling time, onboard storage quantity, adoption rates, travel range, vocations, fuel economy, etc. will inform analysis as to how to optimize station placement and sizing.

- Leveraging previous Market Segmentation Analysis* findings and data
- Using Scenario Evaluation and Regionalization Analysis (SERA) model, informed by Heavy-duty Refueling Station Analysis Model (HDRSAM)

SERA model simulates least-cost hydrogen infrastructure supply systems for FCEV markets

- Energy prices (natural gas, electricity, etc.)
- Renewables (biomass, solar, wind)
- Terrain, rights of way, etc.
- Central and onsite production facilities
- Capacity sized to meet forecasted demand
- Economies of scale balanced with delivery costs
- Truck delivery, rail, and pipeline
- Cost is sensitive to volume, distance
- Seasonal and weekly storage
- Networked supply to multiple cities
- Coverage stations for FCEV introductions
- Station sizes increase with market growth
- Liquid and pipeline delivery networks compete for large stations

Source: https://www.nrel.gov/hydrogen/sera-model.html
Previously in Market Segmentation Analysis

Operation Data Summary

- **Weight-Limited (Class 8 Tractors)**
  - Polk adjusted VIUS analysis indicates 33% of Class 8 tractor fuel usage could be used by tractors that weigh-out
  - NACFE (2015) indicates 2-10% of Class 8 tractors may weigh-out
  - Schoettle et al. (2016) survey indicates 54.6% of Class 8 tractors may weigh-out

- **Multi-Shift (Class 8 and Class 4)**
  - VIUS (2002) indicates 13% of Class 8 tractor fuel usage could be used by tractors multi-shift; ~1% for Class 4 Parcel Delivery
  - Schoettle et al. (2016) survey of Class 8 tractors reports 6.2% of routes are long-haul team-drivers, 34.4% are long-haul with overnight stays
  - **Class 8** is the most likely targeted vehicle class

Accomplishments and Progress: Data Collection

- Assessing key metrics for the analysis: **mileage** for near- and long-term future
- Low and high scenarios for Class 6 box truck is represented by Class 8 and Class 4 box trucks
- Potential increase of up to 50% in each category to an ultimate ~20 mi/gge in 2050 for Class 4 Box truck
- Fuel economy goal of 12.4 mi/kg H₂

Notes and Source:
- Data informed by Argonne National Laboratory, 2022, A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential
- 1 kilogram of hydrogen is 1 gallon of gasoline equivalent (gge)
Accomplishments and Progress: Data Collection

- Assessing key metrics for the analysis: **fuel storage** for near- and long-term future
- Low and high scenarios for Class 6 box truck is represented by Class 8
- Fuel storage is predicted to be cut by roughly 25% by 2050 across the sleeper and day cab, and the box trucks
- Decrease of fuel storage occurs as fuel cell efficiency improves
- Fuel economy and storage significantly impact refueling station design and hence, refueling corridors development

![Chart showing fuel storage for different classes of trucks over time](chart.png)

Source: Data informed by Argonne National Laboratory, 2022, A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential
Accomplishments and Progress: Response to Previous Year Reviewers’ Comments

• This is a new project and was not reviewed in the any previous AMR
Collaboration and Coordination

• Collaboration with LBNL on the electric vehicle (EV) freight analysis using Medium- and Heavy-Duty Electric Vehicle Load, Operations, and Deployment (HEVI-LOAD) software tool
  • Align adoption scenarios and assumptions of simulation models
• Coordination with ANL on hydrogen refueling station cost parameters using latest HDRSAM assumptions

Check out LBNL’s oral presentation on 13th June at 2023 DOE VTO Annual Merit Review!
Remaining Challenges and Barriers

• Challenges are associated with obtaining high quality refueling stations cost data to adequately model their deployment with station parameter changes
• Uncertainty of future adoption rates of FCEVs vs. Alternative powertrain
• Uncertainty of costs of hydrogen and electricity
Proposed Future Work

• Coordinate with national labs to align assumptions to SERA and M/HDV (national/regional) adoption scenarios

• Hydrogen supply network analysis to evaluate the feasibility and cost-effectiveness of:
  • centralized production vs. decentralized production
  • pipeline vs. road transportation

• Economic analysis of hydrogen infrastructure including upfront investment, construction, maintenance, utilization rates, and operational cost, etc.

Note: Any proposed future work is subject to change based on funding levels
Summary

• Derived current and future FCEV parameters for Class 4, 6 and 8 to be used in HEVI-LOAD and SERA simulations
  • Mileage
  • Fuel storage
  • Full truck weight
• Hydrogen refueling stations cost parameters collection commenced and in the process of aligning SERA inputs with HDRSAM
• Modifications to SERA to prepare the model for running hydrogen refueling analysis
• Collaborating with PI laboratory on aligning various parameters and simulation data
Thank You

www.nrel.gov

NREL/PR-5400-86138
Technical Backup and Additional Information
• SERA, though currently a proprietary NREL model, may be made available to the public to use in the future.