Heavy-duty Hydrogen Fueling Station Corridors

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DOE Hydrogen Program
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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

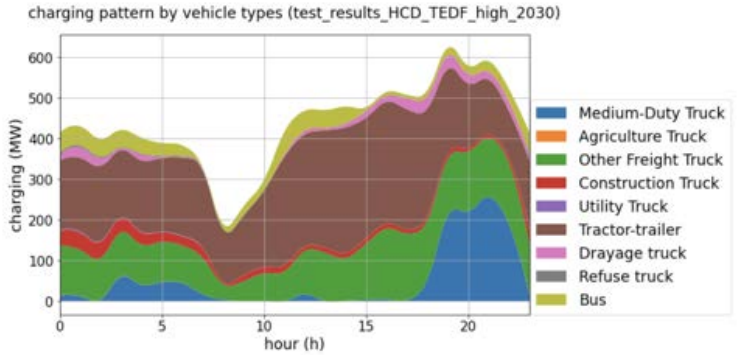
Partners

- 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

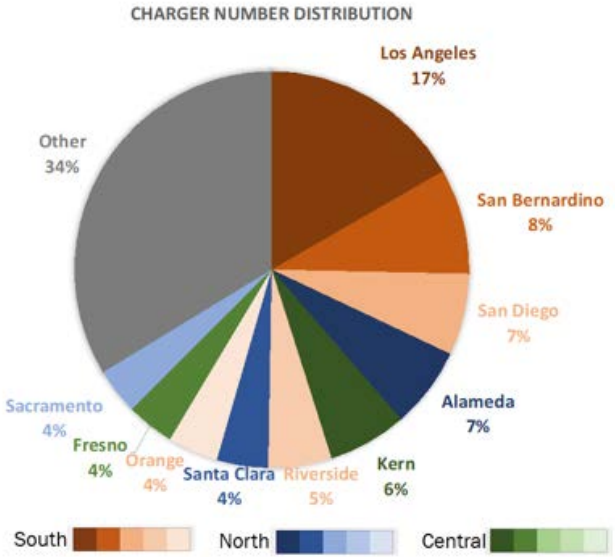
Barriers and Targets

- 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

NREL's *SERA* and LBNL's *HEVI-LOAD* models combine forces to solve ZEV infrastructure needs



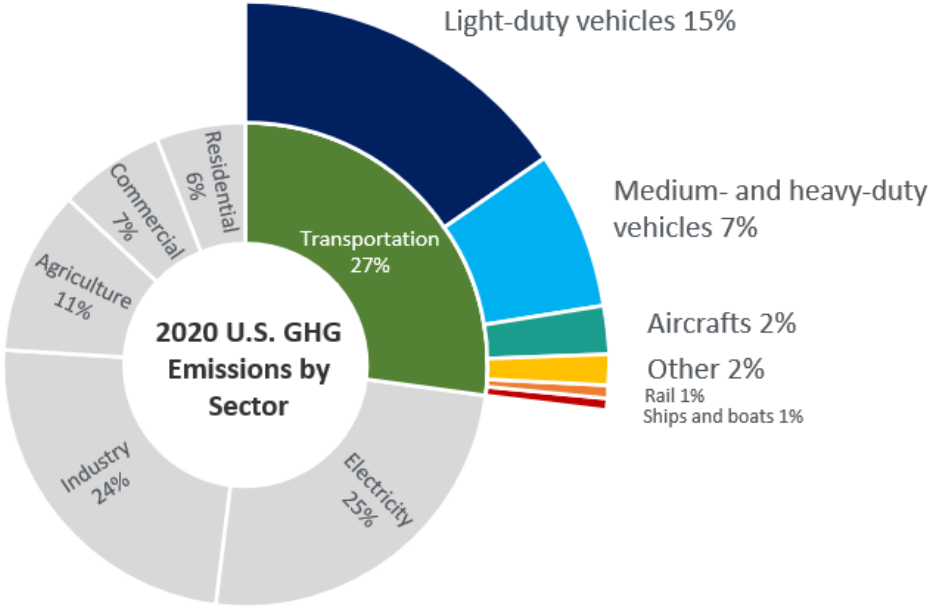
- Project part of ***Medium- and Heavy-Duty Electric Vehicle Load, Operations, and Deployment (HEVI-LOAD) Augmentation for National-Scale Infrastructure Assessment*** project



- **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

Motivation

- 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



Source: https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions
Note: Numbers have been rounded

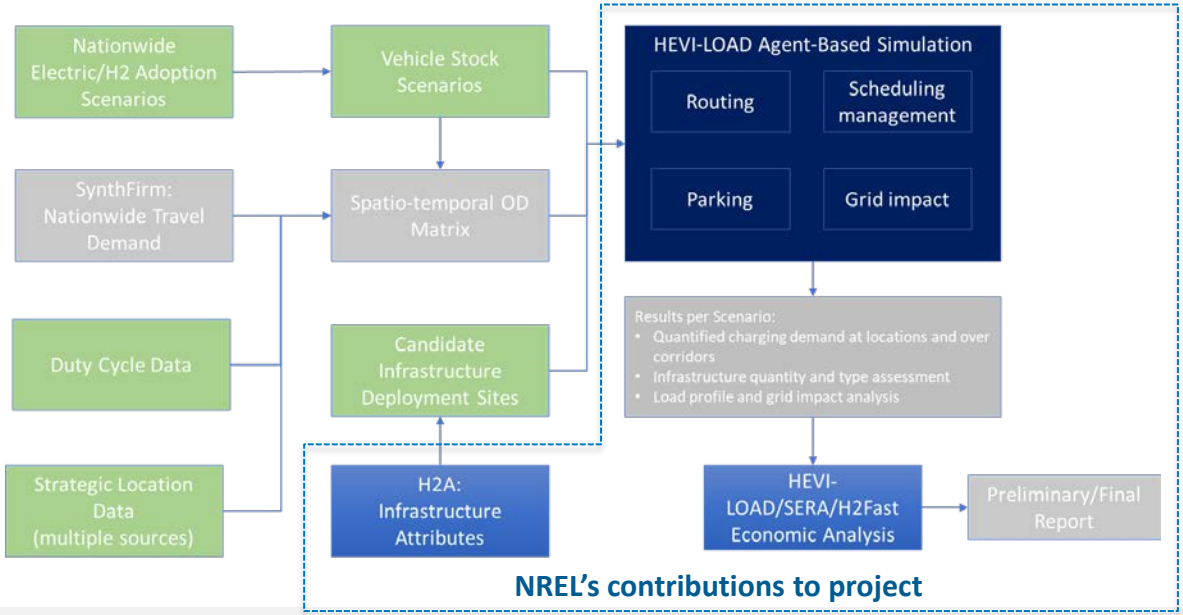
Potential Impact

Photo credit: iStock

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



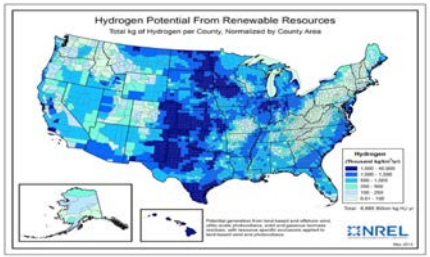
- Leveraging previous Market Segmentation Analysis[*] findings and data
- Using Scenario Evaluation and Regionalization Analysis (SERA) model, informed by Heavy-duty Refueling Station Analysis Model (HDRSAM)

Source: [*] https://www.hydrogen.energy.gov/pdfs/review21/sa169_hunter_2021_o.pdf

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

SERA

Energy Resources → **Hydrogen Production** → **Storage & Delivery** → **Refueling Station Networks**



- Energy prices (natural gas, electricity, etc.)
- Renewables (biomass, solar, wind)
- Terrain, rights of way, etc.

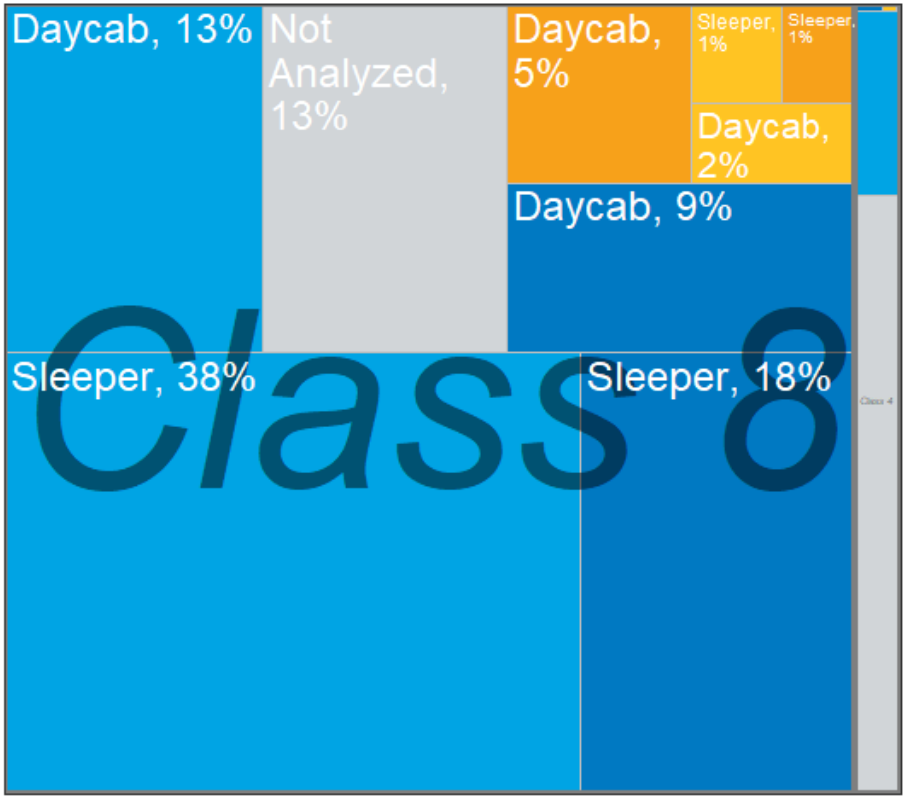
- Central and onsite production facilities
- Capacity sized to meet forecasted demand
- Economies of scale balanced with delivery costs

- 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

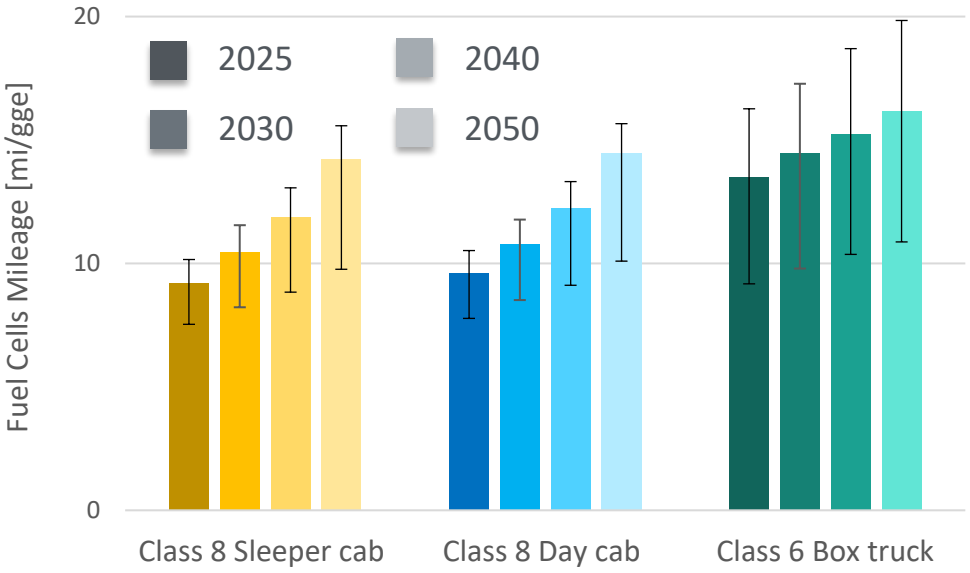


Operation Data Summary

- 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

Source: Hunter, C., et. al., 2021, Market Segmentation Analysis of Medium- and Heavy-Duty Trucks: A Total Cost of Ownership Approach, https://www.nrel.gov/docs/fy21osti/71796.pdf

Accomplishments and Progress: Data Collection



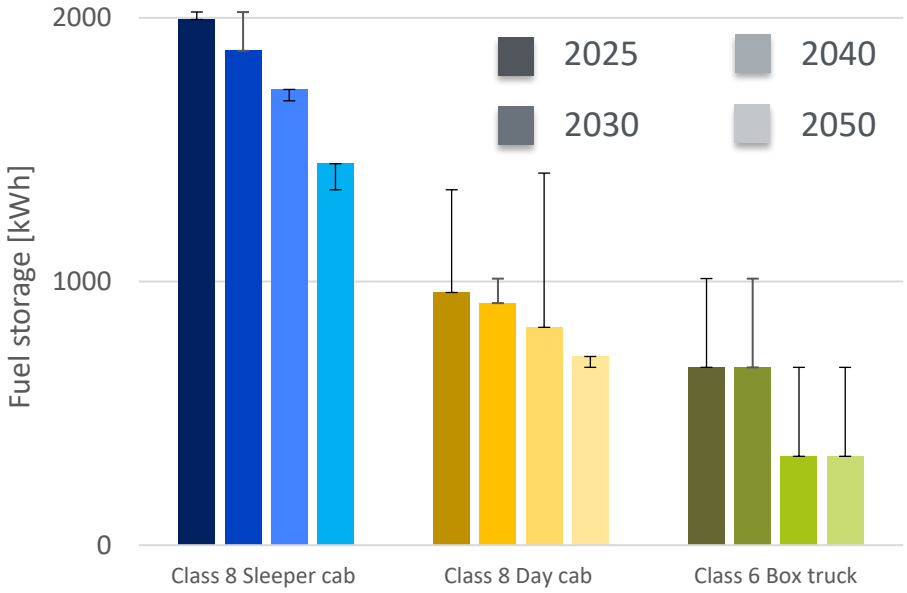
Notes and Source:

- Data informed by Argonne National Laboratory, 2022, A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential
- https://www.energy.gov/sites/prod/files/2020/02/f71/fcto-compressed-gas-storage-workshop-2020-adams.pdf
- 1 kilogram of hydrogen is 1 gallon of gasoline equivalent (gge)

- 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 H_2*

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



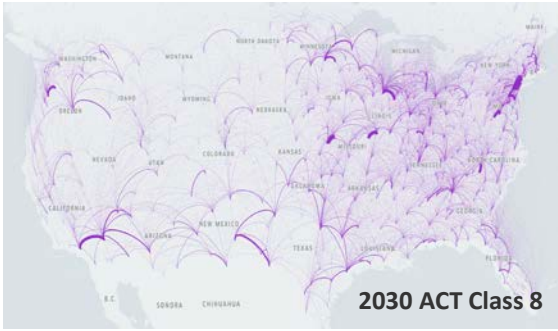
Source: Data informed by Argonne National Laboratory, 2022, A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential

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

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Technical Backup and Additional Information

Technology Transfer Activities

- SERA, though currently a proprietary NREL model, may be made available to the public to use in the future.