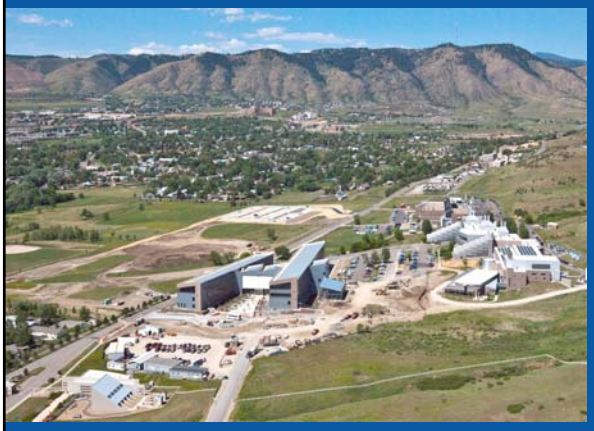
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Natural Gas Vehicles, Fueling Infrastructure, and Economics



EESI Natural Gas Briefing

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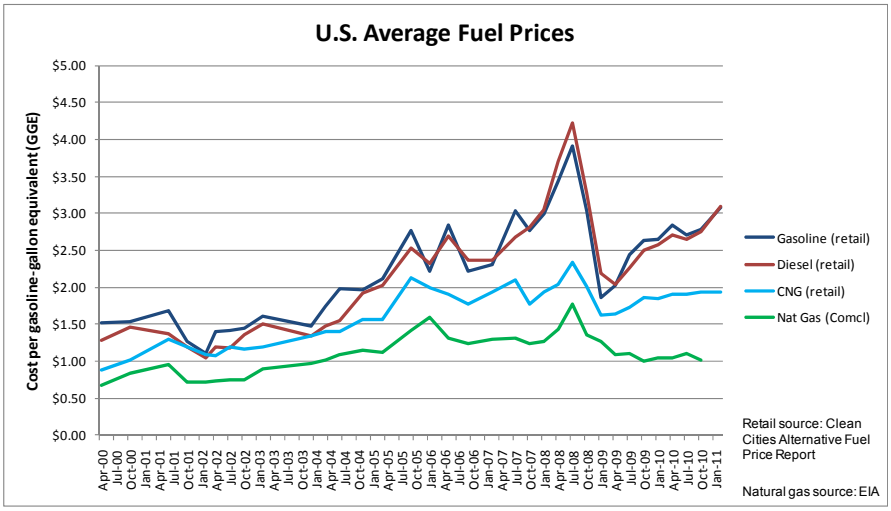
Why Use Natural Gas in Vehicles?

- Economics
  - Fuel prices
  - Vehicle attributes and industry
  - Infrastructure costs
  - Combined cash flow analysis
- Increased energy security
  - Natural gas is 98% from US and Canada
  - Compressed natural gas (CNG) reduces petroleum use by nearly 100% and liquefied natural gas (LNG) by 98% over its entire lifecycle*
- Reduced local air pollution
- Reduced greenhouse gas (GHG) emissions

*Source: Wang and Huang, 1999, www.ipd.anl.gov/anlpubs/2000/01/34988.pdf

Primary Driver: Fuel Cost Savings & Predictability



- Retail CNG is much less volatile than diesel and gasoline
  - Commercial natural gas is even less volatile

Natural Gas Vehicle (NGV) Industry

- Upfitters install the conversion kits
- Two conversion kit companies make bi-fueled kits (that can use gasoline)
- Each kit/engine combination requires Certificate of Conformity from the U.S. Environmental Protection Agency
- U.S Department of Energy and California agencies helping original equipment manufacturers (OEMs) develop new engines

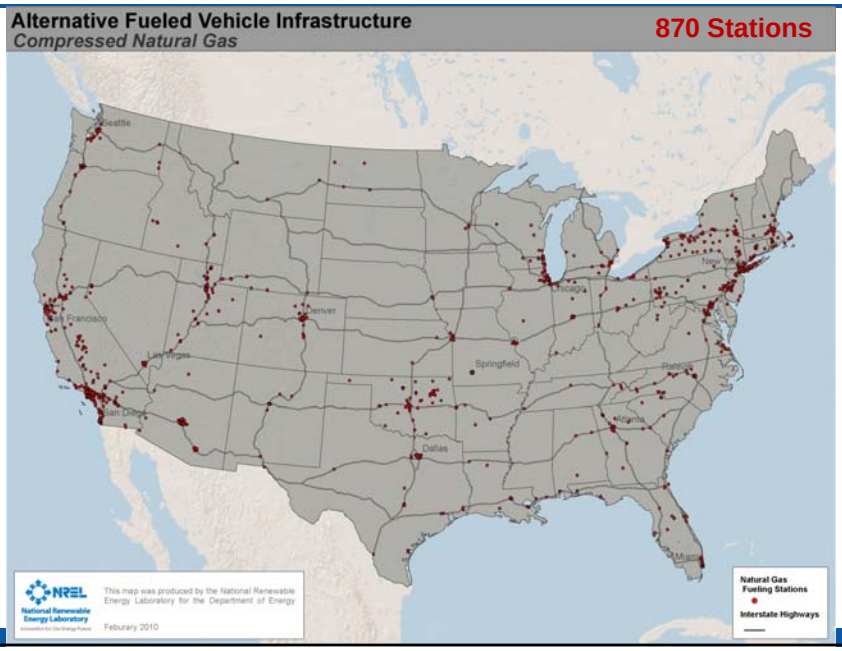
Company	Vehicle Weight
Original Equipment Manufacturers (OEM)	
Cummins Westport	Heavy
Westport Innovations	Heavy (18 Wheeler)
Honda	Light
Conversion Kit Manufacturers	
Altech-Eco	Light & Medium
BAF Technologies	Light & Medium
Baytech Corporation	Light & Medium
Emission Solutions Inc.	Light & Medium
FuelTek Conversion	Light & Medium
IMPCO Technologies	Light & Medium
NaturalDrive	Light & Medium
Prins	Light & Medium
Upfitters	
More than 100	Light & Medium

Cost Drivers for Natural Gas Vehicles

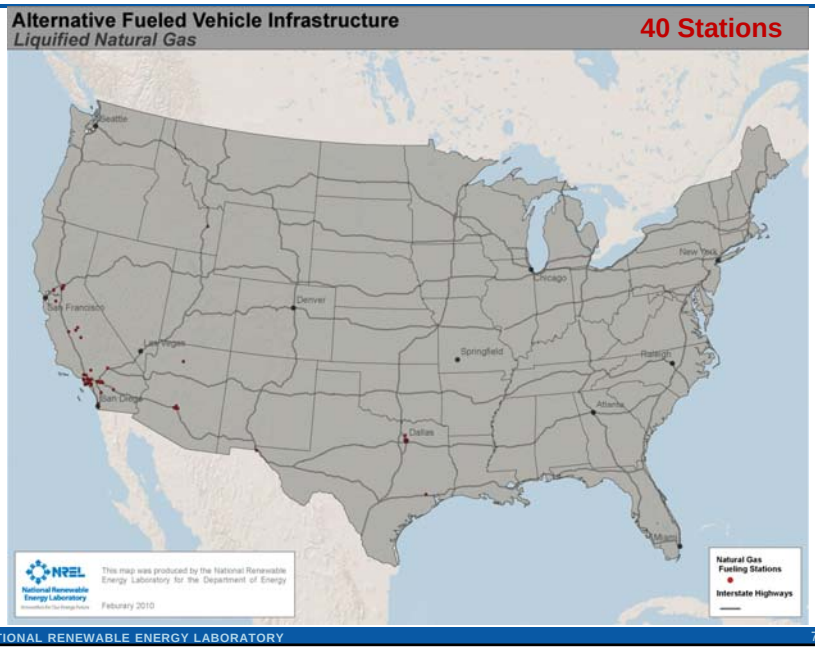
Natural Gas Vehicle Attributes & Cost				
Size	Light	Medium	Heavy	Heavy
Range	≤250 miles	250----------> 400		500+
Example	Commuting Sedan	Delivery Truck	Transit Bus	18-Wheeler
Tanks	Small CNG----------> Large CNG			LNG
Manufacturer	OEM & Conversion	Conversion	OEM	OEM
Incremental or Conversion Cost*	$7000----------->$50,000			

*Bookmark cost estimates come from Honda's "Build and Price" website (March 2011) and the Business Case for Compressed Natural Gas in Municipal Fleets (Caley Johnson, 2010). Incremental cost is the difference between petroleum-fueled vehicle and natural gas vehicle.

CNG Infrastructure



LNG Infrastructure



Cost Drivers for Refueling Infrastructure

Infrastructure Cost Drivers			
Cost Driver	**Range**		
Number of Vehicles	1----------->250		
Fuel per Vehicle	Low----------Medium----------> High		
Required Refueling Speed	Slow----------Medium----------> Fast		
Break between Vehicles	Long----------Medium----------> Short		
Station Type	Slow-fill CNG	Fast-fill CNG	Liquefy
Cost (CNG)*	$7,000----------->$4.5 million		
*Cost estimates are from a BRC Fuelmaker Phill representative and from the Business Case for CNG Vehicles in Municipal Fleets (Caley Johnson, 2010)			

- Compressors are generally the most costly part of a CNG station. More compressors are needed as the volume and speed of compression increases.
- Numerous companies will front the infrastructure cost in exchange for a CNG purchase contract.

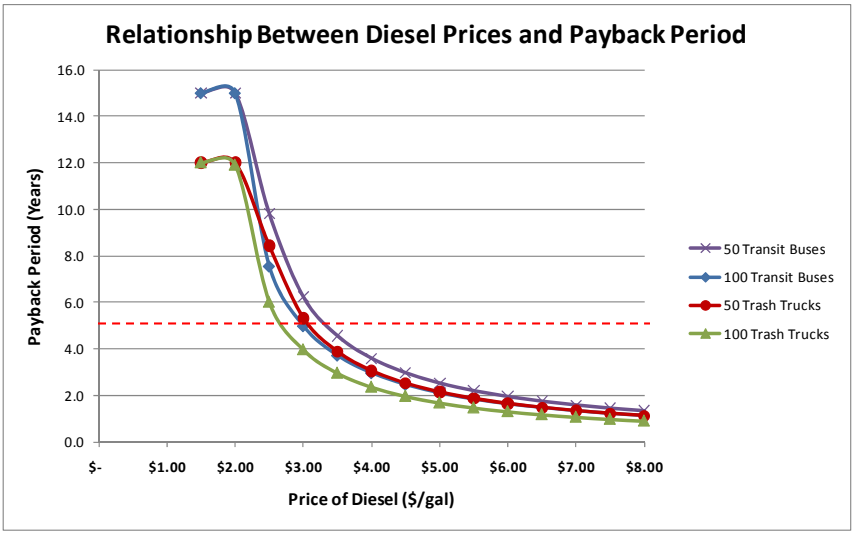
Best Vehicles for Natural Gas

- General rule: Payback is quicker for fleets that use more fuel, unless their infrastructure is a lot more expensive.
- The cost of infrastructure greater for fast refueling, much greater for LNG.

Vehicle's Suitability to use Natural Gas				
Vehicle Type	Annual Fuel Use (GGE)*	Required Range	Available Refueling Time	Equipment
Combo Truck	14,047	Long	Short	LNG
Transit Bus	11,906	Short	Short	Fast CNG
Refuse Truck	9,877	Short	Short	Fast CNG
Para. Shuttle	3,434	Short	Short	Fast CNG
Taxi	3,392	Short	Short**	Fast CNG
School Bus	1,896	Short	Long	Slow CNG
Delivery Truck	1,609	Short	Variable	Fast/Slow CNG
Police Cruiser	1,423	Long	Short	Fast CNG
Light-Duty Vehicle	558	Variable	Variable	Slow CNG

*Source: Alternative Fuels and Advanced Vehicles Data Center, www.afdc.energy.gov/afdc/data/vehicles.html
**Sixty-six percent of taxis are owned and garaged by large companies and leased to multiple drivers . Source: Taxicab, Limousine, and Paratransit Association's 2009 Fact Book.
Red indicates higher cost. Green indicates lower cost.

Economics of an Entire CNG Project



Source: NREL, Vehicle and Infrastructure Cash-flow Evaluation (VICE) model. Ran March 2011. Reflects $30,000 limit on infrastructure tax credit and expiration of vehicle tax incentive. See Business Case for CNG in Municipal Fleets (Caley Johnson, 2010) for details.

Effect of Tax Credits

Payback Period (Years) with Removal of 2010 Tax Credits

Fleet (100 Vehicles)	All Credits*	No Fuel Credit	No Vehicle Credit	No Station Credit	No Credits
Transit Buses	3.6	5.9	5.5	3.6	9.1
Refuse Trucks	2.6	4.6	4.8	2.7	7.8

*All credits as of June 2010

- Fuel ($0.55/gal diesel equiv) and vehicle (≤$32,000/vehicle) credits make a big difference
  - Fuel credit matters most for transit buses
  - Vehicle credit matters most for refuse trucks
- Station tax credit (formerly $50,000) has less influence
- There are synergies between the three credits

Source: Caley Johnson 2010. Business Case for Compressed Natural Gas in Municipal Fleets, www.afdc.energy.gov/afdc/pdfs/47919.pdf

Air Pollution Benefits of Natural Gas

Emissions Reductions in LDVs

Pollutant	Percent Reduced
Volatile Organic Compounds (VOC)	10%
Carbon Monoxide (CO)	20% to 40%
Oxides of Nitrogen (NO_x)	0%
Particulate Matter (PM)	80%
Methane	−400% (increase)

Source: Wang, 1999

Honda Civic GX has won ACEEE's green car award for the past 8 years

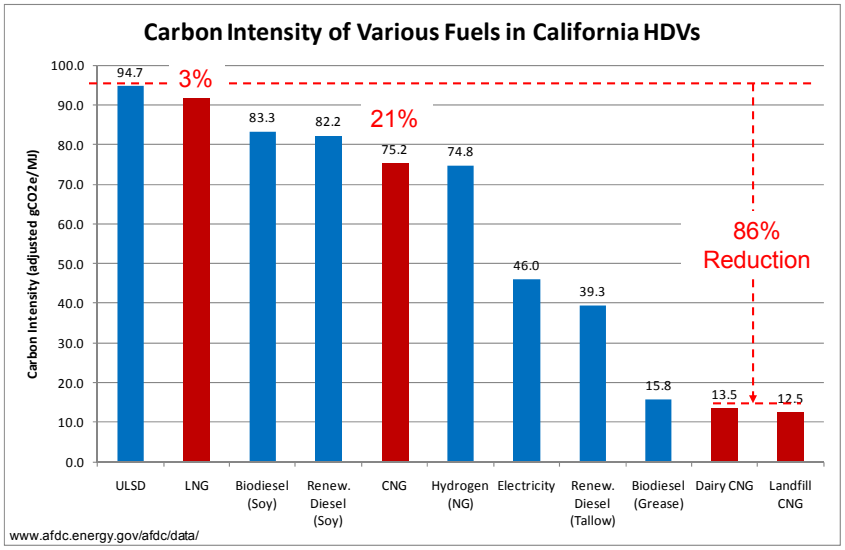
Emissions Reductions in HDVs

NREL/UWV fleet studies have shown reductions in criteria pollutants from a variety of fleets (www.afdc.energy.gov/afdc/vehicles/emissions_natural_gas.html))

Cummins-Westport engine achieved the EPA's 2010 emission standards in 2007

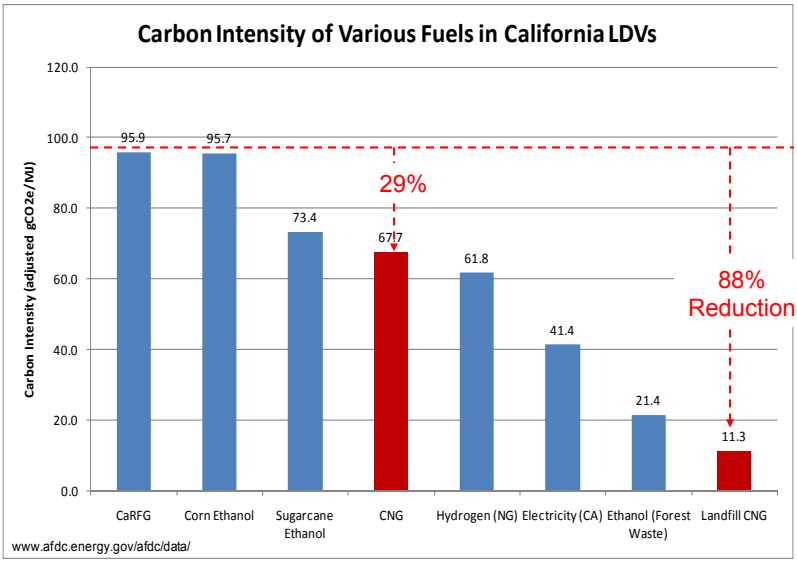
More studies needed comparing CNG emissions to Diesel in a variety of fleets

Lifecycle GHG Emissions from HDVs



Source: California's Low Carbon Fuel Standard Final Regulation Order, April 15, 2010
www.arb.ca.gov/regact/2009/lcfs09/lcfscombofinal.pdf

Lifecycle GHG Emissions from LDVs



Source: California's Low Carbon Fuel Standard Final Regulation Order, April 15, 2010
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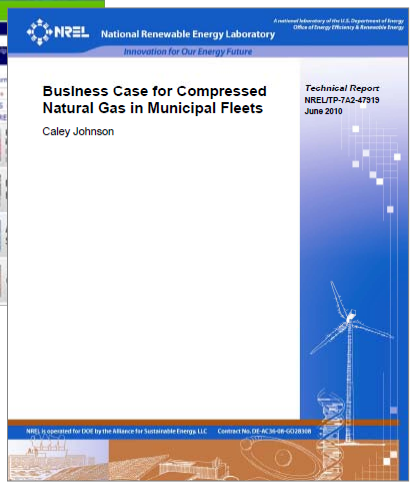
Renewable Natural Gas (RNG)

- Natural Gas (biomethane or biogas) is the natural byproduct of decomposing organic matter.
- Three most economical sources of RNG in US*
  - Landfill gas: ~500 capture and use (50% of suitable size)
  - Livestock operations: ~125 capture and use (2% of suitable size)
  - Wastewater treatment plants: ~105 capture and use (10%)
- Vast majority of RNG is used for electricity generation
- RNG sources are well dispersed throughout the nation
- Infrastructure available for gas collection and cleanup
  - Must remove CO_2, N_2, H_2S, siloxanes, and other contaminants
- Vehicles need purer, more consistent methane than electricity generation
  - Logistics can favor use in vehicles over electricity generation

*Source: Mintz and Wegryzn, 2009, www1.eere.energy.gov/cleancities/pdfs/renewable_ng.pdf

For More Information…

www.afdc.energy.gov/afdc/pdfs/47919.pdf



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