“PEAK OIL”: THE EVENTUAL END OF THE OIL AGE

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Introduction

The Industrial Revolution changed the fundamental organization of human societies. Agrarian communities became eclipsed by modern industrial cities. Transportation, industry, agriculture, communications, leisure, services, and nearly every facet of daily life have been revolutionized by the harnessing of fossil fuels. Currently, living a typical modern lifestyle is more dependent upon the combustion of hydrocarbons in fossil fuels than at any point in human history.

One fossil fuel of particular importance to modern society is oil. Humanity’s dependence upon a reliable and easily obtainable supply of oil places the modern lifestyle in a precarious position. Will this source of energy always be readily available? At what point will global production of this resource peak and then thereafter begin an irreversible decline? What would be the consequences of a peak in global oil production? With the demand for oil continuing to rise unabatedly, how will modern societies adapt if supply is unable to meet demand? What policies will governments implement in an attempt to address these issues?

These are difficult questions without easy answers. However, the implications of such questions for the organization of modern society are profound and deserve to be addressed in a manner that is easily conveyed to a wide audience. The analysis that follows will attempt to answer these questions by reviewing the phenomenon known as peak oil, when oil production peaks and then irreversibly declines. There are varying estimates as to when a global peak in oil production is likely to occur and these differing estimates will be discussed. Methodology will include Hubbert’s peak, named after geophysicist Dr. M. King Hubbert. The late Dr. Hubbert accurately predicted the peak of U.S. oil production and his peak theory has become a benchmark methodology in the formation of oil production curves.

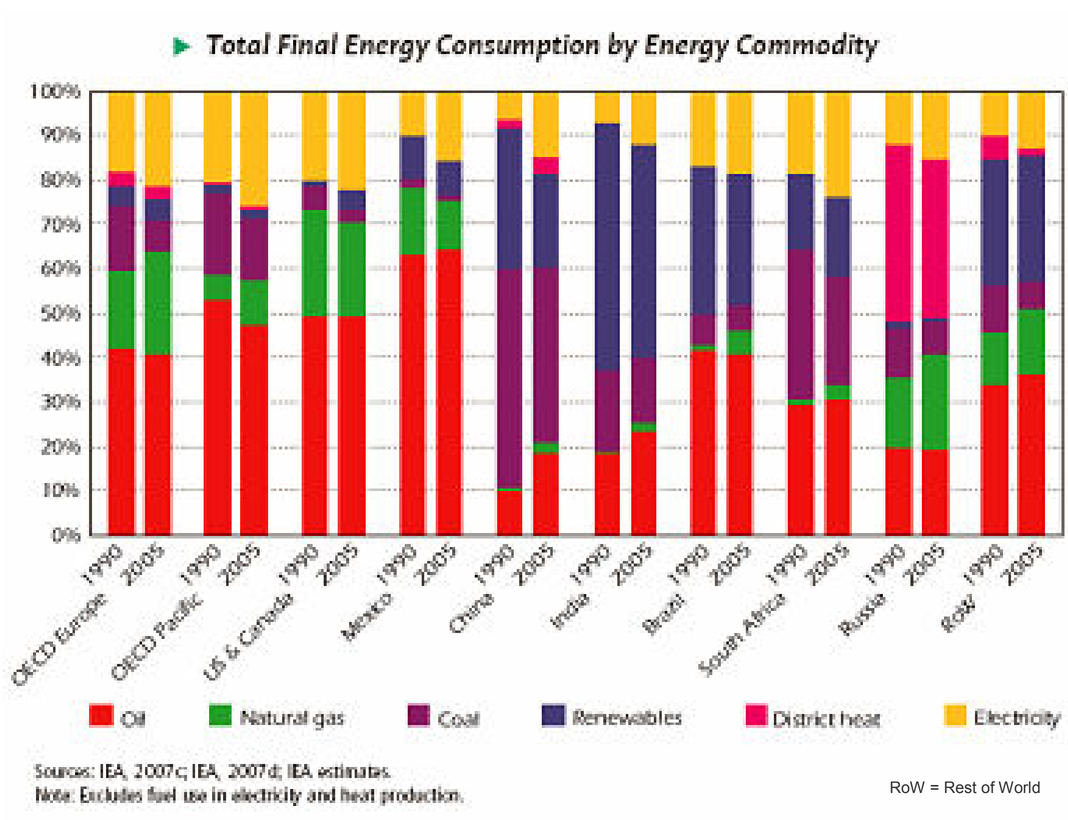
Since modern society is so heavily reliant upon oil, there could be severe consequences associated with peak oil if it is not addressed in time. A scarcity of oil could have significant ramifications for global prices, modern transport, and international affairs. Few individuals would be protected from the effects of oil’s scarcity. At the international level, countries may adopt more belligerent foreign policies due to the increasing importance resources would have in national security concerns. These effects will be explored in further detail.

Will peak oil be adequately addressed by oil markets and private industry? Or will governments have a role to play in the management of an irreversible decline in the supply of oil? Peak oil may not result in a “doom and gloom” scenario if proper proactive steps are taken. Policy options are available now that governments can implement to mitigate the effects of peak oil, and these measures will be briefly outlined in the following analysis.

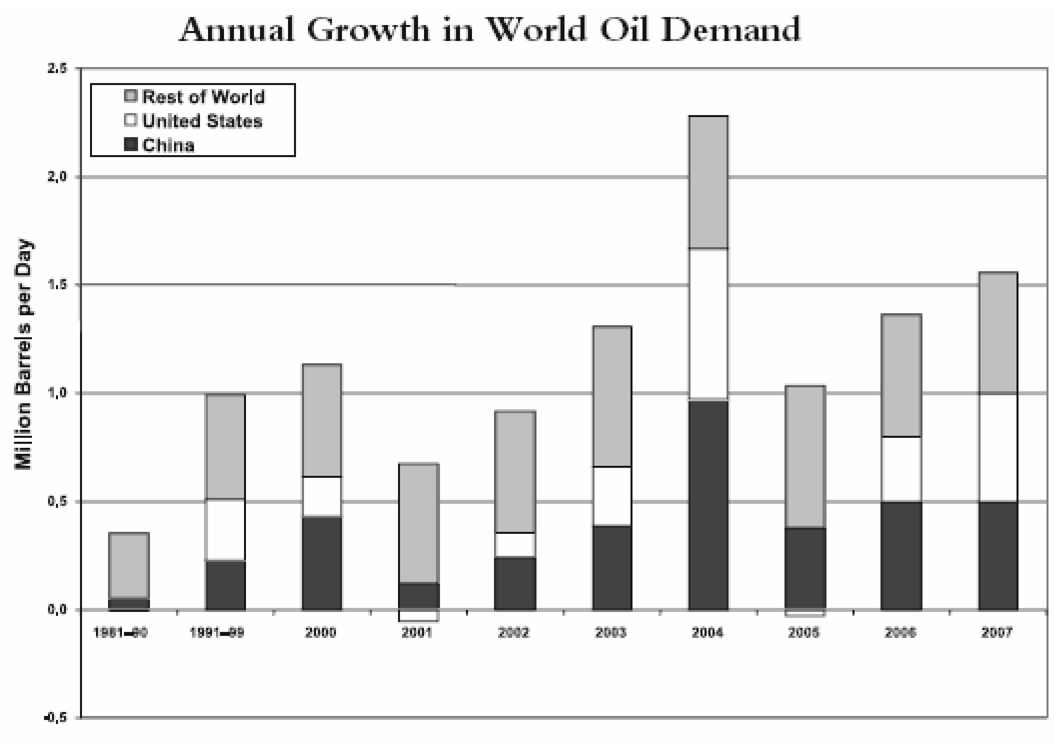
Peak oil is a phenomenon that has received little mainstream attention even though the potential consequences of its untimely arrival could be considerable. Since peak oil challenges the status quo, peak oil's proponents have been subjected to an unfortunate backlash by established interests. It is hoped that this analysis will assist in bringing more attention and clarity to the issue. The better understanding that individuals and policymakers have of peak oil, the more likely it is that appropriate decisions will be made in preparation for the eventual end of the oil age.

The Oil Age

Global Dependence on Oil. The period from 1950 to 2005 saw an eightfold increase in the worldwide demand for oil with demand reaching a tremendous 85 million barrels of oil (bbl) per day. U.S. Energy Information Agency (EIA) data in 2004 indicated that oil demand was increasing at an annualized compound rate of about two percent for previous years (Long, Wood, and Morehouse 2004). U.S. EIA demand projections forecast an increase to 118 million bbl per day by 2030 (U.S. GAO 2007, 1). If current demand trends hold, oil demand could increase by 70% by the year 2050 (IEA 2008a, 1). The chart below shows the current worldwide reliance on oil for energy (IEA 2008b, 19).



In the future, the largest increases in oil demand are projected to come from the developing world. China has been experiencing nearly double-digit economic growth for over a quarter century and it has become voracious in its appetite for oil. Its overall energy demand has increased by 69% from 1990 to 2005 (IEA 2008b, 18). By 2030, China's net oil imports are likely to increase to 13.1 million bbl per day from net imports in 2006 of 3.5 million bbl per day (Hanson 2008). India's economy has also been experiencing rapid economic growth in recent years and its population has been increasing at a faster rate than China's. In 2007, India's demand for oil increased 5.1% with continuous rises forecasted in the future (Whipple 2008). Non-OECD Asian countries, including China and India, could account for 43% of the increase in oil demand that is projected from now until 2030 (U.S. GAO 2007, 1). The figure below indicates the rapid growth in China's oil demand (CFR 2006, 18).



Source: EIA, *Short-Term Energy Outlook*, February 2006 (1981–90 and 1991–99 are annual averages).

Oil demand increases in the developing world are largely driven by consumer demand for automobiles powered by internal combustion engines (Long, Wood, and Morehouse 2004). Economic growth in these countries has brought greater wealth to a larger number of people, and not unlike individuals in OECD countries have done in the past with rising incomes, many of these people are using their wealth to purchase personal transportation for the independence and mobility that owning an automobile provides. The result in the world's largest developing country, China, has been a tripling of passenger travel in the fifteen-year period from 1990 to 2005 (IEA 2008b, 59).

It is OECD countries, though, that still account for the majority of current world oil consumption. One country in particular stands out. The United States accounts for less than five percent of the world's population yet it consumes 25 percent of the world's oil. Per capita oil consumption in the United States is over 15 times greater than that of China. In 2005, one-third of the U.S. trade deficit was attributable to oil (Lugar 2005). Even though the United States is the world's third largest oil producer, its production of oil has been in decline since the early 1970s. The inability of domestic supply to meet demand means that the United States has to import nearly 60% of its oil, and U.S. demand has held steady in the past few years even in the face of rising prices (CFR 2006, 14). The Gross Domestic Product (GDP) of the United States is the largest in the world and there is little doubt that the health of the U.S. economy has important ramifications for the health of the international financial system. In both developed and developing countries, national prosperity is in some degree dependent upon oil.

Worldwide Uses of Oil. Oil is primarily used as a transportation fuel. It is estimated that 70% of the world's oil is used for transport (Simmons 2007). Automobiles, freight trucks, diesel locomotives, jet planes, and tanker ships all utilize the combustion of petroleum distillates for their energy. Travel by road, though, is by far the greatest consumer of oil energy. Road transport accounts for 89% of worldwide transportation energy consumption and increased by 41% between 1990 and 2005. Growth in transportation energy use has been highest for developing countries and transportation as a whole remains the fastest growing end-use energy sector (IEA 2008b, 58-59).

Transportation is the most obvious use of oil, but other uses for oil abound. Petrochemicals are abundant and many products are made with them. Walking through a supermarket or department store, one will see shelves lined with goods that are produced with petrochemicals. Soaps, detergents, plastic containers, cosmetics, polyester clothing, carpeting, and electronic devices are just some of the products containing petrochemicals (Zarroli 2007). The abundance of oil in the 20th century has made these consumer goods affordable and widely available.

Oil and Globalization. Since the turn of the 15th century, Western society has been dominant in the world in terms of influence and wealth, with particular dominance demonstrated after the English Industrial Revolution in the 18th century. The reason can in part be traced to the beginnings of globalization. Whereas Eastern societies such as China preferred to be self-sufficient and resisted outsiders, Western societies considered long-distance trade to be a vital interest. Arabian and Indian merchants were interested in profits like the Western traders were, but they did not have the backing of any powerful state, and thus had no coordinated naval and trade policies. While Chinese, Indian, and Middle Eastern states used taxation of their lands to acquire their main revenues, Western states instead stressed trade as a means to earn revenue for the state (Findlay 1992). International trade, and the commercial rivalry, comparative advantage, and profit-seeking incentives it provided, created the backdrop for the West to adopt freer economic institutions more quickly, thus driving economic growth faster than other societies.

Globalization and international trade have been critical in creating the current prosperity enjoyed by the West, and they will be important determinants of economic success in the world's emerging market economies. The international movement of goods and people integral to making globalization and international trade possible now relies heavily upon oil. Flying on a jet plane from South America to Africa, ferrying goods across thousands of miles of ocean from Asia to North America, and driving cars and freight trucks from one end of Europe to the other are just a few examples of the interconnectedness that oil provides. Oil has made it possible for the scale of globalization that exists today, and it currently fuels the engine of the world economy.

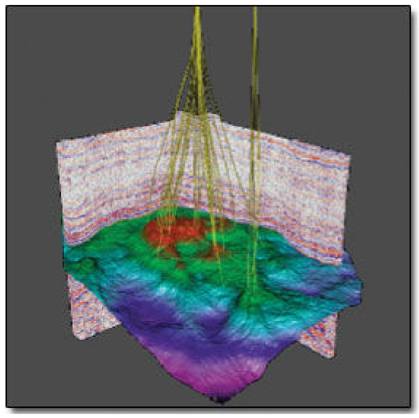
Understanding Oil

Oil's Formation. Oil is a finite resource that was formed over millions of years by geological happenstance. In order for oil to develop into an extractable form, seven criteria must be satisfied. If just one of these criteria is not met, then no extractable oil will be found. These criteria are very specific and the odds of fulfilling them all are extremely small.

1. Organic-rich sediments are preserved on the bed of an ancient sea floor. This process can happen by organisms at the surface dying, settling to the bottom, and ocean circulation patterns preserving the nutrients before they can be broken down by bacteria. Organic-rich sedimentary rocks necessary for the formation of oil constitute less than one percent of all sedimentary rocks, which is a major reason why oil is not more abundant (Deffeyes 2006, 13-15).
2. Over millions of years, these organic-rich sediments have to be buried in rocks below 7,500 feet to reach the needed temperature range of about 175 degrees Fahrenheit. Large organic molecules at this temperature and pressure are broken down to between five and twenty carbon atoms, thereby constituting crude oil (Deffeyes 2006, 15).
3. The sediments and oil cannot be buried further than 15,000 feet. Further than this depth the organic molecules are broken down to one carbon atom and become nearly pure methane. Thus the "oil window" is between 7,500 and 15,000 feet (Deffeyes 2006, 15).
4. Since oil does not dissolve in water and it is less dense than water, it will naturally migrate upward to the surface. It is estimated that 90 percent of oil seeps to the surface. Therefore the remaining 10 percent of oil is trapped underground by such things as fossil reefs, sand lenses, domes, or even sites of meteorite impacts (Deffeyes 2006, 15).
5. Reservoir rocks, e.g. sandstone, limestone, or dolomite, must be present for the oil to be contained. No large open caverns are present in the oil window, and so the oil has to be retained in porous rocks (Deffeyes 2006, 16).
6. These porous rocks need to exhibit permeability, i.e. they need to be connected to one another, for oil to be able to easily flow out of them (Deffeyes 2006, 16).
7. A leak-tight seal known as a cap rock, e.g. salt or anhydrite, must have formed as a barrier between the surface and the oil reservoir. Even a leak as small as one drop per second can drain a billion-barrel oilfield in 100 million years. Since a

number of oilfields are older than this timeframe, a minuscule leak can drain even the largest of potential oilfields (Deffeyes 2006, 16).

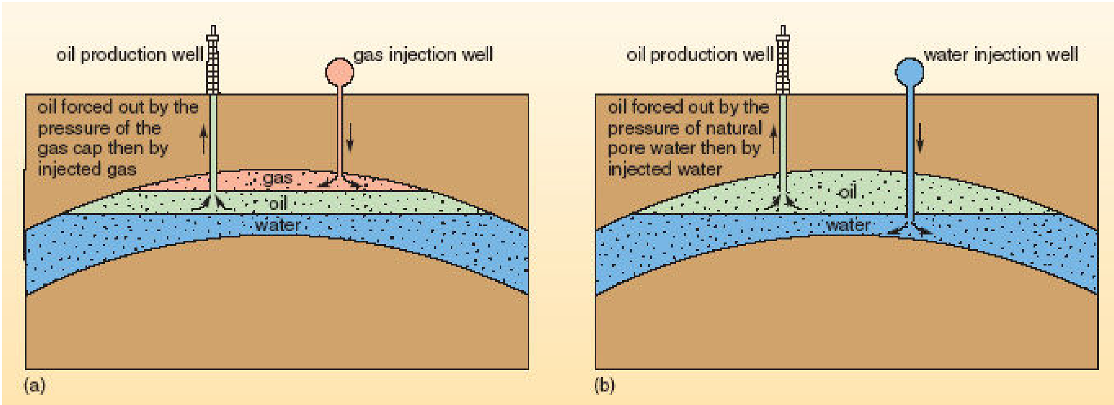
Finding Oil. Detecting oilfields is quite sophisticated and often takes advantage of Global Positioning Systems, digital terrain models, and satellite imagery. Technology now allows for three-dimensional (3-D) seismic data imaging that can provide detailed analysis of potential oil locations. A 3-D visualization of a seismic dataset from the North Sea is included below. Paths of the productions wells are indicated in yellow and the red and green areas show potential petroleum locations (Open University 2008).



Source: The Open University

Once a potential oilfield has been discovered, exploratory drilling is conducted to determine how much, if any, recoverable petroleum is trapped. Instruments lowered down the drill hole provide important information useful for deciding on the economic viability of an oilfield. It is at this time that a producer must weigh the costs of infrastructure investment, regulatory policies, revenue-sharing, and the current and potential future price of oil compared with the believed return possible from the oilfield. If it is believed that the oil well will provide a return that justifies the risks involved, commercial-scale drilling can commence (Open University 2008).

Extracting Oil. Recovering oil from an oil well is not akin to putting a straw into the well and "sucking" out the oil. Instead, natural pressure within the oilfield pushes oil up through the production well. Primary recovery using the natural pressure in the well can extract 5-30% of the oil present. Once this pressure is exhausted, secondary recovery techniques, detailed in the graphic below, are used. If a gas cap (a layer of natural gas on top of the oil) is present, natural gas can be pumped into the gas cap to force the oil out. Alternatively or concurrently, water can be pumped into the aquifer under the oilfield to force out the oil. Secondary techniques can result in a 25-65% recovery rate. Finally, tertiary recovery methods, which can include injecting steam or flooding an oil well with carbon dioxide, can push recovery over 70% in some cases, but these methods are costly and require a cost-benefit analysis to determine their viability. The North Sea provides a good example of recovery rates that oil companies commonly achieve. North Sea oilfields average 30-40% recovery rates (Open University 2008).



Source: The Open University

Summary. There are four important facts that should be emphasized from this section. The first is that oil is a non-renewable resource that can take millions of years to form. Second is that finding reserves of oil is an extremely sophisticated process using the latest technology. Third is that although large reserves of oil may be discovered in a potential oilfield, they may not be economically viable to extract. Fourth is that all of the oil in an oilfield is not extractable, and recovery rates range from five to over seventy percent of the oil present, with thirty to forty percent being typical.

Peak Oil

The concept of peak oil is not difficult to grasp. Dr. Colin Campbell, a former chief geologist and vice president at several Western oil companies, provides a basic explanation of the phenomenon. "It's quite a simple theory and one that any beer drinker understands. The glass starts full and ends empty, and the faster you drink it, the quicker it's gone" (Howden 2007).

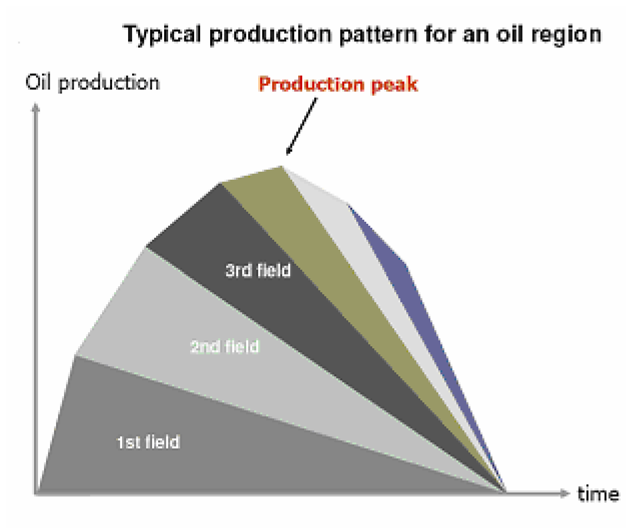
Peak oil can defined as "the critical point at which reservoirs can no longer produce increasing amounts of oil… 'Peak oil' is the point at which maximum production is reached; afterward, no matter how many wells are drilled in a country, production begins to decline" (Maass 2005). In the context of this analysis, peak oil refers to global oil production. Peak oil should not be confused with the point at which the world has exhausted its oil reserves. Instead, peak oil is when the world is at the zenith of production, when more oil is available than at any time in history. Oil production in 60 countries has already peaked, and 10 of the 20 nations that produce about 85% of the world's oil have peaked (Udall 2007). When global oil production has peaked, will peak, or will ever peak has sparked great debate among government agencies, scientists, industry insiders, and energy experts.

Hubbert's Peak. Dr. M. King Hubbert was an American geophysicist working at the Shell research lab in Houston when he discerned that oil production tended to follow a bell-shaped curve. Using an estimate of the ultimately recoverable oil in the United States, he predicted in 1956 that U.S. oil production would peak around 1970. At first Hubbert's prediction was ridiculed, but when it became apparent that his analysis and corresponding prediction were correct, his methodology later became an important benchmark for the formation of oil production curves (Deffeyes 2006, 28).

Dr. Hubbert's peak oil assumptions are simple. The Oil Depletion Analysis Centre provides a succinct summary of these assumptions:

> Operating experience from tens of thousands of oilfields shows that the rate of production always rises to a peak and then begins to fall off when about half the recoverable oil has been extracted. Since the world's total endowment of oil is finite and non-renewable, in due course, as new discoveries become insufficient to offset the natural depletion of existing reserves, overall output will reach its maximum limit and begin to decline. (ODAC 2008)

When graphed this production pattern looks like the following: (EWG 2007, 6)



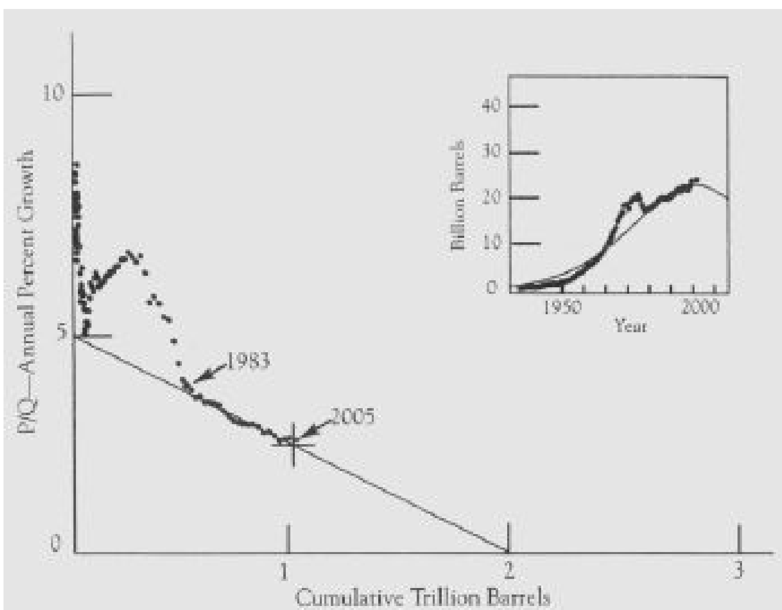
Source: Energy Watch Group Oil Report

Dr. Kenneth Deffeyes, a geologist and former oil and mining consultant who at one time worked with Dr. Hubbert, parsed through Hubbert's methodology. He found striking similarities between Hubbert's equations and those used in biological models. An example of a simple biological model is the growth of weeds in an abandoned lot. At first the weeds are far apart and multiply exponentially. Their rate of expansion is dependent upon the unoccupied space remaining in the lot, though, and so once the weeds have to start competing with one another for resources, the rate at which new weeds appears languishes and then begins a significant decline. Eventually the weeds will stop spreading and reach a steady population at the point when the carrying capacity of the abandoned lot has been reached (Deffeyes 2006, 42).

Peak oil can be thought of in similar terms as the biological model in reverse. The total oil expected to be recovered is analogous to the fixed population of weeds at the lot's carrying capacity (with an exception being that the weeds would have to grow underground). The largest and easiest to extract oilfields are quickly discovered and then drilled. A bonanza of production occurs early on and oil is depleted at a rapid pace. However, as oil becomes harder to find and recovery becomes more difficult, the rate of depletion reaches a peak point and then begins to considerably decline.

Estimates of Peak Oil's Arrival. Deffeyes found that a simple logistic curve based on the equation $P=a(1-Q/Q_t)Q$ best matched Hubbert's methodology for finding peak oil. P stands for the production in a particular year, Q is the cumulative production up to that given year, a represents the rate of annual oil production expressed as a fraction of cumulative production, and Q_t is equal to the total amount of oil expected to be extracted. The most important part of the equation is the portion in parentheses. It makes the equation reliant upon the fraction of total oil left to produce (Deffeyes 2006, 38).

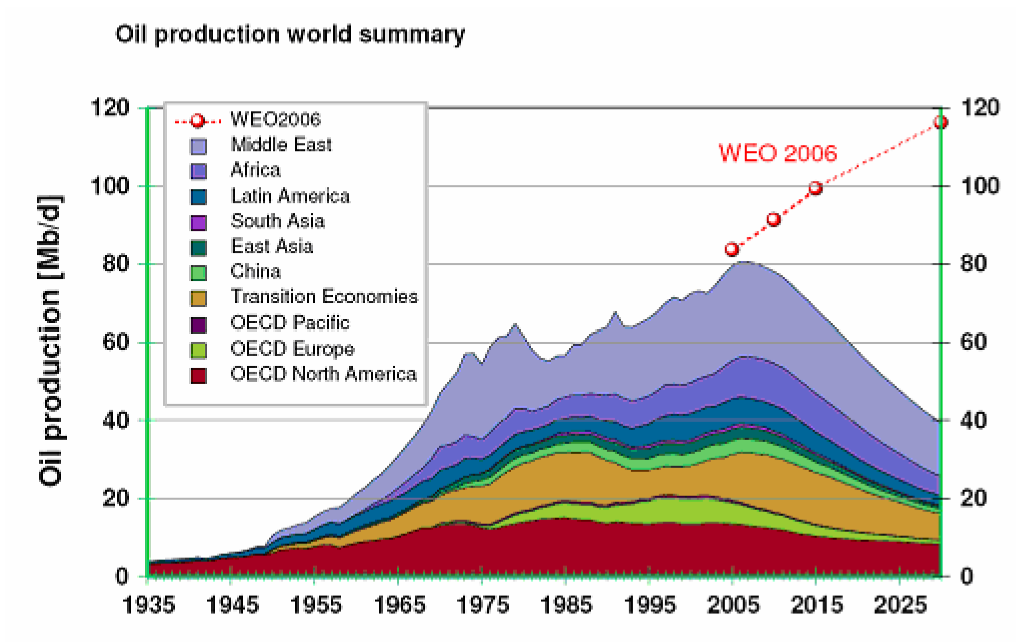
Deffeyes used this refinement of Hubbert's method to determine the peak of world oil production. He used best-fit linear regression to determine a final world cumulative production of 2 trillion barrels, which he grants is a lower number than those reported by optimists such as the U.S. Geological Survey. However, 2 trillion barrels is within ten percent of several analysts' estimates. Deffeyes graphed P/Q versus Q for world oil production and arrived at a startling conclusion: world oil production likely peaked at the end of 2005. The graph below shows world oil production with the peak indicated by the crosshairs. The inset graph is the same data displayed as production versus time and shows the bell-shaped curve that develops when graphing oil production (Deffeyes 2006, 43).



Source: Beyond Oil: The View from Hubbert's Peak

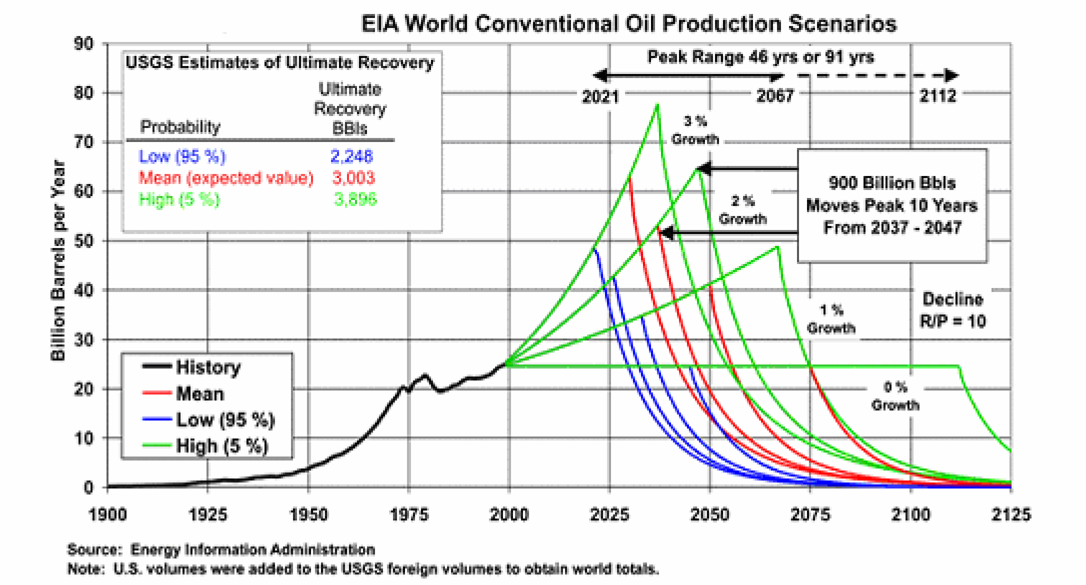
Chevron Chairman and CEO David O'Reilly, though not officially expressing a belief in peak oil, has made comments that lend credence to Deffeye's analysis: "It took us 125 years to use the first trillion barrels of oil. We'll use the next trillion in 30" (O'Reilly 2008). However, the prediction of peak oil using Deffeye's refinement of Hubbert's methodology is by no means the accepted date of peak oil. Currently a bevy of estimates exist, ranging from it has already occurred to it will occur sometime next century. A few detailed estimates will be reviewed including studies conducted by the Energy Watch Group (EWG), the EIA, and the U.S. Government Accountability Office (GAO).

The Energy Watch Group, a German non-profit group of European scientists and a few parliamentarians, completed a comprehensive look at when world oil production is likely to peak. Their results suggested that peak oil happened in 2006, similar to the result found by Deffeyes. Their belief that peak oil has already occurred was based on pessimistic assumptions regarding offshore and deepwater drilling potential coupled with a projection of more significant declines in oil production from the Middle East. The EWG's production forecast, including a line showing the IEA's 2006 World Energy Outlook prediction, is listed below (EWG 2007, 9-10).

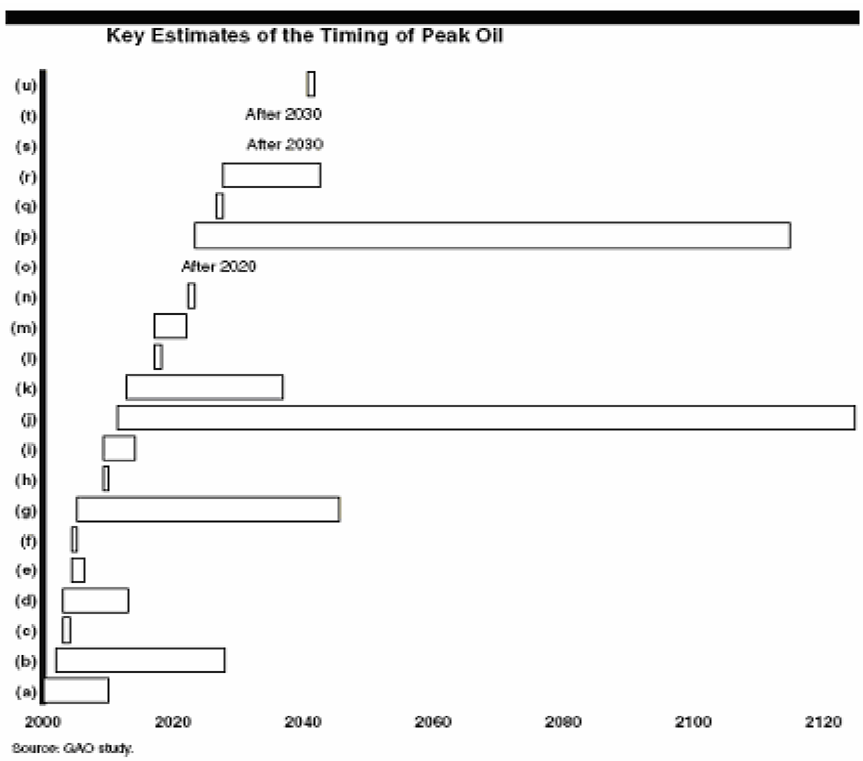


Source: Energy Watch Group Oil Report

The U.S. Energy Information Agency finds such peak oil estimates to be too pessimistic. They conducted a 2004 study of different scenarios for long-term world oil supplies based on U.S. Geological Survey reserve estimates. The EIA study uses two functional forms for forecasting oil production: a constant percentage growth until peak production, and then a constant reserves-to-production ratio of 10 for post-peak decline. The EIA chose not to use the logistic curve because they felt that one function could not accurately represent world production. The results of their analysis led the EIA to state that they did not think peak oil would occur in the near future. However, the EIA did make clear their belief that preparations for peak oil need to begin now: "Given the long lead times required for significant mass-market penetration of new energy technologies, this result in no way justifies complacency about both supply-side and demand-side research and development" (Long, Wood, and Morehouse 2004). The study's results were as follows: (Long, Wood, and Morehouse 2004)



The U.S. GAO looked at several key peak oil studies in their report "Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production." The GAO found that most studies indicated that global oil production has already peaked or that it will peak sometime between now and 2040. In light of these estimates, they reached the conclusion that preparation for peak oil was necessary and needed to begin immediately. A visual representation of the peak oil estimates reviewed by the GAO is included below (U.S. GAO 2007, 13).



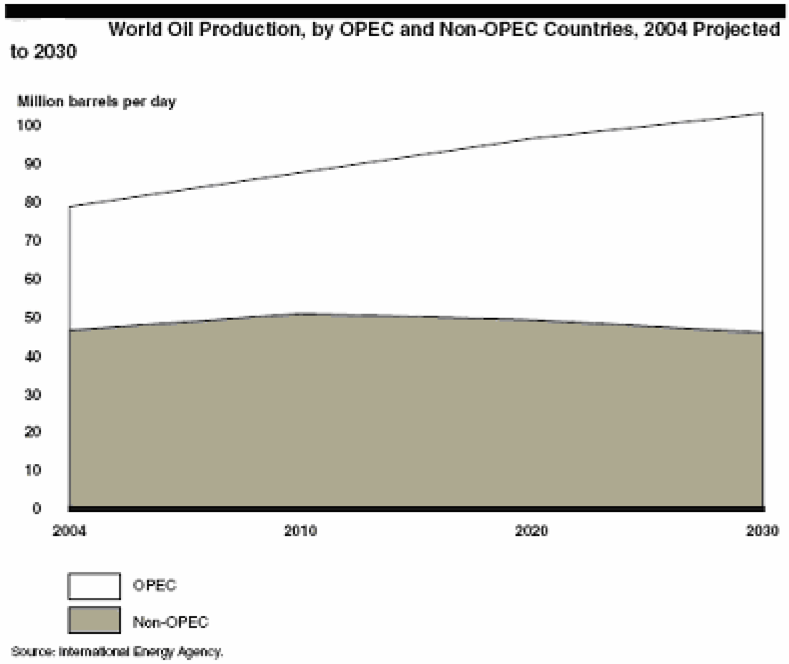
Demand Outstripping Supply. Could it be that world oil production has already peaked or will peak in the near future? With oil prices currently over four times what they were in 2004 and with growing concerns over the ability of the world's oil companies to expand global oil supply to meet increasing demand, this notion does seem credible. Lending further evidence to this belief is that last year, global oil production fell for the first time in six years. From 2006 to 2007, global oil production fell 0.2 percent to 81.53 million bbl per day while oil consumption (including fuel ethanol and biodiesel consumption) during this same period increased by 1.1 percent to 85.22 million bbl per day (Pagnamenta 2008). A February 2005 report by the United States Department of Energy's National Energy Technology Laboratory described the situation this way: "The image is one of a world moving from a long period in which reserves additions were much greater than consumption to an era in which annual additions are falling increasingly short of annual consumption. This is but one of a number of trends that suggest the world is fast approaching the inevitable peaking of conventional world oil production" (Hirsch 2005, 14).

Another sign of insufficient oil supply is that the EIA has begun measuring world oil supply and demand not in terms of conventional oil, as it has always done, but instead in terms of "liquids," which includes synthetic fuels (Klare 2007). Even if peak oil were to occur years from now, the world faces a serious problem: global demand for oil is outstripping the ability of the world's oil companies to supply it. The result, as noted by BP's chief executive Tony Howard, is that, "at least in the medium term, the era of cheap energy is over" (Pagnamenta 2008). The consequences of this supply shortfall, even if not caused directly by a peak in global oil production, will be similar to those of peak oil. The conclusion is simple. Even if peak oil is several years away, the imbalance of global oil supply and demand warrants the implementation of policies in preparation for a switch away from oil dependency. Before discussing these policy options, it is first necessary to comprehensively address the criticisms leveled by peak oil's critics.

Addressing the Claims of Critics

"Rather than ending, the Oil Age has just begun," wrote Dr. David Deming, a geoscientist and staunch critic of environmental sustainability concerns, in a January 2003 piece written for the National Center for Policy Analysis. A number of critics feel that peak oil is not a phenomenon that deserves to be addressed because they believe oil supply will continue to meet demand for many years to come. Their views can be lumped into five general claims as to why a peak in oil production will not happen anytime in the near future. These claims will be outlined and addressed below.

OPEC Reserves. Many government officials believe that OPEC, and in particular Saudi Arabia, will pump enough oil to meet future demand and replenish dwindling production in Non-OPEC oilfields. It is believed that the reason OPEC has not done so already is because of politics, not geological constraints. In the past, the EIA and International Energy Agency (IEA) have often used this assumption to cushion forecasts of future oil supply. The below graph from a previous IEA projection demonstrates this fact (U.S. GAO 2007, 26).



Reported oil reserves in OPEC countries cannot be trusted as accurate and hinging an adequate future supply of oil on significant production increases from OPEC nations is speculative at best. OPEC countries do not allow outside, independent sources to audit their confidential data on reserve figures. This fact is disconcerting since OPEC countries have an incentive to report higher reserves than they actually possess. OPEC quotas for production are based on a member country's oil reserves. In the 1980s, dubious reserve increases were reported by OPEC nations as a means of increasing their production to generate more revenue for the state. These reserve revisions are noted in the table below (Bentley 2002, 197).

Spurious Reserve Revisions

Year	Abu Dhabi	Dubai	Iran	Iraq	Kuwait	Neutral Zone	Saudi Arabia	Venezuela
1980	28.0	1.4	58.0	31.0	65.4	6.1	163.4	17.9
1981	29.0	1.4	57.5	30.0	65.9	6.0	165.0	18.0
1982	30.6	1.3	57.0	29.7	64.5	5.9	164.6	20.3
1983	30.5	1.4	55.3	41.0	64.2	5.7	162.4	21.5
1984	30.4	1.4	51.0	43.0	63.9	5.6	166.0	24.9
1985	30.5	1.4	48.5	44.5	90.0	5.4	169.0	25.9
1986	30.0	1.4	47.9	44.1	89.8	5.4	168.8	25.6
1987	31.0	1.4	48.8	47.1	91.9	5.3	166.6	25.0
1988	92.2	4.0	92.9	100.0	91.9	5.2	167.0	56.3
1989	92.2	4.0	92.9	100.0	91.9	5.2	170.0	58.1
1990	92.2	4.0	92.9	100.0	91.9	5.0	257.5	59.1
1991	92.2	4.0	92.9	100.0	94.5	5.0	257.5	59.1
1992	92.2	4.0	92.9	100.0	94.0	5.0	257.9	62.7
1993	92.2	4.0	92.9	100.0	94.0	5.0	258.7	63.3
1994	92.2	4.3	89.3	100.0	94.0	5.0	258.7	64.5
1995	92.2	4.3	88.2	100.0	94.0	5.0	258.7	64.9
1996	92.2	4.0	93.0	112.0	94.0	5.0	259.0	64.9
1997	92.2	4.0	93.0	112.5	94.0	5.0	259.0	71.7
1998	92.2	4.0	89.7	112.5	94.0	5.0	259.0	72.6
1999	92.2	4.0	89.7	112.5	94.0	5.0	261.0	72.6
2000	92.2	4.0	89.7	112.5	94.0	5.0	259.2	76.9

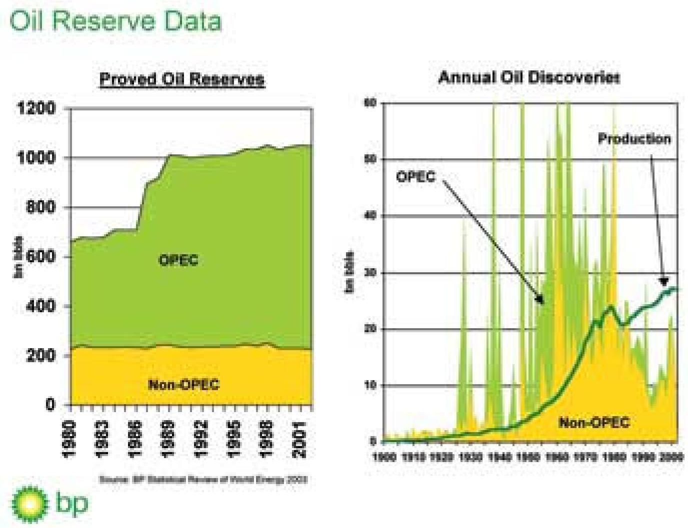
Spurious revisions in proved reserves: Annual data of *proved* oil reserves for the countries indicated, in Gb. Note the step changes, and the sequences of years with no changes. (Not the sort of data to use to find out if global reserves are rising or falling!). Source: *Oil & Gas Journal* (and hence: BP *Statistical Review*), various issues.

However, critics are correct in pointing out that politics can cause notable impacts on oil production in OPEC countries. OPEC is a cartel and has a vested interest in keeping oil prices above the true market-clearing level. For the three decades from 1970 to 2000, doing so resulted in a transfer of wealth on an immense scale: roughly $7 trillion from American consumers to foreign producers (Economist 2003). It is also true, though, that OPEC producers have a vested interest in the world remaining addicted to oil and do not want to see oil reach a price that strongly encourages a switch to alternatives and/or a reduction in demand. With oil prices well above $100 a barrel, this point has certainly been reached. It is unlikely OPEC is interested in maintaining such a high price of oil for an extended period of time.

Saudi Arabia, holder of the world's largest oil reserves, has recently increased production to its highest level in over a quarter century in an attempt to reduce the price of oil and prevent countries from reducing their oil consumption. However, the increase in Saudi production occurred as there was a considerable decline in oil exports from Nigeria due to ongoing violence there, and so the increase was not enough to assuage fears that production may not keep pace with demand (Smallman 2008). Relying on Saudi Arabia to fulfill new global oil demand is just as untenable as trusting OPEC reserve figures. Dr. Sadad Ibrahim Al Husseini, former executive vice president of Saudi Aramco (Saudi Arabia's national oil company and the world's largest oil producer), confirms that Saudi Arabia cannot fulfill the world's rapidly increasing oil demand: "Everyone thinks that Saudi Arabia will pull us out of this mess. Saudi Arabia is doing all it can. But what it is doing, in the long run, won't be enough" (Davis and Gold 2007). Ominous signs from Saudi Arabia's largest oil well provide further proof of this point.

Matthew Simmons, a Harvard Business School graduate and former energy advisor to the 2000 George W. Bush presidential campaign, wrote an influential book on the precariousness of future Saudi oil production titled: *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy*. Simmons studied more than 200 papers relevant to Saudi Arabian oil wells published in the Society of Petroleum Engineers. He found that Ghawar, the largest oilfield in the world that in the past 50 years has produced more than half of all Saudi oil, is being injected with increasing amounts of water in order to maintain production levels. In addition, Ghawar has had to be re-drilled in more costly and geologically complex ways. No oilfield in the world measures up to the size of Ghawar, and when it peaks, which may be soon, there will be no comparable oilfield to take its place. Simmons' research led him to a bleak conclusion: "Saudi Arabia clearly seems to be nearing or at its peak output and cannot materially grow its oil production" (Maass 2005).

Technological Advances. Another claim of critics is that technological advances will substantially increase both proven reserves and production rates of conventional oil; therefore, oil supply will still be able to meet demand. David Yergin, an influential energy consultant and author of *The Prize: The Epic Quest for Oil, Money, and Power*, cites continuing technological advances as an important reason why he thinks oil will continue to be able to fulfill demand (Yergin 2006). However, many energy experts consider this notion to be no more than "wishful thinking" (Whipple 2008). In spite of using extremely sophisticated equipment for oil exploration, discovery rates of conventional oil have been nowhere near historical levels since the peak of oil discovery in 1960. The graphic below indicates that despite significant technological advances, there was a stagnation of proved oil reserves in Non-OPEC oilfields, spurious proved reserve increases in OPEC, and a substantial decrease in the amount of new oil discoveries (Goodstein 2004).



Certainly technology has allowed oil companies to find and extract more conventional oil. For example, expanded exploration and horizontal and deepwater drilling have increased production in a number of places, with Brazil and its multi-billion barrel deepwater oil reserves being a prime example (Associated Press 2007). However, these recovery techniques come with a price. Horizontal drilling is able to produce anywhere from 2.5 to 7 times the amount of oil possible from a vertical well but drilling horizontally can cost as much as 300 percent more than drilling vertically (Helms 2008, 1). Deepwater and ultra-deepwater drilling can currently reach water depths up to 10,000 feet (nearly two miles), by all means an amazing feat. This type of drilling, besides being risky, is very costly. Compared to shallow water drilling, marginal costs of deepwater drilling can be from 3.0 to 4.5 times more expensive. It comes as no surprise, then, that the average market rental rate for deep-sea rigs in the Gulf of Mexico is $210,000 to $300,000 per day (U.S. GAO 2007, 50-51).

Enhanced oil recovery techniques have also been cited as a way to expand conventional oil production, but they are unpredictable. If oil is extracted too quickly or if incorrect secondary recovery techniques are employed, an oil reservoir can be damaged and the amount of recoverable oil can be significantly reduced. Oman provides an excellent real-world example of the limits of technology. Despite using technologically advanced recovery methods, oil production collapsed after 2001 and has been steadily declining since (Maass 2005). In summary, although technology will allow for more extraction of conventional oil, investment risks, underlying physical constraints, and production costs will likely remain too prohibitive for technology to engender the substantial increases in oil supply that will be necessary to meet future demand.

Economic Incentives. Following from the logic in the previous claim, critics have contended that higher oil prices will spur oil companies to find new ways to meet future demand as higher prices make the expansion of conventional oil production more profitable and make substantial increases in the production of non-conventional sources of oil such as oil sands more financially attractive. Chief economist of BP Peter Davies is an adherent of this viewpoint going so far as to say, "We don't believe there is an absolute resource constraint" (Howden 2007). It is apparent that this economic claim has underlying geological flaws but it deserves to be addressed.

Geological constraints on conventional oil production do not bode well for adherents of this claim. Not only will oil companies need to produce enough to replenish declining production in older fields, they will need to produce the additional amount needed to meet estimated demand. This production level would mean an extra 5 million barrels per day each year for the next 4 years to meet projected demand in 2012 (3 million barrels to replace lost production from declining fields plus 2 million barrels to meet additional demand), according to IEA forecasts. This level of production has been called a "daunting and possibly insurmountable challenge" (Klare 2007).

Some of the individuals debunking the claim that conventional production can be significantly increased to meet future demand have been from the oil industry itself, which is surprising since oil companies have an interest in maintaining faith in future production, thereby ensuring continued investor confidence. James Mulva, chief executive of ConocoPhillips, has said, "I don't think we are going to see the supply going over 100 million barrels a day… Where is all that going to come from?" (Davis and Gold 2007) Christophe de Margerie, chief executive of Total SA, had an even bolder statement to make: "One hundred million barrels a day is now in my view an optimistic case. That is not just my view; it is the industry view, or the view of those who like to speak clearly, honestly, and not…just try to please people" (Whipple 2008).

Western oil executives are not the only ones making these remarks. Industry insiders in OPEC have also been sounding the alarm on the ability of producers to considerably expand conventional oil supplies. Chairman of Libya's national oil company has been quoted as saying, "There is a real problem that supply may not increase beyond a certain level, say around 100 million barrels [a day]" (Whipple 2008). Former executive vice president of Saudi Aramco Dr. Sadad Ibrahim Al Husseini has stated that, "in spite of the increases - very large increases - in oil prices over the last four years, we haven't been able to match that with increasing capacity. So, essentially, we are on a plateau" (Silver 2007). Husseini has also suggested that normal economic theory, which proposes that higher oil prices will create enough incentives for a sufficient supply to meet demand, may not properly operate in oil markets because there are fundamental geological constraints to the production of oil (Silver 2007).

Some critics have suggested that non-conventional sources of oil, especially oil sands, will be able to meet the future shortfall between oil supply and demand. However, these critics misunderstand the nature of non-conventional reserves. Production of oil from oil sands requires significant capital investment, is energy-intensive, and can have deleterious effects on the environment. For example, two tons of oil sand must be strip mined for each barrel of oil and the extraction process requires three barrels of water per barrel of oil. In Alberta, Canada, natural gas energy use has been so intense for oil sand operations that the government is considering building a nuclear power plant to help meet energy demand (Appenzeller 2004). In spite of tens of billions of dollars in investment and years of development, production in 2006 from Canada's estimated 180 billion-barrel economically recoverable oil sand reserves was about 1.1 million barrels of oil a day (Davis and Gold 2007). This amount of production is certainly important, accounting for almost seven percent of current U.S. oil needs, but it is not on the scale needed to meet future global oil demand (Brown 2008, 33). Reserves of non-conventional oil have been compared to having $100 million in the bank but "being forbidden to withdraw more than $100,000 per year. You are rich, sort of" (Davis and Gold 2007).

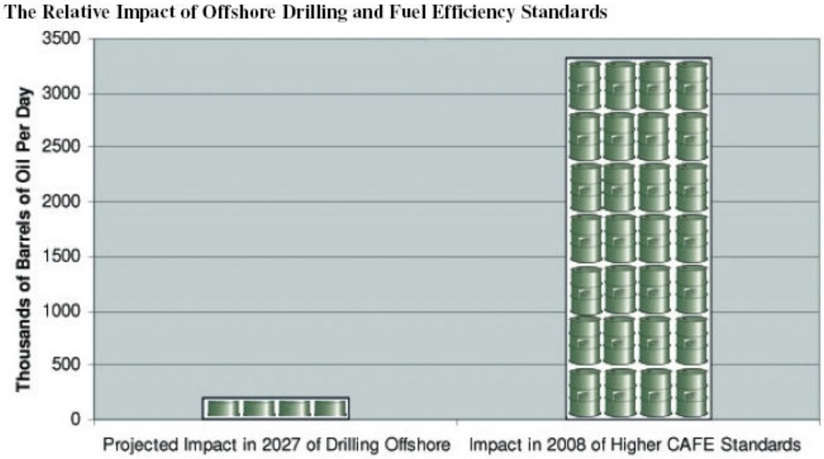
However, critics are correct that non-conventional sources of oil can be important in a country's energy mix. In fact, one country in the world uses a non-conventional source of oil as its primary energy source. Oil shale accounts for over 75% of Estonia's energy supply (Estonia Energy 2001). The use of oil shale has come with a considerable cost, though, according to the journal *Oil Shale*: "Mining and processing of oil shale has resulted in serious environmental pollution. In 2002, 91% (more than a billion cu m [cubic meters]) of the water consumed in Estonia was used in the power industry. About 97% of air pollution, 86% of total waste, and 23% of water pollution in Estonia come from the power industry" (Raukas 2004, 2). Due to production constraints, high energy use, and extensive environmental costs, relying on non-conventional sources of oil to meet global oil demand does not seem like a reasonable proposition.

Government Restrictions. A popular argument from some individuals is that oil companies could provide enough supply to meet demand if governments would allow more drilling in environmentally sensitive areas and reduce burdensome regulations. Shell President John Hofmeister alluded to this argument at an April 2008 congressional hearing in Washington, DC: "The oil industry is struggling…We struggle for access where we can have appropriate investments making the return worthwhile" (Lovley 2008). Proponents of this claim have been most vociferous in the United States. U.S. critics often cite three areas where they feel the U.S. government has had a negative impact on the ability of U.S. oil companies to increase supply: environmental regulations on the construction of new refineries, the current ban on offshore drilling, and the refusal to open the Alaskan National Wildlife Refuge to exploration and production.

In 2005, the U.S. Congress passed comprehensive legislation that made it easier for oil companies to obtain permits for constructing new refineries. The law was drafted in response to complaints from oil companies that building costs, environmental regulations, and opposition from local communities was making the construction of new refineries difficult. The law helps in each regard by providing important tax breaks and by streamlining the Environmental Protection Agency approval process. However, no new refineries were built. Guy Caruso, head of the EIA, believes the real reason behind the lack of new construction is because of long-term decision-making at oil companies, not because of government regulation: "These are 20 and 30-year investments. The economics have been quite good for the past several years. I guess the real issue is the long-term, whether they can assume they'll have the kind of (profits) that we've seen recently continuing" (Doggett 2007). These facts suggest that oil companies do not share the optimistic view of future oil production held by many peak oil critics, and so they have decided not to make the major investments needed for building new refineries.

The Center for Economic and Policy Research conducted an analysis of the potential impact offshore drilling would have on the price of gasoline. After reviewing EIA literature on the topic, they found that offshore drilling would not produce oil for at least a decade, would peak at 0.2 percent of projected world oil production in 20 years, and would be too small to have any material impact on gasoline prices. They compared the impact offshore drilling would have in 2027 against the impact that raising Corporate Average Fuel Economy (CAFE) standards 0.4 miles per gallon per year for the past 22 years would have had in 2008. Their results are below: (Baker and Szembrot 2008, 1-2).

The Relative Impact of Offshore Drilling and Fuel Efficiency Standards



Source: Energy Information Agency and authors' calculations, see text.

One of the ongoing political battles in the United States has been whether or not to open the Alaskan National Wildlife Refuge (ANWR) to oil exploration and production. Unlike offshore drilling, whose impact would likely be more psychological than anything, opening ANWR to drilling would materially impact U.S. oil production. The EIA projects that ANWR oil production could be between 510,000 and 1.45 million barrels per day at the peak of its production, 20 years after the opening of the refuge to drilling. This amount of production could result in a 2 to 6 percent reduction in U.S. oil imports, but it would only account for 0.4 to 1.2 percent of projected world oil consumption in 2030. Though ANWR could reduce the price of a barrel of oil by $1.41 in the most optimistic case, this reduction is nearly inconsequential in the face of current prices well over $100 for a barrel of oil, and the EIA notes that ANWR's impact could be easily offset by OPEC supply restrictions (Lavelle 2008).

Interestingly, the ANWR issue has brought together a unique coalition of people. It is not just peak oil critics in the U.S. who have called for drilling in ANWR. Some of peak oil's biggest proponents have begun to call for opening ANWR to oil exploration and production. Representative Dr. Roscoe Bartlett, founder of the House of Representatives' Peak Oil Caucus, had previously voted against drilling in ANWR because he felt that it should be saved for when it was really needed. Apparently Bartlett now thinks that time has come. In May 2008 he cosponsored H.R. 6107 that would open ANWR to drilling. However, his main reason for supporting the measure was not based on the additional oil supply it would provide:

> I am joining as an original cosponsor of this new bill because it dedicates federal revenues from ANWR to increase federal investments in the research, development, and production of cleaner domestic, alternative, and renewable sources of energy, energy efficiency, and conservation at zero cost to taxpayers. Oil and other fossil fuels are finite. We need to promote aggressive federal investments to transition to cleaner, domestic, renewable forms of energy. (Wright 2008)

Abiotic Oil. A geological claim of a few fringe peak oil critics is that oil is not a finite resource and that it forms abiotically. This claim is made in spite of the ubiquitous opinion of respected geologists that oil is finite and is fully explainable by normal biogenic processes. Even the vast majority of peak oil's most ardent detractors admit to oil's non-renewable nature, and so this claim will be only briefly addressed in light of the lack of scientific evidence to support it.

Dr. Geoffrey Glasby, writing in the journal *Resource Geology*, has thoroughly debunked the abiotic theory of oil. His article, "Abiogenic Origin of Hydrocarbons: An Historical Overview," can be referenced for the technical details why the abiotic theory of oil is scientifically invalid. Relevant to a discussion of peak oil was Glasby's review of a piece by geologist Dale Pfeiffer: "After considering a number of possibilities including the Siljan Ring, offshore Vietnam, Eugene Island in the Gulf of Mexico, and the Dnieper-Donets Basin, he [Pfeiffer] was unable to cite any example of the occurrence of abiotic oil in commercial quantities" (Glasby 2006, 93). Advocates of abiotic oil are correct in saying that hydrocarbons can form abiogenically. Methane is a prime example. However, the amount of methane that is not formed by biological processes accounts for less than one percent of the Earth's methane (Tenenbaum 2005). There is little doubt that oil is a finite, non-renewable resource, and any expectation of finding immense reserves of abiotic oil is completely unfounded.

The Effects of Peak Oil

Peak oil's most obvious effect is on the price of a barrel of crude oil. A good's price is determined by its relative scarcity. When oil demand outstrips available supply, as is currently the case, the price of oil is bid up. Currently the real price of oil is higher than at any point in history. An International Energy Agency (IEA) report on the effect of higher oil prices finds that oil price increases are likely to cause diminished GDP growth worldwide, higher unemployment levels, budget-deficit problems in oil-importing countries, and destabilizing inflationary pressures, with developing countries experiencing the worst of these effects (Birol 2004). Peak oil will exacerbate these problems (or is presently contributing to them), and it will also have many other widespread effects.

Global Prices. When crude oil prices rise, the prices of goods that use petrochemicals as a feedstock will be affected. Since petrochemicals are so prevalent, many manufacturers of consumer goods will experience pressure to raise prices in response to rising costs. An economist with the American Chemistry Council, Kevin Brown, estimates that of the ingredients in shampoo (excluding the water but including the bottle it is packaged in), 100-percent of their value is derived from petroleum-based products. The value of lipstick is also 100-percent based on petrochemicals, the value of tires is 62-percent petrochemical based, and even paper, because of the conversion process from pulp to pages, has approximately 25-percent of its value tied to petrochemicals. Petro-linked price increases have already been announced by six companies: Ticona, Tupperware, Huntsman Chemical, Kimberly-Clark, Dow Chemical, and Bridgestone Tire. Asphalt, a by-product of crude oil refining, has recently been experiencing double-digit price hikes (Weiss, Souder, and Robinson-Jacobs 2008). Peak oil will likely cause continued price increases for the many goods that are produced using petrochemicals.

Food prices will also be adversely affected by peak oil. The two agricultural inputs with the largest price increases for farmers in the last two years have been petroleum-based fertilizers and diesel for farm equipment, with increase rates as high as 45 percent and 37 percent respectively (AFPC 2008, 11). Higher energy costs remain the largest factor driving agricultural industry changes and they will continue to lead price increases in the food sector (AFPC 2008, 3). In addition, the insatiable world demand for oil has already created a boon for synthetic fuels such as ethanol, and competition between food for consumption and food for fuel will become more intense during peak oil and will likely lead to even more increases in food prices. Staff at the International Monetary Fund (IMF) found that biofuels policy in industrial countries has been a key driver of the recent increases in world food prices (S. Johnson 2007). More farmland each year is dedicated to food for fuel, and the incentive to do so will be even greater in the face of dwindling oil reserves, thereby worsening the current global food crisis.

Modern Transportation. Peak oil will cause transportation fuel to be more expensive due to escalating prices of crude oil, though fuel prices will still vary from country to country depending upon the taxes leveled by governments or any price subsidies that might be in effect. The current rise in worldwide fuel prices has led to widespread protests by the groups most affected, such as independent truck drivers. Some of the countries experiencing major fuel protests include France, Portugal, Spain, India, Malaysia, Nepal, South Korea, and Thailand (Reuters 2008). Peak oil will contribute to greater civil unrest in many countries across the globe.

Peak oil will engender more conservation in the transportation sector, especially by individuals. In the United States, the world's largest user of fuel, higher fuel prices have already led to greater use of public transport. Mass transit usage is at its highest level in 50 years. However, the increased ridership has not been entirely positive; it has pushed some public transportation systems to their limits and decreased fuel usage has resulted in a lowering of fuel tax revenue that governments use for infrastructure (A. Johnson 2008). Another sign of conservation due to high fuel prices in the U.S. has been the end of America's love affair with the SUV. SUV sales have dropped off dramatically, SUV resale values continue to deteriorate, and sales of smaller vehicles are on the rise (McAuliffe 2008). In addition to switching away from SUVs, many individuals in the U.S. have been taking advantage of flexible work arrangements with their employers such as telecommuting, and some have even started to look for jobs closer to home (Musbach 2008). These trends will accelerate during peak oil.

Many companies will be affected by increased transportation costs due to peak oil. American automakers, with their heavy reliance upon SUV sales, have already been negatively impacted by high fuel prices and will likely experience even more negative effects unless they are successful in diversifying their product mixes to include more fuel-efficient vehicles and hybrids. Airlines will also be seriously impacted by peak oil. It is estimated that every $1 rise in oil leads to a $465 million increase in the transportation costs of the U.S. airline industry. Another less obvious industry affected by peak oil will be retail. The higher proportion of a family's income that fuel costs consume, the less money consumers will have to spend on discretionary items (Skeel 2008). Peak oil will likely have pervasive effects on national economies.

International Affairs. Dr. Michael Klare, a professor of peace and world security studies at Hampshire College, has written three books on the geopolitics of energy. Klare foresees ominous trends for international affairs as resources become scarcer. He cites five key geopolitical forces that will alter the current global state of affairs and each of these forces will be of significant consequence during peak oil:

1. Rising energy use from emerging economic powers such as China will drive intense competition for resources between established Western powers and rising powers in the developing world. Since Western companies have been very successful in making energy and resource procurement deals, emerging powers will feel they have little choice but to foster expansion of their state-owned energy companies and to make strategic alliances with unsavory regimes to procure the additional resources they desire (Klare 2008).
2. Primary energy supplies will be insufficient to meet elevated levels of demand. The consequences will be global shortages and continued price hikes, causing hardship for individuals everywhere and especially for those living in the developing world (Klare 2008).
3. Energy alternatives will not be brought online in time to avert a painful adjustment away from fossil fuels because the hundreds of billions of dollars in investment required to do so are not being spent. In 2004, the U.S. Department of Energy (DOE) estimated that 86% of world energy was supplied by fossil fuels. DOE projections to 2030 had fossil fuels accounting for the same share of world energy. This reliance on fossil fuels will promote drilling and mining in environmentally sensitive areas, make CO2 reduction goals to avert climate change difficult to achieve, and may make it necessary to expand exploration and production in politically unstable regions of the world (Klare 2008).
4. Energy-importing countries such as the United States and the nations of Europe will experience a loss of power and wealth that will be transferred to energy-

exporting countries such as Saudia Arabia, Iran, Venezuela, and Russia. Evidence of this trend is already clear. Saudi Arabia is awash with oil money, Russia has re-emerged as a powerful force in international relations because of its vast energy reserves, Venezuela has been using a portion of its oil revenues as a geopolitical tool, and Iran has been able to continue enriching uranium despite Western sanctions (Klare 2008).

5. The potential for aggressive foreign policy will undoubtedly increase. In order to obtain better energy deals, major powers such as the U.S., China, and Russia have increased arms deals to oil-producing countries, thereby further destabilizing volatile regions of the world such as Africa and the Middle East. The invasion of Iraq, a country with immense oil reserves, has been cited as an example of the use of military force that might be more prevalent in an energy-strained world. Peak oil will cause pressure for energy-deficit nations to flex their economic and military might in an attempt to wrest precious supplies from oil-rich nations or edge out competitors in the geopolitical struggle for scarce oil (Klare 2008).

Preparing for Peak Oil

U.S. Republican Representative Roscoe Bartlett submitted a House Resolution with seven co-sponsors that indicates the scale required of any solution intended to address peak oil. House Resolution 12 of the 110th U.S. Congress states the following:

> Now, therefore, be it *Resolved*, that it is the sense of the House of Representatives that – (1) in order to keep energy costs affordable, curb our environmental impact, and safeguard economic prosperity, including our trade deficit, the United States must move rapidly to increase the productivity with which it uses fossil fuel, and to accelerate the transition to renewable fuels and a sustainable, clean energy economy; and (2) the United States, in collaboration with other international allies, should establish an energy project with the magnitude, creativity, and sense of urgency of the "Man on the Moon" project to develop a comprehensive plan to address the challenges presented by Peak Oil. (GPO 2007)

Currently this resolution is being reviewed in a House Subcommittee, and in the end it might just be a symbolic gesture instead of binding legislation. However, it is important because it provides policymakers with awareness of the scope of the problem. The 2005 U.S. National Energy Technology Laboratory report mentioned earlier makes it clear that the magnitude of the energy problem peak oil will present, if it is not addressed in time, will be unprecedented: "Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary. Previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary" (Hirsch 2005, 64). A brief discussion of key options for addressing peak oil follows.

Energy Alternatives. Oil's primary use is in internal combustion engines and these engines require liquid fuel, not electricity, for their operation. Transportation infrastructure throughout the world is currently designed for vehicles that use oil and vehicle fleets of internal combustion engines are expected to last for several years to come. Converting modern transport to use different energy sources will be a costly and difficult process.

Fueling automobiles worldwide that use internal combustion engines for their primary energy source will be unsustainable during peak oil. For example, converting the entire grain harvest of the United States into ethanol could only meet 18 percent of U.S. automotive fuel requirements (Brown 2008, 40). Coal-to-liquid technology, though promising, also falls short not because of finite coal reserves, which are vast and abundant, but because it is expensive (three to four times more costly than conventional production of an equivalent amount of oil), faces stiff environmental resistance (without carbon capture and storage, CO_2 emissions from refining and burning coal-derived fuel are twice those emitted by conventional hydrocarbons), and would require a significant increase in current coal production (just replacing 10 percent of the United States' current liquid fuel needs would require a 25 percent increase in coal production) (AAAS 2007). The solution must lie in converting transportation infrastructure and vehicle fleets to use either hydrogen or electricity as their primary energy source.

Production and infrastructure costs, government policies, and consumer preference will probably determine whether hydrogen fuel cells or electric batteries become the prevalent energy source for vehicles. Electric plug-in hybrid vehicles, though, probably have the advantage. The cheapest and easiest way to produce hydrogen is currently by burning fossil fuels, thereby liberating the bound hydrogen. This process is energy-intensive and releases carbon dioxide. To be used as a fuel, the hydrogen then has to be pressurized and cooled to an extremely low temperature for liquid hydrogen or put under intense pressure for hydrogen gas (Muller 2003). Either as a liquid or gas, hydrogen presents many obstacles for infrastructure, production, and safety.

Electric plug-in hybrid vehicles coupled with small internal combustion engines for long-distance travel are completely compatible with current infrastructure and estimated to be capable of running on electricity for the duration of the average American daily commute. A Pacific Northwestern National Laboratory report found that that if all of the vehicles in the United States were converted to electric plug-in hybrids, fully 80 percent (180 million cars) could be charged using current electrical infrastructure by utilizing the excess generating capacity available from the nation's power plants. If these vehicles were set on timers to charge during off-peak electrical hours (nighttime), plug-in hybrids could actually be beneficial to the power grid by normalizing energy usage and production (Bullis 2006).

The additional electric generating capacity needed for powering vehicle fleets of plug-in hybrids or for the production of hydrogen for fuel-cell vehicles could come from solar (see Scientific American's "A Solar Grand Plan" article), solar and wind (see "Addressing Global Warming, Air Pollution Health Damage, and Long-Term Energy Needs Simultaneously" paper by Stanford Professor Mark Jacobson), a combination of renewables (see Chapter 12 of Lester Brown's *Plan B 3.0*), or clean coal and nuclear power (see the Harvard Magazine article "Fueling Our Future"). Using renewable energy sources would be the most preferable option for a multitude of reasons, but an interim period of using non-renewable energy systems might be preferred by some governments that are unwilling to make investments in renewable energy until it is more commercially viable. The unfortunate paradox that could result if this choice were the case is that renewable energy would lack the large-scale investment needed to make it a viable technology.

Without delay, governments need to make a massive commitment to fostering the development of vehicle alternatives and the production of renewable energy through tax incentives, research and development spending, infrastructure construction, additional electric generating capacity, and stricter fuel economy standards. Peak oil presents too many economic, security, and environmental risks for governments to permit demand for larger, heavier, and less fuel-efficient internal combustion engine vehicles to grow. The costs for a revolution in world transportation over the next forty years could be as high as $17 trillion to $33 trillion (IEA 2008a, 7), though a substantial investment would be required anyway for replacing current global transport infrastructure and vehicle fleets, and these costs can be shared by both governments and industry.

Conservation & Efficiency. Conservation measures, such as those mentioned in the Effects of Peak Oil section, should be encouraged and incentivized. In addition, stricter standards to promote further energy conservation should be implemented such as stringent building codes and progressive efficiency for major appliances since solutions to peak oil will almost assuredly require greater electricity usage. Energy efficiency alone will be inadequate to address the challenges of peak oil, though. Consumers will need to adjust their lifestyles as oil becomes scarcer and more expensive (Harris et al. 2008, 177-178).

International Solutions. Since oil is a global market, peak oil is a global phenomenon. Gordon Brown, current prime minister of Britain, has therefore proposed that the problem be addressed through international means (Brown 2008). Certainly coordination between the developed and developing world will be necessary, and during a time of declining world oil production, openness from OPEC nations regarding actual reserves and production potential would be beneficial when developing peak oil mitigation plans. Not unlike current international space projects and climate change goals, peak oil concerns warrant international coordination and cooperation.

Conclusions

The 1859 drilling of the first commercial oil well by Colonel Edwin Drake in Pennsylvania marked a coming change in the way the world would use energy. Countries across the globe are now highly dependent upon oil, especially in the transportation sector. Due to rapid economic growth in the developing world and modern society's extensive reliance upon internal combustion engines, demand growth for oil is likely to continue increasing throughout the world even in the face of a tight global oil market and high prices.

This increased world demand poses problems for providing an adequate global oil supply. Oil is a finite resource formed over millions of years. Its discovery and extraction are highly complex endeavors. In spite of advancing levels of technical sophistication in the oil industry and hundreds of billions of dollars of additional investment, discovery rates of new oilfields have been falling, reserves are being quickly depleted, and there are signs that world production may be beginning to plateau. These facts lead to the conclusion that the world will reach global peak oil, the point at which world oil production peaks and thereafter begins an irreversible decline, at some point in the not-too-distant future.

Peak oil is a real phenomenon and major objections to it do not hold up under closer examination. OPEC reserve figures are questionable and Saudi Arabia may not be able to produce as much oil as has been previously forecasted. Technology, though it will allow for more extraction of oil, will be unlikely to provide the substantial increases in oil supply that will be necessary to meet future demand because investment risks, underlying physical constraints, and production costs will likely remain too prohibitive. The economic incentives generated by higher oil prices will certainly push companies to produce more oil from both conventional and non-conventional sources, but these incentives will be unable to prevent oil from peaking because production has fundamental geological constraints that cannot be overcome. Government restrictions, such as those present in the U.S., can place slight limits on oil production but they are immaterial factors in the global oil market. Abiotic oil, though an interesting concept, is a scientifically invalid theory as indicated by the fact that no significant quantities of abiotic oil have ever been discovered in the approximately 150 years of commercial oil production.

Peak oil's effects will be considerable. It will lead to higher global prices as petrochemical feedstocks become more expensive and more land is devoted to food for fuel at the expense of food for consumption. Modern transportation, a sector extremely dependent upon oil, will be significantly impacted. The increasing scarcity of oil could also have substantial effects on international affairs as energy issues become more prevalent in national security concerns. The adoption of more belligerent foreign policies may be the consequence.

The severity of peak oil's effects can be mitigated by government policy. Government intervention is necessary because of the level of investment that will be needed to adequately address the problems posed by peak oil. Governments need to implement policies that foster the development of vehicle alternatives and promote the production of renewable energy. In addition, private citizens will need to adjust their lifestyles and governments should provide support for oil conservation measures that help them do so. The scale of the problem is immense and some degree of international coordination and cooperation will also likely be required. Peak oil presents many challenges to modern society, but with a strong commitment and the necessary resolve, countries can prepare for the eventual end of the oil age.

References Cited

Agricultural and Food Policy Center (AFPC). 2008. *The Effects of Ethanol on Texas Food and Feed*. College Station: TAMU, Department of Agricultural Economics.

American Association for the Advancement of Science (AAAS). 2007 (June 13). Policy Brief: Coal-to-Liquid Technology. Available at: http://www.aaas.org/spp/cstc/briefs/coaltoliquid/

Associated Press. 2007 (November 9). Oil Discovery Rocks Brazil. *CNN*. Available at: http://edition.cnn.com/2007/WORLD/americas/11/08/brazil.oil.ap/index.html

Appenzeller, Tim. 2004 (June). End of Cheap Oil. *National Geographic Magazine*. Available at: http://ngm.nationalgeographic.com/ngm/0406/feature5/fulltext.html

Baker, Dean, and Nichole Szembrot. 2008 (June). Offshore Drilling and Energy Conservation: The Relative Impact on Gas Prices. Center for Economic and Policy Research. Available at: http://www.cepr.net/documents/publications/offshore_drilling_2008_06.pdf

Bentley, R. W. 2002 (February). Global Oil & Gas Depletion: An Overview. *Energy Policy* 30(3): 189-205.

Birol, Fatih. 2004. Analysis of the Impact of High Oil Prices on the Global Economy. OECD/IEA. Available at: http://www.iea.org/textbase/work/2004/cambodia/bj_session1.3.pdf

Brown, Gordon. 2008 (May 28). Gordon Brown: We Must All Act Together. *The Guardian*. Available at: http://www.guardian.co.uk/commentisfree/2008/may/28/gordonbrown.oil

Brown, Lester R. 2008. *Plan B 3.0: Mobilizing to Save Civilization*. Earth Policy Institute. New York: W.W. Norton & Company.

Bullis, Kevin. 2006 (December 21). How Plug-in Hybrids Will Save the Grid. *MIT Technology Review*. Available at: http://www.technologyreview.com/Energy/17930/

Council on Foreign Relations (CFR). 2006. N*ational Security Consequences of U.S. Oil Dependency*. New York: CFR Publications.

Davis, Ann, and Russell Gold. 2007 (November 19). Oil Officials See Limit Looming on Production. *The Wall Street Journal*, A1.

Deffeyes, Kenneth S. 2006. *Beyond Oil: The View from Hubbert's Peak*. New York: Hill and Wang.

Deming, David. 2003 (January 29). Policy Backgrounder No. 159: Are We Running Out of Oil? National Center for Policy Analysis. Available at: http://www.ncpa.org/pub/bg/bg159/

Doggett, Tom. 2007 (June 15). U.S. Law to Spur New Oil Refineries a Bust So Far. *San Diego Union Tribune*. Available at: http://www.signonsandiego.com/news/business/20070615-1058-usa-refineries-law.html

Economist. 2003 (October 25). The End of the Oil Age.

Energy Watch Group (EWG). 2007 (October). *Crude Oil: The Supply Outlook; Executive Summary*. Ottobrunn: Ludwig-Bölkow-Stiftung.

Estonia Energy. 2001 (February). Estonia Energy Info. Available at: http://www.estoniaenergy.com/

Findlay, Ronald. 1992 (May). The Roots of Divergence: Western Economic History in Comparative Perspective. *American Economic Review* 82(2): 158-61.

Fthenakis, Vasilis, James Mason, and Ken Zweibel. 2008 (January). A Solar Grand Plan. *Scientific American* 298(1): 64-73.

Glasby, Geoffrey P. 2006. Abiogenic Origin of Hydrocarbons: An Historical Overview. *Resource Geology* 56(1): 85-98.

Goodstein, David. 2004. The End of the Age of Oil. *Caltech News* 38(2). Available at: http://pr.caltech.edu/periodicals/caltechnews/articles/v38/oil.html

Government Printing Office (GPO). 2007 (January 4). H. Res. 12 of the 110th Congress.

Hanson, Stephanie. 2008 (June 9). China, Africa, and Oil. *The Washington Post*. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2008/06/09/AR2008060900714.html

Harris, Jeffrey, Rick Diamond, Maithili Iyer, Christopher Payne, Carl Blumstein, and Hans-Paul Siderius. 2008 (August). Towards a Sustainable Energy Balance: Progressive Efficiency and the Return of Energy Conservation. *Energy Efficiency* 1(3): 175-188.

Helms, Lynn. 2008 (January). Horizontal Drilling. *North Dakota Department of Mineral Resources Newsletter* 35(1): 1-3.

Hirsch, Robert L. 2005 (February). *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management*. U.S. National Energy Technology Laboratory.

Howden, David. 2007 (June 14). World Oil Supplies Are Set to Run out Faster than Expected, Warn Scientists. *The Independent*. Available at: http://www.independent.co.uk/news/science/world-oil-supplies-are-set-to-run-out-faster-than-expected-warn-scientists-453068.html

International Energy Agency (IEA). 2008a. *Energy Technology Perspectives: Scenarios & Strategies to 2050; Executive Summary*. OECD/IEA.

International Energy Agency (IEA). 2008b. *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*. OECD/IEA.

Jacobson, Mark Z. 2006 (June 6). Addressing Global Warming, Air Pollution Health Damage, and Long-Term Energy Needs Simultaneously. Dept. of Civil and Environmental Engineering at Stanford University. Available at: http://www.stanford.edu/group/efmh/jacobson/ClimateHealth4.pdf

Johnson, Alex. 2008 (June 11). Jampacked Transit Systems Running on Fumes. *MSNBC*. Available at: http://www.msnbc.msn.com/id/25010939/

Johnson, Simon. 2007 (December). Straight Talk: The (Food) Price of Success. *International Monetary Fund's Finance and Development Magazine* 44(4).

Klare, Michael T. 2007 (October 25). Beyond the Age of Petroleum. *The Nation*. Available at: http://www.thenation.com/doc/20071112/klare

Klare, Michael T. 2008 (April 15). The End of the World as You Know It …and the Rise of the New Energy World Order. *TomDispatch*. Available at: http://www.tomdispatch.com/post/174919

Lavelle, Marianne. 2008 (May 23). Arctic Drilling Wouldn't Cool High Oil Prices. *U.S. News & World Report*. Available at: http://www.usnews.com/articles/news/national/2008/05/23/arctic-drilling-wouldnt-cool-high-oil-prices.html

Long, Gary R., John H. Wood, and David F. Morehouse. 2004 (August 18). Long-Term World Oil Supply Scenarios: The Future Is Neither as Bleak or Rosy as Some Assert. U.S. Energy Information Administration. Available at: http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/2004/worldoilsupply/oilsupply04.html

Lovley, Erika. 2008 (April 2). Oil Execs Ask Congress for Support. *Politico*. Available at: http://www.politico.com/news/stories/0408/9308.html

Lugar, Richard G. 2005 (November 16). Opening Statement for Hearing on the High Costs of Oil Dependence. Senate Committee on Foreign Relations. Available at: http://www.senate.gov/~foreign/testimony/2005/LugarStatement051116.pdf

Maass, Peter. 2005 (August 21). The Breaking Point. *The New York Times Magazine*. Available at: http://www.nytimes.com/2005/08/21/magazine/21OIL.html

McAuliffe, Bill. 2008 (July 13). SUV Love Story Comes to Sad End. *Star Tribune*. Available at: http://www.startribune.com/local/24556834.html?location_refer=Homepage:6

Muller, Richard A. 2003 (July 11). A Pollution-Free Hydrogen Economy? Not So Soon. *MIT Technology Review*. Available at: http://www.technologyreview.com/Energy/13259/

Musbach, Tom. 2008. Easing Commuter Shock: The New In-Demand Perk? *Yahoo! HotJobs*. Available at: http://hotjobs.yahoo.com/career-articles-easing_commuter_shock_the_new_in_demand_perk-415

Oil Depletion Analysis Centre (ODAC). 2008 (May 2). Peak Oil Primer. Available at: http://odac-info.org/peak-oil-primer

Open University. 2008 (May 8). *Earth's Physical Resources: Petroleum*. Available at: http://openlearn.open.ac.uk/course/view.php?id=2292&topic=all

O'Reilly, David J. 2008 (February 26). Real Issues Ad - Trillion Barrels. Chevron. Available at: http://www.chevron.com/documents/pdf/realissuesadtrillionbarrels.pdf

Pagnamenta, Robin. 2008 (June 12). BP Chief's Bleak View on Oil Crisis as Production Gap Keeps Widening. *Times Online*. Available at: http://business.timesonline.co.uk/tol/business/industry_sectors/natural_resources/article4117065.ece

Raukas, Anto. 2004. Opening a New Decade. *Oil Shale* 21(1): 1-2.

Reuters. 2008 (June 11). FACTBOX - The Spread of Protests Over Rising Fuel Prices. Available at: http://uk.reuters.com/article/oilRpt/idUKL1113309220080611?sp=true

Shaw, Jonathan. 2006 (May-June). Fueling Our Future. *Harvard Magazine* 40-48.

Silver, Barry. 2007 (October 31). Former Head of Saudi Aramco: Oil Has Peaked. Global Public Media. Available at: http://globalpublicmedia.com/transcripts/2851

Simmons, Matthew. 2007 (November 14). The Real Oil Shock. *Time*. Available at: http://www.time.com/time/magazine/article/0,9171,1106299,00.html

Skeel, Shirley. 2008 (May 16). What If Gas Cost $10 a Gallon? *MSN Money*. Available at: http://articles.moneycentral.msn.com/SavingandDebt/SaveonaCar/WhatIfGasCost10DollarsAGallon.aspx?page=all

Smallman, Adam. 2008 (June 22). AT A GLANCE: At Oil Summit, Saudi Lifts Output To 27-Year High. *Dow Jones Newswires*. Available at: http://www.lloyds.com/dj/DowJonesArticle.aspx?id=395572

Tenenbaum, David. 2005 (July 25). Methane on Earth. *Astrobiology Magazine*. Available at: http://www.astrobio.net/news/article1657.html

U.S. Government Accountability Office (U.S. GAO). 2007 (February). *Crude Oil: Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production*. Report to Congressional Requesters.

Udall, Randy. 2007 (March 19). Comments to the National Petroleum Council. Energy Bulletin. Available at: http://www.energybulletin.net/node/27424

Weiss, Jeffrey, Elizabeth Souder, and Karen Robinson-Jacobs. 2008 (June 16). Shoppers Pay as Oil Costs Trickle Down. *The Dallas Morning News*. Available at: http://www.dallasnews.com/sharedcontent/dws/fea/shopping/stories/061508dnmetoilboost.445651e.html?npc&nTar=OPUR

Whipple, Tom. 2008 (January 7). The Year in Review. Association for the Study of Peak Oil & Gas - USA. Available at: http://www.aspo-usa.com/index.php?option=com_content&task=view&id=293&Itemid=91

Wright, Lisa. 2008 (June 12). Reps. Bartlett and Walsh: Skyrocketing Gas Prices Demand Development of Domestic Oil Supply in ANWR. Available at: http://bartlett.house.gov/News/DocumentSingle.aspx?DocumentID=94032

Yergin, Daniel. 2006 (March/April). Ensuring Energy Security. *Foreign Affairs* 85(2): 69-82.

Zarroli, Jim. 2007 (November 12). High Oil Prices Affect Many Products. *NPR*. Available at: http://www.npr.org/templates/story/story.php?storyId=16211938