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# IS THE WORLD RUNNING OUT OF OIL?

**S**ince the beginning of the twenty-first century, a fear has come to pervade the prospects for oil and also feeds anxieties about overall global stability. This fear, that the world is running out of oil, comes with a name: peak oil. It argues that the world is near or at the point of maximum output, and that an inexorable decline has already begun, or is soon to set in. The consequences, it is said, will be grim: "An unprecedented crisis is just over the horizon," writes one advocate of the peak oil theory. "There will be chaos in the oil industry, in governments and in national economies." Another warns of consequences including "war, starvation, economic recession, possibly even the extinction of homo sapiens." The date of the peak has tended to move forward. It was supposed to arrive by Thanksgiving 2005. Then the "unbridgeable supply demand gap" was expected to open up "after 2007." Then it would arrive in 2011. Now some say "there is a significant risk of a peak before 2020."[1]

The peak oil theory embodies an "end of technology/end of opportunity" perspective, that there will be no more significant innovation in oil production, nor significant new resources that can be developed.

The peak may be the best-known image of future supply. But there is another, more appropriate, way to visualize the course of supply: as a plateau. The world has decades of further production growth before flattening out into a plateau—perhaps sometime around midcentury—at which time a more gradual decline will begin.

## ABOVEGROUND RISKS

To be sure, there's hardly a shortfall of risks in the years ahead. Developing the resources to meet the requirements of a growing world is a very big and expensive challenge. The International Energy Agency estimates that new development will require as much as $8 trillion over the next quarter century. Projects will grow larger and more complex and there is no shortage of geological challenges. [2]

But many of the most decisive risks will be what are called "above ground." The list is long, and they are economic, political, and military: What policies do governments make, what terms do they require, how do they implement their choices, and what is the quality and timeliness of decision making? Do countries provide companies with access to develop resources and do companies gain a license to operate? What is happening to costs in the oil field? What is the relationship between state-owned national oil companies and the traditional international oil companies, and between importing and exporting countries? How stable is a country, and how big are threats from civil war, corruption, and crime? What are the relations between central governments and regions and provinces? What are the threats of war and turmoil in different parts of the world? How vulnerable is the supply system to terrorism?

All of these are significant and sober questions. How they play out—and interact—will do much to determine future levels of production. But these are not issues of physical resources, but of what happens above ground.

Moreover, decision making on the basis of a peak oil view can create risks of its own. Ali Larijani, the speaker of Iran's parliament, declared that Iran needs its nuclear program because "fossil fuels are coming to an end. We know the expiration date of our reserves." Such an expectation is surprising coming from a country with the world's second-largest conventional natural gas reserves and among the world's largest oil reserves.[3]

This peak oil theory may seem new. In fact, it has been around for a long time. This is not the first time that the world has run out of oil. It is the fifth. And this time too, as with the previous episode, the peak presumes limited technological innovation and that economics does not really matter.

## RUNNING OUT AGAIN—AND AGAIN

The modern oil industry was born in 1859 when "Colonel" Edwin Drake hit oil near the small timber town of Titusville in northwest Pennsylvania. It grew up in the hills and ravines surrounding Titusville in what has become known as the Oil Region. Other production centers also emerged in the late nineteenth century—in the Russian Empire, around Baku, on the Caspian Sea and in the Caucasus; in the Dutch East Indies; and in Galicia, in the Austro-

Hungarian Empire. But Pennsylvania was the Saudi Arabia of the day—and then some—supplying Europe and Asia, as well as North America. The primary market for oil its first 40 years was illumination, to provide lighting, replacing whale oil and other fluids used in oil lamps. Petroleum quickly became a global business. John D. Rockefeller became the richest man in the world not because of transportation but because of illumination.

Yet oil flowing up from the earth's interior was mysterious. Wells might send oil shooting up into the sky and then run dry for reasons no one knew. People began to fear that the oil would run out. The State Geologist of Pennsylvania warned in 1885 that "the amazing exhibition of oil" was only a "temporary and vanishing phenomenon—one which young men will live to see come to its natural end." That same year, John Archbold, Rockefeller's partner in Standard Oil, was told that the decline in American production was almost inevitable. Alarmed, he sold some of his Standard Oil shares at a discount. Later, hearing that there might be oil in Oklahoma, he replied, "Why, I'll drink every gallon produced west of the Mississippi." Yet not long after, new fields were discovered—in Ohio, Kansas, and then the huge fields of Oklahoma and Texas.[4]

Those new supplies appeared just in time, for an entirely new source of demand—the automobile—was rapidly replacing the traditional illumination market, which in any event was being crushed by electricity. The arrival of the motor car turned oil from an illuminant into the fuel of mobility.

In 1914 the European nations went to war thinking it would be a short conflict. But World War I turned into the long, arduous, and bloody battle of trench warfare. It also became a mechanized war. The new innovations from the late nineteenth and early twentieth centuries—cars, trucks, and planes—were, more rapidly than anyone had anticipated, pressed into large-scale military service. One of the most important innovations first appeared on the battlefield in 1916. It was initially code-named the “cistern” but was soon better known as the “tank.” As oil went to Europe to support the mobility of Allied forces, a gasoline famine gripped the United States. In fact, 1918 saw the highest gasoline prices, in inflation-adjusted terms, ever recorded in the United States. In order to help relieve the shortage, a national appeal went out for “Gasolineless Sundays,” on which people would abstain from driving. In response, President Wilson ruefully announced, “I suppose I must walk to church.”

By the time the war ended, no one could doubt oil’s strategic importance. Lord Curzon, soon to become Britain’s foreign secretary, summed it up: “The Allied cause had floated to victory upon a wave of oil.” But for the second time, the fear took hold that the world was running out of oil—partly driven by the surging demand growth from the internal combustion engine. Between 1914 and 1920, the number of registered motor vehicles in the United States grew fivefold. “Within the next two to five years,” declared the director of the United States Bureau of Mines, “the oil fields of this country will reach their maximum production, and from that time on we will face an ever-increasing decline.” President Wilson lamented, “There seemed to be no method by which we could assure ourselves of the necessary supply at home and abroad.”[5]

Securing new supplies became a strategic objective. That is one of the major reasons that, after World War I, the three easternmost oil-prospective provinces of the now-defunct Ottoman Turkish Empire—one Kurdish, one Sunni Arab, and one Shia Arab—were cobbled together to create the new state of Iraq.

The permanent shortage did not last very long. New areas opened up and new technologies emerged, the most noteworthy being seismic technology. Dynamite explosions set off sonic waves, enabling explorers to identify prospective underground formations and map geological features that might have trapped oil and gas. Major new discoveries were made in the United States and other countries. By the end of the 1920s, instead of permanent shortage, the market was beginning to swim in oil. The discovery of the East Texas oil field in 1931 turned the surplus into an enormous glut: oil plunged temporarily to as little as ten cents a barrel; during the Great Depression some gasoline stations gave away whole chickens as premiums to lure in customers.

The outbreak of World War II turned that glut into an enormous and immensely valuable strategic reserve. Out of seven billion barrels used by the Allies, six billion came from the United States. Oil proved to be of key importance in so many different aspects of the struggle. Japan's fear of lack of access to oil—which, in the words of the chief of its Naval General Staff, would turn its battleships into "nothing more than scarecrows"—was one of the critical factors in Japan's decision to go to war. Hitler made his fateful decision to invade the Soviet Union not only because he hated the Slavs and the communists, but also so that he could get his hands on the oil resources of the Caucasus. The German U-boat campaign twice came close to cutting the oil line from North America to Europe. The Allies, in turn, were determined to disrupt the oil supplies of both Germany and Japan. Inadequate supplies of fuel put the brakes on both General Erwin Rommel's campaign in North Africa ("Shortage of petrol," he wrote his wife; "It's enough to make one weep") and General George Patton's sweep across France after the D Day landing.[6]

World War II ended, like World War I, with a profound recognition of the strategic significance of oil—and, for the third time, widespread fear about running out of oil. Those fears were heightened by the fact that, immediately after the war, the United States crossed a great strategic divide. No longer self-sufficient in petroleum, it became a net importer. But for a number of years, quotas limited imports to about 10 percent of total consumption.

Once again, the specter of global shortage receded, as the opening up of the vast fields of the Middle East and the development of new technologies led to oversupply and falling prices. This downward trend culminated in cuts in the world oil price in 1959 and 1960 by the major oil companies that brought five oil-exporting countries together in Baghdad in 1960 to found the Organization of Petroleum Exporting Countries—OPEC—in order to defend their revenues. Oil remained cheap, convenient, and abundant, and it became the fuel for the postwar economic miracles in France, Germany, Italy, and Japan.

But by the beginning of the 1970s, surging in petroleum consumption, driven by a booming world economy, was running up against the limits of available production capacity. At the same time, nationalism was rising among exporting countries, and tensions were mounting in the Middle East. The specter of resource shortage was in the air, prominently promoted by the Club of Rome study *The Limits of Growth* on "the predicament of mankind." To wide acclaim, it warned that current trends would mean not only rapid resource depletion but also portended the unsustainability of industrial civilization.[7]

In October 1973 Arab countries launched their surprise attack on Israel, initiating the October War. In response to U.S. resupply of armaments to a beleaguered Israel, Arab exporters embargoed oil shipments. The oil market went into a hyperpanic, and within months petroleum prices quadrupled. They doubled again between 1978 and 1981 when the Iranian Revolution toppled the pro-Western shah and disrupted oil flows. All this seemed to be proof of the Club of Rome thesis of looming shortages. One most prominent scientist, a former chairman of the Atomic Energy Commission, warned: “We are living in the twilight of the petroleum age.” The CEO of a major oil company put it differently. The world, he said, had reached the tip of “the oil mountain,” the high point of supply, and was about to fall down the other side. This was the fourth time the world was said to be running out of oil.[8]

The fear of permanent shortage ignited a frantic search for new supplies and the double-time development of new resources. Major new provinces were discovered and brought on stream from Alaska’s North Slope and from the North Sea. At the same time, government policies in the industrial countries promoted greater fuel efficiency in automobiles and encouraged electric utilities to switch away from oil to increased use of coal and nuclear power.

The impact was enormous—and surprisingly swift. Within half a decade, what was supposed to be the permanent shortage turned into a huge glut. In 1986 the price of oil collapsed. Instead of the predicted $100 a barrel, it fell as low as $10 a barrel. Prices recovered in the late 1980s, spiked with the Gulf crisis in 1990, and then seemed to stabilize again. But, in the late 1990s, the Asian financial crisis precipitated yet another price collapse.

## THE FIFTH TIME

By the beginning of the twenty-first century, oil prices were once again rebounding. It was around that time that fear about running out of oil began to gain prominence again, for the fifth time. But it was no longer "the oil mountain." It was now something loftier—"the peak." Accelerated growth of oil consumption in China and other emerging economies—and the sheer scale of prospective demand—understandably reinforced the anxiety about the adequacy of future supplies. Peak oil also became entwined with the rising concerns about climate change, and the specter of impending shortage provided further impetus to move away from carbon-based fuels.

The peak theory, in its present formulation, is pretty straightforward. It argues that world oil output is currently at or near the highest level it will ever reach, that about half the world's resources have been produced, and that the point of imminent decline is nearing. "It's quite a simple theory and one that any beer drinker understands," one of the leaders of the current movement put it. "The glass starts full and ends empty and the faster you drink it the quicker it's gone." (Of course, that assumes one knows how big the glass is.) The theory owes its inspiration and structure, and indeed its articulation, to a geologist who, though long since passed from the scene, continues to shape the debate, M. King Hubbert. Indeed, his name is inextricably linked to that perspective—immortalized in "Hubbert's Peak."[9]

## M. KING HUBBERT

Marion King Hubbert was one of the eminent earth scientists of his time and one of the most controversial. Born in Texas, he did all his university education, including his Ph.D., at the University of Chicago, where he folded physics and mathematics into geology. In the 1930s, while teaching at Columbia University in New York City, he became active in a movement called Technocracy. Holding politicians and economists responsible for the debacle of the Great Depression, Technocracy promoted the idea that democracy was a sham and that scientists and engineers should take over the reins of government and impose rationality on the economy. The head of Technocracy was called the Great Engineer. Members wore uniforms and saluted when the Great Engineer walked into the room. Hubbert served as its educational director for 15 years and wrote the manual by which it operated. "I had a box seat at the Depression," he later said. "We had manpower and raw materials. Yet we shut the country down." Technocracy envisioned a no-growth society and the elimination of the price system, to be replaced by the wise administration of the Technocrats. Hubbert wanted to promote a social structure that was based on "physical relations, thermodynamics" rather than a monetary system. He believed that a "pecuniary" system, misinformed by the "hieroglyphics" of economists, was the road to ruin.

Although cantankerous and combative, Hubbert was, as a teacher, demanding and compelling. "I found him to be arrogant, egotistical, dogmatic, and intolerant of work he perceived to be incorrect," recalled one admiring former student. "But above all, I judged him to be a great scientist dedicated to solving problems based on simple physical and mathematical principles. He told me that he had a limited lifetime in which to train and pass on what he knew, and that he couldn't waste his time with people that couldn't comprehend."

Hubbert did not have an easy relationship with his Columbia colleagues. When Columbia failed to give him tenure, he packed up and went to work as a geologist for Shell Oil.[10]

Collegiality was not one of his virtues. Coworkers found him abrasive, overly confident in his own opinions, dismissive of those who disagreed with him, and ill disguised in his contempt of those with different points of view.

"A gifted scientist, but with deep-seated insecurities," in the words of one scholar, Hubbert was so overbearing that it was almost painful for others to work with him. At Shell, the young geologists assigned to him never managed to last more than a year. Finally, the first female geologist to graduate from Rice University, Martha Lou Broussard, was sent to him. "Overpopulation" was one of Hubbert's favorite themes. During her job interview, he asked

Broussard if she intended to have children. Then, in order to convince her not to, he told her to go to the blackboard to calculate at exactly what point the world would reach one person per square meter.

From Shell he moved to the U.S. Geological Survey, where he was in a permanent battle with some of his colleagues. “He was the most difficult person I ever worked with,” said Peter Rose, his boss at the USGS.

Yet Hubbert also became recognized as one of the leading figures in the field and made a variety of major contributions, including a seminal paper in 1957, “The Mechanics of Hydraulic Fracturing.” One of his fundamental objectives was to move geology from what he called its “natural-history phase” to “physical science phase,” firmly based in physics, chemistry, and in particular, in rigorous mathematics. “King Hubbert, mathematician that he is,” said the chief geophysicist of one of the oil companies, “based his look ahead on facts, logically and analytically analyzed.” Four decades after turning him down for tenure, Columbia implicitly apologized by awarding him the Vetlesen Prize, one of the highest honors in American geology.[11]

# AT THE PEAK

In the late 1940s, Hubbert's interest was piqued when he heard another geologist say that 500 years of oil supply remained in the ground. This couldn't possibly be true, he thought. He started doing his own analysis. In 1956 at a meeting in San Antonio, he unveiled the theory that would forever be linked to his name. He declared that U.S. oil production was likely to hit its peak somewhere between 1965 and 1970. This was what became Hubbert's Peak.

His prediction was greeted with much controversy. "I wasn't sure they weren't going to hang me from the nearest light post," he said years later. But when U.S. production did hit its peak in 1970, followed by the shock of the 1973 embargo, Hubbert appeared more than vindicated. He was a prophet. He became famous.[12]

The peaking of U.S. output pointed to a major geopolitical rearrangement. The United States could no longer largely go it alone. All through the 1960s, even with imports, domestic production had supplied 90 percent of demand. No longer. To meet its own growing needs, the United States went from being a minor importer to a major importer, deeply enmeshed in the world oil market. The rapid growth of U.S. oil imports, in turn, was one of the key factors that led to the very tight oil market that set the stage for the 1973 crisis.

Hubbert was very pessimistic on the prospects for future supply. In tones reminiscent of the State Geologist of Pennsylvania in 1885, he warned that the era of oil would be only a brief blip in mankind's history. In 1978 he predicted that children born in 1965 would see all the world's oil used up in their lifetimes. Humanity, he said, was about to embark upon "a period of non-growth."[13]

## WHY SUPPLIES CONTINUE TO GROW

Hubbert used a statistical approach to project the kind of decline curve that one might encounter in some—but not all—oil fields, and then assume that the United States was one giant oil field. Hubbert's followers have adopted that approach to global supplies. Hubbert's original projection for U.S. production was bold and, at least superficially, accurate. His modern-day adherents insist that U.S. output has "continued to follow Hubbert curves with only minor deviations." But it all comes down to how one defines “minor.” Hubbert got the date right, but his projection on supply was far off. Hubbert greatly underestimated the amount of oil that would be found—and produced—in the United States.

By 2010, U.S. production was four times higher than Hubbert had estimated—5.9 million barrels per day versus Hubbert’s 1971 estimate of no more than 1.5 million barrels per day—a quarter of the actual number.[14]

Critics point out that Hubbert left two key elements out of his analysis—technological progress and price. “Hubbert was imaginative and innovative in his use of mathematics in his projection,” recalled Peter Rose. “But there was no concept of technological change, economics, or how new resource plays evolve. It was a very static view of the world.” Hubbert also assumed that there was an accurate estimate of ultimately recoverable resources, when in fact it is a constantly moving target.

Although he seemed a stubborn iconoclast, even a contrarian, Hubbert was actually a man of his times. He made his key projections during the 1950s, an era of relatively low, and flat, prices and a period of technological stagnation. He claimed that he had fully assumed innovation, including innovation that had not yet occurred. Yet the impact of technological change was missing from his projections. The mid-1960s marked the beginning of a new era in technological advance and capabilities.[15]

Hubbert also insisted that price did not matter. Economics—the forces of supply and demand—were, Hubbert maintained, irrelevant to the finite physical cache of oil that can be extracted from the earth. Indeed, in the same spirit, those today who question the imminence of decline are often dismissed by peak adherents as "economists"—even if they are in fact geologists. Yet it is not clear why price—with all the messages it sends to people about allocating resources and making choices and developing new technologies—would apply in so many other realms but not in terms of oil. Activity goes up when prices go up; activity goes down when prices go down. Higher prices stimulate innovation and encourage people to figure out ingenious new ways to increase supply. The often-cited "proved reserves" are not just a physical concept, accounting for a fixed amount in the "storehouse." They are also an economic concept—how much can be recovered at prevailing prices—and they are booked only when investment is made. And they are a technological concept, for advances in technology will take resources that were not physically accessible or economically viable and turn them into recoverable reserves.

The general history of the oil and gas industry, as with virtually all industries, is one of technological advance. New technologies are developed to identify new resources and to produce more from existing fields. For instance, in a typical oil field, only about 35 to 40 percent of the oil in place is produced using traditional methods. Much technology is being developed and applied to raising that recovery rate. That includes the introduction of the digital oil field of the future. Sensors are deployed in all parts of the field, including in the wells. This dramatically improves the clarity and comprehensiveness of data and the communication between the field and a company's technology centers, and allows operators to utilize more powerful computing resources to process incoming data. If widely adopted, the "digital oil field" could also make it possible to recover, worldwide, an enormous amount of additional oil—by one estimate, an extra 125 billion barrels of oil—almost equivalent to Iraq's reserves.[16]

# THE SUPERGIANT

In the 2000s, the imminent decline of output from Saudi Arabia became a central tenet of peak oil theory. The argument focused on the supergiant Ghawar field, the largest oil field in the world. The first well was drilled in Ghawar in 1948, ten years after the original discovery of oil in Saudi Arabia. It took decades to really understand the extent of this extraordinary field, made more complicated by the fact that it is really a network of five fields, which have been developed over decades owing to Ghawar's colossal size. The latest segment went into development only in 2006.[17]

The contention that Saudi Arabia's overall production is in decline is somewhat odd, for Saudi capacity has increased in recent years. After more than sixty years, Ghawar is still, in the words of Saudi Aramco President Khalid Al-Falih, "robust in middle age." Investment requirements are going up. But at a production rate of over 5 million barrels per day, Ghawar continues to be highly productive. The application of new technologies continues to unlock resources and open up new horizons.[18]

# DISCOVERIES VERSUS ADDITIONS

As proof for peak oil, its advocates argue that the discovery rate for new oil fields is declining. But this obscures a crucial point. Most of the world's supply is not the result of discoveries, but of reserves and additions. When a field is first discovered, very little is known about it, and initial estimates are limited and generally conservative. As the field is developed, better knowledge emerges about its reserves and production. More wells are drilled, and with better knowledge, proven reserves are very often increased.

The difference in the balance between discoveries and revisions and additions is dramatic. According to one study by the United States Geological Survey, 86 percent of oil reserves in the United States are the result not of what is estimated at time of discovery but of the revisions and additions that come with further development. The difference was summed up by Mark Moody-Stuart, the former chairman of Royal Dutch Shell, recalling his own days as an exploration geologist out in the field: "We used to joke all the time that much more oil was discovered by the petroleum engineers, developing and expanding the fields, than by us explorers, who actually found the fields."

The examples provided by many fields and basins point to another fundamental weakness of Hubbert's argument and its application to the entire world. In 1956 Hubbert drew a bell-shaped curve; the decline side would be the mirror image of the ascending side. Indeed, he made it so sharp on both sides that for some years it was called "Hubbert's Pimple." Some oil fields do decline in this symmetrical fashion. Most do not. They eventually do reach a physical peak of production and then often plateau and more gradually decline, rather than falling sharply in output. As one student of resource endowments has observed, "There is no inherent reason why a curve that plots the history of production of a type of fossil energy should have a symmetrical bell-shaped curve."[19]

The plateau is less dramatic. But, based on current knowledge, it is a more appropriate image for what is ahead than the peak. And the world is still, it would seem, many years away from ascending to that plateau.

# HOW MUCH OIL?

At the end of 2009, after a year's worth of production, the world's proved oil reserves were 1.5 trillion barrels, slightly more than were at the beginning of that year. That means that the discoveries and revisions and additions were sufficient to replace all the oil that was produced in 2009—a pattern common to many years. Replacing that production is one of the fundamental jobs of the worldwide oil industry. It is challenging and requires enormous investment—and a long time horizon. Work on a field whose reserves were judged proved in 2009 might have begun more than a decade earlier. Replacing reserves is even more challenging because of a natural decline rate in oil fields—on a worldwide basis, about 3 percent.

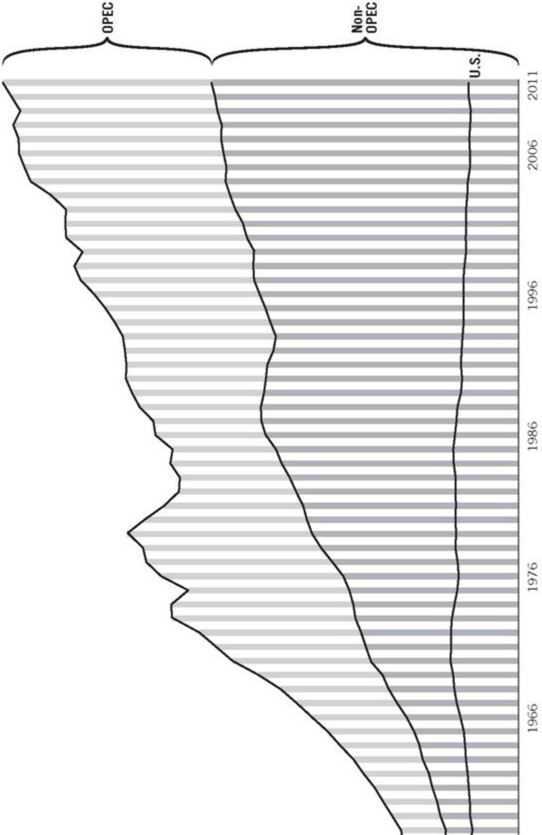
What are the prospects for the future? One answer is drawn from an analysis using a database that includes 70,000 oil fields and 4.7 million individual wells, combined with existing production and 350 new projects. The conclusion is that the world is clearly not running out of oil. Far from it. The estimates for the world's total stock of oil keep growing.

The world has produced about 1 trillion barrels of oil since the start of the industry in the nineteenth century. Currently, it is thought that there are at least 5 trillion barrels of petroleum resources, of which 1.4 trillion is sufficiently developed and technically and economically accessible to count as proved plus probable reserves. Based upon current and prospective plans, it appears the world liquid production capacity should grow from about 93 million barrels per day in 2010 to about 110 mbd by 2030. This is about a 20 percent increase.[20]

But—and there are many *buts*—beginning with all the political and other aboveground risks that have been enumerated earlier. Moreover, attaining such a level in 2030 will require further development of current and new projects, which in turn requires access to the resources. Without access, the future supply picture becomes more problematic.

**WORLD LIQUIDS PRODUCTIONS* 1946–2011**

*Millions of barrels per day*




e oil, natural gas liquids, condensates, and other liquids.

Source: IHS CERA, EIA

Achieving that level also requires the development of more challenging resources and a widening of the definition of oil to include what are called non-traditional or unconventional oils. But things do not stand still. With the passage of time, the unconventionals become, in all of their variety, one of the pillars of the world's future petroleum supply. And they help explain why the plateau continues to recede into the horizon.