Light-Duty Natural Gas Vehicle Update

CRC Advanced Fuel and Engine Efficiency Workshop
Feb. 26th, 2014

Jeff Jetter, Honda R&D Americas Inc.
• Current LD NGV Landscape
• Home Refueling
• Fuel Quality
• Overall Market Considerations
• Current LD NGV Landscape

• Home Refueling

• Fuel Quality

• Overall Market Considerations
NGV Rationale

Energy Security
• Natural gas is an abundant domestic resource; >100 years of supply.
• Use in NGVs displaces petroleum.

Environmental Benefits
• GHG reduction of 20% or more.
• Air quality improvement; reduction in criteria pollutants.

Consumer Benefits
• Lower fuel cost.
• Convenience – potential for home refueling.
NGVs in the US Market

• Multiple models are currently available. Examples:
  • Chrysler Ram 2500
  • Ford E & F Series, Transit Connect
  • GM Impala, Savana, Express
  • Honda Civic

• Various production strategies:
  • Factory assembly line (only Ram 2500 and Civic)
  • Prepped in factory, but NGV components added by an outside company.
  • Non-OEM conversion.

Chevy Impala
Honda Civic
Ram 2500
Civic NGVs on the Honda assembly plant in Indiana
Dedicated vs. Bi-Fuel* NGVs

**Dedicated**
- Engine is optimized for CNG.
- Lower cost than bi-fuel.
- HOV (carpool) lane access
- Generally more incentives available than for bi-fuel.

**Bi-fuel**
- Fuel flexibility.
- Superior range; no range anxiety.

**Other (?)**
- Some NGVs in the EU have a small “reserve tank” of gasoline.
- CNG → gasoline switchover occurs automatically when the CNG runs out; the driver cannot select fuels. (Thereby qualifying for favorable tax treatment.)
- How will such NGVs be classified if they come to the US?

*NGVs, FCEVs, and BEVs only
Currently set to expire in Jan 2019

• Bi-fuel: Can use either CNG or gasoline.
• Dual-fuel: Can inject both fuels simultaneously.
• Note that some entities swap these definitions.
Civic NGV Buyer in California

Purchase Drivers:

1. Access to HOV (carpool) lanes
2. Gasoline – CNG price differential
3. State & local incentives
4. True alternative fuel; domestically produced
5. Personal commitment to “green” issues

Fuel Price Comparison
(Southern California, Feb 24th 2014)

- Gasoline
- CNG at station
- CNG home refueling*

* Special NGV fuel rate. Price shown does not include road taxes or compression cost.

The primary drivers of Civic NGV sales are HOV lane access and low fuel cost.
NGV Challenges

Challenges:

1. Infrastructure
   - Only 672 public CNG stations in the US, as of February 2014.
   - However, the US has an extensive natural gas distribution system. Half of US homes (60 million) have natural gas.

2. Vehicle Price
   - The limited infrastructure hinders NGV sales, thereby preventing the cost-down that would occur with higher production volume.

What could help?:
   - Incentives for public and home refueling infrastructure.
   - Reinstatement of the 50-cent (per gge) tax credit for CNG, and the tax credit for CNG refueling infrastructure.

Sources: EIA 2012; U.S. Census

- Lack of refueling infrastructure remains a key barrier to NGV growth.
- Incentives for infrastructure development could help address this challenge.
• Current LD NGV Landscape

• Home Refueling

• Fuel Quality

• Overall Market Considerations
Honda’s Perspective re: Home Refueling

• A “must have” for the expansion of light-duty NGVs. No other solution for the infrastructure chicken-or-egg issue.

• Provides a bridge to future hydrogen home refueling.
Home Refueling Appliance Development

Examples:

- Liquid Piston
- Multi-Stage Linear Piston
- Hydraulic Compressor
- Chilled-Adsorbent System

Closest to commercialization – 2015
(Privately funded)
Potential Business Model: Customer Lease

General Image:

- **Device Maker**
  - Go Natural
  - GE
  - Eaton
  - Participates in product development
  - Sells refueling device to LDCs

- **Gas Producer**
  - Supplies gas
  - Chesapeake Energy
  - Encana

- **LDCs**
  - Atlanta Gas Light
  - Supplies refueling device to consumers
  - Provides device:
    - Financing (via gas bill)
    - Installation
    - Maintenance

- **Consumer**
  - Purchases NGV
  - Incentives (?)

Company names and logos are used for illustrative purposes only, and do not represent business relationships.

- This model provides a turn-key solution for home refueling.
- Up-front costs are minimized; customers enjoy immediate “return on investment.”
• Current LD NGV Landscape
• Home Refueling
• **Fuel Quality**
• Overall Market Considerations
Natural Gas Quality Survey – Pilot Program

- Conducted by SwRI* under contract from Honda.
- Focus: water content.

Typical Layout of Sampled Stations

Rationale for Survey:
- No survey conducted in > 20 years.
- No fuel quality specification for NGVs.
- Shale gas quality was unknown.

Use of Data:
1. Fuel property data for Honda’s NGV development team.
2. Support development of an ASTM NGV fuel specification.

*Southwest Research Institute
Survey Results – Water Content

- Nozzle (dispenser) samples were generally well below the pipeline limit.
- Pipeline samples exceeded the pipeline limit in Ohio and New York.

Water ppmv

Typical Pipeline Limit (7 lb/MMscf)
2 new CNG/NGV projects underway through the CRC:

**Natural Gas Quality Survey**
- Multiple components & properties
- Report available mid-2014

**CNG Fuel Quality Effects Project**
- Effect of fuel properties on NGV performance

**Ultimate objective:** Inform the ASTM specification development process.
• Current LD NGV Landscape
• Home Refueling
• Fuel Quality

• Overall Market Considerations
Multiple Natural Gas Pathways to Adv. Tech. Vehicles

Which is “best”? Need to consider from a holistic perspective.
### Retail Market Assessment

<table>
<thead>
<tr>
<th>Path</th>
<th>Social Values</th>
<th>Marketability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air Quality</td>
<td>GHG</td>
</tr>
<tr>
<td>Improved Gasoline ICE</td>
<td>Very Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Diesel</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Good</td>
<td>Challenging</td>
</tr>
<tr>
<td>HEV</td>
<td>Very Good</td>
<td>Good</td>
</tr>
<tr>
<td>Natural Gas Vehicles</td>
<td>Very Good</td>
<td>Good</td>
</tr>
<tr>
<td>PHEV</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>BEV</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>FCEV</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

1. Methane leakage needs to be uniformly addressed (extraction, distribution, etc.)
2. Carpool stickers, regional incentives, fuel price
3. Fed tax incentive, state incentives, carpool stickers

NGVs are currently more marketable than BEVs and FCEVs.
Natural gas GHG estimates were ≥ 20% lower than those of gasoline and diesel in all LCA models investigated.
Summary

• NGVs have energy security and environmental benefits.

• Infrastructure is a major challenge. Availability of home refueling is a must.

• The CRC is currently running two CNG-related projects, with the objective of informing the ASTM specification development process.

• Alternative-fuel vehicles cannot benefit society unless the vehicle is marketable.
Proceed always with ambition and youthfulness

Respect sound theory, develop fresh ideas, and make the most effective use of time.

Enjoy your work, and encourage open communication.

Strive constantly for a harmonious flow of work.

Be ever mindful of the value of research and endeavor.

-- Management philosophy of Soichiro Honda