



Natural Gas Vehicles

Opportunities and Challenges in the Transportation Sector

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Shale Gas Plays in the United States

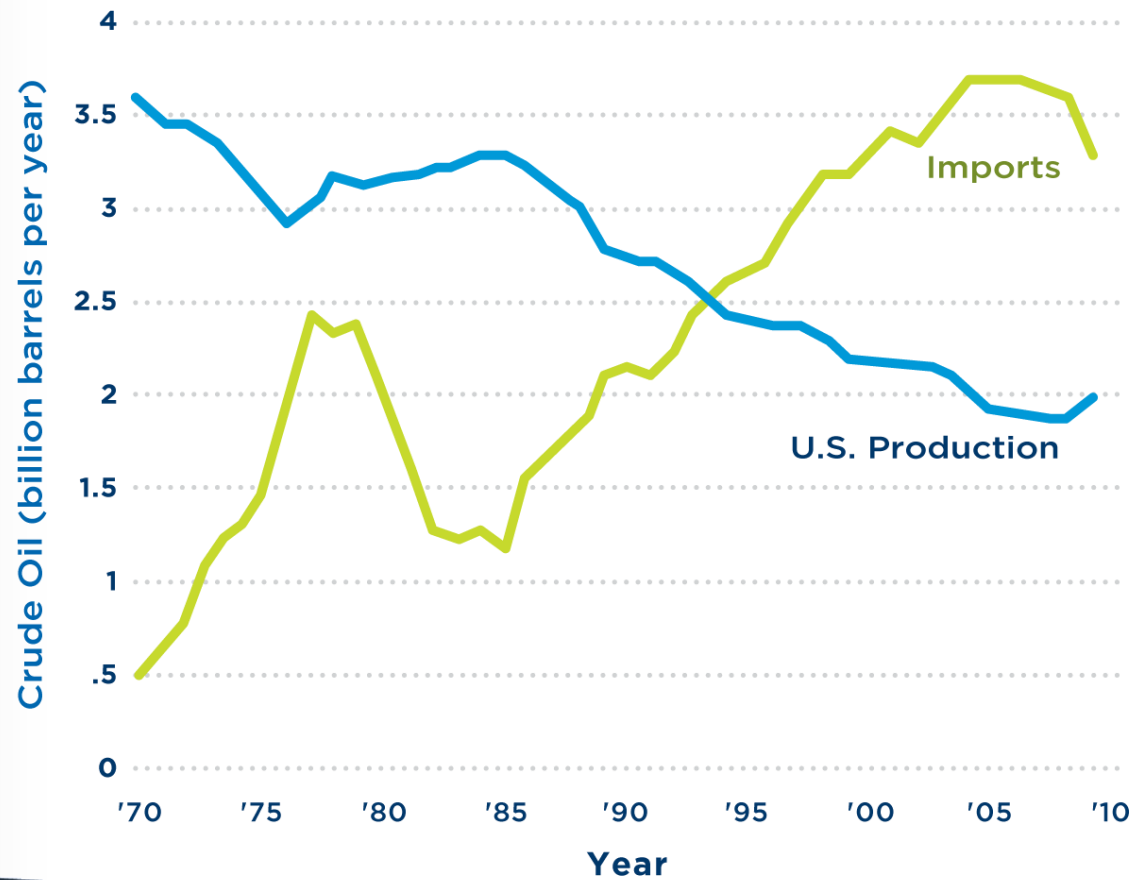


Source: U.S. Department of Energy, Energy Information Administration

Other nations are realizing the potential of natural gas vehicles and moving forward.

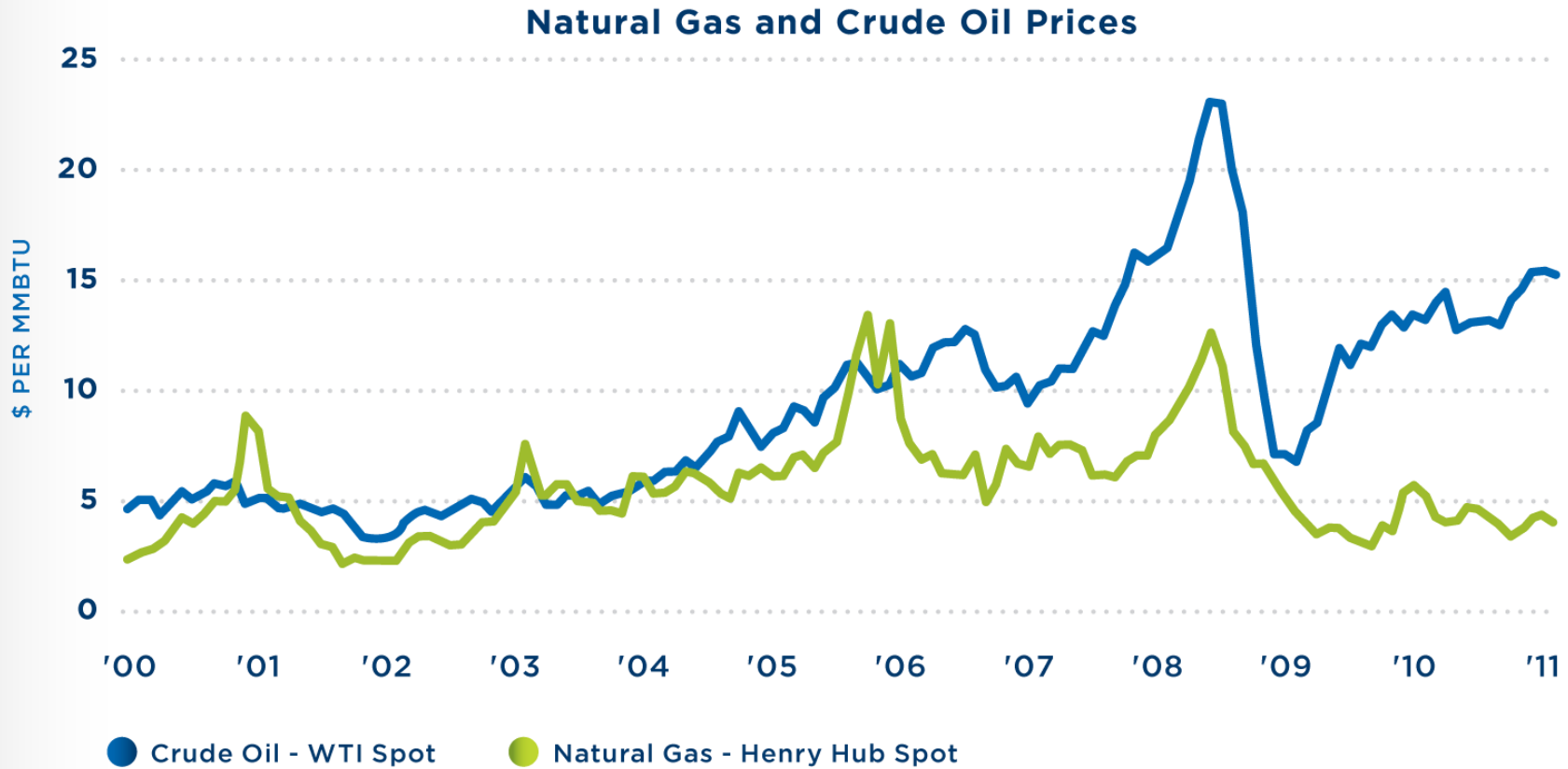


Our dependence on foreign oil has increased over the past decades



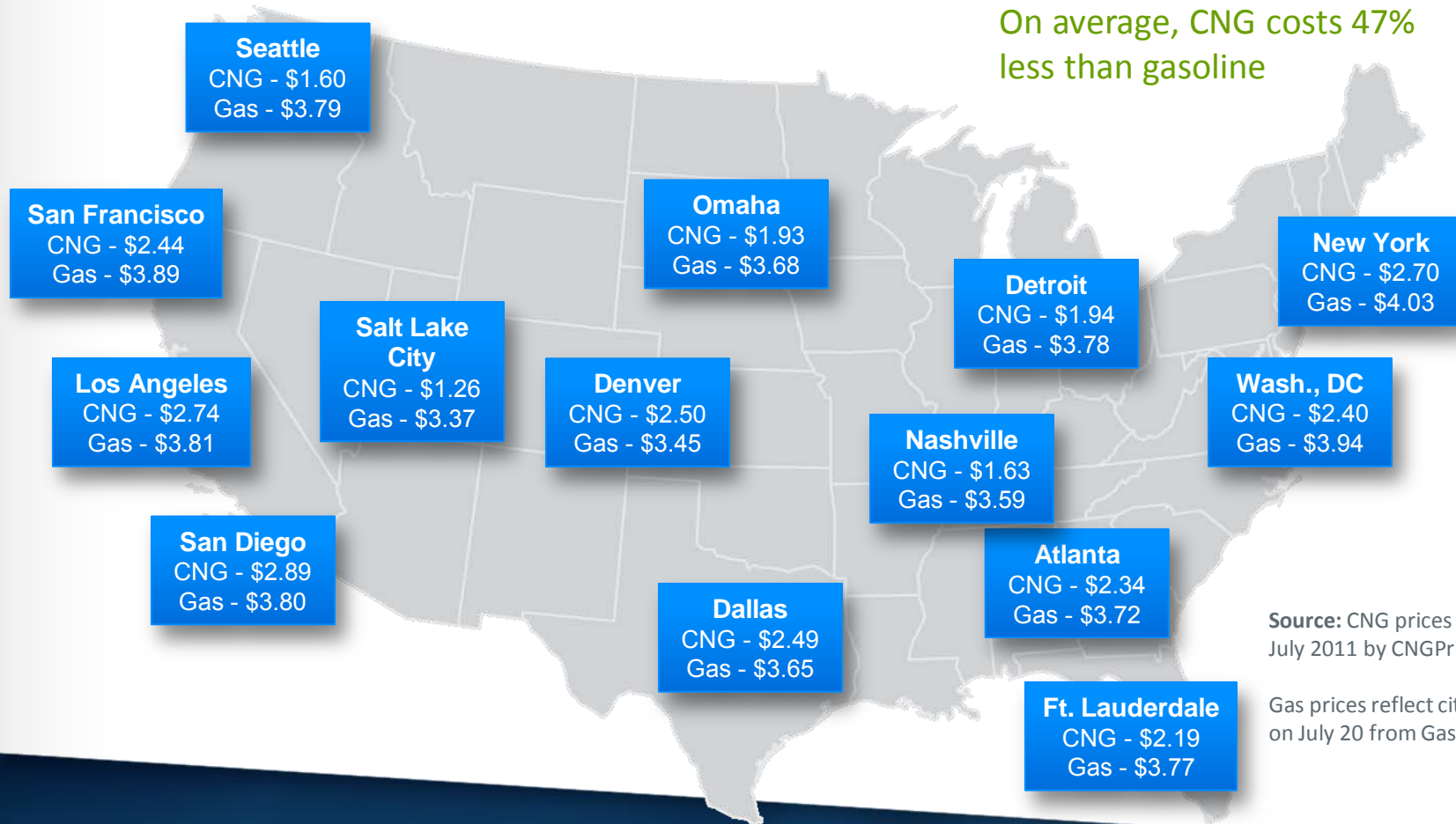
Last year, the United States imported 1.5 billion barrels of oil from dangerous, unstable nations.

The new abundance of natural gas has changed our energy landscape – natural gas prices are independent of oil prices.



Natural gas vs conventional gasoline

On average, CNG costs 47% less than gasoline



Source: CNG prices captured in July 2011 by CNGPrices.com

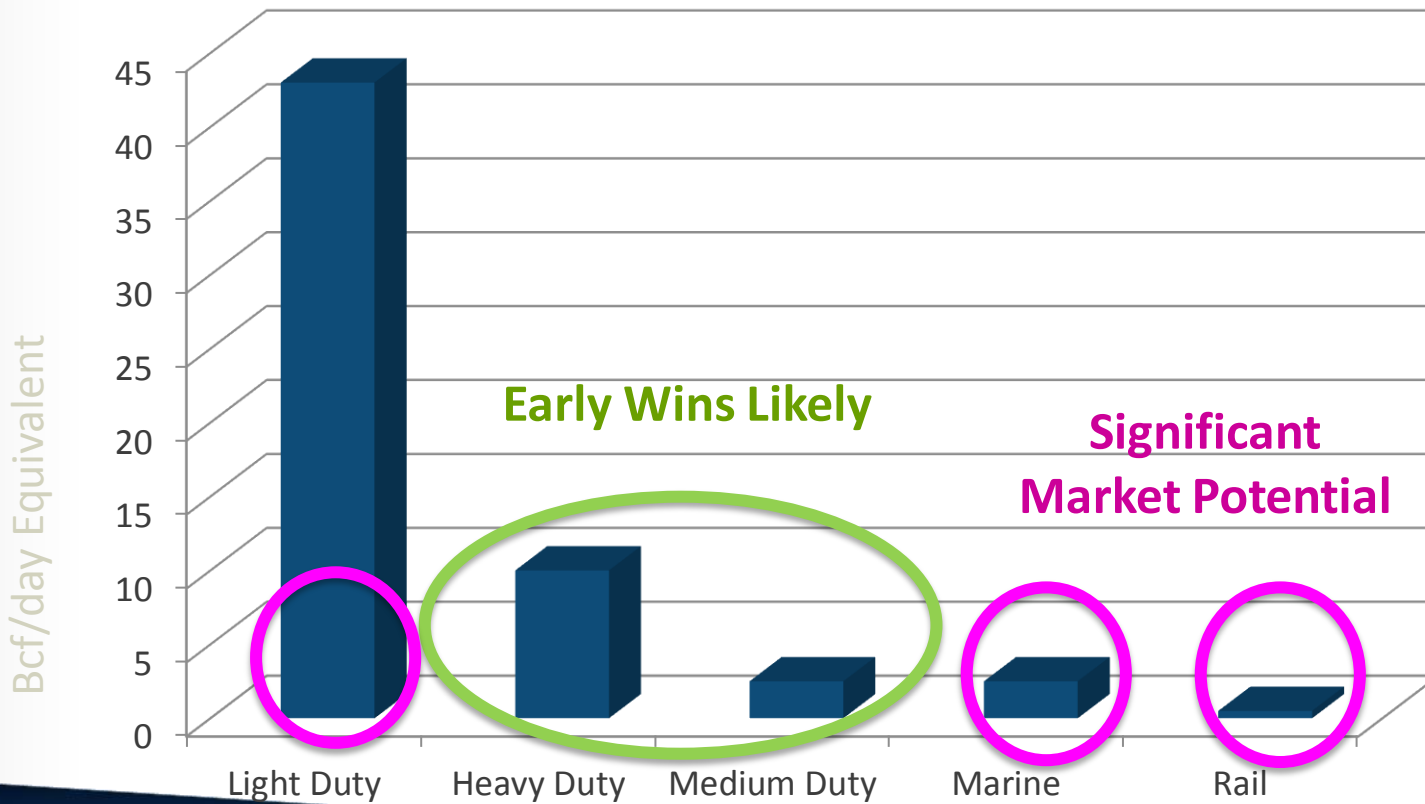
Gas prices reflect city average on July 20 from GasBuddy.com

Momentum is Building for NGVs in North America

IDENTIFYING THE OPPORTUNITIES

Fuel Consumption by Transportation Market Segment

Total Transportation Energy Market Equivalent to 61.6 Bcf/day



Major vehicle manufacturers are *bringing NGVs to the North American market*

Medium and Heavy Duty



Light Duty



HONDA



CHRYSLER



Leading the Way: NGVs in Fleets Across America



- Waste Management announced on May 11th it will convert its entire fleet – over 18,000 trucks – from diesel to CNG.
- UPS, AT&T, Comcast, Sysco, and Ryder have made significant commitments to NGVs in their national fleets.
- One-fifth of city transit buses run on natural gas today, and market share of is growing.
- More than 35 U.S. airports use NGVs in their fleets or encourage NGVs in private fleets operating on premises.



Recent OEM Announcements:

Bi-Fuel Pickup Trucks Hit the U.S. Market



Chevrolet Silverado and GMC Sierra 2500 (bi fuel)

- 650 miles of combined natural gas and gasoline range
- GM previously ended NGV production in 2006 – but is now returning.

Chrysler Ram 2500 (bi-fuel)

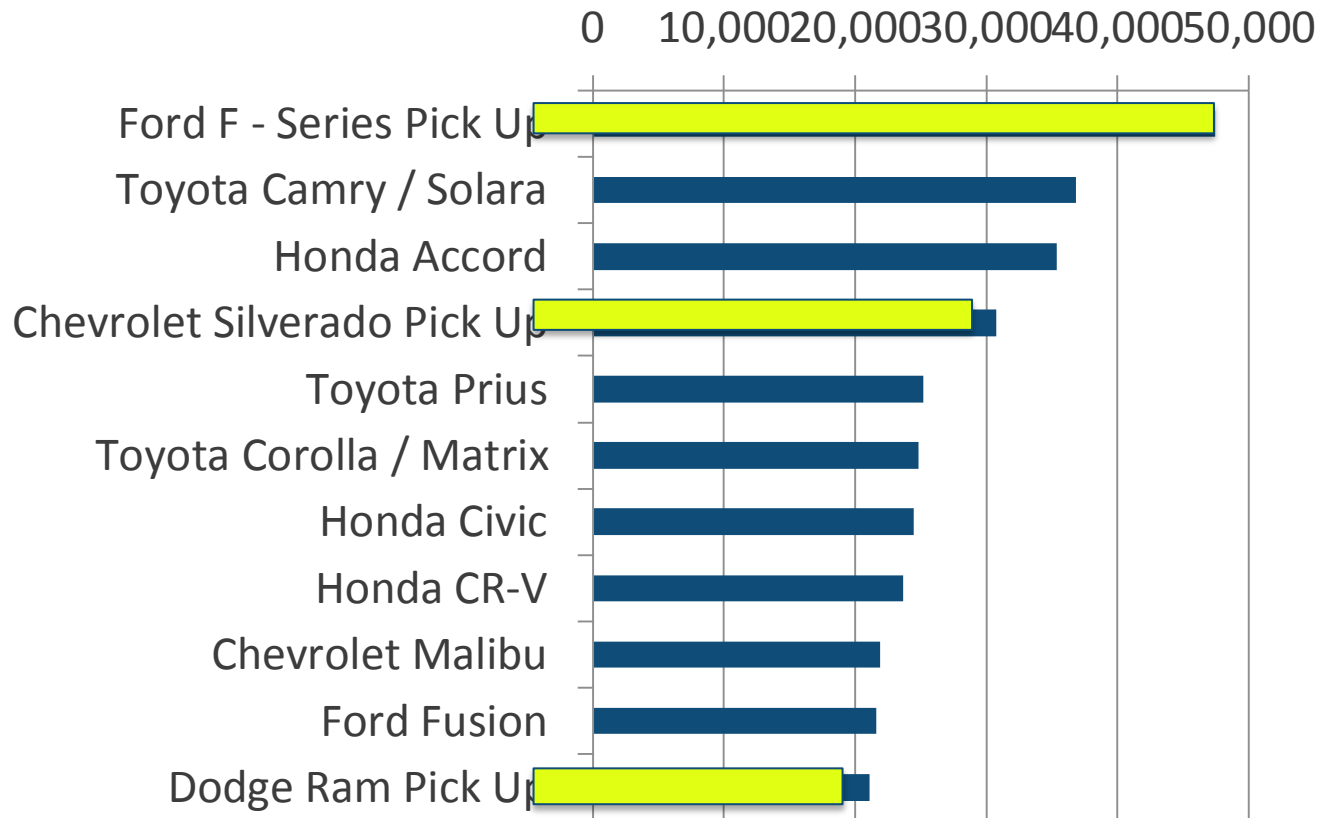
- America's only factory-built, CNG-gasoline bi-fuel pickup truck
- OEM built means more than \$6,000 in savings over comparable vehicle conversions.



In America, Trucks Matter

Not just to fleets, but to retail consumers as well

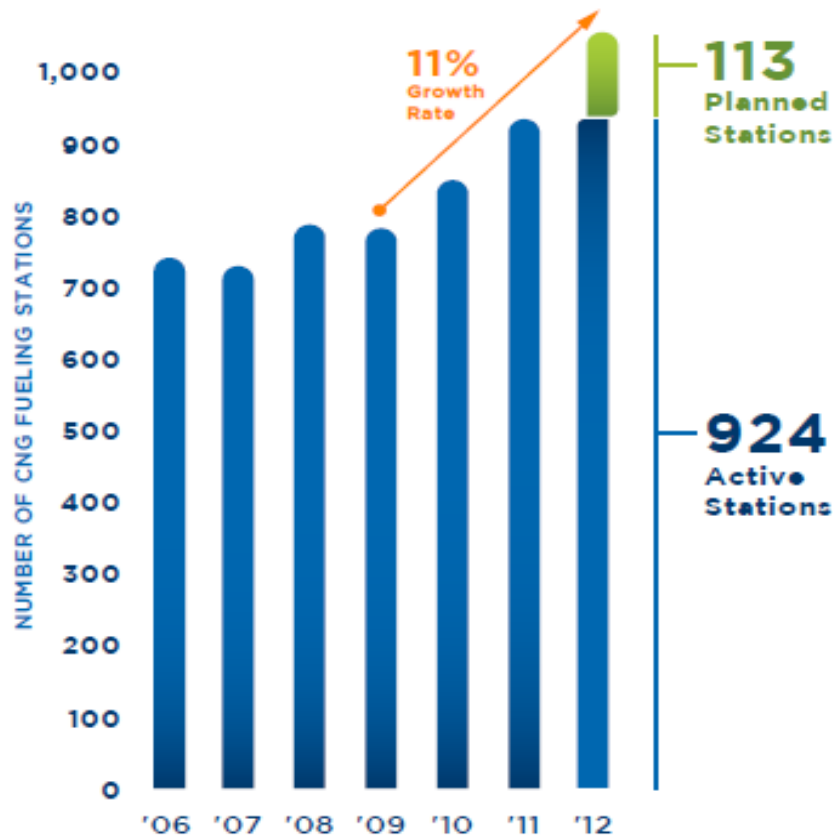
Top Selling Vehicles in U.S. Market, April 2012:



Total Units Sold, Source: Wall Street Journal

NGV Fueling Infrastructure

Our national CNG refueling infrastructure is growing each year.



Annual growth rate 11% over the period 2009 to 2012.

BUILDING A NATIONAL FUELING INFRASTRUCTURE

Progress along the Interstate Highway System



Challenges and Research Needs: Natural Gas Vehicles

- **Refueling Infrastructure**
 - Home refueling compressors
- **Vehicle Range**
 - Improved on-board fuel storage (e.g. novel materials)
- **Fuel Quality/Uniformity**
 - Long-term partnership between vehicle/engine manufactures and natural gas distributors; mitigation technologies may be needed (e.g. filters); research on NG combustion in vehicle engines
- **Quantifying/Reducing Emissions**
 - Emissions data needed for today's vehicles; longer-term strategies could include small scale carbon capture and storage, on-site H₂ reformation

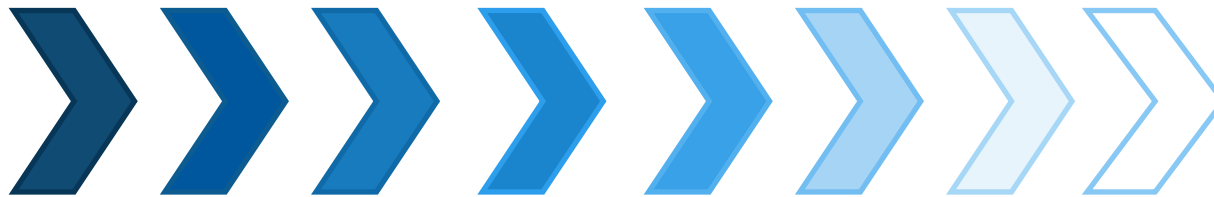
Linked Pathways to a Fuel Cell Vehicle Future

Natural Gas Vehicles

Novel gas storage technologies

On-site reforming

CNG/H₂ mixtures



Hydrogen
Fuel Cell
Vehicles

Electric drive technologies

Battery Electric Vehicles

Natural Gas Fuel Quality

- No recent data exist on natural gas quality at the point of refueling (Refueling can occur at a CNG station, or through a home refueling appliance.)
- There are no federal standards. Natural gas quality is controlled through specifications included in pipeline tariffs, designed to protect pipelines and ensure interchangeability.
- Water is especially problematic for NGVs; examples include hardware corrosion, valve plugging by methane hydrates, and simple volumetric displacement.

e.g., Honda has found pipeline gas in Ohio with water concentrations up to 20 times the typical tariff limit of 7 lbs/MMscf.



Questions or Comments

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