After Petroleum

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Energy Efficiency and Renewable Energy
U.S. Department of Energy

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August 20 - 24, 2006

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--

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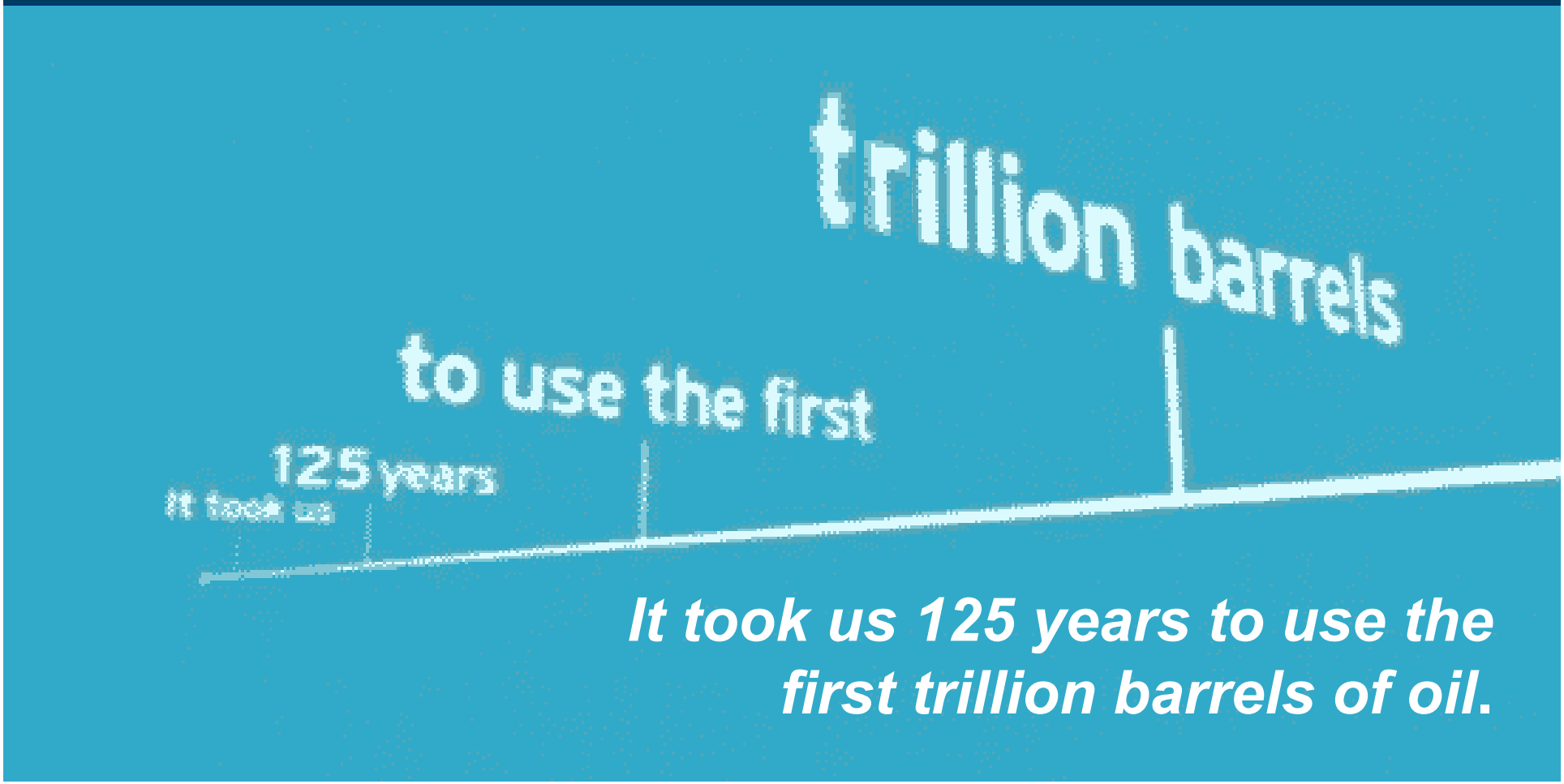
Are We Running Out Of Oil?



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

World Oil Disposition

"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.*

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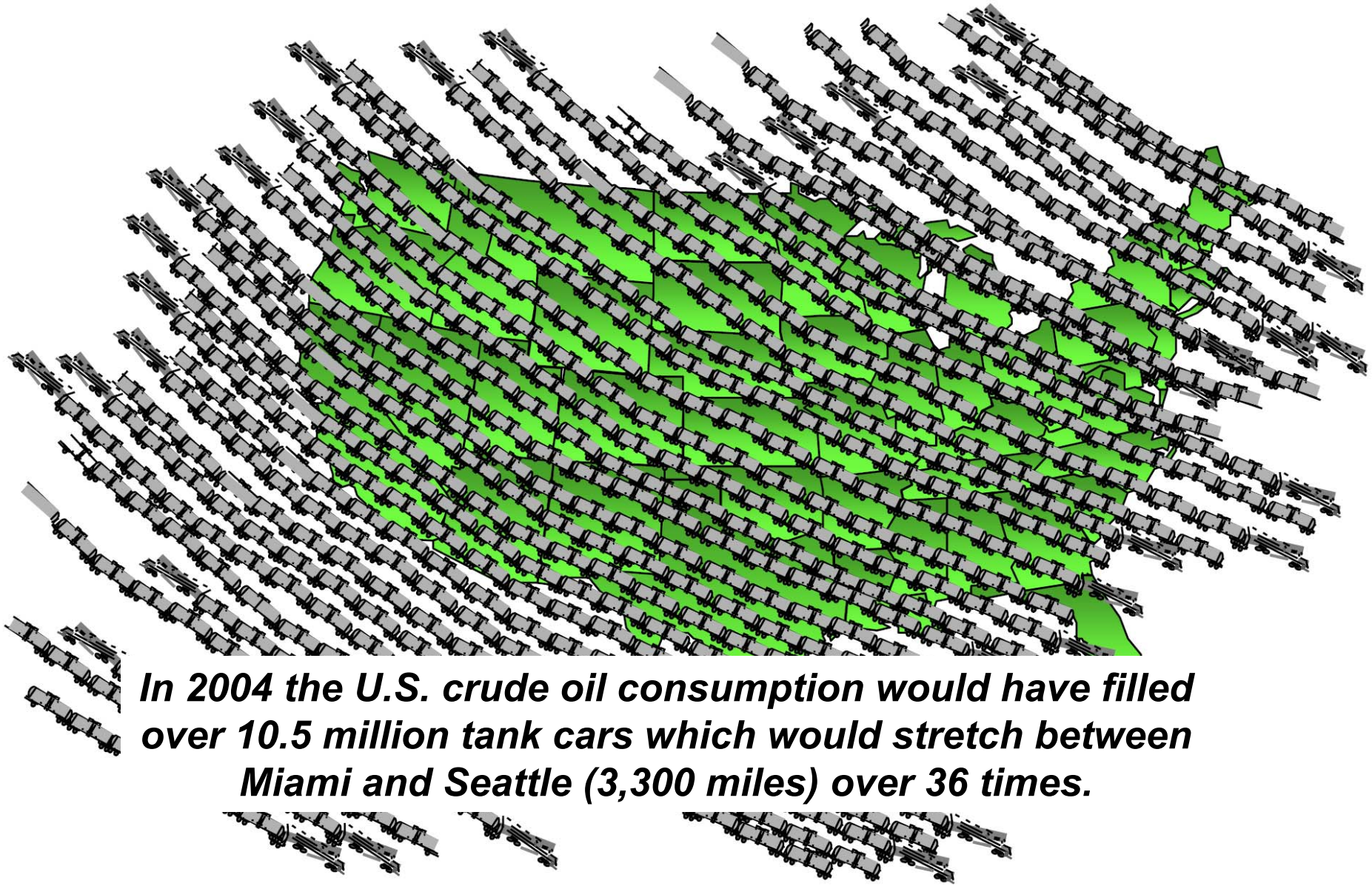
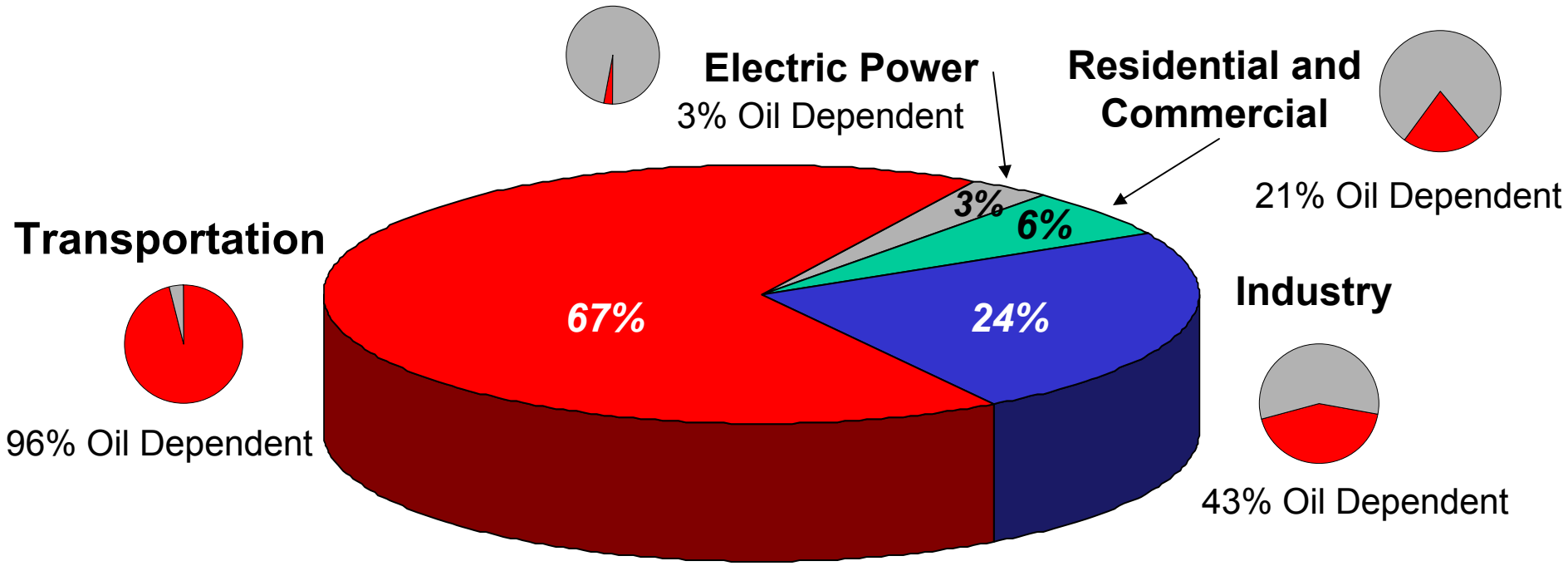
The Magnitude of Our Energy Problem



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.

U.S. Oil Situation

Oil Consumption by End-Use Sector

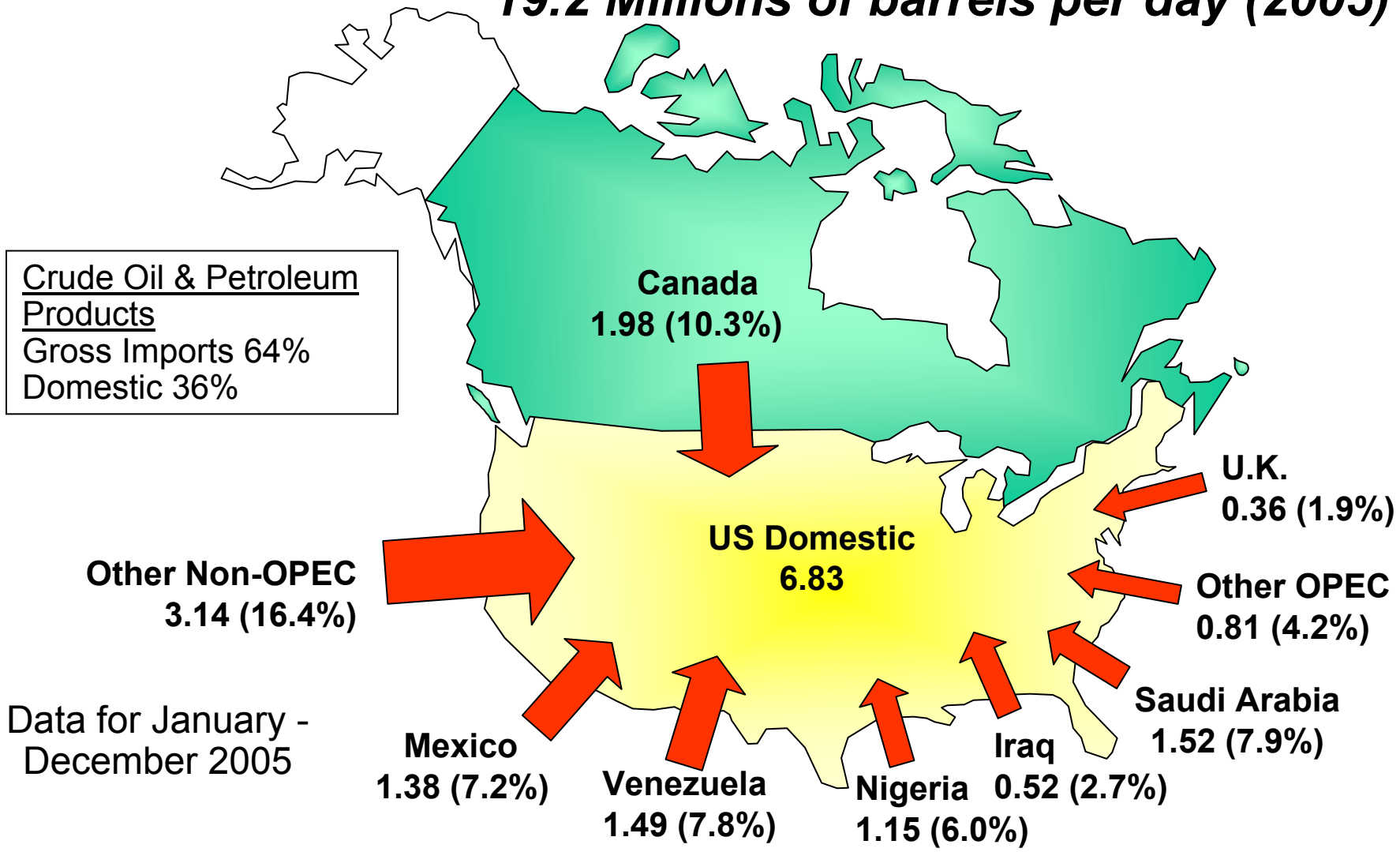


U.S. Oil Dependence Is Driven By Transportation

Source: Sector Oil Dependence from *DOE/EIA Annual Energy Review 2004, August 2005.*

Our Oil Situation

19.2 Millions of barrels per day (2005)



Source: Crude Oil and Petroleum Products, *EIA Petroleum Supply Monthly, February 2006*.

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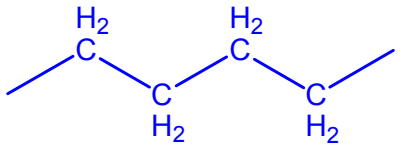
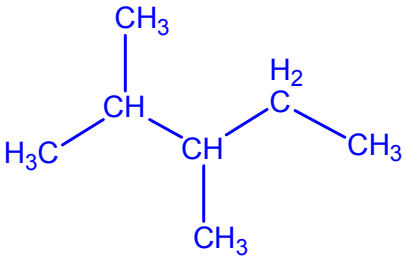
Classes of Hydrocarbons in Motor Fuels

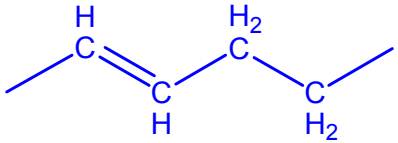
n-paraffin

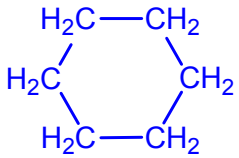


iso-paraffin

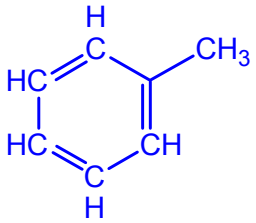


olefin

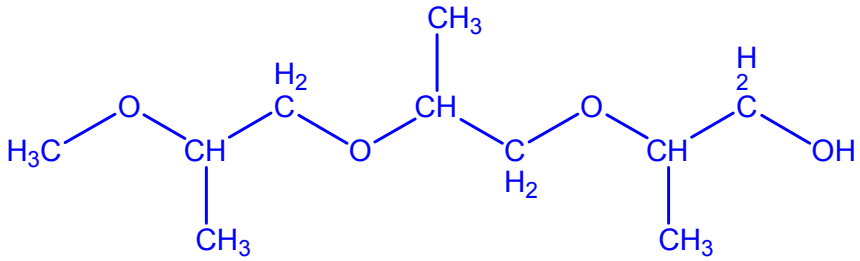




cyclo-alkane



aromatic



oxygenate

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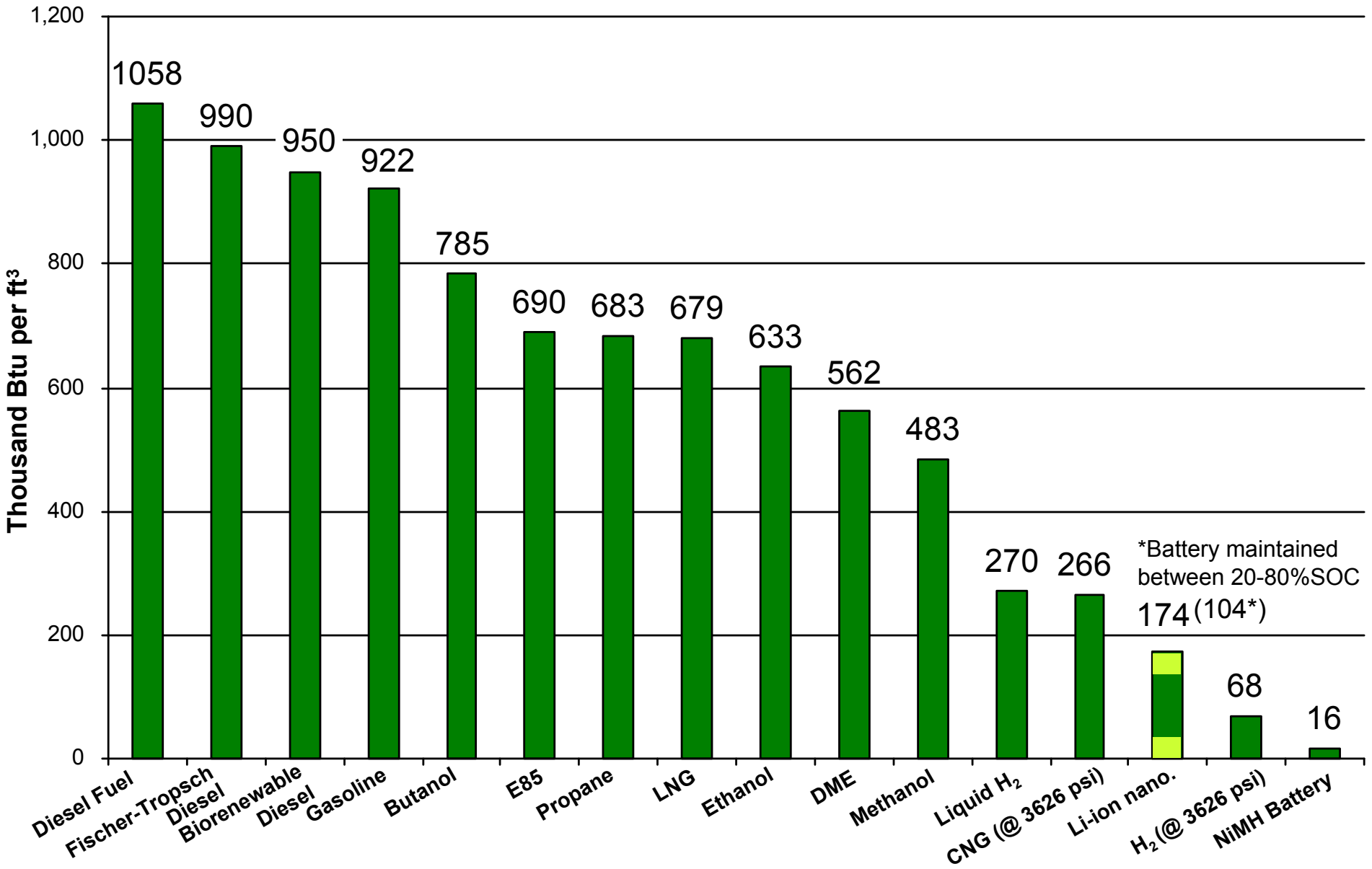
Energy Density of Fuels



Future Transportation Fuels Feedstocks

- [x] Biomass
- [ ] Coal
- [ ] Methane
- [ ] Oil Sands
- [ ] Oil Shale

Ethanol Resource and Use

- 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

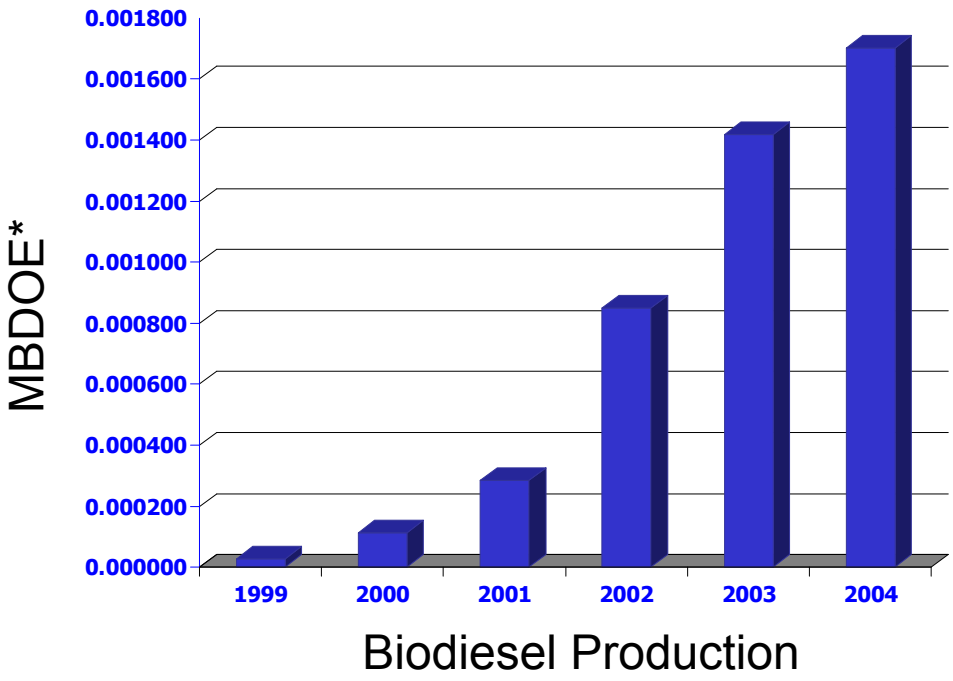
DUPONT The miracles of science™ bp

biobutanol

- "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."

Source: BP DuPont BioFuels website (http://www2.dupont.com/Biofuels/en_US)

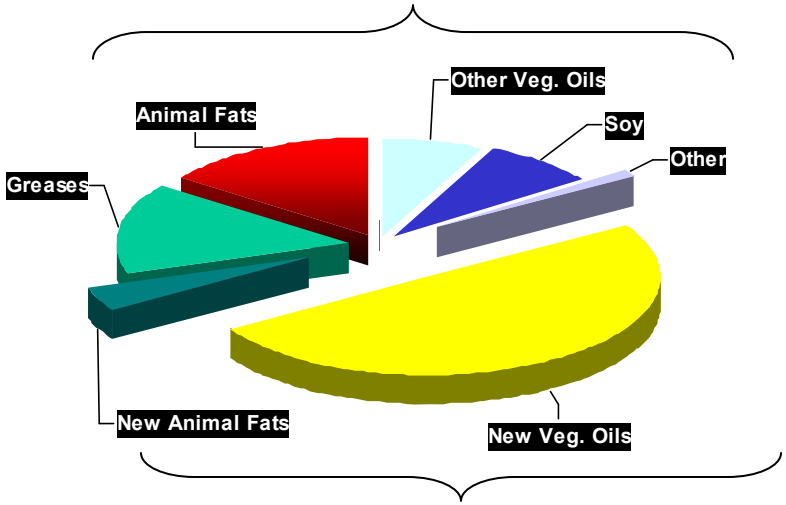
Biodiesel Production and Resource



Biodiesel Production

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

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.

*Million barrels of oil equivalent per day

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

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

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.

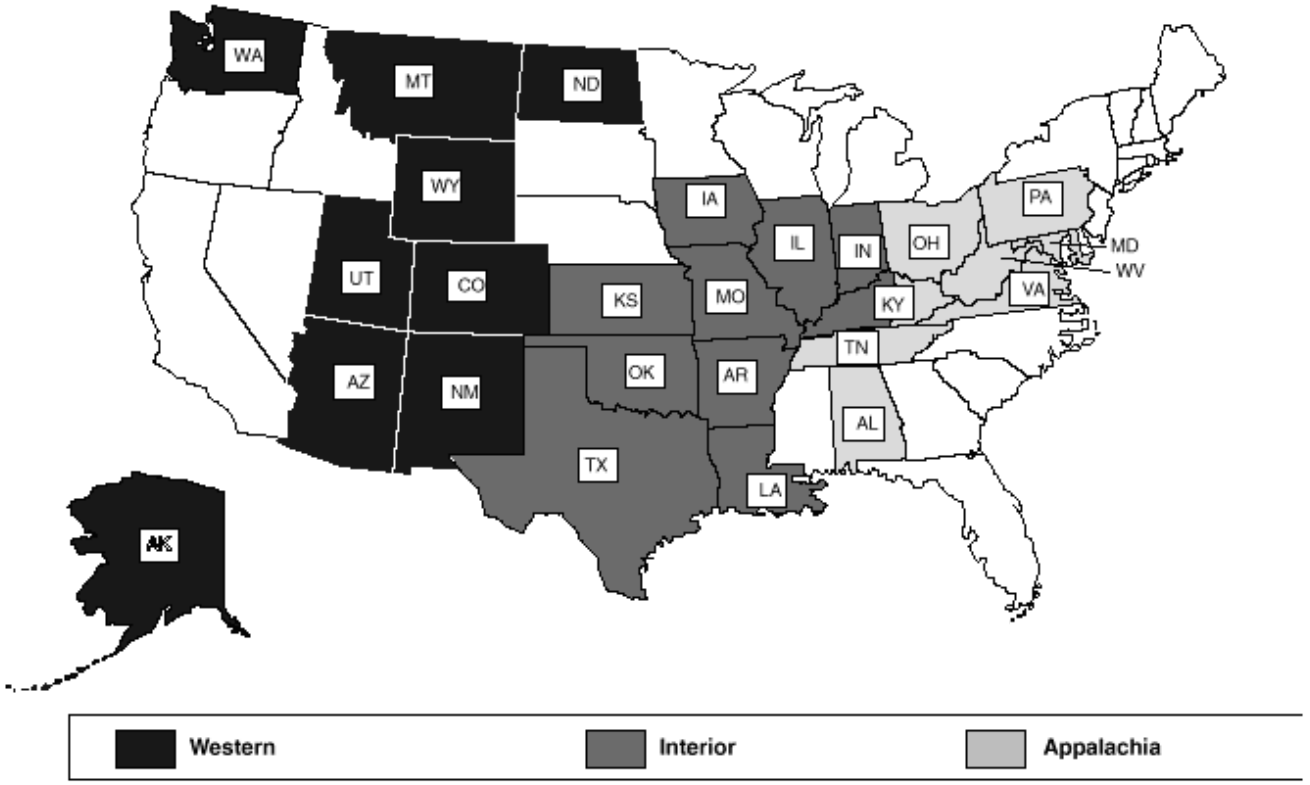
Future Transportation Fuels Feedstocks

- ❑ Biomass
- ☒ Coal
- ❑ Methane
- ❑ Oil Sands
- ❑ Oil Shale

Coal Resource

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

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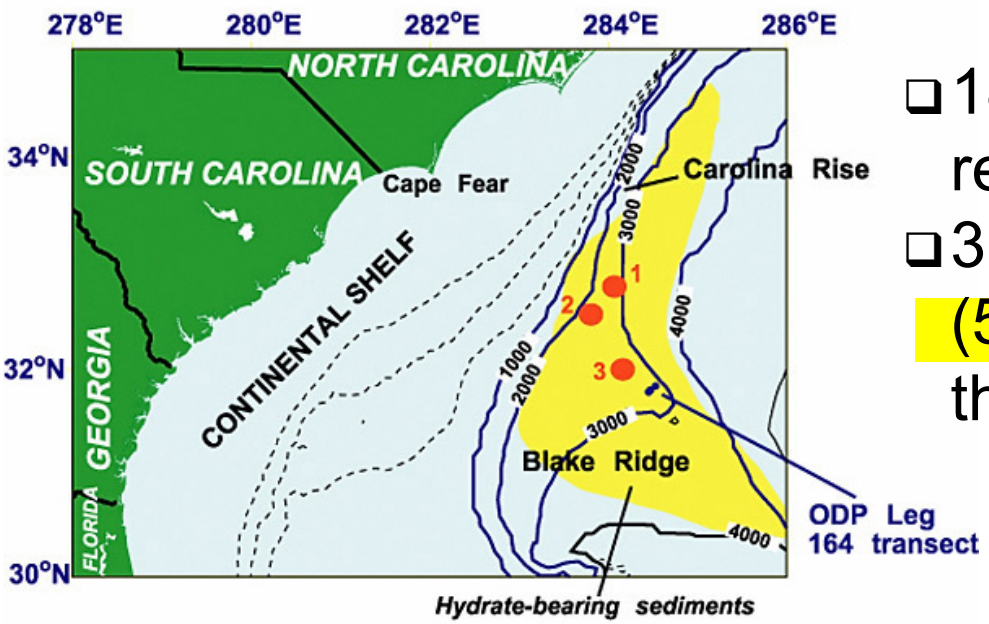
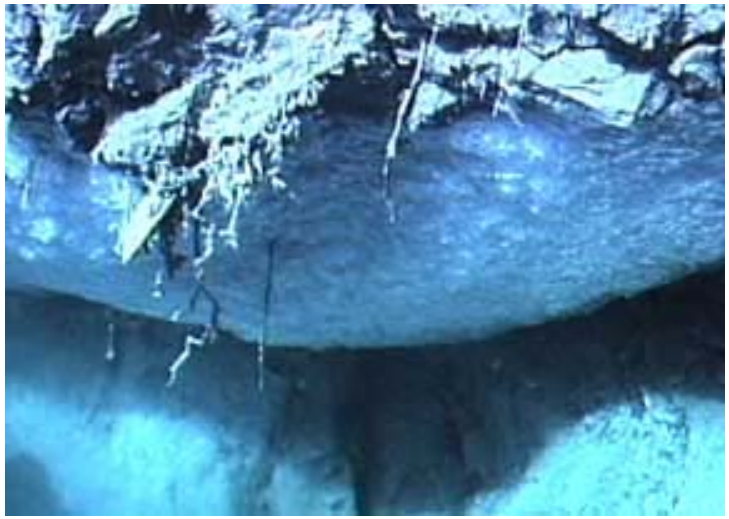
Methane Hydrates



- 187x10^{12} cu.ft. of natural gas reserves in the U.S. (DOE est.)
- 317x10^{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]

Future Transportation Fuels Feedstocks

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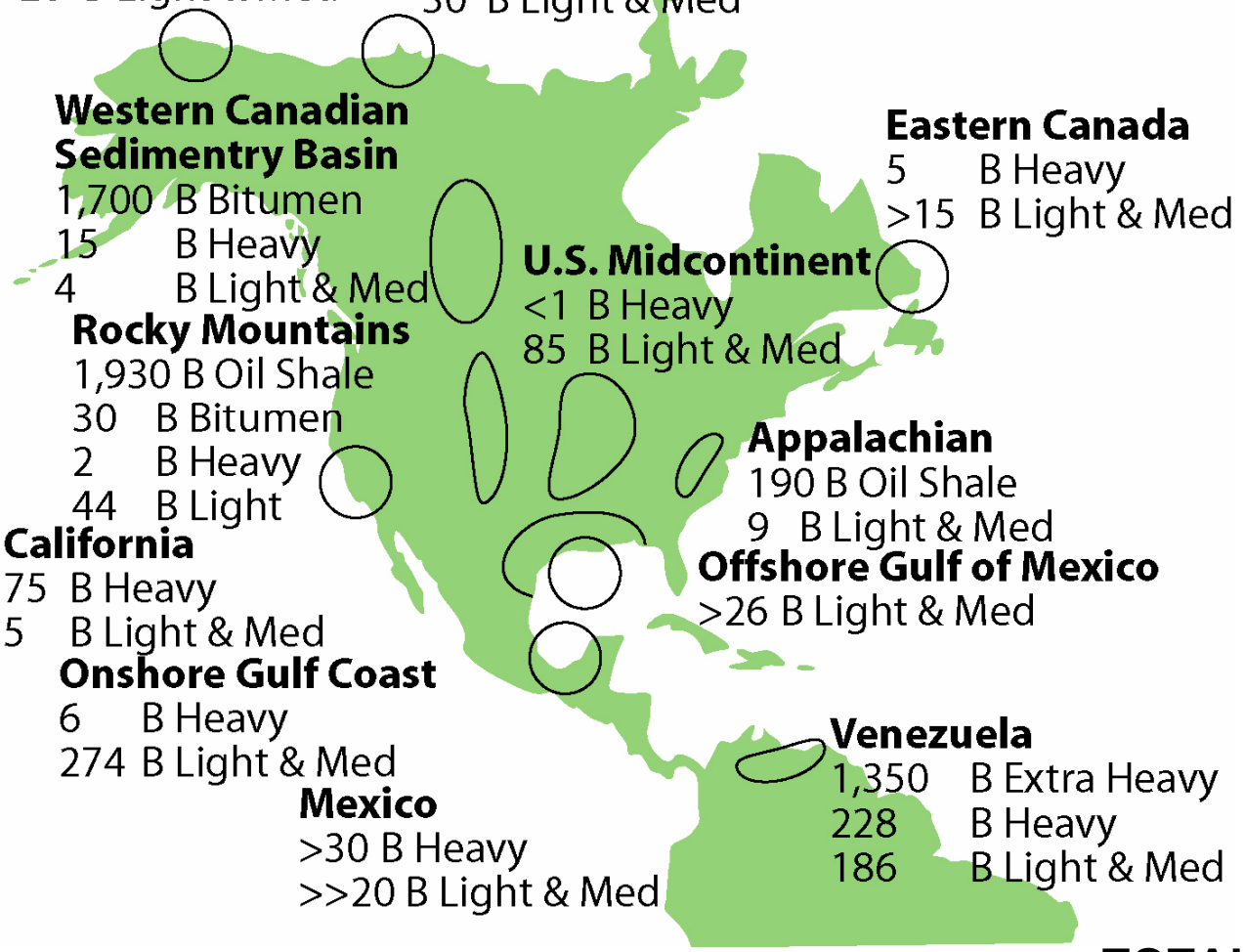
Western Hemisphere Liquid Hydrocarbon Resources

(Billions of Barrels) Map does not include Ecuador or Columbia Resource



North Slope
27 B Heavy
>26 B Light & Med

Northern Canada
60 B Heavy
30 B Light & Med

Western Canadian Sedimentry Basin
1,700 B Bitumen
15 B Heavy
4 B Light & Med

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

California
75 B Heavy
5 B Light & Med

Onshore Gulf Coast
6 B Heavy
274 B Light & Med

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

Eastern Canada
5 B Heavy
>15 B Light & Med

U.S. Midcontinent
<1 B Heavy
85 B Light & Med

Appalachian
190 B Oil Shale
9 B Light & Med

Offshore Gulf of Mexico
>26 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

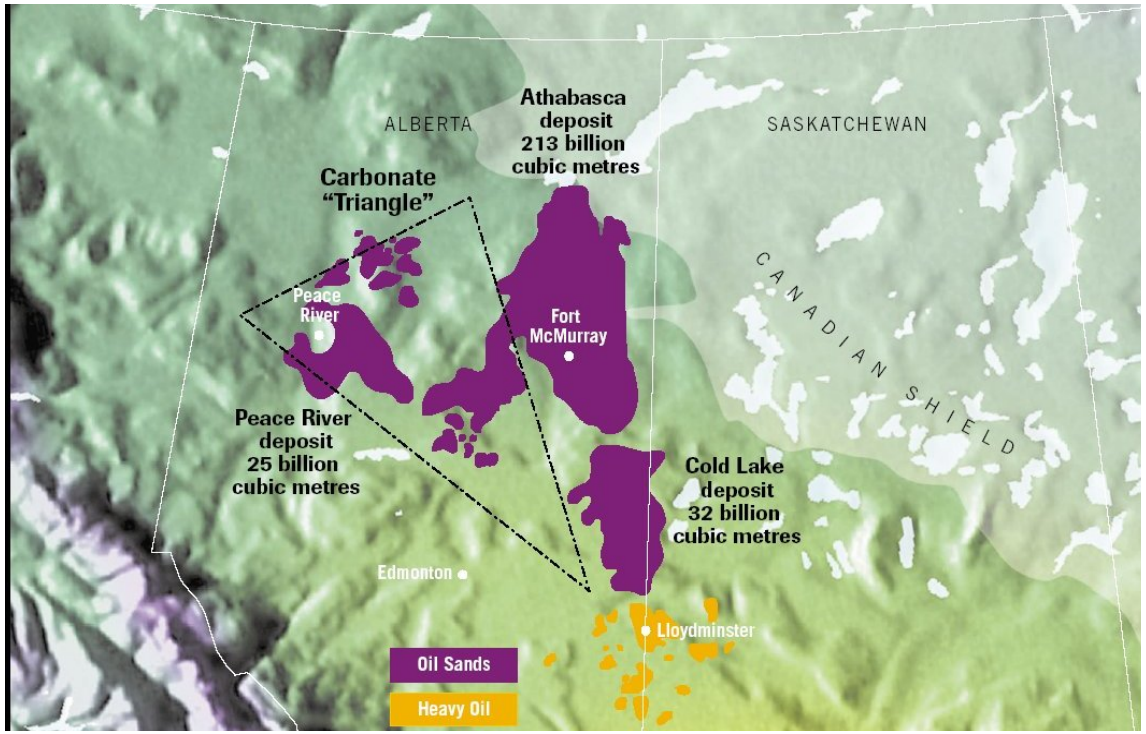
Grand Total
449 B Heavy
724 B Light & Med
1,730 B Bitumen
2,120 B Oil Shale
1,350 B Extra Heavy

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*)

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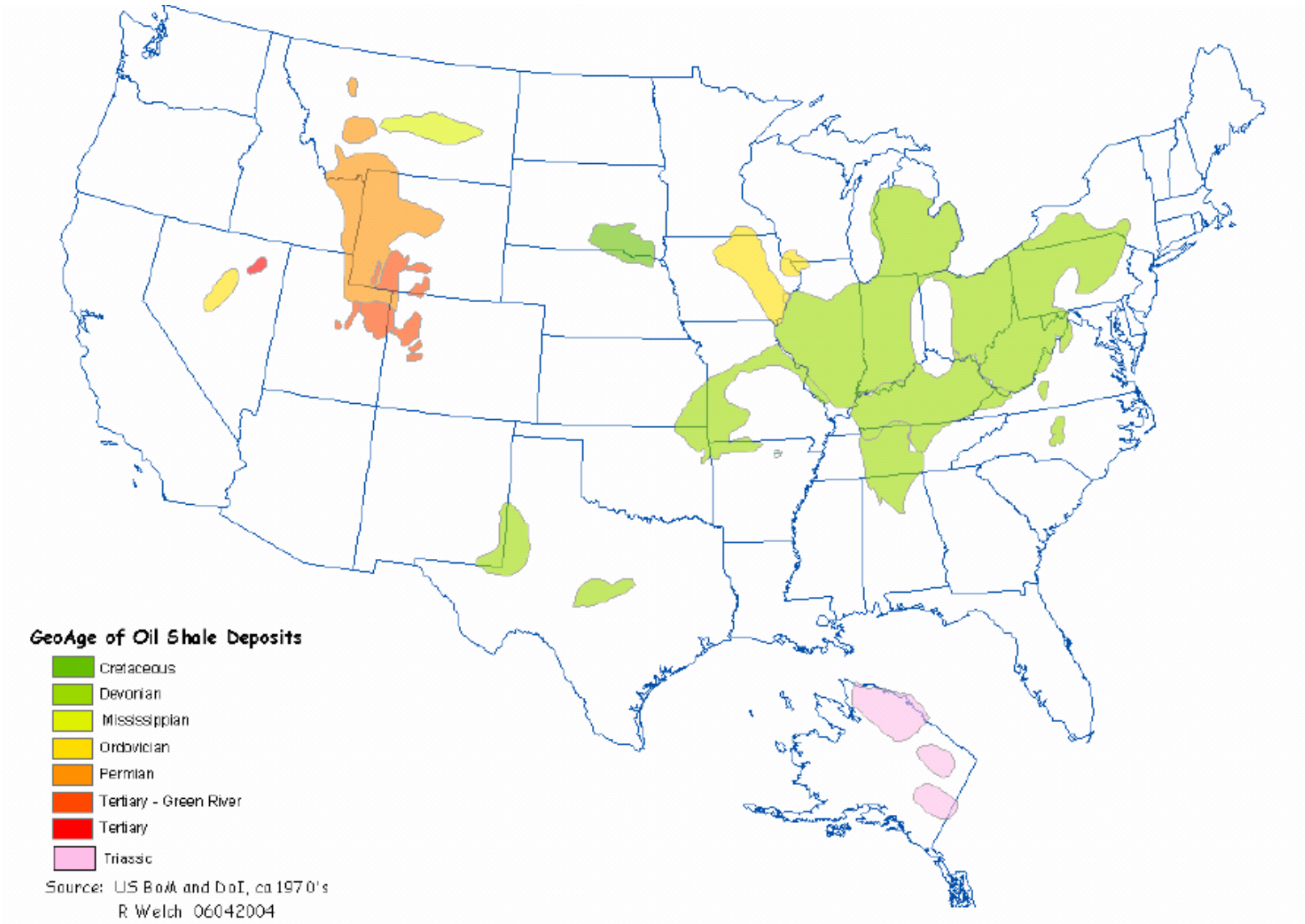
Oil Shale Resource



Source: Dr. T.K. Barna, Assistant Deputy Under Secretary of Defense, *OSD Clean Fuel Initiative*, Congressional Briefing.

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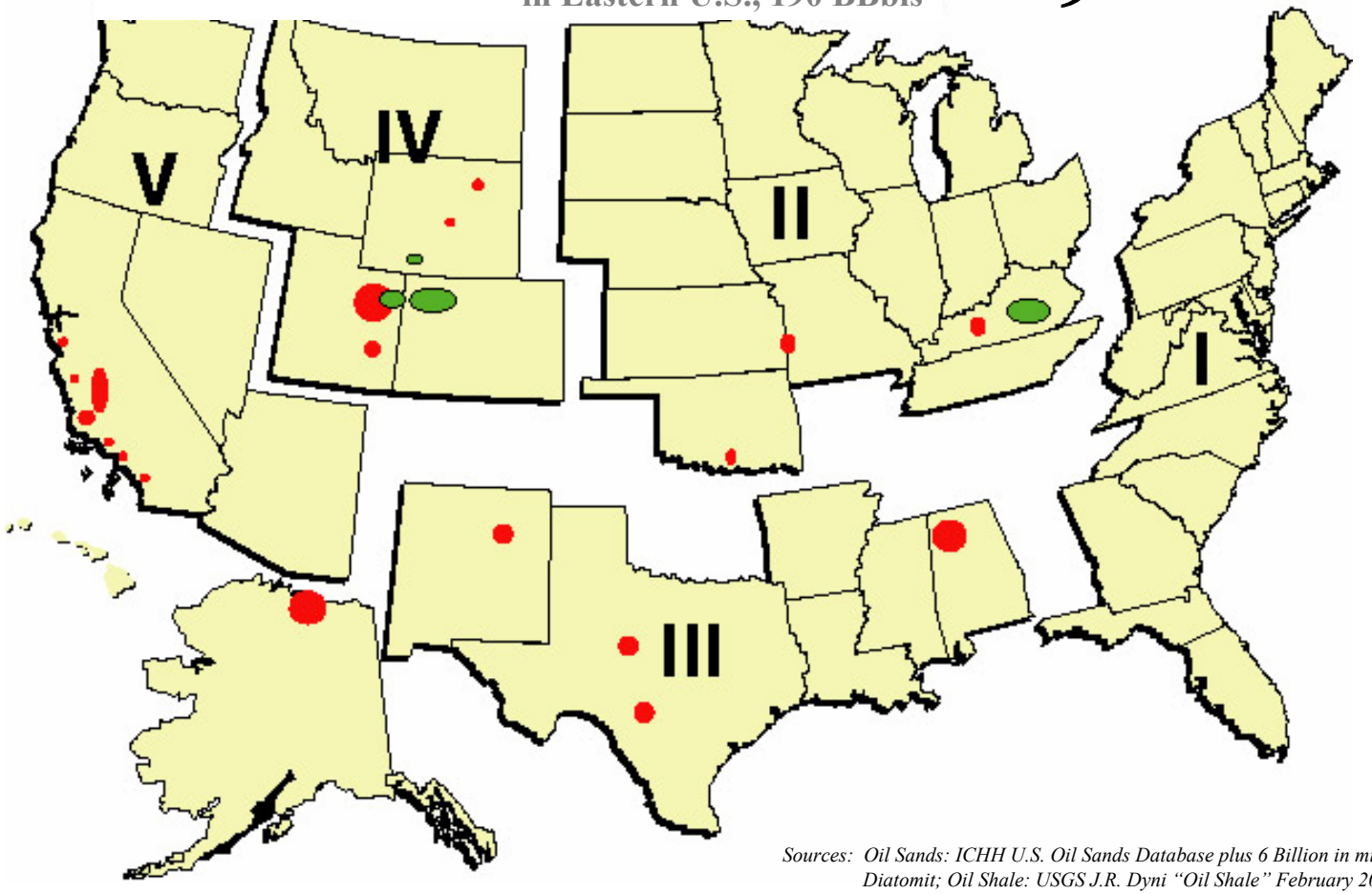
U.S. Oil Sands and Oil Shale Resource

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

2.2 Trillion Bbls



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!