U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

DOE Compressed Gas Storage for Medium and Heavy-Duty Vehicle Applications Workshop

Dr. Ned Stetson, Program Manager– H_2 & Fuel Cell Technologies Office

Univ. of Dayton Research Institute

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Acknowledgements and many thanks to:

DOE Workshop Team:

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Presenters and Expert Panel Members:

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Office of Energy Efficiency and Renewable Energy

Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION

Energy Saving
HOMES, BUILDINGS, & MANUFACTURING

EERE Technologies Offices

Fuel Cells

Bioenergy

Solar Energy

Buildings

Manufacturing

Vehicles

Wind Energy

Water Power

Geothermal

Weatherization

EEERE offices involved with low-cost carbon fiber R&D

Notice of Intent to issue a Funding Opportunity released on 12/16/2019

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Notice of Intent (NOI)

Notice of Intent No. DE-FOA-0002231

Notice of Intent to Issue
Funding Opportunity Announcement No. DE-FOA-0002229

The Office of Energy Efficiency and Renewable Energy (EERE) intends to issue, on behalf of the Fuel Cell Technologies Office, a Funding Opportunity Announcement (FOA) entitled "H2@Scale New Markets FOA".

2) Advanced Carbon Fiber for Compressed Hydrogen and Natural Gas Storage Tanks
This potential area, coordinated with AMO and the Vehicle Technologies Office (VTO), would focus on R&D to reduce the cost of hydrogen and natural gas storage tanks through development of low-cost, high-strength carbon fiber (CF). Projects would seek to achieve targeted high-strength CF properties progressing from small, laboratory-scale to industry relevant scales. Applicants would be highly encouraged to partner with Oak Ridge National Laboratory's (ORNL) Carbon Fiber Technology Facility (CFTF) on the conversion optimization of precursor fibers to CF.

https://eere-exchange.energy.gov/#Foa1de84bbd2f-e759-4a66-979d-bd4f82bdc1e4

Hydrogen fuel cell electric vehicles are commercial

Enabled by prior public/private partnerships focused on technology R&D and cost reductions

Honda Clarity


Toyota Mirai

Over **8,000** | **sold or leased** in the United States

Hyundai Nexo

- **No petroleum, no pollution**
- **Refuels in minutes**
- **More than 360 mi driving range**
- **Over 60 mpgge**

New opportunities in medium and heavy-duty fleets

Industry demonstrates heavy-duty fuel cell trucks

Photo Credit: Toyota

ZH2: U.S. Army and GM collaboration


Photo Credit: General Motors

Fuel cell delivery and parcel trucks fleets

Photo Credit: UPS

Industry plans for extended H_2 infrastructure to support trucks

Photo Credit: Nikola

Fuel cell buses in California Surpass 20 million passengers

Photo Credit: NREL

Starting deliveries in CA and NY

Photo Credit: FedEx

Composite multi-modal containers for transport and stationary storage

Photo Credit: NPROXX

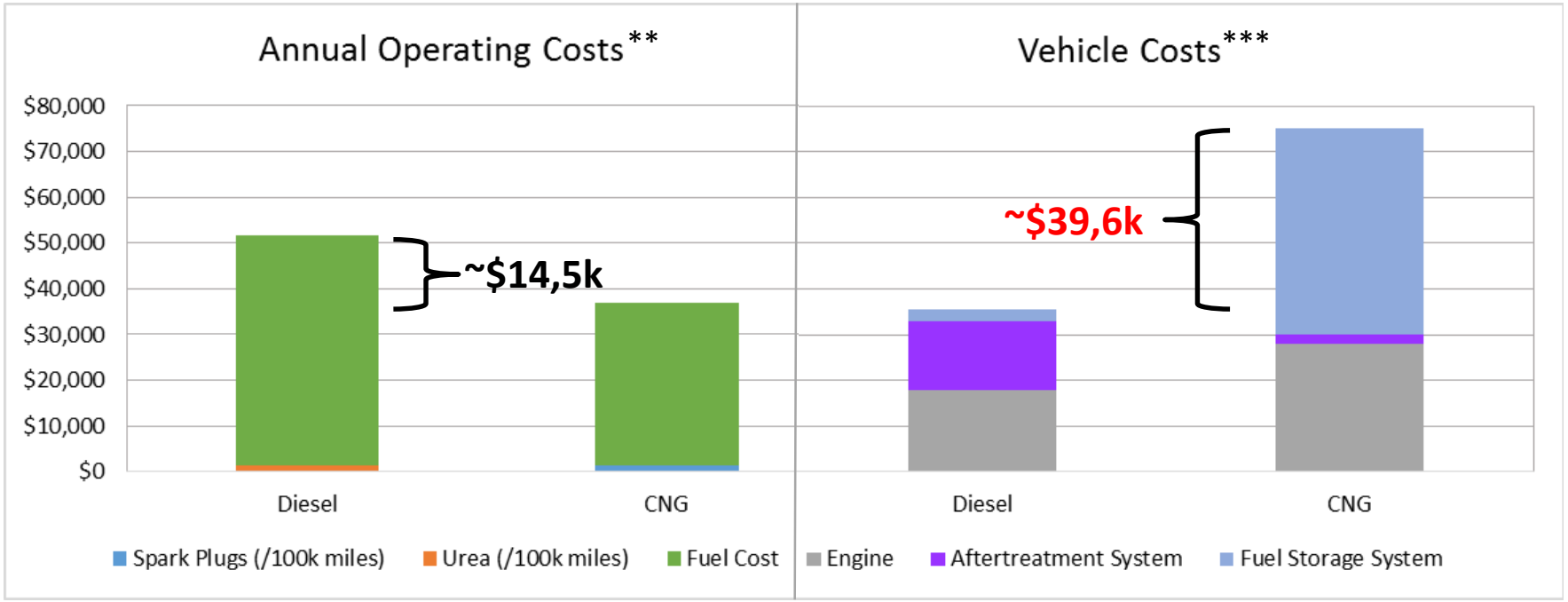
Composite tube trailers for bulk transport


Photo Credit: HexagonLincoln

Fiber reinforced pipeline for low-cost infrastructure

Comparative cost analysis of diesel-baseline vs CNG class 7/8 trucks at 100k miles/yr *

** Preliminary findings, analysis ongoing*
Additional components to be added



*** Factors not fully considered in current analysis:*

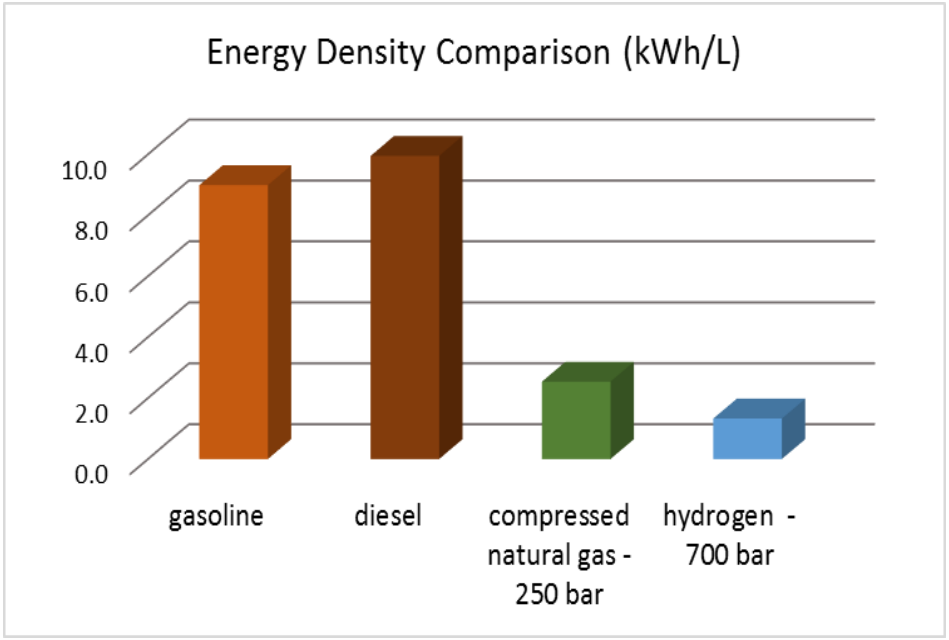
- *Infrastructure costs vary fleet to fleet, some fleets pay for own NG refueling, will integrate into finalized numbers*
- *Maintenance shop upgrade costs for NG vehicles not captured ($100K/ bay*
- *Weight impact for CNG tanks is minor difference in fuel efficiency*

**** Fuel Cost:*

- *~$1 differential; ULSD $3.15, CNG $2.18 GGE;*
- *15% eff. penalty for CNG included*

Challenge of gaseous fuels

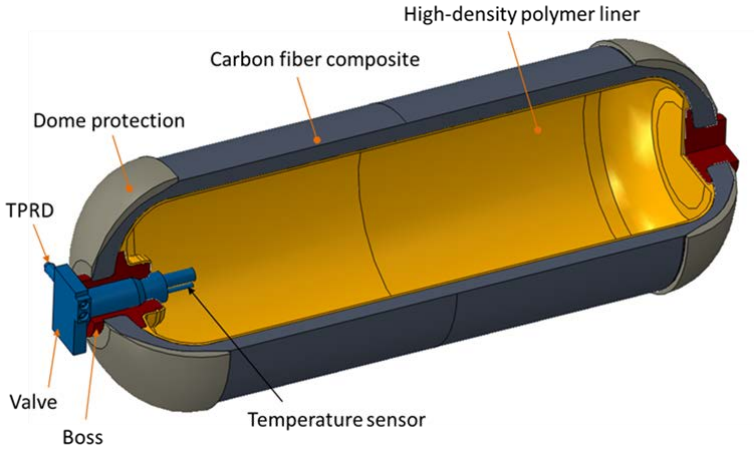
Very Low Energy Density



Even when compressed to high pressures, H_2 and Natural Gas have low energy by volume compared to most other fuels!

Gaseous fuel tanks onboard vehicles are larger than typical gasoline tanks

Hydrogen and Natural Gas are stored in Composite Overwrapped Pressure Vessels



Hydrogen and Natural Gas are low-density gases under all practical conditions on earth

700 bar current status vs. onboard targets

Storage Targets	Gravimetric kWh/kg (kg H_2/kg system)	Volumetric kWh/L (kg H_2/L system)	Costs [1] $/kWh ($/kg H_2)
2020	1.5 (0.045)	1.0 (0.030)	$10 ($333)
2025	1.8 (0.055)	1.3 (0.040)	$9 ($300)
Ultimate	2.2 (0.065)	1.7 (0.050)	$8 ($266)
Current Status [2]			
700 bar compressed (5.6 kg H_2, Type IV, Single Tank)	1.5 (0.044)	0.8 (0.025)	$16 ($533)

The full set of H_2 storage targets can be found on the Program's website:
https://energy.gov/eere/fuelcells/downloads/doe-targets-onboard-hydrogen-storage-systems-light-duty-vehicles

[1] Projected at 100,000 units/year; current costs reported in 2016$

[2] FCTO Data Record #19008, 11/25/2019: https://www.hydrogen.energy.gov/pdfs/19008_onboard_storage_cost_performance_status.pdf

Questions to consider during the workshop

- Performance gaps and technology metrics for compressed gas storage in medium and heavy-duty transportation applications
  - Topics to consider could include, but not be limited by:
    - Expected life, and should it be by fill cycles, miles or time
    - Mass and volume limits
    - Fill time/rate
    - Special consideration due to mounting location
- R&D needs for compressed gas storage in medium and heavy-duty transportation applications and DOE's role in addressing those needs
  - Other than cost reduction, what should be R&D focus areas?
  - Should conformable systems be investigated?
  - Should other storage technologies (e.g., cryogenic or materials) be considered?
  - Are there codes and standards and regulatory barriers?

New ORISE Fellow position available

Position with the Hydrogen Technologies Storage Team

Expertise with technologies relevant to carbon fiber composites for COPVs

"Selected candidates will be members of the FCTO and engage in activities critical to FCTO's Hydrogen Storage Program mission. The research project will focus on the area of carbon fiber composite and compressed hydrogen storage tank systems within the Department of Energy's EERE-FCTO."

Qualifications sought:

A **PhD in Mechanical Engineering** (with a concentration on strength of materials) or **Polymer Science** or a related area is preferred. Candidates with a PhD in **other physical and materials science fields will be considered**. Candidates with experience in the carbon fiber composites and compressed hydrogen and natural gas storage tank system industries will be given preference.

https://www.zintellect.com/Opportunity/Details/DOE-EERE-STP-FCT-2020-1801

Thank You

Dr. Ned Stetson
Hydrogen Technologies Program Manager
Hydrogen and Fuel Cell Technologies Office
Ned.Stetson@ee.doe.gov

energy.gov/eere/fuelcells