“The End of Oil” Bob Lloyd: July 2005

Doomsdayers beware:

Predicting the end of any natural resources has the attendant problem of dealing with past erroneous predictions. In particular, the predictions of the pre 1980s often went spectacularly wrong in light of the next two decades. The aftermath of these early doomsday pronouncements has led to an anesthetizing of the public, even the informed public, against further pronouncements of this ilk. The environmental movement has cried wolf once two often and now they are not going to be believed. But let’s investigate this premise more carefully.

The predictions with regards to non renewable resources have been one area which has been particularly subject to error. The Club of Rome reports which first came out in 1972 suggested that the world would be limited by two fundamental restrictions either lack of resources or by an increase in pollution. The long term predictions were severe and suggested drastic world population declines sometime in the middle of the twenty first century, this century. Unfortunately the report focused more on minerals rather than energy and on the pollutant effects of chemicals other than CO_2. The anthropogenic greenhouse effect was just coming on to the world’s radar at this time and was not yet quite thought to be a serious threat.

The earth’s mineral resources exist in various proportions in the environment with the easily mined parts having concentrations which allow relatively convenient extraction using modest amounts of energy. As the better ores are mined the industry is forced to go to lower and lower grade ores; ores that generally need greater and greater amounts of energy to facilitate the removal of the mineral of concern. As long as the economics are right, the move to poorer ores can be accommodated and for all intensive purposes the reserves of most minerals are in fact pretty much inexhaustible, in the sense that they will never be actually exhausted. Most elements for instance are present in sea water, at least at the parts per trillion level; and there is a lot of sea water. So as long as extraction economics are viable, and this usually means the energy needed is available and sufficiently cheap, the economy will not be limited by lack of minerals in the foreseeable future. This reasoning, and the primacy of energy resources, was not immediately apparent in the earlier doomsday reports and has led to confusion and a severe loss of face by people wishing to protect resources for future generations.

Calling wolf:

The significance of the problem that the earlier reports have caused to any rational investigation of the current world situation cannot be overemphasized. One such incident which gained notoriety was a bet between an economist from the University of Maryland, Julian Simon and the (doomsday) environmentalist Paul Ehrlich. Erhlich was intent on proving that the world would soon run out of resources and a population collapse would ensue. Simon knew the market better and was convinced that market economics would operate and that increased consumption would result in a reduction in costs and (or) substitution for a resource whose price went too high due to shortages. A bet was arranged with Erhlich choosing 5 metals (copper, chrome, nickel, tin, and tungsten) which were to be purchased for a total of US$1,000. The idea was that if the price of the minerals went up, as Ehrlich expected, in a ten year period then Simon would have to pay up the difference in total cost. If, as Simon expected, the price went down then Erhlich would have to pay up.

The bet was resolved in 1990 and went clearly in the favor of market economics and so Erhlich paid Simon a cheque to the value of US$ 576.07.

Failures in prediction by environmentalists, as illustrated in this episode, pretty much dented further efforts to awake the world to a crisis based on shortages of resources. Pollution fared somewhat better to the extent that global warming reached the world stage in the series of negotiations undertaken culminating in the Kyoto agreement. Local level pollution, however, took more of a back seat, in that the more obvious problems were predominantly solved using improved technology and adherence to stricter guidelines, further diminishing environmentalist claims that disaster was just around the corner. In general the global economy has boomed over the last two decades with some of the larger third world nations, including China, aspiring to approach first world standards.

Physical reality versus economic reality:

So what is the problem? The problem is that the world economic picture, painted by economists on a background of free trade and globalisation, has failed to take into account the physical reality of energy in general and fossil fuel resources in particular; especially the state of the world's crude oil supplies. An examination of oil supplies will lead us to the conclusion that we have essentially been led up the garden path by a system of unrestricted marketing and growth dominated economics.

That there has been very little serious outcry or realisation of the situation, at least from the developed world, might be attributed to the fact that in general we are comfortable and have never had it so good. And that scientists have abdicated the operation of the global human situation to economists due to the supposedly self evident success of this approach and the fact that contrary environmentalist meddling could be dismissed in the light of their obvious failures in the past.

The world economy is dominated by crude oil supply which together with natural gas accounts for 63% of the commercial energy used by the world. The graph below (Figure 1) is taken from the oil company BP's "Statistical Review of World Energy 2004" (released in mid 2005)

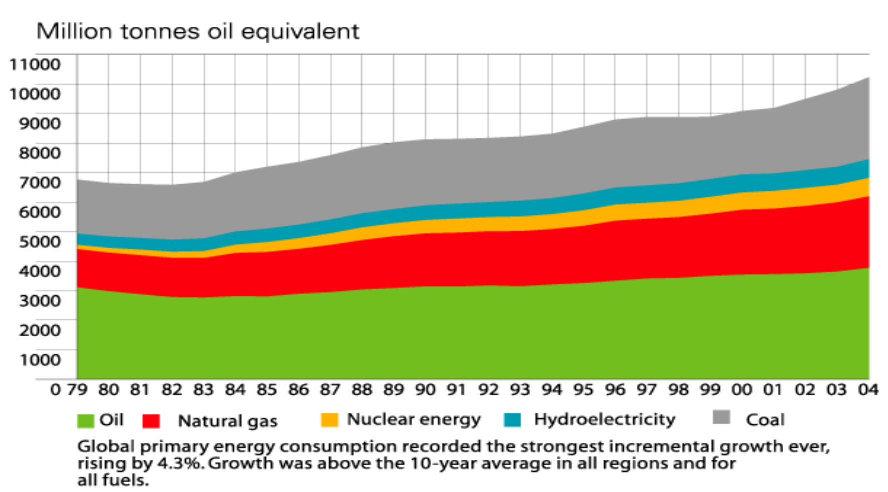


Figure 1: World energy supply

As of early 2005, we were using some 84.7 million barrels a day: an amount which equates to some 31 billion barrels a year or around 4.5 cubic kilometers a year.

What do we know about oil?

Oil is a fossil fuel, it's found in underground deposits ranging in depth from surface seeps to several kilometers. It's composed of mainly carbon and hydrogen with all sorts of impurities including sulphur and oxygen. The really great thing about oil is that it does not need to be mined in the conventional sense, as it is a liquid, and can either flow under natural pressure to the surface or be forced to flow by pumping or pressurizing the deposit with a gas or liquid.

The ease of extraction of crude oil and its high calorific value has made it an extremely cheap source of concentrated energy. The fact that it is a liquid has meant that it can be conveniently transported and stored. The importance of oil to the world's economy does not really need to be stated but it is the:

- Main transport energy source including
  - Land
  - Sea
  - Air
  - Military
- Main feedstock for the petrochemical industry
- Reason for agriculture being able to sustain the present world population:
- Fuel for electricity production in some countries
- Feedstock for bitumen for roads and many other uses

Oil as a fossil fuel; it is created from the biological remains deposited in/on a source rock known as kerogen. The circumstances for the formation of oil are very specific and sequential. To get oil, the kerogen must be covered to prevent oxidization to CO_2, and then deeply buried by subsidence so that it can be heated by the geothermal gradient under pressure by the weight of material above it. This is the hydrocarbon kitchen with temperatures between 65^oC and 260^oC. At the higher temperatures, in deeper deposits, gas will form and at the lower temperatures crude oil. Because we are dealing with gases and liquid: the final stages of reserve formation must include a natural trapping mechanisms that can prevent the materials from floating to the surface and escaping into the atmosphere. Thus the fluid must be trapped by some form of impervious rock. Many mechanisms are available for trapping, including salt domes and shifted anticline formations. Because of the necessary sequence of events to form oil and the specific required trapping mechanisms oil is not spread around the Earth's crust in the same manner as other solid minerals. It can be harder to find and it's generally there or not.

The age when oil deposits were formed is highly variable, Siberian fields discovered at Yuruchbeno in 1983 are around 1 billion years old. More recent deposits were formed as short as 1 million years, but in generally oil deposits are between 10 million years and 260 million years old; the age of the dinosaurs. Crude oil existing today comes in many forms from a light brown liquid such as delivered from Australian fields to dark treacle looking heavy crudes more typical of Venezuelan deposits. Middle Eastern crudes run the full range between light and heavy liquids. In addition to the liquid crude oils, which are generally called conventional deposits, there exists another form of hydrocarbons in mostly solid form. These are the unconventional "oil" reserves and they include tar sands and oil shales. Whether a deposit is called conventional or unconventional depends on the technology around to facilitate it conversion to usable products such as motor spirit or diesel.

The 64 trillion dollar question:

Now to the 64 trillion dollar question, how much oil is there for us to exploit? Due to the perverse nature of oil deposits, mentioned earlier, plus the fact that oil is of considerable strategic importance as well as commercial importance, the exact amounts underground are not able to be determined with great accuracy. In addition political intrigue and vested commercial and national interests in maintaining secrecy, has meant that knowledge of the extent of reserves is not readily available to the public. But seismic surveying and computer modeling of deposits is now very advanced and for identified fields the amount is (at least it can be) known reasonably well.

There are further problems in estimating of how much oil may exist because new deposits are continually being discovered, and oil is being used by the world economy. Thus the estimated reserves that are left are constantly changing. There are big dollars in oil (understatement) so countries/companies have political and financial interests in obscuring the real national figures For instance OPEC: production quotas are set by the size of the country's reserves so it is in national interests to overestimate the reserves - so production can proceed full tilt. This is the origin of the so called political reserves and a source of considerable confusion and unreliability in estimating deposits for OPEC countries.

The 3 Ps:

The ways reserves are estimated are also calculated differently in different countries. Roughly speaking there are the 3 Ps which include:

- Proved reserves (1P)
- Proved and Probable reserves (2P)
- Proved, Probable and Possible reserves (3P)

Proved reserves are the official reserves and are generally considered to be reliable to within 95%. Probable reserves are assigned a probability of actually getting them out of the ground at around 50% and possible reserves are the ones that just might be there if exploration proceeds, with something like a 5 % chance of ever getting them to market.

So problematic in fact is getting reliable estimates of the world's crude oil supplies that the quantity seems to depend on who you ask? On this front there appear to be two main schools of thought:

- The optimists who include mainly economists, and people with a vested interest in the world financial system.
- The pessimists, who mainly include scientists, geologists, ex oil exploration personnel, and people without a personal vested interest in the world financial system.

The weight of opinion is not evenly divided, with the optimists generally being around in far superior numbers. An association devoted to examining the question of how much oil is left, called the "Association for the study of Peak Oil" or ASPO. ASPO was formed in 2000 and is now one of the clearest voices suggesting that crude oil reserves do not exist in quantities as large as portrayed by the mainstream media and energy agencies. In fact they say extraction is close to peaking and once this happens there will be dire consequences for the world economy.

The question of when the world oil supply peaks, however, is a very important one to get right, the world economy does run on oil. And the answer requires us to tread carefully between both foolhardy optimism and counter productive pessimism; both of which are around in copious serves.

In this regards it must be noted that energy is quite different than other kinds of resources, such as minerals which as mentioned earlier can be extracted at very small concentrations, or even made if we have enough energy. For crude oil once the extraction energy (including transportation and refining) is greater than the amount of energy we can realize out of the final product, it is a loss making concern as far as energy goes. This fact is a reflection of the first law of thermodynamics which says that we cannot create energy only change its form.

How much oil is there?

Estimates for the total amount of oil that has ever existed as a recoverable resource is known as the Estimated Ultimate Recoverable (amount that is) or EUR. For oil, such estimates have fallen between 2000 and 3000 billion barrels of petroleum liquids. Figure 2 below gives a selection of estimates of EUR by agencies, individuals and companies over the last 65 years.

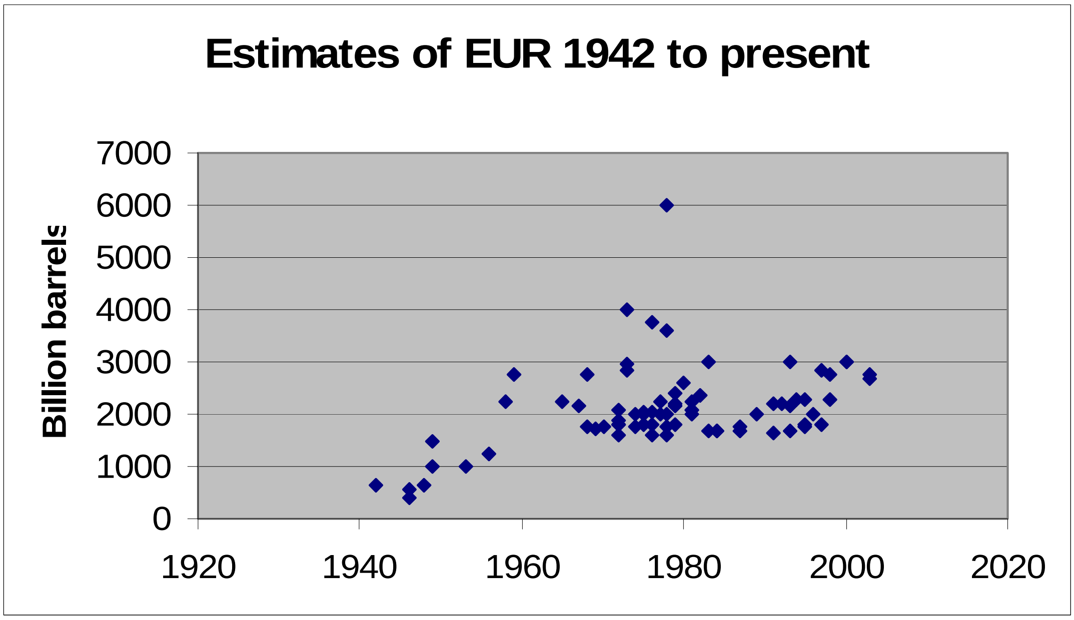


Figure 2: various estimates of EUR

The average of all estimates is 2150 billion barrels with the more recent estimates falling within the range of 2000 billion barrels to 3000 billion barrels. So the amount remaining is less the amount we have already used. This latter amount is known a bit more accurately and was around 1000 billion barrels as of the end of 2002 (End of 2004 it was close to 1055 billion barrels). Note that these figures include natural gas liquids or NGLs from 1965 onwards. The NGLs are the condensates from natural gas. If we exclude the NGLs the total consumption is around 100 billion barrels lower.

Figure 3 shows how the world has been producing (extracting) oil since the mid part of the last century. The rate is expressed in the oil industry standard, that of million barrels per day. As we can see, around 1950 the world was extracting and using around 10 million barrels per day. This quantity rose at pretty much a constant rate of 7 % per annum until 1974 where it took a dive, increased more slowly and took another dive in late 1979. On the graph the pink line is the annual % rate of increase and the dashed line is the % rate of increase averaged over 10 years. The two prominent dips show the oil crises of the 1970s produced by the OPEC embargo in 1974 in retaliation for Israel attacking Egypt and by shortages in 1979 brought about by the revolution in Iran and the following Iran-Iraq war. During the intervening years world consumption actually went negative for a while before resuming a slower growth rate of between 2% and 3 % per annum for the rest of the 20th century.

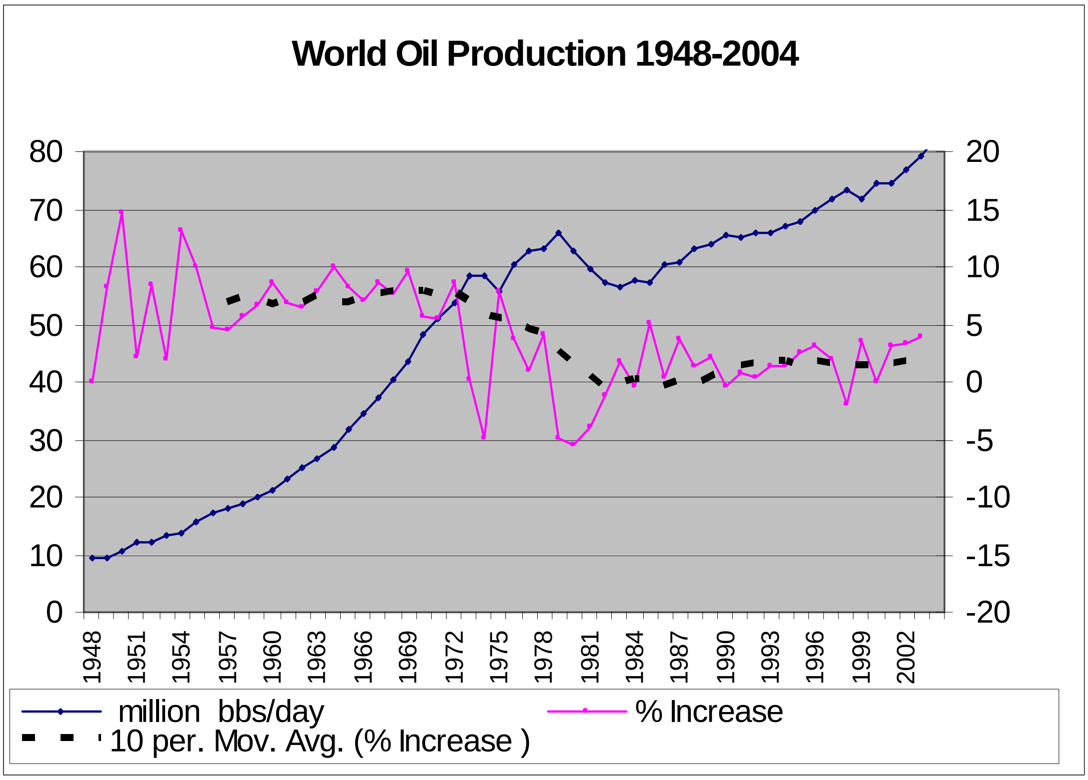


Figure 3: World oil production

The next graph (figure 4) shows the world cumulative production over the same period and as we can see, as of 2002 the world had extracted and consumed around 1000 billion barrels. The cumulative production is obtained by continually adding the previous year's consumption. When we are talking about rates of increase that are roughly constant the important parameter is the doubling time, the time it takes to double consumption. As can be seen for the first half of the 20th century the doubling time was around 11 years corresponding to an annual increase of close to 7%. After the two oil crisis, reduction in consumption, and importantly improvements in global energy efficiency, allowed the doubling time to increase to 21 years (an annual rate of increase of close to 3.5 %).

If the EUR for the world is 2500 billion barrels we have only one quarter of a doubling period left, which at the present rate of increase (close to 4%) will get us to the top of the extraction/ consumption curve (at 1250 billion barrels) in only 4 to 5 years.

This is such a really short time that we might suspect that something is wrong with way it has been worked out. What if we have a larger EUR? The United States Geological Survey (USGS) put out a report in 2000 that the EUR was around 3000 billion barrels, but the way they calculated this amount has been criticized by the pessimists, as being far too high. The report was quite meticulous in the calculations of existing reserves and possible new finds but had a rather fuzzy figure for what is called "reserve growth".

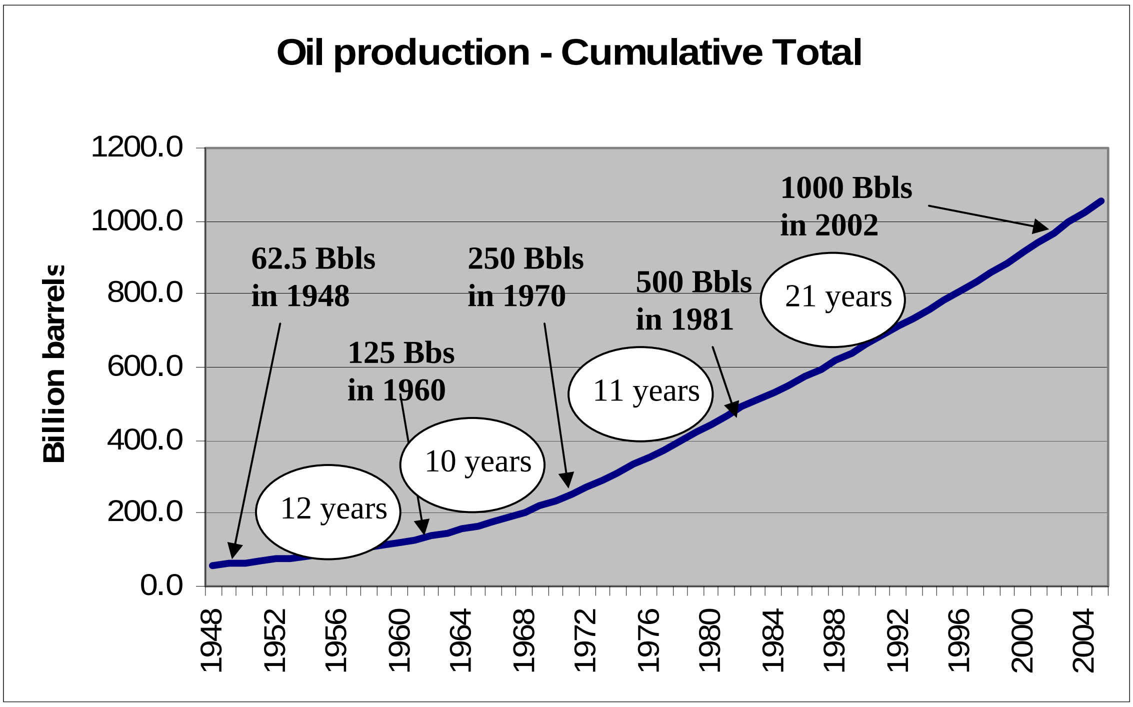


Figure 4: Cumulative world oil production.

This reserve growth was calculated based on historic reserve growth in the US, but the US crude oil reserve accounting system has been much better policed than the reserve accounting system for the rest of the world. In the US, companies regularly used to underestimate their reserves to keep the regulators happy. Doing this they could also keep their shareholders happy by announcing annual increases in reserves and still be confident of actually pumping the increased amount. If we take this overestimate into account the EURs suggested by the USGS and by independent geologists are pretty close at around 2,400 to 2,500 billion barrels of total liquids.

Two methods of accounting for oil reserves:

What about the oil companies surely they know how much oil there is? Well, as mentioned, the oil companies like to keep shareholders happy by announcing regular increases in reserves. What this has meant is that two separate accounting systems have evolved, the public figures released by oil companies and national agencies, and what are called *backdated mean technical reserves*. The latter are calculated by independent consultants using confidential data available to only a small number of specialist oil support agencies. The figure below, taken from Jean Laherrere's paper to the 2005 ASPO annual conference illustrates these two accounting systems. The lines rising diagonally from the bottom left are the public figures; the curves peaking at around 1980 are the backdated mean technical reserves. As of the present time, that is 2005, the two set of figures are intersecting and with the spread in values, suggest somewhere between 800 billion barrels and 1,300 billion barrels of extractable oil is left for the taking. As we have used some 1,100 barrels, as of the end of 2005, this gives an EUR of between 1,900 billion barrels and 2,400 billion barrels.

If the cross over between the two accounting systems is real then the public reserve estimates should start to fall very soon. And they are. BP in their latest statistical yearbook gives the public reserves (remaining) for 2003 as 1,188.3 billion barrels and for 2004 as 1,188.6 billion barrels. The smallest annual increase ever, of only 0.3 billion barrels.

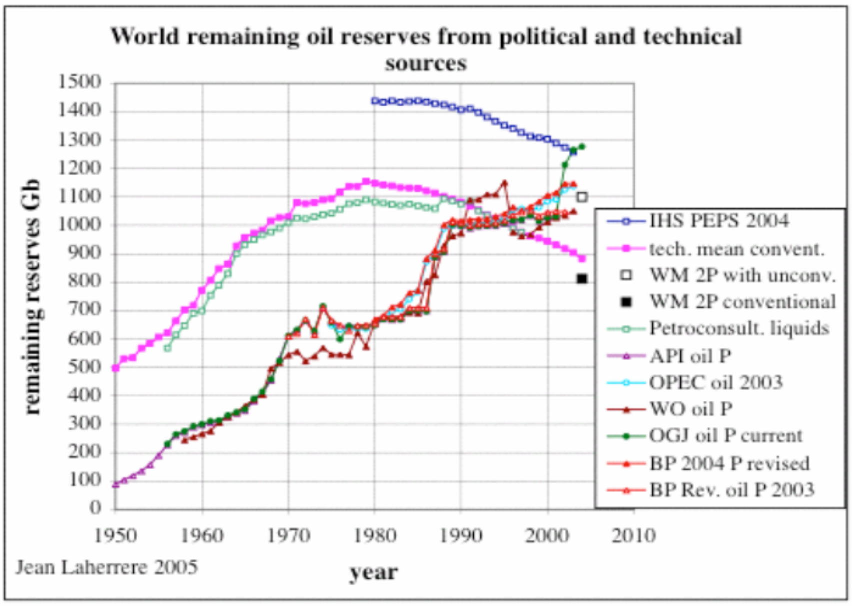


Figure 5: Two accounting systems

Creaming curves:

Another way of trying to estimate the EUR from proved reserves is to use what is called the "creaming curve" This methodology was invented by the Shell Oil Company in the 1980s to track future oil discoveries. It works by realizing that in exploration the easiest fields are generally discovered first. The oil is creamed off the top so to speak. The creaming curve is a plot of the cumulative discovery against the cumulative number of new field wildcats. A wildcat is an oil industry term originating from the early days of exploration in the US and refers to an exploratory well in an area that oil has not yet been proved to occur. The creaming curve below is from Laherrere, for the US and shows that as oil exploration proceeds it becomes necessary to drill more and more wildcats to improve the cumulative discovery.

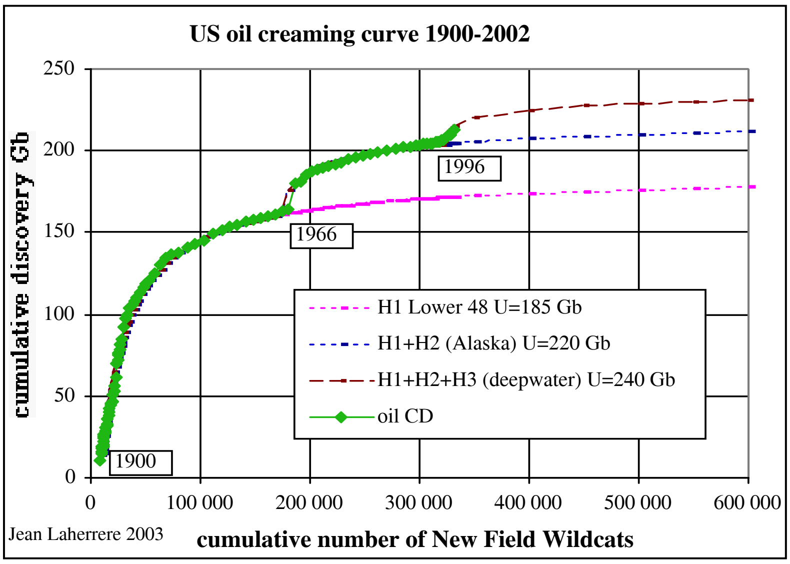
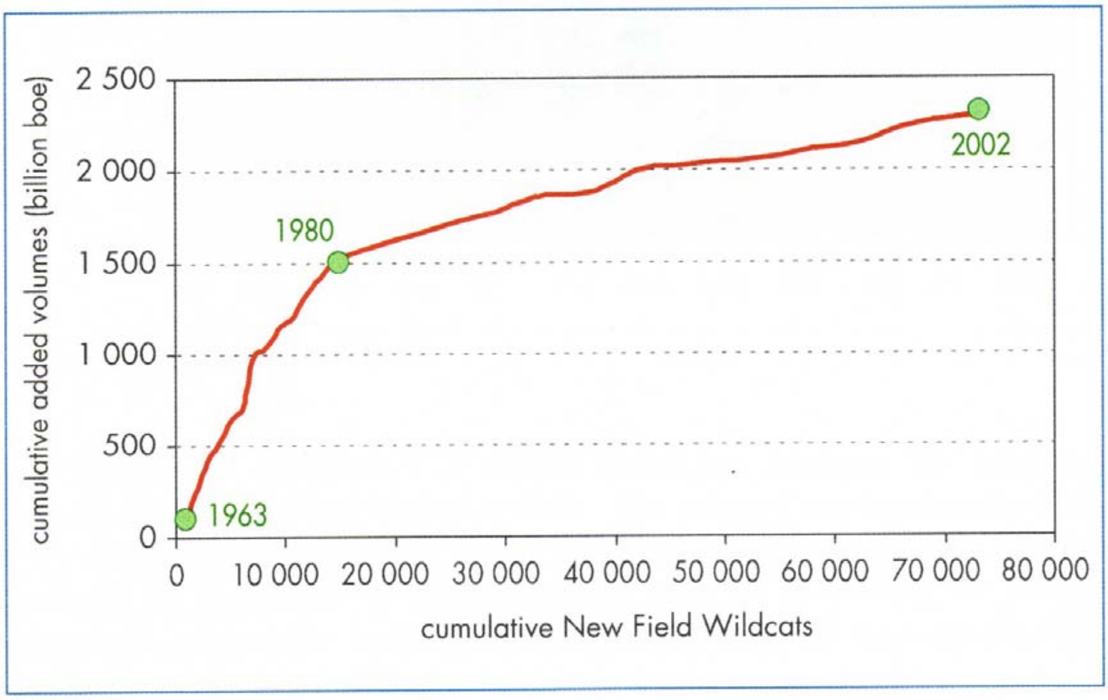


Figure 6: US Creaming curve.

Eventually the point must be reached when either the monetary cost (or more importantly the energy cost, which does not change with the economics) of drilling the increasing number of exploratory wildcats does not warrant the extra amount of oil added to the cumulative discovery. The curve approaches an asymptote or effective ceiling. As can be seen for the US the ceiling is moving towards something around 230 billion barrels.

If we do the same exercise for the world, that is produce a world creaming curve, we get a graph as shown below (figure 7) , this time the data is from the International energy Agency (IEA) in their annual review the "World Energy Outlook 2004".



Source: IEA analysis based on IHS Energy database.

Figure 7: World Creaming curve

As can be seen the ceiling is moving towards somewhere between 2,400 and 2,500 billion barrels; thus further corroborating the earlier EURs of around this amount.

Where is the oil?

It will come to no surprise to know that most of the world's remaining oil lies in the Middle East with Saudi Arabia being the largest single holder of reserves followed by Iran and Iraq. In total a little over 60% of the world's proved reserves are in the Middle East, 11.7 % in Europe including Russia, 9.3% in Africa including Nigeria, 8.5% in South America including Venezuela, 5% in North America, including the US, Canada and Mexico and a paltry 3.5% in the whole of Asia and the Pacific. The figure below (figure 8) from BP illustrates the geographic breakdown of proved reserves.

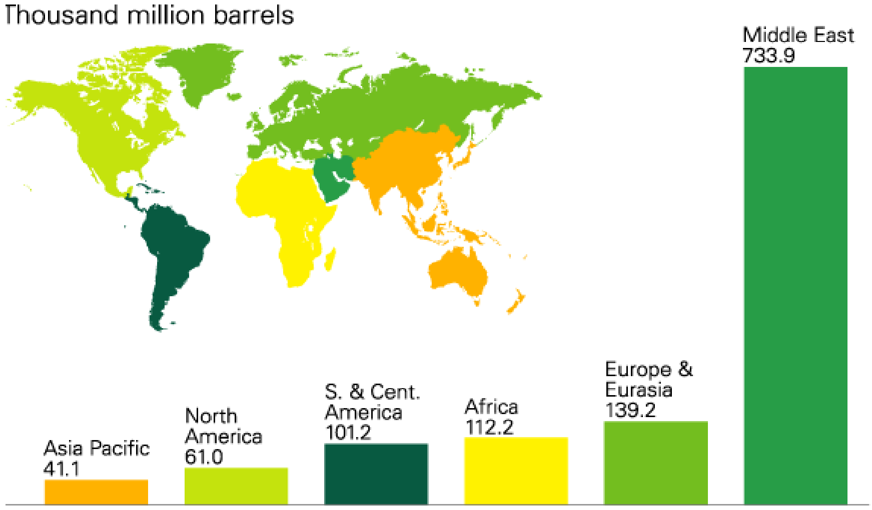


Figure 8: Location of world oil resources.

The other important piece of information about oil reserves is that they are mostly concentrated in the largest fields. The following figure (figure 9), using data from the USGS 2000 report, shows how over 82% of all the worlds oil is in located in 20 of the largest petroleum systems, and the largest of these of course are in the Middle East.

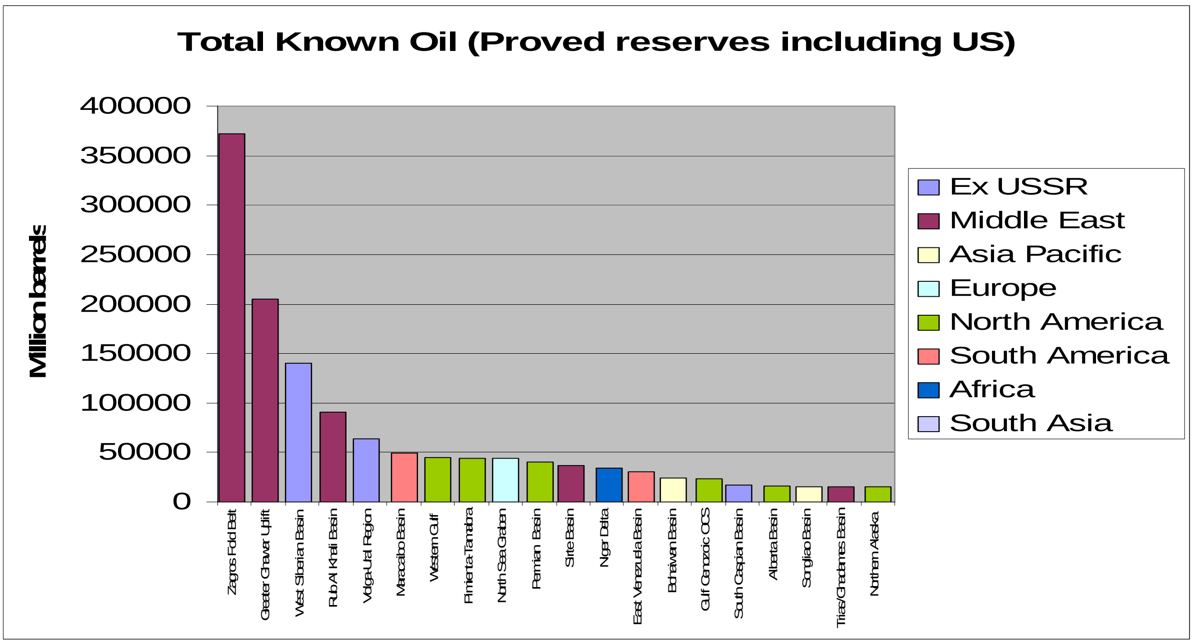


Figure 9: concentration of oil in large petroleum systems.

Now for the really important question- How long will oil last? - The Hubbert Curve:

Figure 10: the Hubbert Curve

Ok we now have a pretty good idea of how much oil the earth was originally endowed with, so we can start to look more carefully at how long it might last. This question has been subject to investigation since at least the early 1940s. The historical "patron of estimators" was a quite remarkable person called King Hubbert, who in a key paper, published in the journal "Science" in February 1949, alerted the world to the possible demise of world fossil fuels. At that time Hubbert worked for the Shell oil company and his results he portrayed were not looked upon favorably by that company at that time. The now famous "Hubbert Peak" is well known as a symbol of the finiteness fossil fuel resources. Hubbert in fact did not give a definite shape, at that time for the curve that he is now well known for. In his own words

> *" –we may announce with certainty that the production curve of any given species of fossil fuel will rise pass through one or several maxima and then decline asymptotically to zero. Hence while there is infinity of shapes that such a curve may have, they all have this in common: that the area under each must be equal or less that the amount initially present."*

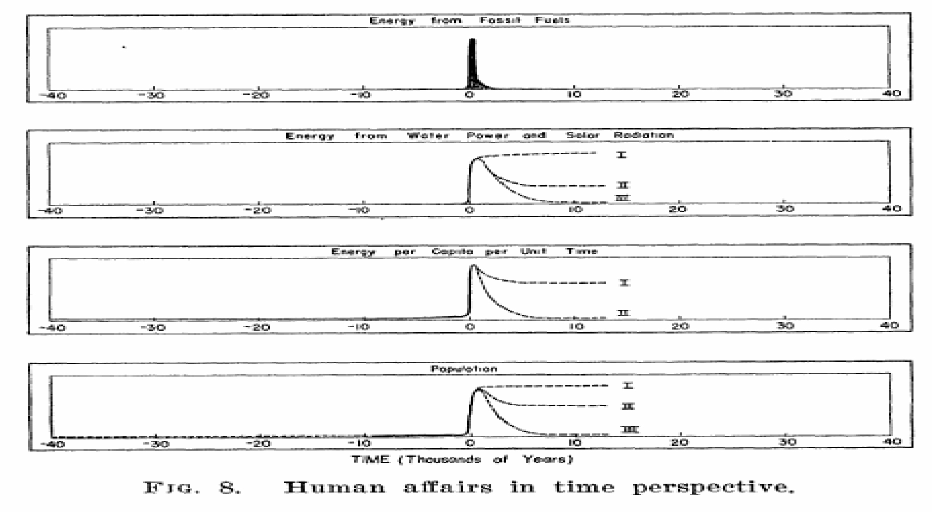


Figure 11: King Hubbert

Figure 12: Hubbert's scenarios from his 1949 paper

The rough, hand drawn, Hubbert curve is shown at the top of figure 12 in a time scale that suggests the short term time blip that fossil fuels will contribute to the world's energy needs.

Hubbert the man:

Hubbert was not a complete pessimist as he is sometimes made out to be, he saw solutions, including using renewable energy (second graph figure 12) and energy efficiency (third graph figure 12) to create a sustainable future for mankind. If renewable sources were not, however,

seamlessly used to replace fossil fuels he suggested a very similar picture to that given by the Club of Rome, a catastrophic collapse in the world population (forth graph figure 12) .
How much oil did Hubbert think there was? In his 1949 paper he gives a total of 320 x 10^9 m3 which converts to 2000 billion barrels or very close to more recent estimates. In 1956 he predicted that the peak of crude-oil production in the United States would occur between 1966 and 1971.It occurred in 1970. Also in 1956 he predicted the world peak would be in 2000. He later (1974) revised this down to 1995 and then up again to the year 2000 (in 1981).

Towards the end of his life he was a very worried man, his main concern was that economics was incompatible with physical reality, he lamented that:

> *"The world's present industrial civilization is handicapped by the coexistence of two universal, overlapping, and incompatible intellectual systems: the accumulated knowledge of the last four centuries of the properties and interrelationships of matter and energy* (Science); *and the associated monetary culture which has evolved from folkways of prehistoric origin* (Economics)*".* My insertions in brackets.

He died in 1989 after a life devoted to finding a way to reconcile the social situation on earth with physical reality and an imposed economic system. Part of his analysis at least was premised on the pretty reasonable premise that discovery has to precede consumption, with a time lag of around 40 years between peak discovery and peak consumption. The peak discovery rate for the US was around 1930 and the peak extraction was some 40 years later in 1970. The peak discovery rate for the world occurred in 1964 suggesting peak in consumption in 2004. Hubbert style analysis has been extended in recent years and is now used by geologists and mathematicians in ASPO to make sense of the current world situation.

Curve fitting:

The figure below (figure 13) gives Jean Laharrere's analysis of the US oil discovery and consumption cycles the green squares are the discovery and the brown diamonds the production. Smoothed curves are fitted to each and it can be seen that the shape of the production curve is pretty close to that of the discovery curve but around 35 years later. The other interesting point about the shape of the US extraction/consumption curve is that it was only changed slightly by the oil price rises of the 1970s and despite an enormous effort by the present administration to lesson their dependence on Middle East oil the production curve is still falling. Evidence from other countries and fields suggest that once an oil field starts declining it is not possible to reverse the process except over the very short term.

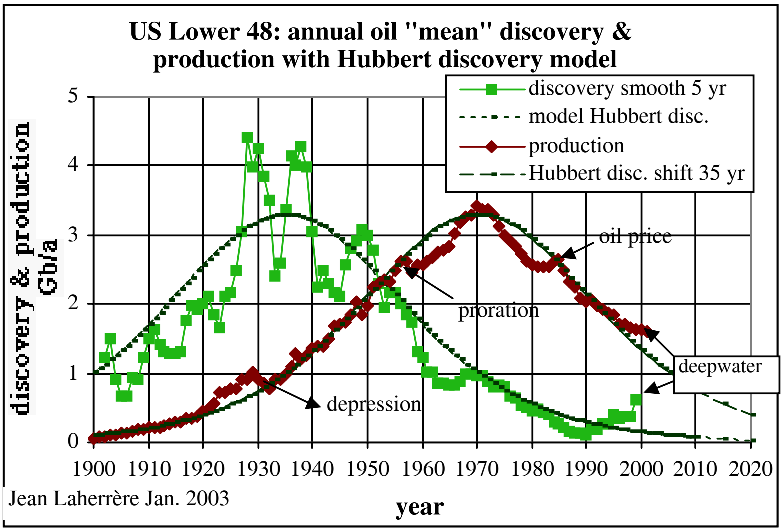


Figure 13: US discovery and production cycles

To get some idea of how this applies to the world as a whole the next figure (figure 14) gives the global discovery record, the red bars indicate what are referred to as super giant fields. These are really big fields with over 5 billion barrels of extractable oil. But the world is using over 30 billion barrels of oil a year so the discovery of a new super giant field would only supply the world for an extra 2 months! No super giant field has been identified since the North Sea field around 1975. As mentioned the peak discovery rate for the world was around 40 years ago in 1964 ever since we have been discovering less and less (on average) per year.

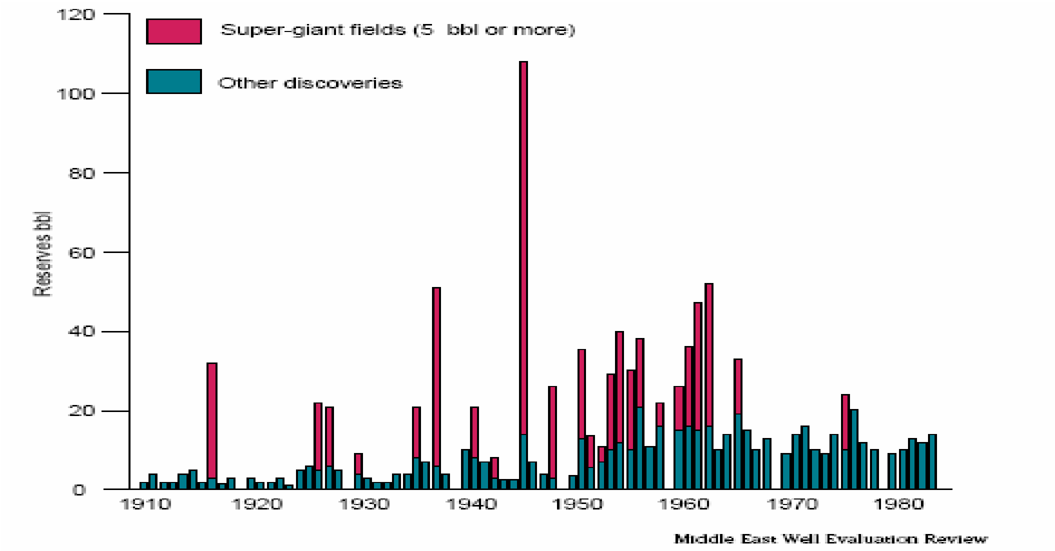


Figure 14: World crude oil discoveries

So discovery is falling off but why should extraction fall of in the same sort of symmetric way? Why can't it just continue flowing at whatever rate we pump it until it's finished, and then stop? To put this question another way, why is the Hubbert curve a nice smooth curve approximating what is called a normal distribution? The answer to this question involves a discussion of geology, mathematics and economics. We will discuss geology and mathematics first and come back to economics later.

First geology, oil wells come in all shapes and sizes, from the early wooden derrick wells, as used by Colonel Drake in the first US oil well in Pennsylvania in 1859 to the modern mammoth off shore rigs used in deep water today. But they all have this in common, the need to extract oil from porous geological strata. If the natural pressure is high enough the oil flows of its own accord and we get a gusher, if not we have to either use a mechanical pump or pressurize the well by pumping a gas or liquid down an adjacent well. Eventually, however, the viscosity of the oil and the porosity of the strata mean that the oil becomes increasingly harder to pump out; and this means that the production of a given well will decline once it passes a peak production rate. The production history of any number of oil wells proves this point. The individual production curves may not be symmetrical or smooth but, and here we come to mathematics, if we add sufficient, independent and irregular curves together we get very close to the normal curve, the familiar bell shaped curve that goes by the trademark of the Hubbert curve. The figure below (figure 15) shows the addition of many countries oil supply curves to give the familiar Hubbert shape.

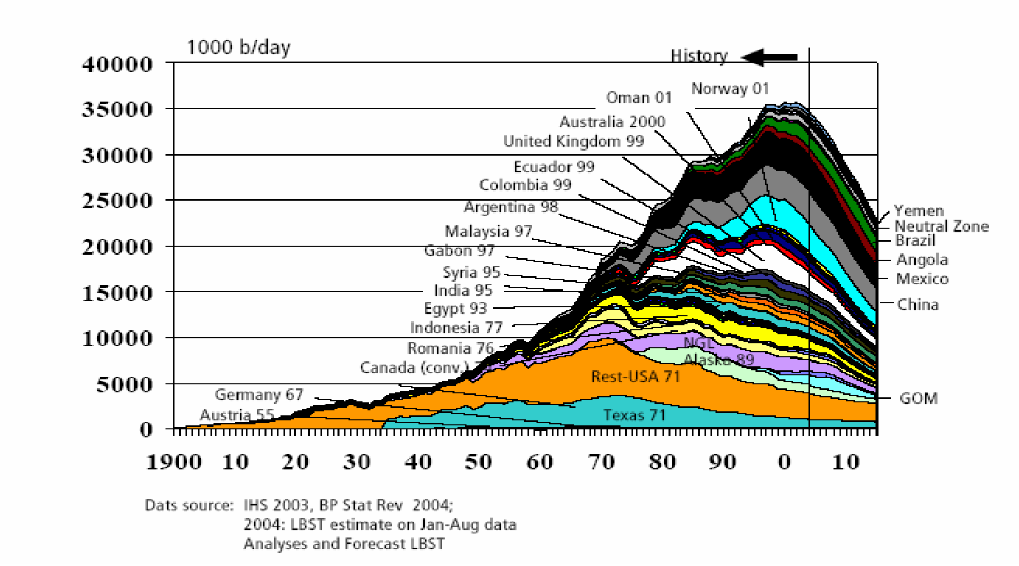


Figure 15: World production curve ex OPEC ex Russia

Whether we can use a single Normal distribution (sometimes called a Gaussian distribution) to model the production curve, or a Logistics function as Jean Laherrere uses (the Logistics distribution is pretty similar in shape to the normal distribution but it is easier to handle mathematically) depends on the intensity and distribution of the discovery cycle. For instance for France, Laherrere fits a model with two superimposed logistics functions. For the world, a single function is appropriate due to the smoothing effect of adding a large number of separate production curves. Below is the world supply modeled for an EUR of 2000 billion barrels, fitting the rate of consumption appropriate to the mid part of last century (figure 16). This is what Hubbert would have seen before the oil crises and it can be seen that the peak would have occurred just before the end of the millennia. If we relax the consumption rate to account for the oil crises the peak shifts out to around 2004 (figure 17). To get the peak out further we need to assume a larger EUR. The next two figures (figures 18 and 19) give the peak at 2012 for an EUR of 2,500 billion barrels and 2018 for the optimistic USGS estimate of 3000 billion barrels.

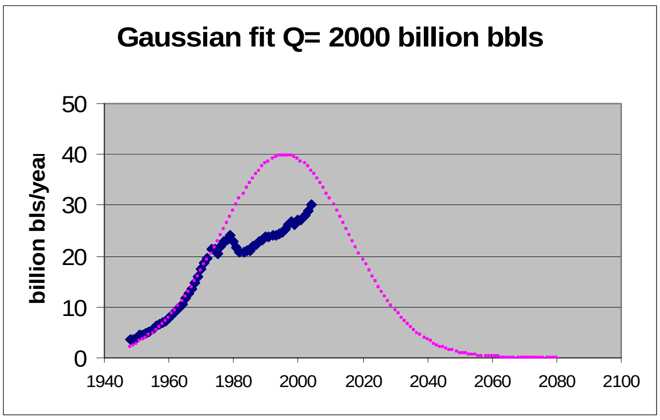


Figure 16: Curve fit to 2000 Billion bbls pre 1970

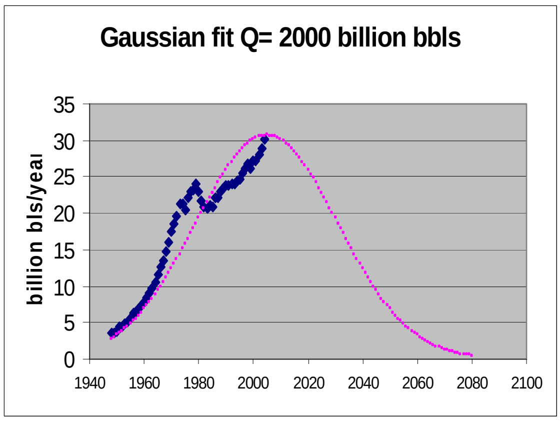


Figure 17: Curve fit to 2000 Billion bbls post 1970

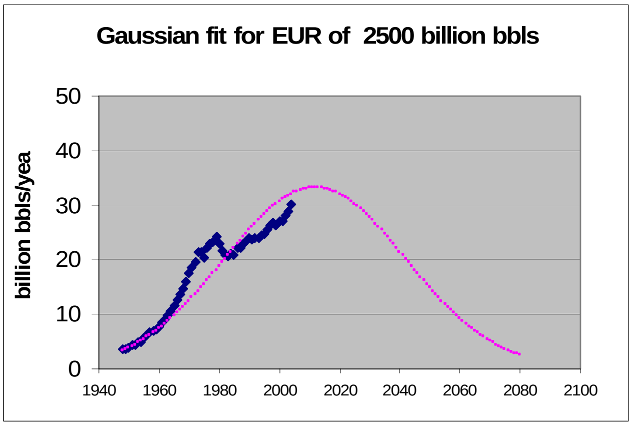


Figure 18: Curve fit 2500 Billion bbls

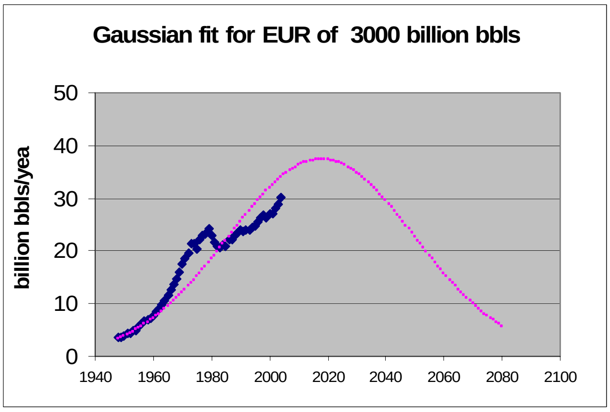


Figure 19: Curve fit 3000 Billion bbls

Two of the most influential agencies for reporting on oil reserves are the International Energy Agency the IEA and the Energy Information Administration, of the US Department of Energy, the EIA. Both of these agencies produced reports in 2004 suggesting that the projected liquid fuels energy needs of the world would be met by existing crude oil reserves. Their data is plotted superimposed on the optimistic 3000 billion barrels of oil curve in figure 20. As can be see it is difficult to reconcile the model supply curve with the agency projections.

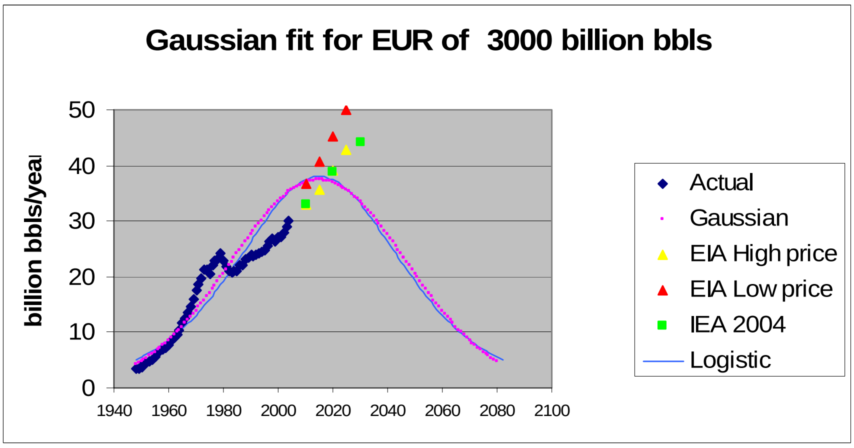


Figure 20: Curve fit to 3000 Billion bbls including IEA and EIA predictions

Where does the IEA think that the extra oil will come from? The next figure (figue 21), which is taken from their report the "World Energy Outlook 2004" gives some suggestions. Simultaneously in 2004 four new supply streams must eventuate. They are the development of existing reserves, enhanced oil recoveries, development of new discoveries and the use of non conventional reserves. To be fair the latter the non conventional reserves, that is the tar sands mainly from Alberta Canada are presently contributing in a small way (of the order of a million barrels per day) . Amore importantly the existing capacity is seen to decline rather rapidly.

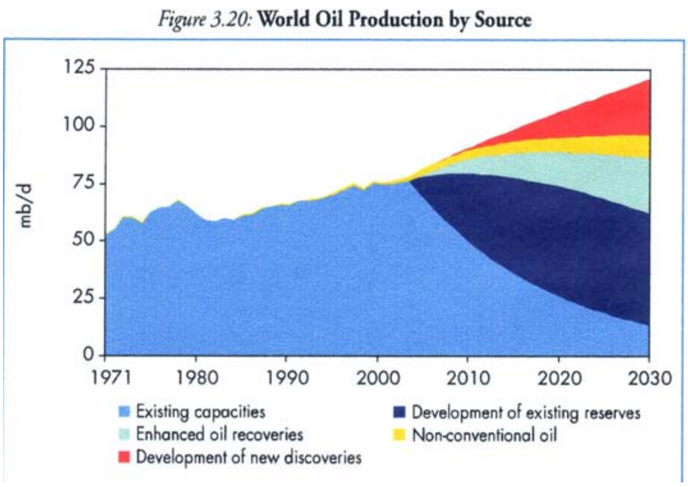


Figure 21: IEA Energy Outlook 2004 for oil production by source.

What about the oil companies how do they see supply meeting demand in the next few decades? The largest non government oil company Exxon Mobil also produced a report in 2004 putting forward their view, it is shown in figure 22 below.

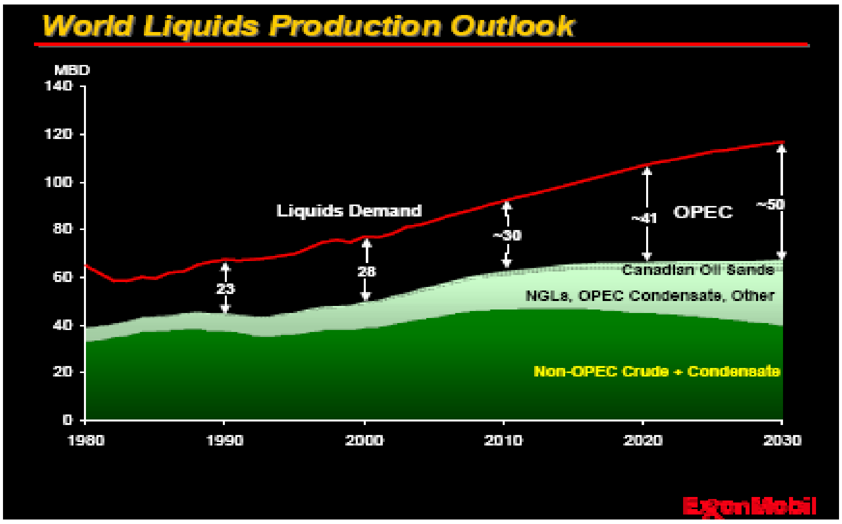


Figure 22: Exxon Mobil scenario for world oil production.

Exxon Mobil sees the contribution from non OPEC oil reaching a plateau around 2010 and the balance of forecast demand being met mainly from natural gas liquids and OPEC. In fact OPEC supply is suggested to increase to 50 million barrels per day by 2030, an increase which many independent consultants believe impossible. Indeed the largest swing suppliers, the Saudis, are only planning to increase their contribution from its present (2005) level of around 9.5 million barrels a day to 12 million barrels a day by 2030 and even this increase is doubted by many in the industry.

Colin Campbell of ASPO has a very different picture he sees the world oil supply peaking very soon around 2007- 2008. His projections given at the recent Oil and Gas Depletion conference held in Lisbon is given below as figure 23 .

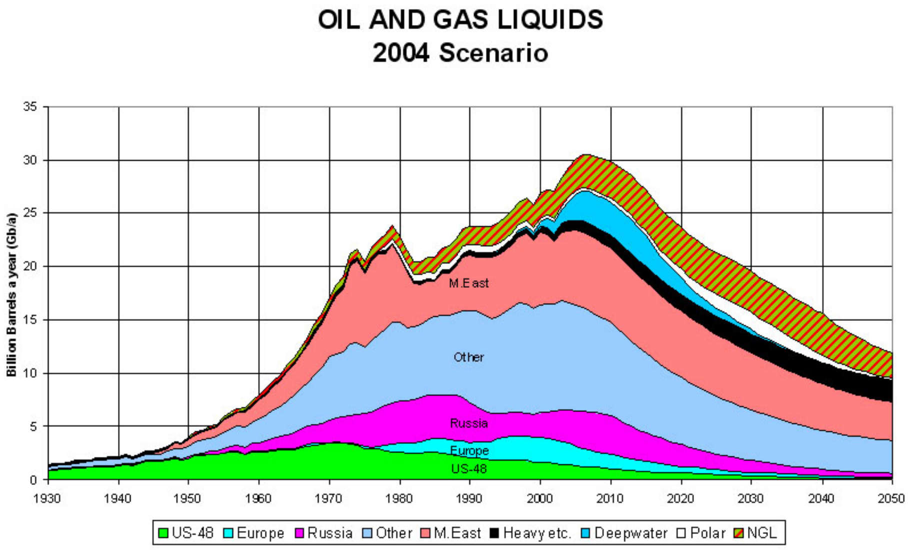


Figure 23: Colin Campbell's 2004 scenario for world oil and gas liquids.

Economics and the price of oil

The final reason for the Hubbert shape is economics Classical economics suggests that as supply is restricted, the price of oil will increase making demand decline. Eventually if the price increases sufficiently, substitutes will replace the threatened resource. The trouble is that there are not too many substitutes for oil.

The classic economic theory of depletable resources (including of course fossil fuels) was considered by an American economist Hottelling as far back as 1931. Hottelling formulated the rule, which is now named after him, that the price of non renewable resources should follow the interest rate. This law can be seen to follow from the argument that for the oil producers it does not matter if they produce a given quantity of oil today at a price $X or at a time in the future at $Y, such that if they put the $X in the bank today they would have the equivalent money $Y at the future time. Hottelling used sophisticated mathematics to show that this conclusion was true but the problem is that in practice it has not happened. That is the price of oil has not followed the interest rate. The figure below (figure 24) shows the price of oil for the last 150 years or so taken from the BP statistical review. The green line shows the price of oil in constant dollar terms and it can be seen that over the period of highest increase in production (the first half of last century) the price of oil steadily declined. It was not until the oil crisis of the mid and late 1970s that the price increased substantially.

And this increase was due to a manipulated market and political events (OPEC and wars) not market forces based on the long term supply of oil. Thus the price of oil has not given the right signal to the consumer that the end of oil is near, perhaps until recently. In particular the flurry of activity from the conservation movement in the 1970s and especially following the oil crisis was dissipated by the crash in oil prices which occurred in the mid 1980s. Now we can see how Erhlich got it so wrong. Erhlich made the bet on the selected metals in 1980 and settled the bet in 1990. He bet when the price of oil was at a peak of around $80 a barrel (2002 dollars) and settled when the price of oil was closer to $15 dollar a barrel (2002 dollars). As one of the main contributing factors to the price of metals is the cost of energy for mining and processing, it is no wonder he lost substantially. In fact if, in hindsight one looks at the price of a whole range of metals one sees the clear presence of the 1979- 1980 oil price spike

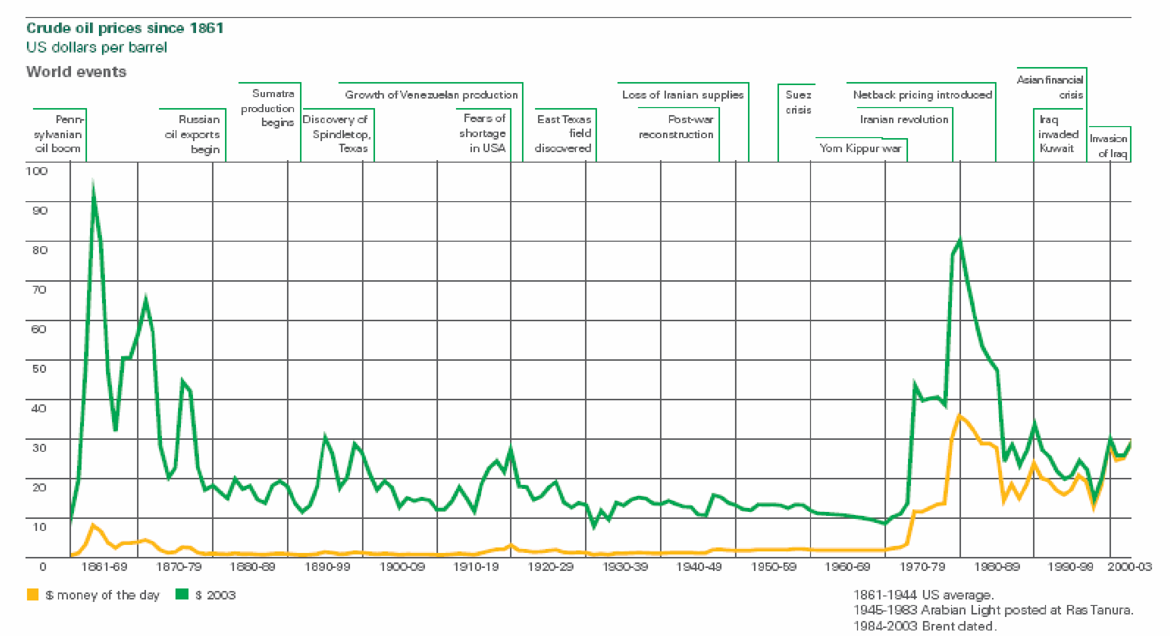


Figure 24: Price of Crude Oil as per BP statistics 2004

The price crash of the mid 1980s took the wind out of the sails of any effort to convince the world that something should be done with regards to energy conservation and to urgently research renewable energy options; so that they could be brought on-stream in an orderly manner as suggested by Hubbert. The buoyant world economy in the latter years of the 20th century driven by globalization and the international concerted move to deregulate vertically integrated energy supply companies has kept energy costs lower than necessary to give price signals to trigger the appropriate investments in really sustainable options. These trends, together with other major political events, including the hyped up war on terror have substantially neutralized any effort to look at the future of the world energy situation in a rational manner.

Back to the cumulative supply curve:

Let's take another look at the cumulative production curve given earlier (figure 4). Because the world is using oil at rate of increase that is approximately constant, that is exponential growth, the important parameter is the doubling time. Whether there is an EUR of 2000 billion barrels or 3000 billion barrels is only going to make a difference of one half of one doubling period. Thus in terms of identifying the problem of peak oil, it is seen that Hubbert foresaw the situation somewhere between 4 and 4.5 doubling periods before the peak and the Club of Rome around 2 to 2.5 doubling periods. Then came the oil crisis and everyone saw the problem but the sight was short-lived because soon after the price of oil crashed and everyone forgot the problem. It was not until ASPO was formed in 2000 that peak oil was again put back on the world agenda. And it has taken some 5 years since then for the rest of the world to start remembering what happened in the late 1970s and see that yes there may be a problem, again. But we now have somewhere between no doubling times (i.e. we are at the peak) and a half a doubling time (i.e. maybe around 10 years). In terms of planning a response this sort of lead time (or absence of lead time) is not exactly optimum.