Black Gold: America and Oil

9/23/08

NOTES 9/18/08 POSTED & ASSIGNMENT #4

INTER/EXTRAPOLATION & EXP. GROWTH?
Questions

• Is America / world running out of oil?

• Can the US be energy-independent?

- Production
- Consumption
- Net Imports

- History
- Projections

Annual Energy Outlook 2007
U.S. Liquid Fuels Supply, Consumption, and Net Imports, 1960-2030 (million barrels per day)

- **Consumption**: History and Projections
- **Domestic Supply**: History
- **Net Imports**: Projections, 61%

*Annual Energy Outlook 2007*
U.S. Liquid Fuels Consumption by Sector, 1970-2030
(million barrels per day)

- **Industrial**
- **Transportation**
- **Residential and Commercial**
- **Electric Power**

**Projections** show an increase in consumption from 1970 to 2030. 

**History** indicates a trend of increasing consumption over the years, with slight fluctuations.

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*Annual Energy Outlook 2007*
World Marketed Energy Use by Fuel, 1980-2030 (quadrillion Btu)

- **Oil**: Historical share 33%, projected 38%
- **Natural Gas**: Historical share 27%, projected 24%
- **Coal**: Historical share 9%, projected 24%
- **Renewables**: Historical share 6%, projected 8%
- **Nuclear**: Historical share 5%, projected 6%

*International Energy Outlook 2006*
World Oil Consumption, 2003-2030
(million barrels per day)

- Electricity
- Transportation
- Industrial
- Commercial
- Residential

2003: 80
2010: 92
2015: 98
2020: 104
2025: 111
2030: 118

International Energy Outlook 2006
World Oil Consumption and Production, 2003, 2015, and 2030 (million barrels per day)

Consumption

- Non-OECD
- OECD

Production

- OPEC Conventional
- Non-OPEC Conventional
- Unconventional

International Energy Outlook 2006
China
1996-2006
from NG
OPEC Conventional Liquids Production (million barrels per day)

- Asia: 2005 - 1.1, 2030 - 0.7
- Middle East: 2005 - 23.5, 2030 - 37.5
- West Africa: 2005 - 4.0, 2030 - 9.2

International Energy Outlook 2007
The World’s 15 Largest Oil Suppliers, 2004

Saudi Arabia and Russia remain leading world oil suppliers

Source: EIA, Short-Term Energy Outlook (October 2004)
World Oil Reserves by Country, as of January 1, 2006
(billion barrels)

Saudi Arabia
Iran
Kuwait
Venezuela
Libya
United States
Qatar
Algeria
Kazakhstan
Azerbaijan
Oman
Ecuador
UK

World Total = 1,293 Billion Barrels

Reserves: economically recoverable in identified deposits
Published Estimates of World Oil Ultimate Recovery

Source: USGS and Colin Campbell
Conventional

What makes a reserve conventional. How are reserves "proven"?

As M.A. Adelman puts it:

*Petroleum engineers estimate the cost of drilling and connecting new wells into a new or existing reservoir. A well can produce an initial daily amount, which will decline over time because of pressure loss, water encroachment and other factors... Because operating expenses per well are fairly constant, the cost per barrel must rise as output declines. When cost just equals the market value of the output, production stops at this "economic limit." The estimated aggregate output of the new wells over time is known as the "proved reserves added" or "reserves booked." In the United States, annual reserve estimates are accurate enough ... But except for the United states and a very few other countries, published reserves are not well defined and estimation methods are not revealed. Year to year changes usually do not mean much of anything...*

Unconventional

What is an unconventional oil reserve?

"Unconventional" petroleum reserves include:

- **Heavy oils**, which can be pumped and refined just like conventional petroleum except that they are thicker and have more sulfur and heavy metal contamination, necessitating more extensive refining. Venezuela's Orinoco heavy oil belt is the best known example of this kind of unconventional reserve. Estimated reserves: 1.2 trillion barrels.

- **Tar Sands**, which can be recovered via surface mining or in-situ collection techniques. Again, this is more expensive than lifting conventional petroleum but not prohibitively so. Canada's Athabasca Tar Sands is the best known example of this kind of unconventional reserve. Estimated reserves: 1.8 trillion barrels.

- **Oil Shale** requires extensive processing and consumes large amounts of water. Still, reserves far exceed supplies of conventional oil.

**US reliance on oil imports rises**

Organization of Petroleum Exporting Countries

1960 Baghdad: Iraq
               Iran
               Kuwait
               Saudi Arabia
               Venezuela
               joint by 8 more later

Non-OPEC for example:
   Canada & Mexico ~ 1/4 of US imports
   Russia, Norway, UK

   Algeria
   Angola
   Ecuador
   Indonesia
   Libya
   Nigeria
   Qatar
   UAE
The Future of Oil

Some Considerations:

- Effect of Events
- Necessity of Assumptions & Models
- Interpolation versus Extrapolation
Crude oil prices rise again in 2004

Short-Term Energy Outlook, November 2004
"Our ignorance is not so vast as our failure to use what we know."

- 1955: elected National Academy
- 1957: elected AAAS
- 1959: Arthur L. Day Medal from Geological Society of America
- 1962: elected President, Geological Society of America
- 1977: Rockefeller Public Service Award
- 1981: Vetlesen prize from Columbia University
Model of M. King Hubbert

Assumptions

• The initial and final rates of consumption are zero
• The initial rise in consumption is exponential
• Scarcity and high cost drive the consumption rate to zero

In 1956, Hubbert predicted that US 48-state oil production would peak between 1965 and 1971. How did he do?
Consumption of a Resource

Rate of Use
Remaining
Used
Hubbert

Production rate: rises and declines exponentially
Total production: “S” curve

\[ Q_d = \frac{170 \times 10^9}{1 + 6.17e^{-0.0667(t-1930)}} \]

\[ Q_p = \frac{170 \times 10^9}{1 + 6.17e^{-0.0667(t-1941)}} \]

\[ Q_r = Q_d - Q_p \] proven reserves

\(Q_d\) cumulative discovery
\(Q_p\) cumulative production lags 11 years
\(Q_r = Q_d - Q_p\) proven reserves
Hubbert Curve

Lower 48 Crude Oil Reserves & Production, 1945-2000

Crude Oil Reserves, Billion Barrels

Crude Oil Annual Production, Billion Barrels

- Lower 48 Reserves
- Lower 48 Production

Peak Reserves 1959
Peak Production 1970
Hubbert prediction: US peak in 1966-71

It peaked in 1970!!
Alaska peaked in 1988
Economics is not much help in making predictions!

**Major Events and World oil Prices**

**1970-2004**

*Oil prices fluctuate widely over past three decades*
Current Events: ANWR

Figure 2. Domestic Crude Oil Production for Three ANWR Resource Cases and the AEO2004 Reference Case, 2000-2025 (million barrels per day)

- Alaskan production, no ANWR (AEO2004 Reference Case)
- Additional Alaskan production, mean ANWR resources
- Additional Alaskan production, high ANWR resources
- Additional Alaskan production, low ANWR resources

Source: National Energy Modeling System runs anwr_bs_d022304b, anwr_lo_d022304b, anwr_hi_d022304b, and neo2004_d101703e

Lower 48 production (AEO2004 Reference Case)
Drilling in the ANWR?

ANWR = Arctic National Wildlife Reserve
USGS (US Geological Survey)
estimates ⇒ $10 \times 10^9$ barrels (9-16)

How much energy?

$10 \times 10^9 \times 5.25 \times 10^6 \text{ Btu} = 52.5 \times 10^{15} \text{ Btu}$

$= 52.5 \text{ quads}$

About a 1/2 a year’s worth of energy
Takes at least 10 years to go into production...
Arctic oil is needed

I would like to answer the Nov. 1 letters of C. W. Heitsch and Theresa L. Conley on drilling in the Arctic National Wildlife Refuge.

First, as a matter of national security, we should not be dependent on foreign energy sources. We need to become energy independent and we need to start doing that today. If the present crisis doesn’t open your eyes, I don’t know if anything could. The terrorists are being supported by oil profits and drug trafficking.

Second, the oil and gas reserves in the Arctic National Wildlife Refuge belong to the American people—not just to the environmentalists, but all of us—and the profits from that source would enrich our treasury. I believe prohibiting exploration in the refuge is criminal, especially now. What makes Heitsch so secure in asserting that our oil supply from the Near East is reliable? Terrorists have been known to blow things up, and governments there in unfriendly hands could decide to cut us off.

We should never become dependent on foreign sources for things that affect our national security.

Arlene McNamara

Furman, Mo.
Current Events: Iraq

Iraq's Oil Production and Consumption, 1980-2004E

Million Barrels per Day

Note: Production includes crude oil, lease condensate, natural gas liquids, ethanol, and refinery gain.
When Will World Oil Production Peak?  
EIA Simple Model

Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)

USGS Estimates of Ultimate Recovery

<table>
<thead>
<tr>
<th>Probability</th>
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Source: Energy Information Administration  
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.
A Large Set of Scenarios

Figure 3. 12 EIA World Conventional Oil Production Scenarios

USGS Estimates of Ultimate Recovery

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Peak Range 46 yrs or 91 yrs

2021

2067

2112

900 Billion Bbils
Moves Peak 10 Years From 2037 - 2047

 Decline R/P = 10

1 % Growth

2 % Growth

3 % Growth

Source: Energy Information Administration

Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.
When Will World Oil Production Peak? EIA Simple Model

Annual Production with 2 Percent Annual Growth & Decline

- USGS Estimates of Ultimate Recovery
  - Probability
    - Low (95%): 2,248 BBls
    - Mean (expected value): 3,003 BBls
    - High (5%): 3,996 BBls

- 2% Growth & Decline
  - High Prices Can Affect Demand 4.1% Decline 1979-1983

Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.
Oil Futures

After geologist M. King Hubbert correctly predicted that U.S. oil production would peak by the early 1970s, analysts adapted his mathematical formula to calculate the peak of world oil. Forecasts vary widely, but there is agreement that once oil peaks, extracting what remains will be vastly more difficult and costly.

Draining the Reliable Giants

More than a third of the world’s oil comes from large fields, relatively easy to tap. But discovery of new giants, and average production for each field, has declined for decades. The largest single producer remains a Saudi Arabian megagiant found in the 1960s.

LARGE OIL-FIELD DISCOVERIES

- Giant: 500 million to 5 billion barrels
- Supergiant: 5 billion to 50 billion barrels
- Megagiant: Over 50 billion barrels

CURRENT AVERAGE PRODUCTION PER FIELD

Thousands of barrels a day

*WORLD OIL: PRODUCTION INCLUDES CRUDE OIL, NATURAL GAS PLANT LIQUIDS, OTHER LIQUIDS, AND REFINERY PROCESSING GAINS OR LOSSES.

HAIM HENRIQUEZ, NG STAFF

SOURCES: BRITISH PETROLEUM, M. H. KERN; NATIONAL PETROLEUM COUNCIL; PEAK OIL, NETHERLANDS FOUNDATION
U.S. Crude Oil Production by Source, 1990-2030
(million barrels per day)

History

Projections

Total

Lower 48 Onshore

Deepwater Offshore

Alaska

Shallow Water Offshore

Annual Energy Outlook 2007