Chapter 6: Environment and Transportation

September 13, 2012
Energy Flow by Sector and Source
Total = 94.6 Quadrillion Btu

US Energy Information Administration (EIA)
http://205.254.135.24/emeu/aer/consump.html
What can we do about Transportation?

Energy Efficiency with respect to transportation

Near term
improve efficiencies of cars/trains/etc.
improve engines/diesel/hybrids/transmissions/weight of automobiles

Medium term
changes in power-train and vehicle technologies
hybrid-electric
fully battery-electric vehicles

Longer term
new technologies
hydrogen fuel cells? Hydrogen distribution infrastructure
Transportation
Global ~22% Carbon Emissions: ~30%

Residential, Industrial, Commercial

Fuels Used in Transportation
Natural gas combined cycle...carbon dioxide capture and storage
FIGURE 2.14 Estimated gasoline-equivalent costs of alternative liquid fuels. For comparison, the costs of gasoline at crude oil prices of $60 per barrel and $100 per barrel are shown on the left. Estimated costs assume that a zero price is assigned to CO₂ emissions. Liquid fuels would be produced using biochemical conversion to produce ethanol from Miscanthus or using thermochemical conversion via Fischer-Tropsch or methanol-to-gasoline. All costs are in 2007 dollars and are rounded to the nearest $5.

Note: BTL = biomass-to-liquid fuel; CBTL = coal-and-biomass-to-liquid fuel; CCS = carbon capture and storage; CTL = coal-to-liquid fuel.
Energy Use by type of vehicle

- Automobiles: 32%
- Light Trucks: 28%
- Other Trucks: 16%
- Aircraft: 9%
- Water: 5%
- Construction & Agriculture: 4%
- Pipelines: 3%
- Trains & Buses: 3%
What are the issues?

Efficiency
Conservation
New Technologies
23.6 km/l
3.785 liters = 1 gallon

23.6 km per liter x 3.785 liters per gallon = 89 km/gallon

Or

89 km/gallon / 1.6 km/mile = 56 mpg
Did you know that the bicycle is the most energy efficient transportation mode? It is 3 times more efficient than walking, 5 times more efficient than using the train and 15 to 20 times more efficient than driving a car.
Physics:

Power = Energy / time

Energy = force x distance

Force for moving a car
Forces for moving a car............................Total Force

Forces due to accelerating
+ 
Forces of going upward (hills)
+ 
Forces for resisting rolling
+ 
Forces associated with aerodynamic drag

= Total Force
Forces for moving a car............Total Force
first piece:
Forces due to acceleration
\[ F = ma \]
= mass of the car \times \text{acceleration}
= mass of the car \times (\text{change in velocity})

Driving:

0-60 miles per hour in 10 seconds..

1 mile = 5280 feet

Initial velocity = 0 mph
Final velocity = 60 mph
Change in velocity = 60 mph/10 seconds
60 miles/hr \times 5280 \text{ft/mi} \times \frac{1 \text{hr}}{3600 \text{s}} = 88 \text{ ft/s}
Per 10 s.....
Acceleration = 8.8 \text{ ft/s}^2
Forces for moving a car

Forces due to accelerating \((F=ma)\)

\[+\]

Forces of going upward (hills)

\[=mgh\]

\[= m \times g \times \text{incline or steepness (slope)}\]

\[= mgs\]
Forces for moving a car.......................... Total Force

Forces due to accelerating \((F=ma)\)

+ 

Forces of going upward (hills) \((F=mgs)\)

+ 

Forces from resistance

\[ F = C_r m v \]

\(C_r\) is specific to a car

...of course so is the mass...
Forces for moving a car.........................Total Force

Forces due to accelerating \((F=ma)\)

+ 

Forces of going upward (hills) \((F=mgs)\)

+ 

Forces from resistance \((F= C_r m v)\)

+ 

Forces from aerodynamic drag
Forces for moving a car.......................... Total Force

Forces due to accelerating \((F=ma)\)

+ 

Forces of going upward (hills) \((F=mgs)\)

+ 

Forces from resistance \((F= C_rmv)\)

+ 

Forces from aerodynamic drag

\(F\) is proportional to \(C_D A_f v^2\)

\(C_D\) is aerodynamic drag coefficient

\(A_f\) is the frontal Area of the car

\(v\) is velocity…it goes as velocity squared
Physics:

Power = Energy / time

Energy = force x distance

Force for moving a car
In gasoline-powered vehicles, over 62 percent of the fuel's energy is lost in the internal combustion engine (ICE). ICE engines are very inefficient at converting the fuel's chemical energy to mechanical energy, losing energy to engine friction, pumping air into and out of the engine, and wasted heat.
What speed should you drive to get the best mileage???

In general, smaller, lighter, more aerodynamic cars will get their best mileage at higher speeds. Bigger, heavier, less aerodynamic vehicles will get their best mileage at lower speeds.
# Motor Fuel Tax Rates for Selected Countries

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>GASOLINE</th>
<th>DIESEL</th>
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<tr>
<td>United States</td>
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WASHINGTON (Reuters) - The U.S. government on Friday imposed the first increase in mileage standards for passenger cars and boosted the floor for sport utilities and pickups beginning with model year 2011 vehicles.

"These standards are important steps in the nation's quest to achieve energy independence," said Transportation Secretary Ray LaHood, who added that work on future mileage programs must take into account the health of U.S.
The standard, which is expected to cost industry $1.4 billion in vehicle design and other changes, would require compacts, sedans and other passenger cars to average 30.2 miles per gallon in combined city/highway driving, up from the 27.5 mpg standard that was established in the late 1970s under the Corporate Average Fuel Economy (CAFE) program.
Toyota Motor Corp expects its *2010 Prius hybrid to get 46 mpg* while estimates for the Insight hybrid made by Honda Motor Co is 41 mpg. Detroit's efforts to revamp its fleet include the Ford Fusion hybrid sedan, due in showrooms this spring, that gets 41 mpg/city.

Toyota Prius 2012
Light trucks, which include pickups and SUVs, would have to average *24.1 mpg in 2011*, compared with 23.5 mpg the previous year. Overall fleet performance would be 27.3 mpg, a 2 mpg increase over 2010, according to the 857-page regulation.

The new standards would save nearly *900 million gallons of fuel and reduce carbon dioxide emissions by 8.3 million metric tons over the lifetime of model year 2011 vehicles*, the Transportation Department said.

The administration calculates more than *$2 billion* in overall benefits to consumers from the program, including less money spent on fuel. Congress has required that the U.S. fleet of cars and light trucks average *35 mpg by 2020*, a 40 percent increase over today's performance.
What is the CAFÉ standard?
Corporate Average Fuel Economy

First enacted by Congress in 1975, the purpose of CAFÉ is to reduce energy consumption by increasing the fuel economy of cars and light trucks. Regulating CAFÉ is the responsibility of NHTSA and the Environmental Protection Agency (EPA). NHTSA sets fuel economy standards for cars and light trucks sold in the U.S.; EPA calculates the average fuel economy for each manufacturer.

Congress specifies that CAFÉ standards must be set at the "maximum feasible level" given consideration for
1. technological feasibility;
2. economic practicality;
3. effect of other standards on fuel economy; and
4. need of the nation to conserve energy.
If the average fuel economy of a manufacturer's annual fleet of car and/or truck production falls below the defined standard, the manufacturer must pay a penalty, currently $5.50 USD per 0.1 mpg under the standard, multiplied by the manufacturer's total production for the U.S. domestic market.

But everything is changing ....
Café Standards
President Obama Debuts 54.5 mpg CAFE Fuel Economy Standard for 2025

Ben Timmins on July 29 2011 4:30 PM

Taking a break from talking about trillions of dollars in national debt, President Obama took a few minutes to announce a deal with automakers to raise Corporate Average Fuel Economy standards to 54.5 mpg by 2025 — essentially double the current mandate.

CAFE standards were already reset in May of 2009, when President Obama mandated that the fuel economy average of an automaker’s product portfolio must reach 35.5 mpg by 2016. Today’s announcement is a continuation of that plan and also the largest mandatory fuel economy increase in history.

Read more:
http://wot.motortrend.com/president-obama-debuts-54-5-mpg-cafe-fuel-economy-standard-for-2025-102217.html#ixzz1ZlYg9xAT
Café Standards
Yesterday, the Obama administration raised the corporate average fuel efficiency (CAFE) standards for the U.S. automobile fleet from 27.5 miles per gallon (mpg) to 35.5 mpg by 2016. According to the government, the new standards will add about $1,000 to the price of new automobiles, but drivers will be able to recoup the cost through buying less gasoline over the life of the vehicles. Maybe. But this convoluted effort to reduce American consumption of gasoline actually functions as a kind of inefficient stealth tax on driving. It’s inefficient because drivers pay more, car companies make less money, and state and federal governments don’t get any extra revenues.

In 2002, the National Academy of Sciences issued a report on CAFE standards which correctly observed:
There is a marked inconsistency between pressing automotive manufacturers for improved fuel economy from new vehicles on the one hand and insisting on low real gasoline prices on the other. Higher real prices for gasoline—through increased gasoline taxes—would create both the demand for fuel efficient new vehicles and an incentive for owners of existing vehicles to drive them less.

In other words, taxing gasoline would achieve the Obama administration’s stated goals of reducing imports of foreign oil and cutting greenhouse gas emissions much more efficiently than labyrinthine CAFE standards—since taxes would apply to all vehicles, not just new ones.

Ultimately, there is no getting around the fact that setting higher CAFE standards is just a way for cowardly politicians to avoid telling their fellow citizens that they should pay more for the privilege of driving.
What are our choices?

Better Technology...more fuel efficient cars
 ..........no fuel cars

China Vies to Be World’s Leader in Electric Cars

TIANJIN, China — Chinese leaders have adopted a plan aimed at turning the country into one of the leading producers of hybrid and all-electric vehicles within three years, and making it the world leader in electric cars and buses after that.

To some extent, China is making a virtue of a liability. It is behind the United States, Japan and other countries when it comes to making gas-powered vehicles, but by skipping the current technology, China hopes to get a jump on the next.
But electric vehicles may do little to clear the country’s smog-darkened sky or curb its rapidly rising emissions of global warming gases. China gets three-fourths of its electricity from coal, which produces more soot and more greenhouse gases than other fuels.

A report by McKinsey & Company last autumn estimated that replacing a gasoline-powered car with a similar-size electric car in China would reduce greenhouse emissions by only 19%. It would reduce urban pollution, however, by shifting the source of smog from car exhaust pipes to power plants, which are often located outside cities.

Beyond manufacturing, subsidies of up to $8,800 are being offered to taxi fleets and local government agencies in 13 Chinese cities for each hybrid or all-electric vehicle they purchase. The state electricity grid has been ordered to set up electric car charging stations in Beijing, Shanghai and Tianjin.
Government research subsidies for electric car designs are increasing rapidly. And an interagency panel is planning tax credits for consumers who buy alternative energy Vehicles. China wants to raise its annual production capacity to 500,000 hybrid or all-electric cars and buses by the end of 2011, from 2,100 last year, government officials and Chinese auto executives said. By comparison, CSM Worldwide, a consulting firm that does forecasts for automakers, predicts that Japan and South Korea together will be producing 1.1 million hybrid or all-electric light vehicles by then and North America will be making 267,000.

The United States Department of Energy has its own $25 billion program to develop electric-powered cars and improve battery technology, and will receive another $2 B for battery development as part of the economic stimulus program enacted by Congress.

Premier Wen Jiabao highlighted the importance of electric cars two years ago with his unlikely choice to become minister of science and technology: Wan Gang, a Shanghai-born former Audi auto engineer in Germany who later became the chief scientist for the Chinese government’s research panel on electric vehicles.
How green are electric cars?

Internal combustion engine 15% efficient

Electricity has to be produced somehow
Efficiency of plants to produce electricity from petroleum ... 38%

Efficiency of electric cars ... 40%

0.40 x 0.38 = 0.15 about the same ... as ICE
Storage of energy/power in an electric car?

Batteries...slow to charge
..........................lose power while charging
..........................can't store very much energy
How does a battery work?
How does a battery work?

In any battery, an electrochemical reaction occurs. This reaction moves electrons from one pole to the other. The actual metals and electrolytes used control the voltage of the battery -- each different reaction has a characteristic voltage. For example, here's what happens in one cell of a car's lead-acid battery:

The cell has one plate made of lead and another plate made of lead dioxide, with a strong sulfuric acid electrolyte in which the plates are immersed.

Lead combines with SO4 (sulfate) to create PbSO4 (lead sulfate), plus one electron.

Lead dioxide, hydrogen ions and SO4 ions, plus electrons from the lead plate, create PbSO4 and water on the lead dioxide plate.

As the battery discharges, both plates build up PbSO4 and water builds up in the acid.

The characteristic voltage is about 2 volts per cell, so by combining six cells you get a 12-volt battery.
Hybrids- two or more distinct power systems....

Power sources include:

On-board or out-board rechargeable energy storage system (RESS)
Gasoline or Diesel fuel
Hydrogen
Compressed air
Human powered e.g. pedaling or rowing
Wind
Compressed or liquefied natural gas
Solar
Coal, wood or other solid combustibles
Electromagnetic fields, Radio waves

Battery-diesel
Electric-petroleum
Sails-steam

Trains
Ships
Planes
Cars
Fuel Cells

A fuel cell is an electrochemical conversion device. It produces electricity from fuel (on the anode side) and an oxidant (on the cathode side), which react in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate virtually continuously as long as the necessary flows are maintained.

Fuel Cell vs. Battery

Fuel cells are different from electrochemical cell batteries in that they consume reactant from an external source, which must be replenished. By contrast batteries store electrical energy chemically and hence represent a thermodynamically closed system.

Hydrogen Fuel Cells

Many combinations of fuel and oxidant are possible. A hydrogen cell uses hydrogen as fuel and oxygen (usually from air) as oxidant. Other fuels include hydrocarbons and alcohols.
Critics charge that the time frame for overcoming the technical and economic challenges to implementing wide-scale use of hydrogen vehicles is likely to be at least several decades, and hydrogen vehicles may never become broadly available. They believe that the focus on the use of the hydrogen car is a dangerous detour from more readily available solutions to reducing the use of fossil fuels in vehicles.