

Highlights from GAO-07-283:
**CRUDE OIL - Uncertainty about Future Oil Supply Makes It
Important to Develop a Strategy for Addressing a Peak and
Decline in Oil Production.**

EMBARGOED UNTIL 11:30 am Eastern March 29, 2007

*The following are exact quotes. Notable highlights are in **Bold**.*

Results in Brief (Pages 4 - 6)

Most studies estimate that oil production will peak sometime between now and 2040, although many of these projections cover a wide range of time, including two studies for which the range extends into the next century. **The timing of the peak depends on multiple, uncertain factors that will influence how quickly the remaining oil is used, including the amount of oil still in the ground, how much of the remaining oil can be ultimately produced, and future oil demand.** The amount of oil remaining in the ground is highly uncertain, in part because the **Organization of Petroleum Exporting Countries (OPEC) controls most of the estimated world oil reserves, but its estimates of reserves are not verified by independent auditors.** In addition, many parts of the world have not yet been fully explored for oil. **There is also great uncertainty about the amount of oil that will ultimately be produced, given the technological, cost, and environmental challenges.** For example, some of the oil remaining in the ground can be accessed only by using complex and costly technologies that present greater environmental challenges than the technologies used for most of the oil produced to date. **Other important sources of uncertainty about future oil production are potentially unfavorable political and investment conditions in countries where oil is located.** For example, more than 60 percent of world oil reserves, on the basis of Oil and Gas Journal estimates, are in countries where relatively unstable political conditions could constrain oil exploration and production. Finally, future world demand for oil also is uncertain because it depends on economic growth and government policies throughout the world. For example, continued rapid economic growth in China and India could significantly increase world demand for oil, while environmental concerns, including oil's contribution to global warming, may spur conservation or adoption of alternative fuels that would reduce future demand for oil.

In the United States, alternative transportation technologies face challenges that could impede their ability to mitigate the consequences of a peak and decline in oil production, unless sufficient time and effort are brought to bear. For example:

- Ethanol from corn is more costly to produce than gasoline, in part because of the high cost of the corn feedstock. Even if ethanol were to become more cost-competitive with gasoline, it could not become widely available without costly

investments in infrastructure, including pipelines, storage tanks, and filling stations.

- Advanced vehicle technologies that could increase mileage or use different fuels are generally more costly than conventional technologies and have not been widely adopted. For example, hybrid electric vehicles can cost from \$2,000 to \$3,500 more to purchase than comparable conventional vehicles and currently constitute about 1 percent of new vehicle registrations in the United States.
- Hydrogen fuel cell vehicles are significantly more costly than conventional vehicles to produce. Specifically, the hydrogen fuel cell stack needed to power a vehicle currently costs about \$35,000 to produce, in comparison with a conventional gas engine, which costs \$2,000 to \$3,000.

Given these challenges, development and widespread adoption of alternative transportation technologies will take time and effort. Key alternative technologies currently supply the equivalent of only about 1 percent of U.S. consumption of petroleum products, and DOE projects that even under optimistic scenarios, by 2015 these technologies could displace only the equivalent of 4 percent of projected U.S. annual consumption. **Under these circumstances, an imminent peak and sharp decline in oil production could have severe consequences, including a worldwide recession. If the peak comes later, however, these technologies have a greater potential to mitigate the consequences.** DOE projects that these technologies could displace up to the equivalent of 34 percent of projected U.S. annual consumption of petroleum products in the 2025 through 2030 time frame, assuming the challenges the technologies face are overcome. The level of effort dedicated to overcoming challenges to alternative technologies will depend in part on the price of oil; without sustained high oil prices, efforts to develop and adopt alternatives may fall by the wayside.

Federal agency efforts that could reduce uncertainty about the timing of peak oil production or mitigate its consequences are spread across multiple agencies and generally are not focused explicitly on peak oil. For example, efforts that could be used to reduce uncertainty about the timing of a peak include USGS activities to estimate oil resources and DOE efforts to monitor current supply and demand conditions in global oil markets and to make future projections. Similarly, DOE, the Department of Transportation (DOT), and the U.S. Department of Agriculture (USDA) all have programs and activities that oversee or promote alternative transportation technologies that could mitigate the consequences of a peak. However, officials of key agencies we spoke with acknowledge that their efforts—with the exception of some studies—are not specifically designed to address peak oil. **Federally sponsored studies we reviewed have expressed a growing concern over the potential for a peak and officials from key agencies have identified some options for addressing this issue.** For example, DOE and USGS officials told us that

developing better information about worldwide demand and supply and improving global estimates for nonconventional oil resources and oil in “frontier” regions that have yet to be fully explored could help prepare for a peak in oil production by reducing uncertainty about its timing. Agency officials also said that, in the event of an imminent peak, they could step up efforts to mitigate the consequences by, for example, further encouraging development and adoption of alternative fuels and advanced vehicle technologies. However, **according to DOE, there is no formal strategy for coordinating and prioritizing federal efforts dealing with peak oil issues, either within DOE or between DOE and other key agencies.**

While the consequences of a peak would be felt globally, the United States, as the largest consumer of oil and one of the nations most heavily dependent on oil for transportation, may be particularly vulnerable.

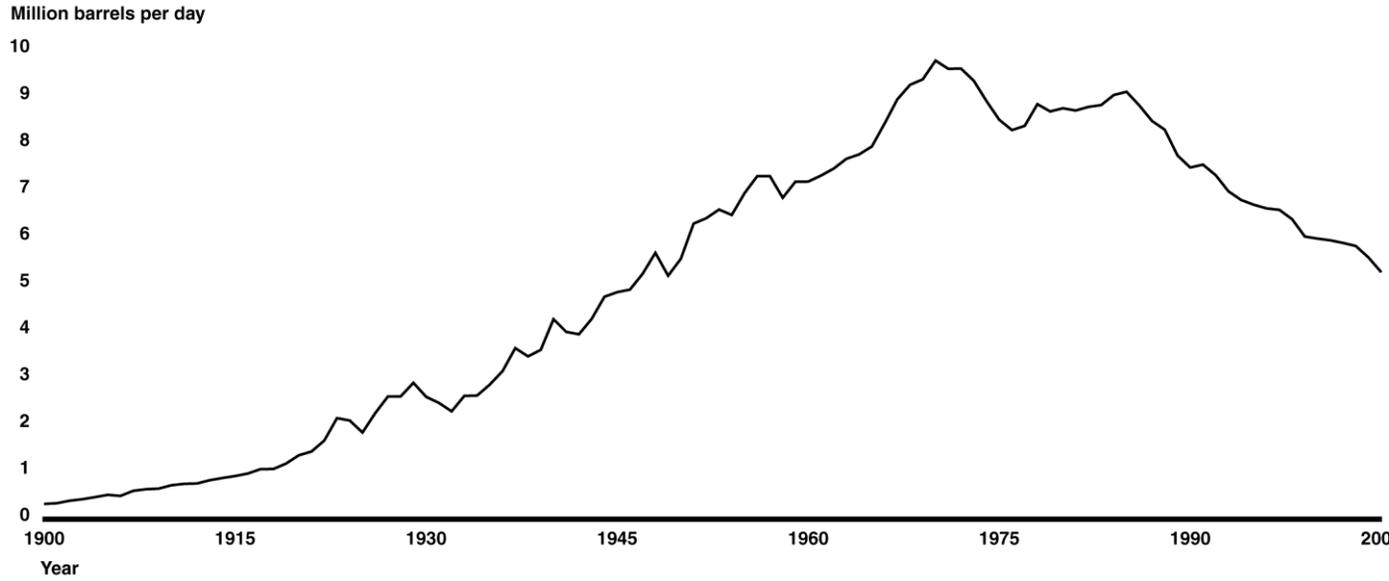
Therefore, to better prepare the United States for a peak and decline in oil production, **we are recommending that the Secretary of Energy take the lead, in coordination with other relevant federal agencies, to establish a peak oil strategy.** Such a strategy should include efforts to reduce uncertainty about the timing of a peak in oil production and provide timely advice to Congress about cost-effective measures to mitigate the potential consequences of a peak. In commenting on a draft of the report, the Departments of Energy and the Interior generally agreed with the report and recommendations.

Notable Statements and Charts

According to IEA, most countries outside the Middle East have reached their peak in conventional oil production, or will do so in the near future.

The United States is a case in point. Even though the United States is currently the third-largest, oil-producing nation, U.S. oil production peaked around 1970 and has been on a declining trend ever since. **(Page 7)**

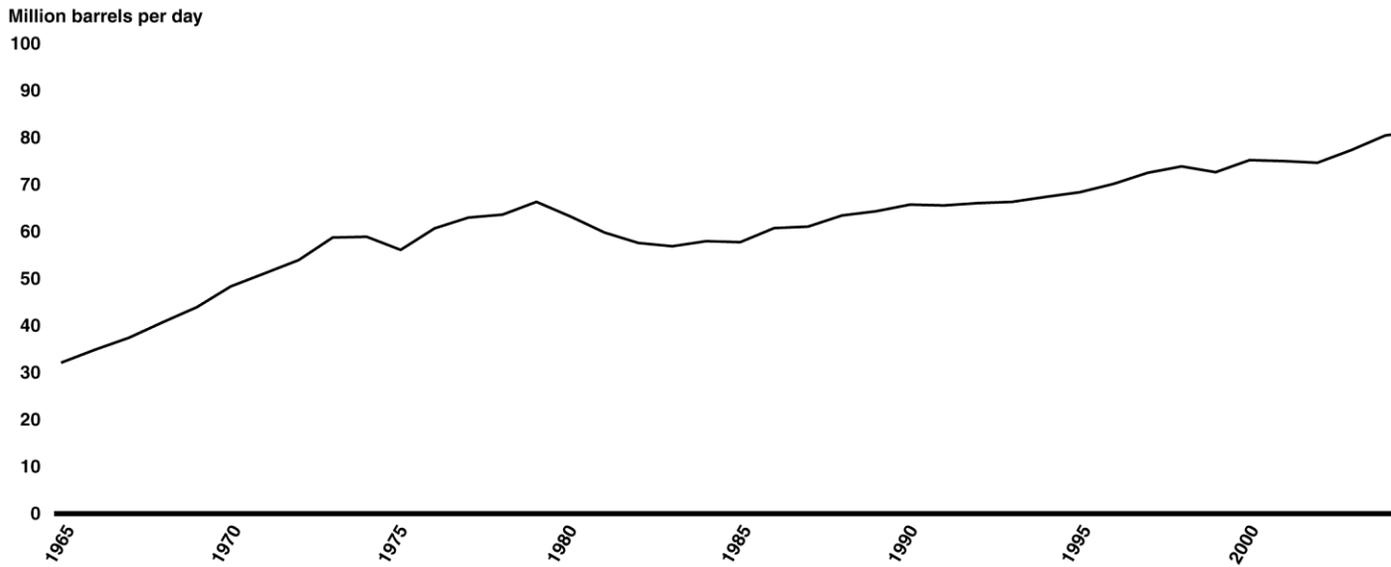
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U.S. Oil Production, 1900 - 2005



Source: GAO analysis of Energy Information Administration data.

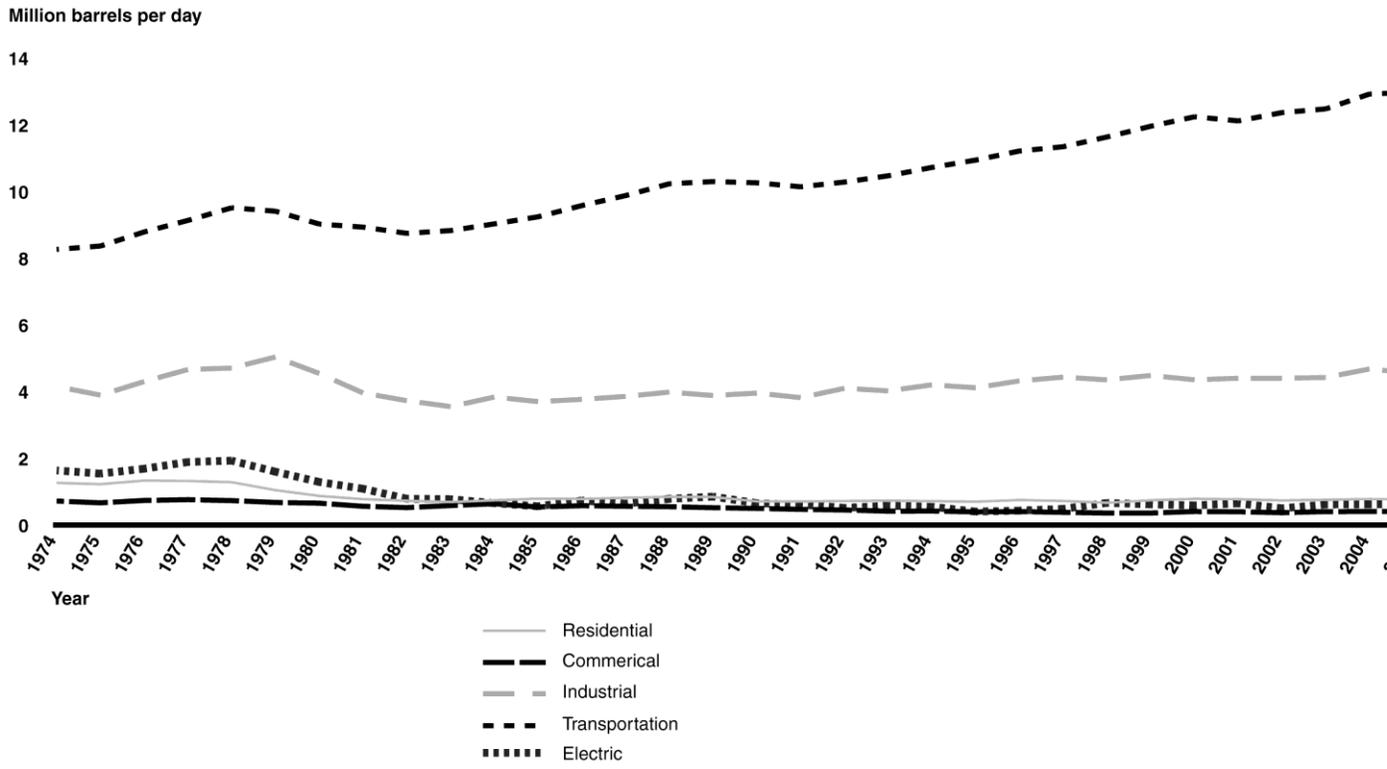
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World Crude Oil and Other Liquids Production, 1965 - 2005



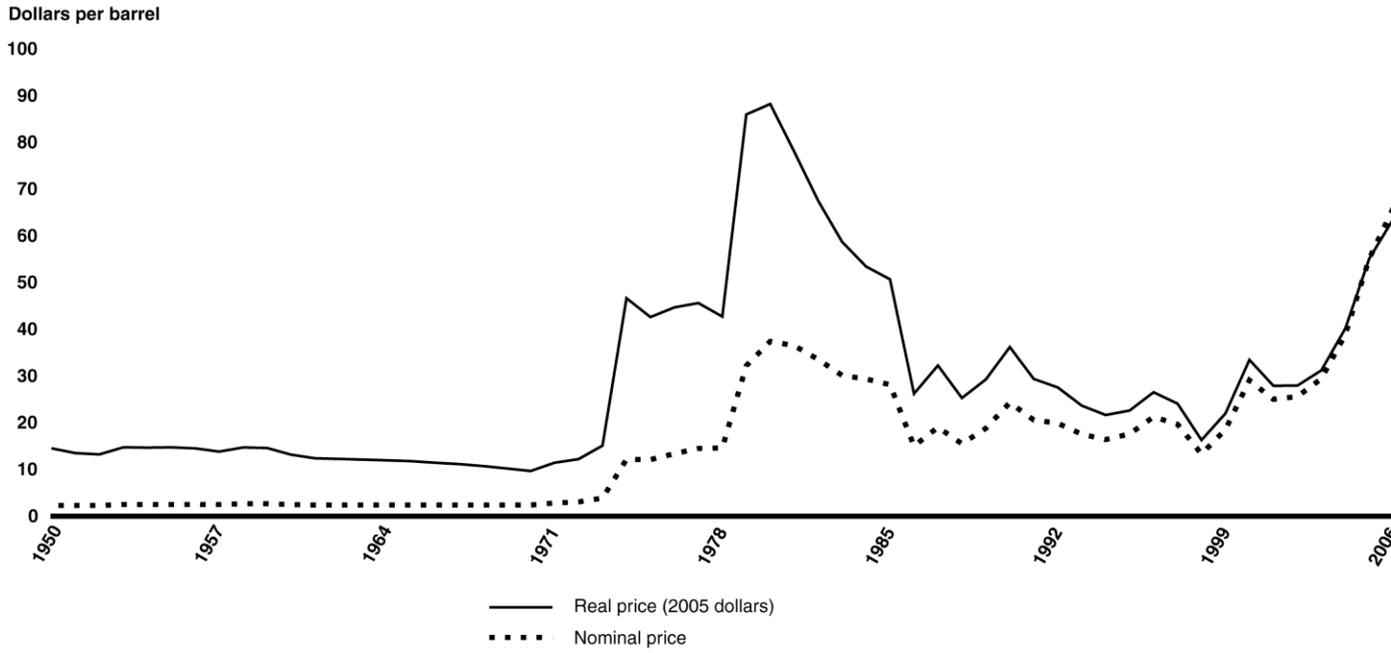
Source: GAO analysis of British Petroleum data.

Annual U.S. Oil Consumption, by Sector, 1974 - 2005



Source: GAO analysis of Energy Information Administration data.

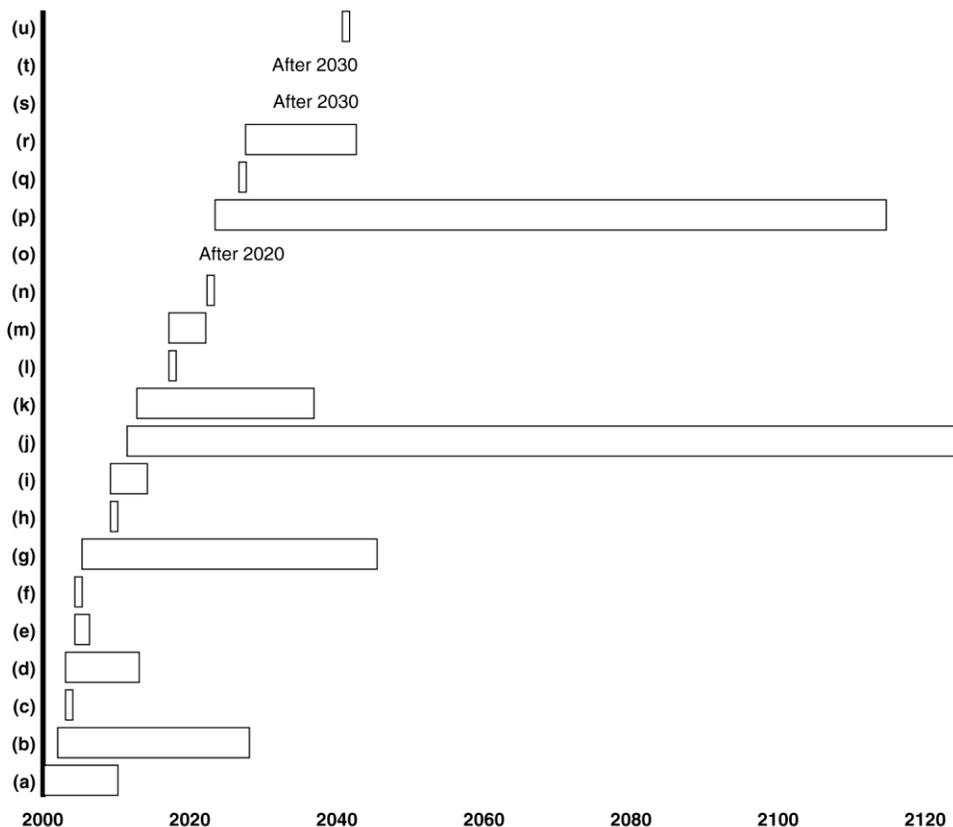
Real and Nominal Oil Prices, 1950 - 2006



Source: GAO analysis of British Petroleum, Energy Information Administration, and Bureau of Labor Statistics data.

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Key Estimates of the Timing of Peak Oil

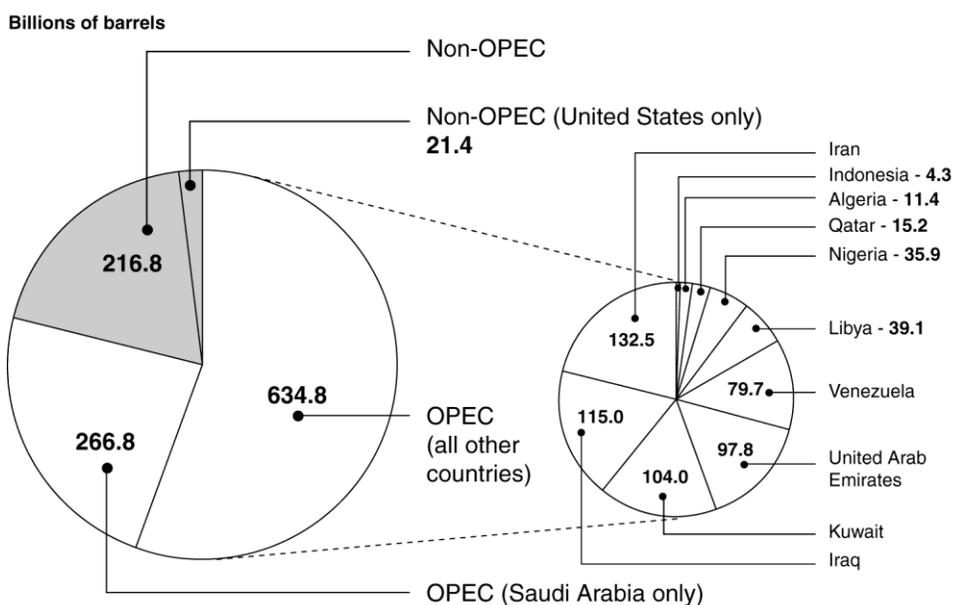


Source: GAO study.

Studies that predict the timing of a peak use different estimates of how much oil remains in the ground, and these differences explain some of the wide ranges of these predictions. **Estimates of how much oil remains in the ground are highly uncertain because much of these data are self-reported and unverified by independent auditors; many parts of the world have yet to be fully explored for oil; and there is no comprehensive assessment of oil reserves from nonconventional sources.** (Page 14).

Some experts believe OPEC estimates of proven reserves to be inflated. For example, OPEC estimates increased sharply in the 1980s, corresponding to a change in OPEC’s quota rules that linked a member country’s production quota in part to its remaining proven reserves. In addition, many OPEC countries’ reported reserves remained relatively unchanged during the 1990s, even as they continued high levels of oil production. For example, **IEA reports that reserves estimates in Kuwait were unchanged from 1991 to 2002, even though the country produced more than 8 billion barrels of oil over that period and did not make any important new oil discoveries.** (Page 14)

World Oil Reserves, OPEC and non-OPEC, 2006



Source: GAO analysis of *Oil and Gas Journal* data.

Limited information on oil-producing regions worldwide also leads USGS to base its estimate of reserves growth on how reserves estimates have grown in the United States. However, some experts criticize this methodology; they believe such an estimate may be too high because the U.S. experience overestimates increases in future worldwide reserves. In contrast, EIA believes the USGS estimate may be too low. (Page 17)

It is also difficult to project the timing of a peak in oil production because **technological, cost, and environmental challenges make it unclear how much oil can ultimately be recovered from (1) proven reserves, (2) hard-to-reach locations, and (3) nonconventional sources.** (Page 18).

EOR technologies currently contribute approximately 12 percent to U.S. production, and **carbon dioxide EOR alone is projected to have the potential to provide at least 2 million barrels per day by 2020.** (Page 18)

It is unclear how much oil can be recovered from nonconventional sources. Recovery from these sources could delay a peak in oil production or slow the rate of decline in production after a peak. **Expert sources disagree concerning the significance of the role these nonconventional sources will play in the future.** DOE officials we spoke with emphasized the belief that nonconventional oil will play a significant role in the very near future as conventional oil production is unable to meet the increasing demand for oil. However, **IEA estimates of oil production have conventional oil continuing to comprise almost all of production through 2030.** Currently, production of oil from key nonconventional

sources of oil—oil sands, heavy and extra-heavy oil deposits, and oil shale—is more costly and presents environmental challenges. (Page 19).

In 2005, worldwide production of oil sands, largely from Alberta, contributed approximately 1.6 million barrels of oil per day, and production is projected to grow to as much as 3.5 million barrels per day by 2030. Oil sand deposits are also located domestically in Alabama, Alaska, California, Texas, and Utah.

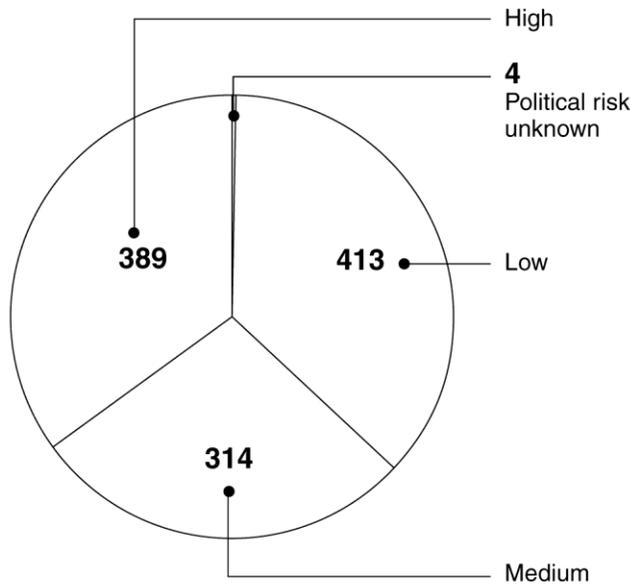
Production from oil sands, however, presents significant environmental challenges. The production process uses large amounts of natural gas, which generates greenhouse gases when burned. In addition, large-scale production of oil sands requires significant quantities of water, typically produce large quantities of contaminated wastewater, and alter the natural landscape. These challenges may ultimately limit production from this resource, even if sustained high oil prices make production profitable. (Page 20).

Using a measure of political risk that assesses the likelihood that events such as civil wars, coups, and labor strikes will occur in a magnitude sufficient to reduce a country's gross domestic product (GDP) growth rate over the next 5 years, **we found that four countries—Iran, Iraq, Nigeria, and Venezuela—that possess proven oil reserves greater than 10 billion barrels (high reserves) also face high levels of political risk. These four countries contain almost one-third of worldwide oil reserves. Countries with medium or high levels of political risk contained 63 percent of proven worldwide oil reserves, on the basis of Oil and Gas Journal estimates of oil reserves.** (Page 21).

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Worldwide Proven Oil Reserves, by Political Risk

Billions of barrels

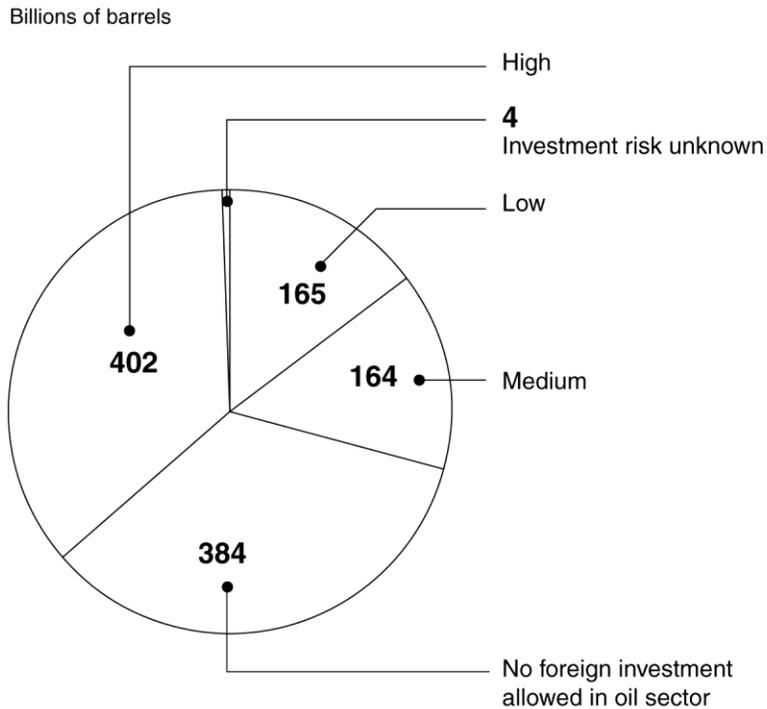


Source: GAO analysis of *Oil and Gas Journal* and Global Insight data.

According to our analysis, 85 percent of the world's proven oil reserves are in countries with medium-to-high investment risk or where foreign investment is prohibited, on the basis of Oil and Gas Journal estimates of oil reserves. (Page 24)

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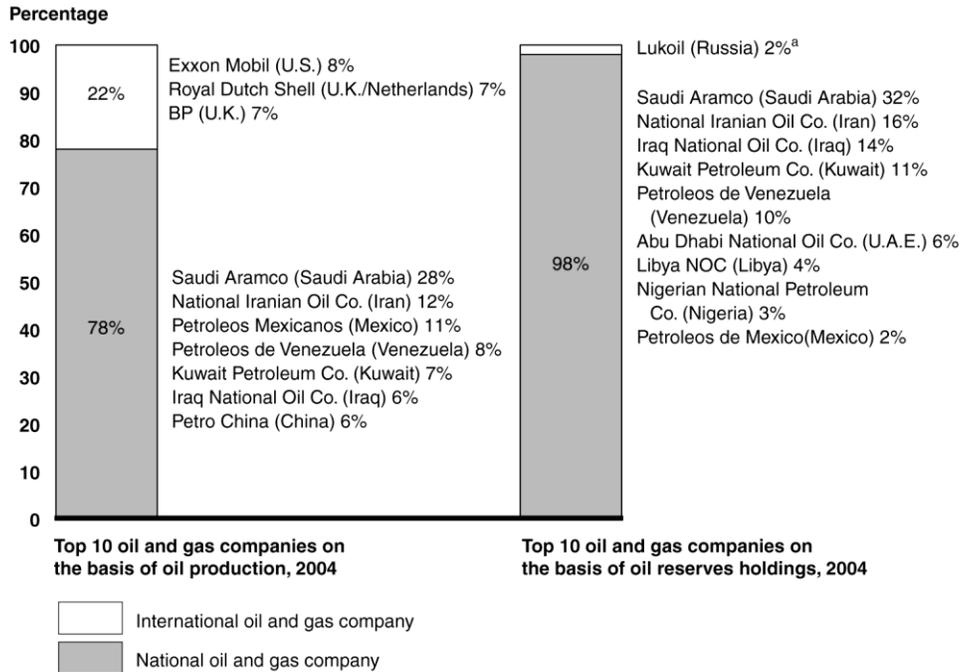
Worldwide Proven Oil Reserves, by Investment Risk



Source: GAO analysis of *Oil and Gas Journal* and Global Insight data.

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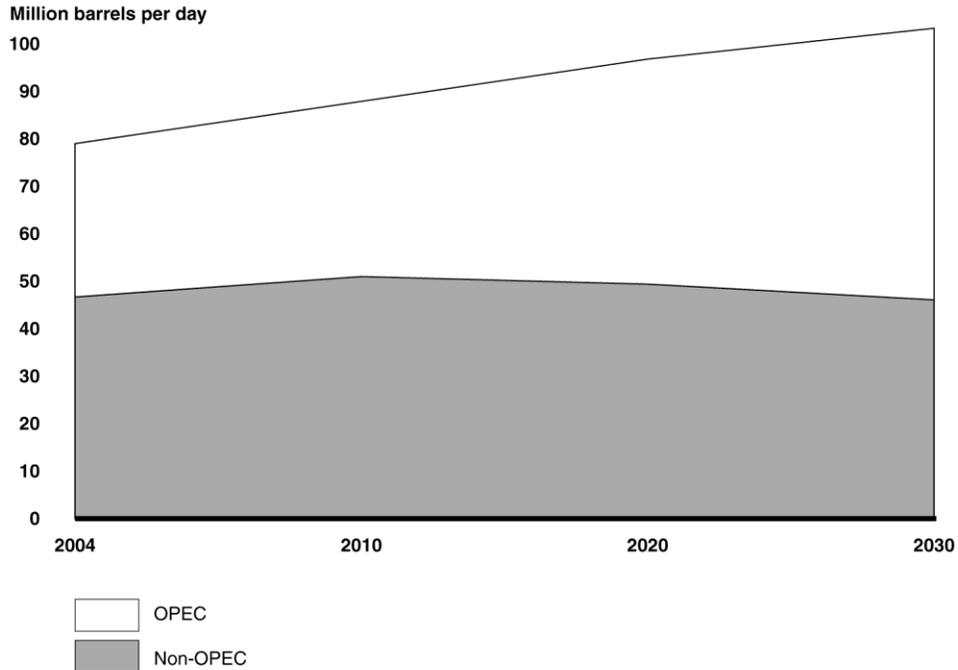
Top 10 Companies on the Basis of Oil Production and Reserves Holdings, 2004



Source: GAO analysis of data from *Petroleum Intelligence Weekly* (Dec. 12, 2005).

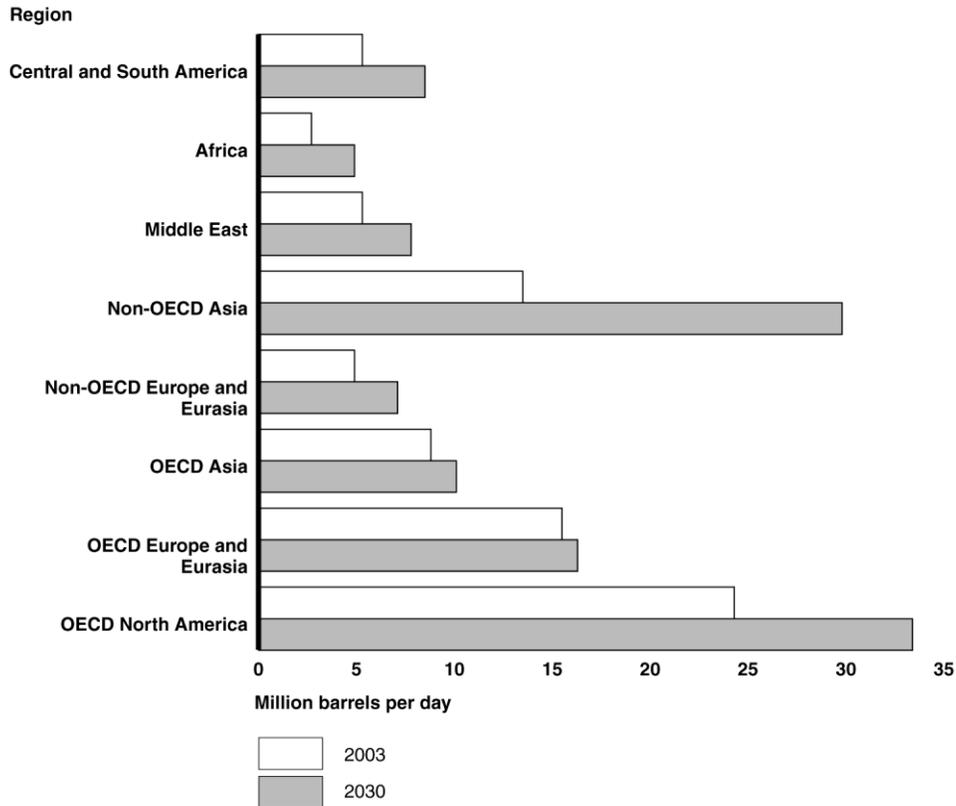
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World Oil Production, by OPEC and Non-OPEC Countries, 2004 Projected to 2030



Source: International Energy Agency.

Daily World Oil Consumption, by Region for 2003 and Projected for 2030



Source: Energy Information Administration.

Factors that create uncertainty about the timing of the peak—in particular, factors that affect oil exploration and production—also create **uncertainty about the rate of production decline after the peak.** (Page 28)

The rate of decline after a peak is an important consideration because a decline that is more abrupt will likely have more adverse economic consequences than a decline that is less abrupt. (Page 29).

In the United States, alternative transportation technologies have limited potential to mitigate the consequences of a peak and decline in oil production, at least in the near term, because they face many challenges that will take time and effort to overcome. If the peak and decline in oil production occur before these technologies are advanced enough to substantially offset the decline, the consequences could be severe. If the peak occurs in the more distant future, however, alternative technologies have a greater potential to mitigate the consequences. (Page 29).

Development and widespread adoption of the seven alternative fuels and advanced vehicle technologies we examined will take time, and significant

challenges will have to be overcome, according to DOE. These technologies include ethanol, biodiesel, biomass gas-to-liquid, coal gas-to-liquid, natural gas and natural gas vehicles, advanced vehicle technologies, and hydrogen fuel cell vehicles. (Page 29).

Because development and widespread adoption of technologies to displace oil will take time and effort, an imminent peak and sharp decline in oil production could have severe consequences. The technologies we examined currently supply the equivalent of only about 1 percent of U.S. annual consumption of petroleum products, and DOE projects that even under optimistic scenarios, these technologies could displace only the equivalent of about 4 percent of annual projected U.S. consumption by around 2015. If the decline in oil production exceeded the ability of alternative technologies to displace oil, energy consumption would be constricted, and as consumers competed for increasingly scarce oil resources, oil prices would sharply increase. In this respect, the consequences could initially resemble those of past oil supply shocks, which have been associated with significant economic damage. For example, disruptions in oil supply associated with the Arab oil embargo of 1973-74 and the Iranian Revolution of 1978-79 caused unprecedented increases in oil prices and were associated with worldwide recessions. In addition, **a number of studies we reviewed indicate that most of the U.S. recessions in the post-World War II era were preceded by oil supply shocks and the associated sudden rise in oil prices.**

Ultimately, however, the consequences of a peak and permanent decline in oil production could be even more prolonged and severe than those of past oil supply shocks. Because the decline would be neither temporary nor reversible, the effects would continue until alternative transportation technologies to displace oil became available in sufficient quantities at comparable costs. Furthermore, because oil production could decline even more each year following a peak, the amount that would have to be replaced by alternatives could also increase year by year. (Page 33-4).

If the peak occurs in the more distant future or the decline following a peak is less severe, alternative technologies have a greater potential to mitigate the consequences. **DOE projects that the alternative technologies we examined have the potential to displace up to the equivalent of 34 percent of annual U.S. consumption of petroleum products in the 2025 through 2030 time frame. However, DOE also considers these projections optimistic—it assumes that sufficient time and effort are dedicated to the development of these technologies to overcome the challenges they face.** (Page 34).

The prospect of a peak in oil production presents problems of global proportion whose consequences will depend critically on our preparedness. The consequences would be most dire if a peak occurred

soon, without warning, and were followed by a sharp decline in oil production because alternative energy sources, particularly for transportation, are not yet available in large quantities. Such a peak would require sharp reductions in oil consumption, and the competition for increasingly scarce energy would drive up prices, possibly to unprecedented levels, causing severe economic damage. While these consequences would be felt globally, the United States, as the largest consumer of oil and one of the nations most heavily dependent on oil for transportation, may be especially vulnerable among the industrialized nations of the world. (Page 38)

While public and private responses to an anticipated peak could mitigate the consequences significantly, **federal agencies currently have no coordinated or well-defined strategy either to reduce uncertainty about the timing of a peak or to mitigate its consequences. This lack of a strategy makes it difficult to gauge the appropriate level of effort or resources to commit to alternatives to oil and puts the nation unnecessarily at risk.** (Page 39)