Compressed Natural Gas: Benefits for Vehicle Fleets
3-PART MESSAGE

LESS CAR

EFFICIENT CAR

CLEAN FUEL

STRAATEGY/TECHNOLOGY

Don’t drive if you can help it:
Walking, Biking, Transit, Carpooling, telecommuting.

If you drive, drive something efficient:
efficient vehicles, LRR tires, maintenance strategies, fleet management, lifecycle-cost-purchasing

Fuel diversity in the vehicle fleet:
- Plug-in passenger cars
- CNG light duty trucks
- CNG/LNG heavy duty
- Biofuel substitution

IMPLEMENTATION

- Building/Land Codes
- Regional Planning Effort
- Safe Routes to School
- Education/Outreach

- Fleet Efficiency Policy
- Fleet Manager Workshop
- Technical support to local governments
- Case study: Eagle Cty 30%

- Western Slope CNG Coll.
- DoE Electric Vehicle planning grant
- RFTA: CNG buses
- CMC/FluxFarm biobutanol
Today’s presentation:

• The high costs of imported oil
• CNG: stable fuel prices over time
• CNG vehicle safety
• Vehicle options
• Return on Investment
Why Alt Fuels?
Oil imports are a risk to U.S. economic security

We are not out of oil, just out of cheap oil. Extraction is becoming increasingly complex and costly:

The old days  Today, on land  Today, offshore
New oil discoveries, but U.S. still uses too much
U.S. has 2% of global reserves, consumes 20% of global production

Blue = Production rising somewhat (Bakken, etc.)
Red = Consumption falling somewhat (recession)

Annual Regional Spending on Gas/Diesel, 2011
Garfield County: $110 million ($50M foreign oil)
Mesa County: $280 million ($120M foreign oil)
CNG and Electricity have advantages:
Lower price, lower volatility, made in U.S.A.

Source: U.S. Energy Information Administration, with electric data added by Mike Ogburn.
“Pump price” of certain alternative fuels are less subject to changes in market prices for energy

### Diesel
Retail price $4.43/GGE (early 2008)
- Crude Oil: 64%
- Taxes: 10%
- Distribution and Marketing: 5%
- Refining: 21%

### Gasoline
Retail price $3.77/GGE (early 2008)
- Crude Oil: 75%
- Taxes: 10%
- Distribution and Marketing: 5%
- Refining: 10%

### CNG
Retail price $2.10/GGE (early 2008)
- Crude Oil: 42%
- Taxes: 18%
- Electricity Pipeline: 6%
- Operations and Maintenance: 9%
- Amortization: 30%
- Fuel Costs: 26%

### Electricity
Retail price $1.14/eGallon
- Crude Oil: 30%
- Taxes: 15%
- Transmission and Delivery: 30%
- Fuel Costs: 25%

Source: US DoE EERE, EIA, and NGVA
Are CNG Vehicles Safe? Yes!
FMVSS regulations include strict alt-fuel requirements.

CNG tank testing for FMVSS 304 typically includes

- Pressure cycling test (13,000 cycles)
- Burst Pressure Testing (2.25x service pressure, ~8000 psi)
- Bonfire Testing (to ensure proper relief valve operation)

See a video of abuse tests at http://www.youtube.com/watch?v=_46pyBNNzFs
Or search for CNG Auto Sales - CNG Safety
Gasoline is dangerous – what about CNG?

Real-world proof of proper tank performance in a crash:

**CNG Civic, rear end crash →**
CNG Tank in trunk survived, no leakage
Driver walked away.

**CNG Vehicle hit by Gasoline Vehicle →**
Gasoline vehicle exploded, burning both cars
CNG tank did not burst during the resulting fire
Safety relief valve vented all fuel, as designed.

On Nov. 9, 2011, Gov. Hickenlooper signed an MOU with Oklahoma Gov. Mary Fallin pledging to use CNG vehicles in their states’ fleets. Eleven other governors have also signed and committed to increased CNG vehicle usage. Several governors traveled to Detroit to deliver the MOU to the Big 3 automakers.
Will a switch to CNG increase demand for natural gas drilling and hydraulic fracturing?
Will a switch to CNG increase demand for natural gas drilling and hydraulic fracturing?

We’d need 88 times more CNG vehicles on the road just to match use by the commercial sector, or 275 times more vehicles to top use by the electric power sector.

- RFTA RFP seeks to select suppliers that use drilling “best practices”
- BioGas fuel sources are being developed in Europe and the U.S.

2012 natural gas consumption: 23.4 trillion CF
Source: U.S. EIA
Compressed Natural Gas

Heavy Duty horsepower, torque as good as diesel

Horsepower and torque match diesel specs
Zero torque loss up to 12,000 feet*
Zero horsepower loss until 8,700 feet*
(*Cummins ISL-G specs vary by HP rating)

Maintenance is different
Periodic tank inspection.
No diesel particulate filters or exhaust fluid.
Spark plugs may require changing at 45,000 miles, fuel filters require periodic draining.

New in 2013:
Cummins Westport ISX12-G
heavy truck engine
400HP - 1,450 lb-ft,
CNG or LNG natural gas
CNG is simple, while Diesels have complex systems to meet EPA 2010 emission standards

- Then: 1990’s diesels had little or no exhaust aftertreatment
- Now: 2010 diesels have DPF filter + SCR catalyst
Compressed Natural Gas
Factory-equipped CNG vehicles are here

Dedicated-CNG light duty

Vehicle availability
Light duty car and van availability very limited.
No pickups are available as CNG-only

CNG-only
No gasoline backup. Range is typically about 40% less than gasoline vehicle.

Cargo capacity may be less
Depends on placement of CNG tanks
  -Honda tank fills 80% of trunk
  -Optional GMC van tank is placed in cargo area

Horsepower nearly the same.
Maintenance is similar.
Compressed Natural Gas
Factory-equipped CNG vehicles are here

Bi-Fuel Gasoline-CNG vehicles

Vehicle availability
Pickups truck options are improving.
Varies by manufacturer.
Car & van options are limited: after-market only.

Horsepower nearly the same
Slight horsepower drop vs gasoline.
Typically less than 10% loss, only at peak power.

Maintenance is similar
Only the fuel system changes. Periodic tank inspection necessary. Cleaner burning fuel means cleaner oil, less wear

Reduced cargo capacity
Depends on placement of CNG tanks. CNG takes up to 4x more space per "gallon" stored.
CNG Pickups – Return on Investment

CNG bi-fuel option cost is very competitive vs diesel engines.

Tax credits make CNG vehicles equal or less than diesel to buy.

CO State Tax Credit is 35% on CNG option in tax year 2013 up to $6,000, 25% credit in 2014-2018.

Note: miles-to-payback and savings calculations are based on Mesa/Garfield fuel prices as of August 2013.

Private Sector Companies:
CNG vehicle cost...
vs Diesel: NO INCREASED COST!
Ongoing savings $400-$600 per yr

vs gasoline: payback at 50k-70k mi
Ongoing savings $900-$1300 per yr

Tax Free Organizations:
CNG vehicle cost...
vs Diesel: payback at 40k-70k mi
Ongoing savings $400-$600 per yr

vs gasoline: payback at 80k-105k mi
Ongoing savings $900-$1300 per yr

VEHICLE PURCHASE PRICE

Base Pickup Truck (gasoline) $7,500 Diesel
Base Pickup Truck
Base Pickup Truck CNG
Base Pickup Truck $10,000 CNG
Sign up with Refuel Colorado

Contact CLEER for a free fleet payback analysis

Mike Ogburn | Energy Engineer
mogburn@cleanenergyeconomy.net
(970) 704-9200
|www.CleanEnergyEconomy.net
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CLEER
Clean Energy Economy for the Region
BACKUP SLIDES
Facility considerations for gaseous fuels
Building upgrades may be required

• CNG is lighter than air. LNG can puddle, then evaporate. Ventilation required. NFPA 52 governs natural gas vehicles in buildings.
• Propane is heavier than air. Ventilation and attention to drains is required. NFPA 58 governs propane vehicles in buildings.
• The fleet maintenance building should be evaluated by an engineering firm. Costs could be low, or high… it depends!

**Ventilation:** Five air changes per hour

**Methane or hydrocarbon sensors:** If CNG or propane are detected, ventilation increases or garage doors open

**Electrical systems:** Special conduit, lighting and motors may be required near ceiling, or near floors.

**Heating systems:** No open flames. Closed combustion only.
Fueling facilities

LNG station: heavy duty vehicles only

Low pressure, but very cold: -260 degrees F

Thanks to John Gonzales, NREL
Fueling facilities
Fast Fill CNG station
24/7 credit card station is preferred

Thanks to John Gonzales, NREL
Fueling facilities
Time Fill CNG Station
Typically not available to the public
Fueling facilities
CNG home fueling, time fill
Costly at present; new appliances being designed

Thanks to John Gonzales, NREL
Fueling facilities
Fast + Time-Fill CNG Station
City of Grand Junction does this. Fast fill open to the public 24/7.

Fills in 10 minutes or less
Fills overnight
Fueling facilities
CNG station cost examples

(Pricing that follows is for discussion only.)

Fueling system prices vary:

- Specifics of a fueling site greatly affect pricing.
- Pressure available from the gas utility greatly affects compressor capacity and fill speed.
- Demand pricing of the electric utility affects operational cost. Lots of electricity is used to compress natural gas from the feeder pipe into CNG storage tanks and vehicles.
Fueling facilities
Fuel Maker FMQ: Overnight CNG fill

1 or 2 hoses
0.5 to 4.0 gallons per hour
10-hour filling period = 5 to 40 GGE of CNG
Price varies by fill rate, $10,000 to $40,000
(gas dryer not included)
Fueling facilities
Time-Fill CNG

Cost
$5,000 per single-hose post
$1,000 for second hose on post

Plus
$300,000 compressor for 20 gal/hr.
10-hour filling period
= 200 GGE of CNG

$650,000 compressor for 100 gal/hr.
10-hour filling period
= 1,000 GGE of CNG
Fueling facilities
Fast-Fill CNG costs

Station price varies. One example: $1,150,000
Storage vessels (+ hydraulic intensifier) give very fast first-fills
10 hour period = 1,900 GGE of CNG

Large vehicle example:
60 gallons in 6.5 minutes
Second 60 gal in 8.5 minutes
Five 60-gallon fills per hour

Pickup example:
20 gallons in 2.5 minutes
Second 20 gal in 2.5 minutes
Fourteen 20-gallon fills / hour

(Reality will probably be a blend of these two examples)
Fueling facilities
RFTA CNG “Direct Fill” for 22 buses

• Minimal storage with 3 large compressors: $2.5 million
  - Can fill a 150-gallon bus tank in about 15 minutes.
• Unique large-fleet solution. Not ordinarily required.

Photos Courtesy of Denver Metro Clean Cities Coalition
Which CNG fueling scenario seems better?

Option 1: Buy a small time-fill system, $40,000
- Becomes obsolete as your fleet grows, or if fast-fill becomes available
- Lets a fleet try CNG by themselves, but investment value may be lost.

Option 2: Buy a time fill system, locate it behind locked gates
- Three fleets buy separate 10-vehicle time-fill stations for $350,000 each.
- Combined, they can fill **600 gallons in 10 hours** overnight.
- Closed to the public.

Option 3: 3 fleets pool funds to buy a $1.1 million fast-fill
- Central location can fill **1,900 gallons in 10 hours.**
- **Spare capacity is available to the public.**
- Offer 24/7 credit card access.
Part 1. Vehicles and Fuels
Alt-Fuels Overview

Cost comparisons
CNG and electricity have advantages:
Lower price, lower volatility

Source: U.S. Energy Information Administration, with electric data added by Mike Ogburn.
### National Average Price Between September 28 and October 12, 2012

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiesel (B20)</td>
<td>$4.18/gallon</td>
</tr>
<tr>
<td>Biodiesel (B99-B100)</td>
<td>$4.39/gallon</td>
</tr>
<tr>
<td>Electricity</td>
<td>$0.11/kWh*</td>
</tr>
<tr>
<td></td>
<td>$1.14/eGallon**</td>
</tr>
<tr>
<td>Ethanol (E85)</td>
<td>$3.47/gallon</td>
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<tr>
<td>Natural Gas (CNG)</td>
<td>$2.12/GGE</td>
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<tr>
<td>Propane</td>
<td>$2.56/gallon</td>
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<tr>
<td>Gasoline</td>
<td>$3.82/gallon</td>
</tr>
<tr>
<td>Diesel</td>
<td>$4.13/gallon</td>
</tr>
</tbody>
</table>


* Average price per kilowatt hour in 2012 from U.S. EIA.

** eGallon is a concept that conveys a price for a “GGE” equivalent for electricity that is more recognizable than kWh [http://energy.gov/articles/egallon-how-much-cheaper-it-drive-electricity](http://energy.gov/articles/egallon-how-much-cheaper-it-drive-electricity)
Natural gas costs 80% less per unit of energy than crude oil

Price Difference: Natural Gas vs. Oil
On an Energy Equivalent Value,
January 1994 - February 2013

What fleet owners and managers want to know: Driving range of Alt Fuel Vehicles.

Given the amount of energy I was able to fit on my vehicle, how far can I go?

- Gasoline
- Diesel
- B20 Biodiesel
- E85 Ethanol
- LPG
- CNG
- LNG
- EV

<----(worse)    Resulting Alt Fuel Vehicle Driving Range in Miles    (better)------>

(Tesla)
# Alt Fuels most likely to succeed in each vehicle class:

Based on a combination of vehicle availability, energy density, efficiency, cost savings

Note: this is a subjective analysis meant to simplify a complex market. Fleet needs may vary.

| Class 1- 0 to 6,000 pounds | Plug-in Hybrid or Electric Passenger Vehicles | -Gallons per year are low, so savings is low for CNG, LPG, etc.  
-Many plug-in options in this class |
|----------------------------|---------------------------------------------|-------------------------------------------------------------------|
| Class 2- 6,001 to 10,000 pounds  
Class 3- 10,001 to 14,000 pounds | CNG or LPG, bi-fuel Pickup trucks & work vans | -no plug-in options in this class  
-bi-fuel CNG or LPG options available  
-good payback if annual VMT is high |
| Class 4- 14,001 to 16,000 pounds  
Class 5- 16,001 to 19,500 pounds  
Class 6- 19,501 to 26,000 pounds | CNG or LPG  
Medium duty trucks  
School and shuttle buses | -good payback if annual VMT is high  
-vehicle can be designed for tanks  
-CNG or LPG medium duty engines exist  
-Good if fleet VMT matches driving range  
-Low fuel/maint costs; fast charging options |
| Class 7- 26,001 to 33,000 pounds | CNG  
Short haul trucks,  
Refuse trucks,  
Transit buses | -Natural gas heavy duty engines exist  
-Good payback if annual VMT is high  
-Vehicle design can fit CNG tanks |
| Class 8- >33,000 pounds | LNG  
Long-haul trucks | -Fuel usage too high for CNG  
-Natural gas heavy duty engines exist  
-LNG required due to high fuel usage |