Global Overview of Petroleum Resources

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USGS 2000 — New estimate of future world oil and gas resources—30 year time frame (1995-2025)—Not Ultimate, 1st time, 32,000 pages, documentation

Undiscovered Resource Estimates are Geologically Based using Total Petroleum Systems (Fluids not just rocks)—1st time

Reserve (Field) Growth are Statistically Based Estimates for the World (30 Year Forecast)-1st Time

Extensive Methodology Review and Endorsement (AAPG, NAS) 5 year project (1995-2000), 41 Employees (100 man year), transparency of methodology

World Energy Consortium—38 organizations

It is a benchmark—used by the IEA, DOE (EIA); Climate Modelers (Stanford, MIT, PEW); Individuals (Cavallo, 2002; Edwards, 2002; Greene, 2004)

All Information is Digital (DDS-60, 4 CDs, 13 other CDs on regional geology—115,000 distributed), 346 publications

Website [http://energy.usgs.gov](http://energy.usgs.gov)~1.2 million downloads/yr
USGS World Petroleum Assessment 2000

- Undiscovered Resources (TPS) and Reserve Growth Components
- Natural Gas Revolution (the missing 0.5 TBOE of natural gas)
- Calibration of USGS 2000 World Assessment
- Arctic—the New Frontier
- Unconventional Resources—the Barnett—Texas
- Summary
THE VOCABULARY OF RESOURCE ASSESSMENT:

- Cumulative production
- Reserves
- Reserve growth
- Undiscovered resources
  - Conventional
  - Unconventional (continuous)
Total Petroleum System Processes
(Includes Undiscovered Resources)

Armentrout, 2001
PRESENT DAY GENERATION & MIGRATION

Oil Transformation Ratio

- 0.00 - 0.01
- 0.01 - 0.50
- 0.50 - 0.95
- 0.95 - 1.00

Baghdad

SAUDI ARABIA

KUWAIT

Arabian Gulf

TURKEY

SYRIA

IRAN

JORDAN
**Definition:** Reserve growth is the observed increase in reserves for a particular field over time. That is, the initial estimates of reserves in many fields is lower than the ultimate volume of oil produced from that field.

**Causes of reserve growth:**
- Conservative initial estimates (SEC requirements, corporate psychology)
- Exploration technology (e.g., 3-D, 4-D seismic)
- Drilling technology (horizontal, multilateral, directional)
- Production technology (enhanced oil recovery)
Giant Oil Fields of the World
(>500 MMBO, excl. U.S. and Canada),
1981 to 1996

-5 -4 -3 -2 -1 0 1 2 3 4 5

Changes in recoverable oil (BBO)

TOTAL VOLUME IN 1996 = 777,015 MMBO
TOTAL VOLUME IN 1981 = 616,630 MMBO
POSITIVE CHANGE = 142 FIELDS
NEGATIVE CHANGE = 27 FIELDS
UNCHANGED = 17 FIELDS
NET CHANGE = 160,385 MMBO
15-YR CHANGE FACTOR = 1.260

Decreasing field size

Data source: IHS
From Klett and Schmoker, 2003
Relative Amount of Field Growth in Giant Oil Fields (excl. U.S. and Canada)

Data source: IHS (1981 through 1996)
Reserve Growth Summary

- In U.S. has accounted for 85% of all reserve additions in last 15 years
- First time assessed for world by USGS, known for 30 years (Odell, 1973)
- In USGS 2000, we estimated it to be as much as Undiscovered conventional resources (World & U.S.)
  - Oil Reserve Growth (688 BB)
  - Natural Gas Reserve Growth (3660 TCF; 610 BBOE)
  - NGL Reserve Growth (42 BB)
USGS 2000 Oil Endowment
(graduated green color)
of assessed provinces superimposed on
“Earth by Night” image
Conventional Oil Endowment of the World

1. Former Soviet Union
2. Middle East and North Africa
3. Asia Pacific
4. Europe
5. North America
6. Central and South America
7. Sub-Saharan Africa and Antarctica
8. South Asia

Conventional Oil Endowment in Billions of Barrels
- Less than 1 BBO
- 1 - 20 BBO
- 20 - 40 BBO
- 40 - 80 BBO
- 80 - 160 BBO
- Greater than 160 BBO
USGS World Petroleum Assessment 2000 Oil
(128 World Provinces & U.S., Means Billion barrels)
EFF. 1/1/96

- Oil Endowment: 3,021
- Remaining Oil: 2,311 (76.5%)
- Discovered Oil: 2,289 (76%)

- Undiscovered Conventional: 710
- Reserve Growth (Conventional): 891
- Remaining Reserves: 688
- Cumulative Production: 732
- Produced: 23.5%
- Undiscovered: 24%
USGS 2000 Natural Gas Endowment (graduated red color) of assessed provinces superimposed over “Earth at Night” Image
Conventional Natural Gas Endowment of the World

1 Former Soviet Union
2 Middle East and North Africa
3 Asia Pacific
4 Europe
5 North America
6 Central and South America
7 Sub-Saharan Africa and Antarctica
8 South Asia

Conventional Natural Gas Endowment in Trillions of Cubic Feet
- Less than 6 TCF
- 6 - 120 TCF
- 120 - 240 TCF
- 240 - 480 TCF
- 480 - 960 TCF
- Greater than 960 TCF
USGS World Petroleum Assessment 2000
Natural Gas (128 World Provinces & U.S., Means Billion barrels oil equivalent [BBOE]) EFF. 1/1/96

- Natural Gas Endowment: 2,567 BBOE
- Remaining Natural Gas: 2,275 BBOE (88%)
  - Increase: 11.4%
- Discovered Natural Gas: 1,701 BBOE (66.3%)
  - Increase: 33.7%
USGS 2000 World Petroleum Endowment
(128 World Provinces & U.S.)
(Conventional Oil, Natural Gas, NGL, Means in Billion Barrels, EFF. 1/1/96)

<table>
<thead>
<tr>
<th>Petroleum Endowment</th>
<th>Remaining Resources</th>
<th>Discovered Resources</th>
<th>Remaining Reserves</th>
<th>Cumulative Production</th>
<th>Annual Consumption</th>
</tr>
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<tbody>
<tr>
<td>OIL 3,021</td>
<td>OIL 2,311</td>
<td>OIL 2,289</td>
<td>1,758 (29.7%)</td>
<td>OIL 710</td>
<td>43 (0.7%)</td>
</tr>
<tr>
<td>NATURAL GAS 2,567</td>
<td>NATURAL GAS 2,275</td>
<td>NATURAL GAS 1,701</td>
<td>N. GAS 292</td>
<td>N. GAS 292</td>
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<tr>
<td>NGL-324</td>
<td>NGL-317</td>
<td>NGL-117</td>
<td>NGL-48</td>
<td></td>
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</tr>
<tr>
<td>5,912</td>
<td>4,903 (82.9%)</td>
<td>3,973 (67.2%)</td>
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</tbody>
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Ahlbrandt, 2002
The Coming Oil Crisis?

“..the peak of production will soon be passed—possibly within three years—Dave White, Chief Geologist, USGS, 1919

“the peak of production will be reached in 1989, Campbell, 1989; prior to 2000”—Campbell, 1994; Duncan, 1997; “in 2004”—Campbell, 1997; “in 2010”, Campbell, 2000--subsequently very dire consequences—most people die, we return to caves—“Olduvai Theory”
The Olduvai Theory of Industrial Civilization by R.C. Duncan (1997)
As posted on oilcrisis.com
CONVENTIONAL OIL ONLY
Ignored:
"Unconventional" enhanced recovery
Tar sands
Oil shales
Gas liquification advances

GIANT DISCOVERIES 400 FIELDS >0.5 BBO

TREND HERALDS END OF GIANT DISCOVERIES—
50% of all discovered to date came from GIANT FIELDS
Logistic growth curves of cumulative production and their derivatives which give the rates of production.

(a) single-cycle curve

(b) multiple-cycle curve

Hubbert, 1959
Hubbert Curve—peak production marks midpoint of depletion

PRODUCTION

Barrels of Oil Per Year

TIME → 50%

PLATEAU CONCEPT

Barrels of Oil Per Year

Initial Development 3-5 Years

Present

20-25%

Plateau Production 6-10 Years or Longer
E.G. North Sea
PV ~ 20-25 Years

Depletion

Reserve Growth

Additions to Inventory as Needed, Through Investment

Slow Decline
Recent Oil and Natural Gas Reserve Estimates

- **World oil in BBO**
- **World gas in BBOE**
- **OPEC oil in BBO**

*Oil & Gas Journal, 2003*
Published Estimates of World Oil Ultimate Recovery

Source: Campbell, EIA
Comparison of World Oil and Natural Gas Resource Endowment Estimates

Ahlbrandt et al., 2005
World Petroleum Reserves are at all time high about 5 times larger than reserves at end of WWII (1945)

Remaining Reserves ~891 BBO (1/1/96), 1,100 BBO (1/1/2001)—Increase of 15% using IHS Data

Increase of 36% using 2003 O&J Data (includes 175 BBO from Canadian tar sands)

Currently Consuming about 28 BBO / Year

Oil and Natural Gas Reserve Additions Are Increasing
Possible Changes in Organization Share of Oil

PERCENT OF OIL RESOURCES

Reserves

- Reserves
  - 28.6%
  - 7.2%
  - 64.3%
- Reserves + Undiscovered
  - 36.7%
  - 10.4%
  - 52.9%

- Other
- OECD
- OPEC
OR is it Natural Gas?

- Much less utilized worldwide than oil (11% produced vs. 23% for oil)
- LNG and GTL technology make it increasingly viable—The Natural Gas Revolution
- Environmental benefits or detriments
- The conventional / unconventional linkage
- Where is the missing half trillion BOE of gas?
In seven years, 23% of oil and 31% of natural gas USGS 2000 estimates (whole world) have been realized.

18% of estimated oil and 27% of estimated natural gas have been added (Only provinces assessed).

Reserve growth added three times the volumes of new field discoveries:
- 26% of estimated oil volume
- 52% of estimated natural gas volume

USGS 2000 estimates seem reasonable assuming linear rated of reserve additions.
Calibration of USGS Oil and Natural Gas Estimates
1st 7 Years of 30 year forecast

Klett et al., in press
Oil Reserve Additions:
Reserve Growth vs. Undiscovered

Klett et al., in press
Natural Gas Reserve Additions: Reserve Growth vs. Undiscovered

Klett et al., in press
12 EIA World Conventional Oil Production Scenarios

USGS Estimates of Ultimate Recovery

<table>
<thead>
<tr>
<th>Probability</th>
<th>Ultimate Recovery BBls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (95 %)</td>
<td>2,248</td>
</tr>
<tr>
<td>Mean (expected value)</td>
<td>3,003</td>
</tr>
<tr>
<td>High (5 %)</td>
<td>3,896</td>
</tr>
</tbody>
</table>

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

Peak Range 46 yrs or 91 yrs

900 Billion Bbls Moves Peak 10 Years From 2037 - 2047

EIA, 2003
Arctic Share of Undiscovered Petroleum

- **OIL & NGL**
  - Arctic: 20.5%
  - World: 79.5%

- **GAS**
  - Arctic: 27.6%
  - World: 72.4%

- **TOTAL PETROLEUM**
  - Arctic: 23.9%
  - World: 76.1%
The Barnett Shale is a Continuous (Unconventional) Type Accumulation

From Pollastro and others (2003)
Thermally mature Barnett Shale is present over most of the Fort Worth Basin and Bend Arch is the primary source rock that has produced >2 BBO and >7 TCFG from Paleozoic conventional reservoirs.

Most production from the Barnett Shale is at Newark East field.

R.M. Pollastro, USGS (AAPG Bulletin, in press)
The Barnett Shale is the source rock for both indigenous gas and most conventional oil and natural gas produced from Ordovician to Permian age carbonate- and clastic-rock reservoirs in the Fort Worth Basin-Bend Arch area and thus, defines a Barnett-Paleozoic TPS.

From Pollastro (2003)
USGS Barnett Shale – Assessment Results

Greater Newark East Barnett AU: 14.6 TCFG
Extended Barnett Shale AU: 11.6 TCFG
Total Mean Undiscovered Resource: 26.2 TCFG

(from Pollastro and others, 2004)
A Prospective Depletion Curve for the World's Conventional and Non-Conventional Oil to 2080

3000 x 10^9 bbls of non-conventional oil

3000 x 10^9 bbls of conventional oil

actual as modelled

Odell, 1998
An Energy Scenario
A Complex Story of Interacting Variables and Uncertain Reserve Figures

ASSUMPTIONS
- USGS 2000 World Resources
- World GDP 2%
- No major wars or economic collapses
- Global free flow of energy products to consumers
- Major construction of international transport and refining infrastructure
- Globalization develops
- Population increases
- More nations prosper
- New energy sources viable at end of period
- Moderate conservation and efficiency increases
- National oil companies and private companies cooperate
(TPS) Estimates of Future Oil and Gas Resources made by USGS in 2000 are reasonable and on trend.

Reserve Growth is three times more significant than new field discoveries. Large potential in Middle East, Volga Urals, West Siberia, Algeria, North Sea—USGS detailed studies.

2015-2020 Oil Peak for Non-OPEC oil using USGS 2000?

OPEC undiscovered largely onshore, OECD and others largely offshore and undiscovered resources less concentrated in OPEC compared to previous estimates.

The Arctic is the next frontier (21 new provinces)

Transition to natural gas is occurring, is the missing half Trillion BOE of natural gas in the Arctic?

Increasing Emphasis on Unconventional Resources