Examining the Costs and Benefits of Technology Pathways for Reducing Fuel Use and Emissions from On-road Heavy-duty Vehicles in California

Ben Sharpe
Delivering the Green: The Future of California’s Freight Transportation System – Forum 2
Sacramento, CA  April 26, 2013
Topics

• Project motivation and scope
• Technology Options and Pathways for Heavy-Duty Vehicles (TOP-HDV) model description
• Results
• Conclusions
Project Motivation and Scope

Climate change

Air quality

Energy security/diversity

Timeline: 2010 – 2050

Scope: Heavy-duty vehicles operating in California
Policies Affecting Heavy-Duty Vehicles in California

**Criteria Pollutant-Focused Measures**
- National Clean Diesel Campaign
- Grants for vehicle or technology purchase
- R&D funding

**Voluntary, Incentive-based**
- Grants for vehicle purchase (e.g. HVIP)
- SmartWay Program
- Tax credits
- R&D funding
- Demonstration project funding

**Greenhouse Gas Focused Measures**
- Fleet renewal and purchase requirements
- PM and NOx control requirements
- Engine emission standards
- Anti-idling
- Diesel sulfur levels
- Low Carbon Fuel Standard
- Tractor-trailer GHG Rule
- Vehicle and engine performance standards (proposed in CA)

- Incentive-based policy in California
- Regulatory program in California
- Policy administered at the federal level
- CA and US policy harmonized
Lifecycle Emissions Modeled in TOP-HDV

Fuel production and transportation

Fuel production, refining, and distribution

Material acquisition, processing, and vehicle assembly

Vehicle manufacturing

Vehicle operation

Vehicle scrappage

GHGs and criteria pollutants

Energy

Vehicle activity
Lifecycle End-User Costs Modeled in TOP-HDV

UP-FRONT CAPITAL COSTS

- Vehicle purchase
- Infrastructure purchase and installation

ACTIVITY-RELATED COSTS

- Fuel
- Periodic maintenance
Lifecycle Societal Costs Modeled in TOP-HDV

- **Climate change**
  - GHGs and pollutants
  - $/ton

- **Air quality impacts**
  - PM, NOx, HC, CO, SOx
  - $/ton

- **Energy security**
  - $/gallon

- **Noise pollution**
  - $/mile
Six Scenarios of the TOP-HDV Model

**Baseline**
Business-as-usual technology and fuel evolution

**High Efficiency**
Larger annual improvements in fuel efficiency and faster adoption of hybrids

**Plug-in and EVs**
*High Efficiency* fuel efficiency improvements; rapid adoption of hybrids, PHEVs, and EVs

**Fuel Cell Vehicles**
*High Efficiency* fuel efficiency improvements; rapid adoption of hybrids and FCVs

**Alternative Fuels**
*High Efficiency* fuel efficiency improvements; rapid adoption of hybrids, NGVs, and low-carbon fuels

**80in50**
Technology and low-carbon fuel adoption rates as necessary to reduce CO$_2$e by 80% vs. 1990 levels by 2050
Zero emission technology development and deployment for long-haul trucking is critical to meeting CA’s air quality and climate targets.

Drayage (short-haul) operations

Vision Tyrano: battery-dominant H₂ fuel cell tractor → currently being deployed

Enabling steps:
- Large improvements in H₂ fuel cell durability and reliability
- Advances in H₂ storage tanks
- Significant cost reductions
- Sufficient H₂ infrastructure

Future concept??

FCV and 80in50 scenarios assume large-scale adoption of long-haul H₂ fuel cell tractors
All Scenarios: CO$_2$-equivalent Emission Trends

1990 levels

80% lower than 1990 levels

Baseline  High Efficiency  PHEVs+EVs  FCVs  Alternative Fuels  80in50
80in50 Scenario: CO$_2$e Reduction Breakdown

Impact of annual fuel efficiency improvements in new vehicles

Impact of adoption of advanced technology vehicles

Impact of transition to lower carbon fuels

- 80in50
- Turnover, adv. vehicle adoption
- Fuel efficiency improvements
- Low carbon fuel feedstocks
80in50 Scenario: Cost Breakdown

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2035</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2045</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
All Scenarios: Net Present Value of 2010-2050 Costs

Net Present Value (2010) Using 2.1% Real Discount Rate

Baseline
High Efficiency
PHEVs+Evs
FCVs
Alternative Fuels
80in50

-6%
-6%
-7%
-7%
-11%

Million US Dollars (2010$)

$0
$100,000
$200,000
$300,000
$400,000
$500,000
$600,000
$700,000
Conclusions

• End-user costs are an order of magnitude larger than externality costs

• CO$_2$e reduction breakdown of the 80in50 scenario
  – Increased annual efficiency of new vehicles is most important in first half of the study period
  – Impact of zero emission vehicles most important in second half of the study period

• 80in50 scenario provides savings vs. the Baseline and other four scenarios in terms of NPV of total societal costs (end user cost + externality costs)
Acknowledgements

• Special thanks to my dissertation committee
  – Prof. Alissa Kendall
  – Prof. Mark Delucchi
  – Prof. Dan Sperling

• The International Council on Clean Transportation

Thank You!

ben@theicct.org