FEDERAL RESERVE BANK OF ATLANTA

Economic Review

Number 2, 2009

The Peak Oil Debate

Laurel Graefe

FEDERAL RESERVE BANK OF ATLANTA
Economic Review
Volume 94, Number 2, 2009

The Peak Oil Debate

Laurel Graefe*

For the past half-century, a debate has raged over when "peak oil" will occur—the point at which output can no longer increase and production begins to level off or gradually decline. Determining how long the oil supply will last has become even more pressing because the world's energy supply still relies heavily on oil, and global energy demand is expected to rise steeply over the next twenty years.

This article seeks to bring the peak oil debate into focus. The author notes that a number of factors cloud the energy outlook: Estimates of remaining resources are typically given as a range of probabilities and are thus open to interpretation. Variations also occur in estimates of future oil production and in the ways countries report their reserve data.

The lack of a common definitional framework also confuses the debate. The author provides definitions of frequently used terms, delineating types of reserves and conventional versus nonconventional resources. She also discusses how technological innovations, government policies, and prices influence oil production.

Regardless of the exact timing of peak oil production, the world must address the challenge of adapting to a new model of energy supply. Perhaps the world would be better served, the author notes, if the peak oil debate could be more solution-oriented, focusing on discovering the best way to transition to a world with less conventional oil rather than locking horns about discrepancies in terminology.

JEL classification: Q40, Q41
Key words: peak oil, oil supply, oil prices, conventional reserves, Hotelling

The *Economic Review* of the Federal Reserve Bank of Atlanta presents analysis of economic and financial topics relevant to Federal Reserve policy. In a format accessible to the nonspecialist, the publication reflects the work of the bank's Research Department. It is edited, designed, and produced through the Public Affairs Department.

Views expressed in the *Economic Review* are not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System.

To sign up for e-mail notifications when articles are published online, please visit www.frbatlanta.org and click the "Subscribe" link on the home page. For further information, contact the Public Affairs Department, Federal Reserve Bank of Atlanta, 1000 Peachtree Street, N.E., Atlanta, Georgia 30309-4470 (404.498.8020).
ISSN 0732-1813

* The author is a senior economic research analyst in the Atlanta Fed's research department.

The Peak Oil Debate

Laurel Graefe
The author is a senior economic research analyst in the Atlanta Fed's research department. *She thanks Tom Cunningham and Gary Alden for helpful comments and suggestions.*

The debate about when the world will reach peak oil production is not a new one. But recently, as the price of crude oil has been unusually volatile, the issue of peak production has received heightened attention in the media, and the tone has changed in the discussions among oil industry and energy watchdogs about the future of global oil supply.

The term "peak oil" is not about running out of oil; we will likely have oil to pump for generations to come. Peak oil refers instead to the inevitable point at which the world's energy output can no longer increase, and production begins to level off or decline. At first glance this issue would not appear to be controversial. After all, it is largely a question of geology—how much oil is left? The disagreements center around basic aboveground supply-side constraints and demand-side factors. On the supply side, how much will oil companies invest in capacity? How will extraction and refining technology advance? Or how many hurricanes or wars will occur in oil-producing regions? On the demand side, how fast will global economic growth be? (See the sidebar on page 4.) What impact will future environmental policies have on oil consumption?

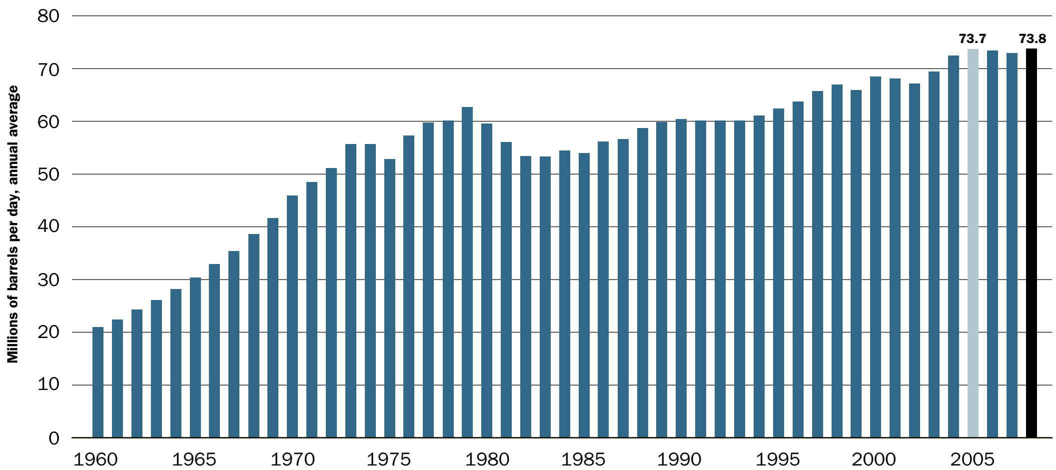
One may wonder what makes oil so special; why don't we think of oil just like other physical nonrenewable commodities? You don't often hear of debates on the timing of the demise of gold, or diamonds, or zinc. So what's the fuss about?

Countless numbers of popular books, papers, and blogs are fully committed to either proving or debunking the theory that world oil production either already has peaked or will peak soon. Merely entering a discussion about peak oil can prove to be rather sticky, given the heated, often apocalyptic aspect of the debate. The sense that the peak oil argument tends to be fear-based often plays to people's emotions, adding more fervor to the dispute.

What is fascinating is how little the two sides of the argument have changed over the history of the debate. People have been calling for the beginning of the end of oil for more than half the past century. (Keep in mind that the industrial use of oil began only about 100 years ago.[1]) Those who announce that the world is about to reach (or has already reached) peak always have counterparts who disagree. The nonbelievers had yet another victory in early 2009 when the 2008 production figures were released, showing that annual oil production increased to a record high in 2008, dismissing an increasingly popular prediction that world oil output had peaked in 2005 (see figure 1). The doomsayers, of course, must eventually be right—given the fact that oil is an exhaustible resource and will ultimately run out—though they haven't been right so far. But the counterargument that oil production hasn't peaked yet, so it isn't going to, doesn't prove terribly convincing.

Despite the shortage of middle-of-the-road discourse, this topic should not be dismissed as fringe. Figure 2 demonstrates how, despite the increasing use of nonpetroleum resources such as natural gas and renewables, the world still relies heavily on oil for a considerable portion of its energy supply. In fact, in its *International Energy Outlook 2009*, the Energy Information Administration (EIA) projects that world energy demand will grow by nearly 45 percent between

Figure 1
World crude oil production



Note: Data include extra-heavy crude, lease condensate, and liquids processed from Canadian oil sands. Natural gas liquids are excluded.
Source: EIA (2009b)

2006 and 2030, with about a fifth of new supply needing to come from oil (EIA 2009a, 1, 22). Clearly then, having a better understanding of the future oil supply situation and the associated risks is a major global issue today and will remain a central concern for the short, medium, and long term.

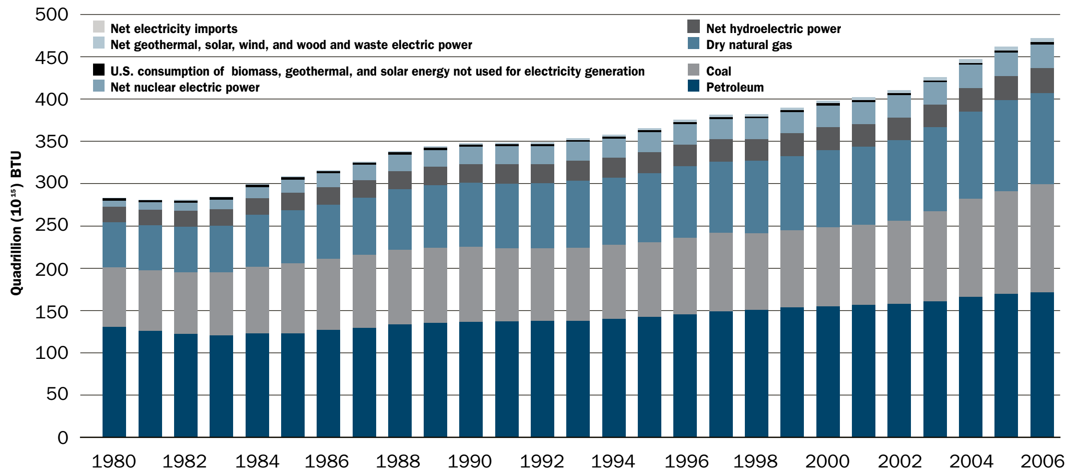
How much is left?

Experts tend to agree that oil production—whether for an individual field, a country, or the world as a whole—more or less follows a bell curve. What is more ambiguous is the exact shape and asymmetry of the curve: Will production taper off slowly once production peaks, or will it undulate steadily for many years, or will it drop off steeply? The topic becomes even more divisive when an effort is made to pinpoint how far along the curve global production is today and the level at which the world will peak in the future. Most of the debate lies in the fuzzy nature of information at the margin. (See the sidebar on page 7.)

A number of unknowns cloud the energy outlook and foster flexible interpretations of the supply data that are available. First, the world's oil resources are often found deep below the earth's surface, making even the best estimates susceptible to large revisions. Official estimates of remaining resources rarely come in the form of one concrete number but rather as a range of different estimates that are each assigned a probability. The U.S. Geological Survey (USGS) (a bureau of the U.S. Department of the Interior), for example, estimates with 95 percent certainty that the world's undiscovered conventional petroleum is at least 0.4 trillion barrels and with 5 percent certainty that undiscovered resources are at least 1.2 trillion barrels, with the mean estimate at 0.7 trillion barrels undiscovered (USGS 2000, table AR-1). These statistics are therefore open to interpretation and, depending on how they are analyzed, can be used on either side of the debate to prove a point. The same variation occurs in estimates of how much of the earth's oil resources will actually come into production; some analysts consider only "proved reserves," or those with a 90 percent probability of being produced, whereas others look at (higher) estimates of

1. Cambridge Energy Research Associates (CERA) (2006) calculates that the current era marks the fifth time that peak theorists have claimed the world is running out of oil, and each time technology and the opening of new frontier areas have dismissed assertions of a decline.

Figure 2
World energy consumption by energy type



Source: EIA, *International Energy Annual 2006*, December 2008

reserves with a lower probability of coming into production. Still others focus on entirely different indicators of the earth's remaining resources.[2]

Another factor that obscures the outlook for oil supply is that individual countries take different approaches to sharing their reserve data. For instance, while the U.S. policy is to publically share its reserve estimates, Saudi Arabia, the country thought to have the largest petroleum holdings on earth, maintains a high level of secrecy about its reserves. This practice provokes skepticism about whether the disclosed quantity of reserves is somehow politically or otherwise motivated.

In addition, the fact that production estimates must rely heavily on assumptions about factors that tend to be difficult to predict, such as the state of technology, the economy, the environment, geopolitics, and so on, leaves even more room for guesswork and bias.

Fortunately, most of the studies of peak oil recognize similar players and consider similar risks. Where the controversy arises is that some articles cite similar dynamics and statistics only to reach opposing conclusions. The peak oil discussion would become much clearer if the terminology were more uniform; simple analytical mix-ups can lead to large discrepancies in estimates.[3]

Definitions of remaining resource types

While measuring the world's existing oil and forecasting the rate of extraction is already a complex matter, the lack of a common definitional framework adds more confusion. This section provides definitions of selected terms that are often used—and often used in a fast and loose way.

Types of reserves. *Proved* reserves, commonly labeled 1P, consist of the reserves "reasonably likely" to be producible using current technology at current prices, with current commercial terms

2. Bentley, Mannan, and Wheeler (2007) make a case for analyzing peak oil production using estimates of proved plus probable reserves (2P) instead of considering only proved reserves. CERA (2006) and Kovarik (2003) contend that scientists should be looking at estimates of total global resources, arguing that production capacity will rise well beyond today's measures of proved reserves, led by technological advancement, resource discovery, and increasing production of unconventional resources.
3. Sweetnam (2008) identifies several steps that could remove some of the guesswork from analysis of future oil supply, including gaining a better understanding of future technology on costs and maximum recovery factors, improving knowledge of the drivers of long-term oil demand, and developing an agreed-on terminology to more clearly distinguish substantive issues from those arising from inconsistent use of terms.

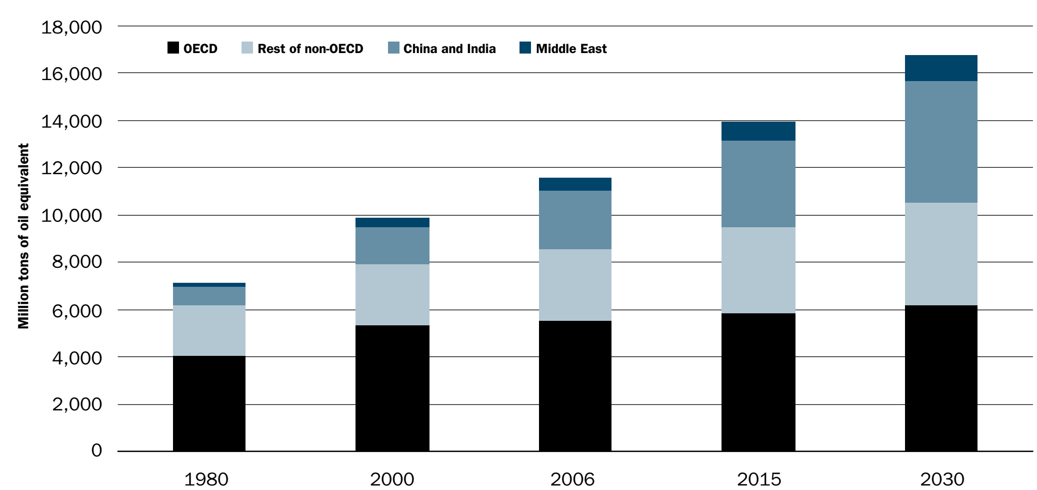
Sidebar 1

Global energy demand: The growing role of consumption in developing countries

In 2005 energy consumption in emerging and developing economies (countries that are not members of Organisation for Economic Co-operation and Development [OECD]) exceeded consumption in developed (OECD) countries for the first time in history (International Energy Agency [IEA] and OECD 2008). Much of the increase in energy demand in the next few decades is expected to continue to come from non-OECD countries as they further develop their industrial sectors and support the emergence of an urban middle class. According to the IEA, if current policies remain in place, the world's primary energy needs will be nearly 50 percent higher in 2030 than they were in 2006, with non-OECD countries accounting for more than 85 percent of the increase.

The figure shows historical demand and the IEA's baseline forecast for global energy demand through 2030. Combined energy consumption in China and India, which represented only about 10 percent of the world's total energy use in 1980, is expected to account for nearly a third of the total in 2030.

World primary energy demand



Source: IEA and OECD (2008)

and government consent. While "reasonably likely" can be interpreted in more than one way, the most common is reserves with a 90 percent probability of being produced, or P90. However, when reserve figures are quoted, they are commonly referred to only as "proved" without specifying the estimated probability of production (P95, P90, or some other percentage).

Proved reserves are subdivided into "proved developed," which can be produced with existing wells and perforations or reservoirs where minimal additional investment is required, and "proved undeveloped," which require additional capital investment (drilling new wells, installing gas compression, etc.) to bring the oil and gas to the surface.

Probable reserves are those that are "reasonably probable" to be produced using current or likely technology at current prices, with current commercial terms and government consent.[4] Probable reserves are usually considered at the median of the distribution function, or P50. They are also known as 2P, or proved plus probable reserves.

4. Notice how measures of proved and probable reserves are directly associated with current or likely technology and policy, making estimates highly susceptible to large revisions based on these aboveground, nongeologic factors, which can vary significantly in a short period of time.

Possible reserves are those having a chance of being developed under favorable circumstances—typically, those with a 10 percent certainty of being produced, or P10. In the industry, possible resources are often referred to as 3P, signifying proved plus probable plus possible reserves.

While these definitions are in theory somewhat clear-cut, in practice statistics on global oil reserves are not so straightforward because there is no transparent or audited internationally agreed-upon procedure for reporting reserves. Confusion can arise as different countries and companies often report only "reserves," without distinguishing which type (and therefore with how much certainty) they are reporting.

Conventional versus nonconventional sources. An important distinction between the different types of reserves is that between conventional and unconventional hydrocarbons.[5] In general, whether a deposit is considered conventional is determined by the difficulty involved in extracting and producing the resource. There are two primary methods of classification—one economic and one geological.

People have been calling for the beginning of the end of oil for more than half the past century.

In economic terms, *conventional* oil is oil that can be extracted and produced under existing (or foreseeable) technological and economic conditions. *Nonconventional* resources are those that are more difficult and expensive to put into production. Note that while this classification provides a valuable concept, it describes a moving target (and just as with proved reserves, the estimate will change over time as technology advances) and involves a good deal of speculation about future economic circumstances and technological evolution.

The more precise, geological definition from the USGS differentiates between conventional and nonconventional oil on the basis of petroleum's density (API gravity) and resistance to flow (viscosity). According to Meyer and Attanasi (2003), the USGS defines conventional (light) oil as having an API gravity of at least 22° and a viscosity less than 11cP (a higher API gravity and lower viscosity indicate a less dense, thinner liquid).[6]

Nonconventional (heavy) oil is then loosely defined as any petroleum liquid having less than 22° API gravity. Nonconventional oil includes extra-heavy oil, with less than 10° API and a viscosity below 10,000cP. Nearly all of the world's discovered *extra-heavy oil* is located in Venezuela's Orinoco Oil Belt.

Oil sands, also referred to as natural bitumen or tar sands, are a denser, thicker version of heavy oil, with an API gravity below 10° and a viscosity greater than 10,000 cP. At present, the only large-scale commercial oil sands production takes place in Canada's Alberta oil sands region, home to 70 percent of the world's total discovered bitumen resources.[7]

Figure 3 shows the estimated volume of the world's conventional oil reserves as well as heavy oil and oil sands petroleum resources deemed by the USGS to be technically (but not necessarily commercially) recoverable given currently available technology and industry practices. Although the combined amount of nonconventional resources actually exceeds the quantity of conventional oil reserves, nonconventional liquids accounted for only about three billion barrels (less than 4 percent) of the 85 billion barrels of oil produced in 2006 (EIA 2009a, 22).

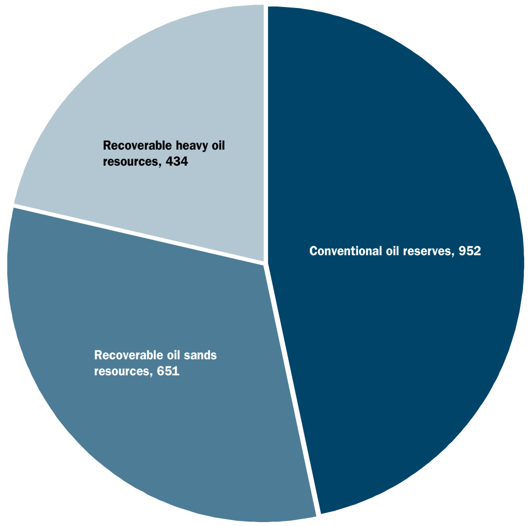
---

5. Much of the uncertainty regarding peak oil outcomes stems from experts' differing opinions about the ability of large-scale nonconventional resource projects to produce at a rate necessary to both keep up with rising demand and replace conventional liquids production.
6. About three-quarters of the earth's conventional oil resources are located in just a handful of giant oil fields, representing only about 1 percent of the number of the world's oil fields (Gerling 2007).

   API gravity measures how heavy or light the liquid is. An API gravity greater than 10° indicates that the oil is light enough to float on water; petroleum with a gravity of less than 10° is heavier and will sink.

   Centipoise (cP) is the unit of measurement for viscosity, or resistance to flow. Water at 70°F has a viscosity of about one cP.
7. The volume of discovered original oil in Canada totals just under 1.7 trillion barrels. However, only about 10.5 percent of that (179 billion barrels) was classified as technically recoverable in 2005 (Meyer and Attanasi 2007).

Figure 3
World's known recoverable petroleum resources (billions of barrels)



Source: U.S. Geological Survey (2003)

Other nonconventional resources. Some other oil resources are often categorized as nonconventional, depending on whether a study is defining oil by its physical attributes or its economic viability (Lepez 2007, 103–7; Schindler and Zittel 2008, 20–22).

Oil shale is created at heavy industrial installations that process kerogen (intermediate organic compounds found in certain types of sedimentary rock) at extremely high temperatures. Most of the world's shale (about 1.5 trillion barrels) is located in the western United States, notably Colorado and Utah. According to Dyni (2006), the USGS estimates that the world's total shale oil resource is equivalent to about 2.8 trillion barrels of oil; however, little of that total is considered to be recoverable under current conditions given the high economic and environmental costs associated with oil shale production today.

Deepwater petroleum is found beneath up to 500 meters of water; ultradeep oil is found at water depths as great as 2,000 meters. Although deepwater reservoirs tend to be geologically similar to those found in shallower areas or onshore, producing oil from such water depths presents extensive logistical and technological challenges.

Synthetic oil is liquid fuel created by chemically converting natural gas (gas-to-liquids), coal (coal-to-liquids), or biomass, but the process is generally very expensive.

Polar oil resources are those located north of the Arctic Circle and south of the Antarctic Circle. Challenges are posed by the extreme climate and remote locations. In a 2008 assessment of oil resources in the Arctic Circle, the USGS (2008) estimates that the area holds some 90 billion barrels of undiscovered oil.[8] The study notes that the majority of these resources are located offshore, adding that "the extensive Arctic continental shelves may constitute the geographically largest unexplored prospective area for petroleum remaining on earth."

Natural gas liquids (NGLs), liquid components of natural gas, are often included in nonconventional oil estimates. NGLs include condensate (low vapor pressure), natural gasoline (intermediate vapor pressure), and liquefied petroleum gas (high vapor pressure).

8. In addition to oil deposits, the study also identified 1,669 trillion cubic feet of natural gas and 44 billion barrels of natural gas liquids located north of the Arctic Circle.

Sidebar 2

Aboveground factors and peaking demand

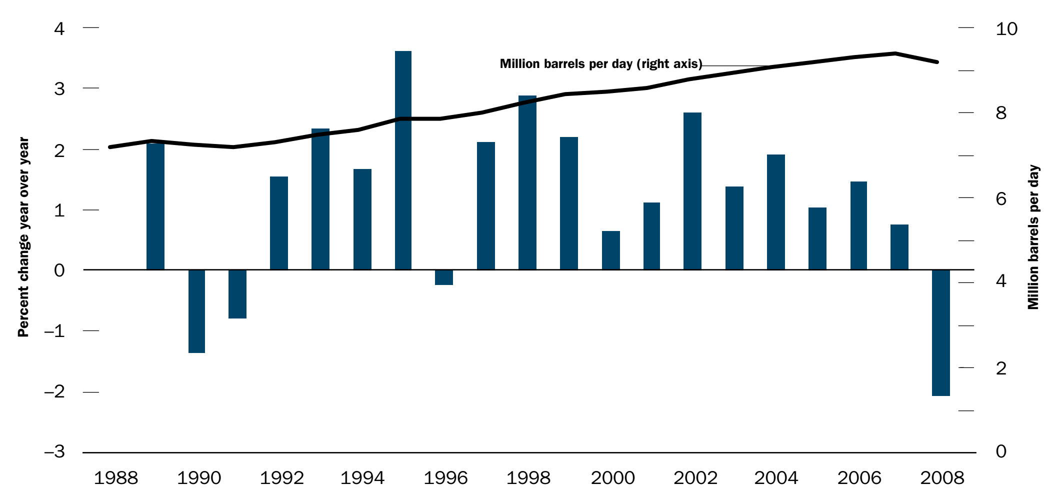
The time at which peak oil production will occur is determined not only by the amount of resources that exist underground and the portion of those resources that can be extracted but also by future oil demand, which will govern the speed at which the extractable resources are depleted. While estimates of the earth's total resource endowment are primarily concerned with physical belowground conditions, the future ability to extract oil and the path of future demand are equally determined by circumstances aboveground.

Low prices discouraging investment is just one example of an aboveground issue that arguably can have just as much effect on the path of oil production as physical supply. Evolving technology, economic growth, fiscal regimes, geopolitics, and environmental preferences and regulations are all aboveground factors that will help determine the timing of peak oil production.

For example, some claim that the peak oil debate is moot simply because global energy demand will peak before global supply does. Subscribers to this philosophy cite economic slack, efficiency advancements, and/or consumption cutbacks in response to climate change as reasons why a peak in oil production will be driven by demand-side, rather than supply-side, constraints.

A growing school of thought maintains that U.S. gasoline consumption peaked in 2007 as a result of firm pump prices, higher fuel efficiency, evolving transportation habits, and the increasing role of renewable fuels for transportation (see the figure). Cambridge Energy Research Associates (CERA), an energy consulting group with a well-known stance that world oil production will not peak in the near term, is a prominent subscriber to the theory that demand for gasoline in the United States has already peaked (Campoy 2008).

U.S. demand for motor gasoline



Source: U.S. Department of Energy

Extracting and refining these nonconventional energy resources tends to be much more capital- and energy-intensive than for conventional oil, making them more expensive to produce than conventional sources. And given the relatively high environmental impact of processing nonconventional resources, legislation restricting or taxing their use often further increases production costs.

Still, despite their drawbacks, nonconventional resources will likely play an increasingly important marginal supply role in the future as reserves that are easier and cheaper to produce become depleted.[9] The incentive for innovation and investment in more economically and environmentally efficient energy production methods (hydrocarbon-based or renewable) will grow as the world exhausts conventional reserves.

The role of technology

As these descriptions of reserves demonstrate, a large gap exists between what is thought to be the earth's total petroleum resource endowment and the portion of those resources that are considered recoverable. Technological advancement has played an essential role in narrowing that gap as innovation has allowed more usable oil to be produced in a more cost-effective manner.

For example, as oil is extracted, the pressure within the oil field diminishes and the water levels rise, contributing to a decline in the production rate. The decline can be delayed or reduced by injecting gas or water into the reservoir to increase the pressure or by heating the oil or injecting chemicals to reduce the viscosity of the oil. Today, these techniques of enhanced oil recovery (EOR) are commonly applied to aging fields to increase the amount of extractable oil (U.S. Department of Energy 2008).

Nonconventional resources will likely play an increasingly important marginal supply role as reserves that are easier and cheaper to produce become depleted.

Another major technological innovation for oil producers is advanced drilling techniques that allow more precise well exploration and development. While standard vertical drills allow producers to access a reservoir only from directly above, *directional* or *horizontal* wells enable producers to reach underground reservoirs in a much more flexible, efficient manner (Feuillet-Midrier 2007, 89–90).

New technologies have also allowed for major advances in companies' ability to produce oil located beneath the ocean floor. Offshore extraction technologies have evolved in the past half-century from platforms reaching oil a few hundred feet below the water's surface and a few thousand feet below the ocean floor to today's major installations that are capable of drilling tens of thousands of feet. These advances have opened up new expanses of hydrocarbon reserves, including deep basins of deposits in the U.S. Gulf of Mexico and the North Sea and off the coast of Brazil and West Africa.

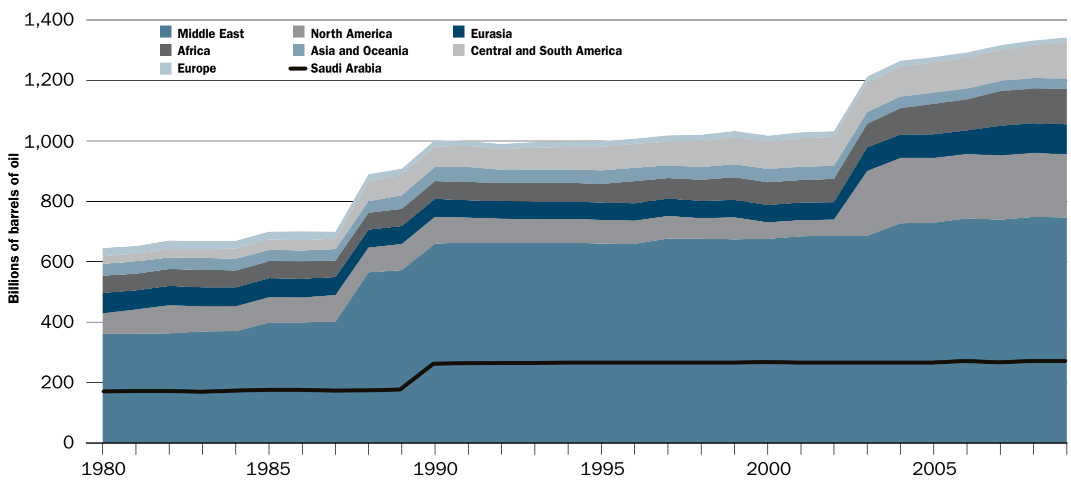
Advancements in recovery techniques, coupled with improvements in instruments geologists use to see what lies beneath the earth's crust, have made previously unreachable (and undiscovered) deposits viable for production, thus leading to increased measurements of recoverable reserves. Many disbelievers in the theory that oil is nearing peak production argue that oil reserves will continue to grow over time as technological evolution makes production of seemingly out-of-reach resources plausible. Maugeri (2009) points out that the world's 2.3 trillion barrels of proved reserves (one trillion of which have already been consumed) account for only a segment of the earth's original petroleum deposits. He argues that the reason just a portion of the earth's original deposits are considered reserves is that easily accessible conventional oil has been abundant for most of the industry's history, providing little incentive for significant investment in innovation of nonconventional oil production techniques. However, Maugeri notes that, as the "easy" oil is used up, technological advancement will ensue, and reserves will grow as resources from undiscovered and mature fields and nonconventional sources become viable.

But it may not be entirely realistic to make predictions about future oil supply on the assumption that some yet-to-be-created technology will establish access to what today are considered to be inaccessible and inefficient resources. Besides, a growing scarcity of conventional oil and the accompanying high oil price could just as easily justify investment in alternative energy and conservation technology as advancements in oil recovery techniques.

---

9. The EIA estimates that unconventional liquid fuel production (including biofuels) will average 13.4 million barrels per day in 2030, up 30 percent from 2006 production, and account for more than 12 percent of total world liquids output (EIA 2009a, 21–22).

Figure 4
World proved crude oil reserves



Note: Data cover the period January 1980–January 2009 and include conventional crude oil and condensate reserves and, beginning in 2003, Canadian oil sands reserves.
Source: EIA; PennWell Corporation, *Oil and Gas Journal*, February 2009

Government-controlled reserves

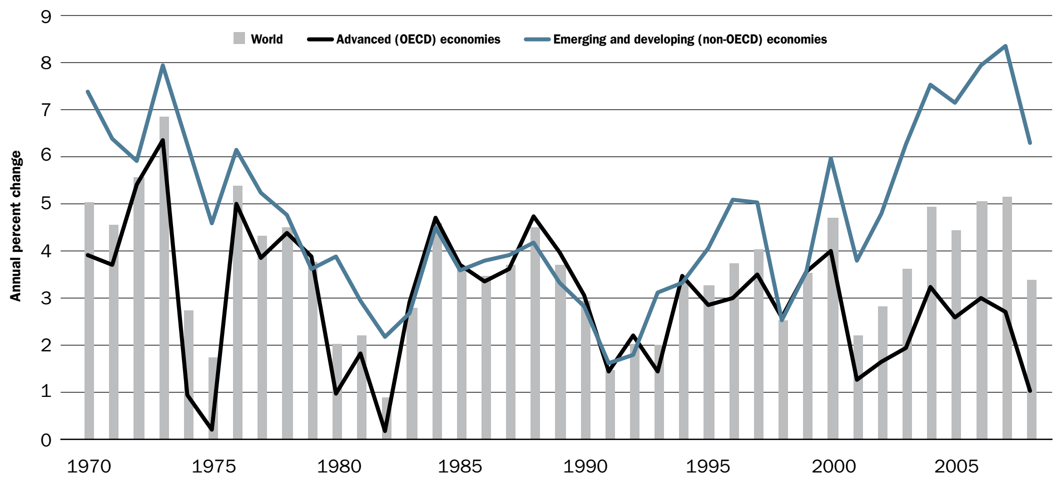
According to the EIA (2009b), in 2007 88 percent of the world's proved reserves were owned by government-controlled oil companies—with over three-quarters of those reserves located in OPEC (Organization of the Petroleum Exporting Countries) countries—which are not subject to external auditing (see figure 4).[10] This situation, skeptics claim, is reason to be cautious about accepting official reserve data as fact.

The most prominent example of disagreement about remaining supply is doubtless the case of Saudi Arabia, which controls what are reportedly the world's largest conventional oil reserves. Some experts claim that the Saudis are intentionally overstating the country's reserves to encourage short-term demand and deter conservation and investment in alternative energy; such investment would accelerate if peak oil were thought to be approaching and would eventually decrease the overall value of the Saudis' reserves as the world diversifies away from oil.[11] After all, OPEC members have an unusual incentive to overstate their reserves because the cartel's export limits are based on member countries' reserve estimates. Many analysts point to a period in the late 1980s during which six of the eleven OPEC members reported large increases in reserve estimates, resulting in higher production quotas. If indeed OPEC reserve estimates are inflated, the world may actually be much closer to peak oil than the official numbers indicate.

On the other hand, there is also an argument that some of the world's oil exporters, including Saudi Arabia, are instead under-reporting reserves, taking advantage of expected high future returns on oil and saving for future generations. OPEC, however, maintains that its reported reserves are accurate, claiming that "availability is not an issue" and asserting that the "world's remaining resources of crude oil and natural gas liquids are clearly sufficient to meet demand increases for the foreseeable future" (OPEC 2008, 2).

10. Rogoff (2006) argues that investment in future oil production is greatly inhibited by the tendency of many oil-exporting countries to seek national control over oil production.
11. For example, Simmons (2005) claims that the Saudis have been deliberately overstating reserve capabilities for decades, maintaining that assessing the true quantity of reserves remaining in Saudi Arabia is the most significant issue in petroleum politics today. Petroleum geologist Colin Campbell (2004) asserts that OPEC countries are inflating their reported reserves for political reasons: to increase production quotas and/or make credit more accessible.

Figure 5
Global real GDP growth



Source: International Monetary Fund, World Economic Outlook Update, January 2009

Saudi oil production has been rather erratic over time largely because the oil-rich country has historically functioned as a price stabilizer, increasing output when prices spike and cutting back if prices fall below a comfort zone. However, in recent years, despite the Saudis' best efforts to influence the market, global prices have been exceptionally inelastic to supply announcements (to increase production when prices were at their peak and decrease when they dipped to lows in late 2008 and 2009). One could argue that OPEC's poor pricing power during the oil price spike and the subsequent drop in 2007 and 2008 was in part a reflection of market participants' distrust in the cartel's (Saudi Arabia's) ability to increase production enough to satisfy global oil demand.

The role of prices

During the five-year period from 2003 through 2007, global economic growth accelerated precipitously, led by the world's increasingly energy-intensive developing countries (see figure 5); this rapid growth placed significant pressure on the global oil balance and contributed to an unprecedented price spike. From January 2007 through July 2008, the price of crude oil nearly tripled (figure 6), jolting businesses and consumers around the globe. The high prices were generally thought to be at least in part a result of tightening oil market fundamentals (energy demand outpacing supply); some, however, including OPEC, maintained that market fundamentals were healthy but that financial market speculation and movements in the dollar exchange rate were driving the run-up in prices (OPEC 2008).[12]

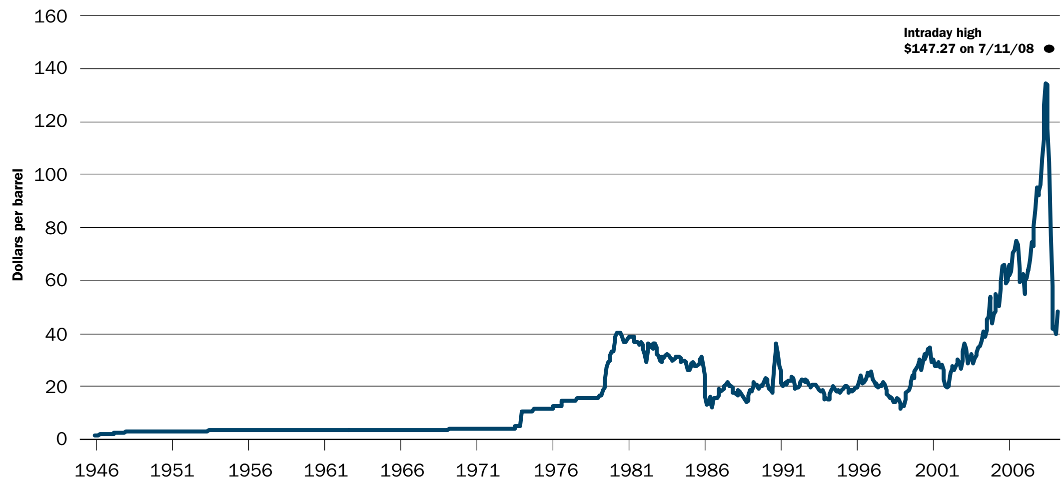
Regardless of the cause, the oil price spike had undeniable economic and social consequences across the globe. Hamilton (2009, 40) considers the 2007–08 oil price spike a critical factor that helped tip the United States into recession, finding that, "had there been no oil shock, we would have described the U.S. economy in 2007:Q4–2008:Q3 as growing slowly, but not in recession." A wide range of estimates gauge the negative effect of a rising oil price on the global economy, with impacts on developing economies and oil-importing countries generally considered to be much greater than in developed countries.[13]

12. Hamilton (2009, 42) finds that, while speculative investment and low interest rates may have played a role in the price increase, "some degree of significant oil price appreciation during 2007–08 was an inevitable consequence of booming demand and stagnant production."

13. For a review of estimates of the global economic implications of an increase in the price of oil, see Rogoff (2006).

Figure 6

Spot West Texas Intermediate oil price



Note: Data cover the period January 1946–March 2009.
Source: *Wall Street Journal*, monthly

However, the price spike also had an upside: Consumers began to drive less and conserve more, while businesses and producers set out ambitious plans to invest in energy-saving technology and upgrade outdated equipment. Alternative (both nonconventional and renewable) sources of energy, which historically had been price prohibitive, emerged as attractive substitutes to $145 per barrel oil and gasoline above $4 a gallon. World oil demand plummeted as record prices and a worldwide economic slowdown forced consumers to cut back on their energy use. But just as talk of a new green era was entering the mainstream, crude prices retreated as quickly as they had come.

What role do prices ultimately serve in respect to long-term oil supply? Some economists would point out that, even absent any major policy initiatives, society should naturally move away from conventional oil as it approaches peak because rising prices will make substitutes more economically attractive. Hotelling (1931) explained that a rising oil price in anticipation of future supply declines will allow time for a transition to an alternative or nonconventional source of energy (or more conservation) before the cut-back becomes physically necessary. According to Hotelling's rule, as long as information is transparent and markets are free to operate efficiently, since the price of oil includes the knowledge of future supply declines, preparation for peak oil will occur naturally because the market will establish an efficient allocation of oil over time. [14]

However, as this article has described, information about the global oil market is far from being fully transparent. Current supply data are incomplete and often difficult to interpret, and the future paths of technological innovation and demand are difficult to foresee. Additionally, markets are not entirely free to incorporate expectations about the future. In reality, political leaders do not necessarily act in the most economically efficient manner but instead implement taxes or subsidies or act to maximize short-term profits at the expense of long-term outcomes.[15] OPEC, for example, functions as a cartel to deliberately influence market prices by colluding to withhold supply, thereby

14. The rationale behind Hotelling's rule is that anyone selling an exhaustible resource today is forfeiting the opportunity to sell it in a future market in which it might be more highly valued and therefore is incorporating a "scarcity rent" in the resource price today.

15. For a further discussion of Hotelling's rule and its criticism, see Chermak and Patrick (2002) and Gaitan, Tol, and Yetkiner (2006).

distorting market pricing.[16] In addition, Morgan Stanley ("Fuel subsidies" 2008) estimates that half the world's population receives some form of fuel subsidy or price control. Although some of these policies were rolled back in attempts to shore up government fiscal positions during the price spike and subsequent economic collapse, government price intervention still cushions a significant percentage of global oil demand from market incentives.

Looking ahead: Investing in future supply and understanding options

Low energy prices, generally thought to encourage economic growth, can also have longer-term negative effects as they discourage efforts toward conservation and efficiency and impede future production projects.[17] Delayed investment spurred by soft energy prices could create an environment of lagging supply and price spikes.[18] This risk is particularly apparent in the case of nonconventional and alternative resources, which tend to be relatively expensive to produce.[19] Fatih Birol, the chief economist at the IEA, estimates that about $100 billion in projects were either delayed or canceled in 2008 because of a combination of low oil prices and credit accessibility issues (IEA 2009).

The supply of energy as we have known it is in the process of transition. Today's "easy" conventional oil that the world relies upon as a primary energy source is being depleted, and, regardless of the exact timing of peak oil production—be it this year or fifty years down the road—the world faces the challenge of adapting to a new model of energy supply. Although the peak oil literature tends to concentrate heavily on the scenarios of peaking world oil production, the true underlying issue is a fear that the transition from conventional oil to substitutes will be expensive and chaotic, leaving insufficient time for supply substitution and adaptation.

This adaptation process—which involves using more renewable resources and conservation and developing new technology and processes to better access hydrocarbon deposits and more efficiently extract and refine nonconventional sources—has already begun. But the road to the future energy balance—one with dwindling amounts of conventional oil—is far from mapped out.

It is possible that the world's vast endowments of hydrocarbon resources will be heavily relied upon to answer this growing call for substitutes for the conventional oil supply. However, there is also potential for an energy future largely diversified away from hydrocarbon use. Most likely, future energy sources will be a combination of the two. Perhaps the peak oil literature would better serve society by being more solution-oriented, focusing on discovering the best way to transition to a world with less conventional oil rather than locking horns about discrepancies in terminology.

---

16. Kaufmann and Cleveland (2001) reason that the basic Hotelling model's inability to describe the empirical relationship between oil prices and production justifies a more active government role in the transition from oil.
17. CERA (2009) estimates that the decline in the price of oil could result in oil supply growth between 2009 and 2014 being half that anticipated when prices were at their peak (7.6 million barrels per day [mbd] of the total potential future net growth of 14.5 mbd are considered to be at risk.)
18. Stevens (2008) explains why insufficient investment by oil companies, rather than belowground physical supply factors, will likely be the driver behind an oil supply crunch.
19. For example, according to a report by the Canadian Energy Research Institute (McColl 2009), oil prices will have to average at least $70 per barrel (West Texas Intermediate) in order for capital investment in Canadian oil sands projects to continue.

References

Bentley, R.W., S.A. Mannan, and S.J. Wheeler. 2007. Assessing the date of the global oil peak: The need to use 2P reserves. *Energy Policy* 35, no 12:6364–82.

Cambridge Energy Research Associates (CERA). 2006. Peak oil theory—"World running out of oil soon"—is faulty; could distort policy and energy debate. Press release. November 14. http://www.cera.com/aspx/cda/public1/news/pressReleases/pressReleaseDetails.aspx?CID=8444 (accessed June 24, 2008).

———. 2009. Low oil prices putting supply growth at risk. Press release. March 27. http://www.cera.com/aspx/cda/public1/news/pressReleases/pressReleaseDetails.aspx?CID=10189 (accessed April 20, 2009).

Campbell, Colin J. 2004. *The coming oil crisis*. Essex, England: Multi-Science Publishing Co. Ltd.

Campoy, Ana. 2008. Prices curtail U.S. gasoline use. *Wall Street Journal*, June 20, A4.

Chermak, Janie M., and Robert H. Patrick. 2002. Comparing tests of the theory of exhaustible resources. *Resource and Energy Economics* 24, no. 4:301–25.

Dyni, John R. 2006. Geology and resources of some world oil-shale deposits. USGS Scientific Investigations Report 2005-5294. June. http://pubs.usgs.gov/sir/2005/5294/ (accessed April 20, 2009).

Energy Information Administration (EIA). 2008. *International energy outlook 2008*. June 30. http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2009).pdf (accessed June 16, 2009).

———. 2009a. *International energy outlook 2009*. May 27. http://www.eia.doe.gov/oiaf/archive/ieo08/index.html (accessed June 11, 2009).

———. 2009b. Who are the major players supplying the world oil market? *Energy in brief: What everyone should know about energy*. January 28. http://tonto.eia.doe.gov/energy_in_brief/world_oil_market.cfm (accessed February 2, 2009).

Feuillet-Midrier, E. 2007. *Oil and gas exploration and production.* In *Oil and gas exploration and production: Reserves, costs, contracts*. Revised ed. Translated by Jonathan Pearse. Paris: Editions Technip.

Fuel subsidies: Crude measures. 2008. *The Economist*. May 29. http://www.economist.com/finance/displaystory.cfm?story_id=11453151 (accessed April 2, 2009).

Gaitan, Beatriz S., Richard S.J. Tol, and I. Hakan Yetkiner. 2006. The Hotelling's rule revisited in a dynamic general equilibrium model. Papers of the annual IUE-SUNY Cortland Conference in Economics. In *Proceedings of the Conference on Human and Economic Resources*, 213–38. Izmir University of Economics.

Gerling, J.P. 2007. Crude oil and natural gas liquids. In *2007 Survey of Energy Resources*, 41–92. World Energy Council 2007. http://www.worldenergy.org/publications/survey_of_energy_resources_2007/default.asp (accessed June 11, 2009).

Hamilton, James D. 2009. Causes and consequences of the oil shock of 2007–08. NBER Working Paper No. w15002, May.

Hotelling, Harold. 1931. The economics of exhaustible resources: The peculiar problems of mineral wealth. *Journal of Political Economy* 39, no. 2:137–75.

International Energy Agency (IEA). 2009. World Economic Forum: Oil industry might face future supply problems. Dow Jones. January 29, 2009. Press archives. http://www.iea.org/journalists/headlines.asp (accessed February 2, 2009).

International Energy Agency (IEA) and Organisation for Economic Co-Operation and Development (OECD). 2008. World energy outlook 2008. Paris.

Kaufmann, Robert K., and Cutler J. Cleveland. 2001. Oil production in the lower 48 states: Economic, geological, and institutional determinants. *Energy Journal* 22, no. 1:27–49.

Kovarik, Bill. 2003. The oil reserve fallacy: Proven reserves are not a measure of future supply. Radford University. http://www.runet.edu/~wkovarik/oil/ (accessed July 10, 2008).

Lepez, Vincent. 2007. Hydrocarbon reserves. In *Oil and gas exploration and production: reserves, costs, contracts*. Revised ed. Translated by Jonathan Pearse. Paris: Editions Technip.

Maugeri, Leonardo. 2009. Squeezing more oil out of the ground. *Scientific American*, April 1. http://www.sciam.com/article.cfm?id=squeezing-more-oil-edit-this (accessed April 2, 2009).

McColl, David. 2009. The eye of the beholder: Oil sands calamity or golden opportunity? Canadian Energy Research Institute.

Meyer, Richard F., and Emil D. Attanasi. 2003. Heavy oil and natural bitumen—strategic petroleum resources. U.S. Geological Survey. Fact Sheet 70-03, August. http://pubs.usgs.gov/fs/fs070-03/fs070-03.html (accessed October 10, 2009).

———. 2007. Natural bitumen and extra-heavy oil. In *2007 survey of energy resources*, 119–44. World Energy Council 2007. http://www.worldenergy.org/publications/survey_of_energy_resources_2007/default.asp (accessed June 11, 2009).

Organization of the Petroleum Exporting Countries (OPEC). 2008. *World oil outlook 2008*. http://www.opec.org/library/World%20Oil%20Outlook/WorldOilOutlook08.htm (accessed April 13, 2009).

Rogoff, Kenneth. 2006. Oil and the global economy. http://www.nes.ru/public-presentations/Papers/Oil%20and%20the%20Global%20Economy_Rogoff__v2.pdf (accessed June 11, 2009).

Schindler, Jörg, and Werner Zittel. 2008. *Crude oil: The supply outlook*. Rev. ed. Energy Watch Group. February. http://www.energywatchgroup.org/Oil-report.32+M5d637b1e38d.0.html (accessed October 2008).

Simmons, Matthew R. 2005. *Twilight in the desert: The coming Saudi oil shock and the world economy*. Hoboken, N.J.: John Wiley & Sons Inc.

Stevens, Paul. 2008. *The coming oil supply crunch*. Chatham House Report. August 7. http://www.chathamhouse.org.uk/publications/papers/view/-/id/652/ (accessed November 20, 2008).

Sweetnam, Glen. 2008. Long-term global oil scenarios: Looking beyond 2030. Energy Information Administration. Presented at the EIA 2008 Energy Conference, Washington, D.C., April 7.

U.S. Department of Energy. 2008. Enhanced oil recovery/CO2 injection. February. http://www.fossil.energy.gov/programs/oilgas/eor/ (accessed April 14, 2009).

U.S. Geological Survey (USGS). 2000. U.S. Geological Survey World Petroleum Assessment 2000—Description and Results. U.S. Geological Survey Digital Data Series 60. http://pubs.usgs.gov/dds/dds-060/ (accessed February 15, 2009).

———. 2008. Circum-Arctic resource appraisal: Estimates of undiscovered oil and gas north of the Arctic Circle. USGS Fact Sheet 2008-3049. http://pubs.usgs.gov/fs/2008/3049/fs2008-3049.pdf (accessed April 2, 2009).