The Gap Between Realistic Expectations and Our Transportation GHG Emissions Targets

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Contexts for Technology-Based Assessments

1. It’s “the vehicles that are driven” that have impact: so it is powertrains and fuels in the in-use vehicle fleet that matter.

2. Time scales for assessment are critical: 2020 limited potential for change; 2050 greater potential for change.

3. Regional economic context in the global context will determine growth in regional demand for transporting people and goods. (Many different world regions.)

4. The future availability and price of petroleum is a critical input to assessments of new technology development and deployment.

5. Useful to start with the evolving transportation energy context: cost, availability; “greenness” of petroleum-like fuels and of biofuels, and of electricity, and hydrogen.
1. Recent CERA projection: petroleum plus tar sands (etc.) plus biofuel supply projected to grow at about 1% per year, 2010 to 2035.

2. 2004 WBCSD Sustainable Mobility Project projection: transportation fuel demand (largely petroleum-based) grows at about 1.7% per year 2010 to 2035.

3. Plausible that (at least in U.S.) natural gas will be significantly cheaper than petroleum-based fuels.

4. Petroleum consumption, energy use, and GHG emissions are all important (and different) issues: Energy and GHG emissions must be evaluated on a well/source-to-wheels basis.

5. The evolving GHG emissions’ impacts of the various fuels/energy sources over time need to be understood.
Future Global Oil Supply

![Graph showing future global oil supply trends from 1990 to 2070.](graph)

- **Reference Case Liquids Capacity (IHS CERA 2009)**
- **Conventional Crude Capacity (IHS CERA 2009)**
- **Peak–Campbell 2002**

**Legend**:
- **Historical Production**
  - **1.1 trillion barrels cumulative**
- **Unconventional Oil**
- **Conventional Oil**

**Key Data**:  
- **2.4 trillion barrels post-2010**  
- **1.9 trillion barrels post-2010**  
- **0.9 trillion barrels post 2010**

Source: Cambridge Energy Research Associates.  
60907-9_2107
Figure 2.12: Worldwide transport-related fuel use – all transport modes

Source: Mobility 2030: WBCSD Sustainable Mobility Project Report 2004
<table>
<thead>
<tr>
<th>Fuel source</th>
<th>Fuel</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Corn grain, sugar</td>
<td>Ethanol</td>
<td>Limited volume (~10%)</td>
</tr>
<tr>
<td>1. Crops, seeds, etc.</td>
<td>Biodiesel</td>
<td>Limited volume (~1%)</td>
</tr>
<tr>
<td>3. Biomass (non-food: cellulosic biomass, wood waste, algae)</td>
<td>Ethanol, Gasoline/diesel/butanol</td>
<td>Potential; R &amp; D stage</td>
</tr>
<tr>
<td>4. Oil sands/ heavy oil</td>
<td>Gasoline/diesel</td>
<td>Production volumes increasing</td>
</tr>
<tr>
<td>5. Oil shale/coal</td>
<td>Gasoline/diesel, etc.</td>
<td>Potential; development stage; higher GHG</td>
</tr>
<tr>
<td>6. Various</td>
<td>Natural gas</td>
<td>Lower cost; use unclear</td>
</tr>
<tr>
<td>7. Natural gas/ electricity, etc.</td>
<td>Hydrogen</td>
<td>Major infrastructure issues; uncertain</td>
</tr>
<tr>
<td>8. Coal, natural gas, nuclear, renewable</td>
<td>Electricity</td>
<td>Political pressure; market unclear</td>
</tr>
</tbody>
</table>
Balancing Optimism with Realism

We are usually too optimistic because:

1. In this well-established arena, steady improvement in the technologies are likely, but many factors “degrade” performance.

2. Also, because many of the technologies are well established, “breakthroughs” are less likely.

3. Achieving significant penetration of improved or new technologies takes longer than we anticipate.
Trends: History of steadily increasing horsepower/acceleration

Average new U.S. car characteristics

Data source: USEPA 2009
Key Steps in Estimating Impacts of Scenarios

1. Predicting fuel consumption and GHG emissions for given propulsion system, vehicle, and fuel.


3. Model for in-use vehicle fleet.

4. Quantitative scenarios for availability of fuel (and energy) streams over the appropriate timeframes.

5. New technology introduction timeframes and deployment rates over time.

6. Life-cycle GHG analysis capability.

1. Improving mainstream technology
   • More efficient engines (e.g. turbocharged downsized gasoline and diesel engines, charge-sustaining hybrids)
   • More efficient transmissions
   • Vehicle weight, drag, and performance reduction
   • Liquid fuels from biomass

1. Transitioning to new energy sources
   • Electricity (PHEVs, BEVs)
   • Natural gas (spark-ignition engine)
   • Hydrogen (fuel cells)
Relative Fuel Consumption of Future Cars, by Powertrain (at 100% ERFC)
Relative fuel consumption of cars modal input over time to 2050
New Technology Deployment Rates

1. Especially difficult question: uncertain and contentious!

2. Need to consider deployment of new technology in several phases: e.g., pilot production; initial market-pulled growth; increasing and substantial growth; asymptotic leveling-off of sales.

3. Previous major vehicle technology changes took more than ten years to achieve significant volume production (e.g., significantly-increasing-volume phase for diesel in Europe: 1985 10%, 2005 50%: 8 - 10% growth per year).
Sales market share modal inputs to 2050
Clean Energy Sources Over Time

Alternative fuel availability modal inputs to 2050
Average New Vehicle Fuel Consumption Over Time

![Average new vehicle fuel consumption, L/100km](chart.png)
Results: Fleet Fuel use in 2030

2030 U.S. Fleet fuel use probability distribution
[Bil L gasoline equivalent/year]
Results: Fleet Fuel use in 2050

2050 U.S. Fleet fuel use probability distribution
[Bil L gasoline equivalent/year]
Results: Fleet GHG Emissions in 2030 and 2050

2030 and 2050 U.S. Fleet GHG Emissions probability distribution [Mt CO$_2$ equivalent/year]
Results: Major Contributing Variables to Fuel use

2030 and 2050 U.S. Fleet fuel use ranked major contributing variables [Bil L gasoline equivalent/year]
Results: Fleet Fuel use and GHG Emissions out to 2050

U.S. Fleet Fuel Consumption [Bil L gasoline equivalent/year] and GHG emissions uncertainty profile over time [Mt CO$_2$ equivalent/year]
Results by Segment: Fleet Fuel Consumption

Fleet Fuel consumption modal output by powertarin share to 2050
Strategic Issues:
Reducing US LD Vehicle GHG Emissions

- Extrapolation scenarios
- No change
- Hydrogen
- Electricity
- Biofuels
- Demand reduction

Need low GHG emitting transitions

Target
60 to 80% reduction
Summary

1. Need for more sophisticated “assessing” of the viable fuel/energy options

2. Performance of the various technology options is relatively well defined (out to about 2030)

3. Technology improvement rates, deployment rates, and cost issues, are especially challenging

4. Uncertainties (of many kinds) make this a “pathways” rather than “end states” problem

5. What are useful approaches for examining plausible reductions by 2050? Develop policies to promote the more promising opportunities
Three Important Energy and GHG Emissions Paths Forward

1. **Improve:** increase the fuel efficiency of mainstream transportation vehicles and develop alternative liquid hydrocarbon fuel sources which can displace petroleum and reduce GHG emissions.

2. **Conserve:** reduce the demand for energy intensive personal and freight transportation services.

3. **Transform:** shift transportation’s energy requirements (and propulsion technologies) to alternatives with much lower GHG emissions.
## Analysis M-1: Table of Input Assumptions (1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2030 Values</th>
<th>2010 Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Mode</td>
</tr>
<tr>
<td>Total light vehicles Sales in 2030</td>
<td>9,387</td>
<td>18,403</td>
</tr>
<tr>
<td>Future Scrappage Rate(2011+)</td>
<td>65%</td>
<td>80%</td>
</tr>
<tr>
<td>%Sales Gasoline-Turbo in 2030</td>
<td>6%</td>
<td>12%</td>
</tr>
<tr>
<td>%Sales Diesel in 2030</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>%Sales HEV in 2030</td>
<td>3%</td>
<td>10%</td>
</tr>
<tr>
<td>% Sales PHEV in 2030</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>%Sales BEV in 2030</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>%Sales FCHEV in 2030</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>% car (vs. light trucks)</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td>VKT-Annual-Growth(2006-2020)</td>
<td>0.26%</td>
<td>0.50%</td>
</tr>
<tr>
<td>VKT-Annual-Growth(2020-2030)</td>
<td>0.07%</td>
<td>0.25%</td>
</tr>
<tr>
<td>VKT-Annual-Growth(2030+)</td>
<td>-0.40%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

### Emphasis on Reducing Fuel Consumption (ERFC)

- **ERFC Cars**
  - 40% | 80% | 100% | 73% | 12% | 17% | 50% |
- **ERFC Light Trucks**
  - 30% | 70% | 100% | 67% | 14% | 22% | 50% |

### Electricity Use

- **PHEV Elec consumption (Kwh/100km) in 2030**
  - 12 | 24 | 35 | 24 | 5 | 20% | 36  |
- **BEV Elec consumption (Kwh/100km) in 2030**
  - 12 | 24 | 36 | 24 | 5 | 20% | 36  |
- **FCV Hybrid Electric Energy use (MJ/100km)**
  - 30 | 115 | 200 | 115 | 35 | 30% | 115 |
- **Utility Factor**
  - 30% | 48% | 66% | 48% | 7% | 15% | N/A |
## Analysis M-1: Table of Input Assumptions (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2030 Values</th>
<th>2010 Values</th>
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<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Mode</td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%blend cellulosic ethanol in 2030</td>
<td>4%</td>
<td>14%</td>
</tr>
<tr>
<td>%blend corn ethanol in 2030</td>
<td>2%</td>
<td>8%</td>
</tr>
<tr>
<td>%electricity from clean sources in 2030</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td>%bio-diesel</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>%tar sands in 2030</td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td><strong>WTW Coefficients [gCO2 eqv/MJ]</strong></td>
<td></td>
<td></td>
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<tr>
<td>Ethanol WTW in 2030</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Corn Ethanol WTW in 2030</td>
<td>60</td>
<td>69</td>
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<tr>
<td>Gasoline WTW in 2030</td>
<td>81</td>
<td>92</td>
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<tr>
<td>Diesel WTW in 2030</td>
<td>82</td>
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<tr>
<td>Bio-Diesel WTW in 2030</td>
<td>56</td>
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<tr>
<td>Electricity WTW in 2030 [gCO2/kWh]</td>
<td>376</td>
<td>970</td>
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<tr>
<td>Hydrogen WTW in 2030</td>
<td>93</td>
<td>123</td>
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<tr>
<td>TarSand WTW in 2030</td>
<td>92</td>
<td>105</td>
</tr>
<tr>
<td><strong>FC Relative in 2030</strong></td>
<td></td>
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</tr>
<tr>
<td>FC-r NA-SI cars in 2030</td>
<td>0.44</td>
<td>0.70</td>
</tr>
<tr>
<td>FC-r Turbo cars in 2030</td>
<td>0.39</td>
<td>0.62</td>
</tr>
<tr>
<td>FC-r Diesel cars in 2030</td>
<td>0.37</td>
<td>0.59</td>
</tr>
<tr>
<td>FC-r HEV cars in 2030</td>
<td>0.21</td>
<td>0.42</td>
</tr>
<tr>
<td>FC-r PHEV cars in 2030</td>
<td>0.21</td>
<td>0.42</td>
</tr>
<tr>
<td>FC-r NA-SI LT in 2030</td>
<td>0.45</td>
<td>0.71</td>
</tr>
<tr>
<td>FC-r Turbo LT in 2030</td>
<td>0.39</td>
<td>0.61</td>
</tr>
<tr>
<td>FC-r Diesel LT in 2030</td>
<td>0.35</td>
<td>0.56</td>
</tr>
<tr>
<td>FC-r HEV LT in 2030</td>
<td>0.22</td>
<td>0.43</td>
</tr>
<tr>
<td>FC-r PHEV LT in 2030</td>
<td>0.22</td>
<td>0.43</td>
</tr>
</tbody>
</table>
Transportation Demand Reduction Models and Analysis

1. Limited analysis in this area to date: an important area!

2. Recent study “Moving Cooler An Analysis of Transportation Strategies for Reducing GHG Emissions” (Cambridge Systematics, Inc., 2009) illustrates the potential:
   • Near-term strategies (e.g., parking fees/controls, congestion pricing
   • Long-term/maximum results (e.g., transit expansion, active traffic management)
   • Land use transitions (e.g., link smart growth, transit, non-motorized travel) can reduce travel demand
   • How can such studies of changes in demand be connected to technology change impact studies (there are feedbacks)