The Future of Natural Gas as a Transportation Fuel

A Presentation for the DOE EIA 2013 Energy Conference, Washington, DC

Dr. Michael Gallagher
Secretary’s Request

Examine ways to accelerate future transportation fuels prospects through 2050

Address four critical areas: fuel demand, supply, infrastructure and technology

Answer this key question:

*How can governments stimulate the technological advances and market conditions that will reduce GHG emissions by 50% relative to 2005 levels?*
U.S. Transportation: What’s Different?

Power

- Renewable Energy: 13%
- Nuclear: 1%
- Natural Gas: 25%
- Coal: 42%
- Other: 19%

Transportation

- Petroleum (including biofuel blends): 99%
- Other: 1%
  - Natural gas
  - Electricity
  - Hydrogen

Sources:
- http://www.eia.gov/energy_in_brief/renewable_electricity.cfm
Shale Gas Plays in the United States

Source: U.S. Department of Energy, Energy Information Administration
**IDENTIFYING THE OPPORTUNITIES**

Fuel Consumption by Transportation Market Segment

*Total Transportation Energy Market Equivalent to 61.6 Bcf/day*

- **Light Duty**
- **Heavy Duty**
- **Medium Duty**
- **Marine**
- **Rail**

Early Wins Likely

Significant Market Potential

Bcf/day Equivalent
Modeling Input Cost Assumptions For Class 7&8 Natural Gas Trucks

- Incremental RPE of NG Class 7&8 Combination Trucks

![Chart showing the trend of NG System Incremental RPE from 2010 to 2050, with upper and lower bounds indicated.](chart.png)
Class 7 & 8 Market Shares of New Diesel and Natural Gas Trucks: Reference & High Oil Case

No expected penetration of Natural Gas in Class 7&8 in Low Oil Cases due to absence of fuel price advantage.

In Ref and High Oil Price scenarios market share for natural gas can be very strong – based on fuel economics.

Expect mostly LNG, starting in high fuel use fleet applications.

Cost reductions and increasingly accessible dispensing required for growth, but could be compelling.
Heavy Duty Fleet - Natural Gas Consumption

- Combined consumption of Natural Gas in Classes 3 to 8 equates to between 1.5 and 3 TCF.
  - Annual US gas consumption today is ~23 TCF, so HD trucks would increase NG demand by <15%.
- Transition to NG is equivalent to 10 to 20 billion DEG per year petroleum displacement (0.6 to 1.4 MM BoE / day) by 2050.
Light Duty NGVs: A Deeper Look at Technology Potential

- European state of the art demonstrates near term potential for fuel efficient, practical NGVs
- Common powertrain architecture to gasoline; enables common technology advances for NGVs:
  - Downsizing, highly boosted engines, direct injection
  - CNG hybrids
  - Transmission
  - Chassis (light-weighting, aero)

- Wide range of fuel economy potential
  - How do you optimize for economics when fuel costs are low?

- Can scale and production integration reduce cost premiums?

- Historical issues of luggage space being resolved by OEM integration
- Higher fuel use applications and vehicles likely to transition first.
  - Eg – fleets and pick-ups
- Greater infrastructure challenges for personal transport
Estimating LD CNG Incremental Costs

- Low and High bound on incremental costs used to model range of uncertainty in projections.
- With assumptions used, significant reductions in incremental costs are possible.
Assuming Technology, Infrastructure and Other Hurdles are Resolved
Range of Light Duty Vehicle Fleet Shares in 2050 (3 Year, All Oil Prices, All-in Technology Combination)

- Internal Combustion Engines remain dominant, but used with multiple fuels and part of hybrid / PEV systems.
Volvo Car Group Unveils V60 Bi-Fuel Car with Westport Natural Gas Fuel System at NGV 2013 Gothenburg

- Since 2009, Westport—the sole supplier of natural gas fuel systems to Volvo Car Group—has developed and installed natural gas systems for the Volvo V70 estate car at a facility located inside Volvo's main production centre in Gothenburg, Sweden.

- The new Volvo V60 Bi-Fuel car runs on either compressed natural gas (CNG)/biomethane or petrol (gasoline), and is a sporty estate car.

- With a powerful 213 horsepower engine, the Bi-Fuel system offers a total driving range of 1,120 kilometers. When renewable CNG (biomethane) is used as a vehicle fuel, greenhouse gas emissions are significantly reduced compared to petrol.

- "Demand for natural gas vehicles in Sweden is expected to increase in response to the pending extension of the Government of Sweden alternative fuel tax incentive program," - Ian Scott, Executive Vice President, Westport.

- The new V60 will expand Volvo Car Group's Bi-Fuel product line. Westport and Volvo Car Group are currently in discussions to expand the Volvo V60 Bi-Fuel car into other markets.

- Natural Gas Vehicles, a Global Strategic Business Report, projects that the number of natural gas vehicles (NGVs) in Sweden will triple between 2010 and 2018, from 31,179 to 92,657.

- Sales for the new product will start in October 2013 in Sweden.
U.S. Fleet - Total Fuel Use

Combined Light and Heavy-Duty Vehicle Fuel Use

Figure ES-13. Range of 2050 LDV and HDV On-Road Fuel Use, Assuming All Alternatives are Successfully Commercialized (3-Year, All Oil Prices, All-in Combination)

NG: 1 to 3 quad HD, 3 to 9 quad LD
# Infrastructure: Natural Gas Fuel Dispensing

## Investment required, but technology options exist

<table>
<thead>
<tr>
<th></th>
<th>Fuel Production</th>
<th>Fuel Dispensing</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG (for LD)</td>
<td>$0…?</td>
<td>$100 - $200bn</td>
</tr>
<tr>
<td>LNG</td>
<td>$20 - $40bn</td>
<td>$10 - $20bn</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$30 - $90bn</td>
<td>$300 - $500bn</td>
</tr>
<tr>
<td>Bio Gasoline</td>
<td>$100 - $250bn</td>
<td>$20 - $40bn</td>
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<tr>
<td>Electricity</td>
<td>TBD</td>
<td>$70 - $130bn</td>
</tr>
<tr>
<td>Bio Diesel (GTL - BTL)</td>
<td>....</td>
<td>....</td>
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</tbody>
</table>

### Fleet centric CNG/LNG
- Modular additions to existing sites
- Dedicated new CNG/LNG stations
- Home refueling

### Increasing infrastructure requirements as diversity of use increases

- Urban Fleets
- HD Fleets
- Private LD Fleets
- Personal LD Consumers

**Westport**
Natural Gas Vehicles: Summary Thoughts

- Market opportunities for both LD and HD vehicles
- Few technical barriers to NGV expansion
- Similar powertrain architecture to gasoline and diesel is an advantage
- Potential for a strong economic value proposition if natural gas prices remain low
- Sustained effort required on infrastructure expansion to resolve fuel availability
- Continued market demand required to justify expanded OEM product offerings
Electric Vehicle Insights

• Battery cost, energy density, degradation and longevity are the highest R&D investment priorities.
  
  • A breakthrough beyond those expected for lithium-ion batteries is necessary to increase the driving range of a BEV so that it can be a substitute for a conventional vehicle.
  
  • By 2020, battery costs will likely be in the range of $200 to $500 per kWh, which is above the Department of Energy targets for commercialization.

• The highest priority for charging infrastructure is to enable convenient and affordable home charging.

• Electricity generation and transmission for a large grid-connected vehicle population is not a constraint, as potential capacity additions can be included in existing long-term asset planning processes.
Global Truck Market Opportunity

- China first, followed by India and Europe

**China LNGV Population**

- **118% CAGR**

**Natural Gas Stations in China**

- **33% CAGR**

Sources: China Automotive Technology and Research Center, www.chinaev.org, China Road Transport Association, Westport analysis
Strong Growth in China

- First announced Weichai Westport JV in 2008; formal JV commenced July 2010
- Light-duty component business has >60% share in China*
- Existing NG engine business demonstrating strong growth in China
- Current priorities: launch Westport HPDI technology for Asian market in 2013 with broad LNG infrastructure
- Westport revenue model
  - Sale of components to JV and to vehicle OEMs
  - Participate in the JV’s profitability

### Weichai Westport Financial Summary

<table>
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<tr>
<th>USD$MM</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Q1 2013</th>
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</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td>$ 9.9</td>
<td>$ 19.0</td>
<td>$ 44.8</td>
<td>$ 109.8</td>
<td>$ 272.1</td>
<td>$ 105.9</td>
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<tr>
<td><strong>Cost of revenue</strong></td>
<td>8.1</td>
<td>15.7</td>
<td>35.9</td>
<td>90.1</td>
<td>234.3</td>
<td>98.8</td>
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<tr>
<td><strong>Expenses</strong></td>
<td>1.6</td>
<td>2.5</td>
<td>6.4</td>
<td>14.1</td>
<td>28.1</td>
<td>3.7</td>
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<tr>
<td><strong>Net income</strong></td>
<td>$ 0.1</td>
<td>$ 0.8</td>
<td>$ 2.4</td>
<td>$ 5.6</td>
<td>$ 8.2</td>
<td>$ 2.9</td>
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<tr>
<td><strong>Net income %</strong></td>
<td>1.3%</td>
<td>4.2%</td>
<td>5.4%</td>
<td>5.1%</td>
<td>3.0%</td>
<td>2.7%</td>
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<tr>
<td><strong>WPT 35% interest</strong></td>
<td>-</td>
<td>-</td>
<td>$ 0.6</td>
<td>$ 1.9</td>
<td>$ 2.9</td>
<td>$ 1.0</td>
</tr>
<tr>
<td><strong>Engines sold</strong></td>
<td>720</td>
<td>1,696</td>
<td>3,602</td>
<td>8,451</td>
<td>22,025</td>
<td>8,529</td>
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</tbody>
</table>

*Westport began reporting its income from WWI in July 2010
Accelerated Market Adoption

- Adoption rate in leading markets moving faster than the gasoline to diesel transformation
- Clean Energy Fuels, Shell, Encana, ENN, and others are leading the build-out of natural gas stations and fuelling infrastructure around the world

Data sources:
1. MacKay & Co., & Wards Auto Group, a division of Penton Media, Inc.
2. ACEA
3. Westport
4. Westport
Thank you...

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US Road Transport and Freight

Freight Traffic 2007
billions tons

8,779
1,940
715
Road
Rail
Inland Waterways

Source: American Railroad Association, US Coastguard, Commodity Flow Survey (CFS), Bureau of Transport Statistics
The surge in unconventional oil & gas production has implications well beyond the United States.

Source: IEA WEO 2012
Different trends in oil & gas import dependency

While dependence on imported oil & gas rises in many countries, the United States swims against the tide.

Source: IEA WEO 2012
Cummins Westport Joint Venture - Spark Technology

- 50:50 JV established in 2001
- Renewed agreements 2004 and 2012
- Delivered over 35,000 engines
- Industry leading OEM availability

- Key recent growth driver:
  - refuse trucks in North America – approaching 50% natural gas market penetration
  - Medium and heavy truck applications

<table>
<thead>
<tr>
<th>ISL G</th>
<th>ISX12 G</th>
<th>ISB6.7 G</th>
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<tbody>
<tr>
<td>8.9L SEGR</td>
<td>11.9L SEGR</td>
<td>6.7L SEGR</td>
</tr>
<tr>
<td>250–320hp</td>
<td>320–400hp</td>
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</tr>
<tr>
<td>660–1,100 lb-ft</td>
<td>1,150–1,450 lb-ft</td>
<td></td>
</tr>
<tr>
<td>available now</td>
<td>2013 launch</td>
<td>2015 launch</td>
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CWI Engines in North America by Segment (cumulative through Q3 2012)