Alternative fuels for heavy duty vehicles

Anthony Greszler
Volvo Group Truck Technology

Presented to

Energy Use and Policy in the U.S. Trucking Sector

Resources for the Future
Volvo Group 2012

- Trucks
  - Volvo
  - Renault
  - Mack
  - UD
  - Eicher

- Construction Equipment
  - Volvo
  - SDLG

- Buses
  - Volvo
  - Prevost
  - Nova Bus

- Volvo Penta

- Volvo Aero

- Net Sales 2011, 36 EUR bn
- 98,000 Employees

- Graph showing distribution:
  - 64% Trucks
  - 21% Construction Equipment
  - 7% Buses
  - 3% Penta
  - 2% Aero

Volvo Group Headquarters
Volvo Group Truck Technology
2  10/12/2012
Projection – Provided by US DOE in 2009

**Projection Oil Consumption by Vehicle Type**

*Presuming 75% Reduction in Light-Duty Oil Consumption*

- Million Barrels per Day in 2050
  - 1.16
  - 2.11
  - 4.26

**Oil Consumed (Million Barrels per Day)**

- 2000
- 2005
- 2010
- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050

**Vehicle Types**

- Cars
- Light Trucks
- Heavy Trucks

*Light duty oil consumption reduction from AEO 2007 reference case modeled via increased fuel economy and shifts to flex-fuel, hybrid-electric, and plug-in hybrid-electric vehicles.*
"Well-to-wheel” analysis (Volvo study)

Energy efficiency and Greenhouse gases

Feedstock supply and production capacity are critical limitations.
Natural gas
viable today for North America

- Domestically available
- Less expensive than diesel

Trucking Consumes:
35 Billion Gallons of Diesel

Trucking Pays:
$136 Billion

Natural gas:
$1.50 to $2.00 cheaper than diesel on a BTU equivalent basis
Class 7&8 Combination Market Shares of New Diesel and Natural Gas Trucks – Reference Oil Price Case
“Diesel engines will remain the powertrain of choice for (heavy duty) vehicles for decades to come because of their power and efficiency. There are, however, opportunities to improve the technology. Significant fuel economy improvements in diesel powered trucks are possible. Indeed, the fuel economy (mpg) for new Class 7&8 HD vehicles, which consume more than 70% of the fuel in the trucking fleet, could be doubled.”
Overview: 2 types of natural gas as fuel
LNG vs. CNG

- Range per 100 gals tank space:
  - Diesel: 650 mi
  - LNG: 380 mi
  - CNG: 170 mi

- Tank size per 100 mi:
  - Diesel: 15 gal
  - LNG: 26 gal
  - CNG: 58 gal
GHG Impact of NG as Motor Fuel

- Well-to-Tank CO₂ per Ca. LCFS
  - Domestic CNG 72% of diesel
  - Domestic LNG 76-88% of diesel
- Tank-to-Wheels (engine efficiency impact) at Tailpipe (including CO₂ & CH₄)
  - 115 - 180% of diesel - stoichiometric NG
    - Heavily dependent on duty cycle
  - 105 - 130% of diesel – lean burn
  - 102 - 110% of diesel - lean burn (Direct Inject.)
- Methane emissions from LNG tank venting may become significant in older (less-used) vehicles.
- Net Result – GHG Emissions
  - Stoichiometric CNG: 83 - 130% of diesel
  - Lean Burn CNG or LNG: 76 - 114% of diesel
  - Lean Burn LNG DI: 78 - 97% of diesel
  - Plus emissions from tank venting with LNG

Approximate GHG Relative to Diesel

Excludes tailpipe methane
Natural Gas Conclusions

• Sustained fuel cost differential will likely drive the commercial market.

• Immediate potential GHG benefit of approximately 15%
  – Need focus on efficiency in fuel production and engine to realize GHG benefits
  – Need to evaluate and improve engine technologies
  – Should consider alternate pathways to use NG like DME

• Political Drivers
  – Energy security
  – Imported petroleum displacement
  – Regional economic stimulus

• Long Term Impact
  – Cumulative GHG savings as volume grows
  – Low cost NG may delay other alternatives
  – Venting of CH4 from older LNG vehicles may become a problem (CH4 has 25 times GWP of CO2)
Volvo NG Products
Methane Diesel engines (Dual Fuel)

- A small injection of diesel as ignition
- 50-75% diesel substitution
- Diesel engine efficiency
- Possible to run on diesel only

Two truck offerings
- Volvo FL/FE
  - 7L engine
  - CNG tanks
- Volvo FM
  - 13L engine
  - LNG tanks
  - Penta 16L genset
MACK Terrapro — Natural gas

- **Engine**
  - Cummins Westport ISL G
  - 9 L, 320 HP, 300 HP, SI, Stoichimetric
  - Three-way catalytic converter
  - Compressed or liquid natural gas (CNG, LNG)

- **Plan to expand 2013**
  - Plan to offer natural gas MACK Pinnacle, MACK Granite
  - Cummins Westport ISX12 G engine
Example of current Volvo offering – conventional
Giant Eagle: VNM 200 with Cummins ISL-G CNG spark ignition

66,000 GCW
carries equivalent of 84 gallons of diesel
350 mile range

Shield covers CNG “scuba tanks” mounted along each frame
Methane Detector required
The Cummins 12 Liter SI engine in our VNL for 2013

**ISX11.9 G Technical Profile**

- 11.9L displacement
- Maximum rating:
  - 400 HP
  - 1350 (1450) lb.ft.
- Spark Ignited
- Stoichiometric CEGR
- Wastegate turbo
- Maintenance-free aftertreatment
- Operates on CNG/LNG/RNG
- Manual / Automatic trans capable
- Integrated engine brake

Carbon fiber (CNG) “Scuba” tank +1,000 - 1,500 lbs*

3-way catalyst + 300 lbs.
On the horizon with natural gas...our own pilot injected engine

- Best for Long Haul applications
- **Nearly as efficient as the diesel engine**
- Uses Liquified Natural Gas (LNG)
  - Liquid state at -260 degrees
  - Requires special cryogenic tanks to maintain pressure and temperature
- LNG tank hold time is 7 to 10 days
- Uses small % diesel for pilot injection
  - “mini” SCR/DPF systems being developed = less weight/pace

Special cryogenic pressurized tanks for HPDI (-230 F) engines
(-200 F) for SI engines + 350 – 500 lbs*

Small Diesel fuel tank (10 gal)
VOLVO CNG Buses

VOLVO 7900 Gas

VOLVO 7900 Gas Articulated

NOVA LFS

G9B 300

Cummins ISL-G

Coming in 2013
Our vision: Climate-Neutral Transportation Solutions

1972: proponent of environmental solutions

1980: Volvo’s core values: quality, safety, environmental care

2010: reduce CO$_2$ emissions at least 50% by 2012
Seven trucks running on renewable fuels

A technology demonstration
Biogas

• There are several driving forces for an increased use of methane (natural gas and biogas) as a fuel
  – Availability, cost, energy security, environmental impact
  – Biogas is also renewable and has lower GHG impact, especially if produced from digestion of waste
• The Volvo Group’s position is that biogas is an important fuel for a number of our products
DME Should be Considered as a Fuel Alternative

- DME could play a strong role in the transition from petroleum based fuels and as a biofuel
  - Producible from a wide variety of fossil and bio based materials
    - Natural gas conversion to DME vs. flashing off at oil wells or from landfill gas
    - Highest biomass to fuel conversion efficiency
  - Relatively easy to store and transport (liquefies at low pressure & no venting)
  - High well-to-wheel efficiency
  - Clean (near zero soot) combustion
  - Excellent diesel cycle fuel (high cetane)
  - Non toxic and low GWP
  - Cost Effective
Our direction for future fuels?

- **Fossil- and renewable diesel fuels**
  Dominant fuel for at least two decades

- **Natural gas, biogas:**
  Viable for regional use

- **Di-Methyl Ether (DME)**
  Good candidate for long-term future fuel:
  - derived from natural gas
  - transportable
  - sustainable
  - CO$_2$ neutral

- **Fully Electric**
  - Vehicles with light and short distance operation can be Plug-in suitable

All fuels can be combined with hybrid drivelines when appropriate
One technology solution is not enough!

Our industry is experimenting

Energy efficiency

Alternative fuels