The (Sobering) Fundamentals of Transport Energy Strategies

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Climate Change Workshop

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US Transportation Trends Unsustainable

- Gasoline is being “re-carbonized” due to increasing use of tar sands and heavy oil
- Vehicle travel continues to increase (~2%/yr)
- Transit accounts for 2% of passenger travel
- Increases in vehicle performance, size, and weight are offsetting vehicle efficiency improvements of 1-2%/yr
- Net effect: GHG emissions from transportation continue to increase in California, US, and world

Where does this lead??
Public and private R&D funding needs to increase to support devt of biofuels, plug-in hybrids, and hydrogen

Kammen & Nemet (2005)
Strategies to Reduce GHG Emissions

I. Reduce vehicle travel
   - More and better transit, smart growth, road pricing

II. Improve efficiency of “conventional” vehicles
   - Including diesels and hybrids
   - Carrots and sticks

III. Introduce low-carbon fuels and electric vehicle technologies
   - Biofuels (not corn-ethanol)
   - Electricity (plug-in hybrids and battery EVs)
   - Hydrogen (with fuel cells)
I. Reduce Vehicle Travel

- Widely accepted that:
  - Better management of land use and some densification is desirable
  - People should walk and bike more
But all forces and trends lead to MORE travel

(More travel per day per capita instead)

Grübler #7
I. Reduce Vehicle Travel

• Widely accepted that:
  - Better management of land use and some densification is desirable
  - People should walk and bike more

• Reality check
  - People value personal transport and mobility/accessibility
  - Conventional transit (buses, rail) not suited to suburban land use patterns and diffuse jobs
  - People willing to commute long distances to get larger houses and lots. More people are moving to exurbs and traveling more.

• What is possible?

  *Sacramento Blueprint includes ambitious travel reduction scenario for 2050 that results in 16% less travel per household. But, since number of HHs will almost double, the net effect is a 75% increase in travel.*
Change in transportation is slow. Complex mix of public and private entities, important public service and indirect economic functions, slow turnover of vehicles.

Major technology changes happen slowly, and mostly in concert with changes in behavior and policy. “Disruptive technologies” face especially large barriers in transportation.
But Many Ways to Dramatically Reduce GHGs
GHG emissions per Km, relative to gasoline-powered ICE, full energy cycle

<table>
<thead>
<tr>
<th>Fuel/Feedstock</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cells, Hydrogen with Solar Power</td>
<td>-90 to -85</td>
</tr>
<tr>
<td>Cellulosic Ethanol</td>
<td>-90 to -40</td>
</tr>
<tr>
<td>Battery EVs, California power mix</td>
<td>-60 to -30</td>
</tr>
<tr>
<td>Fuel Cells, Hydrogen from NG</td>
<td>-40 to -10</td>
</tr>
<tr>
<td>Gasoline Hybrid Vehicle</td>
<td>-35 to -10</td>
</tr>
<tr>
<td>Diesel</td>
<td>-25 to -15</td>
</tr>
<tr>
<td>Corn Ethanol</td>
<td>-25 to +5</td>
</tr>
<tr>
<td>Gasoline</td>
<td>-</td>
</tr>
</tbody>
</table>

Actual impacts could vary considerably. These estimates reflect a large number of assumptions and should be treated as illustrative.

Adapted from GREET, Delucchi LEM model, MIT
II. Improve Efficiency of Conventional Vehicles

• Much is possible at little or no cost
  ▪ What is cost effective? In part depends on whether one measures over 3 years, or life of vehicle.

• AB 1493 (Pavley bill) requires 30% reduction in GHGs by new vehicles in 2016

• Diesel and hybrid technology provide potential for up to 1/3 more reduction

• Many policy instruments
Much efficiency innovation, but offset by increased power, size, and weight of new vehicles (US)

(Gasoline) hybrids are important, but not THE solution

- **Short term**
  - Market growing slowly (1.5% of new sales 6 years after being introduced) (higher in CA)
  - Compact car hybrids cost ~$3,500 extra (bigger premium for bigger vehicles)
  - Fuel economy improvements are 10-50%
  - Some people willing to pay for “doing good”

- **Long term**
  - ~$1500 premium for 50% improvement in ~15 years
  - If aggressively implemented and if power/size is held constant, then net fuel economy improvement is ~1.5-2%/yr – roughly offsetting increases in vehicle travel
III. Introduce low-carbon fuels and electric vehicle technologies
Biofuels

Gaining popularity because…

• Easy to implement
  ▪ Minimal change in vehicles and CAFE benefit make them attractive to automakers
  ▪ Fuel distribution fairly easy, though somewhat more costly than gasoline (exacerbated by seasonal fluctuations, regional supply variations, scale issues, co-products)

• Potent alliance between enviros, farm interests, and those concerned with national security

BUT …

• Biodiesel is very expensive, except from recycled oils

• Corn etoh has no air quality benefit, minimal GHG benefit, and requires large amounts of land (15% of corn land used to replace 2% of gasoline)

• Cellulosic ethanol has large energy/enviro benefits and large production potential, but cost and technology are uncertain, and is attracting minimal R&D and private investment

• Little appeal to consumers (when used in combustion engines)
Plug-in Hybrids (and Battery EVs)

Gaining popular attention as easy option to get large, quick energy/enviro improvements.

Good news …

• Very large energy/enviro improvements are possible
• Attractive to electric utilities and potentially to consumers

But …

• Requires larger, heavier, more durable batteries than gasoline HEVs, with much higher vehicle/battery cost
• No business model for oil industry

Best Case Timeline

• 10% of new cars in 2020: 1st vehicles in 3 years; 6 more years to get to 1% market penetration (like gasoline hybrids); another 5 years to get to 10% penetration
  • PHEVs face much tougher barriers than gasoline hybrids (more expensive, more complex design/customer issues)
Other Promising Option is Hydrogen
H2 costs likely to be comparable to those of biofuels and plug-in hybrids

- **GEA = Gasoline Efficiency Adjusted** – scaled to hybrid vehicle efficiency

**Source:** National Academies (2004)
Hydrogen (w/ Fuel cells)

• FCs 2x more efficient than combustion engines
• Energy/environmental impacts potentially very large (depending on feedstock, production processes, distribution modes)
• Attractive to automakers because zero emissions, potentially easier to manufacture, and potentially more attractive to customers
• Fits oil company “business models”

But ….

• FC system costs and performance still need great improvement
• Fuel supply still problematic (though large hydrogen industry already exists)
Summary

• Transportation trends are unsustainable
• Improved efficiency (and fuel economy) must be number one strategy, but it is not enough to meet oil/GHG goals
• No silver bullet.
• Biofuels, plug-in hybrids, and hydrogen all face huge obstacles. None will provide large near term benefits. All will take a LONG time.
• Unlikely that one fuel will fully dominate; likely to be regional differences
• Need policy and business leadership now for all fuel/vehicle strategies
Need to Take Advantage of California Uniqueness (California Exceptionalism)

• Resources and Economics
  ▪ Manufacturing is expensive, agriculture is mostly specialty crops, land is expensive, no coal

• Markets and Consumers
  ▪ Greener, more willing to adopt new products

• Politics
  ▪ Less influence by coal and Detroit interests
  ▪ Unique regulatory powers (AQ)

• Capabilities
  ▪ Strong universities and research capabilities
  ▪ Entrepreneurial business environment
Thank You
• specific policies; address time frames; low hanging fruit; plant seeds about role of consumers, industry, govt; how to change consumer behavior;
Take-away messages

• Improved efficiency (and fuel economy) is important but not enough to meet oil/GHG goals

• No silver bullet. Promising non-petroleum, low-carbon alternatives are:
  ▪ Biofuels
  ▪ Electricity (PHEVs and BEVs)
  ▪ Hydrogen

• These energy strategies all provide potentially large benefits, but all also face huge challenges

• All energy transitions take a LONG time

• Unlikely that one fuel will fully dominate. Likely to be regional differences, and likely to be mix of options into foreseeable future
Fuel Cells Are Looking Up

![Graph showing annual fuel cell patents and stock price for several companies over time.](Image)
What do Conventional Hybrids Tell Us About Future of FCVs

- Market growing slowly
  - Huge regional variations in sales
  - Low sales of Accord "power hybrid" (~3% of Accords) and Ford Escape, but they have huge markups relative to gasoline models
  - Willingness to pay for “doing good”?
- Path to FCVs? Yes, from technology and consumer perspectives

**US Hybrid Sales 2004–2006**

<table>
<thead>
<tr>
<th>Current month by volume</th>
<th>Apr-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota Prius</td>
<td>8,234</td>
</tr>
<tr>
<td>Toyota Camry Hybrid</td>
<td>86</td>
</tr>
<tr>
<td>Toyota Highlander Hybrid</td>
<td>3,768</td>
</tr>
<tr>
<td>Lexus Rx 400h</td>
<td>2,247</td>
</tr>
<tr>
<td>Lexus GS 450h</td>
<td>141</td>
</tr>
<tr>
<td>Honda Civic Hybrid</td>
<td>3,087</td>
</tr>
<tr>
<td>Ford Escape/Mariner Hybrid</td>
<td>3,420</td>
</tr>
<tr>
<td>Honda Accord Hybrid</td>
<td>614</td>
</tr>
<tr>
<td>Honda Insight</td>
<td>110</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>21,707</td>
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Hybrids as % of Mixed Model Sales, April 2006

<table>
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<tr>
<th>Model</th>
<th>Total sales</th>
<th>Hybrid sales</th>
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<tr>
<td>Highlander</td>
<td>10,712</td>
<td>3,768</td>
<td>35.2%</td>
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<td>Rx330/400h</td>
<td>8,890</td>
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<td>31,259</td>
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<td>Accord</td>
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<td>614</td>
<td>1.9%</td>
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To reach stable carbon levels of 450-550 ppm, world emissions need to decline dramatically – by as much as 90% from projected levels.
Principal Long Term Energy Options for Vehicles

- Petroleum-like fuels from unconventional fossil sources
  - Used in combustion engines
  - Made from tar sands, heavy oil, remote gas, coal, and oil shale
  - BAU path – with potentially disastrous environmental implications

- Hydrogen
  - Used in fuel cells
  - Many sources (including nuclear and fossil)

- Electricity
  - Used in BEVs and plug-in hybrids
  - Many sources (including nuclear and fossil)

- Biofuels
  - Used now in combustion engines (with little energy/enviro benefit)
  - Can be made from lignicellulose (residues, grasses, trees), as well as starch and sugar (corn, sugar cane, etc)
# Hybrids as % of Mixed Model Sales, April 2006

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Switchgrass

Miscanthus, One Season’s Growth
Courtesy Steve Long, University of Illinois (and Lee Lynd)
Fuel Cell Vehicles

FCVs must be perceived as “better” than ICEVs, and thus marketable at higher prices. Many car companies believe they are.

- On board electricity and new lifestyle uses
- Mobile electronics, tools & appliances
- Emergency electricity
- Vehicle to grid power
- Low emissions, energy use
- New vehicle designs
- Electric-drive feel
Why are other alternatives gaining momentum?

- Backlash against hydrogen
  - Enviros hostile/skeptical to Bush Administration proposals (plus concerned about “black” hydrogen)
  - Jealousy by competing interests (energy efficiency, renewables) – ZERO sum game?
- Impatience with Bush Administration initiatives on energy
- Heightened concern about oil due to high gasoline prices, Middle East tension, and increasing concerns about global warming – “need to do something now”
- Popular perception that PHEVs and cellulosic ethanol are easy to implement and ready for primetime
- Farm lobby exploiting economic and political opportunity
- Unusual alliance of farm, enviro, and national security interests
However, H2 and FCVs are still a focus

- US DOE hydrogen budgets increasing
- US DOE states that H2/FCV is still a promising long-term vision, but other alternatives may play a role
- Automotive OEMs still strongly support FCVs, and some are bullish on production goals (2012-2015)
- Domestic and international H2/FCV demonstrations and partnerships are expanding
- CA Administration still strongly supports Hydrogen Highway and FCVs
GHG Emission Reduction in Transport

• What are the strengths and weaknesses of alternative scenarios for achieving a transition to a low-emission transportation sector in California?
  § What are the most promising policy options for pursuing this goal?
  § How much will the transition cost and how can equity issues be addressed?
  § The roundtable will explore both near-term and long-term options including a) demand management (public transit, smart growth), b) efficiency/technology (emissions regulations, Pavley Bill, hybrids), and c) alternative fuels (biofuels, etc.).
  -specific policies; address time frames; low hanging fruit; plant seeds about role of consumers, industry, govt; how to change consumer behavior;

• Ford's efforts to improve fuel economy and push into alternative fuels dominated Ford's annual shareholder meeting on Thursday, according to Reuters. Bill Ford said that in addition to working on ethanol, biofuels and hybrids, the company is also looking keenly at plug-in hybrid technology.
Vehicle Travel in US Increasing Much Faster Than Population (and Highway Capacity)

- GDP (+166%)
- VMT (+157%)
- Lt Duty Energy Use (+61%)
- Population (+42%)
- Lane Miles (+18%)
Cost-effectiveness of GHG Options for Vehicles

These reduce costs and GHGs, so why don’t they happen?