Chapter 2

Liquid Fuels

World liquids consumption increases from 84 million barrels per day in 2005 to 99 million barrels per day in 2030 in the IEO2008 high price case. In the reference case, which reflects a price path that departs significantly from prices prevailing in the first 8 months of 2008, liquids use rises to 113 million barrels per day in 2030.

The demand for liquid fuels and other petroleum[4] increases strongly in the *IEO2008* reference case. World use of liquids grows from 83.6 million barrels oil equivalent per day[5] in 2005 to 95.6 million barrels per day in 2015 and 112.5 million barrels per day in 2030. Much of the increase in total liquids consumption is projected for the nations of non-OECD Asia and the Middle East, where strong economic growth is expected, and nearly three-quarters is projected for use in the transportation sector.

In addition to the reference case, *IEO2008* includes a high price case that helps to quantify the uncertainty associated with long-term projections of future oil prices. In the high price case, which reflects a price path that is closer, in real terms, to prices prevailing during the first 8 months of 2008, world liquids consumption increases by only 0.7 percent per year on average from 2005 to 2030, as compared with 1.2 percent per year in the reference case. World liquids use in the high price case totals 99.3 million barrels per day in 2030, as the liquids share of total energy consumption declines from 37 percent in 2005 to 30 percent in 2030.

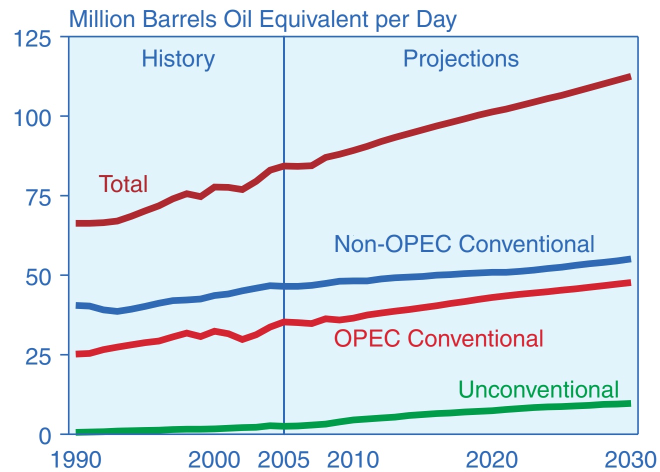
To meet the increment in world liquids demand in the *IEO2008* reference case, 28 million barrels per day of additional supply will be required by 2030 (Figure 26 and Table 3). In the reference case projections, sustained high world oil prices bolster the economic prospects for development of unconventional resources and enhanced recovery of conventional resources, as well as for conventional supplies in OPEC and a number of non-OPEC nations (such as Kazakhstan and Brazil) with significant potential for development of conventional resources. Total non-OPEC liquids production in 2030 is projected to be 15 million barrels per day higher than in 2005, representing 53 percent of the increase in total world production over the 2005 total.

Unconventional resources (including oil sands, extra-heavy oil, biofuels, coal-to-liquids [CTL], and gas-to-liquids [GTL]) from both OPEC and non-OPEC sources are expected to become increasingly competitive in the reference case (Figure 27). World production of unconventional resources, which totaled only 2.5 million barrels per day in 2005, increases to 9.7 million barrels per day in 2030, accounting for 9 percent of total world liquids supply in 2030 on an oil equivalent basis. Biofuels, including ethanol and biodiesel, will be an increasingly important source of unconventional liquids supplies, largely because of the growth in U.S. biofuels production. In the *IEO2008* reference case, U.S. biofuels production in 2030 is projected to be 1.2 million barrels per day, accounting for nearly one-half of the increase in world biofuels production over the projection period.

World Liquids Consumption

World liquids consumption in the *IEO2008* reference case increases from 84 million barrels per day in 2005 to 113 million barrels per day in 2030, mainly as a result of increases among the emerging economies of the world, where strong economic growth is expected throughout the projection period. Liquids remain the

Figure 26. World Liquids Production in the Reference Case, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea.. **Projections:** EIA, Generate World Oil Balance Model (2008).

[4]Liquid fuels and other petroleum (also referred to as liquids) include petroleum-derived fuels and non-petroleum-derived fuels, such as ethanol and biodiesel, coal-to-liquids, and gas-to-liquids. Petroleum coke, which is a solid, is included. Also included are natural gas liquids, crude oil consumed as a fuel, and liquid hydrogen.

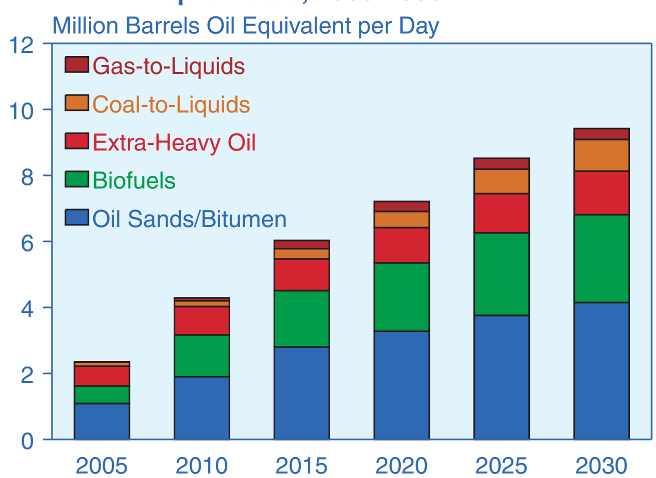
[5]Throughout this chapter, liquids consumption and production are reported in million barrels oil equivalent per day.

Table 3. World Liquid Fuels Production, 2005-2030
(Million Barrels Oil Equivalent per Day)

Source	2005	2010	2015	2020	2025	2030	Average Annual Percent Change, 2005-2030
OPEC							
Conventional Oil[a]	35.3	36.5	39.8	43.0	45.3	47.7	1.2
Extra-Heavy Oil	0.6	0.9	0.9	1.0	1.1	1.3	3.0
Bitumen	0.0	0.0	0.0	0.0	0.0	0.0	—
Coal-to-Liquids	0.0	0.0	0.0	0.0	0.0	0.0	—
Gas-to-Liquids	0.0	0.0	0.2	0.2	0.3	0.3	—
Biofuels	0.0	0.0	0.0	0.0	0.0	0.0	—
OPEC Total	**36.1**	**37.4**	**40.9**	**44.4**	**46.7**	**49.3**	**1.3**
Non-OPEC							
Conventional Oil[a]	46.5	48.2	49.6	50.9	52.5	55.1	0.7
Extra-Heavy Oil	0.0	0.0	0.0	0.0	0.0	0.1	—
Bitumen	1.1	1.9	2.8	3.3	3.8	4.2	5.5
Coal-to-Liquids	0.1	0.2	0.3	0.5	0.7	1.0	8.2
Gas-to-Liquids	0.0	0.1	0.1	0.1	0.1	0.1	—
Biofuels	0.5	1.3	1.7	2.1	2.5	2.7	6.7
Non-OPEC Total	**48.2**	**51.8**	**54.7**	**57.0**	**59.8**	**63.2**	**1.1**
World							
Conventional Oil[a]	81.9	84.8	89.4	93.9	97.8	102.9	0.9
Extra-Heavy Oil	0.6	0.9	1.0	1.1	1.2	1.3	3.2
Bitumen	1.1	1.9	2.8	3.3	3.8	4.2	5.5
Coal-to-Liquids	0.1	0.2	0.3	0.5	0.7	1.0	8.2
Gas-to-Liquids	0.0	0.1	0.2	0.3	0.3	0.3	—
Biofuels	0.5	1.3	1.7	2.1	2.5	2.7	6.7
World Total	**84.3**	**89.2**	**95.7**	**101.3**	**106.5**	**112.5**	**1.2**

[a]Includes conventional crude oil and lease condensate, natural gas plant liquids (NGPL), and refinery gain.
OPEC = Organization of the Petroleum Exporting Countries (OPEC-13).
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use. **Projections:** Generate World Oil Balance Model (2008).

Figure 27. World Production of Unconventional Liquid Fuels, 2005-2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, Generate World Oil Balance Model (2008).

most important fuels for transportation, because there are few alternatives that can compete widely with liquid fuels. With world oil prices remaining relatively high through 2030, the increasing cost-competitiveness of non-liquid fuels causes many stationary uses of liquids (that is, for electric power generation and for end uses in the industrial and building sectors) to be replaced by alternative energy sources, which increases the transportation share of liquids consumption. On a global basis, the transportation sector accounts for 74 percent of the total projected increase in liquids use from 2005 to 2030; the industrial sector accounts for virtually all of the remainder (Figure 28).

Strong expansion of liquids use is projected for the non-OECD countries, fueled by robust economic growth, burgeoning industrial activity, and rapidly expanding transportation use. The most robust regional growth in liquids consumption is projected for non-OECD Asia and the Middle East (Figure 29). In non-OECD Asia, liquids use expands by 16 million barrels per day over the projection period, from 15.3 million barrels per day in 2005 to 30.8 million barrels per day in 2030. Among the nations of non-OECD Asia, China and India account for much of the growth in liquids demand, and together they account for 11.5 million barrels per day (74 percent) of the regional increment in liquids use. Liquids consumption in non-OECD Asia is projected to surpass that in the United States (currently the world's largest liquids-consuming nation) by 2020, and in 2030 it is projected to exceed U.S. consumption by nearly 40 percent.

In the Middle East, liquids consumption is projected to increase by 3.6 million barrels per day from 2005 to 2030. Three major factors contribute to the growth in oil consumption in the Middle East:

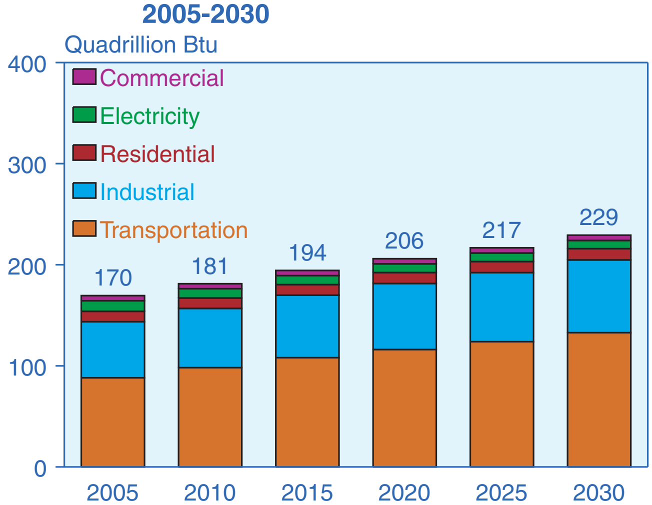
- First, although the population in the Middle East is relatively small, the nations of the region have recorded relatively high birth rates over the past several decades, so that at present a substantial portion of the population is young and reaching driving age, increasing the demand for personal motorization [*1*].
- Second, energy use is heavily subsidized in many of the resource-rich nations of the region. In Iran, for example, gasoline prices average $0.42 per gallon, shielding consumers from the high free-market price of gasoline. As a result, consumption has continued to increase strongly in Iran, by an estimated 9 percent per year since 2004 [*2*].
- Finally, many of the world's major oil-exporting nations are in the Middle East, and as world oil prices have continued to rise, so too have their per-capita incomes. As standards of living have improved, demand for personal motorization has increased, and many nations of the region have seen double-digit growth in automobile sales in recent years [*3*].

In contrast to the non-OECD nations, liquids consumption in the OECD nations generally grows more slowly, reflecting expectations of slow growth or declines in population and relatively slow economic growth in most of the OECD nations over the next two decades. Whereas liquids consumption in the non-OECD countries is expected to increase by 2.2 percent per year on average from 2005 to 2030, OECD liquids use increases by 0.3 percent per year. Sustained high world oil prices are expected to have a more pronounced impact on the use of liquids in the OECD countries, where many consumers are not shielded from high market prices by subsidies like those in place in many of the larger non-OECD consumer nations, including China, India, and many of the OPEC member countries. As a result, OECD countries respond more rapidly to high oil prices in the *IEO2008* reference case projection, switching away from liquids wherever possible and reducing demand in the transportation sector by adopting more efficient motor vehicles and reducing vehicle-miles traveled.

World Oil Prices

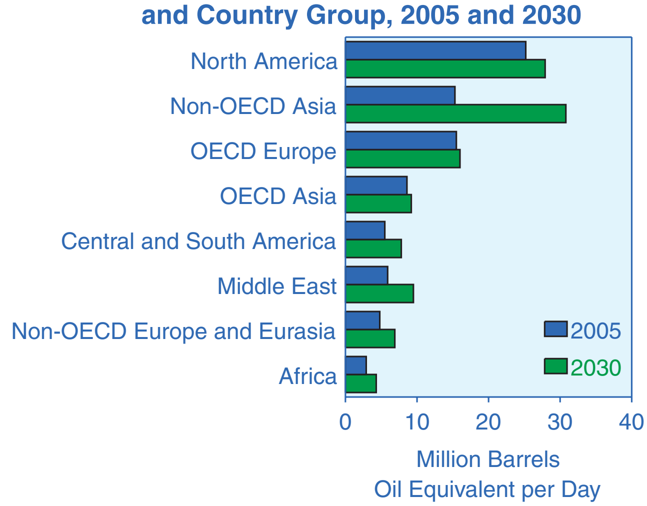
A major factor in the *IEO2008* projections is the assumption for future world oil prices. The impacts of world oil prices on energy demand are a considerable source of uncertainty in the mid-term projections. Following the large increases in world oil prices over the past several years, expectations for future prices also have been raised. In 2006 U.S. dollars, oil prices in the *IEO2008* reference case are about 94 percent higher in 2025 than projections made only 5 years ago in EIA's *International Energy Outlook 2003*. The world oil price cases in

Figure 28. World Liquids Consumption by Sector, 2005-2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2008).

Figure 29. World Liquids Consumption by Region and Country Group, 2005 and 2030



Sources: **2005:** Derived from Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2008).

IEO2008 are consistent with those in the *Annual Energy Outlook 2008*.

In every year since 2003, the average price of West Texas Intermediate (WTI) crude oil, which is indicative of world oil prices as a whole, has been higher than the average for the previous year. Prices in 2007 were nearly double 2003 prices in real terms. Prices rose further into the third quarter of 2008. A variety of factors have caused the increases, including strong demand growth in non-OECD Asia and the Middle East, no growth in production from the members of the Organization of the Petroleum Exporting Countries[6] (OPEC) since 2005, rising costs for oil exploration and development, across-the-board increases in commodity prices, and a weaker U.S. dollar.

In the *IEO2008* reference case, prices ease somewhat in the medium term, as anticipated new production—both conventional and unconventional (in Azerbaijan, Brazil, Canada, Kazakhstan, and the United States, for example)—reaches the marketplace. Ultimately, however, markets are expected to remain relatively tight. In nominal terms, world oil prices in the *IEO2008* reference case decline from their current highs to around $70 per barrel in 2015, then rise steadily to $113 per barrel in 2030 ($70 per barrel in inflation-adjusted 2006 dollars).

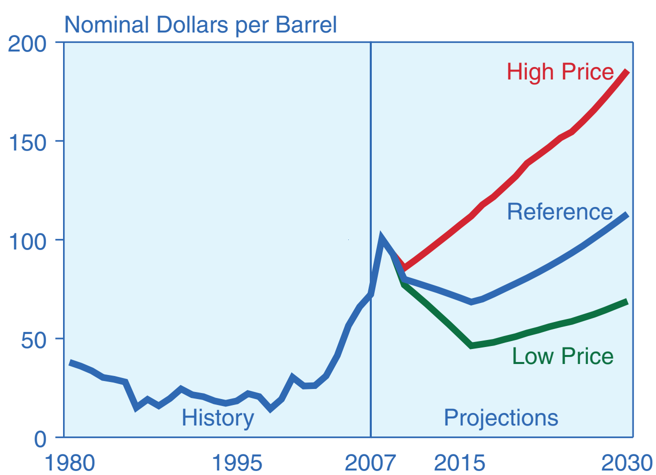
In addition to the reference case, *IEO2008* includes high and low price cases, which help to quantify the considerable uncertainty associated with long-term projections of future oil prices (Figure 30). Given the price levels that prevailed in the first 8 months of 2008, however, the high price case appears to provide a better reflection of current oil market conditions than does the *IEO2008* reference case. The low and high price cases define a substantial range of $117 per barrel (in nominal dollars). In the high price case, world oil prices in 2030 are nearly 65 percent higher than projected in the reference case, at $186 per barrel in nominal terms. Because high world oil prices slow the growth of demand in the long term, world liquids consumption in the high price case totals only 99.3 million barrels per day in 2030, 13 million barrels per day lower than in the reference case.

In the long term, four factors determine the price of oil: growth in world liquids demand, high production costs for accessible non-OPEC conventional liquids resources, OPEC investment and production behavior, and the cost and availability of unconventional liquids supply. It is essential to distinguish between factors that affect prices in the short term versus the long term, particularly given the current price environment.

The reference case assumes that OPEC producers will choose to maintain their market share of world liquids supply, and that OPEC member countries will invest in incremental production capacity so that their conventional oil production represents approximately 40 percent of total global liquids production throughout the projection. As a result, strong economic growth, especially in the developing world, supports a consistent upward trend in world oil prices after 2015.

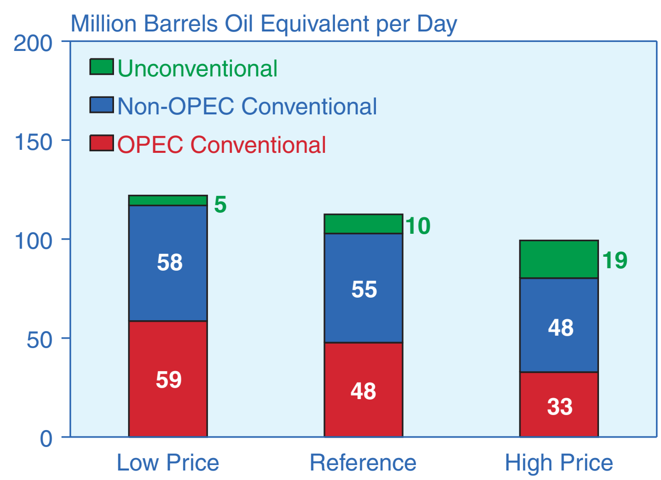
The composition of supply also differs substantially between the reference and high price cases (Figure 31).

Figure 30. Nominal World Oil Prices in Three Cases, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, *Annual Energy Outlook 2008*, DOE/EIA-0383(2008) (Washington, DC, June 2008), web site www.eia.doe.gov/oiaf/aeo.

Figure 31. World Liquids Supply in Three Cases, 2030



Source: Energy Information Administration, Generate World Oil Balance Model (2008).

[6]Ecuador officially rejoined OPEC on October 1, 2007. Throughout this chapter, all references to OPEC include Ecuador. In addition, all time series have been updated to reflect country groupings as of March 1, 2008, so that Ecuador's liquids production is included in the OPEC totals for 1980 through 2030.

As prices rise in the high price case, the development of previously uneconomical unconventional supplies is encouraged. As a result, unconventional resources account for a much larger portion of total liquids supply than in the reference case in 2030 (nearly 20 percent, as compared with about 9 percent in the reference case). Conventional supplies decline over the projection period in the high price case, by 1.5 million barrels per day, compared with an increase of 21.0 million barrel per day in the reference case. The high price case assumes that OPEC member countries will maintain their production at near current levels, and that they will be willing to sacrifice market share as demand for global liquids continues to grow. The high price case also assumes that oil resources in non-OPEC countries will be less accessible and/or more expensive than assumed in the reference case.

Multiple factors restrict conventional liquids production in the high price case, so that more expensive unconventional liquids are needed to meet world demand. In particular, access to non-OPEC resources is expected to be limited, with resource-rich countries such as Kazakhstan and Mexico being unable to increase their conventional liquids production or unwilling to do so for geopolitical reasons. In addition, OPEC is expected to constrain total liquids production to current levels, reducing the OPEC market share of conventional liquid supplies to 33 percent in 2030 in the high price case. Although conventional production in the OECD countries decreases slightly (by 4 percent over the 2005-2030 period), their total liquids production (both conventional and unconventional) is expected to increase relative to the reference case, as higher prices make the extraction of additional barrels of unconventional petroleum liquids, such as oil sands, more economical. The higher prices and limited access to conventional resources also result in more significant increases in production of unconventional liquids in non-OPEC developing countries than are projected in the reference case.

In the low price case, OPEC is assumed to increase its conventional oil production to obtain approximately a 44-percent share of total world liquids production. The low price case also assumes that conventional oil resources in non-OPEC countries will be more accessible and/or less costly to bring to market, because of more rapid technology advances, more attractive fiscal regimes, or both, than in the reference case. As a result, non-OPEC conventional oil production is higher in the low price case than in the reference case. Nominal world oil prices decline to about $46 per barrel in 2016 in the low price case, before climbing to $69 per barrel in 2030. The low world oil prices discourage fuel conservation and reduce the incentive for development of non-petroleum liquids. In the low price case, conventional supplies in 2030 are 14 million barrels per day higher than in the reference case. Non-OPEC conventional production totals 58.4 million barrels per day in 2030 in the low price case, compared with 55.1 million barrels per day in the reference case.

Non-OPEC nations increase international access to domestic resources in the low price case and improve the financial regimes governing the extraction of those resources. OPEC is assumed to increase its conventional liquids production share of total liquids to 48 percent in 2030 from 42 percent in 2005. Changes in the political and fiscal environments of the OPEC member countries are expected to result in increased production of relatively inexpensive conventional resources, thus reducing the economic competitiveness of unconventional liquids production around the world and of conventional liquids production in the industrialized OECD nations and reducing unconventional liquids production to approximately one-half the level projected in the reference case.

World Liquids Production

In the *IEO2008* reference case, world liquids production increases by 28 million barrels per day from 2005 to 2030 to meet projected growth in demand. Increases in production are expected for both OPEC and non-OPEC producers. About 47 percent of the total world increase in liquids supplies is expected to come from OPEC member countries. Thus, in 2030, OPEC production is projected to total 49 million barrels per day and non-OPEC production 63 million barrels per day.

The reference case assumes that OPEC producers will choose to maintain their market share of world liquids supply, and that OPEC member countries will invest in incremental production capacity so that their conventional oil production represents approximately 40 percent of total global liquids production throughout the projection. Increasing volumes of conventional liquids (crude oil and lease condensate, natural gas plant liquids, and refinery gain) from OPEC members contribute 12.4 million barrels per day to the total increase in world liquids production, and conventional liquids supplies from non-OPEC countries add another 8.6 million barrels per day.

The *IEO2008* projections are based on a two-stage analytical approach. Projections of liquids production before 2015 are based largely on a project-by-project assessment of production volumes and associated scheduling timelines, with consideration given to the decline rates of active projects, planned exploration and development activity, and country-specific geopolitical situations and fiscal regimes. There are often lengthy delays between the point at which supply projects are announced and when they begin producing. The extensive and detailed information available about such projects, including project scheduling and the investment and development plans of companies and countries, makes it possible to take a detailed approach to modeling supply.

Because projects generally are not publicized more than 7 to 10 years before their first production, project-by-project analyses are unlikely to provide an accurate representation of company or country production plans and achievable production volumes after 2015. Instead, production decisions made after 2015 are assumed to be based predominantly on resource availability and the resulting economic viability of production. Geopolitical and other "above-ground" constraints[7] are not assumed to disappear entirely after 2015, however. Longstanding above-ground factors for which there are no indications of significant future changes—for instance, the government-imposed investment conditions currently in place in Iran, or OPEC adherence to production quotas—are expected to continue to affect world supplies long after 2015.

For some resource-rich countries it is assumed that current political barriers to increasing production will not continue after 2015. For instance, both Mexico and Venezuela currently have legislation that restricts foreign ownership of hydrocarbon resources. Their nationalization of resources has discouraged investment—both foreign and domestic—and hindered their ability to increase or even maintain historical production levels. In the reference case, both Mexico and Venezuela are assumed to ease restrictions at some point after 2015, allowing some additional foreign investment or involvement in their oil sectors that will facilitate increases in liquids production, including from deepwater prospects in Mexico and heavy oils in Venezuela's Orinoco belt.

Iraq is another resource-rich country where currently there are significant impediments to investment in the upstream hydrocarbon sector. Liquids production in Iraq dropped substantially after the U.S.-led invasion in 2003. From 2003 to 2004 production declined from 2.0 million barrels per day to 1.3 million barrels per day, and it has been relatively slow to recover since then, not yet reaching the peak production level of 2.6 million barrels per day that was achieved in 2000. Although Iraq's production levels are not expected to increase substantially in the near term, it is assumed that the conflict will end eventually and that renewed investment and development activity will ensue, resulting in fairly significant growth in production from 2015 through 2030.

Non-OPEC Production

The world oil prices projected in the *IEO2008* reference case are expected to encourage producers in non-OPEC nations to continue investment in conventional liquids production capacity and increase investment in enhanced oil recovery (EOR) projects and unconventional liquids production. Non-OPEC production increases steadily in the projection, from 48 million barrels per day in 2005 to 63 million barrels per day in 2030, as high prices attract investment in areas previously considered uneconomical.

Non-OPEC conventional liquids production in the reference case increases from 47 million barrels per day in 2005 to 50 million barrels per day in 2015 and 55 million barrels per day in 2030. Unconventional liquids production from non-OPEC suppliers rises to 5 million barrels per day in 2015 and 8 million barrels per day in 2030. In the high price case, non-OPEC unconventional liquids production rises to 16 million barrels per day in 2030, as high prices encourage the development of these alternative fuel sources. In contrast, in the low price case, fewer unconventional resources become economically competitive, and non-OPEC production of unconventional liquids rises to only 4 million barrels per day in 2030.

Among non-OPEC producers, the lack of prospects for new, large conventional petroleum liquids projects and declines in production from existing conventional fields result in heavy investment in the development of smaller fields. Producers are expected to concentrate their efforts on more efficient exploitation of fields already in production, either through the use of more advanced technology for primary recovery efforts or through EOR. Those efforts are expected to allow non-OPEC producers to maintain or slow production declines but not to raise production volumes.

Large increases in non-OPEC production of conventional petroleum liquids are expected to come from regions with recent large discoveries that have high undiscovered resource potential but are not yet producing. Significant gains in conventional production are projected for the Caspian area (Kazakhstan) and South America (Brazil) (Figure 32). Canada also is expected to be a major non-OPEC supplier of liquids, with bitumen (oil sands) production more than compensating for projected declines in its conventional oil production.

The most significant decline in non-OPEC liquids production is projected for the North Sea, which includes offshore production from Norway, the United Kingdom, the Netherlands, and Germany. The production projections for the North Sea are lower in *IEO2008* than

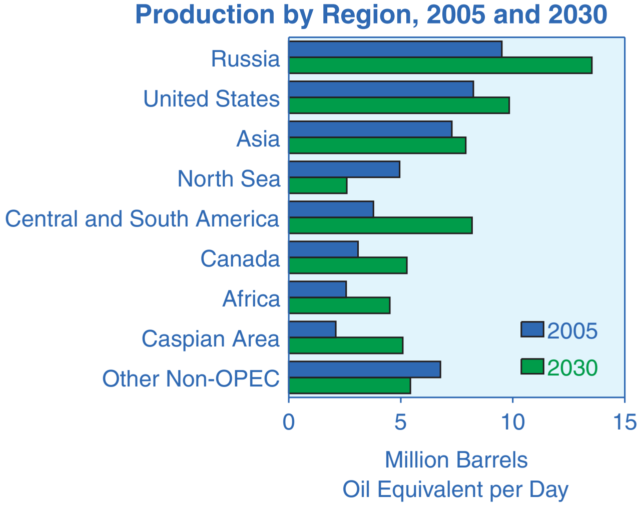
[7]"Above-ground" constraints refer to those nongeological factors that might affect supply, including: government policies that limit access to resources; conflict; terrorist activity; lack of technological advances or access to technology; price constraints on the economical development of resources; labor shortages; materials shortages; weather; and other short- and long-term geopolitical considerations.

they were in *IEO2007*, because the anticipated rates of production decline are steeper than expected previously and because of delays in the startup of offshore fields by Norway and by the United Kingdom (which accounted for a combined 98 percent of total North Sea production in 2006). Although the long-term projections of production levels have been reduced, there are positive indications of future prospects for both Norway (with the opening of the Barents Sea for exploration) and the United Kingdom (with the development of Buzzard field).

Liquids production from non-OECD Europe and Eurasian producers rises from 11.9 million barrels per day in 2005 to 18.9 million barrels per day in 2030. More than one-half of the increase is attributed to production increases in Russia, which is the country with the largest projected increase (by volume) in non-OPEC liquids production in the *IEO2008* reference case, at 4.0 million barrels per day from 2005 to 2030.

The Caspian Basin region accounts for a sizable portion of the liquids production projected for non-OECD Europe and Eurasia in *IEO2008*. Overall, production from the Caspian Basin is projected to grow at an average rate of 3.6 percent per year, resulting in an increment of 3.0 million barrels per day over the 2005-2030 period. Kazakhstan alone accounts for 2.3 million barrels per day of the projected increase, primarily as a result of the development of its Kashagan field and the expansion of gas reinjection at Tengiz, but also because undiscovered fields in its Caspian territory are expected to be developed before 2030. The growth of Kazakhstan's production will depend not only on resource availability and extractability, however, but also, because of its geographical position, on the opening of export routes—a task that will require regional cooperation.

Figure 32. Non-OPEC Conventional Liquids Production by Region, 2005 and 2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **2030:** Energy Information Administration, Generate World Oil Balance Model (2008).

Azerbaijan and Turkmenistan are other Caspian producers expected to increase their production in the reference case. Turkmenistan's production is projected to grow by more than 6 percent per year in the mid-term and somewhat more slowly in the long term, in light of the government's evolving attitude toward foreign investment. Azerbaijan's production is projected to grow rapidly, to a peak production of 1.3 million barrels per day in the next decade, followed by a decline to 1.0 million barrels per day in 2030.

In Central and South America, Brazil's liquids production is projected to grow at an average annual rate of 4.4 percent from 2005 to 2030, resulting in an increase of 3.8 million barrels per day over the period. Capacity expansions at Brazil's currently producing fields result in production increases through 2015, and recent discoveries in the Campos and Santos Basins—which suggest the presence of other large fields in the same formation—are projected to lead to additional production increases in the longer term.

North America's conventional liquids production is projected to fall by an average of 0.5 percent per year from 2005 to 2030, mainly as a consequence of the expected exhaustion of attractive conventional prospects in Canada and a lack of available capital for the development of conventional resources in Mexico, especially in the deepwater Gulf of Mexico. Increasingly, North America's future liquids production is expected to rely on unconventional production—especially, from Canada's bitumen resources. In total, North America's liquids production is projected to increase by 2.9 million barrels per day over the period, at an average annual rate of 0.7 percent.

In the United States, total liquids production increases from 8.2 million barrels per day in 2005 to 10.3 million barrels per day in 2022, then falls to 9.8 million barrels per day in 2030. The near-term profile of U.S. liquids production is determined largely by lower 48 offshore production. Deepwater production in the Gulf of Mexico increases from just under 1.0 million barrels per day in 2005 to a peak of 2.0 million barrels per day between 2013 and 2019 before beginning to decline. U.S. biofuels production is projected to rise from 0.2 million barrels per day in 2005 to 1.2 million barrels per day in 2030 (on an oil equivalent basis), with the United States accounting for nearly one-half of the total increment in world biofuels production in the *IEO2008* reference case.

In Africa, almost 70 percent of non-OPEC conventional liquids production currently comes from four countries: Egypt (28 percent), Equatorial Guinea (16 percent), Sudan (15 percent), and Congo-Brazzaville (10 percent).

In combination, the four are expected to retain approximately a 70-percent share of Africa's non-OPEC conventional production through 2030. Although the resources of Egypt, the current top producer of conventional petroleum liquids, are well developed and primary recovery from many of its fields already is in decline, secondary recovery and EOR efforts are expected to stabilize Egypt's production from previously developed reservoirs in the mid-term. In 2030, Sudan is expected to be the largest non-OPEC producer in Africa, at 0.9 million barrels per day, with most of the growth occurring after 2020.

Conventional liquids production in Congo-Brazzaville more than doubles in the *IEO2008* reference case, from 0.2 million barrels per day in 2005 to 0.6 million barrels per day in 2030, which would make it the region's third largest non-OPEC producer. Recent field discoveries, including Moho Nord Marine 1 and Pegase Nord Marine 1, have served both to increase international interest in the region and to promote the possibility of additional large finds in the future. Given that most of the recent discoveries have been in deepwater locations where there has been little previous exploration, growth in the country's production is expected to come from known and potential deepwater resources.

Non-OPEC producers in Asia are projected to increase their total liquids production from 7.2 million barrels per day in 2005 to 8.6 million barrels per day in 2030. China is Asia's largest non-OPEC producer of total liquids by far, at 3.7 million barrels per day in 2005, followed by India at 0.8 million barrels per day, and Malaysia at 0.7 million barrels per day. China's production is expected to be maintained at about 4.0 million barrels per day through 2030, and India's production is projected to increase to slightly more than 1.2 million barrels per day in 2030.

Liquids production from Australia/New Zealand is projected to increase from 0.6 million barrels per day in 2005 to 0.7 million barrels per day in 2030. Near-term increases in crude oil and condensate production are expected for both Australia and New Zealand, mainly as a result of recent discoveries and developments in offshore basins (such as the Carnarvon Basin). A decline to lower, relatively stable production levels is projected over the longer term. For both countries, production of natural gas plant liquids (NGPL) is projected to remain around current levels in the near term, followed by significant growth as recently discovered large fields are developed and the natural gas is extracted and processed. With the expected surge in NGPL production, total conventional liquids production is projected to increase slightly from 2005 to 2030.

In addition to increasing their production of conventional liquids, both China and India are expected to increase biofuels and CTL production. Unconventional liquids production in China rises to 0.4 million barrels per day in 2030, with CTL accounting for 65 percent and biofuels the remainder. In India, unconventional production rises to 0.2 million barrels per day in 2030, with 44 percent attributed to CTL and 56 percent to biofuels. Advances in technologies—for instance, direct coal liquefaction that would improve the efficiency of CTL production and make it more economical—are not expected to become commercially viable until late in the projection period.

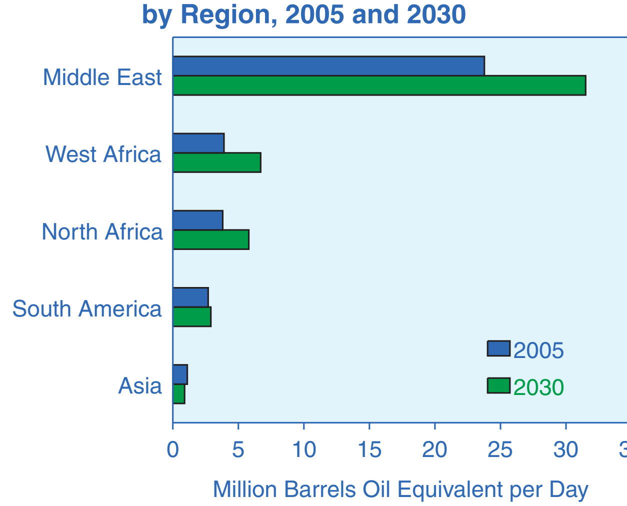
OPEC Production

OPEC's total liquids production increases at a 1.3-percent average annual rate from 2005 to 2030 in the *IEO2008* reference case, resulting in the production of 49.3 million barrels of liquids per day in 2030, of which 31.8 million barrels per day originates in the Middle East (Figure 33). By volume, the largest increase in the individual OPEC countries' liquids production is projected for Saudi Arabia: from 11.1 million barrels per day in 2005 to 13.7 million barrels per day in 2030.

The most rapid growth in OPEC production is projected for Qatar, where total liquids production rises at an average annual rate of 4.3 percent over the projection period, including an increase in GTL production to 0.2 million barrels per day in 2030. In addition, Qatar's NGPL production increases at an average annual rate of 6.1 percent, and its crude oil and condensate production increases by an average of 3.1 percent per year.

The second-fastest growth rate in liquids production among the OPEC countries is projected for Angola, averaging 3.7 percent per year from 2005 to 2030. Almost all

Figure 33. OPEC Conventional Liquids Production by Region, 2005 and 2030



Sources: **2005:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **2030:** Energy Information Administration, Generate World Oil Balance Model (2008).

the increase is expected to consist of crude oil and lease condensate production from offshore projects. Established OPEC production targets (in December 2007, Angola received a target of 1.9 million barrels per day) are not expected to impede project development in Angola, and its production in 2030 is projected to be 3.1 million barrels per day in the reference case.

Iraq's liquids production also grows substantially, by an average of 3.1 percent per year, depending on developments in the country's political situation. The *IEO2008* projections assume that the conflict in Iraq will be resolved well before 2030, making resource availability the main determining factor in its ability to meet growing domestic demand. From 2005 to 2015, Iraq's liquid fuels production is projected to grow by only 1.4 percent per year, but from 2015 to 2030 the average annual growth rate increases to 4.3 percent.

Total liquids production in Iran also is expected to be restricted by geopolitical factors through 2015. Those factors are not limited to international relations but also include a variety of other non-resource-related factors that range from the effectiveness of the national oil company's operations to the ability of the government and foreign investors to agree on contractual terms. In the *IEO2008* reference case, Iran's oil production remains relatively stable through 2015, both because of financial and political constraints on developing new oil or natural gas prospects and because of anticipated competing demands for natural gas that would limit its use (and thus effectiveness) for improving oil recovery through natural gas reinjection. The reference case does not project large increases in Iran's liquids production, because it does not assume improvements in either the political or investment environment for the country.

For Venezuela, liquids production is constrained by investor concerns over government actions that nationalized the upstream hydrocarbon sector, as well as the possibility of further mandated changes in contract terms. Venezuela's total liquids production falls somewhat in the reference case, from 2.9 million barrels per day in 2005 to 2.5 million barrels per day in 2010, before beginning a steady recovery to 3.5 million barrels per day in 2030. This is a much more pessimistic outlook for Venezuela's production profile than in past *IEO*s. In *IEO1999*, which was published only a month after Hugo Chavez assumed the Venezuelan Presidency, the country's annual liquids production was projected to reach 5.5 million barrels per day in 2020—2.4 million barrels per day more than projected in the *IEO2008* reference case.

Unconventional Production

Unconventional liquids play an increasingly important role in meeting demand for liquid fuels over the course of the *IEO2008* projection. In the reference case, 8.6 percent of world liquids supply in 2030 is projected to come from unconventional sources, including 1.6 million barrels per day originating from OPEC and 8.1 million from non-OPEC countries. Although unconventional production volumes vary between the *IEO2008* price cases (from 19.0 percent in the high price case to 4.0 percent in the low price case), the geographic locations and types of unconventional production remain relatively unchanged.

OPEC's unconventional production consists predominantly of extra-heavy Orinoco oil production in Venezuela and GTL production in Qatar, with 2030 production volumes ranging from 1.1 to 2.1 million barrels per day and 0.2 to 0.5 million barrels per day, respectively, in the high and low price cases. Although the resources to support production at those levels abound in the two countries, large investments will be required to produce them, and the timing of such investments is uncertain.

Outside the OPEC member countries, unconventional liquids production comes from a much more diverse group of countries and resource types. As a whole, non-OPEC unconventional liquids production is projected to increase by more than 6.4 million barrels per day from 2005 to 2030, with 72.4 percent coming from OECD countries. By volume, the largest contributors to the non-OPEC increase are expected to be bitumen (Canadian oil sands) and biofuels, with production increases of 3.1 and 2.2 million barrels oil equivalent per day, respectively, from 2005 to 2030.

Although bitumen and biofuels are viewed as having the most potential for significant contributions to global liquids supply, they also show the most significant variations in production levels among the price cases as a result of the effects of different price assumptions on production economics and competing supply from conventional liquids. The projected increases from 2005 to 2030 in Canada's bitumen production range from less than 0.3 million barrels per day in the low price case to 7.6 million barrels per day in the high price case, and the increases in biofuels production ranging from 1.2 million barrels per day in the low price case to 3.7 million barrels per day in the high price case. In the reference case, the most significant increases in biofuels production from 2005 to 2030 are projected for the United States (1.0 million barrels per day) and Brazil (0.5 million barrels per day). Increases of approximately 60 thousand barrels per day are projected for South Africa, China, India, and Argentina.

Like biofuels production, CTL production volumes vary among the price cases, although they do not add as much to total liquids production. In the low price case, South Africa is the largest CTL supplier, producing 112,000 barrels per day in 2030, with China, India, and the United States contributing smaller volumes. In the reference case, the United States and China increase their CTL production by 242,000 and 246,000 barrels per day, respectively, from 2005 to 2030; South Africa increases its production by only 209,000 barrels per day but still remains the dominant CTL supplier, at 340,000 barrels per day in 2030. In the high price case, improved production economics result in the expansion of CTL projects around the world and the production of 2.7 million barrels per day in 2030—2.5 million barrels per day more than was produced in 2005.

In all three cases, non-OPEC production of extra-heavy oil, GTL, and shale oil contributes a relatively small fraction of liquids to the world market. Mexico is expected to be the only non-OPEC supplier of extra-heavy oil, with volumes ranging from 19,000 to 120,000 barrels per day in 2030 in the low and high price cases, respectively. In the reference and low price cases, South Africa is the world's only non-OPEC supplier of GTL; however, in the high price case the United States and South Africa produce approximately the same volumes, at just over 120,000 barrels per day in 2030. Similarly, shale oil production is expected to originate from only one country in the reference and low price cases (Estonia), but in the high price case the United States produces 144,000 barrels of shale oil per day in 2030.

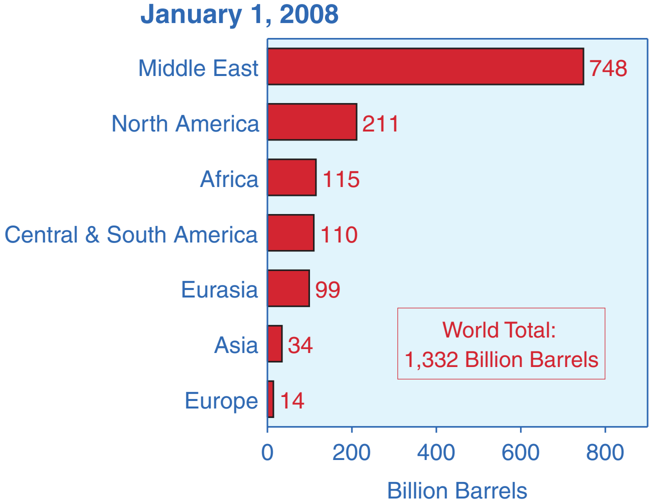
Oil Reserves and Resources

As of January 1, 2008, proved world oil reserves, as reported by the *Oil & Gas Journal*, were estimated at 1,332 billion barrels—14 billion barrels (about 1 percent) higher than the estimate for 2007 [*4*]. According to the *Oil & Gas Journal*, 56 percent of the world's proved oil reserves are located in the Middle East (Figure 34). Among the top 20 reserve holders in 2008, 11 are OPEC member countries that, together, account for 69 percent of the world's total reserves (Table 4).

Proved reserves of crude oil are the estimated quantities that geological and engineering data demonstrate with reasonable certainty can be recovered in future years from known reservoirs, assuming existing technology and current economic and operating conditions. Companies whose stocks are publicly traded on U.S. stock markets are required by the U.S. Securities and Exchange Commission (SEC) to report their holdings of domestic and international proved reserves, following specific guidelines. Country-level estimates of proved reserves are developed from the data reported to the SEC, from foreign government reports, and from international geologic assessments. Estimates are not always updated annually.

Whereas proved reserves include only those estimated quantities of crude oil from known reservoirs, they are only a subset of the entire potential oil resource base. Resource base estimates include estimated quantities of both discovered and undiscovered liquids that have the

Figure 34. World Proved Oil Reserves by Geographic Region as of January 1, 2008



Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 105, No. 48 (December 24, 2007), pp. 24-25.

Table 4. World Oil Reserves by Country as of January 1, 2008
(Billion Barrels)

Country	Oil Reserves
Saudi Arabia	264.3
Canada	178.6
Iran	138.4
Iraq	115.0
Kuwait	101.5
United Arab Emirates	97.8
Venezuela	87.0
Russia	60.0
Libya	41.5
Nigeria	36.2
Kazakhstan	30.0
United States	21.0
China	16.0
Qatar	15.2
Algeria	12.2
Brazil	12.2
Mexico	11.7
Angola	9.0
Azerbaijan	7.0
Norway	6.9
Rest of World	70.3
World Total	**1,331.7**

Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 105, No. 48 (December 24, 2007), pp. 24-25.

potential to be classified as reserves at some time in the future. The resource base may include oil that currently is not technically recoverable but could conceivably become recoverable in the future as technologies advance.

Readers may notice that, in some cases in the *IEO2008* projections, country-level volumes for cumulative production through 2030 exceed the estimates of proved reserves. This does not imply that resources and the physical limits of production have not been considered in the development of production forecasts, or that the projections assume a rapid decline in production immediately after the end of the projection period as reserves are depleted. EIA carefully considers resource availability in all long-term country-level projections, the aggregation of which gives the total world production projection; however, proved reserves are not an appropriate measure for judging total resource availability in the long run.

In order to construct realistic and plausible projections for liquids production, and especially for petroleum liquids production, underlying analysis must both consider production beyond the intended end of the projection period and base production projections on the physical realities and limitations of production. The importance of approaching an assessment of liquids production in this way is illustrated by the recent history of U.S. reserve estimates. Whereas the United States reported 22.1 billion barrels of proved reserves in 1998, proved reserves of 21.0 billion barrels were reported in 2008—a decrease of only 1.1 billion barrels despite the cumulative 32.1 billion barrels of liquids supplied from U.S. reserves between 1998 and 2007.

Proved reserves cannot provide an accurate assessment of the physical limits on future production but rather are intended to provide insight as to company- or country-level development plans in the very near term. In fact, because of the particularly rigid requirements for the classification of resources as proved reserves, particularly by the U.S. SEC,[8] even the cumulative production levels from individual development projects may exceed the initial estimates of proved reserves.

EIA attempts to address the lack of applicability of proved reserves estimates to long-term production projections by developing a production methodology based on the true physical limits of production (see box on page 34). By basing the long-term EIA production assessments on resources, rather than reserves, EIA is able to present projections that are physically achievable and can be supported beyond the 2030 projection horizon in *IEO2008*. The realization of such production levels depends, however, on future growth in world demand, taking into consideration such above-ground limitations on production as profitability and specific national regulations, among others.

References

1. "Middle East Population Growth Poses Huge Change for Middle East and North Africa," *International Herald Tribune* (January 18, 2007); and United Nations Population Fund, web site www.unfpa.org/worldwide (accessed April 23, 2008).
2. International Energy Agency, "Oil Market Report" (March 11, 2008), p. 18, web site http://omrpublic.iea.org/omrarchive/11mar08full.pdf; and *Middle East Economic Survey*, Vol. 50, No. 13 (March 26, 2007), web site www.mees.com (subscription site)
3. R. Kirk, "Explosive Oil Consumption Growth in the Top Oil Exporting States," *Energy Bulletin* (July 25, 2006), web site www.energybulletin.net/node/18475.
4. "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 105, No. 48 (December 24, 2007), pp. 24-25, web site www.ogj.com (subscription site).

[8]The U.S. SEC guidelines are seen as particularly rigid because of the limited extraction technologies they recognize, and because they base the economic viability of reserves on oil prices for the last day of trading in a year rather than an annual average. Under current rules, a company can generally meet the "reasonable certainty" standard necessary to establish proved reserves only by using actual production or flow tests. In June 2008, the SEC formally proposed changes to the guidelines that would not only expand the extraction technologies recognized and the price used to determine economic viability but also expand the resources eligible to be classified as oil reserves by including oil sands and other unconventional oil deposits.

Defining the Limits of Oil Production

Preparing mid-term projections of oil production requires an assessment of the availability of resources to meet production requirements, particularly for the later years of the 2005-2030 projection period in *IEO-2008*. The *IEO2008* oil production projections were limited by three factors: the estimated quantity of petroleum in place before production begins ("petroleum-initially-in-place" or IIP), the percentage of IIP extracted over the life of a field (ultimate recovery factor), and the amount of oil that can be produced from a field in a single year as a function of its remaining reserves.

Total IIP resources are the quantities of petroleum—both conventional and unconventional—estimated to exist originally in naturally occurring accumulations.[a] IIP resources are those quantities of petroleum which are estimated, on a given date, to be contained in known accumulations, plus those quantities already produced, as well as those estimated quantities in accumulations yet to be discovered. The estimate of IIP resources includes both recoverable and unrecoverable resources.

Published estimates of global IIP resources vary widely across sources, from about 13 trillion barrels to more than 24 trillion barrels. An estimate of 20.8 trillion barrels is used for the *IEO2008* reference case (see table below). Conventional crude oil and lease condensate account for about 40 percent (9 trillion barrels) of the total IIP worldwide, and unconventional petroleum resources account for the remainder. For instance, there are an estimated 2.3 trillion barrels of extra-heavy oil in Venezuela and an estimated 2.1 trillion barrels of petroleum in shale rock in the United States alone.

The second factor that limits oil production is the ultimate recovery factor. For most producing fields, the ultimate recovery factor is larger than the current recovery factor, which is defined as the sum of cumulative production plus remaining reserves as a percentage of IIP. Typically, estimates of the current recovery factor for a particular field increase over time, reflecting the effects of three interrelated factors: technology, economics, and knowledge about the field.

In general, as producers develop a field they learn more about its characteristics and are able to apply additional or more efficient recovery techniques. In addition, the efficiency of recovery can also be improved by developments in technology, either in the oil industry specifically (such as new reservoir fracturing techniques) or in industry generally (such as more powerful computer processors). Such efficiency gains can lower the cost of extracting a field's reserves significantly, making production more profitable and lowering the price at which production is justified.

Remaining reserves, by definition, are limited to those quantities considered economical to produce. Thus, estimates of current recovery factors based on reserves are affected by changes in production costs, oil prices, and fiscal regimes (such as tax rates). Estimates of current recovery factors can decline if adverse economic factors—such as low oil prices, high production taxes, or inadequate investment in field maintenance—arise and are expected to persist. For example, the two latter factors currently affect both Russia and Venezuela.

Current recovery factors for oil fields around the world typically range between 10 and 60 percent; some are over 80 percent. The wide variance is due largely to the diversity of fluid and reservoir characteristics for different deposits. For example, Canada's oil sands are markedly different from Saudi Arabia's Ghawar field

(continued on page 35)

Petroleum-Initially-In-Place Resource Estimates Used in the *IEO2008* Reference Case
(Trillion Barrels)

Resource	OPEC Middle East	Other OPEC	United States	Other Non-OPEC	Total
Conventional Crude and Condensate	2.6	2.6	0.9	2.9	**9.0**
Natural Gas Plant Liquids	0.3	0.3	0.2	0.4	**1.2**
Extra-Heavy Crude	0.0	2.3	0.0	0.0	**2.3**
Bitumen	0.0	0.0	0.0	2.4	**2.4**
Shale Oil	0.0	0.0	2.1	0.7	**2.8**
Source Rock	0.9	0.9	0.3	1.0	**3.1**
Total	**3.8**	**6.1**	**3.5**	**7.4**	**20.8**

Sources: I.H.S. Energy, web site http://energy.ihs.com (subscription site); U.S. Geological Survey, "Oil and Gas Resources," web site http://energy.usgs.gov/oilgas.html; Nehring Associates, "Significant Oil and Gas Fields of the United States Database," web site www.nehringdatabase.com (subscription site); World Energy Council, "Survey of Energy Resources 2007," (London, UK, September 2007), web site www.worldenergy.org/documents/ser2007_final_online_version_1.pdf; and EIA analysis.

[a]World Petroleum Council, "Petroleum Resources," *The WPC Newsletter*, No. 20 (January 2000), web site www.world-petroleum.org/newsletter/issue20.htm.

Defining the Limits of Oil Production (Continued)

in terms of both fluid properties and the geophysical characteristics of the rock that contains the oil. For the global average ultimate recovery factor, petroleum engineers often cite a value of one-third for conventional oil deposits; however, no verifiable studies have been conducted to estimate ultimate recovery factors at the field level for all fields worldwide. Even if such a study were conducted it would not provide a definitive value for the upper limit of global recovery, because technologies, oil prices, and taxes change over time.

In 2005, the U.S. Department of Energy commissioned "basin potential studies," with the goal of providing a better understanding of the potential impact of technology advances on recovery factors for conventional oil in the United States.[b] The results suggested that long-term recovery factors in the United States could vary from as little as 40 percent for mid-continent resources to as much as 72 percent for resources in the Gulf Coast States. To put those percentages in perspective, cumulative U.S. oil production as a percentage of estimated discovered IIP averages 33 percent and ranges from 23 percent to 44 percent, depending on the U.S. region. The studies suggest that improvements in technology have the potential to raise ultimate recovery factors to 60 percent for U.S. areas that already are in production or open to exploration.

An additional factor limiting oil production is the fraction of a field's reserves that can be produced in a given year—which in turn is affected both by the physical characteristics of oil flowing through a porous rock reservoir and by financial considerations. Oil flows more slowly through fields with thicker oil and/or lower permeability. Unless a field is close to the end of its productive life, it is physically difficult to produce more than 10 to 15 percent of its remaining reserves in a single year. From a financial standpoint, oil producers maximize returns on investment by matching the timing of investments to the timing of physical oil production. They will lose money if they expand production facilities by too much or too long before the oil begins to flow.

On a field-by-field or regional basis, the proportion of reserves produced in a single year may vary widely. For example, in the United States, 13.3 percent of the onshore reserves in Texas and 5.1 percent of the reserves in Utah were produced in 2006. For the United States as a whole, 7.9 percent of reserves were produced in 2006.

[b]Office of Fossil Energy – Office of Oil and Natural Gas, U.S. Department of Energy, "Ten Basin-Oriented CO2-EOR Assessments Examine Strategies for Increasing Domestic Oil Production" (prepared by Advanced Resources International, Arlington, VA, February 2006), web site http://fossil.energy.gov/programs/oilgas/eor/Ten_Basin-Oriented_CO2-EOR_Assessments.html; and *Evaluating the Potential for "Game Changer" Improvements in Oil Recovery Efficiency from CO_2 Enhanced Oil Recovery* (prepared by V.A. Kuuskraa and G.J. Koperna, Advanced Resources International, Arlington, VA, February 2006), web site http://fossil.energy.gov/programs/oilgas/publications/eor_co2/Game_Changer_Document_2_06_with_appendix.pdf.