Surviving Two Billion Cars
Transforming Vehicles, Fuels, and Mobility

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2 Billion Vehicles in 2020 (globally)!

Source: Sperling and Gordon (2009), based on DOE, JAMA, other projections
The Problem
In the next 10 years, the world will consume 1/4 of all oil consumed through its entire history.

Source: Sperling and Gordon (2009), based on U.S. DOE/EIA data.
Future of Oil? Undulating Plateau vs Peak Oil

Source: Sperling and Gordon (2009), adapted from Cambridge Energy Research (2006)
Oil Problem #1:
Middle East Gaining More Control of Oil Production

Source: IEA reference scenario

[Graph showing market share of Total OPEC, Non-OPEC non-conventional oil, Non-OPEC conventional oil, and OPEC market share from 2005 to 2030]
The problem is not running out of oil!

Oil Problem #2: Shift to High-Carbon Unconventional Oil

Supply “Curve” of World Hydrocarbon Resources

IEA, 2005
To stabilize atmospheric CO$_2$ concentration, need to decarbonize the energy system at several times the historical rate of 0.3%/y. Even if the electric sector is completely decarbonized by 2100, stabilization at 550 ppm (450 ppm) => 3 (5) fold reduction in carbon emissions from direct fuel use vs. IS92a.

Humans Need to Dramatically Reduce CO$_2$ Emissions to Stabilize the Climate

Some scientists now say 350 ppm may be necessary to avoid catastrophic climate change.
Transportation Plays Large Role in Climate Change and Oil Security in US and California

Transportation accounts for 2/3 of oil in US and ¾ in California

- California: 38%
- U.S.: 28%
- Worldwide: 23%
- E.U.: 21%

Direct share* transport CO2 emissions

EIA, 2006
So What Should Be Done?
“Detroit churches pray for ‘God’s bailout’ of auto industry”

SUVs on altar of Greater Grace Temple, a Pentecostal church in Detroit, as congregants prayed to save the auto industry. NY Times, 12/7/08

...SUV sales increased that month (Dec 2008)
Transforming Transportation

- Transforming vehicles ("easiest")
- Transforming fuels (hard)
- Transforming mobility (hardest)
First Leg
Transforming Vehicles

- Large potential to improve efficiency of conventional vehicles.
- Even larger potential to reduce oil use and GHGs with advanced (electric-drive) vehicles.
No progress in recent decades, especially in US (and Australia). Automotive industry is highly innovative, but efficiency innovations have been used to offset increased weight, size, and power. Can we stop the horsepower race and use efficiency innovation for improved fuel economy? Policy plays key role!

Average Vehicle Characteristics
Percent Change from 1987 to 2006 (USA)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Economy</td>
<td>5% Lower</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>29% Heavier</td>
</tr>
<tr>
<td>Horsepower</td>
<td>86% Higher</td>
</tr>
<tr>
<td>0 to 60 Time (sec)</td>
<td>35% Faster</td>
</tr>
</tbody>
</table>

Source: US EPA
The horsepower race…

Ferrari 308 GTS, 1984
7.3 secs from 0-60, 230 hp
(Tom Selleck as Magnum, PI)

Toyota RAV4, 2008
7.3 seconds from 0-60, 269 hp

*Toyota SUV today = Ferrari in 1984*
New U.S. CAFE and California GHG Standards

- 35.5 mpg by MY 2016 (~155 gCO$_2$/km) (EU is aiming for 120g by 2015)
- ~40% increase from today’s 25 mpg (255 gCO$_2$/km)
Electric vehicle experiment of 1990s largely failed … but led to improved batteries and electric drivetrains which are now making comebacks in hybrids, fuel cell vehicles... and battery-electric vehicles!
HEV Sales Rising Slowly
Batteries Getting Steadily Better, But Still Expensive

Source: IEA (2009), from Johnson Control – SAFT, 2005 and 2007
### Vehicles With Batteries Will Continue to be Expensive?!

<table>
<thead>
<tr>
<th>VEHICLE TYPE</th>
<th>RETAIL PRICE INCREASE [$2007]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cars</td>
</tr>
<tr>
<td><strong>2008 Gasoline ICE retail price</strong></td>
<td>$19,600</td>
</tr>
<tr>
<td>Increment in 2008 over Gasoline ICE:</td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>+ $1,700</td>
</tr>
<tr>
<td>Current Turbo Gasoline</td>
<td>+ $700</td>
</tr>
<tr>
<td>Current Hybrid</td>
<td>+ $4,900</td>
</tr>
<tr>
<td>Gasoline SIE</td>
<td>+ $2,000</td>
</tr>
<tr>
<td><strong>2035 Gasoline ICE retail price</strong></td>
<td>$21,600</td>
</tr>
<tr>
<td>Increment in 2035 over Gasoline ICE:</td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>+ $1,700</td>
</tr>
<tr>
<td>Turbo Gasoline</td>
<td>+ $700</td>
</tr>
<tr>
<td>Hybrid</td>
<td>+ $2,500</td>
</tr>
<tr>
<td>Plug-in Hybrid</td>
<td>+ $5,900</td>
</tr>
<tr>
<td>Battery Electric</td>
<td>+ $14,400</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>+ $5,300</td>
</tr>
</tbody>
</table>

NAS, 2009
Newly Aggressive US and California Vehicle Policies, But Short Term Focus

- Obama’s new fuel economy (and GHG) standards: 35.5 mpg by 2016 (155 g/km)
  - 40% increase from today
  - Extends California’s GHG standards to rest of country
  - Large bonus points proposed for BEVs
- Tax credits for advanced low carbon vehicles (up to $7500)
- Increased R&D spending – especially for batteries
- Cash for clunkers (minimal effect on GHGs and fuel use)
- California ZEV requirement (for 2014)
  - 12,500 BEVs or 5000 FCVs
  - 58,000 PHEVs
- No fuel/GHG policies for trucks, maritime, or rail (except minor rules in California—such as required improvements in aerodynamics for heavy trucks)
Future of Plug-in Vehicles?

- **China likely to play large role** *(18 million e-bikes sold in 2008)*
- Battery electric vehicles likely to be small city cars.
- Most PHEVs likely to have small batteries ("enhanced" Prius)

**Battery cost must drop sharply, durability must increase**
Another Transformation: Connecting Vehicles to Buildings and Electricity Grid
Second Leg
Transforming Fuels

- Transportation is almost totally dependent on oil today (everywhere except Brazil)
  - Some use of corn ethanol in US and NG in Argentina, Pakistan, Brazil and a few other countries
- Future fuels will be a mix of biofuels, electricity, and hydrogen
Many Promising Replacements
Some better than others...

- Fuel Cells, hydrogen
- Biofuel, wood
- Battery Electric, natural gas
- Hybrid Electric, full hybrid
- Battery Electric, US power mix
- Diesel
- Ethanol, corn
- Natural Gas
- Gasoline, conventional
- Battery Electric, new coal
- Gasoline, tar sands
- Gasoline, coal

Carbon Emissions Relative to Conventional Gasoline
Fuel *du jour* Phenomenon
Disruptive and wasteful

- 30 years ago – Synfuels (oil shale, tar sands, heavy oil, coal)
- 20 years ago – Methanol
- 15 years ago – Electricity (Battery EVs)
- 5 years ago – Hydrogen (Fuel cells)
- 2 years ago – Ethanol
- Today – Electricity (Plug-in hybrid vehicles)
- *What’s next?*

Government poor at picking winners ...
Need durable policy such as low carbon fuel standards
US Fuel Policy

- Biofuels mandate ("renewable fuel standard") (adopted 2007)
- California: low carbon fuel standard (adopted 2009)

(EU is also moving toward a low carbon fuel standard)
California Low Carbon Fuel Standard

*adopted by California April 23, 2009*

**Design Features**
- Requires 10% reduction in carbon intensity of fuels (gCO₂-eq/MJ)
- Based on lifecycle measurements (well to wheel)
- Imposed on oil refiners
- Companies can buy and sell credits

**Advantages of LCFS concept**
- Inspires innovation
- Robust/durable
- Performance based
- Doesn’t pick winners
- Encompasses all fuels: NG, petroleum, unconventional oil, biofuels, electricity, H₂

*Policy framework for transforming oil companies and transport fuels … Supports BEVs, PHEVs, and FCVs*
Third Leg: Transforming Mobility and Land Use

In US (and Australia?), we’ve created a transportation monoculture where “sprawl is the law.” Many opportunities for innovation!
California’s SB 375 Law Is First Step in US to Reduce Vehicle Use

• Sets targets for each metropolitan area

• Local governments have flexibility in how they reduce GHGs from passenger travel
  ▪ Land use, public transportation, road and parking pricing
Potential Impacts of Land Use and Transit Strategies on GHG Emissions in California

Source: ARB Scoping Plan, based on Rodier (2008)
California’s Pioneering Role

- 2002: AB1493 signed (Pavley vehicle stds)
- 2006: AB32 signed
- 2008: SB375 signed
- 2012: AB32 regulations take effect
- 2020: Reduce GHG emissions to 1990 levels

Reduces VMT

AB32 scoping plan adopted
California’s GHG (and Oil) Goals

California GHG Emissions (MMTCO2e/yr)

Historical  Forecast  Targets

28%
California Climate Policy Model

- Model and leader, not island
- Comprehensive plan for entire economy
- Stimulate innovation in technology, behavior, institutions
- Target specific GHG reductions with broad array of rules and incentives
  - Energy efficiency stds, Renewables Portfolio Standard, Low Carbon Fuel Standard, etc
- Overlay cap-and-trade program (and offsets) to create price signal for carbon
  - In California, cap and trade accounts for only 20% of planned reductions in 2020
Cap and Trade (and Carbon Taxes) Have Small Effect on GHGs from Transport sector

- $50/ton CO$_2$ price would increase gasoline prices only ~$0.45/gallon
- Oil companies would not be responsive because they have few choices
- Drivers are unresponsive at these price levels

Cap & Trade accounts for only ~20% of targeted GHG reduction in California

Need something more effective than cap and trade (and carbon taxes) to motivate change and innovation with transport fuels
Sperling’s 5 Point Plan to Transform Transport in US

1. Increased R&D investments (and training of scientists and engineers)
   - Batteries, fuel cells, and lightweight materials

2. Accelerate advanced vehicle commercialization
   - Zero emissions requirement (California … and US?)
   - Tax credits for hybrids, fuel cell, battery-electric vehicles

3. Performance Standards for fuels and vehicles
   - CAFE, California GHG standards for vehicles
   - LCFS

4. Market instruments to align regulations with market
   - Feebates
   - Fuel price floor

5. Reform institutions and realign incentives to reduce sprawl and VMT
   - Reform transport funding to reward reduced VMT and stimulate investment in new mobility services
   - Remove incentives for sprawl (fiscalization of LU, zoning, engineering rules)
Question of Will and Vision, More Than Cost!

• Consider hydrogen and fuel cells, which many think is most expensive and difficult transition …
  ▪ $55 billion extra over 15 years for vehicles and fuels, to get to 10% market penetration (NRC/NAS, 2008)

• Meanwhile, US spends ~$8 billion/year on subsidies for corn ethanol
"We stand at a crossroads. One path leads to despair, the other to destruction. Let's hope we choose wisely."

Woody Allen

I’m more optimistic despite much evidence to the contrary...