After Petroleum

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FCVT Program Mission
To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.
--EERE Strategic Plan, October 2002--
It took us 125 years to use the first trillion barrels of oil.

We’ll use the next trillion in 30.

Source: www.willyoujoinus.com
Outline

- Our Oil Situation
- Future Transportation Fuel Feedstocks
- Utilization Issues
- Summary
“The world uses just about 83 million barrels of oil a day, and there’s about 85 million worth production, so there’s a very tight excess supply… For decades to come, we’re going to be based on fossil fuels providing energy.” - James Mulva, Chairman and CEO, ConocoPhillips Corporation, Meet the Press, June 18, 2006.
In 2004 the U.S. crude oil consumption would have filled over 10.5 million tank cars which would stretch between Miami and Seattle (3,300 miles) over 36 times.
Oil Consumption by End-Use Sector

- **Transportation:** 96% Oil Dependent
- **Electric Power:** 3% Oil Dependent
- **Residential and Commercial:** 6% Oil Dependent
- **Industry:** 21% Oil Dependent
- **U.S. Oil Dependence Is Driven By Transportation**

Our Oil Situation

19.2 Millions of barrels per day (2005)

Data for January - December 2005

Canada 1.98 (10.3%)
US Domestic 6.83
Mexico 1.38 (7.2%)
Venezuela 1.49 (7.8%)
Nigeria 1.15 (6.0%)
Iraq 0.52 (2.7%)
Saudi Arabia 1.52 (7.9%)
Other OPEC 0.81 (4.2%)
U.K. 0.36 (1.9%)
Other Non-OPEC 3.14 (16.4%)

Crude Oil & Petroleum Products
Gross Imports 64%
Domestic 36%

Classes of Hydrocarbons in Motor Fuels

- **n-paraffin**
- **iso-paraffin**
- **olefin**
- **cyclo-alkane**
- **aromatic**
- **oxygenate**
Energy Density of Fuels

- Diesel Fuel: 1,058
- Fischer-Tropsch: 990
- Biorenewable Diesel: 950
- Butanol: 922
- E85: 785
- Propane: 690
- LNG: 683
- Ethanol: 679
- DME: 633
- Methanol: 562
- Liquid H₂: 483
- CNG (@3626 psi): 270
- Li-ion nano: 266
- H₂ (@3626 psi): 174
- NiMH Battery: 68

*Battery maintained between 20-80% SOC
Future Transportation Fuels Feedstocks

- Biomass
- Coal
- Methane
- Oil Sands
- Oil Shale
0.126 MBDOE* of ethanol produced in 2004 (from 11 percent of the corn crop)
8.2 MBD of gasoline used by cars and light trucks (2003)
2.3 MBD of crude oil imported from the Middle East (2005)
75 percent of imported Middle East crude oil by 2025 – Target goal for replacement***

* Million barrels of oil equivalent per day
** Million barrels per day
*** “Breakthroughs on this and other technologies will help us reach another great goal: to replace more than 75 percent of our oil imports from the Middle East by 2025.” – President Bush’s State of the Union Address on January 31, 2006
BP and DuPont Partnership on Biofuels

“DuPont and BP have created a partnership to deliver advanced biofuels ...(The) first product - biobutanol - will be introduced by the end of 2007.”

“Advantages

- Can be blended at higher rates into conventional fuels which can be used in unmodified vehicles;
- Higher energy content than conventional biofuels; and
- Can be more easily incorporated into existing fuel supply.”

Biodiesel Production and Resource

Existing Feedstock Supplies:
0.096 MBDOE

Potential Additional Feedstock Supplies:
0.108 MBDOE per year
Potential for more than 0.204 MBDOE biodiesel by 2015.

Feedstock analysis from NREL/TP-510-34796, June 2004.
Life cycle analysis from NREL/TP-580-24772, May 1998

[2002 U.S. on-road diesel fuel use - 2.3 million barrels per day**].

*Million barrels of oil equivalent per day

**Source: Transportation Energy Data Book, Edition 24, December 2004, USDOE, ORNL-6973
2nd Generation Biodiesel

- Renewable raw materials: vegetable oils and animal fats
- Proprietary Process of Finland’s Neste Oil Corp.
  - Differs from transesterification process (biodiesel) and gasification/F-T conversion (BTL)
  - Hydrotreated biodiesel with similar properties to BTL or GTL
- 100% hydrocarbon type paraffinic biobased diesel fuel
- Can be integrated with oil refinery
- Yields prime diesel fuel
  - Very high cetane number (up to 99)
  - Good cold properties (-30°C)
  - Free of aromatics and sulfur
  - Reduces NOx and particulate emissions
  - Good stability; no storage stability problems
- Fits existing engines and fuel logistics

Sources: Neste Oil Investor Presentation.
Green Car Congress, 10 August 2006.
Future Transportation Fuels Feedstocks

- Biomass
- Coal
- Methane
- Oil Sands
- Oil Shale
U.S. Coal Reserves (2003)

Demonstrated Reserves = 496 Trillion Short Tons
(~0.9 Trillion barrels of coal-to-liquid fuel)

Source: U.S. DOE/Energy Information Administration, October 2004
Future Transportation Fuels Feedstocks

- Biomass
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Methane Hydrates

- $187 \times 10^{12}$ cu.ft. of natural gas reserves in the U.S. (DOE est.)
- $317 \times 10^{15}$ cu.ft. of methane gas ($56$ Trillion BOE*) in hydrates in the U.S. (USGS est.)

*Barrels of oil equivalent

Gas hydrate forming beneath a rock ledge above a seafloor approx. 250 mi. east of Charleston, S.C. [Source: *GT Research Horizons*, Spring-Summer 2002]
- Biomass
- Coal
- Methane
- Oil Sands
- Oil Shale
Western Hemisphere Liquid Hydrocarbon Resources
(Billions of Barrels) Map does not include Ecuador or Columbia Resource

North Slope
27 B Heavy
>26 B Light & Med

Canadian Sedimentary Basin
1,700 B Bitumen
U.S. Midcontinent
<1 B Heavy
85 B Light & Med

Rocky Mountains
1,930 B Oil Shale
30 B Bitumen
2 B Heavy
44 B Light

California
75 B Light & Med

Onshore Gulf Coast
6 B Heavy
274 B Light & Med

Mexico
>30 B Heavy
>>20 B Light & Med

Venezuela
1,350 B Extra Heavy
228 B Heavy
186 B Light & Med

Totals

Canada
80 B Heavy
>49 B Light & Med
1,700 B Bitumen

U.S.A.
<111 B Heavy
>469 B Light & Med
30 B Bitumen
2,120 B Oil Shale

Mexico & Venezuela
>258 B Heavy
>>206 B Light & Med
1,350 B Extra Heavy

Grand Total
449 B Heavy
724 B Light & Med
1,730 B Bitumen
2,120 B Oil Shale
1,350 B Extra Heavy

TOTAL ~6.4 Trillion Barrels

Source: ICHH Heavy Oil and Bitumen Database, NPTO Light Oil Database
Canada’s Oil Sands Resources Stagger The Imagination

**World’s largest single hydrocarbon resource**

- 2.5 trillion barrels of oil in Canada’s oil sands
- 0.3 trillion barrels of oil or 12 percent of the resource considered “recoverable” with today’s technology

- Global oil demand for next 100 years could be met if all of Canada’s bitumen could be recovered and refined

Data Source: *Canada’s Oil Sands and Heavy Oil*, Petroleum Communication Foundation, April 2002 (originally from *Alberta Oil Sands Technology Research Authority*)
Source: Dr. T.K. Barna, Assistant Deputy Under Secretary of Defense, OSD Clean Fuel Initiative, Congressional Briefing.
U.S. Oil Sands and Oil Shale Resource

Oil Sands in Lower 48 States, 65 BBbls
  In Alaska, 19 BBbls
Oil Shale in Rocky Mountains, 1930 BBbls
  in Eastern U.S., 190 BBbls

\[ \text{\{ } 2.2 \text{ Trillion Bbls} \text{\}} \]

Sources: Oil Sands: ICHH U.S. Oil Sands Database plus 6 Billion in mineable California Diatomit; Oil Shale: USGS J.R. Dyni “Oil Shale” February 2000
Utilization Issues

- Combustion characteristics
- Effects on engine components
- Effects on emissions
- Lubricity or lubrication requirements
- Blending limitations
Summary

- U.S. oil dependence is driven by transportation.
- After petroleum feedstocks available for conversion to transportation fuels include biomass, coal, methane, oil sands, and oil shale.
- The U.S. (and North and South America) have enormous hydrocarbon resources that could be used to produce liquid transportation fuels.
- Several issues need to be addressed by research to enable efficient and low emission utilization of these feedstocks for transportation fuels.
And the present now will soon be the past
The order is rapidly fading
The first one now will later be last

*For the times, they are a-changing*

-- Bob Dylan

*Expect to pay more!*