Why Oil Will Cost $5 per Barrel in 2010

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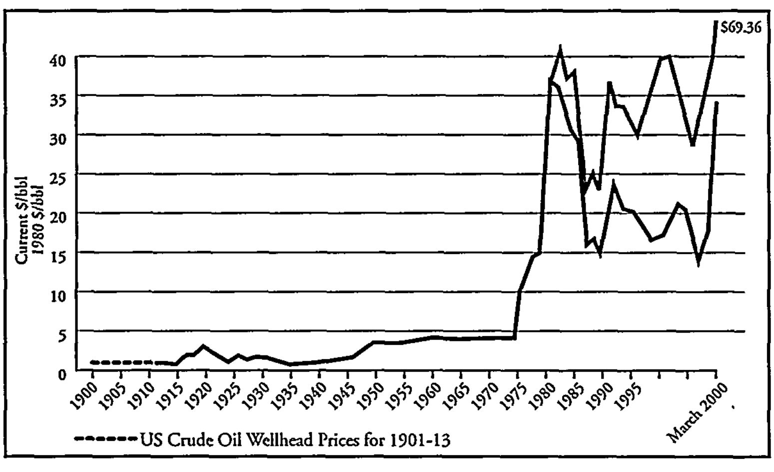
In the past year-and-a-half, the price of oil has fluctuated from as low as $9 per barrel—for West Texas Intermediate (WTI) crude, the standard basis for oil price quotation in the United States—to as high as $34 per barrel in March 2000.[1] This dramatic swing in price, which more than tripled in only 17 months, is not an unusual occurrence in the history of the oil industry over the past 30 years. There have been many periods of upheaval, and over the course of the 20th century the price of oil has gone from less than $2 per barrel to over $40 per barrel and almost back again. In 1980 dollars, this would be from $1 per barrel

FIGURE 1: West Texas Intermediate Average Posted Price



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to almost $70 per barrel, as shown in Figure 1. However, during the first seven decades of the century, when oil was produced and sold by private oil companies, the price was relatively stable at about $2 per barrel. Volatility began with the successful price hikes initiated by the Organization of the Petroleum Exporting Countries (OPEC) cartel countries in 1973. Given this volatility in price, it is important to consider what the appropriate price of oil should be according to reasonable principles.

The question of what is "reasonable" is certainly one of the controversial problems in determining an appropriate price for oil. For the OPEC countries, highly dependent on oil exports, the answer is clear: the price should be as high as possible so that oil revenues can support the economic development of these less-developed countries. However, this reasoning may not be completely correct. Indeed, in countries like the Netherlands, the wealth generated by the oil industry has caused a slowdown of growth in non-oil sectors, resulting in an overall drag on the whole economy (the famous "Dutch disease"). For the oil-importing countries, clearly the most desirable cost of oil is the lowest possible price since oil is an input into the production of many other products and, therefore, is a production factor whose lower cost would enable greater production of other goods and services. However, governments in oil-consuming countries often implement high taxes on gasoline, thus preventing consumers and businesses from reaping the benefits of low oil prices.[2] Additionally, it is important to consider the idea that lower oil prices stimulate greater oil consumption, thereby producing greater hydrocarbon pollution of the atmosphere—a worry to all countries concerned with global warming and the harmful impacts on health caused by auto-based air pollution and the burning of fossil fuels.

The choice of a best price for oil probably cannot come from considering the interests of producers or consumers alone. Perhaps a more useful way to state the question is: What price would market-based economics dictate under competitive conditions? From this perspective, one could evaluate adjustments to the economic price based on considerations of equity and non-economic social welfare. In the analysis below, we set out an explanation of the factors that contribute to determining the price of oil and show what that price should be under expected technological and competitive conditions in the current decade. By considering the geopolitics of the oil industry, we can provide an understanding of the implications of the economic pressures on OPEC and other governments' policies.

Our basic findings are first that the known supply of oil, in terms of proved reserves, has repeatedly increased, often dramatically, during the 20th century. (See Table 1)

TABLE 1: Proven Reserves, Oil Production, and Net Change in Reserves *(billion barrels)*

Decade	Proven Crude Oil Reserves at Beginning of Decade	Net Change in Reserves from Previous Decade	Oil Production for the Decade
1900	n.a.	–	
1910	n.a.	–	
1920	13.40	–	
1930	33.05	19.65	
1940	62.53	29.48	
1950*	103.63	41.10	
1960	275.70	172.07	
1970	539.76	264.06	208
1980	641.92	102.16	216
1990	1,001.57	359.66	246
2000	1,034.67	33.10	n.a.

*Started in 1952

SOURCES: Reserves data from *Oil and Gas Journal* data file, and from USGS "Distribution and Quantitative Assessment of World Crude Oil Reserves and Resources," 1983. Production data from annual *BP Sunsacau Review of World Oil/Energy*, 1971-1998.[3]

The demand for oil has also increased over the years, though not fast enough to use up the available supply. In addition, there has been a steady effort towards energy conservation as a result of the first oil shock of 1973 that followed the Arab-Israeli war and the subsequent shock in 1979 stimulated by the Iranian revolution. The renewed environmental concerns and increasing potential availability of competitive alternative energy sources such as fuel cells operating on natural gas or hydrogen as well as the substitution of oil by other cost-competitive fuels should push the value of oil down. For this reason the price of oil should approximate the cost of producing it in the least-efficient production location of the marginal producer. The price of oil should drop to this level because of the declining growth rate of demand for oil, as well as the increasing supply of reserves. With both of these pressures, there will be an excess supply of oil available in the market, leading to downward price pressure until at the margin the last drop of oil purchased has a price equal to the cost of producing that last drop (from the most costly, or least efficient, producer needed to supply total demand at that level). Given our expectations about the level of oil demand by the year 2010, and the supply of oil by OPEC countries, we expect that Venezuela will be the highest-cost OPEC producer whose output will be globally traded. The marginal cost of production in Venezuela will be similar to today's—namely about $5 per barrel.[4]

This situation is examined below, looking first at oil supply, then at oil demand, and then at the combination of these factors.

SUPPLY

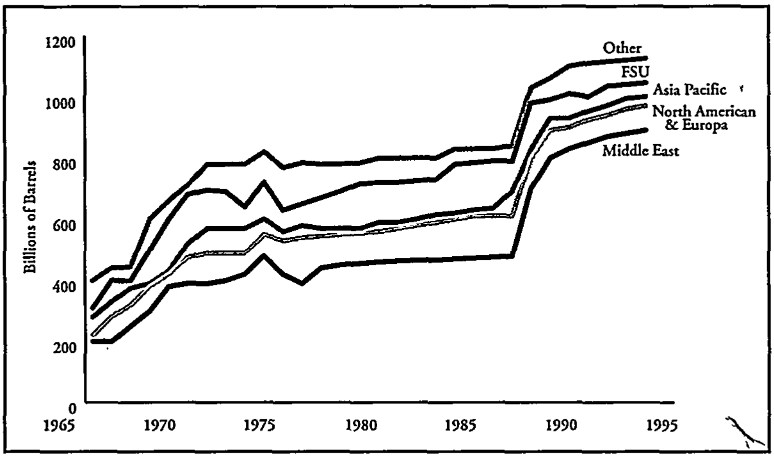
The supply of oil can be viewed in three ways. The first method is to look at proven reserves, or the amount of oil known to exist and be technically extractable. The second method consists of considering the amount of oil that is economically feasible to extract at given oil prices and lifting costs. Finally, the supply of oil may be quantified by examining the probable reserves, or the amount that is known to be discovered plus the amount that is anticipated to exist based on geological conditions. These distinctions are not trivial given the sensitivity of market prices to the levels of oil supply. Indeed, history has shown that market prices for oil react strongly to news of increases in the global oil supply. Examples of this include discoveries in Venezuela in the 1930s, in Saudi Arabia in the 1940s, in Alaska and the North Sea in the 1960s, in the Gulf of Mexico and West Africa in the 1970s, in Colombia in the 1980s, and in the Caspian Sea in the 1990s.

The amount of oil in proven reserves has fluctuated substantially over the past 100 years. Oil became a significant commodity when the automobile was established as an important form of transportation in the first decade of the 20th century. By 1914, the U.S. Bureau of Mines forecast that the supply of oil would last no longer than 10 years. However, by the time of the Great Depression, world oil reserves were estimated at about 50 billion barrels in total. Despite continued forecasts of declining reserves, new discoveries caused the estimates to fluctuate and even increase through the 1960s. With the onset of the first OPEC oil price shock in 1973, doomsday predictors once again saw the end of oil reserves in the not-too-distant future. Yet major discoveries increased proven reserve estimates to more than 600 billion barrels in 1980. With the development of new technologies in the past 20 years, proven reserves have again increased to over one trillion barrels worldwide. Figure 2 shows the trajectory of proven oil reserves during the latter half of the 20th century, though the source of these data provides slightly higher values of reserves from previously cited data. Increases in proven oil reserves come primarily from three fundamental sources:

1. Discovery of new oil reserves around the world;
2. Technological advances that make recovery of known reserves more efficient;
3. Statistical games played by the principal oil producers (i.e. incorrect data).

Each of these factors requires careful consideration.

FIGURE 2: Proven Oil Reserves, Second Half of the 20th Century
(Left scale: billions of barrels)



Discovery of new oil reserves around the world has occurred frequently through the past century, as is evident from the figure and from Table 1. After the initial discoveries in Pennsylvania and Ohio during the mid-1800s, the industry grew rapidly in the first part of the 20th century with the introduction of the automobile. The discovery of major fields in Texas and Oklahoma in the 1920s and the discovery of enormous reservoirs in Mexico and Venezuela in the 1930s marked the beginning of the continued upward trajectory of proven reserves experienced throughout the rest of the century. Unquestionably, the main discoveries of the century were the Iran, Iraq, and Saudi Arabia fields in the 1940s and the offshore fields in the North Sea in the 1960s.

However, the last two decades have differed importantly from the rest of the century because increases in reserves have come from both new discoveries and new technology. The discovery of new reserves jumped sharply in this period primarily due to technological advances in exploration. Texaco Chairman Peter Bijur noted, "Based on seismic data analyzed using 3-D visualization technology, we have the confidence to drop a drill bit into water 7,000 feet in depth and drill down—and even sideways—another 20,000 feet. From a single seven-inch bore hole, modern-day explorers can discover hundreds of millions of barrels of oil."[5]

In addition to the technology of exploration, there have been major advances in the ability of oil companies to extract the maximum amount of oil from the reservoirs. Bijur further notes, "Technology also allows us to increase yield. Where 40 percent was considered impressive just two decades ago, we can now extract 70 percent or more of a field's reserves."[6]

A final complexity in measuring oil reserves is the gamesmanship used by oil-producing countries to inflate or deflate their reserve estimates. It may serve the producers well to show growing demand and declining supply in order to convince the public that oil reserves are declining. By understating its reserves, a given country can contribute to apparent supply shortages, which are likely to help force the price of oil up. On the other hand, a country can improve its bargaining position within OPEC by declaring higher oil reserves than those it truly possesses. Furthermore, a country may sell some oil secretly into the market while appearing to be keeping to its agreed production limit within the cartel. Thus, the producing countries can manipulate oil reserves data to suit their aims.[7] Table 2 below illustrates drastic changes in the reserves published by the producing countries, underlining the fact that such occurrences are not just occasional oddities.

TABLE 2: Spurious Reserve Revisions *(Billion barrels)*

	Abu Dhabi	Subai	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	162.6	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
P50 Estimates by Petroconsultants								
1996	57.7	1.0	64.7	77.4	52.0	8.2	222.6	27.4
Annual Production								
1998	0.69	0.11	1.31	0.77	0.66	0.20	2.95	1.23

SOURCE: Dr. C.J. Campbell, "Geopolitics of Energy," Issue 20, December 1998.

The table highlights the enormous increases in declared oil reserves by Abu Dhabi, Dubai, Iran, and Iraq in 1988, Saudi Arabia in 1990, and Venezuela in 1988. In fact, most of the Middle Eastern OPEC countries declared huge increases in reserves in 1988 even though no technological breakthroughs or discoveries were declared in that year. This kind of data reliability question adds another aspect of doubt to the ability to draw economic conclusions about oil prices. Researchers can only try to mitigate this problem through careful analysis.

However, even if we ignore the data discrepancies that reduce reserve estimates, the trajectory of oil prices will still be downward because new discoveries and new lifting technologies will increase the overall oil reserves. As long as demand is at all sensitive to the price of oil, these increases in reserves will produce a lower oil price. The *International Energy Outlook 98* expects that oil prices will generally stay low because non-OPEC nations will be able to continue to expand oil production in the short term. Improvements in technology associated with oil exploration, development, and production will allow the non-OPEC producers to achieve these expectations.[8] These influences have kept the price of oil from rising even in the face of increasing demand from global oil consumers over the years—although certainly the price run-up in early 2000 presents a strong counter argument. It is clear that OPEC policy decisions to drastically cut supply during the past 30 years have effectively influenced oil prices on at least three occasions: 1973-1974, 1979-1980, and 1999-2000.

Thus, it is clear that the overall supply of oil reserves has provided only pressure toward lower oil prices during the past several decades. The decisions by OPEC countries in particular to withhold production of some of those reserves into oil for refining into downstream products such as gasoline have produced the occasional supply contractions and consequent price hikes that accompany the general pressure for price declines. Consider next the impact of demand conditions.

DEMAND

At the beginning of the 20th century, oil was used primarily for the production of kerosene for lighting and heating residential and industrial buildings. As the automobile became a popular mode of transportation in the early 1900s, gasoline demand overtook kerosene demand and became the dominant fuel. This pattern has prevailed ever since, as industrialization spread around the world. Even as European and North American growth slowed in the latter part of the century, increases in the emerging automobile markets caused continued overall growth in oil demand.

Demand is growing for both transportation fuel and electric power worldwide. The demand for oil grew during the 1990s at about 1.1 percent per year.[9] Despite this continued growth, there are two trends that will soon reduce demand for oil and gasoline. The first is the greater efficiency in operating internal combustion auto engines.

The average efficiency of a passenger car is about 13 percent (approximately 20 miles per gallon). This means that 87 percent of the fuel is wasted in exhaust emissions and other unproductive uses "...because about five to seven gallons of fuel are required to deliver one gallon worth of energy to the wheels of a conventional car..."[10] With major improvements in fuel injection, some of the new automobile engines, especially diesel engines, achieve efficiency levels of about 20 percent (approximately 27-28 miles per gallon). Daimler-Chrysler and General Motors have claimed that they will achieve 40 percent efficiency within five years using diesel fuel. While this is a major improvement over past efficiency, it is still quite low relative to the amount of energy wasted. Of course, the most fuel-efficient alternative at the moment is the replacement of the internal combustion engine with the fuel cell. Development work in this field by automakers is very active and promising, and is encouraged by both environmental groups and government agencies.[11]

The second trend that will reduce gasoline demand is the desire to further reduce vehicle exhaust emissions. Governments around the world have been recommending that carbon dioxide emissions must be reduced to avoid climate changes. In 1992, the United Nations convened a forum, the Framework Convention on Climate Change, to consider this problem and to recommend policy guidelines to member countries. In the 1997 Kyoto Climate Control Protocol, participating countries agreed to recommend the adoption of a goal of extensive pollution reduction. [12] In highly simplistic terms, this agreement, if ratified by the member countries of the U.N. Convention on Climate Change, will call for the reduction of fossil-fuel pollution to five percent below the level that existed in 1990. For the emissions targets specified by the Protocol to be achieved by industrialized countries solely through reduction of fossil fuel use, projected energy demand in 2020 would have to be scaled back by 40 to 60 quadrillion Btu—equivalent to between 20 and 30 million barrels of oil per day. The expectation is that, with fuel-switching opportunities, emissions trading, and other offers allowed under the Protocol, such as reforestation, a more modest reduction in fossil fuel use will be needed.[13]

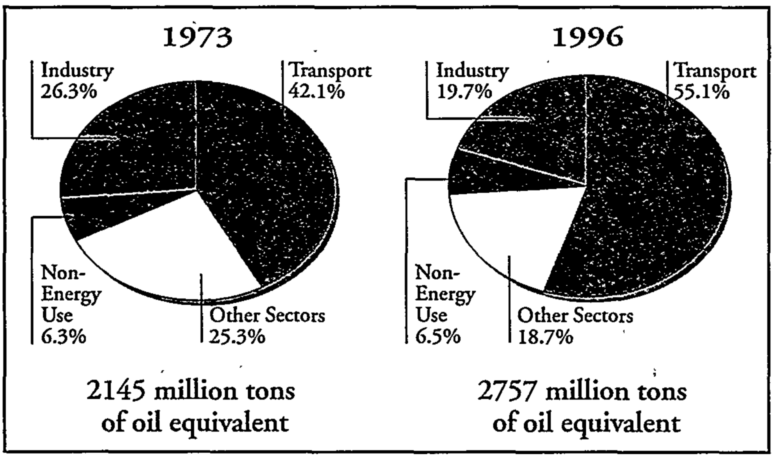
According to the International Energy Agency (IEA), a looming uncertainty not addressed in *IEO 98* relates to the consequences that may flow from commitments under the Kyoto Protocol. In North America, half of all growth in carbon emissions in the *IEO 98* projections is associated with increased use of oil, especially in transportation. The Kyoto initiative could prompt changes in the fuel use characteristics of motor vehicles, with the possibility that as much as eight million barrels per day of oil demand growth—estimated at 12.9 million barrels per day for all the industrialized countries—could be curtailed.[14]

To one extent or another, this environmental concern will require conversion of auto engines to alternative energy inputs, such as low-carbon fuels and hydrogen. The technology for building hybrid and fuel-cell cars is already being used with functioning prototypes. Yet, the current hurdle is cost. A fuel-cell-driven engine costs about $9,000 per engine to produce. Additionally, the cost of amortizing new fuel storage facilities for customers to fill up must also be considered. It is still not clear what would be the best marketing infrastructure to refuel fuel-cell cars. Also, it remains to be seen how quickly assembly costs can be reduced by improvements in production techniques and economies of scale.

Additionally, the efficiencies of using natural gas for power generation might lead to the replacement of oil in this capacity. While still a fairly wasteful process, gas cycle units will eventually result in energy efficiencies of about 50 percent, compared with 35 percent efficiency using oil.[15]

Use of oil for non-automotive applications includes two main client sectors: airlines and ambient heating, and industrial uses. Use of oil in production of petrochemicals is negligible in this context, constituting only about three percent of total oil production. The distribution of oil use across industrial sectors for 1973 and 1996 is shown in Figure 3.

FIGURE 3: 1973 and 1996 Shares of World Oil Consumption



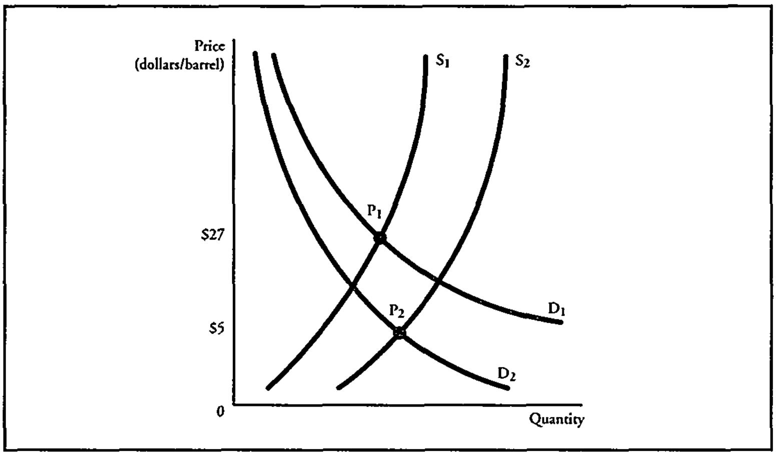
SOURCE: International Energy Agency, "Key World Energy Statistics, 1998," 33.

The above figure illustrates that transportation fuel consumption clearly dominates among oil uses, accounting for 55 percent of total use in the most recent year shown. Electric power generation constitutes another 20 percent of total usage, followed by residential and commercial heating, farming, etc. Finally, the use of oil in non-energy applications such as production of petrochemicals and asphalt for paving makes up only 6.5 percent of total use, nearly constant since the 1970s.

COMBINING SUPPLY AND DEMAND

The combination of increases in oil supply and reduction of oil demand will create a scenario leading to the convergence of oil prices with the marginal cost of production of the least-efficient producer. Figure 4 describes this tendency, using quantities of oil based on today's proven reserves and demand characteristics.

FIGURE 4: The Oil Market in the Early 21st Century



Simply put, the S_1 curve is the supply of oil in January 2000 based on all existing conditions and the West Texas Intermediate quotation. The supply curves are fairly steep, reflecting low supply elasticity over the short term. The relative inelasticity of oil supply results from the fact that the amount of oil available to the market is limited to the amount of reserves actively being produced, while a certain amount of additional oil requiring higher extraction costs would be available at higher prices. The demand curve D_1 is likewise the sum of all uses of oil including fuel for motor vehicles, jet fuel, electric power generation, and petrochemicals. These demand curves are not very steep, reflecting the possibility of replacing oil with alternative energy sources at higher prices. The intersection point of the two curves is the price of WTI, or $27 per barrel according to the S_1 and D_1 curves. The authors' estimates of supply curve S_2 and demand curve D_2 reflect the increased-supply and decreased-demand conditions and influences described in the previous sections. P_2 reflects the projected price of WTI in January 2010. These data are all presented in terms of price levels in the year 2000, not taking future inflation into account.

D_2 shows a decline in oil demand based principally on substitution of natural gas and on environmental restrictions that will force automakers to use alternative fuels, beginning with low-carbon fuels and leading to fuel cells that burn hydrogen.

If supply conditions do not change, the demand reduction alone will produce a substantial drop in the oil price during the decade ahead, barring any aggressive OPEC production constraint outside of market forces. S_2 reflects the continued application of recent technology to existing oil fields as well as the expected discovery of additional fields. This estimate is largely an extrapolation of the past oil supply experience from 1970 until 2000. Even if demand conditions do not change, this supply shift will cause a downward movement in oil prices. Thus, when the two shifts are combined, the supply and demand lines intersect at P_2, the marginal cost of the highest cost major producer, estimated to be $5 per barrel in 2010.

This graphical presentation illustrates that the price will shift toward the production cost of the highest marginal cost producer who is identified by examining the overall demand for oil in the next ten years and the various available sources of supplies. For this level of demand, the highest marginal cost producer is Venezuela.[16]

KEY DRIVERS OF OIL PRICES THIS DECADE

Why should one believe that oil prices will move down to $5 per barrel by the end of this decade? The principal drivers of this major downturn in price are the replacement of oil by natural gas in power generation and replacement of gasoline for powering motor vehicles, initially by low-carbon fuels and then by hydrogen-based fuel cells, along with the continuing decline in the cost of finding and producing oil.

The development of technology for the replacement of gasoline is already a reality. Daimler-Chrysler, Toyota, and General Motors all have announced the introduction of fuel-cell-driven cars for sale beginning in 2004. Amy Myers Jaffe and Robert A. Manning wrote recently in *Foreign Affairs* that:

> All the major manufacturers have made large investments in post-internal combustion cars, and already have new prototypes of 'hybrid' cars (that is, cars that run on both gasoline and electricity) and fuel-cell cars to be mass-marketed by 2005-2015, if not sooner. Toyota and Honda are already marketing hybrid models in the United States that [they claim] get 80 miles to the gallon, and experts say that by 2015 these post-combustion cars will make up at least 20 percent of new vehicles.[17]

FUEL CELLS

Fuel cells operate on the same basic principle as batteries to generate electricity. One key difference is that their fuel is external rather than internal so they do not need to be recharged. Therefore they can run as long as fuel is available. A single fuel cell generates only a small amount of electricity, so many cells are needed to create enough power to run a car.

This switch to fuel cell cars will occur over several years. However, given the heightened concern for environmental degradation and climate change (especially smog in cities, ozone depletion, and global warming), the process is expected to move fairly quickly. Pollution control has become a central concern of governments around the world and is very likely to lead to policies that meet the Kyoto Protocol spirit, if not the published targets.

Even with a pessimistic outlook on the likely success of major environmental protection efforts, the automobile engines that use gasoline are becoming much more efficient. Automakers are predicting that they will achieve an average of over 30 miles per gallon for vehicles produced in the year 2005, compared with about 20 miles per gallon today. Efficiency is being achieved by the more intensive use of diesel engines, through the use of hybrid gasoline-electric powered vehicles, and by using gasoline to produce hydrogen-run fuel cells.

Additionally, the use of oil is also under attack for environmental reasons. Fortunately fuel-cell technology is applicable here as well. Fuel cells have demonstrated the ability to channel over 50 percent of the input into usable energy output, relative to the existing use of oil, which is 35 percent efficient.

GOVERNMENT POLICY CONSIDERATIONS

Many current analyses of the oil industry focus on using policy to force the price of oil down from its existing lofty height. The arguments generally support intervention from industrial countries' governments to pressure oil-producing countries to increase output. Yet, some analysts see no problem with the high price since they expect it to drop rapidly in the near future due to suppliers' interest in taking advantage of the windfall profits now available.

It is just this kind of timing that may lend support for the Kyoto Protocol and other environmental protection initiatives that will require reduced emissions. This may stimulate development of more cost-competitive fuel cells and other technologies based on non-oil energy sources. If the backlash against high oil prices is strong enough, the push for fuel cells could easily force the replacement of a large percentage of gasoline-powered automobiles by 2010. Likewise, the installation of fuel cells for electric power generation could dramatically cut the use of oil for this purpose over the next decade.

Even without this added pressure, the environmental movement has demonstrated (in the 1999 Seattle protests against the World Trade Organization, for example) that it can mobilize people and public opinion sufficiently to bring the global warming issue into the limelight, potentially forcing governments to undertake pro-environment policies much sooner than might have been expected only a few years ago.

Consistent with the Kyoto Protocol, governments of industrial countries are likely to begin implementing regulations that will give private industry financial incentives to voluntarily reduce its carbon emissions. Furthermore, pollution regulations will be tightened and incentive policies will be implemented, allowing companies to trade pollution credits among themselves. The effect of these policies will be an overall reduction in carbon dioxide emissions and encouragement to use fuel cells and natural gas to replace oil in both motor vehicles and power production.

The most logical recommendation for governments in consuming countries is to place incentives on the use of fuel-efficient machines. This will have two desirable consequences: (1) helping to reduce the dependency on cartel-influenced oil and its price; and (2) helping to reduce the level of atmospheric contamination, particularly of carbon dioxide that contributes to global warming.

THE GEOPOLITICS OF THE OIL PRICE

The above discussion may appear sound on economic grounds but out of touch with political realities of OPEC strategy and consuming-country government policies. Certainly, the argument takes the consuming-country governments into account by reasoning that they are likely to implement significant pollution-abatement policies in this decade. However, with regard to the sources of oil supply, we can look at the distribution of production and the potential impact of various OPEC strategies. Table 3 shows the current and estimated demand for oil and production of oil for the year 2010 by region and by OPEC members as the key suppliers.

The top half of this table projects that the current level of global oil consumption of approximately 74 million barrels per day is expected to rise to about 101 million barrels per day by the end of the decade, according to the International Energy Agency. Given the demand factors discussed above, we expect the demand for oil to grow more slowly than the IEA projections. In conservative terms, the authors anticipate that increasing the efficiency in automobile use of gasoline from an average of 20 miles per gallon to 28 miles per gallon will reduce demand for oil by five million barrels per day. Additionally, stricter environmental policies will cut another eight million barrels per day from consumption by switching auto and electric power fuel to natural gas and hydrogen, leaving a total demand of about 88 million barrels per day.

The supply of oil today comes primarily from non-OPEC sources and this reality will not change. As shown in the above table, one-third of total current supply comes from OPEC countries while two-thirds comes from the other producing countries including the United States, Russia, Mexico, and Norway. The International Energy Agency expects the increase in 2010 demand for oil to be supplied mainly by OPEC countries, estimating that OPEC output will increase to 48.8 million barrels per day, compared with 27.5 million barrels per day presently. We expect a smaller increase in OPEC production to about 39 million barrels per day by 2010. In either case, the increases in oil output will be subject to the OPEC countries' willingness and ability to raise their production.[18]

TABLE 3: Oil Supply and Demand, 2000 and 2010

		Year 2010 (estimates)	
	Year 2000	IEO	Authors
Demand (millions of barrels per day)			
OECD countries	47.1	52.0	41.0
Non-OECD	26.9	49.4	47.4
Total demand	74.0	101.4	88.0
Supply (millions of barrels per day)			
Non-OPEC	46.5	52.6	49.0
OPEC	27.5	48.8	39.0
Total supply	74.0	101.4	88.0
OPEC production by country (mb/d)			
Saudi Arabia	8.9	16.5	12.0
Iran	3.7	5.2	3.9
Venezuela	3.6	4.7	4.2
UAE	2.4	4.8	3.5
Kuwait	2.1	5.1	4.3
Nigeria	2.3	6.1	5.2
Iraq	1.7	3.5	3.0
Others	2.8	2.9	2.9
Total OPEC	27.5	48.8	39.0

SOURCES: International Energy Agency, *International Energy Outlook, 1998;* authors' estimates.

Looking specifically at OPEC output by country, it is clear that Saudi Arabia holds the key to future production. Currently, this country doubles the production capacity of any other producer and it is expected to increase to triple all other countries' production in 2010, except for Nigeria, which is growing rapidly due to active investment by private oil companies. The increased output of Saudi Arabia is expected due to the low cost associated with marginal production and the fact that oil produced sooner will probably generate a higher present value of income than oil produced later. For the same reason, we expect that Kuwait will increase its output substantially. While one cannot predict with any certainty these production shifts over time, the capacity clearly exists. If the OPEC countries do not fill in the gap between supply and demand, then the non-OPEC producers may do so. Alternatively, consumption may drop to lower levels more quickly than projected in our conservative table, due to more ambitious government conservation policies.

The OPEC cartel policy could put pressure on the oil price in the year 2010, just as in the current world. However, in 2010 there will be readily available and less costly alternatives for energy supply. Therefore, non-OPEC production will be able to fill much of the gap if OPEC successfully keeps the price above the marginal cost of $5 per barrel between now and the end of the decade. Also, within OPEC, the trend is to allow foreign private oil companies to carry out new exploration, production, and transportation of oil. This means that in the future it will be more difficult for the countries to choose to reduce their oil supply because increasing amounts of that supply will be in the hands of the private oil companies. At most, it appears that cartel strategy could slow the trend toward $5 per barrel, but certainly not stop or reverse the trend.

In conclusion, the combined activities of technology and private oil companies are producing more abundant oil at lower costs. Technology will also contribute by producing more efficient machines that will gradually reduce demand for oil. The social and governmental demands for reduced pollution from auto emissions and from power generation also portend a move to reduce oil consumption, by switching to alternative energy sources such as fuel cells. The result will be a lower price for crude oil, not much higher than the one that prevailed in the first seven decades of the last century.[19] ■

NOTES

[1] "Let's look again at what happened in 1998. In the 12 months to December 1998, average monthly crude oil prices declined 50 percent or $14 per barrel. Brent closed on December 10, 1998 at $9.13 per barrel. In the subsequent nine months, Brent appreciated an astonishing 150 percent or $15 per barrel. This is not stability; it is extreme volatility." Robert Priddle, International Energy Agency, December 9, 1999. (Brent crude is quoted for the North Sea oil traded in the London market. It is 3 percent to 6 percent lower than the West Texas Intermediate quotes for U.S. oil. Note by the authors.)

[2] "Even though the politics of oil have become less divisive, some outdated attitudes unfortunately persist in some quarters. One remnant is excessive product taxation. In some Organization for Economic Cooperation and Development countries, for example, the composite of oil product price is between $110 and $120 per barrel. Only $20 to $30 of that goes toward actual production, transportation, refining, and marketing costs. The rest, something like $90 to $100, goes to government as consumption taxes." Ali Al-Naimi, Minister of Petroleum and Mineral Resources, Saudi Arabia, December 9, 1999.

[3] These estimates are certainly subject to argument. For example, a 1944 study for the U.S. War Production Board showed global estimated crude oil reserves of 55 billion barrels for 1940; a study by the USGS in 1920 showed estimated global reserves of 43 billion barrels at that time.

[4] The cost to produce a barrel of Persian Gulf oil in OPEC nations ranges between $0.99 and $1.49 per barrel, depending on oil field size. DOE/IEA 0484 (98), *International Energy Outlook.*

[5] Peter Bijur, "A New Era for Energy Suppliers: Challenges and Opportunities," speech at Center for Strategic and International Studies Conference, Washington, DC, December 8-9, 1999.

[6] Ibid.

[7] Of course, the countries cannot all leak undeclared reserves into global oil supply without causing the price of oil to decline. Consequently there is a natural limit to this cheating, namely the recognition that too much undeclared oil exporting will cause the cartel's influence on prices to diminish.

[8] International Energy Agency, *International Energy Outlook 1998.*

[9] International Energy Agency, *Key World Energy Statistics 1998*, 33.

[10] Paul Hawken, et al., "Reinventing the Wheels," in *Natural Capitalism*, 28.

[11] See, for example, Hawken et al., 22.

[12] See Michael Grubb, *The Kyoto Protocol: A Guide and Assessment* (London: Royal Institute of International Affairs, 1999).

[13] International Energy Agency, *International Energy Outlook, 1998*, 2.

[14] Ibid., 3.

[15] Research and development efforts are under way to design fuel cells that could be used to generate electricity. In a few instances, large-scale demonstration projects have been employed, but with limited success. In other cases, smaller units have been sold in niche markets, predominantly in situations in which they are used as backup systems where continuity of electric supply is imperative. The major problem to be overcome before fuel cells can be deployed widely for power generation is that of cost, from $3000-$4000 per kilowatt, contrasted with $500 to $1000 per kilowatt from a conventional gas-fired combustion turbine. Another problem is service life. Commercial fuel-cell power plant applications lasting more than 10 years have not been demonstrated as being feasible, but electric utility companies expect a service life of at least 20 years for the equipment that they purchase.

[16] Estimated costs of marginal production are: Saudi Arabia, Kuwait, and UAE, $1 per barrel; Iran, Iraq, and Nigeria, $2-3 per barrel; Venezuela and other OPEC, $4-5 per barrel. Other countries have higher estimated marginal per barrel production costs in the year 2000. Source: authors' estimates.

[17] Amy Myers Jaffe and Robert A. Manning, *Foreign Affairs* 79(1) (January-February 2000): 20-21.

[18] If the OPEC countries see that high oil prices cause more rapid replacement of oil with other fuels, then this factor will also stimulate them to raise output and allow prices to fall.

[19] Sheikh Zaki Yamani has made a similar projection of low oil prices within the next five years, due to rising supplies of crude oil and reduced demand due to fuel cell technology, in his statement in June, 2000, cited at: www.telegraph.com and in *Tomorrow's Oil* (June 2000): 1-4. This same perspective has been echoed by EXXON President Lee Raymond in recent speeches, in which he emphasizes the declining cost of producing the oil.