The Engine/Energy Transition to Tomorrow

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New Appointment

Vice President
Of
Big Decisions
Fred & Myrtle
And the
Helicopter Ride

What is changing?

• Higher vehicle pricing for new technology
• Higher cost of Ultra Low Sulfur diesel fuel
• SCR for 2010 -- cost implications
• The shifting economics of diesel operation
• Concern about Green House Gases
What are your alternatives?

- Get out your checkbook
- Conserve diesel fuel however you can
- Change vehicle specifications
- Bus and Truck specs for fuel economy
- Consider other alternatives
- Manage better

Question

When was the first Diesel Truck sold in the United States?
Why Diesel?
What are your alternatives?

Consider an Alternative to Diesel Fuel

Alternative Diesel Fuel Challenges

• Cost

• Performance

• Emission reduction trade-offs

• Infrastructure and fuel availability

• Impact on engine components
Alternative Fuel Options

• Fuels
  - Biodiesel
  - Di-Methyl Ether (DME)
  - Ethanol
  - Methanol
  - Gas to liquid
  - Coal to liquid
  - Water/diesel emulsions
  - Ethanol/diesel emulsions
  - Natural Gas (CNG / LNG)
  - Propane
  - Hydrogen
  - Hythane (NG + H)
  - Biofuels (non-biodiesel ester)

• Criteria
  - Availability
  - Chemistry
  - Efficiency
  - Emissions
  - Infrastructure
  - Price
  - Safety

Alternative Fuel Properties

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Diesel</th>
<th>Biodiesel</th>
<th>MeOH</th>
<th>EtOH</th>
<th>NG</th>
<th>LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>C_{18}H_{36}</td>
<td>C_{18}H_{26}O_{2}</td>
<td>CH_{3}OH</td>
<td>C_{2}H_{5}OH</td>
<td>CH_{4}</td>
<td>C_{2}H_{8}</td>
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<tr>
<td>Cetane No.</td>
<td>40+</td>
<td>40+</td>
<td>10</td>
<td>10</td>
<td>--</td>
<td>5</td>
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<tr>
<td>Octane No.</td>
<td>--</td>
<td>--</td>
<td>95</td>
<td>95</td>
<td>120</td>
<td>95</td>
</tr>
<tr>
<td>Energy (LHV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>btu/gal(x1000)</td>
<td>128</td>
<td>119</td>
<td>57</td>
<td>76</td>
<td>85(LNG)</td>
<td>84 1000(CNG)</td>
</tr>
<tr>
<td>btu/cu. ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Storage (relative vol.)</td>
<td>1</td>
<td>1.1</td>
<td>2.3</td>
<td>1.7</td>
<td>1.7 (LNG)</td>
<td>1.6 3.7 (CNG)</td>
</tr>
</tbody>
</table>
**What about natural gas?**

- Cleaner burning than diesel
- Abundant supply in North America
- Engine efficiency improving over diesel
- Renewable fuel – LFG to LNG
- Can be less expensive to operate than diesel
- Latest technology engines available

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**ISL G – Next Generation Natural Gas Engine**

8.9 litre Stoichiometric EGR engine:
- Lowest emissions
  - 0.20 g/bhp-hr NOx
  - 0.01 g/bhp-hr PM
- Higher efficiency
- Diesel-like reliability & durability
- Improved performance - Higher clutch engagement torque
- 250-320 Ratings
- Increasing OEM Availability
- Fourth generation

Launched June, 2007
### 2007 ISL G Benefits

- Meets 2010 Emission Standards
- More fuel efficient
- No exhaust system related maintenance costs
- Improved clutch engagement torque (+34%)
- 80% of design based upon diesel engine platform
- Uses a renewable fuel found in North America
- Substantial GHG Reductions

### ISL G Applications/OEMs

- **REFUSE**
- **URBAN TRANSIT**
- **VOCATIONAL**
- **FUTURE**
What about the cost of change?

- Standard CWI LCC model default assumption set
  - Not whole vehicle cost
  - Incremental natural gas related capital, and engine, fuel system, detection maintenance
  - Also includes capital and maintenance required for fuel infrastructure, and maintenance facilities
- $1 Million facility modifications for both refuse and transit
- 50 truck fleet refuse and 70 bus fleet transit - actual property-southern US
- Urban Bus analysis assumes CNG
- Refuse analysis assumes LNG Fuel Prices:
  - Diesel Fuel (refuse): $2.30 / gallon ($0.05 added for ULSD)
  - Diesel Fuel (urban bus): $2.20 / gallon ($0.05 added for ULSD)
  - Liquid Natural Gas (refuse): $1.72 DGE (prior to application of Highway Bill excise tax credit)
  - Natural Gas (transit): $1.70 DGE (prior to application of Highway Bill excise tax credit)
  - Includes commodity, O&M, electricity and $2 Million station 80% FTA funded
- Assume that Highway/Energy Bill tax credit flows fully & completely to end-user
  - Actual impact on end-user TBD
- Assume Energy Bill credit applies to net incremental cost after FTA funding (83%) is applied (Urban Bus only)
- Maximum $12,000 Energy Bill Credit to OEM for Hybrid (no Highway Bill credits)
- Assume that Energy & Highway Bill provisions remain in effect beyond 2010
- Diesel Electric Hybrid fuel economy benefit assumed to be 20%, based on recent projections from fleets (e.g. Ottawa)

LCC Analysis - Refuse Collection
Diesel / NG Pathways to 2010

**Diesel**
- ULSD
- Active Diesel Particulate Filters
- CEGR (ISC/ISL)
- NOx Adsorber or SCR
  - SCR more efficient but a liquid that will be regulated and taxed
- Crank Case Ventilation (CV) '07
- Lube Oil
  - Will require new, low ash oil
- New Oil Filters

**Natural Gas**
- No change, CNG or LNG capable
- Replace Oxicat with Three Way Catalyst
- Add CEGR (ISL G)
- No NOx adsorber required
- No CV required – reduced maintenance vs. LBSI
- No Change, Low Ash Oil in use today
  - CES20074
  - Fleetguard Filter

\[
\begin{align*}
1.2 \text{ NOx} + 0.01 \text{ PM in 2007} \\
0.2 \text{ NOx} + 0.01 \text{ PM in 2010}
\end{align*}
\]

Why Natural Gas Engines for Buses & Trucks?

**Emissions Leadership**
- ISL G is the only Urban Bus and Truck engine that met 2010 EPA Emissions at launch in 2007

**Emerging Economic Benefits**
- Continuous reliability improvement
- ISL G Improved Efficiency
- Greatest benefits in high fuel use applications

**Energy Security**
- Reduced reliance on imported oil
- Lower fuel costs
- Pathway to hydrogen
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Remember
Change is Inevitable

*Except from a Vending Machine*
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