An Oil Crisis is Probably Imminent

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1.0 Introduction

Several studies and much data available on the internet indicate that there is a strong likelihood that the world is about to enter an era when oil becomes scarce and oil prices increase significantly. Well over half of all oil produced in the world is used as transportation fuel. Oil is the primary source of transportation fuel for almost all forms of transportation – cars, trucks, trains, ships and aircraft. It is also essential for a wide range of petrochemical products that we use every day. An oil crisis will have a profound effect on the developed and developing world economies. Not only will transportation fuel costs increase dramatically, but the cost of all goods and services dependent on transportation will rise dramatically. This problem is further complicated in that development and exploitation of potential alternative fuels should not exacerbate pollution and the global warming problem.

This report identifies and summarizes several previous studies and government reports. It also presents and discusses available data and the results of the author's additional analysis of the available data. Based on this data and analysis the author believes that this problem is real and that the era of very expensive oil may have already started.

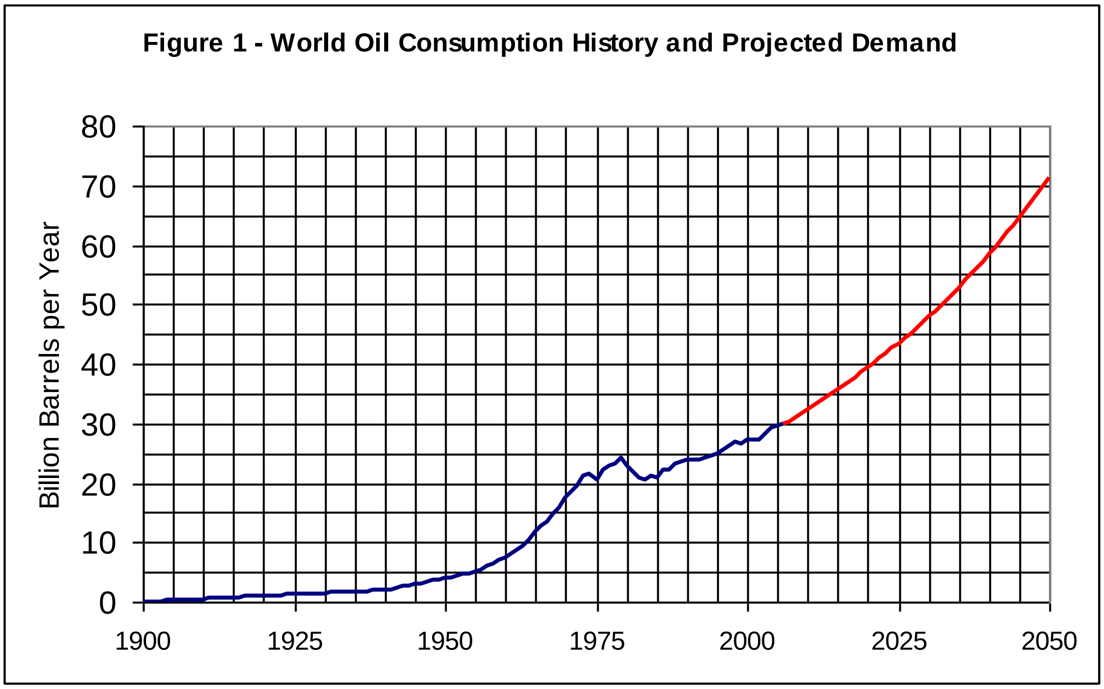
This report also identifies and discusses potential alternative transportation fuel sources. The U.S. Government and private industry apparently recognized, starting in the Reagan administration, that an oil crisis will occur in the foreseeable future and have provided research funding for many alternative fuels. While some of the research is proving fruitful, it appears that there are no near-term alternatives to oil-based fuels that can immediately step in and alleviate the problem. Neither the Government nor the press has publicized this as a major issue.

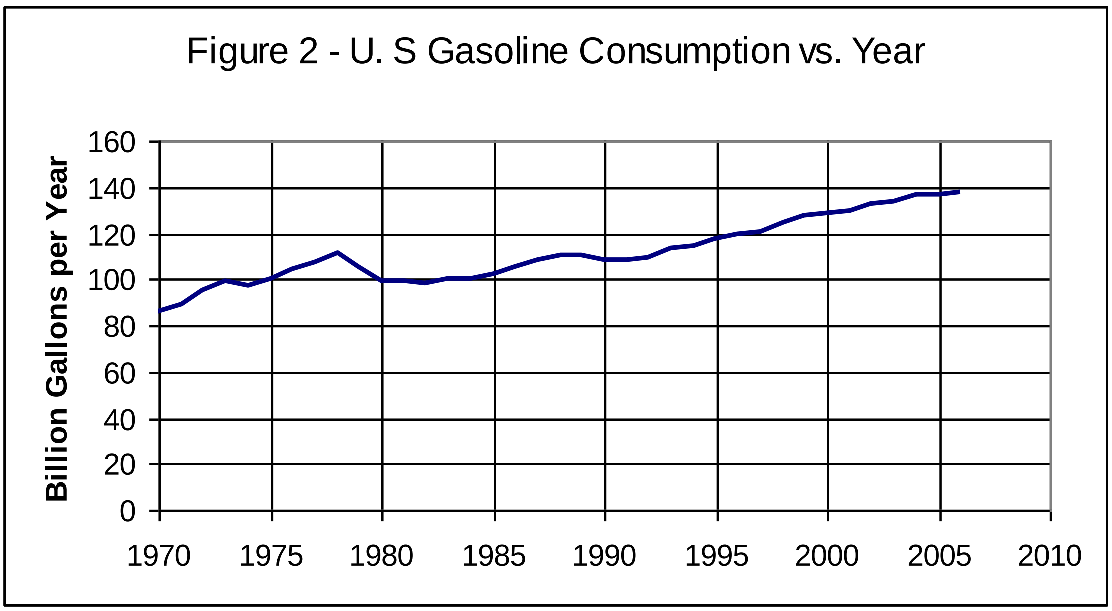
The objective of this report is to alert people to the probability of an imminent oil crisis. This will allow them to make their own decisions regarding the likelihood of such a crisis and to plan for how best to cope with the issue.

2.0 Oil Availability in the Future

The world-wide amount of oil consumed in 2006 was 29.8 billion barrels. To put this in perspective, this amount of oil would fill a container whose base is one mile by one mile and whose height is just over one and one-eighth miles.

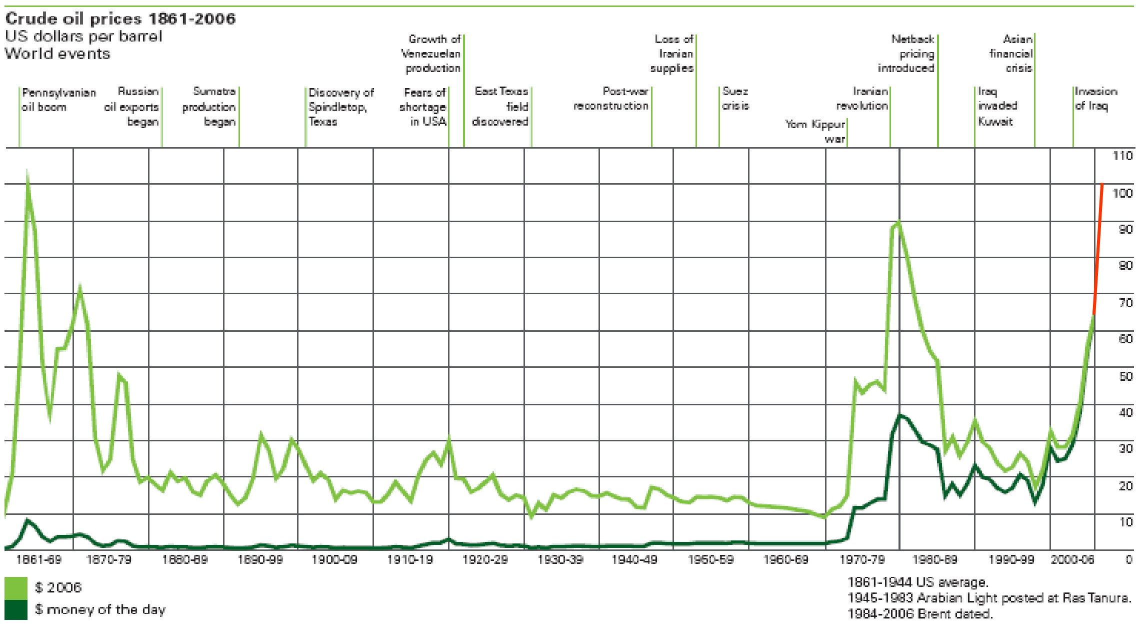
Total cumulative historical world oil production reached over 1,030 Billion barrels in 2006. Projected demand for oil is predicted to increase at the rate of about two percent per year into the foreseeable future. See Figure 1 and "Long-Term World Oil Supply Scenarios," reference 1. The U.S. consumed approximately one-fourth of world oil production or approximately 7.5 billion barrels in 2007. U.S. oil consumption is still increasing every year and developing nations, primarily China and India, have significantly increased their consumption in recent years. U.S. gasoline consumption increased steadily at a rate of about 2 billion gallons per year during the period from 1986 through 2004. See figure 2 which is based on data from reference 2.



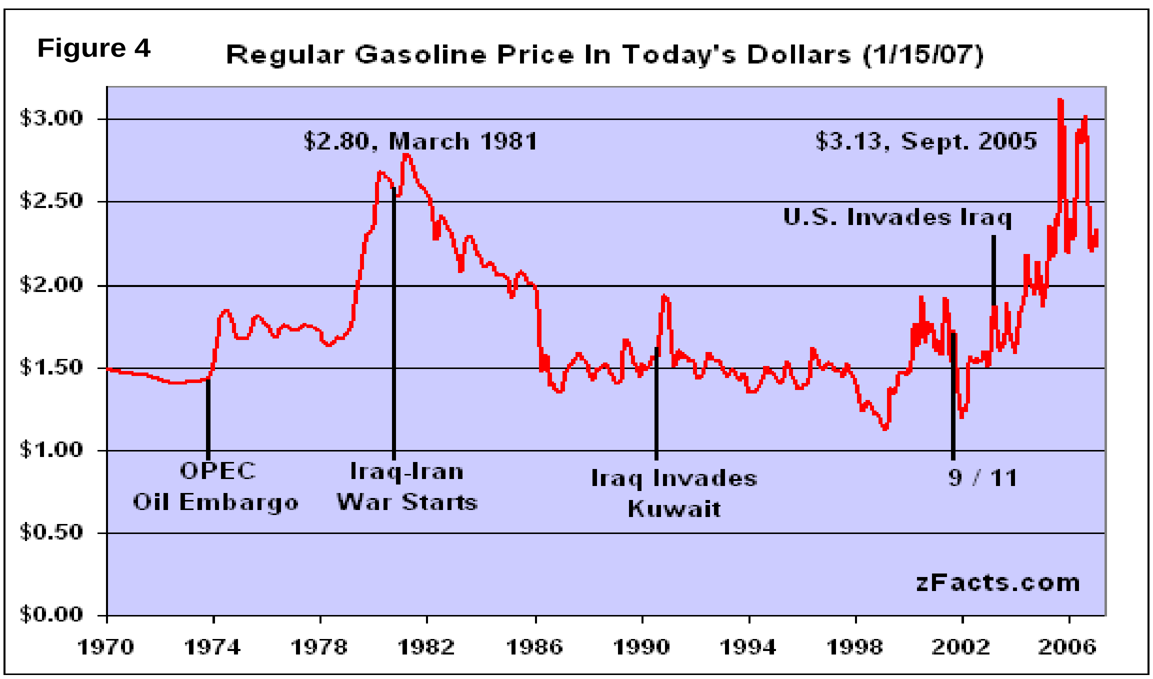


Oil was relatively cheap throughout most of the 1900's. See Figure 3 from "BP Statistical Review of World Energy 2007," Reference 3. Prices started increasing dramatically after the Yom Kippur war in 1970. When oil prices hit $90 per barrel (2006 dollars) in 1979 consumption was sharply reduced due to shortages and higher prices. This apparently caused oil prices to decrease over the next decade where they remained relatively low until 2002.

Figure 3



During the period from 1986 through 2003 the price of gasoline averaged about $1.50 per gallon and stayed under $2.00 per gallon (2007 dollars). See figure 4 from reference 4. This encouraged many people to purchase SUVs and other poor mileage vehicles. Oil prices have sharply increased since 2003, reaching over $100 per barrel in January 2008.



Reference 3, "BP Statistical Review of World Energy 2007," includes a series of spread sheets listing the proved oil reserves, production and consumption of each country from 1980 through 2006. Proved reserves of oil are the quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions. The reserves at the end of 2006 totaled 1,208 billion barrels or 1,317 billion barrels when Canadian tar sands are included. The accuracy of these figures is uncertain since many of them are provided by the country with no independent expert analysis.

Table 1 presents the reserves, production and consumption rates of the top 25 oil producing countries in 2006. All twelve OPEC countries are included in this group. Each of these countries produced at least one-quarter billion barrels in 2006. These countries have 95 percent of the world total reserves.

Table 1 - Top 25 Oil Producing Countries in 2006 (in years of production remaining order)

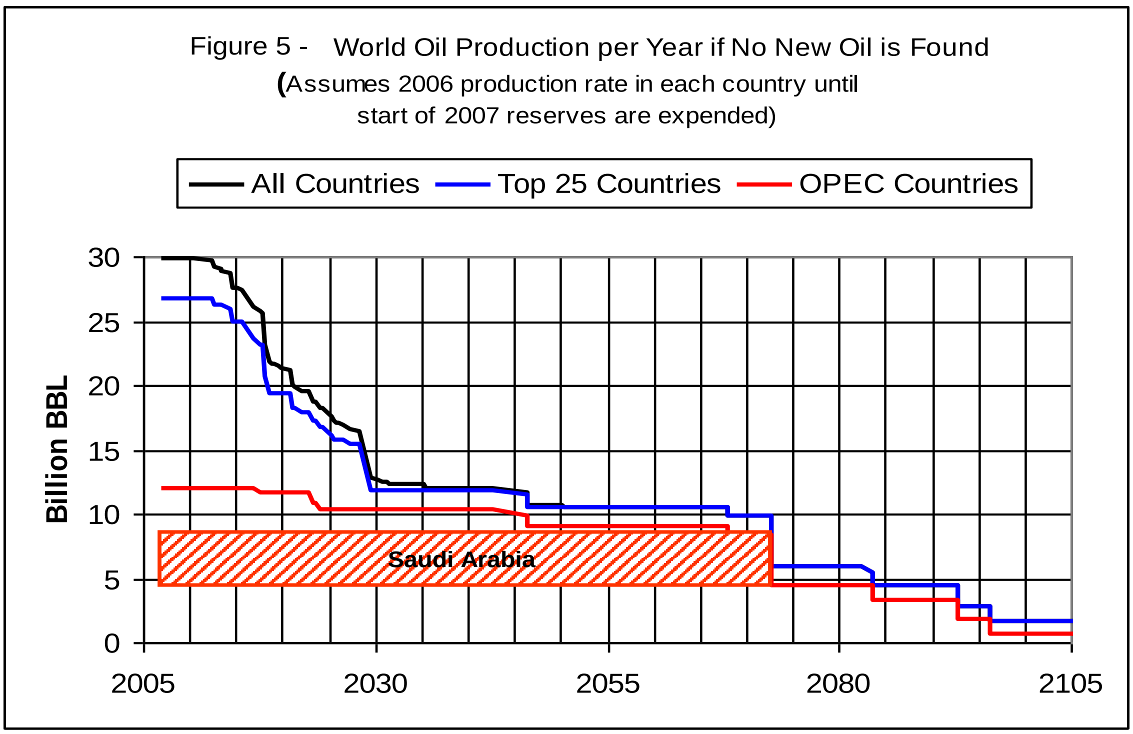
Country	Resrves Billion BBL	Production Billion BBL/Year	Consumption Billion BBL/Year	Production/ Consumption	Years of Production Remaining *	Last Year of Production *
United Kingdom	3.870	0.597	0.650	0.9	6.5	2012.5
Argentina	1.972	0.261	0.161	1.6	7.5	2013.5
Norway	8.499	1.014	0.079	12.8	8.4	2014.4
Mexico	12.908	1.344	0.720	1.9	9.6	2015.6
Indonesia **	4.301	0.391	0.376	1.0	11.0	2017.0
USA	29.922	2.508	7.515	0.3	11.9	2017.9
China	16.271	1.345	2.718	0.5	12.1	2018.1
Canada	17.093	1.148	0.811	1.4	14.9	2020.9
Malaysia	4.200	0.273	0.182	1.5	15.4	2021.4
Algeria **	12.270	0.732	0.095	7.7	16.8	2022.8
Angola **	9.035	0.514	0.017	30.2	17.6	2023.6
Brazil	12.182	0.660	0.765	0.9	18.5	2024.5
India	5.693	0.294	0.940	0.3	19.3	2025.3
Oman	5.572	0.271	0.022	12.4	20.5	2026.5
Russian Federation	79.540	3.566	0.998	3.6	22.3	2028.3
Qatar **	15.207	0.413	0.040	10.3	36.8	2042.8
Nigeria **	36.220	0.898	0.011	84.8	40.3	2046.3
Libya **	41.464	0.670	0.087	7.7	61.9	2067.9
Saudi Arabia **	264.251	3.963	0.732	5.4	66.7	2072.7
Kazakhstan	39.828	0.520	0.081	6.5	76.5	2082.5
Venezuela **	80.012	1.031	0.206	5.0	77.6	2083.6
Iran **	137.490	1.585	0.609	2.6	86.7	2092.7
United Arab Emirates **	97.800	1.084	0.149	7.3	90.2	2096.2
Kuwait **	101.500	0.987	0.100	9.8	102.8	2108.8
Iraq **	115.000	0.730	0.138	5.3	157.6	2163.6
Totals	1152.100	26.800	18.202			

* Assumes production level remains constant until reserves are exhausted (also = R/P)
** OPEC Country

Looking at Table 1 it can be seen that the OPEC countries export far more oil than they consume and are therefore primarily motivated by money. Since most of the OPEC countries are awash with cash, with current production rates and recent oil prices, they are probably not very motivated to significantly increase production which will cause them to use up their reserves more rapidly. The UAE is an outstanding example of an OPEC country that does not seem to be able to spend its current oil income fast enough.

Figure 5 shows the results of the author's analysis of 2006 reserves and production by country based on data from reference 3. The analysis computed the reserves / production ratio (R/P) for each country and assumed that this would be the number of years that the country would be able to keep producing at the 2006 rate. The data was then sorted in decreasing years of production remaining order and then the total world oil production per year was computed. Breakouts for the top 25 producing countries and the OPEC countries were also computed.

The large production countries that run out of oil by 2015 include UK and Norway (North Sea), USA, Mexico, China and Canada. Most of the OPEC countries do not run out of oil until 2042 or later. Production contributions from the non-top 25 countries were 3.6 billion barrels in 2006 and decrease to less than 1 billion barrels in 2029 and beyond. Production will start declining rapidly in 2012 and decline steeply in 2018. The total production of all but the OPEC countries will be less than 2.5 billion barrels in 2030 and beyond. The red shaded area represents Saudi Arabia's reserves and production. The large drop in 2073 is when Saudi Arabia runs out.



This data is not a realistic detailed forecast of the future since those countries that are past their peak production will gradually reduce production, rather than maintain the 2006 production level and then suddenly cease production. Also, it is inevitable that additional oil will be discovered and that estimates of oil in existing fields will be increased. The data do show, however, that OPEC will control most of the world's oil reserves in the not too distant future and that we can expect significant production decreases over the next 15 years.

In early 2000 the M. King Hubbert Center Petroleum Engineering Department of the Colorado School of Mines published a study “World Oil Supply – Production, Reserves, and EOR,” Reference 5. This study, based on estimated 1998 oil reserves, projected an increased oil production through the year 2010 and a steep decline starting then. The decline was based on when various producing countries would run out of oil at their current production rates. See Figure 6.

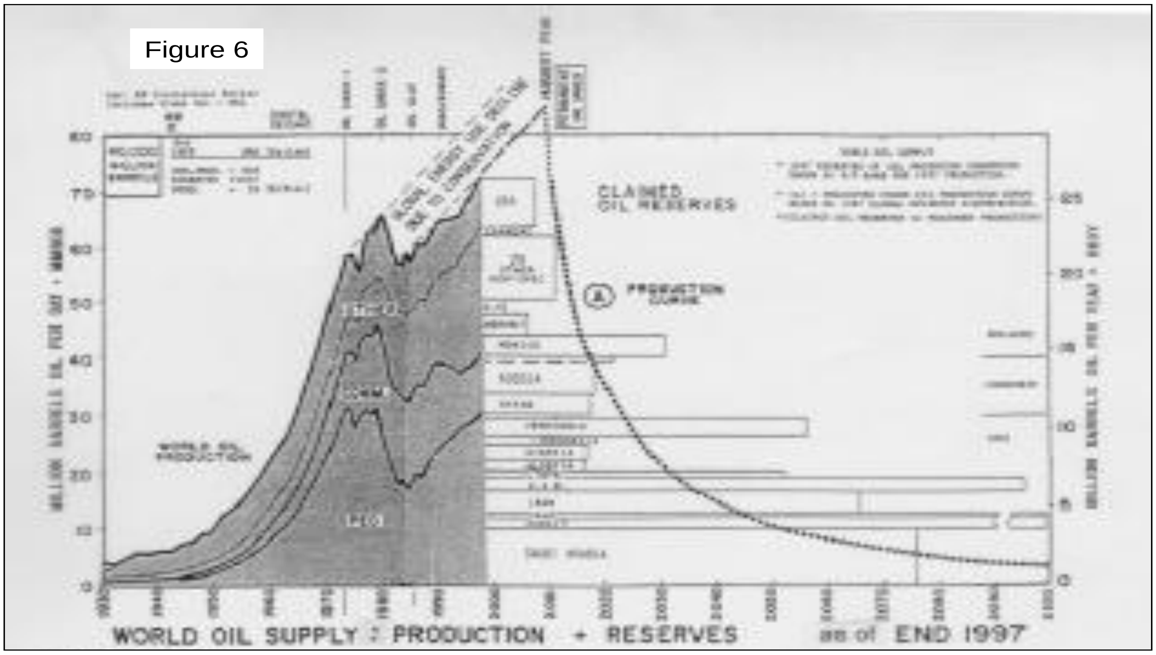
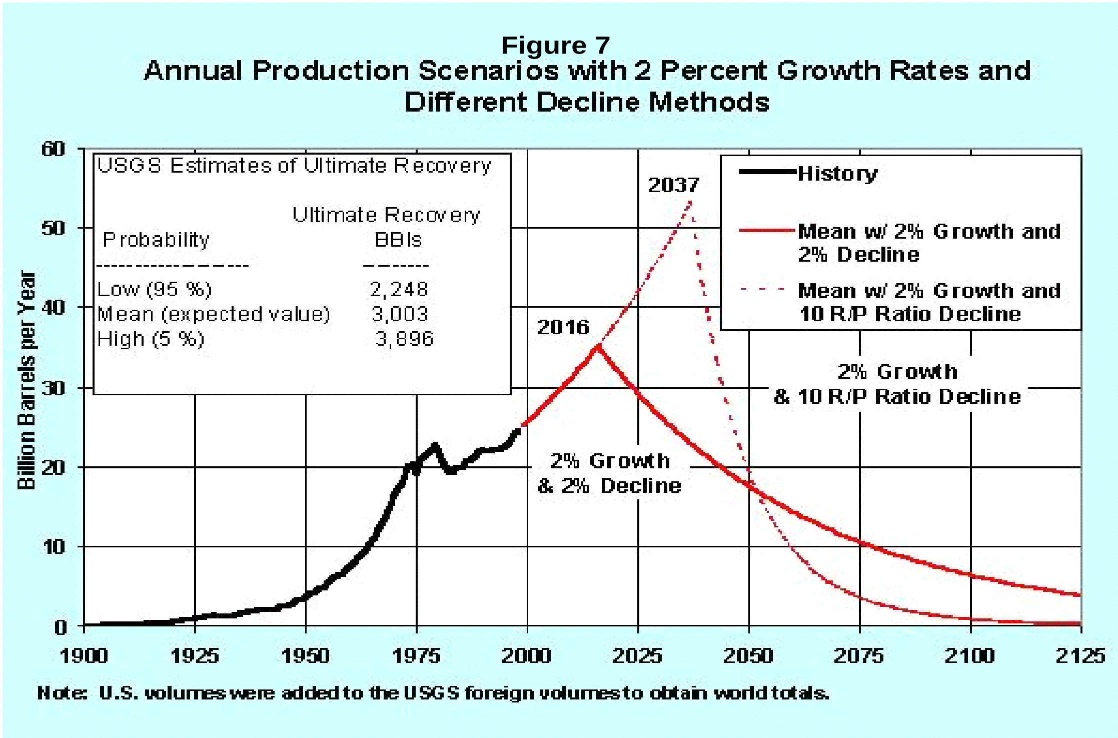


Figure 6

Later in 2000 the U.S. Energy Information Administration (EIA) published “Long Term World Oil Supply (A Resource/Production Path Analysis),” which is summarized in Reference 6. The presentation focused on when conventional oil production will peak and the effect of different estimates of the world conventional oil base. This study uses USGS estimates that the world ultimate total oil recovery will be 2,248 billion barrels (low), 3,003 billion barrels (mean or expected) or 3,896 (high). The low estimate has already been exceeded since the world consumption to date and the estimated reserves at the start of 2007 total about 2,347 billion barrels. With the “expected scenario” amount it is estimated that an additional 656 billion barrels will be added to the ultimate recovery amount in the future.

Figure 7, from this study, shows two production vs. time scenarios, both of which assume ultimate total amount of oil recovery will be 3,003 Billion barrels. One scenario assumes that production will increase at the rate of 2 percent per year until 2016 and then decline at the rate of 2 percent per year thereafter. The second scenario assumes that production will increase at the rate of 2 percent per year until 2037 and then decline with a Reserves / Production (R/P) ratio of 10. R/P is a rough estimate of years of production remaining. The area under both curves (total consumption) is identical.

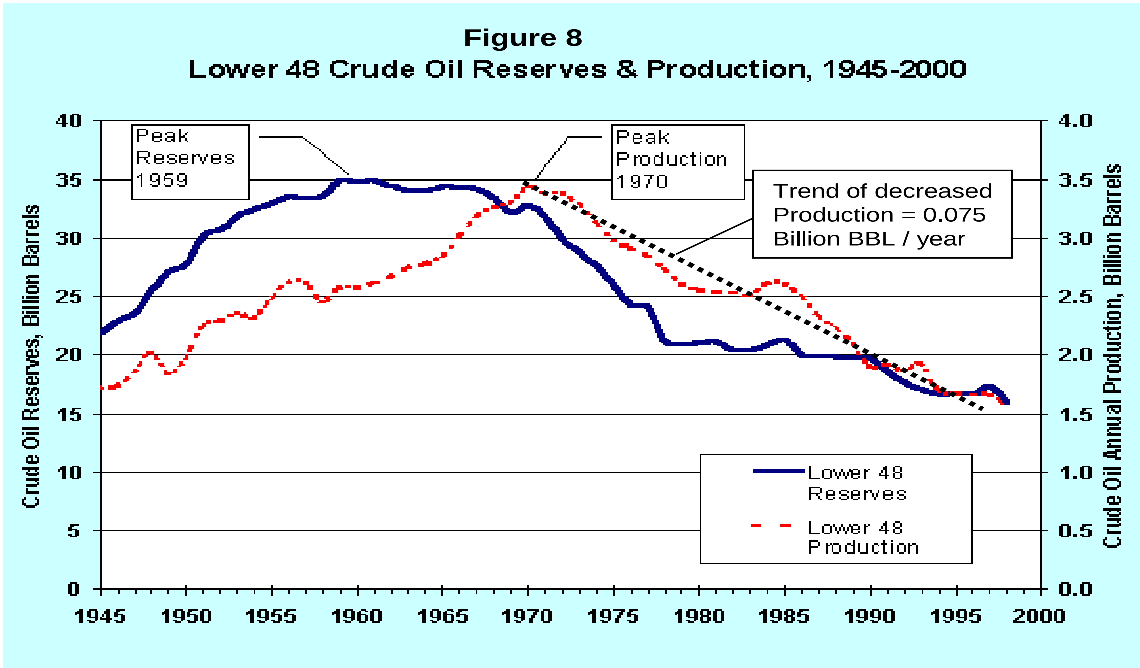


The EIA report authors' rationale for the steeper curve is provided as follows. "The reason for setting R/P equal to 10 is based on the United States lower 48 experience. The R/P ratio was around 12 in the 1940's and 1950's, dropped below 10 in the 1960's, was around 8 in the1970's and 1980's and has been around 10 in the 1990's. Therefore, a world R/P of 10 seems a reasonable assumption to reflect a mature state of world oil production, as it does for the United States."

This may not be a good rationale since the U.S. has, for the past several years, been an oil producer that also needed to import oil. Higher production reduced the amount of oil that needed to be imported. There was, therefore, a high priority for producing as much as possible as soon as possible. This is not the case for countries that produce more than they consume.

Figure 8 from Reference 6 shows the U.S. lower 48 oil reserves and production vs. year. The production decline is a gradual constant slope over many years. Note that the reserves seem to stay flat and even increase during the early 1980's. This is due to new oil finds and improved recovery rates from existing oil fields. The reserves would have been depleted by 1981 if no additional oil was added to the reserves after 1970 and production remained as shown.

Figure 9, from reference 7, shows a growing gap between world new oil discovery and production. Fortunately, this is not the whole story. The world oil reserves grew from 667 billion barrels in 1980 to 1,208 billion barrels in 2006, a total of 541 billion barrels. During this same period 627 billion barrels were simultaneously produced.



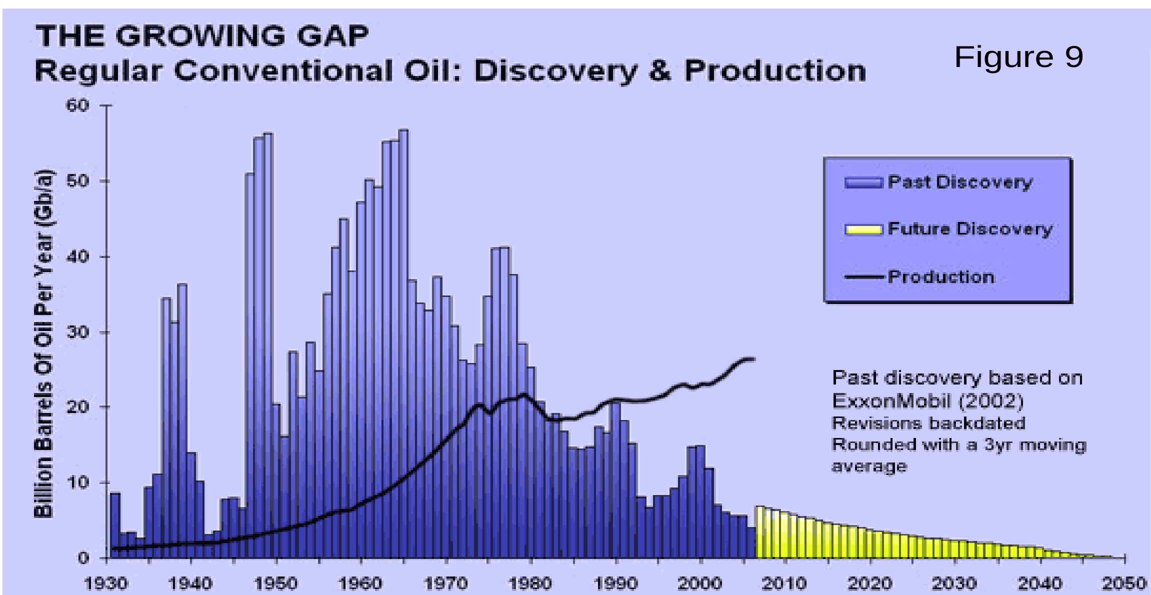
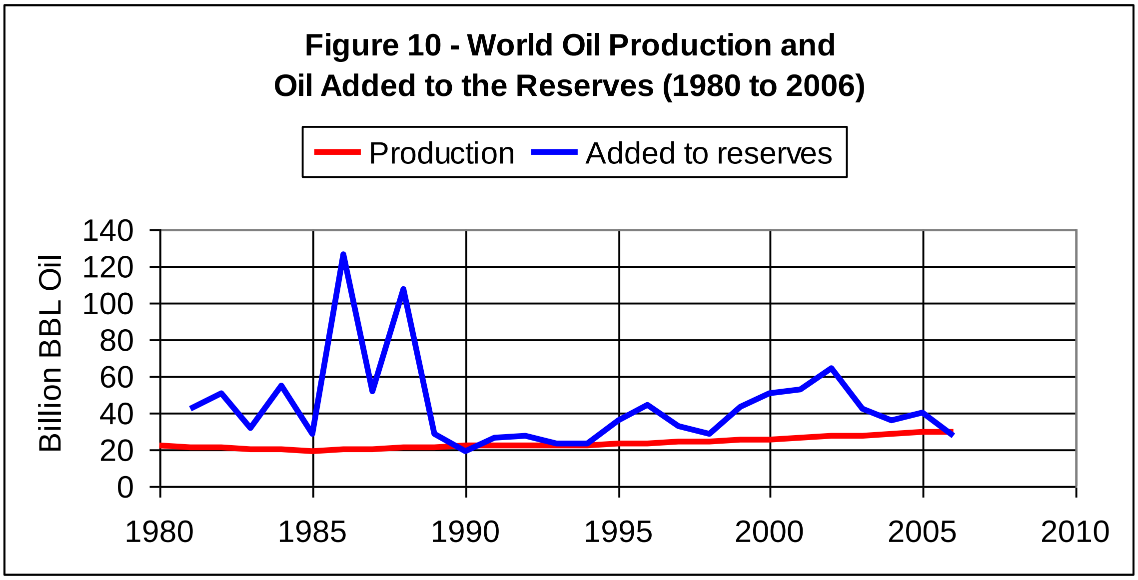


Figure 10 shows total world oil production and amount of oil added to the reserves per year during the period from 1980 to 2006. Note that the "added to reserves" amounts significantly exceed the production amounts in most years. The "added to reserves" amounts were computed by the author as "reserves in Year X minus reserves in Year X – 1 plus production in year X." The oil added to the reserves on top of new oil discovery comes from "reserve growth," which refers to the process by which the initial identified reserves of an oil field increase over time as new drilling and new knowledge make it apparent and quantifiable that there is more oil than was first thought.



An oil crisis will begin the year after oil production, based on availability, has peaked. From that point on there will be a growing gap between demand and consumption. The Hubble study estimated that this peak would occur in 2010. The two EIA estimates shown in Figure 7 indicate that it may occur in 2016 or 2037.

Reference 8 is an article "Exxon Mobile takes the position that peak oil is unlikely for another 25 years" published in May 2007. This article discusses new technology that is expanding the petroleum resource base as a function of many truly novel scientific and engineering developments. One of the greatest constraints on future oil production, according to Exxon Mobil, is the political fact that much of the world is essentially "off-limits" to exploration and production. Exxon's position is:

> "A peak in petroleum liquids production, resulting solely from resource limitations, is unlikely in the next 25 years. Predictions of an imminent peak based on [the methodology developed by Shell Oil Co. geologist M. King Hubbert] in 1956 do not adequately account for resource growth from application of new technology, knowledge and capability, which combine to increase recovery, open new producing areas and lower economic thresholds.
>
> "Supplies from OPEC and non-OPEC countries, gas-related liquids and unconventional resources are growing. Furthermore, nations with the largest remaining resources produce under long-term restraints not envisioned in Hubbert's method. The ultimate peak in petroleum production may result from factors other than resource limitations."

Exxon Mobil forecasts an increase in demand for petroleum liquids from about 85 million barrels per day (31 billion Barrels per year) in 2006 to 115 million barrels per day (42 billion barrels per year) in 2030, or average growth in demand of about 438 million barrels per year. Worldwide, over the next 25 years, the ability of the petroleum industry to meet this demand will depend, in great measure, on what Exxon calls "adequate access to petroleum resources." This latter term includes ensuring that the oil industry has access to drill in areas not previously explored or exploited, such as geographically or politically isolated areas, as well as areas of deep water or extreme climate, that require the development of new technology.

Two U.S. areas that are now off limits to oil exploration are the Arctic National Wildlife Refuge (ANWR) in Alaska and the Eastern Gulf of Mexico off the Florida coast. ANWR is expected to contain approximately 10 billion barrels of oil reserves. See reference 9. Even if ANWR is opened for production, the anticipated 10 billion barrels would increase world reserves by less than one percent. The Eastern Gulf of Mexico, off the Florida coast, is off-limits for oil exploration by Federal law until at least 2022.

Reference 7 states that "Several notable scientists have attempted independent studies, most notably Colin Campbell and the Association for the Study of Peak Oil and Gas (ASPO). ASPO's 2005 model suggests that 'regular' oil peaked in 2004. If heavy oil, deepwater, polar and natural gas liquids are considered, the oil peak is projected for around 2010." Figure 11 presents ASPO's Oil and Gas production history and projected future profiles based on an analysis performed in 2005 which shows oil production declining after 2010.

In the past several years study of when oil will peak has been receiving increased attention. ASPO has focused attention on this issue and continues to gather and analyze oil production, consumption and reserves data. They use this data to refine their estimates of when oil will peak. They also hold annual conferences and have a web site dedicated to this subject: http://www.peakoil.net/

ASPO's latest peak oil forecasts, based on the results of 13 different models, are shown in figure 12. This figure depicts the average forecast for peak crude oil plus Natural Gas Liquids (NGL), which are considered to be equivalent to traditional oil, reaching a production plateau around 81 +/- 4 million barrels per day (29.6 +/- 1.5 billion barrels per year) with a decline after 2010 +/- 1 year.

Reference 10, "Peaking of World Oil Production: Recent Forecasts," by R. L. Hirsch, published in February 2007, documents predictions of when oil production will peak by numerous experts and organizations. Their range of estimates extends from late last year to an apparent denial that it will ever happen. Many experts forecast that the peak will occur by 2010 or 2012. Another group believes the peak year will be between 2015 and 2020. Cambridge Energy Research Associates, Inc. (CERA) a leading advisor to international energy companies, governments, financial institutions, and technology providers, forecasts that oil production will not peak until after 2030. OPEC denies that oil production will ever peak.

Figure 11

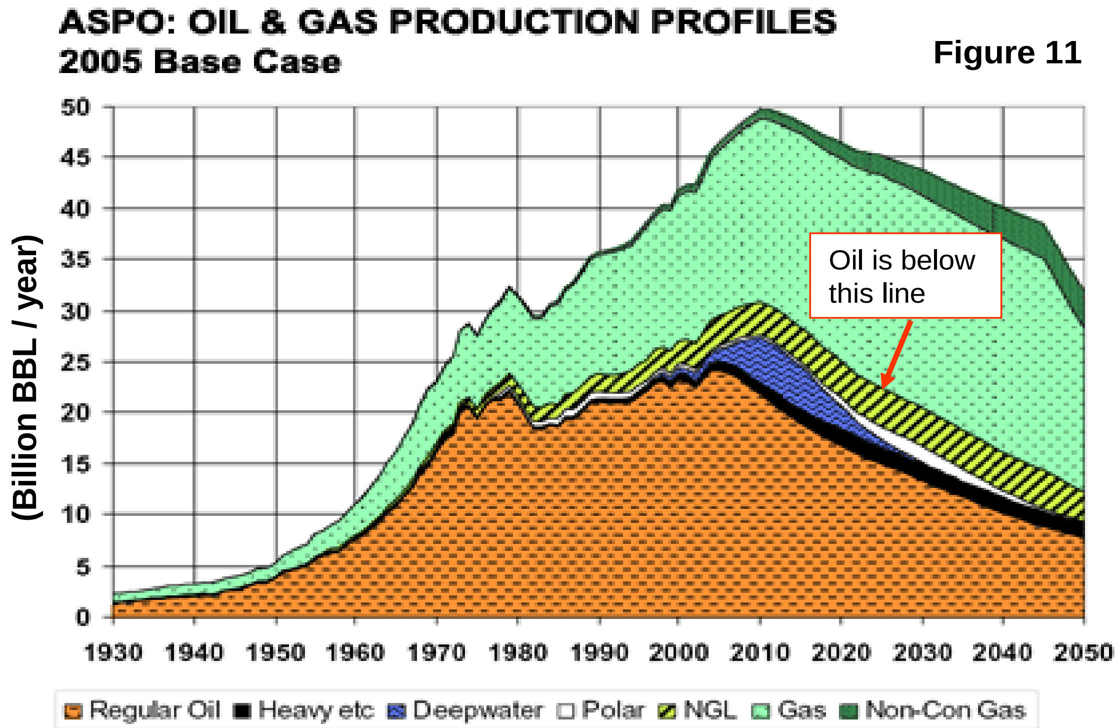
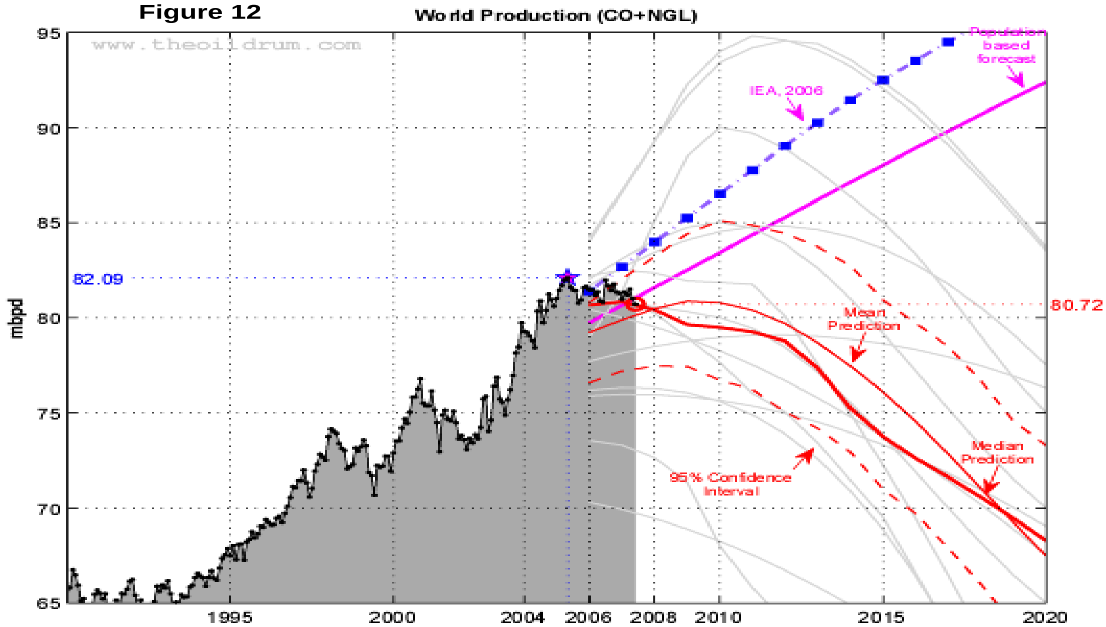
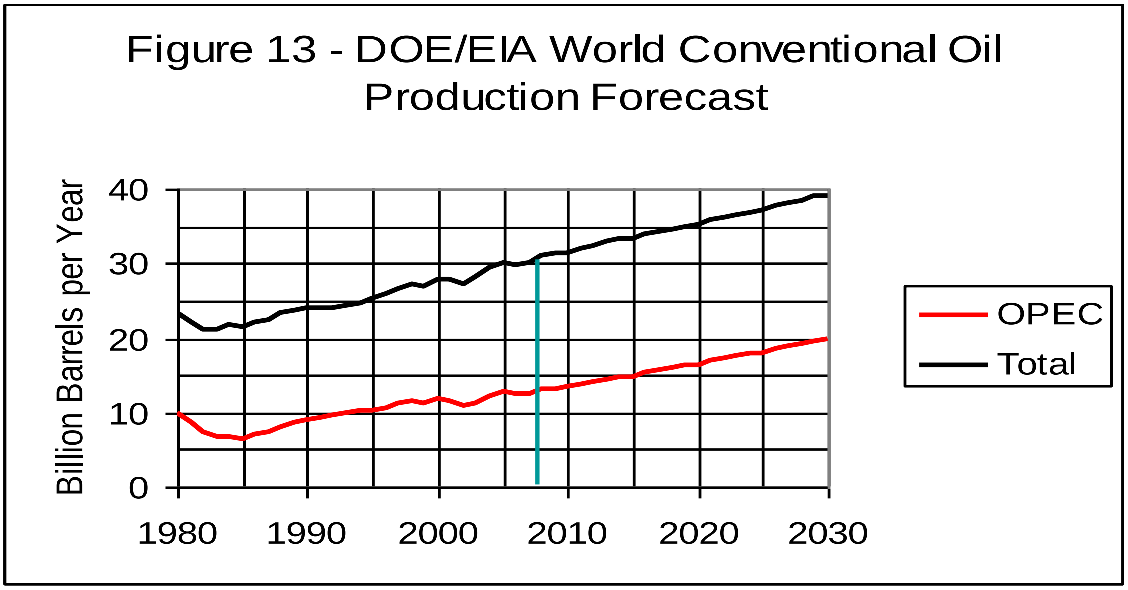


Figure 12



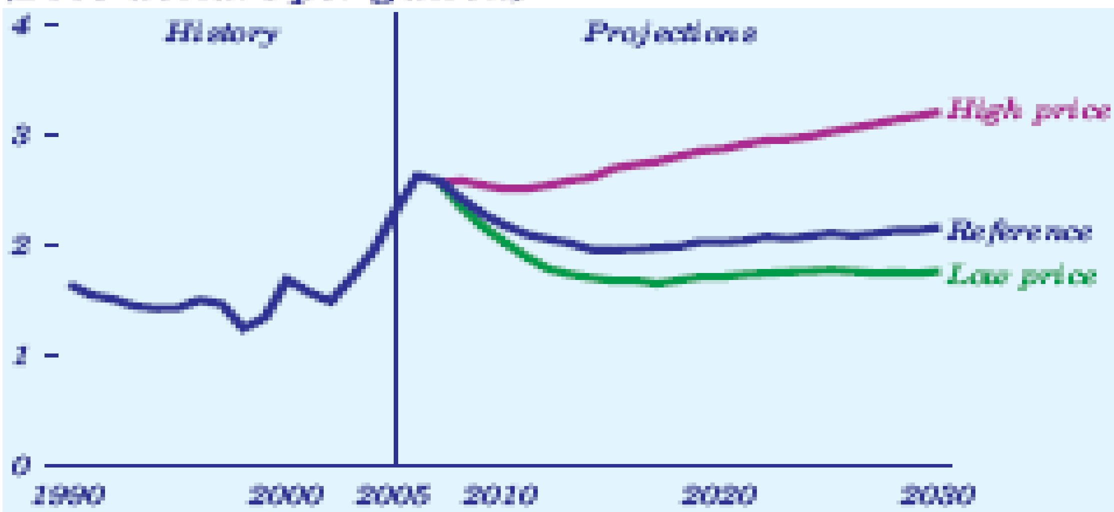
Reference 11, the DOE/AIE Annual International Energy Outlook document, released in May 2007 indicates that oil production will steadily increase at least through 2030 (see figure 13.) The AIE reference case (most likely estimate) projects that U.S. domestic oil production will be approximately 2 billion barrels per year through 2030 and U.S. oil imports will increase steadily from 2005 to 2030. “Sustained high world oil prices will support a substantial increase in non-OPEC liquids production. Non-OPEC production in 2030 is projected to be 12 million barrels per day higher than in 2004, representing 35 percent of the increase in total world production over the 2004 total. The estimates of production increases are based on current proved reserves and a country-by-country assessment of ultimately recoverable petroleum, as well as the potential for unconventional liquids production." Documentation of data and analysis supporting this assertion does not seem to be available on the Internet.



The DOE report forecasts that the price of oil will moderate from February 2007 levels to about $50 per barrel in 2014 before rising to $59 per barrel in 2030 (2005 dollars.) *[The per barrel price of oil reached $100 in January 2008.]* The reference case projections for average U.S. motor gasoline prices follow the same trend, rising from $1.95 per gallon in 2014 to $2.15 in 2030. See Figure 14. In the high price case, with the price of imported crude oil projected to rise to more than $100 per barrel in 2030, the average price of U.S. motor gasoline follows the higher price path of world oil prices, increasing from $2.61 per gallon in 2014 to a high of $3.20 (2005 dollars) per gallon in 2030. *[The average price of gas was $3.11 per gallon in the U.S. in November 2007.]*

Reference 12 is a "Short-Term Energy Outlook" published by DOE on November 6, 2007. This document does not revise the May 2007 EIA forecasts. It states that global oil markets will likely remain stretched, as world oil demand has continued to grow much faster than oil supply outside of the Organization of the Petroleum Exporting Countries (OPEC), putting pressure on OPEC and inventories to bridge the gap. Additional fundamental factors contributing to price volatility include ongoing geopolitical risks, Organization for Economic Co-operation and Development (OECD) inventory tightness, and worldwide refining bottlenecks. As a consequence, crude oil prices are expected to remain high and volatile. Total U.S. petroleum consumption is expected to increase by 0.5 percent in 2007 and 1.0 percent in 2008, despite the higher oil and petroleum product prices. Continued economic growth and colder average temperatures this winter than last winter combine to push demand higher.

Figure 14 *Average U.S. delivered prices for motor gasoline, 1990-2030 (2005 dollars per gallon)*



Reference 13, "Why Are Oil Prices So High?" is a supplement to the above document. This document provides some answers to this question. The EIA believes that the following supply and demand fundamentals are the main drivers behind recent oil price movements:

> "<u>Strong world economic growth driving growth in oil use</u> Global oil consumption rose by 1.1 million barrels per day in 2006, and is projected to rise by 1.1 million barrels per day in 2007 and 1.5 million barrels per day in 2008."
>
> "<u>Moderate non-OPEC supply growth</u> Non-OPEC production increased by 0.2 million barrels per day in 2006, and is projected to rise by 0.6 and 0.9 million barrels per day in 2007 and 2008, respectively. Non-OPEC production growth remains concentrated in a few areas and it has faced some downward revisions to expectations due to delays in projects and growing production declines in some non-OPEC nations, especially Mexico, the United Kingdom, and Norway."
>
> "<u>OPEC members' production decisions</u> Facing rising OECD inventories and relatively weak prices late last year, OPEC announced plans to cut production in November 2006 and February 2007 by 1.2 and 0.5 million bbl/d, respectively. Although OPEC members' actual production cuts were about half of the planned amounts, the cuts reversed the slide in world oil prices. In response to rising prices and falling OECD inventories, OPEC recently announced plans to raise production by 0.5 million barrels per day beginning in November 2007. However, OPEC's announcement has not yet dampened upward price pressure, and it is

> unlikely that these higher volumes will be enough to halt the downward trend in commercial inventories over the next several months."
>
> "Low OPEC spare production capacity EIA's outlook for continued rising oil consumption and moderate non-OPEC production growth suggests that OPEC members' crude production will average about 31.5 million barrels per day in 2008, an increase of about 500,000 barrels per day from fourth quarter 2007 levels. Under this scenario, world surplus production capacity will remain fairly low at around 2 to 3 million barrels per day."
>
> "Organization for Economic Cooperation and Development (OECD) inventory tightness, Worldwide refining bottlenecks   While OECD commercial inventories were 150 million barrels above their 5 year average at the end of September 2006, EIA projects that OECD commercial stocks will be about 10 million barrels below the 5 year average by the end of this year. Even with a moderate increase in OPEC output beginning in the fourth quarter of 2007, EIA projects that inventories will continue to decline relative to the average in the first quarter of 2008, and will move toward the lower end of the 5 year range through 2008."
>
> "Excess capacity in the refining industry has been shrinking as refined product demand has grown   Low excess refining capacity leaves less of a buffer for periods when the supply and demand balance becomes unusually tight."
>
> "Ongoing geopolitical risks and concerns about supply availability   A lack of political stability continues to threaten production in several OPEC nations, including Iraq, Nigeria, Venezuela, and Iran."

Only one new oil field was discovered in 2007 off the coast of Rio de Janeiro, Brazil. It is estimated to contain between 5 and 8 billion barrels of oil. See reference 14. The new Brazilian field is under 7,060 feet of water, almost 10,000 feet of sand and rocks, and then another 6,600-foot thick layer of salt. Getting the oil out will be a formidable challenge. It will take years because the petroleum is so deep under the earth's surface, meaning any impact on oil prices probably won't come soon.

3.0 Potential Substitutes for Oil Derived Transportation Fuels

In 2006 ninety-six percent of U.S. transportation fuels were derived from oil and sixty-nine percent of U.S. oil was used to make transportation fuels. See reference 15.

Table 2 from reference 16 presents a breakdown of the different petroleum products and the amount used in different sectors of the U.S. in 2003.

Possible substitute transportation fuels include natural gas, shale oil and tar sands, biofuels (ethanol and biodiesel), coal, hydrogen, and electricity. Figure 15, from reference 11, shows the history and U.S. DOE forecast to 2030 for the worldwide production of all of these fuels except the last two. Each of these potential alternate fuels is discussed below. Other alternative energy sources such as nuclear power, solar power, wind power, wave power, etc. can be used to generate electricity, but are not directly suitable as fuels for modern transportation.

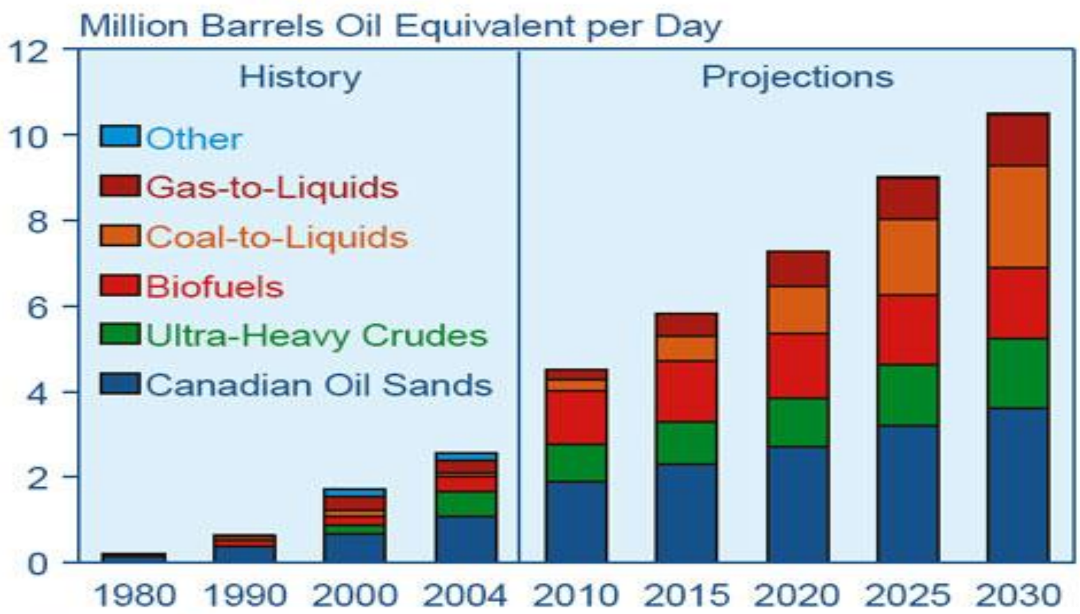
Table 2

Detailed Consumption of Petroleum in the U.S. by Fuel Type and Sector - 2003 (Thousand of barrels per day)

	Residential	Commercial	Industrial	Transportation	Electric Power	Total
Motor Gasoline	-	20	159	8,665	-	8,844
Distillate Fuel Oil	421	236	603	2,455	51	3,766
LPG	429	76	1,648	10	-	2,163
Kerosene/Jet Fuel	27	9	7	1,608	-	1,651
Residual	-	30	87	250	291	658
Asphalt & Road Oil	-	-	513	-	-	513
Petroleum Coke	-	-	398	-	61	459
Lubricants	-	-	78	73	-	151
Aviation Gas	-	-	-	18	-	18
Other Petroleum	-	-	1,435	-	-	1,435
Total	877	371	4,928	13,079	403	19,658

Distillate fuel oil includes diesel and heating fuel

Figure 15 World Unconventional Liquids Production in the Reference Case, 1980-2030



Note: "Other" includes shale oils and other unidentified sources of unconventional liquid fuels.

Practical exploitation of a substitute fuel requires not only that huge quantities of that fuel be generated, but that vehicles be made to efficiently use that fuel and appropriate production and distribution infrastructures be implemented to produce and transport this fuel to the consumers in an efficient manner. The production and distribution infrastructures for oil based fuels have evolved over many decades at great expense. The cost of developing equivalent infrastructures for new fuel types may be huge and may take many years to put in place.

Another primary consideration is that the substitute fuel be non-polluting and that it does not exacerbate global warming.

Transportation fuel users, for the purposes of this report, fall into two major categories. The first category includes personally owned vehicles like cars, SUVs and light trucks. These vehicles have relatively small fuel tanks and generally make relatively short trips, many of which are discretionary. The second category includes heavy trucks, trains, planes and ships. These vehicles make long non-discretionary trips and have very large fuel tanks. Some alternative fuels are only applicable to the first category of fuel users and are impractical for the second category.

3.1 Natural Gas

Natural gas has long been considered an alternative fuel for the transportation sector. Natural gas has been used to fuel small vehicles since the 1930's. There are over 130,000 Natural Gas Vehicles (NGVs) on the road in the U. S, and more than 2.5 million NGVs worldwide. The transportation sector accounts for 3 percent of all natural gas used in the United States. Technology has improved to allow for a proliferation of natural gas vehicles, particularly for fuel intensive vehicle fleets, such as taxicabs and public buses. Several disadvantages of NGVs prevent their mass-production, including limited range, trunk space, higher initial cost, and lack of refueling infrastructure. See Reference 17.

Natural gas can be made into three forms. One kind is the low-pressure form used for home cooking and heating. It comes from the underground pipe from the gas company. Another form is compressed natural gas (CNG). This form is compressed into high-pressure fuel cylinders (typically 3,000 to 4,000 pounds per square inch) to power a car or truck. It comes from special CNG fuel stations. The third form is liquefied natural gas (LNG). LNG is made by refrigerating natural gas to condense it into a liquid. The liquid form is much denser than natural gas or CNG. Liquefied natural gas is made by refrigerating natural gas to minus 270 degrees Fahrenheit to condense it into a liquid. The liquefaction process removes most of the water vapor, butane, propane, and other trace gases, that are usually included in ordinary natural gas. The resulting LNG is usually more than 98 percent pure methane.

Most natural gas vehicles use compressed natural gas (CNG). This compressed gas is stored in similar fashion to a car's gasoline tank, attached to the rear, top, or undercarriage of the vehicle in a tube shaped storage tank. A CNG tank can be filled in a similar manner, and in a similar amount of time, to a gasoline tank. One can even refuel at home using low pressure natural gas and a compressor. Several vehicles are available today (such as the Honda Civic CGX and the Ford Crown Victoria) that operate on compressed natural gas. Some run on natural gas only and others can run on natural gas or gasoline.

Natural gas supplies roughly 20 percent of U.S. energy demand. It has been plentiful at real prices of roughly $2/Mcf (thousand cubic feet) for almost two decades. Over the past 10 years, natural gas has become the fuel of choice for new electric power generation plants and, at present, virtually all new electric power generation plants use natural gas.

Part of the attractiveness of natural gas was resource estimates for the U.S. and Canada that promised growing supply at reasonable prices for the foreseeable future. That optimism turns out to have been misplaced, and the U.S. is now experiencing supply constraints and high natural gas prices. Supply difficulties are almost certain for at least the remainder of the decade. See reference 16.

As recently as 2001, a number of credible groups were optimistic about the ready availability of natural gas in North America. For example:

> In 1999 the National Petroleum Council stated "U.S. production is projected to increase from 19 trillion cubic feet (Tcf) in 1998 to 25 Tcf in 2010 and could approach 27 Tcf in 2015…. Imports from Canada are projected to increase from 3 Tcf in 1998 to almost 4 Tcf in 2010."
>
> In 2001 Cambridge Energy Research Associates (CERA) stated "The rebound in North American gas supply has begun and is expected to be maintained at least through 2005. In total, we expect a combination of US lower-48 activity, growth in Canadian supply, and growth in LNG imports to add 8.95 billion cubic feet per day of production by 2005."
>
> The U.S. Energy Department's Energy Information Administration (EIA) in1999 projected that U.S. natural gas production would grow continuously from a level of 19.4 Tcf in 1998 to 27.1 Tcf in 2020.

The current natural gas supply outlook has changed dramatically. Among those that believe the situation has changed for the worse are the following:

> CERA now finds that "The North American natural gas market is set for the longest period of sustained high prices in its history, even adjusting for inflation. Disappointing drilling results … have caused CERA to revise the outlook for North American supply downward … The downward revisions represent additional disappointing supply news, painting a more constrained picture for continental supply. Gas production in the United States (excluding Alaska) now appears to be in permanent decline, and modest gains in Canadian supply will not overcome the US downturn."

> Raymond James & Associates finds that "Natural gas production continues to drop despite a 20 percent increase in U.S. drilling activity since April 2003. U.S. natural gas production is heading firmly downwards…"
>
> "Lehman now expects full-year U.S. production to decline by 4% following a 6% decline in 2003. …. Domestic production is forecast to fall to 41.0 billion cubic feet a day by 2008 from 46.8 in 2003 and 52.1 in 1998. After a sharp 12% fall in 2003, Canadian imports are seen dropping..."
>
> The National Petroleum Council (NPC), an oil-industrial association, now contends that "Current higher gas prices are the result of a fundamental shift in the supply and demand balance. North America is moving to a period in its history in which it will no longer be self-reliant in meeting its growing natural gas needs; production from traditional U.S. and Canadian basins has plateaued."

Natural gas would be a prime candidate as an alternate to oil produced fuels except for the fact that it is becoming in short supply. This basically eliminates natural gas as a viable alternative to oil based fuels. It also does not bode well for the future of electricity generation or the price of natural gas for home heating and cooking.

3.2 Oil Shale and Tar Sands

Oil shale and tar sands lie at opposite ends of the oil lifecycle. Oil shales are a precursor to oil that has not yet been buried deep enough for kerogen (solid bituminous materials) to be converted into useful hydrocarbons. Tar sands are near the end of the oil cycle having been degraded beyond their prime by slow chemical reactions.

3.2.1 Oil Shale

Oil shale was formed millions of years ago by deposition of silt and organic debris on lake beds and sea bottoms. Over long periods of time, heat and pressure transformed the materials into oil shale in a process similar to the process that forms oil; however, the heat and pressure were not as great. Oil shale generally contains enough oil that it will burn without any additional processing, and it is known as "the rock that burns".

A conservative estimate of the worldwide oil shale resource is more than 2.5 trillion barrels of oil equivalent, with roughly 2 trillion barrels located in the United States. While oil shale is found in many places worldwide, by far the largest deposits are found in the United States in the Green River Formation, which covers portions of Colorado, Utah, and Wyoming. Estimates of the oil within the Green River Formation range from 1.2 to 1.8 trillion barrels. Not all of these resources are recoverable. Even a moderate estimate of 800 billion barrels of recoverable oil from oil shale in the Green River Formation is three times greater than the proven oil reserves of Saudi Arabia. See reference 18.

More than 70% of the total oil shale acreage in the Green River Formation, including the richest and thickest oil shale deposits, is under federally owned and managed lands. Thus, the federal government directly controls access to the most commercially attractive portions of the oil shale resource base.

Oil shale can be mined and processed to generate oil that is similar to oil pumped from conventional oil wells. Extracting oil from oil shale is more complex than conventional oil recovery and currently is more expensive. The oil substances in oil shale are solid and cannot be pumped directly out of the ground. The oil shale must first be mined (using the room-and-pillar method or surface mining) and then heated to 450-550°C in the absence of oxygen (a process called retorting). The resulting liquid must then be separated and collected. See reference 19.

An experimental process under development by the Shell Oil Company, referred to as "Thermally Conductive In Situ Conversion," involves heating the oil shale to 650-700°F for two to four years, to enable kerogen conversion while it is still underground, and then pumping the resulting liquid to the surface. See reference 20.

While oil shale has been used as fuel and as a source of oil in small quantities for many years, few countries currently produce oil from oil shale on a significant commercial level. Many countries do not have significant oil shale resources, but in those countries that do have significant oil shale resources the oil shale industry has not developed because historically the cost of oil derived from oil shale (currently greater than $60 per barrel) has been significantly higher than conventional pumped oil. Shell's experimental "In Situ" process may be considerably less expensive.

Relatively high prices for conventional oil in the 1970s and 1980s stimulated interest and some development of better oil shale technology, but oil prices eventually fell, and major research and development activities largely ceased. More recently, prices for crude oil have again risen to levels that may make oil shale-based oil production commercially viable, and both governments and industry are interested in pursuing the development of oil shale as an alternative to conventional oil.

3.2.2 Tar Sands

Tar sands is a common name of what are more properly called bituminous sands, but also commonly referred to as oil sands or (in Venezuela) extra-heavy oil. They are a mixture of sand or clay, water, and bitumen – an extremely heavy crude oil. The use of the word tar to describe these deposits is a misnomer, since tar is a man-made substance produced by the destructive distillation of organic material. Although it appears similar, the material in tar sands is a naturally-occurring, extremely heavy form of crude oil in which the lighter fractions of the oil have been lost and the remaining fractions have been partially biodegraded by bacteria. As a result, the term "oil sands" is technically more accurate. About two tons of tar sands are required to produce one barrel of oil.

Most of the world's oil (more than 5 trillion barrels) is in the form of tar sands, although it is not all recoverable. While tar sands are found in many places worldwide, the largest deposits in the world are found in Canada (Alberta) and Venezuela, which each have about one-third of the world's total tar sands resources, and much of the rest is found in various countries in the Middle East. Canada's northern forest contains at least 174 billion barrels of recoverable heavy oil, equivalent to five years' supply for the planet. Venezuela has perhaps even more in the Orinoco River delta. In the United States, tar sands resources are primarily concentrated in Eastern Utah, mostly on public lands. The in-place tar sands oil resources in Utah are estimated at 12 to 20 billion barrels.

Conventional crude oil is easily extracted from the ground by drilling wells into the formations, into which light or medium density oil flows under natural reservoir pressures. Tar sand deposits must be strip mined or made to flow into producing wells by in situ techniques which reduce the oils viscosity using steam and/or solvents. These processes use a great deal of water and require large amounts of energy.

The heavy crude oil or crude bitumen extracted from these deposits is a viscous, solid or semisolid form of oil that does not easily flow at normal ambient temperatures and pressures, making it difficult and expensive to process into gasoline, diesel fuel, and other products. Despite the difficulty and cost, oil sands are now being mined in Canada on a vast scale to extract the oil, which is then converted into synthetic oil or refined directly into petroleum products by specialized refineries.

As a result of the development of these reserves, most Canadian oil production in the 21st century is from oil sands or heavy oil deposits, and Canada is now the largest single supplier of oil and refined products to the United States. Venezuelan production is also very large, but due to political problems its oil production has been declining since the start of the 21st century.

Northern Alberta Canada's oil sands production was about one million barrels per day in 2004. Production is expected to be 2.2 million barrels per day (0.8 billion barrels per year) by 2015.

Tar sands production is very hard on the environment and contributes to global warming. Extracting the bitumen (crude oil) from the thick and sticky mix of clay, sand and water is no easy feat and for every barrel of oil extracted, somewhere between two and four-and-a-half times as much water is needed to thin-out the mixture and separate the bitumen from the sand. To obtain this staggering volume of water, whole streams and rivers in the region have been drained and diverted. Most of this water ends up contaminated with acids, mercury and other toxins. This wastewater has left Northern Alberta studded with toxic dumping pools, better known as ‘tailing ponds.’ Not only are the tar sands being blamed for Western Canada’s first ever bout of acid rain, the residues pumped into the Athabasca River have increased cancer rates downstream, particularly among First Nations (Indian) communities dependent upon the waterway. Every barrel of synthetic oil produced releases 188 pounds of carbon dioxide equivalent into the atmosphere, three times as much carbon overall as conventionally produced gasoline. See reference 21.

It costs about $25 a barrel to produce crude from Canada's oil sands. By comparison, it can cost as little as about $5 a barrel to produce crude in the Middle East and $15 in the deep waters of the Gulf of Mexico.

3.3 Biofuels

Two popular biofuels are ethanol and biodiesel.

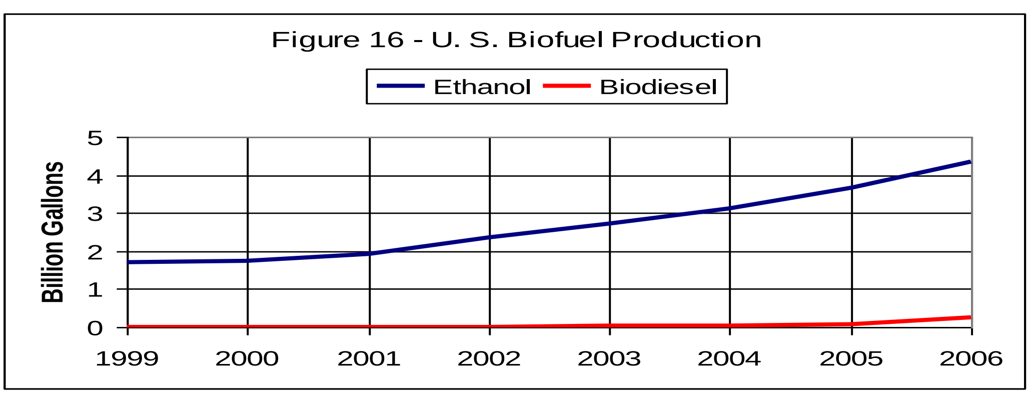
3.3.1 Ethanol

Ethanol, also known as ethyl alcohol or grain alcohol, can be used either as an alternative fuel or as an additive to gasoline.

Pure, 100% ethanol is not generally used as a motor fuel; instead, a percentage of ethanol is combined with unleaded gasoline. Any amount of ethanol can be combined with gasoline, but the most common blends are E10 and E85. See reference 22.

> E10 is 10% ethanol and 90% unleaded gasoline. E10 is approved for use in any make or model of vehicle sold in the U.S. Many automakers recommend its use because of its high performance and clean-burning characteristics. Today about 46% of America's gasoline contains some ethanol, most as this E10 blend.
>
> E85 is 85% ethanol and 15% unleaded gasoline. E85 is an alternative fuel for use in flexible fuel vehicles (FFVs). There are currently more than 6 million FFVs on America's roads today, and automakers are rolling out more each year. In conjunction with more flexible fuel vehicles, more E85 pumps are being installed across the country. When E85 is not available, these FFVs can operate on straight gasoline or any ethanol blend up to 85%.

The production of ethanol in the U.S. is increasing rapidly. Figure 16 shows that ethanol production increased from 1.7 billion gallons in 1999 to over 4.3 billion gallons in 2006. Ethanol production is in 2007 estimated to be approximately 6.5 billion gallons.



Taxpayers provide ethanol producers with a $0.51 per gallon tax credit (subsidy). This subsidy is called the "Volumetric Ethanol Excise Tax Credit" (VEETC) and remains in effect through December 31, 2010. Total ethanol subsidies are actually higher. A 2006 report by the International Institute for Sustainable Development estimated that if one took into account state renewable fuel tax breaks and direct agricultural subsidies, the total ethanol subsidy is actually $1.05 to $1.38 per gallon of ethanol. See reference 23. Ethanol and corn producers were given over $6.825 billion in subsidies for ethanol produced in 2007. The U.S. has a tariff of 54 cents per gallon on imported ethanol.

Ethanol is manufactured using a fermenting process in a manner similar to the way moonshine is created. The energy content of gasoline is about 116,000 British Thermal Units (BTUs) or 121 megajoules (MJ) per gallon. The energy content of ethanol is about 76,000 BTUs or 80.4 MJ per gallon. If a vehicle gets 30 miles per gallon using gasoline it should also get about 29.0 miles per gallon using E10 and about 21.2 miles per gallon using E85.

Most U.S. ethanol is currently produced using corn. Corn and other starches and sugars are only a small fraction of biomass that can be used to make ethanol. Advanced Bioethanol Technology allows fuel ethanol to be made from cellulosic (plant fiber) biomass such as agricultural forestry residues, industrial waste, material in municipal solid waste, trees, and grasses. Cellulose and hemicellulose, the two main components of plants - and the ones that give plants their structure - are also made of sugars, but those sugars are tied together in long chains. Advanced bioethanol technology can break those chains down into their component sugars and then ferment them to make ethanol. This technology turns ordinary low-value plant materials such as corn stalks, sawdust, or waste paper into fuel ethanol.

Ethanol is controversial in that some experts claim that it takes more energy to produce ethanol from corn than the resultant energy content of the ethanol produced. Also, according to the Argonne National Lab the consumption of 10% ethanol blends reduces greenhouse gas emissions by 12-19% compared to conventional gasoline. Many other experts have published papers concluding that ethanol production and consumption significantly increase pollution and greenhouse gas emissions relative to the production and consumption of conventional gasoline.

Ethanol Production Energy Requirements

The ethanol lobby claims that there is a 30 percent net gain in BTUs from ethanol made from corn. This infers that it requires 58,462 BTUs or 93 MJ to produce each gallon of ethanol.

In a 2004 report the U.S. Department of Agriculture reported that the energy ratio for ethanol production is 1.67. See Reference 24.

The U.S. Department of Energy apparently does not seem to have a documented position on the issue of how much energy is needed to produce a gallon of ethanol, at least on the internet.

Reference 25 and many other articles on the internet cite a report by David Pimentel and Tad Patzek. These scientists calculated all the fuel inputs for ethanol production—from the diesel fuel for the tractor planting the corn, to the fertilizer put in the field, to the energy needed at the processing plant—and found that ethanol is a net energy-loser. According to their calculations corn ethanol requires 29% more fossil energy to produce than the ethanol contains. In comparison, a gallon of gasoline contains about 116,000 BTUs per gallon. But making that gallon of gas—from drilling the well, to transportation, through refining—requires around 22,000 BTUs.

Reference 26 is a study by Argonne National Laboratory that concludes that corn ethanol requires 26% less fossil energy to produce than the energy content of the ethanol, cellulosic ethanol requires 90% less fossil energy, and soybean-based biodiesel requires 69% less fossil energy than biodiesel contains. "A review of Pimentel/Patzek reveals that they made pessimistic assumptions and had double-counted certain energy costs without detailed elaboration.

Many other researchers have published reports that provide a wide range of estimates of the amount of energy needed to produce ethanol.

A very informative report on the amount of energy needed to produce ethanol is Reference 27 "Ethanol: A Look Ahead" a 2007 study by the MIT Laboratory for Energy and the Environment. This study recognizes that the energy inputs to produce ethanol from corn include: agricultural energy use (corn seed production; nitrogen, phosphate, and potash fertilizer production and application; lime production and application; herbicide and insecticide production and application; farm machinery fossil fuel consumption; and farm electricity consumption), corn transport (diesel fuel consumption assuming a roundtrip from the farm and corn storage station to the ethanol processing plant; semi-trailer truck capacity; semi-trailer truck loaded and unloaded engine efficiency) and ethanol processing (natural gas and electricity energy utilized by the ethanol processing plant to convert corn to ethanol. The report recognizes that there is much variability found within the agricultural sector, where seasonal effects, soil characteristics, and geographic locations significantly influence required energy related inputs such as fertilizer application and yield as well as technological variability. The energy required to produce a gallon of ethanol will vary from state-to-state and even from farm-to-farm within each state. This is the reason why different researchers arrive at different estimates of the energy needed to produce a gallon of ethanol. The MIT report uses a Monte Carlo analyses methodology and presents results in terms of distributions instead of single values.

The MIT report notes that "the Iowa corn (kernel) ethanol scenario represents the current best practice case for corn kernel ethanol production, since Iowa has the highest crop yields for the lowest agricultural inputs. The mean (average) Net Energy Value (NEV) to required produce ethanol from corn kernels in Iowa is 3.8 MJ/liter." [NEV = Energy in one unit of fuel - Energy needed to produce one unit of fuel.] This is equivalent to an energy-out to energy-in ratio (Eout/Ein) of 1.22. The highest efficiency one-half percent of the farms in Iowa have a corn kernel ethanol NEV of approximately 11.0 or more (Eout/Ein = 1.89) and the lowest efficiency one-half percent of the farms in Iowa have an ethanol NEV of approximately -2.0 or less (Eout/Ein = -0.91).

The MIT report goes on to note that "a key element of the corn ethanol energy debate focuses on the allocation of energy and greenhouse gas emissions between corn ethanol production, and the byproduct dried distillers grain with solubles (DDGS) used for livestock feed. During the fermentation processes, starch from the kernel is converted to ethanol while the remaining mass is used to produce DDGS. A 20% to 40% co-product credit range has been used to account for this. Using a 20% co-product credit nearly doubles the Iowa Corn (kernel) Ethanol's NEV value from 3.8 to 7.2 MJ/liter." (Eout/Ein = 1.51). "Approximately 70% of the DDGS can be gasified to produce all of the facility's process steam, or 77% of the DDGS could be consumed to provide all the facility's steam and electricity needs using combined heat and power." Doing this would raise the Iowa corn average NEV to 15.4 MJ/liter (Eout/Ein = 3.66). "Though utilizing the energy content of DDGS provides significant fossil energy and greenhouse gas savings, economic drivers such as the DDGS market price and natural gas prices are likely to determine the role that DDGS plays as a fuel in the corn ethanol production system."

The MIT report shows that corn grown in Georgia, a traditionally non-corn producing state, instead of Iowa, results in an average NEV that decreased from a positive 3.8 MJ/L (in Iowa) to a negative 7.6 MJ/L (Eout/Ein = 0.74) and resulted in a 47% increase in Green House Gas (GHG) emissions. This is due to increased fertilizer inputs and irrigation and lower corn yields. The very best Georgia farms have and Eout/Ein = 1.74 or more and the very poorest farms have an Eout/Ein = 0.48 or less. Any time that Eou/Ein is less than 1.0 it means that more energy is needed to produce the ethanol than is contained in the ethanol produced.

Most U.S. ethanol is now made from corn kernels. As additional farm land is used to produce corn for ethanol, the amount of energy and pollution per gallon of ethanol produced will increase due to the decreased fertility of the land. The best farm land in the country is now being used to grow corn for ethanol.

The MIT study also reports that making ethanol from cellulosic sources such as switchgrass, rather than corn, has far greater potential to reduce fossil energy use and greenhouse gas emissions. Making ethanol from corn stover (stalks and leaves), other agricultural wastes and wild grasses would consume less energy, but the technology for converting them to ethanol may not be economically viable for another five or so years. Average Eout/Ein ratios for producing ethanol from Iowa corn stalks = 5.89, Alabama swithchgrass = 20.1, and Iowa swithchgrass = 19.1).

Reference 28 states that "The use of "next-generation" cellulosic biomass feedstock has the potential to dramatically expand the resource base for producing biofuels in the future. So far, however, the costs of producing liquid fuels from cellulosic biomass are not competitive with petroleum-derived fuels, even with the recent rise in petroleum costs. Various government and industry-sponsored efforts are under way to lower the costs of making liquid fuel from cellulosic biomass by improving the conversion technologies. The economic competitiveness of biofuels and the development of the conversion pathways, will depend on the future price of petroleum. Since these conversion technologies are close to being viable, their deployment is important so that operators can streamline new facilities. Government incentives such as loan guarantees and guaranteed markets for new cellulosic biofuel production facilities can play an important role in the early stages of the second generation of biofuels."

If it takes 58,462 BTUS to produce each gallon of ethanol (using Eout/Ein = 1.3 as claimed by the ethanol industry) then 6.5 billion gallons of ethanol requires 3.28 billion equivalent gallons of gasoline to produce and yields the equivalent energy of 4.26 billion gallons of gasoline. This is a net gain of 984 million equivalent gallons of gasoline. Assuming the subsidy for this was $1.05 per gallon of ethanol produced, or $6.825 billion total, the subsidy per net equivalent gallon of gasoline displaced from the produced ethanol was $6.94 per gallon. One barrel of oil contains 5.8 million BTUs of energy. 984 million gallons of gasoline contains the same equivalent BTUs of energy as 19.7 million barrels of oil, which is approximately ¼ of one percent of the 7.5 billion barrels of oil consumed by the U.S. in 2007. This is also equivalent to taxpayers purchasing oil at $346 per barrel and then giving it to ethanol producers to sell back to us at roughly $3 per gallon.

Ethanol yield (gallons/acre) for sugar cane under good tropical conditions, as in Brazil, is double that for corn in the U.S. Sugar cane ethanol is seven times more energy efficient. Its net energy production cost, expressed as Eout/Ein = 9.0 while corn ethanol has an Eout/Ein = 1.3 (assuming that the ethanol lobby figure is correct.) See reference 29.

<u>Ethanol Production Greenhouse Gas Generation and Pollution</u>

The reference 27 MIT report concludes that greenhouse gas (GHG) resulting from ethanol production is highly dependent on seasonal effects, soil characteristics, and geographic locations and the technology used to produce the ethanol. The report concludes that average GHG emissions (gCO2 - equivalent/MJ) for the following ethanol production scenarios, relative to the production and consumption of gasoline, are:

Iowa Corn (Kernel) Ethanol	100 %
Iowa Corn (Kernel) Ethanol w/ 20% coproduct credits	80 %
Georgia Corn (Kernel) Ethanol	147 %
Iowa Corn (Kernel) Ethanol plus DDGS	42 %
Iowa Corn Stover Ethanol	29 %
Alabama Switchgrass Ethanol	6 %
Iowa Switchgrass Ethanol	7 %

Rising ethanol production has added to a fertilizer-saturated dead zone in the Gulf of Mexico, and researchers say they expect the 7,900-square-mile patch to keep pace with demand. The zone of oxygen-depleted water was discovered in 1985 and has been growing steadily since then. Nitrogen-based fertilizer, running off fields in Corn Belt states into the Mississippi River, is considered the prime culprit. The zone this year (2007) is the third-largest on record, after 2002 and 2001. According to U.S. EPA estimates, up to 210 million pounds of nitrogen fertilizer enter the Gulf of Mexico per year. Scientists said they expected the tonnage to increase with corn acreage, especially since corn absorbs less nitrogen per acre than other crops like soybean and alfalfa. U.S. farmers planted more than 93 million acres of corn in 2007, the most since 1944. Environmentalists are warning the gulf could reach a tipping point where it is unable to maintain stability. “The ecosystem might change or collapse as opposed to being just impacted,” said Matt Rota of the New Orleans-based Gulf Restoration Network. See reference 30.

Reference 31 is a Los Angeles Times article about two studies published February 7 in the journal Science. “One analysis found that clearing forests and grasslands to grow the crops releases vast amounts of carbon into the air -- far more than the carbon spared from the atmosphere by burning biofuels instead of gasoline.” The second study found that converting existing farmland in the U.S. from food to biofuel crops increases greenhouse gas emissions as food production is shifted to other parts of the world which is resulting in the destruction of more forests and grasslands to make way for farmland. “The study found that clearing an Indonesian peatland rain forest to make way for a biofuel plantation -- a conversion that is occurring rapidly to satisfy Europe's rising demand for biodiesel -- releases so much carbon that a net reduction in emissions would not begin for 423 years. Cutting down a tropical rain forest in Brazil to grow soybeans for biodiesel increases carbon emissions for 319 years.”

Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007, passed by Congress and signed by President Bush in December 2007, requires U.S. production of 36 billion gallons of biofuels by 2022. See reference 32.

The 2007 Energy Act required biofuel production quantities per year are defined in Table 3. Renewable biofuel includes biofuels made from corn starch. Advanced biofuels excludes biofuels made from corn starch. Cellulosic biofuels are limited to those made from any cellulose, hemicellulose or lignin that is derived from renewable biomass. Biomass-based diesel excludes biodiesel made from corn starch. Advanced and cellulosic biofuel production will slowly phase in starting in 2009 and 2010, respectively. Also, 15 billion gallons of corn kernel ethanol will still be permitted to be produced in 2022. The reference 27 MIT study shows that corn kernel ethanol production will result in relatively low Eout/Ein ratios, compared with advanced and cellulosic biofuel production.

Table 3 - Billion of Gallons of Biofuel Production per Year

Year	Renewable Biofuel	Advanced Biofuel	Cellulosic Biofuel	Biomass-based diesel
2006	4.00	0	0	0
2007	4.70	0	0	0
2008	9.00	0	0	0
2009	11.10	0.60	0	0.50
2010	12.95	0.95	0.10	0.65
2011	13.95	1.35	0.25	0.80
2012	15.20	2.00	0.50	1.00
2013	16.55	2.75	1.00	to be defined
2014	18.15	3.75	1.75	to be defined
2015	20.50	5.50	3.00	to be defined
2016	22.25	7.25	4.25	to be defined
2017	24.00	9.00	5.50	to be defined
2018	26.00	11.00	7.00	to be defined
2019	28.00	13.00	8.50	to be defined
2020	30.00	15.00	10.50	to be defined
2021	33.00	18.00	13.50	to be defined
2022	36.00	21.00	16.00	to be defined

The 2007 Energy Act does not define oil displacement goals or even require that the equivalent amount of oil displaced per year by the biofuels program be reported.

Even if it takes NO energy to produce 36 billion gallons of ethanol in 2022 the energy equivalent amount of oil displaced would be 472 million barrels of oil or 6.3 percent of 2007 U.S. oil consumption. More likely the energy equivalent oil displacement in 2022 will be 5 percent or less of the 2007 U.S oil consumption. This will come at the possible cost of ruining the northern coast of the Gulf of Mexico and releasing huge amounts of greenhouse gases into the atmosphere as food production is shifted to other parts of the world.

3.3.2 Biodiesel

Biodiesel is made by transforming animal fat or vegetable oil using an alcohol like methanol and a chemical process that separates glycerine and methyl esters (biodiesel) from fats or vegetable oils. Glycerine is used in many common products including soap and is highly marketable. Biodiesel can be directly substituted for diesel either as neat fuel (B100) or as an oxygenate additive, typically 20% (B20). Biodiesel can be used in the pure form, or blended in any amount with diesel fuel for use in compression ignition engines. Biodiesel significantly lowers polluting engine emissions, particularly hydro carbons, carbon monoxide, and nitrous oxides. Any standard diesel engine will operate well on biodiesel. See reference 33.

In Europe, the largest producer and user of biodiesel, the fuel is usually made from rapeseed (canola) oil. In the United States, the second largest producer and user of biodiesel, the fuel is usually made from soybean oil or recycled restaurant grease. Only 250 million gallons of biodiesel was consumed in the United States in 2006. U.S. Biodiesel production is predicted to double in 2007.

The energy content of diesel is about 138,400 BTUs per gallon. *(A gallon of diesel has 19.3 percent more energy content than a gallon of gasoline.)* The energy content of biodiesel is about 130,000 BTUs per gallon. If a vehicle gets 30 miles per gallon using diesel it should expect to get about 29.6 miles per gallon using B20 and about 28.2 miles per gallon using B100.

The cost of biodiesel is higher than diesel fuel. Pure biodiesel sells for about $1.50 to $2.00 per gallon before taxes. Fuel taxes will add approximately $0.50 per gallon. A mix of 20% biodiesel and 80% diesel will cost about 15% to 20% more per gallon over the cost of 100% diesel. The U.S. Department of Energy (DOE) and Agriculture (USDA) have major research and development programs under way to reduce the cost of biodiesel production. These agencies have jointly funded research to identify high oil content crops with diesel market potential. DOE programs include long-term research for production of algal strains with high lipid content and development of biodiesel conversion technologies using algal lipids and higher plant oils. See reference 34.

U.S. producers receive a tax credit (subsidy) of $1.00 per gallon of biodiesel produced from virgin oil. The virgin oil can be obtained from animal fats or oilseeds. Producers of biodiesel from recycled cooking oil are granted a tax credit of $0.50 per gallon. This is in addition to other subsidies provided to farmers for growing the crops used to produce the biodiesel.

3.4 Hydrogen

There is an inexhaustible supply of hydrogen in the world’s atmosphere and water. It is the most abundant element in the universe. As a fuel, it burns cleanly without contributing to pollution or global warming. If hydrogen could be made to be a practical fuel it would be ideal for small vehicle use. Because of this, much government and industry research has recently been focused on overcoming hydrogen related problems.

Hydrogen powered vehicles can use internal combustion engines, similar to gasoline engines, or fuel cells, which directly convert hydrogen into electricity, which then powers an electric motor. A fuel cell is a device that converts energy from chemical reactions directly into electrical energy. The simplest fuel cell 'burns' hydrogen in a flameless chemical reaction to produce electricity. In order to 'burn' the hydrogen a fuel cell needs a source of oxygen and this is usually obtained from air. The only by-product from this type of fuel cell is water. Fuel cells are more efficient than internal combustion engines. Hydrogen internal combustion engines are a mature technology. BMW and Ford each have prototype hydrogen powered vehicles that use internal combustion engines. Fuel cells need much improvement before they can be used practically in hydrogen powered vehicles. Chrysler, Ford, GM, Honda, and Toyota each have prototype hydrogen fuel cell cars.

Almost all of the hydrogen produced in the U.S. today is by steam reforming of natural gas. Other production methods, include biological water splitting, photoelectrochemical water splitting, reforming of biomass and wastes, solar thermal water splitting and renewable electrolysis. See reference 35. None of these methods are currently able to facilitate cost competitive production of enough hydrogen to significantly replace oil.

Hydrogen has many advantages as a fuel for vehicles, but a big disadvantage is that it is difficult to store. This is because at normal temperatures hydrogen is a gas. Potential solutions to this problem are to strongly compress the hydrogen or liquefy it. Large amounts of energy are needed for this – an estimated 20 to 40 per cent of the energy content of the fuel. One kilogram (2.2 pounds) of hydrogen contains about the same energy as one gallon of gasoline. The volume of one kilogram of liquid hydrogen is 0.5 cubic feet. Liquid hydrogen has a temperature of -434.5 degrees Fahrenheit. The volume of one kilogram of gaseous hydrogen at 10,000 pounds per square inch (PSI) pressure is 1.18 cubic feet. The volume of one gallon of gasoline is 0.134 cubic feet. A two cubic foot tank will hold about 15 gallons of gasoline (weighing about 47 pounds). A 7.5 cubic foot tank is required to hold 15 kilograms (weighing 33 pounds) of liquid hydrogen. A 17.7 cubic foot tank is required to hold 15 kilograms of gaseous hydrogen at 10,000 PSI. Tanks designed to hold hydrogen at extremely high pressures or at liquid hydrogen temperatures are heavy and expensive.

Another alternative for storing hydrogen is in the form of a hydride. Metal hydrides are chemical compounds formed when hydrogen gas reacts with metals. The most useful metal hydrides react near room temperature at pressures a few times greater than the earth's atmosphere. Metal hydrides are the safest way to store flammable hydrogen gas. Typical metal hydrides are powders whose particles are only a few millionths of a meter (microns) across. Currently available hydrides are not able to absorb or release hydrogen fast enough for practical use in vehicles. Also, they can only absorb about 4 percent of their weight in hydrogen.

In 2002 the U.S. Department of Energy launched FreedomCAR - a partnership with automakers to advance high-technology research needed to produce practical, affordable hydrogen fuel cell vehicles that American consumers will want to buy and drive.

In his 2003 State of the Union Address, President Bush announced a $1.2 billion Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the technology needed for commercially viable hydrogen-powered fuel cells—a way to power cars, trucks, homes, and businesses that produces no pollution and no greenhouse gases. Through partnerships with the private sector, the President's Hydrogen Fuel Initiative seeks to develop hydrogen, fuel cell, and infrastructure technologies needed to make it practical and cost-effective for large numbers of Americans to choose to use fuel cell vehicles by 2020.

Reference 36 is the home page for the U.S. Hydrogen Program. It is an excellent web site that contains vision documents, roadmaps, program technology plans and annual progress reports on each of the technology projects sponsored by the Hydrogen Program. In reviewing the 2006 progress reports it appears that much progress is being made, but it is not obvious that all of the critical program objectives will be achieved in time to make fuel cell vehicles a practical alternative to gasoline and diesel vehicles by 2020. Note that in Figure 15 DOE does not include hydrogen as a significant potential unconventional fuel, even by 2030.

3.5 Coal

World proven coal reserves at the end of 2006 totaled 909 trillion tonnes (metric tons which equal 2,200 pounds each) of coal, of which 479 trillion tonnes are anthracite (hard) and bituminous and 430 trillion tonnes are sub-bituminous and lignite. This is an energy equivalent of 3,470 trillion barrels of oil. Ninety percent of the coal reserves are in nine countries: U.S. (27%), Russia (17%), China (13%), India (10%), Australia (9%), South Africa (5%), Ukraine (4%), Kazakhstan (3%) and Poland (2%). See reference 3.

Anthracite is coal with the highest carbon content, between 86 and 98 percent, and a heat value of nearly 15,000 BTUs-per-pound. It is most frequently associated with home heating. Bituminous coal has a carbon content ranging from 45 to 86 percent carbon and a heat value of 10,500 to 15,500 BTUs-per-pound. It is the most plentiful form of coal in the U.S. and is used primarily to generate electricity and make coke for the steel industry. Sub-bituminous coal has a 35 to 45 percent carbon content and a heat value between 8,300 and 13,000 BTUs-per-pound. This coal generally has a lower sulfur content than other types, which makes it attractive for use because it is cleaner burning. Lignite, sometimes called brown coal, is a geologically young coal which has the lowest carbon content, 25-35 percent, and a heat value ranging between 4,000 and 8,300 BTUs-per-pound. It is mainly used for electric power generation.

World coal production in 2006 was 6.2 trillion tonnes with an R/P ratio of 147 years. U.S. coal production was 1.05 trillion tonnes with an R/P ratio of 234 years. See reference 3.

Coal fired power plants produce 52 percent of all U.S. electricity. Coal is the lowest-cost fossil source for electricity generation.

Coal-fired power plants spew 59% of total U.S. sulfur dioxide pollution and 18% of total nitrous oxides every year. They are also the largest polluter of toxic mercury pollution, largest contributor of hazardous air toxics, release about 50% of particle pollution and release over 40% of total U.S. carbon dioxide emissions, a prime contributor to global warming. See reference 37. The environmental effects of mining include water pollution and land disturbance as well as the release of another greenhouse gas, methane, which is entrained in the coal.

The key to making coal power plants a non-contributor to global warming is carbon capture and sequestration (CCS). This process captures the carbon dioxide and sequesters it by pumping it underground in a manner that does not allow it back to the surface. There are three carbon sequestration experiments underway at this time in Norway, Canada and Algeria. The U.S. DOE has an experiment underway called FutureGen. FutureGen is an initiative to build the world's first integrated sequestration and hydrogen production research power plant. The ten year $1.5 billion project, started in 2003, is intended to create the world's first zero-emissions fossil fuel plant. When operational, the prototype will be the cleanest fossil fuel fired power plant in the world.

Reference 38, “The Future of Coal,” is an excellent report that presents the results of a study performed by an interdisciplinary MIT faculty group who examined the role of coal in a world where constraints on carbon dioxide emissions are adopted to mitigate global climate change. They conclude that carbon capture and sequestration is technically feasible but that further study is needed to determine the economically best ways to do this. They do not believe that the three on-going sequestration projects are adequate to determine the information needed to determine safe sequestration procedures. They also offered constructive critique of the FutureGen project, pointing out deficiencies and recommending remedies. They have many detailed technical findings and recommendations that lay out a program of research and demonstration projects leading to practical implementation of coal power plants with minimal pollution and CO2 release into the atmosphere. Even if these recommendations are followed it will take many years before significant results are achieved.

Gasoline, diesel fuel, methanol, and other chemicals can be produced from coal. South Africa has produced gasoline and diesel fuel from coal for many years. During World War II Germans produced gasoline and diesel from coal since they could not import oil from the Middle East.

German researchers Franz Fischer and Hans Tropsch pioneered the process of producing synthetic fuel from coal and gas in 1920. See reference 39. Steam and oxygen are passed over coke at high temperatures and pressures; hydrogen and carbon monoxide are produced and then reassembled into liquid fuels. Sulfur and other pollutants such as ash and mercury are removed. The sulfur can be sold as a byproduct. If hydrogen is needed for fuel cells, these plants can also provide it. The gasoline and diesel produced are high grade and clean, meeting the “clean diesel” requirements of the U.S. However, the process is resource intensive.

Sasol, the world’s largest synthetic fuels producer, was founded in 1950 with the original Fischer-Tropsch (FT) technologies for synthesizing fuel and enhanced it from there. Sasol has a coal-to-fuel plant in South Africa, which produces 150,000 barrels of oil a day. Sasol is building two coal-to-liquid plants in China. The two projects, in the Ning Xia and Shaan Xi provinces, are expected to cost about $3 billion each and to have a combined annual production of 60 million tonnes or 450 million barrels of oil. The resultant fuel would cost about $15 to $20 per barrel to produce. China currently needs to import 100 million tonnes of oil a year and is keen to reduce its reliance on the Middle East. See reference 40. Neither of these projects will use carbon capture and sequestration. Sasol is also developing plans for a third coal to fuel plant in China and one in India.

Earlier this year two pieces of legislation were introduced in Congress to facilitate coal-to-liquid fuel processing in the U.S.: The “Coal-to-Liquid Fuel Promotion Act of 2007” sponsored by Senators Bunning and Obama and the "Coal-to-Liquid Fuel Energy Act of 2007" sponsored by Senator Bunning. A hearing on this subject was held in September 2007 by the House Science & Technology Committee's Subcommittee on Energy and Environment. The hearing had expert testimony that addressed the advantages and disadvantages of coal to liquid production. The witnesses agreed on two things: that conventional CTL processes carry a very heavy carbon dioxide burden and that the industry will require federal support if it is to develop.

The proponents for CTL pointed to CCS processes to ameliorate the carbon burden and using a coal-biomass mixture that could bring the lifecycle emissions below that of conventional petroleum diesel. Opponents highlighted the problems with reliance on CCS; argued that rough parity or slightly better CO2 emissions compared with petroleum fuels doesn't address the issue of reducing carbon emissions from transportation; and pointed to better uses of coal - such as the production of electricity for plug-in hybrids via an integrated gasification combined cycle (IGCC) process with CCS. See reference 41.

The Energy Independence and Security Act of 2007 contains provisions for $240 million funding in each of the years 2008 through 2012 for large scale carbon capture and sequestration research. See reference 32.

Reference 38, the MIT "The Future of Coal" report, includes an appendix on the subject of using coal to produce liquid transportation fuel. They estimate that with $70 billion in capital investment and about 250 million tons of coal per year (25 percent of current U.S. production) the U.S. could produce about 0.475 billion barrels of liquid fuel per year without pollution or carbon dioxide release to the atmosphere. This is after carbon capture and sequestration technology has matured.

3.6 Electricity

Electricity is used to power public transportation systems in major cities including the MTA in New York City, the CTA in Chicago, BART in San Francisco, Metro in Washington DC, and the Metro in Paris to name a few. These systems use what is referred to as tethered electricity since the cars are directly connected to electrified rails or wires.

Electricity can also be used as a fuel in small vehicles. The electricity is stored in batteries and the batteries operate an electric motor. Electric motors have 90 percent efficiency in terms of converting the potential of electrical energy into mechanical energy. This compares to gasoline internal combustion engines having a 35 percent or less efficiency in terms of converting the potential energy of gasoline into mechanical energy.

Battery technology is the limiting factor for using electricity as a transportation fuel. Typical lead-acid batteries get about 60 watt-hours to the kilogram. Nickel metal hydride batteries, used to power hybrid vehicle, get up to 120 watt-hours to the kilogram. Still further advanced lithium-ion batteries are approaching 200 watt-hours to the kilogram.

Small lithium-ion batteries are used to power many electronic devices, including laptop computers, cell phones and camcorders. In the past they have had safety problems which caused fires. They are presently not suitable for use in vehicles.

Several automobile companies currently manufacture and sell hybrid vehicles, including Ford, Honda, Nissan and Toyota. Hybrid vehicles use both an internal combustion engine and electric motors. The only source of external energy put into the vehicle is gasoline or diesel fuel. Electricity is generated by the electric motors, acting as generators in braking the vehicle, and by the internal combustion engine powering a generator. Electricity is stored in nickel metal hydride batteries which then power the motors either by themselves or in conjunction with the internal combustion engine to propel the vehicle. Hybrid vehicles get higher mileage, thus lowering gasoline consumption. Hybrid vehicles typically cost about $5,000 more than gasoline engine only vehicles in the same class. The extra cost is amortized through lower fuel consumption, with a typical break even point of around five years.

Plug-in hybrid vehicles also use both an internal combustion engine and an electric motor. External energy is put into the vehicle as gasoline or diesel and by electricity obtained by plugging in to a normal wall socket. Electricity can also be obtained by braking as in pure hybrid vehicles. Plug-in hybrids can use the internal combustion engine to both propel the vehicle, in conjunction with the motor, and to charge the battery; or only to charge the battery. If the internal combustion engine is used only to charge the battery then it can be much smaller than if used for propulsion.

Electric only vehicles use only an electric motor for propulsion and batteries which are charged using electricity obtained by plugging in to a normal wall socket.

Practical plug-in hybrid and electric-only vehicles suitable as alternatives to internal combustion only and hybrid vehicles are not yet commercially available due to the lack of a practical battery.

Battery characteristics needed for successful plug-in hybrid and electric-only vehicle use include: low cost, safety, wide temperature operating range, long battery life, high number of charge and discharge cycles, rapid charge and discharge rates, and high energy storage capacity to weight ratios. Many companies are spending significant efforts and funding to develop lithium-ion batteries with these characteristics. It is expected that lithium-ion batteries suitable for use in plug-in hybrids and electric only vehicles will soon be available and that practical and affordable plug-in hybrids and electric vehicles become commercially available in the next few years.

There have been several recent breakthroughs that are encouraging for the development of practical plug-in vehicle batteries.

> Stanford University researchers have found a way to use silicon nanowires to significantly boost the power of rechargeable lithium-ion batteries. The new version, developed through research led by Yi Cui, assistant professor of

materials science and engineering, produces 10 times the amount of electricity of existing lithium-ion batteries. The new battery uses nanowire anodes. The lithium is stored in a forest of tiny silicon nanowires, each with a diameter one-thousandth the thickness of a sheet of paper. The nanowires inflate to four times their normal size as they soak up lithium. But, unlike other silicon shapes, they do not fracture. See reference 42.

ExxonMobil Chemical and its Japanese affiliate, Tonen Chemical Corporation, are developing a prototype microporous film for lithium-ion battery (LIB) separators that it expects will dramatically improve lithium-ion battery power and safety performance in hybrid-electric vehicle (HEV) applications. The film offers the potential to reduce the size and weight of HEV batteries, according to ExxonMobil Chemical, thereby contributing to HEV system cost reduction and to improvements in design flexibility and durability. See reference 43.

GM plans to introduce an advanced hybrid vehicle called the Chevrolet Volt to the U.S. by as early as 2010. The Chevrolet Volt, unveiled to the press on 7 January 2007 at Detroit's North American International Auto Show, is the first-ever series hybrid concept car shown by a major manufacturer. Its 1.0-liter, 3-cylinder turbocharged engine runs an onboard 53-kilowatt generator that recharges a 16-kilowatthour lithium-ion battery made of 80 four-volt cells. The battery pack's volume is 100 Liters. GM's targeted maximum weight for the pack is 180 kilograms (400 pounds). The company also wants the battery to last at least 10 years, through 4,000 full-discharge cycles. The battery pack would charge in less than 6.5 hours, power a 120-kW electric motor delivering 320 newton-meters of peak torque, and go 64 km (40 miles) in all-electric mode on battery charge alone. The 12-gallon gasoline tank would add an additional 965 km (600 miles) to that range. "We don't have a battery pack yet," said Tony Posawatz, the vehicle line director. He confirmed that the vehicle shown in Detroit doesn't yet run. See reference 44.

In January 2007 General Motors Corp. announced it awarded advanced battery development contracts to two suppliers to design and test lithium-ion batteries for use in the Saturn Vue Green Line plug-in hybrid SUV. A GM spokesman said that "Thanks to critical relationships with the U.S. government, collaborative research with Ford and DaimlerChrysler under the United States Advanced Battery Consortium (USABC), significant progress has been made in battery research, but a lot of testing and development is still needed. Together, with our suppliers, we intend to address the issues relating to thermal management, storage capacity, recharge times, driving range and cost reduction." The two test batteries, one from Cobasys – A123Systems and the other from Johnson Controls – Saft, will be evaluated in prototype Saturn Vue Green Line plug-in hybrids beginning later this year. While both are lithium-ion batteries, the chemistry differs significantly. The suppliers also use unique methods in the design and assembling of the battery packs. See reference 45.

One huge advantage that plug-in hybrid and all electric cars have is that the infrastructure to support them is already in place. All that is needed to fuel these vehicles is access to a 120 volt power outlet.

3.7 Conservation and Doing Without

Figure 1 shows that oil consumption was increasing at a rate of about 7 percent per year in the period between 1955 and 1973. In 1973 the price of oil increased sharply and oil use decreased for two years in response to the Arab oil embargo. Oil consumption then started slowly increasing again until 1979 when the price of oil hit $90 (2006 dollars) per barrel. Oil consumption then dropped every year between 1980 and 1983 even though oil prices went down significantly during this period.

Between 1973 and 1983 oil consumption was reduced drastically from the trend of the preceding years due to the higher cost and lack of availability of gasoline, diesel and other oil related products. Oil consumers conserved oil by driving less, car-pooling, using more public transportation, purchasing more fuel efficient vehicles, changing from oil to natural gas or electric heat, etc.

In the period after 1983 world oil consumption increased at the rate of approximately 2 percent per year for the next 20 years - much lower than the 7 percent per year increases in the years prior to 1973. The seemingly unlimited availability of oil at a relatively low cost encouraged oil consumers and politicians to forget about conserving oil. They purchased many gas guzzling vehicles that will be on the road for many years.

The Independence and Security Act of 2007 contains a provision that requires auto manufacturers to increase the industry-wide Corporate Average Fuel Economy (CAFÉ) for new automobiles, SUVs and small trucks to 35 miles per gallon by 2020 compared to the previous 25 mpg CAFE, which was established in 1975. The Act also contains many other energy conservation requirements related to appliance and light bulb efficiency. See reference 32.

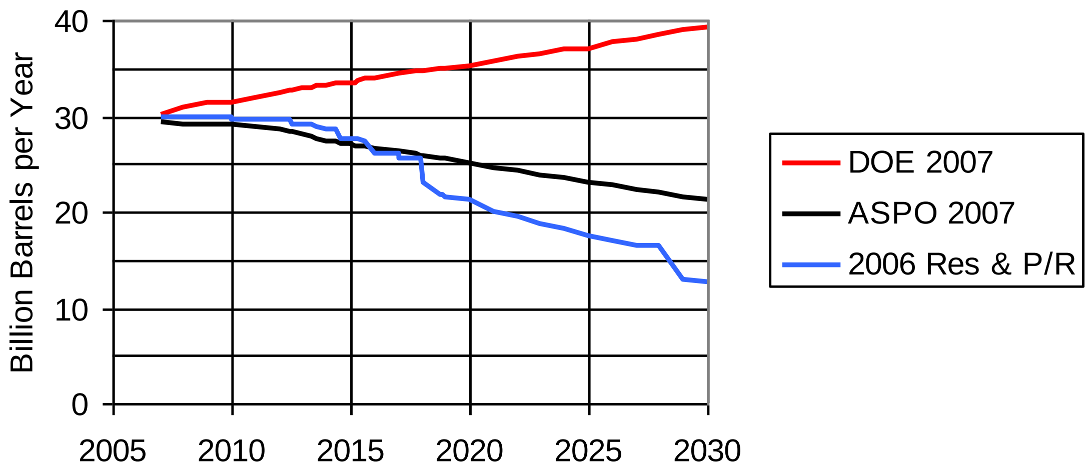
If the U.S. DOE forecast that peak oil production will occur after 2030 is correct, then the new fuel economy standards will be helpful. If peak oil production occurs in the next few years as forecast by ASPO, then the new fuel economy standards are too little too late.

4.0 Observations and Thoughts

The world is not about to run out of oil. More than half of all the oil ever discovered is still in the ground in the form of proven reserves. If no new oil is discovered it would take 40 years to use the known proven reserves if consumed at the current rate.

Many experts, as documented by the Association for the Study of Peak Oil (ASPO), believe that oil production has already peaked or will peak within the next five years. Analysis of 2006 reserves and production rates shows a trend similar to the 2007 ASPO forecast extrapolated to 2030. The U.S. Department of Energy forecasts that oil production will not peak until after 2030. See figure 17. The rate at which new oil fields are being discovered has been decreasing rapidly since 2000. The fact that only one new oil field with 5 to 8 billion barrels was discovered in 2007 lends further credence to the ASPO forecast.

Figure 17 - DOE and ASPO World Oil Production Forecasts and BP End of 2006 Reserves and 2006 Production Rates



The DOE/AIE Annual International Energy Outlook document, released in May 2007 states that oil production will steadily increase at least through 2030. "Estimates of production increases are based on current proved reserves and a country-by-country assessment of ultimately recoverable petroleum, as well as the potential for unconventional liquids production." It would be helpful if DOE would publish a document that lists the country-by-country assessments of ultimately recoverable petroleum. If the DOE forecast is accurate then huge amounts of new oil will have to be discovered and exploited in the next few years since the 2006 reserves and production rates show just the opposite trend.

In reviewing the potential alternate transportation fuel resources the author makes the following observations.

Natural gas is an ideal transportation fuel that could significantly offset oil consumption fairly easily. Unfortunately, our supplies of natural gas are rapidly diminishing. Natural gas will soon have the same problem as oil in terms of consumption demand versus production ability. The decreased availability of natural gas has already driven up the price significantly and historical natural gas consumers, including many electric power generation plants, will soon need to look for alternatives to facilitate their needs. Natural gas does not appear to be a viable alternate for the transportation fuel problem.

There is a huge amount of oil available in oil shale and tar sands, perhaps several trillion barrels. Exploitation of Canadian tar sands is already providing a small contribution to oil production. Unfortunately it is very expensive to extract this oil and it is resulting in an ecological disaster in Canada. If oil prices demonstrate that they will remain high there will be probably be more effort expended to exploit oil shale and tar sands. The negative environmental impacts and need for significant amounts of water reduce the desirability of exploiting this resource. It will take many years, perhaps decades, before these known reserves are able to produce a significant quantity of oil and the amount of oil that is actually produced will probably not be enough to offset the decrease in traditional oil production. The desirability of exploiting oil shale and tar sands will further diminish if other alternative transportation fuels are found to solve the problem in a less expensive and more environmentally friendly manner.

There is a huge amount of information and misinformation available on the internet concerning ethanol and biodiesel. Proponents aver that using ethanol reduces pollution and greenhouse gas emissions while others aver that ethanol production and usage significantly increases pollution and release of greenhouse gas while also increasing the dead zone in the Gulf of Mexico. The ethanol industry claims that there is 30 percent more energy in the ethanol produced than the energy required to produce it. Analysis shows that even if the ethanol industry is correct the amount of oil saved in the production of 6.5 billion gallons of ethanol in 2007 is energy equivalent to about 19.7 million barrels of oil, which is only about 1/4 of one percent of the 7.5 billion barrels of oil consumed in the U.S. in 2007. For this, taxpayers provided over 6.8 billion dollars in subsidies to corn farmers and the ethanol industry and the price of corn has increased dramatically.

MIT Laboratory for Energy and the Environment studies indicate that with further research that ethanol has the potential to displacing significant amounts of oil, but that it will take at least 5 years for this research to yield results.

The Energy Independence and Security Act of 2007 requires that ethanol production increase to 36 billion gallons per year by 2022. Even if it takes NO energy to produce 36 billion gallons of ethanol in 2022 the energy equivalent amount of oil displaced would be 472 million barrels of oil or 6.3 percent of 2007 U.S. oil consumption. More likely the energy equivalent oil displacement in 2022 will be 5 percent or less of the 2007 U.S oil consumption. This will come at the possible cost of ruining the Gulf of Mexico near the mouth of the Mississippi river and releasing huge amounts of greenhouse gases into the atmosphere as food production is shifted to other parts of the world. Perhaps the worst aspect of this legislation is that it gives people the impression that ethanol is making the U.S. significantly less dependent on oil imports when, in fact, it is not.

The only good measure of the effectiveness of ethanol and biodiesel production would be the equivalent number of barrels of oil displaced by such production. No one seems to be interested in calculating such a measure.

Large scale use of hydrogen will require many technology breakthroughs before becoming practical. Hydrogen related research should continue, but it should not be counted on to alleviate oil shortages in the foreseeable future.

One very viable means of producing transportation fuels is using coal-to-liquids technology. The U.S. has huge coal deposits that can be used to make fuels for all types of transportation using the Fischer-Tropsch process. South Africa, China and India are already exploiting this technology. DOE recognizes that coal-to-liquids will be a major alternative to oil by 2030. This process can be used to make transportation fuels without major contributions to pollution or global warming if effective carbon capture and sequestration is employed. Negative environmental effects of coal mining would still include water pollution and land disturbance as well as the release of methane, which is entrained in the coal. The U.S. does not have any efforts at this time to implement coal-to-liquids technology. It is also likely that appropriate investments in coal-to-liquids will not be made until it is recognized that biofuels are not the answer to decreased oil production.

The most interesting alternative to oil for transportation fuel is electricity in the form of lithium-ion batteries in plug-in hybrid vehicles. Such vehicles are far more efficient than gasoline and diesel vehicles and use electricity that can be produced using totally non-polluting fuels such as nuclear, solar, wind and wave power. Practical lithium-ion batteries are not yet available, but the technology appears to be maturing rapidly with possible availability of practical batteries as soon as 2010. It will take many years to replace existing cars, SUVs and small trucks assuming that practical, affordable and reliable plug-in hybrids become available in 2010.

Reference 16, "Peaking Of World Oil Production: Impacts, Mitigation, & Risk Management" by R. L. Hirsch, et. al. is a report that presents the results of a study sponsored by an agency (not identified) of the U.S. Government. This study recognizes that an oil crisis is imminent and attempts to identify ways of alleviating it. It is an excellent study that addresses the related issues in a realistic manner. A major conclusion of this report is:

> "Any transition of liquid fueled, end-use equipment following oil peaking will be time consuming. The depreciated value of existing U.S. transportation capital stock is nearly $2 trillion and would normally require 25 – 30 years to replace. At that rate, significantly more energy efficient equipment will only be slowly phased into the marketplace as new capital stock gradually replaces existing stock. Oil peaking will likely accelerate replacement rates, but the transition will still require decades and cost trillions of dollars."

All things considered, it appears that the best approach for reducing our need for foreign oil is a program that emphasizes conservation measures, facilitates transitioning small vehicles to plug-in hybrids when they become available, revamps the biofuels program to emphasize high Eout/Ein biofuel production from biomass that requires a minimum of fertilizer and displacement of food production, and recognizes that coal-to-liquids production will be a primary source of transportation fuel.

If DOE is correct in forecasting that oil will not peak until after 2030 we have time to develop coal-to-liquids technology and production facilities (assuming that the true utility of biofuels is soon recognized to be limited) and transition small vehicles to plug-in hybrids (assuming that lithium-ion battery technology matures in the next few years.)

If ASPO experts are correct in forecasting that oil has already peaked, or will peak within the next five years, we are going to have a dire transportation and financial crisis that will not be easy to resolve.

<u>About the Author</u>

The author is a retired aerospace engineer with 44 years of professional technical and management experience. He has worked for Philco-Ford Aeronutronics, TRW Systems Group, Central Intelligence Agency/Office of Development and Engineering, and General Dynamics/Advanced Information Systems Group. He has conducted many technical analyses and studies throughout his career to support the development and operation of complex aerospace systems.

He was motivated to pursue analysis of the oil problem by reading several internet articles about the world running out of oil. It was soon discovered that many articles and reports on the internet are biased and present data that supports only one side of the related issues. The author has attempted to seek the truth. The above report attempts to present the important parts of the entire story in an unbiased manner with references to supporting data on the internet.

The author thanks Robyn McFarland, an ex-coworker, for reviewing the report and making editorial contributions.

The author intends to continue studying this issue and publish updated versions of this report as the story unfolds and as additional information becomes available. Any <u>constructive</u> critique of the report and additional applicable information is welcomed. Please send to krberge@earthlink.net. Please indicate a relationship to this report in the email subject line since the author deletes email from senders not in his address book.

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