Midwest Transportation Consortium

Energy Issues in Transportation

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Figure 2: Primary Energy Consumption by Sector, (quadrillion Btu)
US Oil Use for Transportation

- US uses roughly 25% of world’s oil production
- Take a snapshot using Energy Information Administration data for week of 02/15/02
- All values are barrels (42 gallons) per day
Inputs

- Crude oil 14,388,000
- Crude Oil Imports 8,034,000 (58%)
- Domestic Crude Production 5,927,000 (42%)

- Totals do not add due to movements in and out of Strategic Petroleum Reserve and other inventories
<table>
<thead>
<tr>
<th>Products Supplied</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>8,428,000</td>
</tr>
<tr>
<td>Jet Fuel</td>
<td>1,666,000</td>
</tr>
<tr>
<td>Distillate Fuel Oil</td>
<td>3,891,000</td>
</tr>
<tr>
<td>Residual Fuel Oil</td>
<td>850,000</td>
</tr>
<tr>
<td>Other Oils</td>
<td>4,947,000</td>
</tr>
<tr>
<td>Total</td>
<td>19,782,000</td>
</tr>
</tbody>
</table>
Visualizing 19,782,000 barrels
“The extraction and use of energy is the single largest impact on the environment.” Peter Berle, former President of the Audubon Society
Environmental Impact

- Particulates
- VOCs (Volatile Organic Compounds)
- SOx (sulfur compounds including sulfuric acid)
- NOx (nitrogen compounds including nitric acid)
- Heavy metals
Environmental Impact

- Greenhouse gases: global warming
- Primarily carbon dioxide
- One third of US greenhouse gas emissions trace to transportation
Figure 4: Projected U.S. Carbon Dioxide Emissions by Sector, Fuel, 1990-2020 (million metric tons carbon equivalent)
How Can We Respond?

- A technological revolution
- Hydrogen and fuel cells
- Freedom Car
Technological Revolution

- A new technology outperforms an old one and takes over
- Is it that simple?
- An example in transportation
The Dinosaur
A Contender
The Winner
Steam to Diesel: A Sudden Switch?

- Steam from 1820s to 1940s-1950s
- Diesels took over in 1940s-1950s
- Electrification in early 1900s (tunnels, cities)
- Diesels even took market from electricity in 1940s and beyond
Some History

- Diesel engine developed in late 1800s
- Small diesel locomotives appeared in 1920s in cities, industrial plants
- Diesels quite well developed just before WW2
- War interrupted transition: US needed huge transportation increase; steam production capacity in place; infrastructure in place; technology known
Some History

- At end of WW2, many steam locomotives worn out
- Economy transitioned to civilian needs
- Time for change arrived
- Steam “suddenly” replaced by diesels
- “Suddenly” was preceded by over 50 years of research, demonstration
Fuel Efficiency

- Steam locomotive 7-8 percent efficient
- Electric locomotive connected to a coal-fired power plant 20-25 efficient
- Diesel locomotive 25-30 percent efficient
- Was this the issue that drove transition?
So What Killed the Dinosaurs?

- Pollution – as a local nuisance and fire hazard, not a national clean air or global warming issue
- Labor intensity
- Infrastructure
- Lack of braking power
- All tied to maintenance costs
What Happened to Electrics?

- Expensive, maintenance intensive infrastructure: wires or third rails
- Only justifiable for high volume traffic in areas where pollution is a concern
- Not a total technological loser; a diesel locomotive is really an electric locomotive carrying its own diesel engine and generator: no wires
Fuel Cells: The Answer?

- Fuel cell powered by hydrogen
- Fuel cell makes electricity that can power a vehicle
- Highly scalable to different sizes
- Fuel cell exhaust is water plus heat
- Potential replacement for internal combustion engine
Fuel Cell Basics: PEM Technology
**Fuel Cell Basics**

**Fuel cells utilize** an electrochemical process to produce electrical power without combustion, with heat and water as the primary byproducts.

*Source: Sure Power Corp.*
Ford Concept Car
Hypercars

- Concept stated by Amory Lovins of Rocky Mountain Institute
- Light weight, carbon fiber cars
- Powered by fuel cells running on hydrogen from renewable sources
- High efficiency systems
Hypercars

- Plug in a parked Hypercar, leave it running
- Hypercar can make electricity for the grid
- Owner gets paid by the parking meter
- Power plants follow people around
- Mobile distributed generation
- GM “skateboard” concept car
Efficiency - Gasoline Engine

- About 20 percent
- Much of energy converted to heat and wasted through radiator
- Significant parasitic loads (pumps, fans, etc.)
Efficiency - Fuel Cell Car

- Fuel cell 70-80 percent efficient
- Inverter and motors 80 percent efficient
- Total system 56-64 percent efficient
Efficiency - Fuel Cell Car

- But if hydrogen is made by a reformer that is 30-40 percent efficient, total system efficiency drops to 17-26 percent efficient.

- If hydrogen made by renewables or from fossil fuels at centralized reformers, hydrogen storage is an issue.
Efficiency - Electric Battery Car

- Inverter and motors 80 percent efficient
- Batteries 90 percent efficient
- System 72 percent efficient
Efficiency – Electric Battery Car

- But if batteries recharged by coal fired power plant at 33 percent efficiency, system drops to 24 percent efficient
- Unless battery performance improves, vehicle range is an issue
Side by Side Comparison

- Internal combustion engine 20%
- Fuel cell 17-64%
- Batteries 24-72%
The Dilemma

- Fuel Cell produces water and heat for exhaust
- Battery powered car has no exhaust
- But...
The Dilemma

- Will the fuel cell car run on hydrogen produced by renewable resources like wind or solar or...
- ...will it run on gasoline processed through a relatively low efficiency reformer?
- Will the electric battery car be recharged by renewable technologies like wind and solar or...
- ...will it really be powered by coal?
The Dilemma Restated

- If fuel cell powered automobiles use no less fossil fuel per mile than internal combustion engine powered cars do today, where are the energy and pollution savings?
What is the Best Solution

- A fuel cell powered car getting 17 miles per gallon (Ford’s projection for their fuel cell SUV)?
- A hybrid electric (like the Honda Insight) that gets 60+ miles per gallon?
Policies and Subsidies

- Virtually all energy production is subsidized
- A maze of tax incentives
- Nuclear research and waste disposal
- Military protection of oil
- CAFÉ (Corporate Average Fuel Efficiency)
- Pollution
Policies and Subsidies

- Have shaped the energy system we have
- Can shape the energy system of the future
- What do we as a nation want?
Midwest Transportation Niches

- Alternative fuels
- Alternative lubricants
- Transporting biomass-based fuels and chemicals
- Idle reduction
Alternative Fuels

- Ethanol
- Biodiesel
Ethanol

- Now made from corn kernels
- Animal feed is byproduct
- Used as an oxygenate in gasoline
- Flexible Fuel Vehicles can run as high as 85% ethanol
- Less energy per gallon than gasoline
- Subsidized
Ethanol

- Research on making ethanol from alternative crops (e.g. sweet sorghum, sugar beets)
- More alcohol per acre
- Research on making ethanol from cellulose such as corn stalks
- Lower cost feedstock
Ethanol

- Commercial plants operating throughout Midwest
- Problems with MBTE oxygenate (groundwater contamination) may open market for more ethanol
**Biodiesel**

- Made by reacting plant or animal oil with alcohol
- Soy oil commonly used in Midwest
- Canola oil commonly used in Europe
- Glycerin is byproduct
Biodiesel

- Less energy per gallon than petroleum diesel
- Poor cold weather performance
- Expensive
- Research on using waste animal fats as cheaper feedstock
- Research on improving quality/value of glycerin
Biodiesel

- First commercial plants operating
- National Biodiesel Training Facility established in Nevada, Iowa
- EPA requirement to remove 97% of sulfur from petroleum diesel in 2006 will open market for biodiesel additive as lubricant
Lubricants

- Soy based oils and greases
- Hydraulic oil
- Fifth wheel grease
- Rail grease
- Other applications
- Agriculture-Based Industrial Lubricants (ABIL) program at University of Northern Iowa
Transporting Biomass

- Great potential to make chemicals and fuels from biomass waste materials
- Biomass wastes difficult to transport (low energy density)
- Optimizing production/transport a problem that is not resolved
- Has implications for economic development pattern
Idle Reduction

- Trucks typically idle their engines at truck stops to provide heat, power equipment, keep engine warm
- “Long-haul trucks idling overnight consume 838 million gallons of fuel annually” Argonne National Laboratory
- Idling produces large amounts of pollution
- Idling increases wear on engine
Idle Reduction Approaches

- On board auxiliaries
- Shore power
- IdleAir Technologies
On Board Auxiliaries
Shore Power
Idle Reduction

- Diesel locomotives even worse
- Seldom shut down except for repair
- Far fewer locomotives than trucks, but each locomotive bigger energy consumer
Questions and Discussion