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Fossil fuels future production

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-Present basic facts

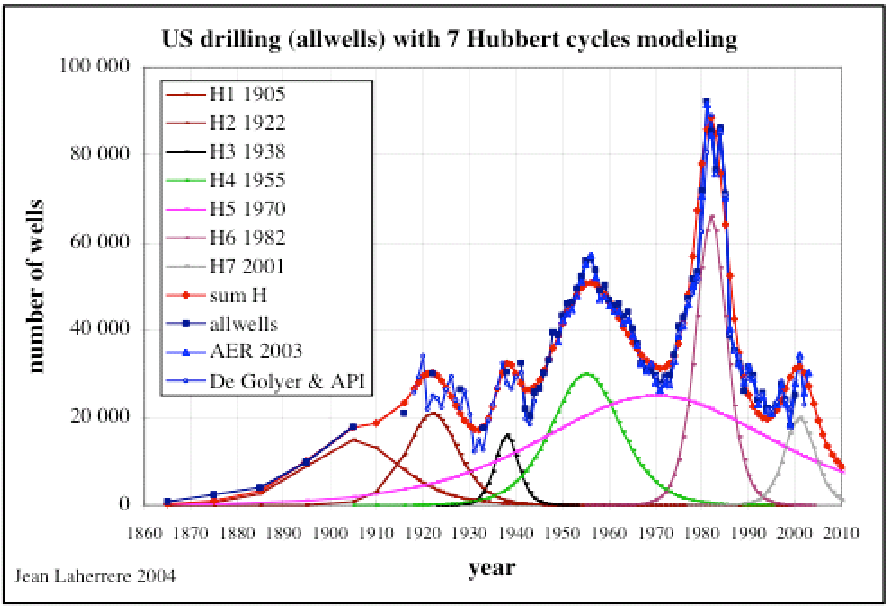
-What goes up must come down, life is made of cycles

-what was born will die: the sun, the earth, mankind and civilization

-a new birth replaces a death

Every natural event can be modelled with several cycles

Figure 1: **US drilling activity modelled with 7 cycles**



-Society of consumption and growth

-society of consumption with a culture of constant growth

Growth is the Santa Claus of politicians to solve all problems such as social security, retirement, but there is no "Plan B" other than the next generation will pay for our excesses

Saint Exupery wrote: "We do not inherit the Earth from our parents, we borrow it from our children" (taken from old Indian popular wisdom)

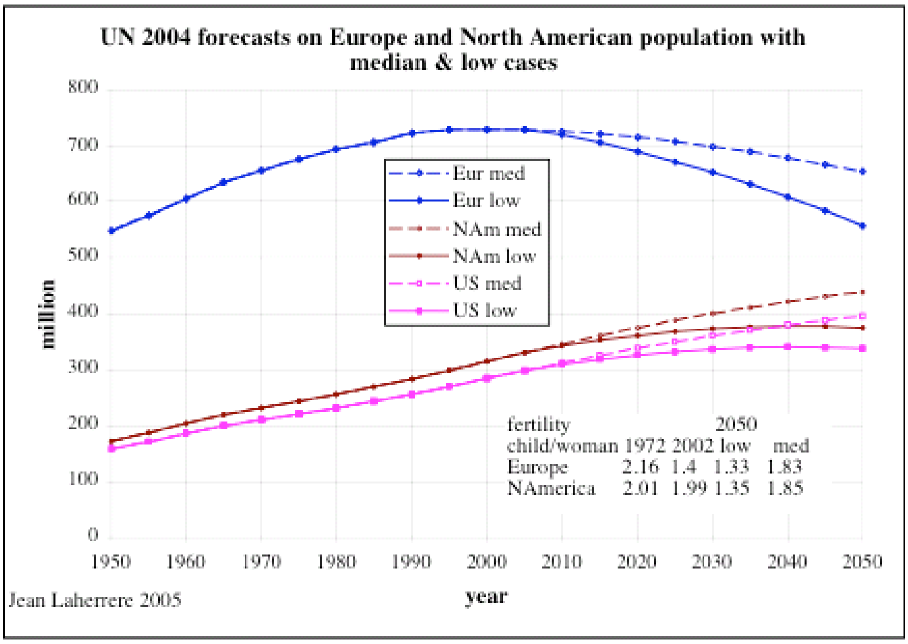
-constant growth has no future in a limited world

bacteria doubling every half an hour in a world without constraints will occupy the solar system in one week and the universe in 11 days!

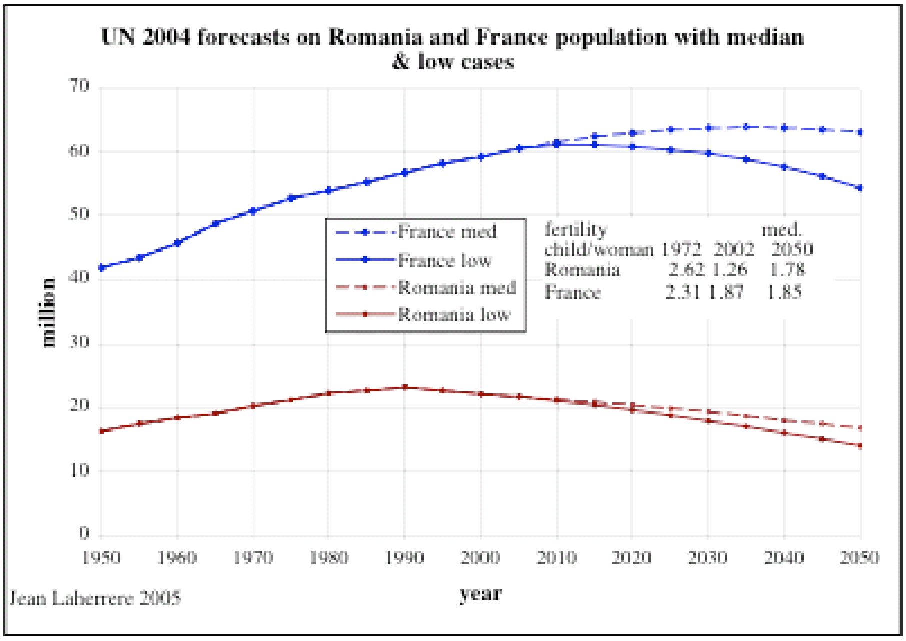
-decline (or even no growth) is a politically incorrect word, even in Europe where the population is peaking now, unpleasant events are ignored.

From the UN 2004 forecasts (with doubtful political hypotheses on fertility rate, where reality likely will be between low and median cases), in the next 50 years Europe will lose more than 100 millions people (Romania 7 and France 1), when North America will gain about 100 millions. They are two different futures!

Figure 2a: **Europe & North America population from UN 2004 forecast 1950-2050**



France is peaking soon when Romania has peaked in 1990.
Figure 2b: **Romania & France population 1950-2050**



-Reporting data
-Lack of definitions
-words such as energy, oil, reserves, conventional, reasonable, sustainable, are badly defined on purpose, in order to report what suits reporter's motive
-most debates come from lack of clear definition
-the product oil is also badly defined and oil production can be either 72 Mb/d for crude, including some condensate and synthetic oil from oilsands (1.7 Mb/d), but not NGL (Natural Gas Liquids), or 83 Mb/d for liquids (the oil demand is for liquids), or regular oil (Campbell) 66 Mb/d. Condensate (at wellhead) and NGL (at gas plants) are badly reported. In North Sea, UK reports only condensate, when Norway reports condensate (m3) and NGL (t). The demand is almost always for liquids, but supply is often for crude oil: OPEC quotas are only for crude oil

-as OPEC members cheat on quotas, production data is badly reported and the only reliable data on shipped oil on seas is from a scout company: Petrologistics in Geneva with spies in every harbour. Neither losses (Kuwait fires), nor thefts , nor oil used overseas by the US military forces (USDOE/EIA 1992) are reported
-oil is reported in barrels, cubic meters or tonnes, but barrel has no legal definition, except an industrial one and USDOE, in their reports, are obliged to add after the unit barrel "(42 US gallons)", when legal liquid barrel in Texas is 31.5 US gallons
-converting oil in barrels into oil in tonnes requires knowing the density of the oil, but it is often unspecified and it varies with time for the same field
-the symbol "bbl", often used for barrel, has no known meaning and could be a blue barrel to indicate crude oil

-Behaviour in front of uncertainty
-**Reserves: Uncertainty is presented as certainty**
-reserves represent what will be recovered in future or expected future production
-resource is what is in the ground; reserves are only a small part of resource
-reserves are always used with plural, but almost always given with one value, when they should be reported as a range
-reserves are uncertain, but the SEC (Securities and Exchange Commission) which deal with "*reasonable certainty* "(as FDA for new product) and refuse the probabilistic approach because the risk aversion of bankers and shareholders
-reserve growth occurs when reserves are reported as the minimum, but not statistically when reported as mean (expected) value
-there is no worldwide reserve rule and the SEC rules for the companies listed in the US are obsolete and different from the rest of the world, obliging to ignore probable reserves and probabilistic approach
-uncertainty should be represented by reporting a large range with 3 values: minimum, most likely or mean, maximum), but medias and stock markets want only one value
-deterministic approach versus probabilistic approach depends upon the risk aversion and the knowledge of probability. Experts are assumed to be always right. Explorers are wrong 8 times out of ten in wildcat drilling. Managers and engineers are more risk averse than explorers.
-any measure has to be reported with a number of significant digits compatible with the accuracy of the measure, but now few bother to estimate the accuracy and most reserve data is given with an unrealistic accuracy. Reporting any data with more than 2 significant digits shows that the author is incompetent.
-unequal distribution: out of more than 50 000 oil & gas fields less than 2% are giants fields (over 500 Mboe) and they retain over 75 % of the total discoveries.
-law of diminishing return = creaming curve= cumulative discoveries (mean values) versus cumulative number of New Field Wildcats = NFW
-UNFC reserve rules issued in 1997 were never accepted by the oil industry and the new classification to gather petroleum, coal and uranium is a poor compromise, hiding under words the discrepancy between fossil fuels
-OPEC members fight each other on the quotas, which are based in particular on reserves. Between 1985 and 1990, OPEC members increased their oil reserves by more than 50% and 300 Gb was added (gas reserves were not)
-field reserves are confidential in most countries except Norway, UK and the US federal lands.
-Russian oil reserves are a State secret and reporting oil reserves can be punished by a 7-year jail sentence.
-publishing data is a political act and depends upon the image the author wants to give (rich in front of a banker (or quotas) or poor in front of a tax collector). The author chooses within the

large range of uncertainty the value he prefers (close to minimum or maximum). It is why reserve definitions are numerous, ambiguous or badly used. The most flawed data comes from OPEC members because of the fight for quotas. The worldwide-accepted reserve definition by SPE/WPC/AAPG is not respected and contains contradictory items (probable in deterministic and probabilistic approaches).

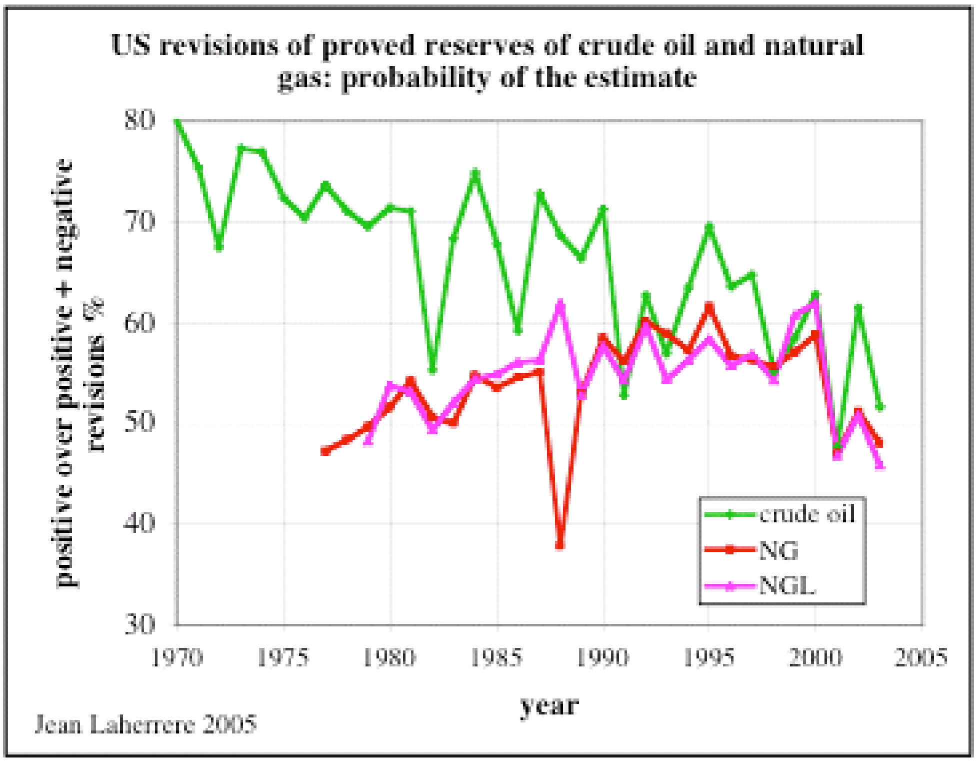
Aggregation of mean values is correct when it is not for proved values (a Monte Carlo simulation should be run).

There are three worlds, the world of economists having only access to political data, believing that technology can do anything, the world of technicians having access to real data and knowing the limits of techniques, and the world of managers or politicians who have to show growth to be well considered.

-Probability of US proved reserves

Despite that US proved reserves are ruled by deterministic approach (SPE refused the probability approach until 1997), it is easy to compute the probability of the estimate by dividing the annual positive revisions of past estimates by the sum of positive plus negative revisions to get the probability.

Figure 3: **Revisions of US proved reserves giving the probability of the estimate**



The trend is obvious for oil, decreasing from 75 % in 1970 to about 50 % soon and going towards 40%, which is roughly the probability of the mean value. For gas and gas liquids, the probability was about 50% in 1980, raises a little and is down again below 50% in 2003.

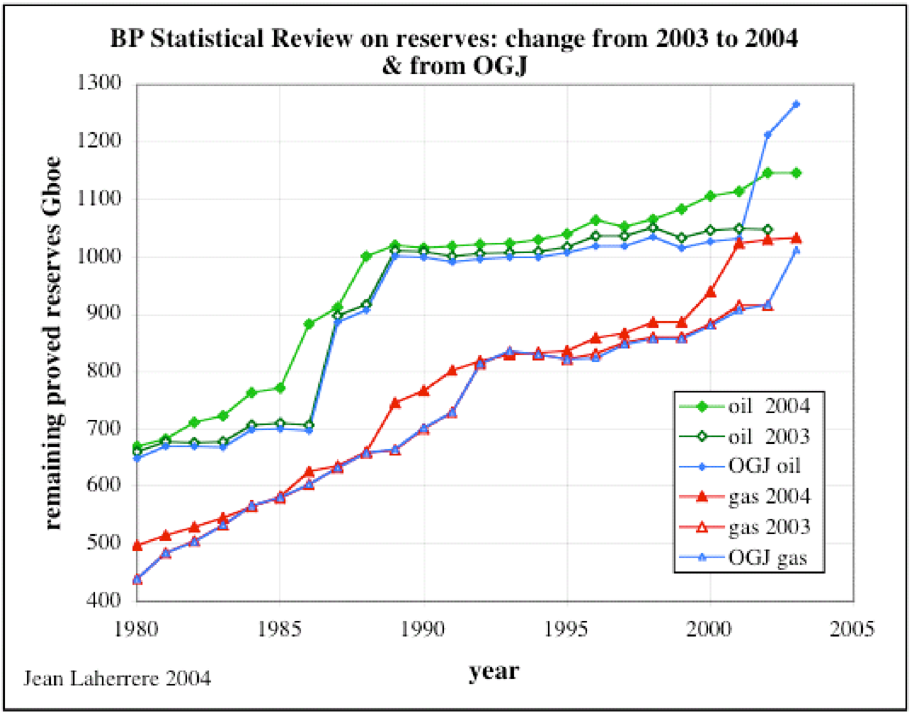
There could not be any more reserve growth in the US because negative revisions are equal or even greater than positive revisions. The most negative revision in 2003 was for the federal offshore of Louisiana being 616 Mb against 289 Mb positive revision for oil, 129 Mb negative against 89 Mb positive for NGLP and 2.9 Tcf negative against 1.9 Tcf positive for gas.

US Proved reserves as described to follow SPE/WPC rules, where proven is assumed to correspond to a probability of 90% ; it is wrong, present US proved reserves are about the SPE/WPC proven + probable !

-Political motives

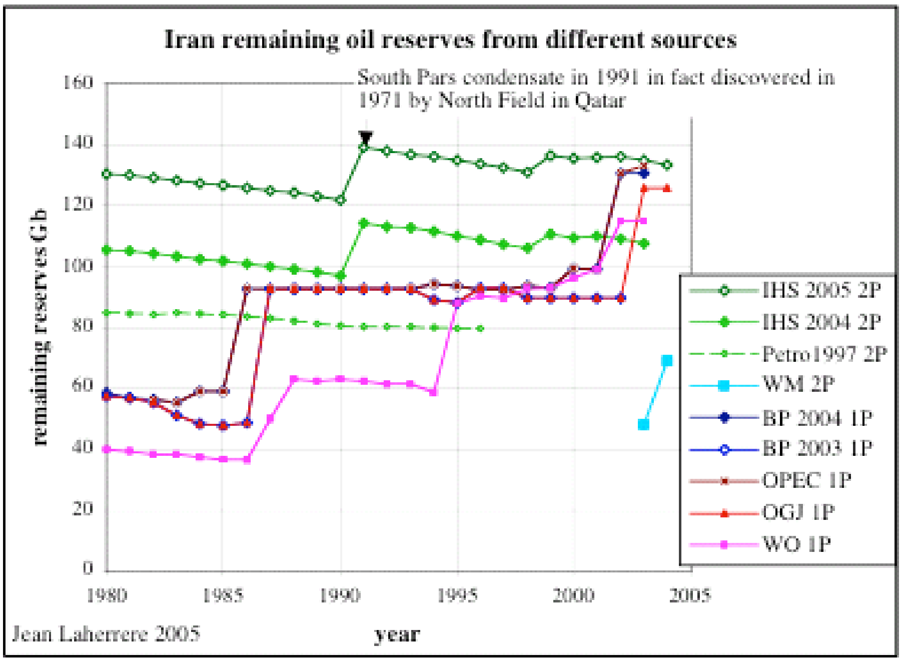
Political reserves at year end are reported by governments before the end of the year (technical studies are not done yet) as an answer to an enquiry sent by OGJ and the results are published by OGJ on the last week of December as remaining proved reserves (under SEC rules, proved reserves should be estimated with oil price on December 31st, when they are not yet known!). The estimates are the current values and are never revised by OGJ whereas WO revises them for the previous year. BP Statistical Review was reporting OGJ data and not its own data in order not to upset OPEC members (they did it once in the past but were reprimanded and they do not want to do it again). These reserves up to 2003 were assumed to be conventional estimates excluding oilsands and natural gas liquids (NGL) outside US and Canada, but the production data was including these oilsands and NGL. When in 2003 OGJ included for Canada 175 Gb of reserves from the Athabasca oilsands (making Canada the second largest in front of Iraq), BP did not follow six months later. But in 2004 they include for Canada the part of the oilsands reportedly developed by the Canadians (11 Gb), and increase the previous estimate of end of 2002 by 99 Gb. But in order not to attribute this increase to 2003 discoveries, they revised their previous estimates since 1980. In fact they backdated their increase, as for end 2002 the 2003 value was 1048 Gb against 1146 Gb for the 2004 value.

Figure 4: **Change on remaining reserves by BP Statistical Review from 2003 to 2004**



It is interesting to detail the reportings for Iran, BP's has increased to follow the Iranian statement at 130 Gb (no wish to question it) for proved reserves, but technical data from IHS 2P, which was just over 100 Gb last year, is moved to over 130 Gb, when WO 1P is less , but WM reports 2P only about 50 Gb last year and now they have moved up to 70 Gb . The difference is large, as it is for Saudi Arabia, showing the uncertainty of the Middle East reserves as well as the political involvement. It is obvious that IHS is now using more political data than geological data.

Figure 5: **Iran remaining reserves from different sources and different years**



-Personal motives
Message depends often upon one person who is in charge
Oil forecasts from IEA have changed drastically from the last 6 years with different long-term analysis directors
Figure 6: **IEA 1998 forecast by JM Bourdaire: there is a problem,** as future demand has to be provided by unspecific non-conventional supply, when conventional will peak

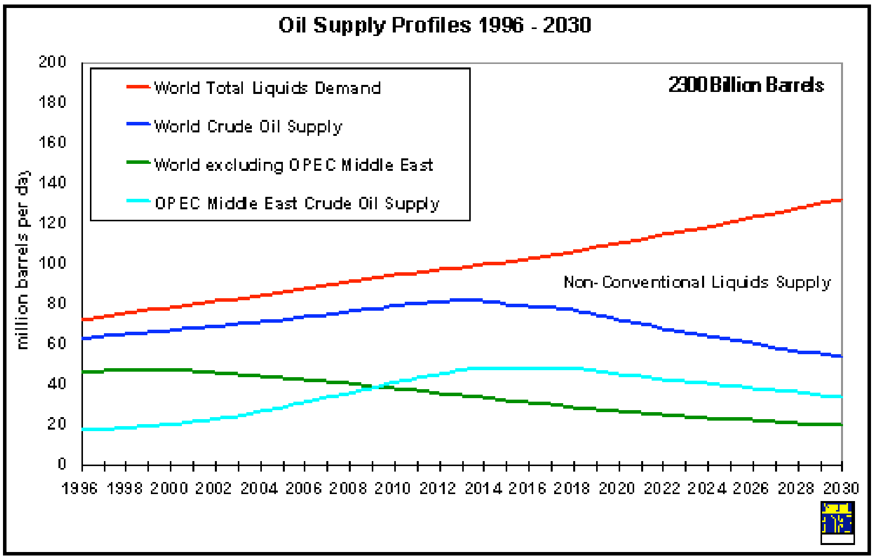


Figure 7: **IEA 2002 forecast by O. Appert: there is no problem**, no peak and unconventional is minor

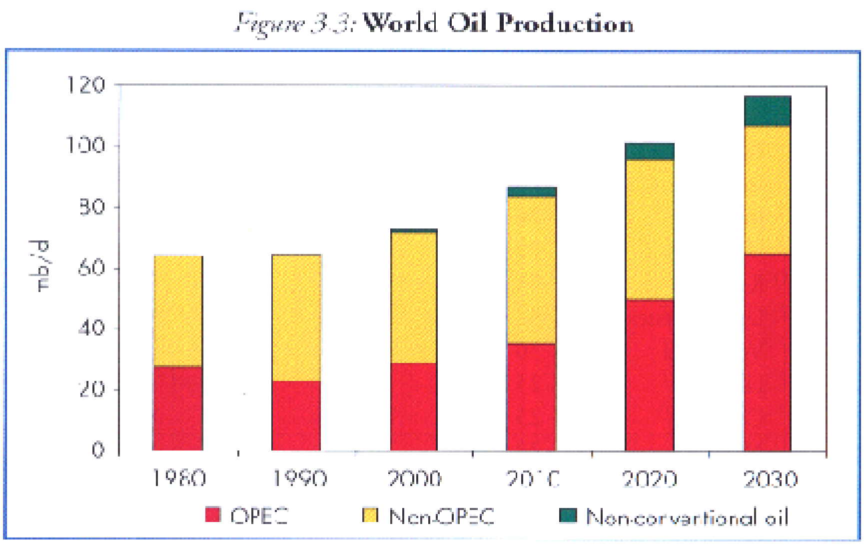
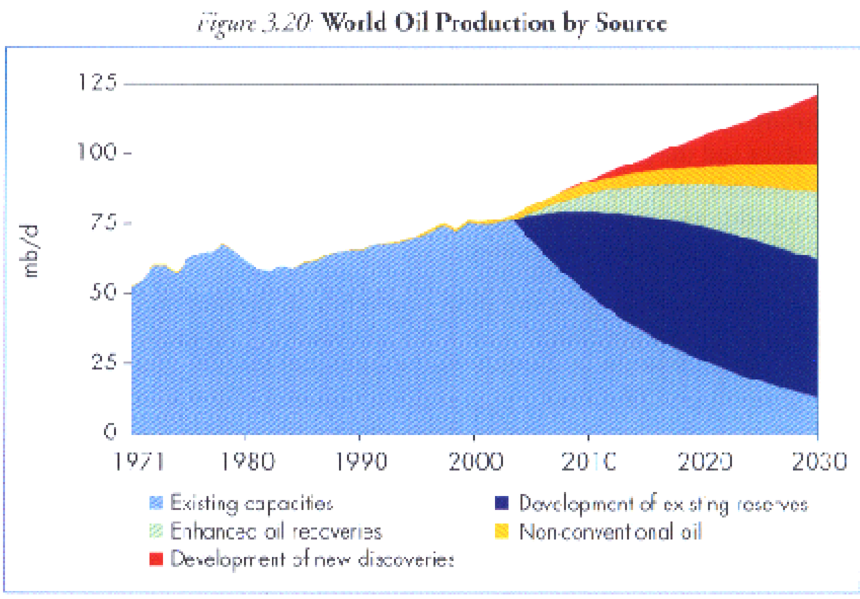


Figure 8: **IEA 2004 forecast by F.Birol: there could be problem** as new discoveries, new development and EOR are needed, but unconventional is minor

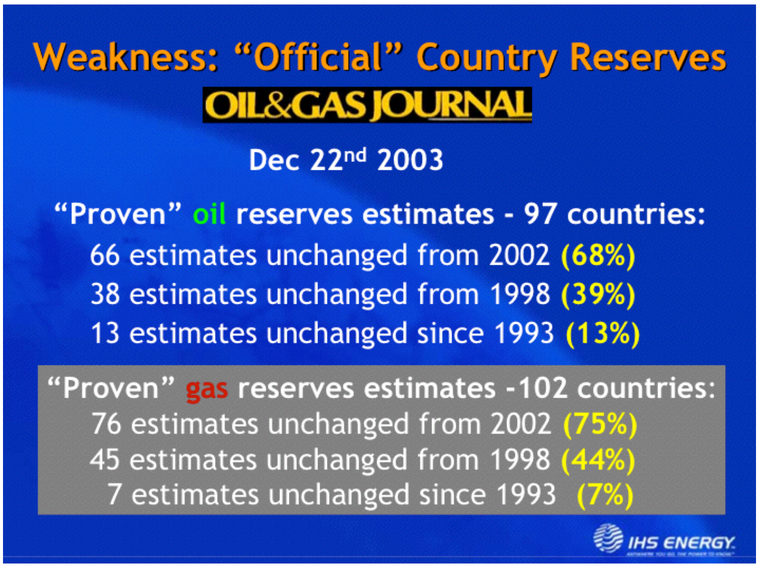


It is the same with USGS world reserves estimates from 1987 to 2001, when T.Ahlbrandt replaced C. Masters. Masters used inferred reserves considering no reserve growth, when Ahlbrandt uses proved reserves for the US and proven+probable for the rest of the world, and he assumes that proven+probable will have the same reserve growth as proved reserves in the US, which is plain wishful thinking.

-Reserves data

IHS shows the lack of change in official country reserves, but forgets to mention the wrong addition of proved reserves to get the world proved reserves

Figure 9: **Official estimate of reserves published by OGJ**



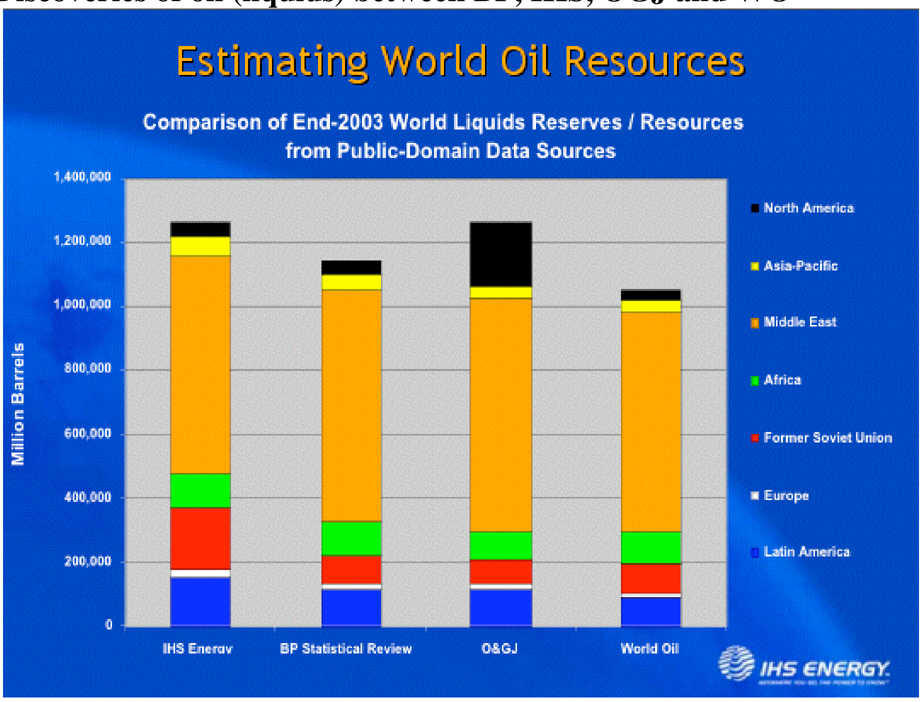
The different sources shows discrepancies of more than 15% but each reports more than 8 significant figures as if the accuracy was about one millionth of percent!

USDOE/EIA Nov. 2004 reports the world proved reserves at end 2003

end 2003	oil Gb	gas Tcf
BP Stat. Review	1 146.387 085	6 253.636 984
Oil & Gas journal OGJ	1 265.025 583	6 078.592
World Oil WO	1 050.691 3	6 805.829 8
Cedigaz		6 349.498 545

IHS (Chew 2004) reports also the detail of the large discrepancies between their estimates and BP, OGJ and WO.

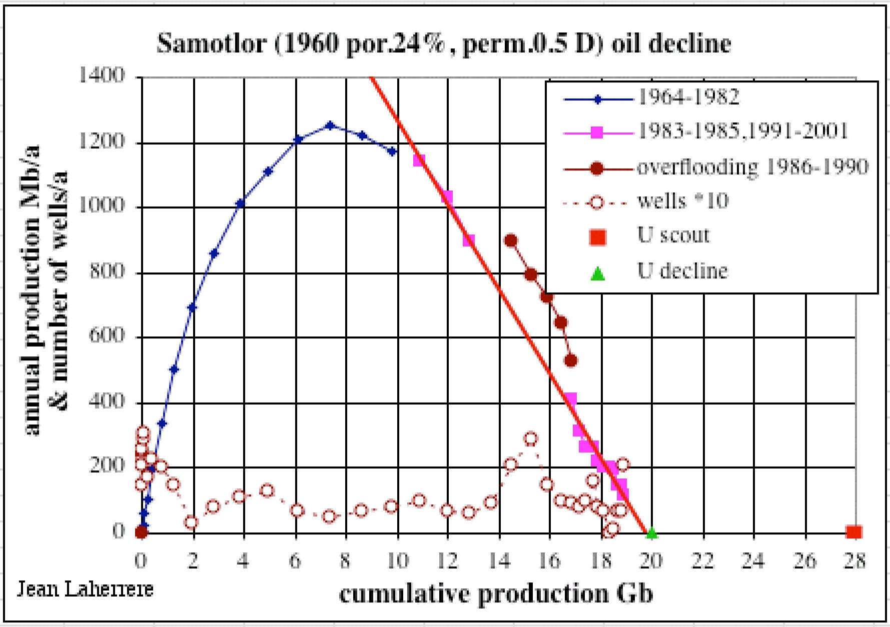
Figure 10: **Discoveries of oil (liquids) between BP, IHS, OGJ and WO**



-Corrected database to obtain world homogeneous mean values

FSU reserve database is still under the Soviet classification introduced by Khalimov in 1979 (WPC Bucharest) and described by the same Khalimov in 1993 as grossly exaggerated, since the recovery factor was assumed to be the theoretical maximum (or 3P). Furthermore, in order to comply with the Soviet Plan, oilfields were over flooded. Estimating field reserves from the decline of the major FSU fields, we concluded that FSU estimates have to be corrected by 30% to obtain the mean value. Samotlor the largest oilfield is a good example as the decline is quite pronounced (overflooding from 1986 to 1990), leading to an ultimate of 20 Gb when official estimate is about 28 Gb.

Figure 11: **Oil decline of Samotlor, largest FSU oilfield**



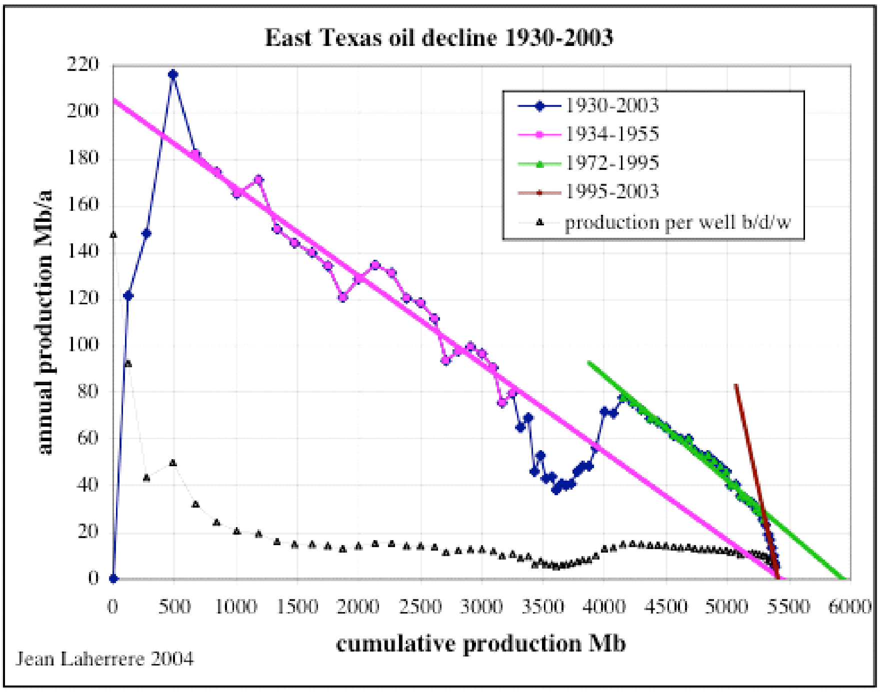
-Reserve growth

USGS 2001 report estimated that over 700 Gb would be added in 2025 as reserve growth of past discoveries, without any justification except that old fields in US such as Sunset Midway (heavy oil unconventional oilfield) have been growing in the past. Reserve growth is often attributed to technology progress and rarely to bad reporting

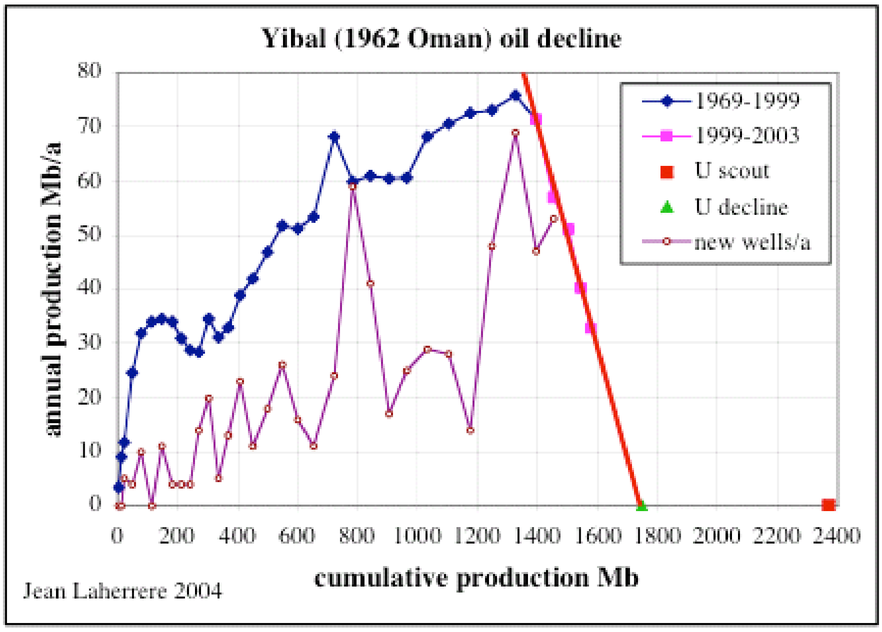
Reserve growth has to be attributed to technology only when the decline decreases with new techniques.

But the largest USL48 oilfield East Texas has been produced from 1930 for several decades only by primary recovery with a decline trending towards 5.5 Gb, unitization and water injection raised the production from 1972 to 1995 with a decline trending towards 6 Tb, but since 1995 the production is collapsing towards an ultimate of 5,5 Gb (same as from primary recovery) and the field is almost depleted. It is a good example of hope of reserve growth, which disappears at the end.

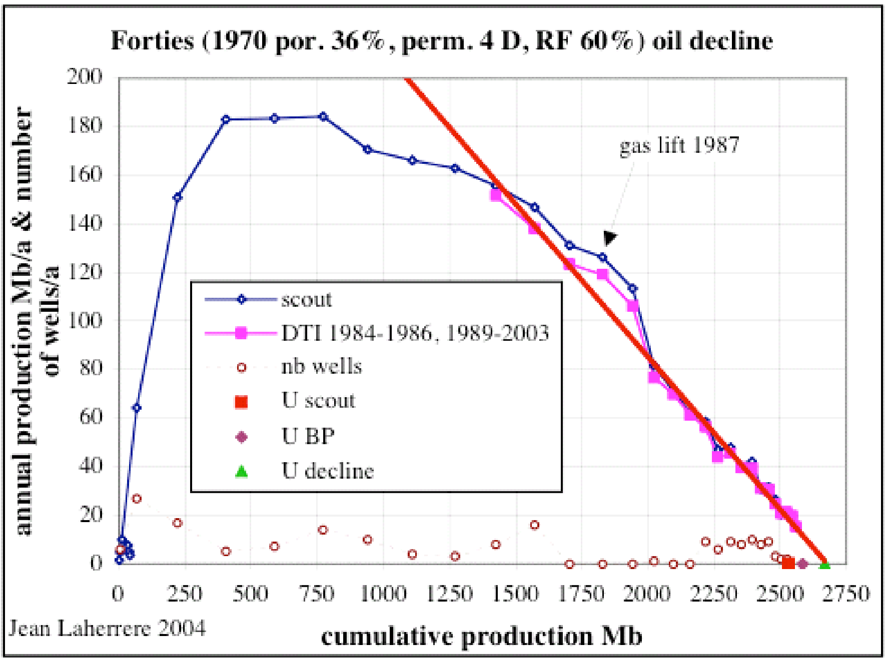
Figure 12: **Oil decline of East Texas, largest US L48 oilfield 1930-2003**



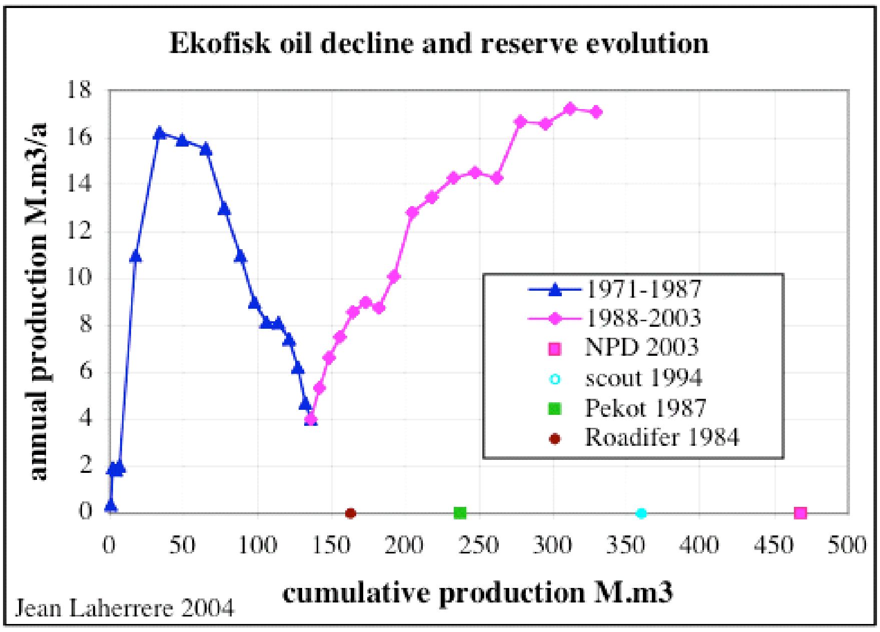
Shell operates most of Oman production and uses the best technology (Oman is considered as the Shell school). But lately the use of too much technology (horizontal wells) led to increased production followed by a sharp decline
Oman's largest oilfield, Yibal, has been produced with many horizontal wells and now oil decline is sharp, leading to much lower recovery than reported.
Figure 13: **Oil decline of Yibal, largest field in Oman, 1969-2003,** operated by Shell



Forties was declining when in 1987 gaslift was introduced with a fifth platform and for two years production was above the previous decline, but since 1989 to 2003, the decline is the same as before the new technology. I presented this graph 7 years ago and the decline has not changed since.
Figure 14: **Oil decline of Forties (UK North Sea) 1984-2003** operated by BP



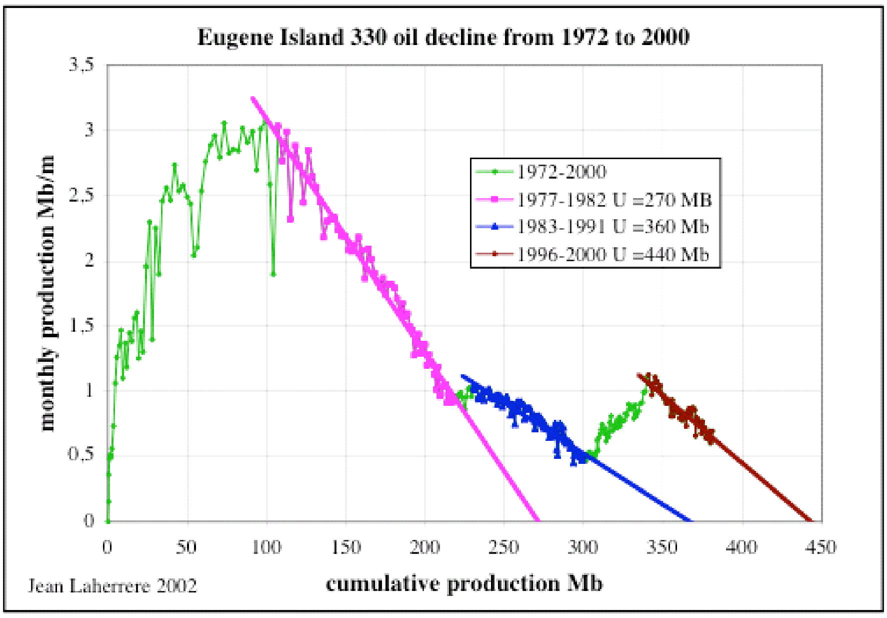
After these examples of negative growth (worsening decline) or no change, there are some examples of positive growth, but these cases are always under exceptional conditions, which are not to be extrapolated to the rest of the fields.
Ekofisk oilfield in Norwegian North Sea has been producing since 1971 and has not yet reached its peak
The reservoir is a special chalk, which under production has compacted considerably, leading to a seafloor subsidence of about 7 meters, which forced to raise the platforms with huge expenditures. Reserves have risen from 160 to 460 M.m3.
Figure 15: **Oil decline of Ekofisk (Norway) 1971-2003**



But Ekofisk growth cannot be applied to the rest of North Sea fields, which have not for reservoir such compacting chalk and where the seafloor does not subside.

Cooper in Wall Street Journal claimed in 1999 that Eugene Island 330, an oilfield in the Gulf of Mexico (GoM) (the third largest in 2001), was an example of reserves which were regenerated from oil coming from the mantle (abiogenic oil as claimed by astronomer Gold who drilled two dry holes in Sweden on this theme) and that oil could be considered as renewable. The increase of reserves from the Middle East after 1985 was therefore explained! EI 330 was assumed to have increased from 60 to 400 Mb. Looking at the monthly oil production versus cumulative production shows a first phase of primary production (1977-1982), then secondary production (1981-1991) trending towards 360 Mb and a third phase (1996-2000) trending towards 440 Mb. This third phase is a real growth but it can be explained by the fact that this field is on one of the largest faults of the GoM (the Red Fault which was surveyed by many universities and can be found on the web) and that this fault allows the reservoir to be quickly recharged from the source-rock because the large decrease in pressure after 24 years of production.

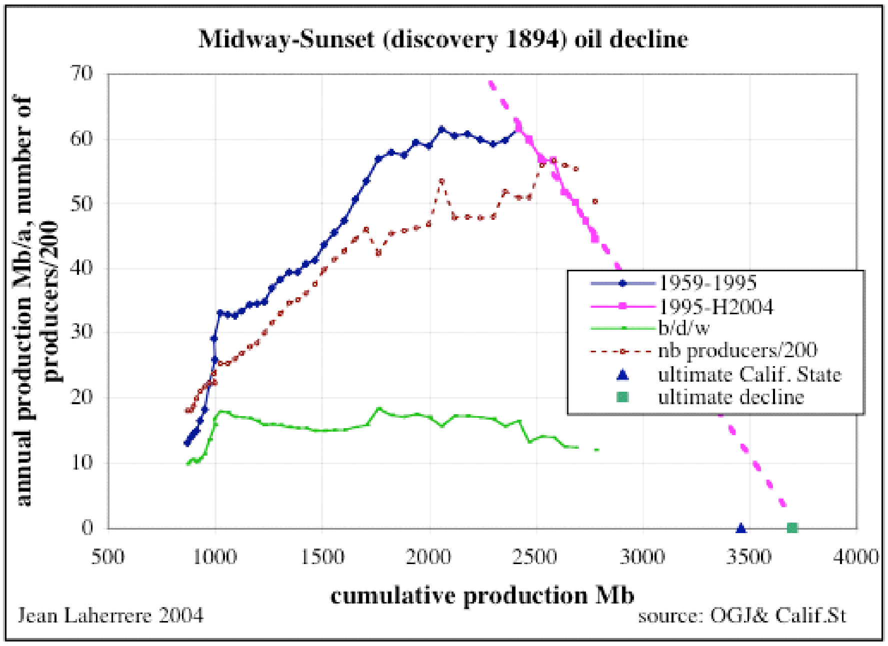
Figure 16: **Oil decline of Eugene island 330 (Gulf of Mexico) 1972-2000**



But Cooper's claims were wrong on reported reserves, as reserves were estimated by MMS in 1986 as 460 Mb but in 2001 as 410 Mb, still he was right on some unusual growth of about 80 Mb from decline, but not 360 Mb and the abiogenic claim is plain non-sense, because the explanation is clear and still exceptional, as few fields have such fast connection to source-rock. Usually the move of oil from source-rocks to reservoir takes million years (it is much faster for gas).

Sunset-Midway heavy oilfield in California was found in 1894 and is used by USGS as best example of reserve growth . But it is an unconventional field for having produced for more than 100 years, using steam injection and producing through more than 10 000 wells. The production increases with the number of wells. Oil ultimate reserves are reported by the State as 3.5 Gb when decline estimate is about 3,7 Gb. This field cannot be compared with an average production of 15 b/d/w to new discovery in deepwater of the GoM producing more than 10 000 b/d/w.

Figure 17: **Oil decline of Midway-Sunset California, 1959-2003**, discovered in 1894, heavy oil



The conclusions from all these examples is that there is a real evolution of field reserves with time and the result from now to the end of production could be either positive or negative or close to zero. The problem is that it is only at the end of world oil production that the result will be known and many undeveloped fields risk never to be produced, like presently the 300 undeveloped discoveries in North Sea, which are in my database. My guess is that the result will be close to zero, most likely negative.

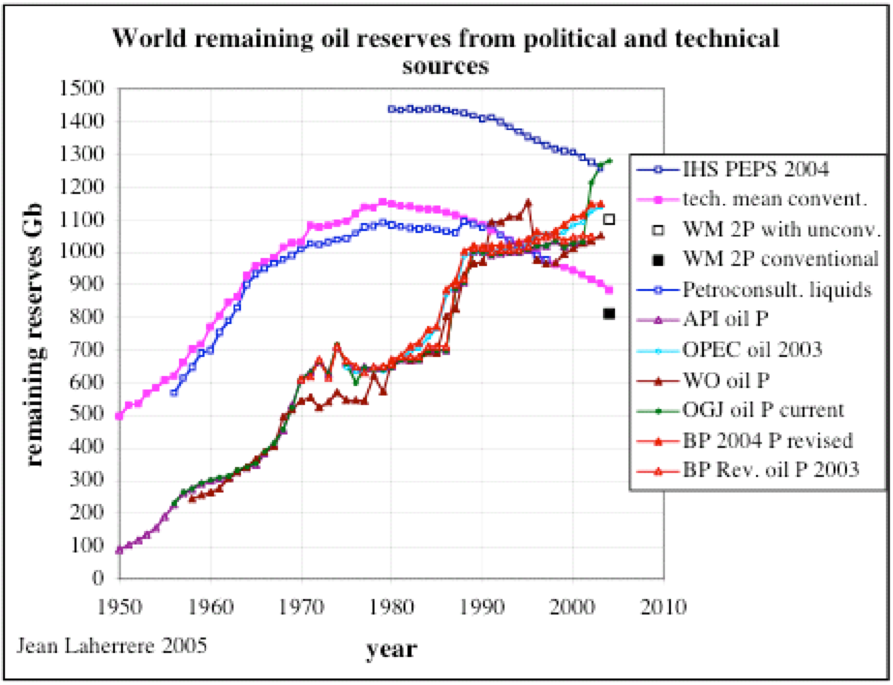
The USGS 2000 report estimates that it is impossible to know the growth of world reserves, but instead of doing nothing, they prefer to use the US reserve growth. But applying the growth estimated from old US oilfields proved reserves to the growth of the rest of the world proven+probable reserves is like comparing temperatures in New York and Paris without bothering to check that one is in Fahrenheit when the other is in Celsius ! Adding about 700 Gb for world reserve growth is completely unjustified and unscientific, it is plain wishful thinking! Unfortunately most official agencies (USDOE, IEA) do not have the technical data neither the competency and rely on USGS estimates.

-World remaining oil reserves

The following graph displays the world remaining oil reserves from political sources (OPEC, OGJ, WO, BP Statistical Review, API), which are proved values, and from technical sources (IHS, Petroconsultants and WM), which are proved plus probable, as well as mine, which corrects to mean values.

All political data has been growing from 1950 up to now, showing for the second half of 1980s the 300 Gb increase from OPEC when fighting for the quotas and the increase in 2002 when OGJ went from conventional reserves to unconventional, adding 175 Gb for Canadian oilsands. At the contrary technical sources show a decrease since 1980, but show also a large difference between IHS and WM. My corrected value for oil excluding extra-heavy oils only is closer to WM than to IHS, which has added political values.

Figure 18: **World remaining oil reserves from political and technical sources**

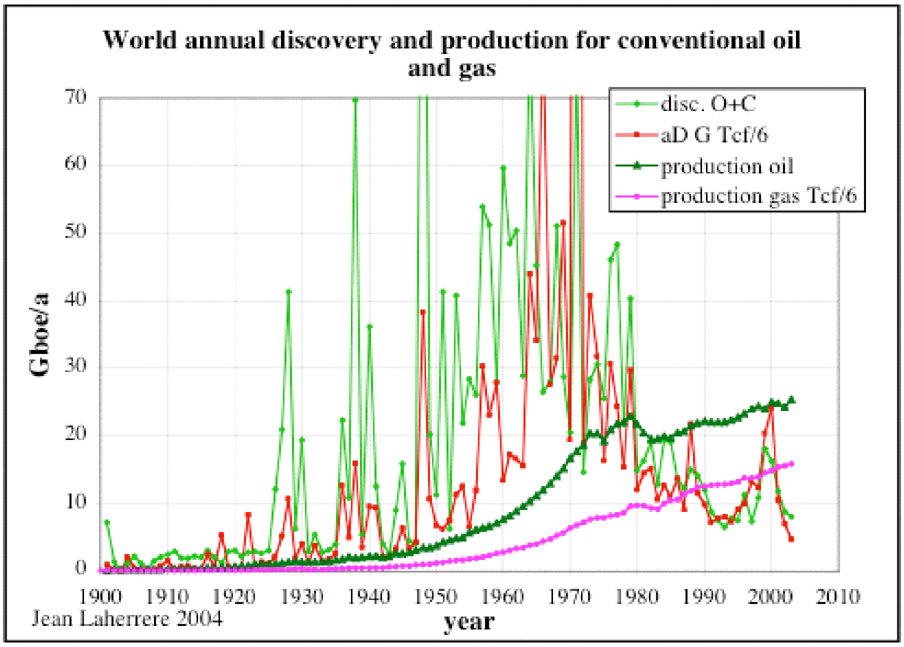


It is obvious that there is a great need for real field data in particular for the Middle East, but, as long as quotas are used in OPEC, there is no chance to get real data.

-Annual production

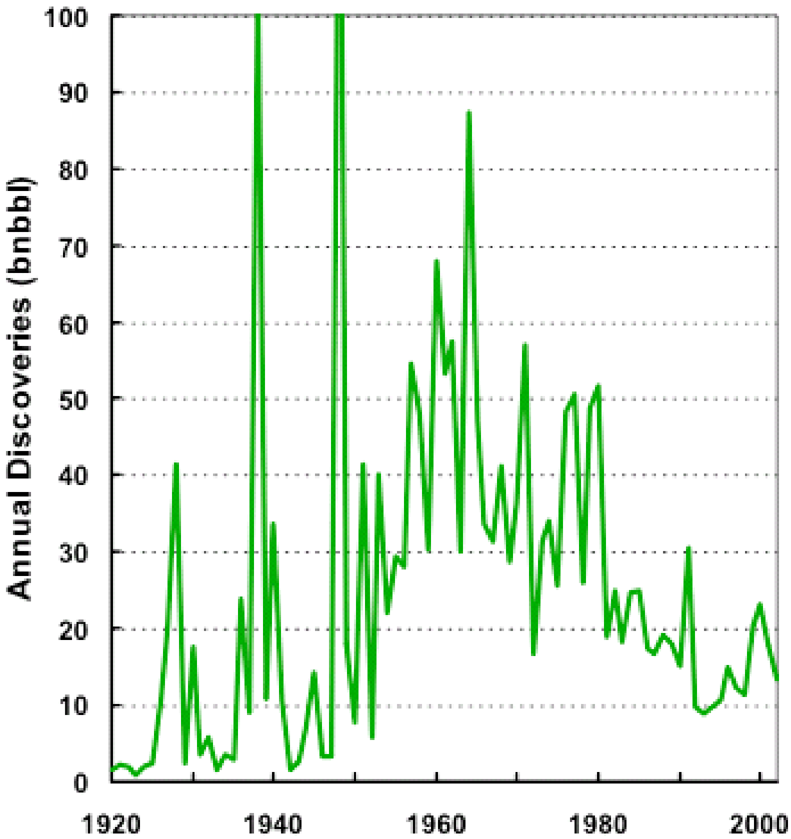
From my database the plot for annual conventional oil and gas is compared to production. The sharp decline of oil discovery since 1980 below the production level shows why the remaining reserves are declining. The deepwater (also shallow Kashagan in Caspian) burst around 2000 has already passed. For gas since 1980 discovery is in average about the same as production, leading to about flat remaining reserves.

Figure 19: **World annual conventional oil and gas discovery**



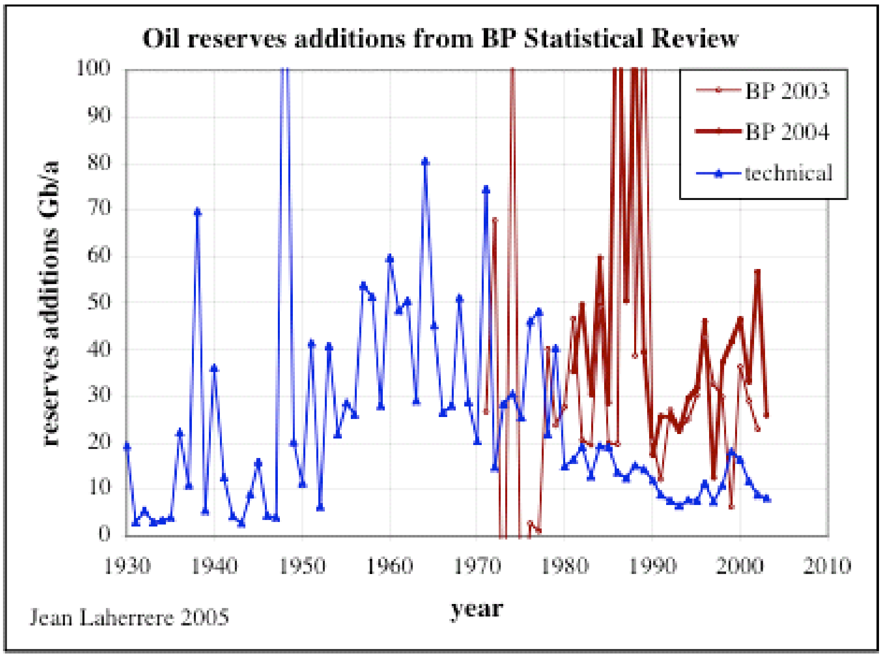
My plot is similar to the one published by Exxon (Longwell 2002), because it is based on the same technical backdated database, as well as the one published by BP geologist Harper (ASPO 2003).

Figure 20: **World annual oil discovery from BP geologist Harper**

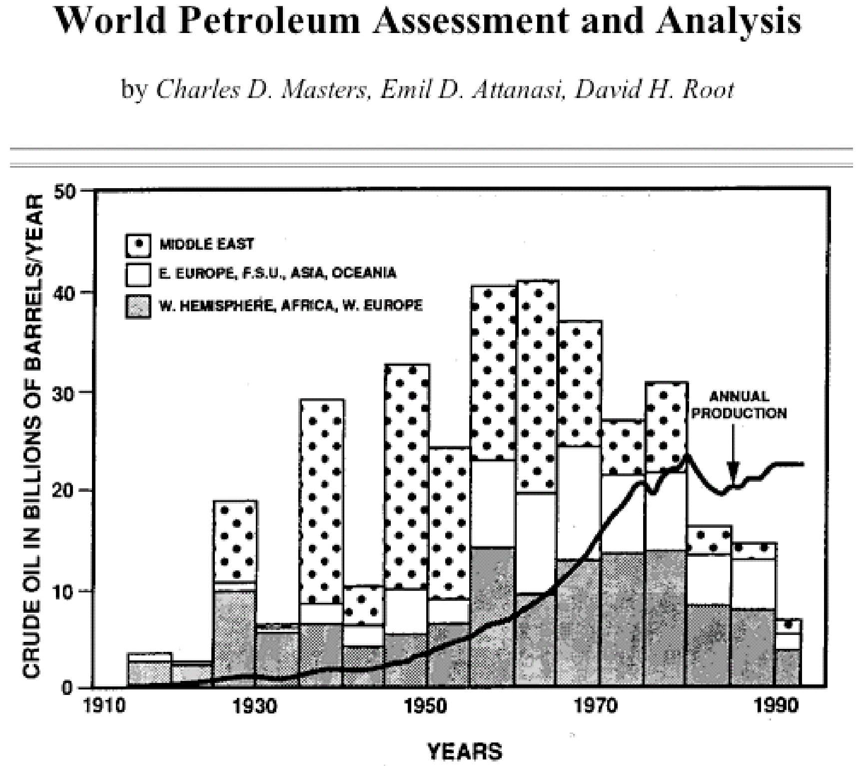


Harper's graph is very different from the values published by BP Statistical Review, which reports government data.

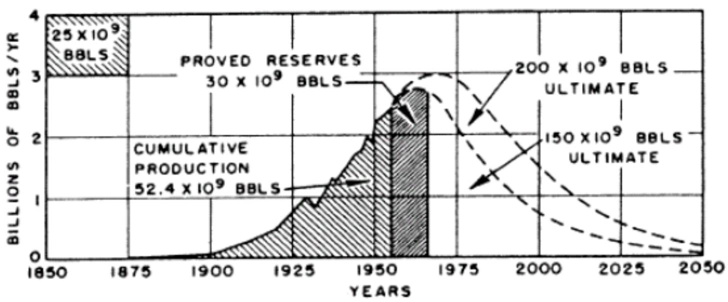
Oil discovery peak is around 1960 according to Harper BP, but addition of proved reserves from BP Review peaks around 1985, when OPEC members added reserves fighting about quotas!
Figure 21: **Oil reserves additions from BP Statistical review and technical sources**



The discovery graph from USGS in 1994 (Masters WPC) grouping on a 5-year period displays the same peak in the 60s.
Figure 22: **Oil discovery and production from Masters USGS 1994**



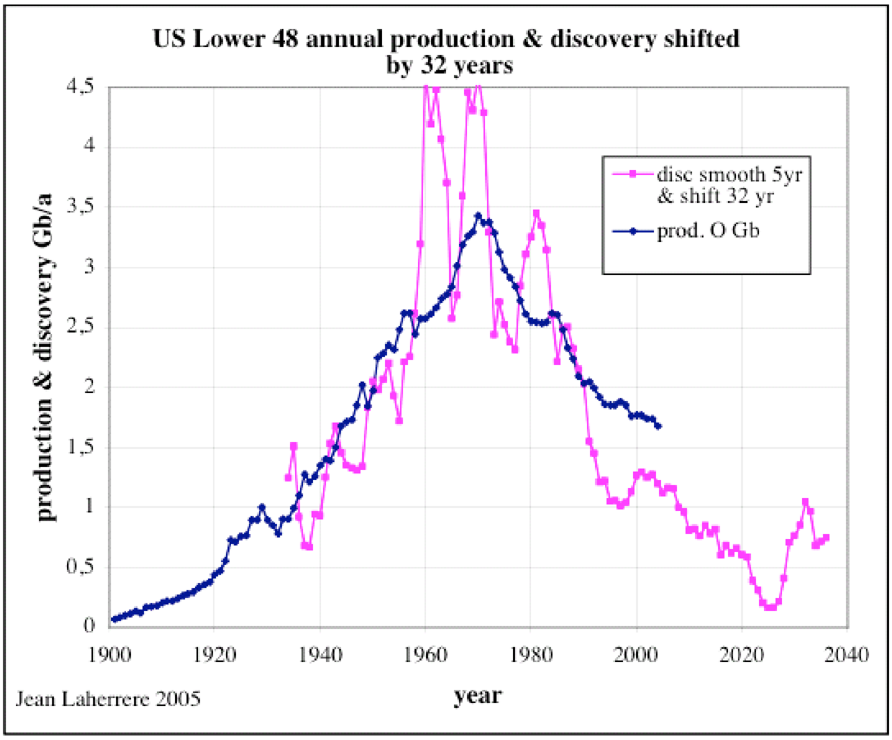
King Hubbert (geophysicist with Shell and USGS) forecast in 1956 that US oil would peak in 1970. Hubbert has drawn by hand two symmetrical curves (without giving any equation) where the area below the curve (counting squares) is equal to two ultimates, one being 150 Gb (his own estimate) giving a peak in 1965 and the second being 200 Gb (the largest estimate from an enquiry of W. Pratt) giving a peak in 1970.
Figure 23: **Hubbert's forecast in 1956**



Hubbert forecast was ignored at the time, but recognized after the oil peak of 1970, and, happily for him, his first own estimate was forgotten and also the real ultimate of the US Lower 48 is very close to the round value of 200 Gb (see figure 28) which was in 1956 the highest estimate.
«Backdated mean» values are very difficult to get in the US, but fortunately a 1990 report (USDOE/EIA 90-534) allows to get them up to 1990 after adding a growth from MMS function, and after 12990 by taking the discoveries from annual reports and also MMS and consultants reports.
The correlation between production and shifted mean discovery is fairly good, with a shift of 32 years. Both curves look symmetrical and can be explained by the fact that there is a large number of oil explorers and oil producers (over 20 000 producers). It is the case of random when a large

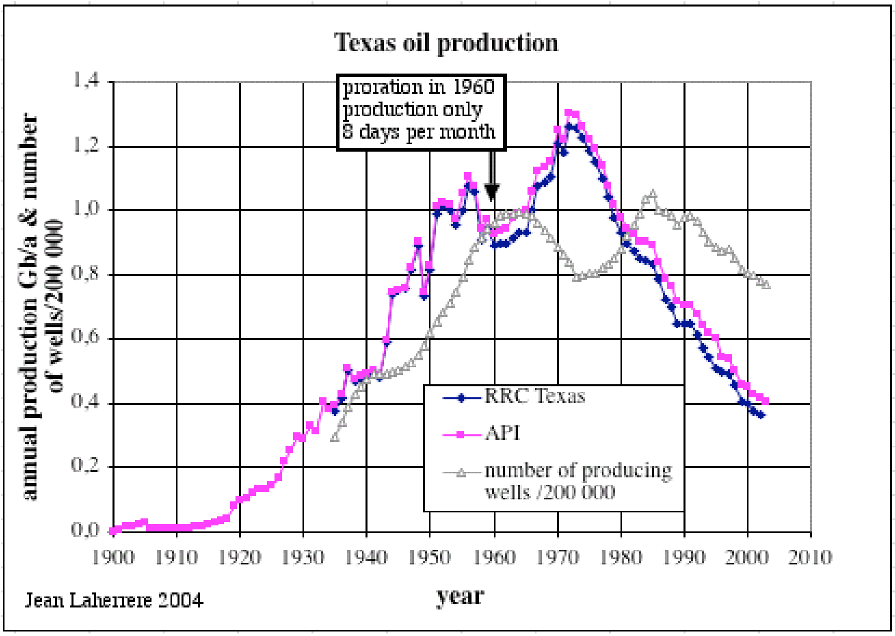
number of actors act independently the result is normal (Gauss curve): it is the theorem of central limit. It is interesting to notice that oil production deviates from normal in 1930 (depression) 1960 (proration) and 1980 (high price), times where political or financial constraints obliged producers to act in the same direction and the result was not normal during these constraints.

Figure 24: **US L48 oil production and «backdated mean» discovery shifted by 32 years**



The same symmetrical shape is found in Texas oil production showing also the number of producers (divided by 200 000) ; the decline from 1970 to 2003 is symmetrical to the rise from 1920 to 1957, where production was upset by proration: in 1960 Texas production was allowed only 8 days per month.

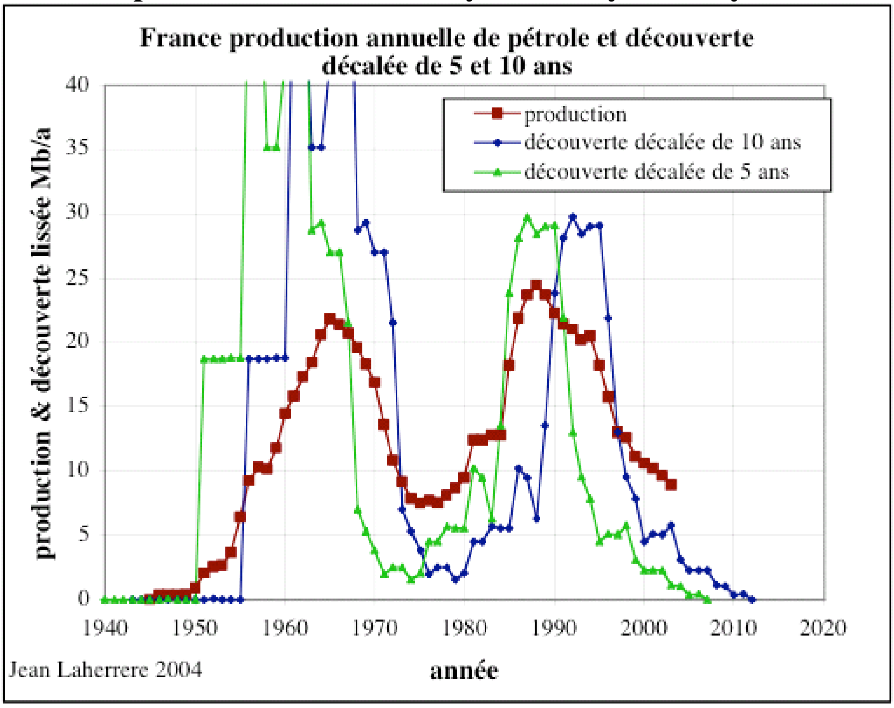
Figure 25; **Texas oil production 1900-2003**



The one cycle pattern is found in countries with a large number of basins and producers, but in most of other countries several cycles are found such as in France and the UK.

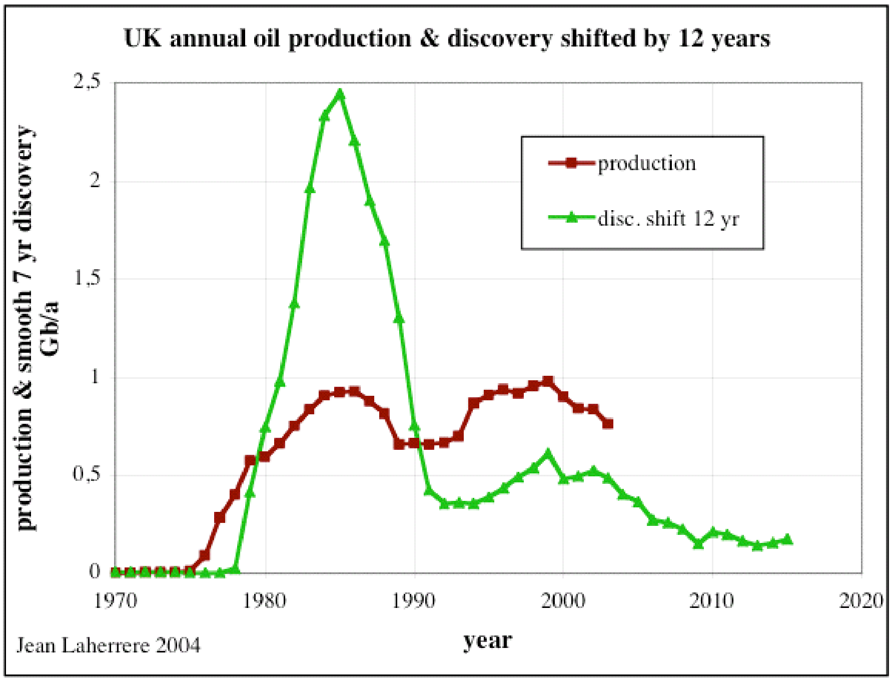
France oil discovery displays two cycles and fits the oil production when the shift is 10 years for the first production peak and 5 years for the second production peak. France, running short of oil, was in a hurry to produce oil and the shift is small, and even smaller the second time.

Figure 26: **France oil production and discovery shifted by 10 & 5 years**



UK oil discovery displays two cycles (the first one being much higher than the second one) and the two discovery peaks fit with the two production peaks (about same size) with a single shift of 12 years. The UK, because it was exporting oil, did not produce the first discovery at full and left some reserves for the second peak.

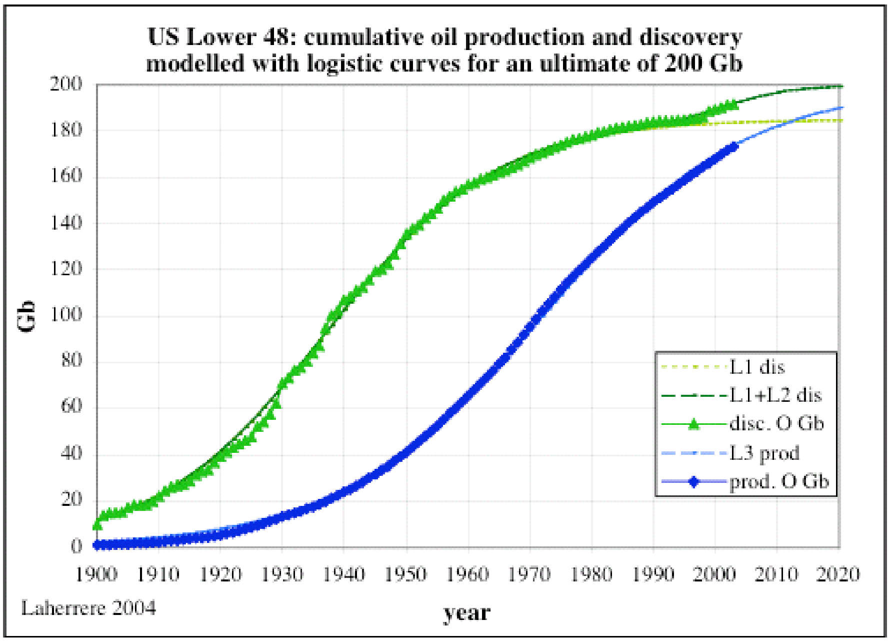
Figure 27: **UK oil production and discovery shifted by 12 years**



-Cumulative oil production & discovery

The correlation between discovery and production is even better when dealing with cumulative. US Lower 48 cumulative discovery can be easily modelled with two logistic curves (the second being deepwater and minor) leading towards an ultimate of 200 Gb. The oil production is modelled with only one logistic curve with the same 200 Gb ultimate. The shift at mid point (100 Gb) is about 30 years as in figure 24.

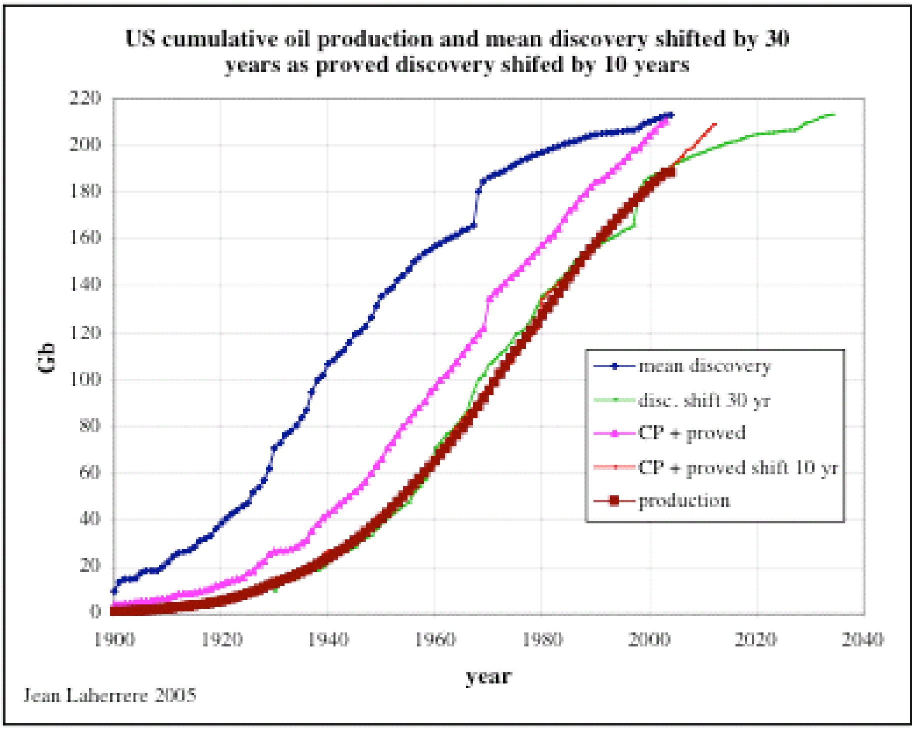
Figure 28: **US L48: cumulative oil production modelled with a logistic curve for an ultimate of 200 Gb and discovery modelled with 2 cycles** (2nd= deepwater)



In the US Lower 48 there is little left to be discovered and it is mainly in deepwater; most majors have closed their onshore exploration.

For the full US including Alaska, the oil production fits very well the cumulative mean discovery with a shift of 30 years. The fit with a shift of 10 years with the cumulative production plus the remaining proved reserves as reported by the USDOE (API before 1979) could seem as good as the mean values except for the last few years, where proved reserves suggest a higher production than mean values. The coming years will tell better which forecast is right.

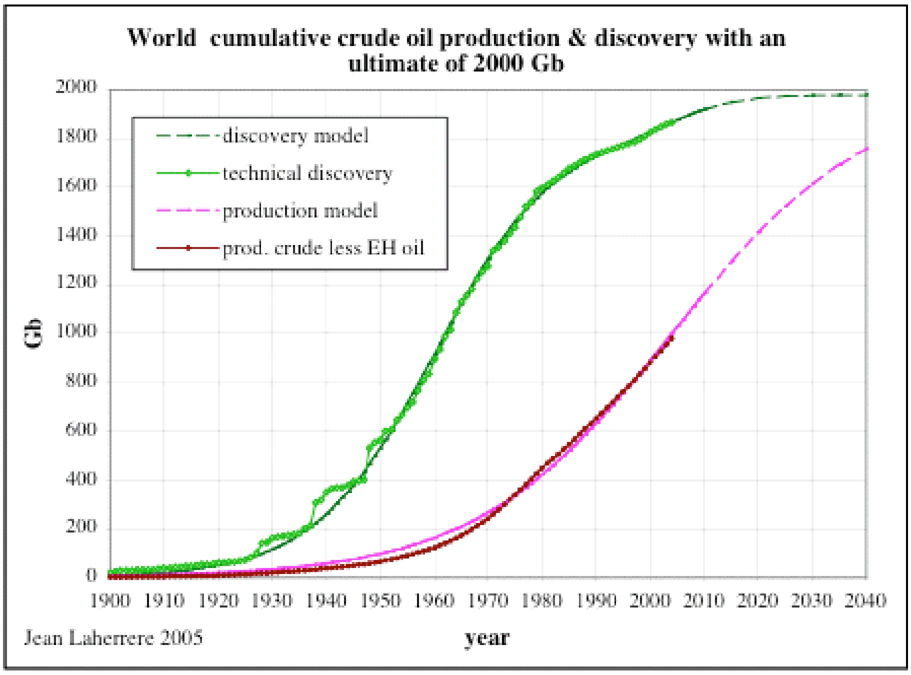
Figure 29: **US oil cumulative production, mean discovery as shifted by 30 years and cumulative production plus proved remaining reserves as shifted by 10 years**



The Bush government pushes to drill the Alaska National Wildlife Refuge, but oil companies are reluctant to go, in particular the ones who have the results of the well KIC drilled in 1985 and still confidential by special derogation (why?). I am ready to bet 1000 $ that if ANWR is drilled no giant will be found, only ridiculous oilfields such as Badami, the closest field which, estimated by BP to contain 120 Mb, was developed and abandoned after producing only 4 Mb in 4 years (cost >100 000 $/b/d!)

My field database is corrected in order to be between IHS and WM estimates and to offer a round oil ultimate of 2 Tb (2000 Gb). The cumulative world oil discovery is easily modelled with one major S curve and one minor (deepwater), when the production fits well with one S curve for an ultimate of 2000 Gb.

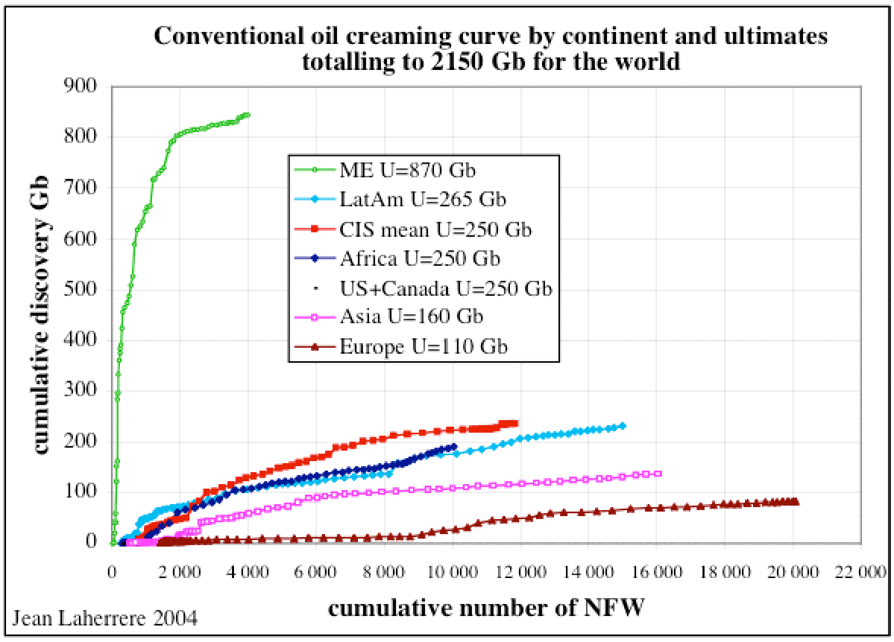
Figure 30: **World cumulative conventional oil with logistic models for a 2000 Gb ultimate**



-Ultimates and inequality of continent reserve distributions

The best way to obtain the ultimate is to extrapolate the creaming curve, which is the cumulative mean discovery versus the cumulative number of exploratory wells (New field Wildcat= NFW). Creaming curve can be modelled easily with several hyperbolas and the ultimate is the asymptote of the last hyperbola. The oil creaming curves by continent show a large range with the most gifted being largely the Middle East with an ultimate of 870 Gb when FSU, Africa, Latin America and North America have about 250 Gb, and Europe with only 110 Gb. The total for the world is now corrected by 10% to get 2000 Gb

Figure 31: **Creaming curves for conventional oil by continent with ultimates**



A complete study done by four retired geologists (Alain Perrodon, father of Petroleum Systems, Gerard Demaison, first geochemist to quantify the petroleum system generation, Colin Campbell and myself) with four reports from 1994 and 1998, has estimated in detail the potential for oil and gas of most Petroleum Systems and found for the world the following ultimates:

	mini	mean	maxi
Conventional oil	1700	1800	2200
Conventional gas liquids	200	250	400
Non-conventional liquids	300	700	1500
Ultimates liquids Gb	2300	2750	4000
Conventional gas	8500	10000	13000
Non-conventional gas	1000	2500	8000
Ultimates gas Tcf	10000	12500	20000

My present mean ultimate is 2000 Gb for conventional (different definition) oil
3000 Gb for liquids (include now refinery gains and synthetic oil)
10 0000 Tcf for conventional gas
2000 Tcf for unconventional gas

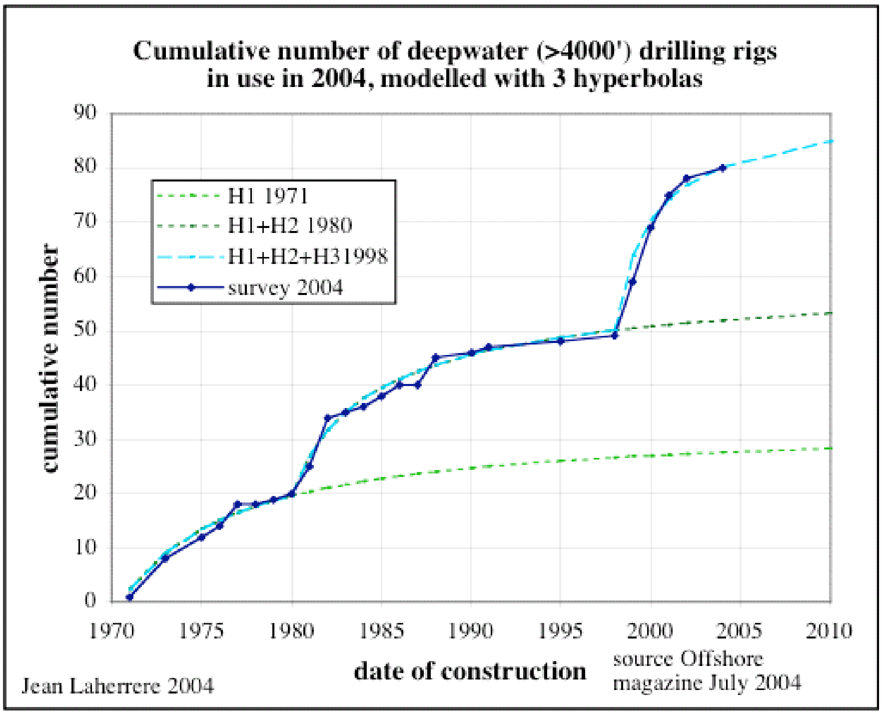
The world conventional reserves estimated by the USGS are the following

Year of study **1984 1987 1991 1994 2000**

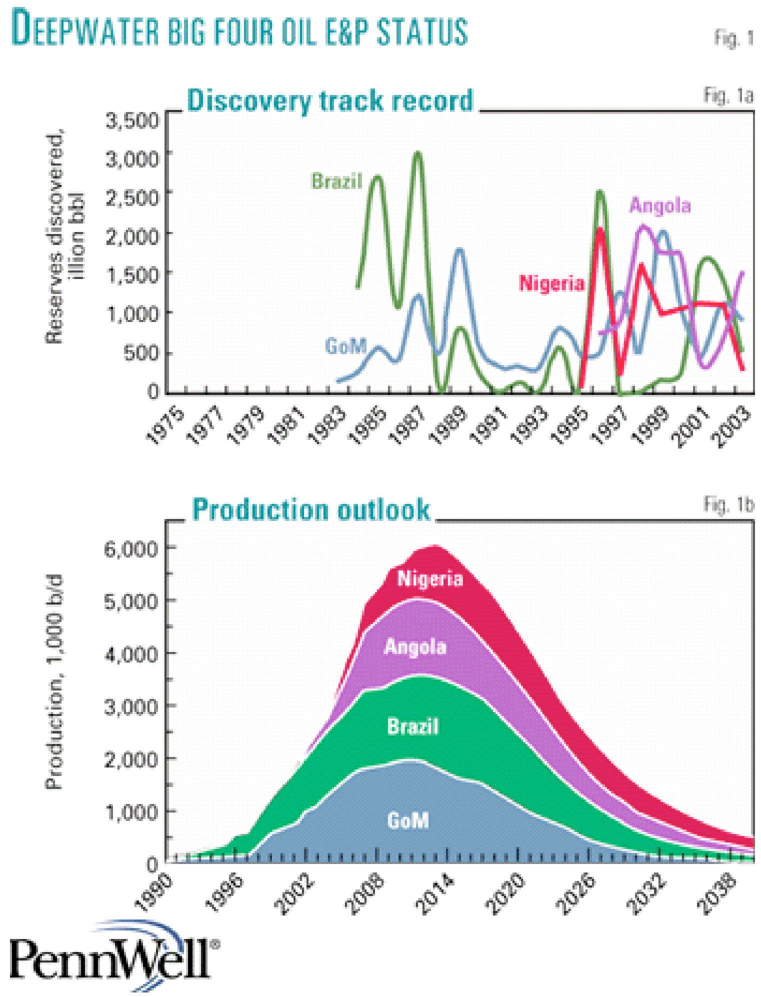
oil	Gb	1719	1744	2171	2273	3021
NGL	Gb				192	377
gas	Tcf		9282	10512	11567	15401

The step between 1994 and 2000 is the change of the head of the study !
But the USGS 2000 is in fact the estimate at end of 1995 and the almost 10 years of new data does not seem to confirm their results, in particular on the US with their ultimate of 362 Gb which is far from our estimate of 230 Gb as seen in figure 29.

-Deepwater
Deepwater is the last frontier. Its definition was first 200 m (the base of the continental shelf), now it is 400 or 500 m, even more. Large discoveries are concentrated in four countries Gulf of Mexico, Brazil, Angola and Nigeria, with the same geological pattern; reservoir being sands from turbidites, sediments coming from the shelf in larger volume and short times in catastrophic event, such as the slide of the Nice airport, within a diapyric tectonic (salt or shale) affecting the seafloor at sedimentation time.
Deepwater is described often as a new technology but in fact this technology started in the 70s with the dynamic positioning drillship.
The number of rigs presently in use in water, over 4000 ft, is plotted versus the date of construction and shows 3 cycles, one starting in 1971 but with negative geological results (except in the Gulf of Mexico), a second starting in 1980 with the high oil price and the last one starting in 1998 with low oil price but looking for large prospects missing onshore and in shallow water.
Figure 32: **Cumulative number of deepwater drilling rigs in use in 2004, modelled with 3 hyperbolas**



Sandrea 2004 displays the following graph for the four big deepwater (>500 m) producers: Gulf of Mexico, Brazil, Angola and Nigeria peaking in 2012 at 6 Mb/d.
Figure 33: **Deepwater oil discovery and production from Sandrea**



Exploration of these four deepwater basins (which extend shallow water producing areas) is well underway, except for the Mexican deepwater of the GoM and no new basin has been found in the rest of the world. Deepwater discoveries are on the decline and it is surprising that large oilfields are found only in the four countries as described above. These four countries have good turbidites reservoirs, accumulated in seafloor troughs due to diapyric tectonic (salt = GOM, Brazil & Angola and shale = Nigeria). All deepwater exploration outside these four countries has been mainly unsuccessful. 8 dry wells have been drilled by ONGC (cost 350 000 $/d) in the deep West India on big reef prospects. A giant oilfield (Kikeh) has been found in deep Malaysia but the potential of the area is small compared to the four above.
All Petroleum Systems of the world have been evaluated (even Arctic with ODP) and the progress of geochemistry is such that few wells drilled through the source-rocks are enough to tell the potential of a Petroleum system.

-Liquids production and oil demand
Our first studies were only for conventional oilfields as data on unconventional was not in the database and our forecast was for conventional production . But oil demand is for liquids and we were obliged to add the unconventional oil plus the natural gas liquids plus other liquids and also refinery gains. Our basic data for production is from the USDOE, which has the best database on the web, except that they do not provide extra-heavy oil production.
World liquids or 2004 in Mb/d

Crude oil less extra-heavy	71
NGPL	7
Refinery gains	2

Extra-heavy	1.7
Other liquids	1
All liquids	83

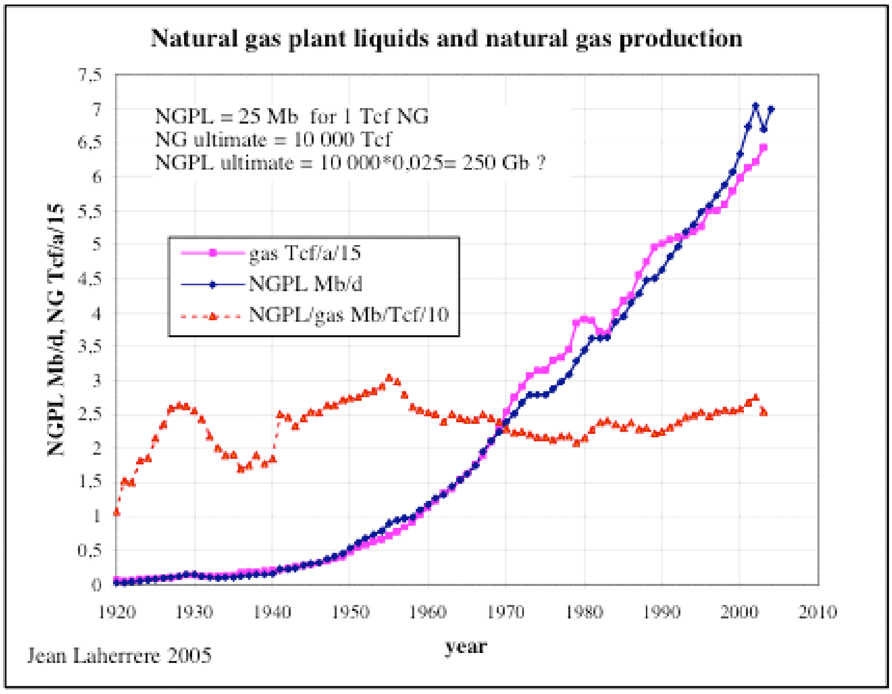
The most important producers of other than crude oil are from USDOE for 2002

2002 Mb/d	crude oil	NGPL	refinery gain	other liquids	liquids
World Total	66,8	7,0	1,9	1,05	76,9
United States	5,7	1,9	1,0	0,42	9,0
Brazil	1,5	0,0	0,1	0,22	1,8
South Africa	0,0	0,0	0,0	0,17	0,2
Venezuela	2,6	0,2	0,0	0,10	2,9
Saudi Arabia	7,6	1,0	0,0	0,08	8,7

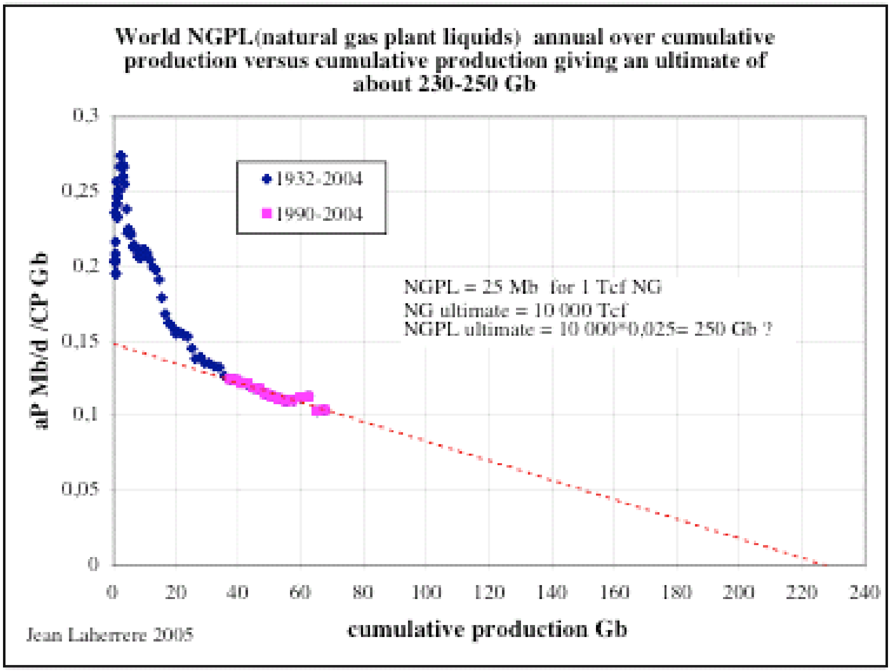
Other Liquids in USDOE include alcohol fuels, liquids produced from coal and oil shale, non-oil inputs to methyl tertiary butyl ether (MTBE), Orimulsion, and other hydrogen and hydrocarbons for refinery feedstocks. Brazil 220 000 b/d is alcohol from sugar cane (BTL) and South Africa 170 000 b/d is synthetic oil from coal (CTL).

Refinery gains occur as we deal with volume and not with weight. As the demand is mainly for light products, refineries crack heavy oil and also use hydrogen (from natural gas) to obtain lighter oil, increasing the volume

Natural gas liquids gather condensates, which are produced at wellhead by just depressurization and are often measured with crude oil, as well as the natural gas plant liquids (NGPL) from processing plants.
World production of NGPL follows closely the natural gas production (marketed volume) and is 7 Mb/d now with an average for the last decades of 25 Mb per Tcf of natural gas (marketed).
Figure 34: **World production of NGPL and NG 1920-2003**



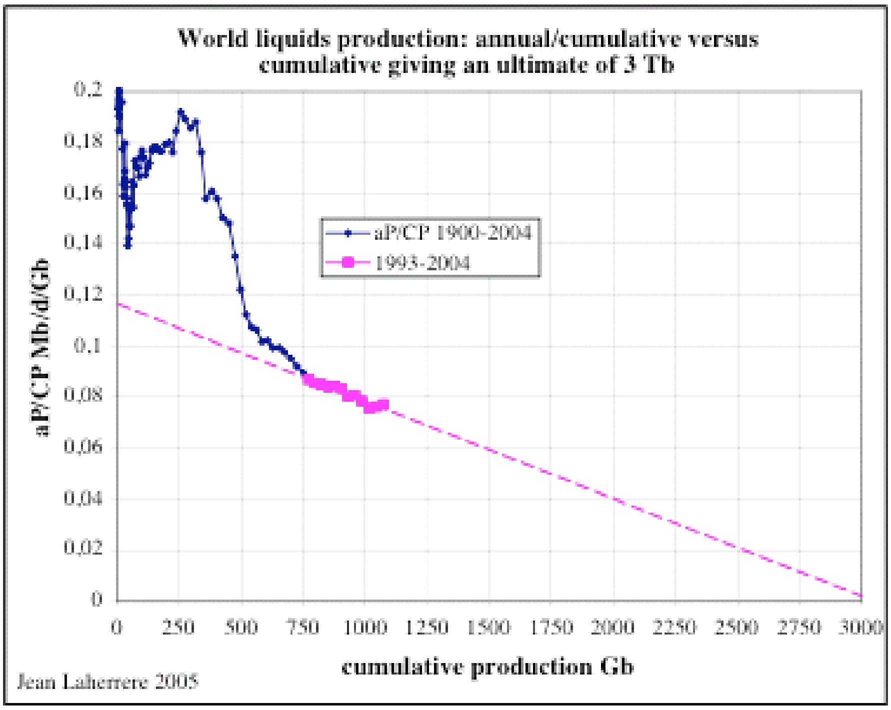
The linear extrapolation of the world annual/cumulative production for the last 15 years leads to an ultimate of 230-250 Gb of NGPL
Figure 35: **World NGPL: annual/cumulative versus cumulative giving an ultimate of 230 Gb**



A 250 Gb ultimate for NGPL agrees perfectly with the ultimate of conventional gas of 10 000 Tcf with an average of 25 Mb/Tcf

The similar linear extrapolation for liquids production on the last 12 years gives an ultimate of 3000 Gb.

Figure 36: **World liquids: annual/cumulative versus cumulative giving an ultimate of 3000 Gb**

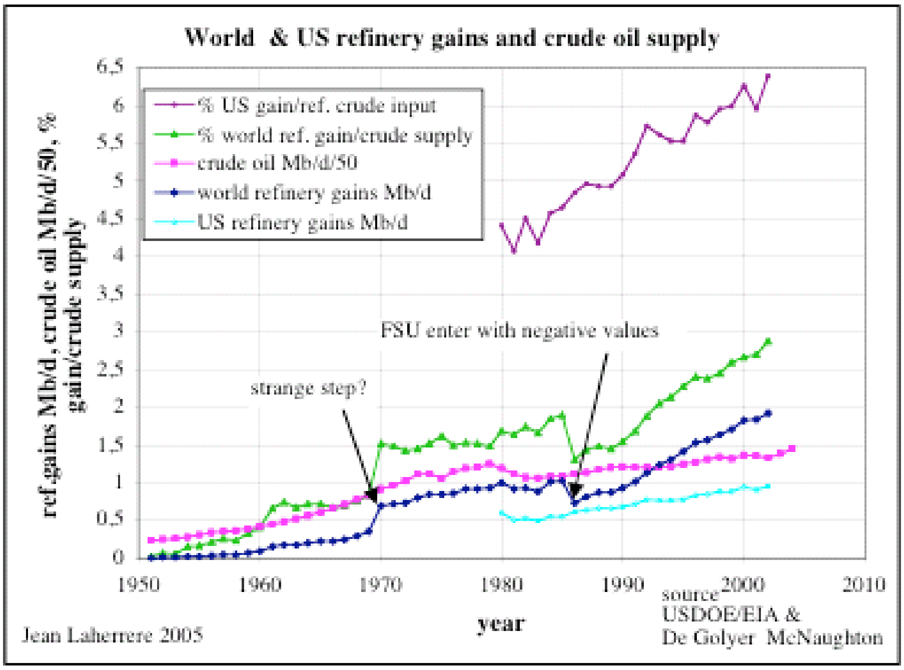


With liquids ultimate at 3 Tb, and since the crude less extra-heavy ultimate is 2000 Gb, it leaves 1000 Gb for the following items:

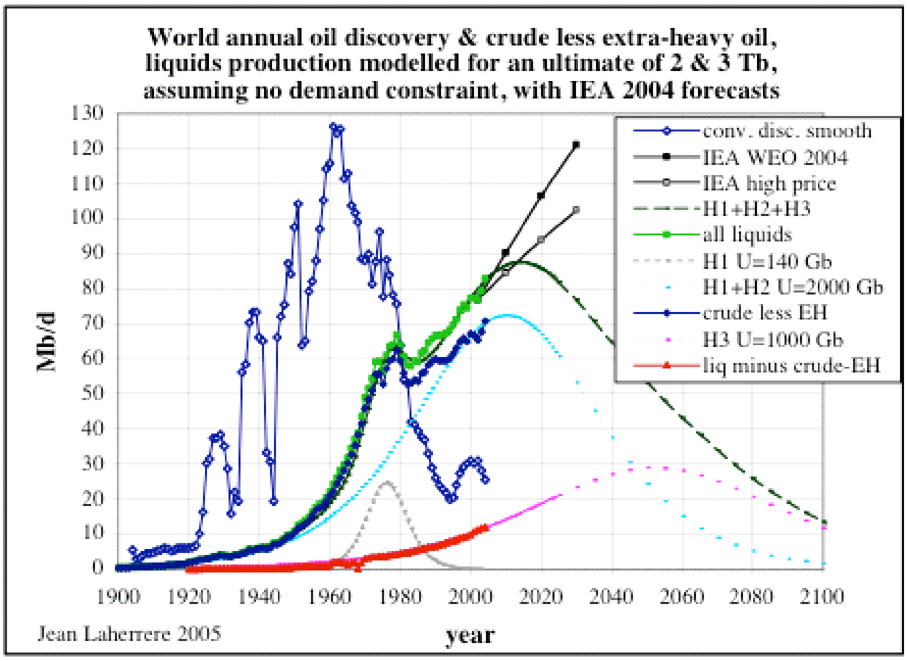
-extra-heavy oils estimated at 500 Gb,

-NGPL estimated at 250 Gb

-other liquids and refinery gains left with 250 Gb
It is hard to forecast the ultimate of synthetic oil from biomass, coal and nuclear (getting straight hydrogen from high temperature reactors and transforming it in oil with carbon (CO2?) but the potential could be high. As for refinery gain, the data is rare and lousy, in particular in FSU where USDOE data introduces suddenly negative values in 1986, a step down which seems to be equal to the step up in 1970.
The percentage of refinery gain versus crude oil supply is in 2000 about 2% when it was about 1% in 1985, but for US the percentage is now over 6%, when it was 4% in 1980. the cumulative production of refinery gains is over 15 Gb, and it is difficult to estimate how much will be produced in the future. Light oil was preferred in the past by refiners, but now heavy oil is more produced, in particular in Saudi Arabia. Cracking the remaining oil by refiners will continue to increase and could represent a significant percentage. It is why 250 Gb for refinery gains and other liquids is a good guess but could be higher.
Figure 37: **World & US refinery gains and percentage of crude oil supply**



From this rounded ultimate at 2 Tb for crude less extra-heavy EH and 3 Tb for liquids, we can first model the “crude less EH” with 2 Tb and the difference with liquids with an ultimate of 1 Tb.
We prefer to model future annual production with a simple curve where the area below the curve is equal to the ultimate, and which is fitted to 2004 value with the same slope as the last few years. We use a Hubbert curve, which is the derivative of the logistic, because some of the past cumulative productions fit well a logistic curve. This simple curve will represent the supply if there is no constraint on the demand, as it was during the oil shocks of 1973 & 1979 or during the economic depression of 1930. As Paul Volcker said, there is a 75% probability that a depression will occur in the next 5 years, **it is likely that oil demand will be chaotic and instead of a peak the oil production will show a bumpy plateau.**
Our forecast is for an oil peak in the 2010s at l 90 Mb/d, when USDOE and IEA 2004 forecasts are for 120 Mb/d in 2030 with an oil price of 25 $2003/b in 2030. IEA forecasts an alternative with high price (35 $/b in 2030 ?) with a production of 103 Mb/d in 2030. IEA is a consumer club, which wants to satisfy the growth goal of its members.
Figure 38: **World oil discovery and oil production forecast (no demand constraint) for an ultimate of 3Tb for liquids & 2Tb for crude less EH oil compared to IEA**



2030 at

Hirsch et al (2005), from the National Energy Technology Laboratory of the Department of Energy, has published in February 2005 an article where he forecasts the future production of non-conventional oils, which will be added to the peak of conventional oil. Three scenarios are considered from the date of the crash program of these unconventional oils compared to peak oil.

forecast 10 years later after action is taken in Mb/d	
-extra-heavy oils =EH	8
-CTL	5
-EOR	3
-GTL	2
-energy savings (efficient cars)	1
-total	16

shale oil and BTL are excluded

Figure 39: **Hirsch's graph for additional liquids (ET, CTL, EOR, GTL & savings) wedge after 15 years from start**

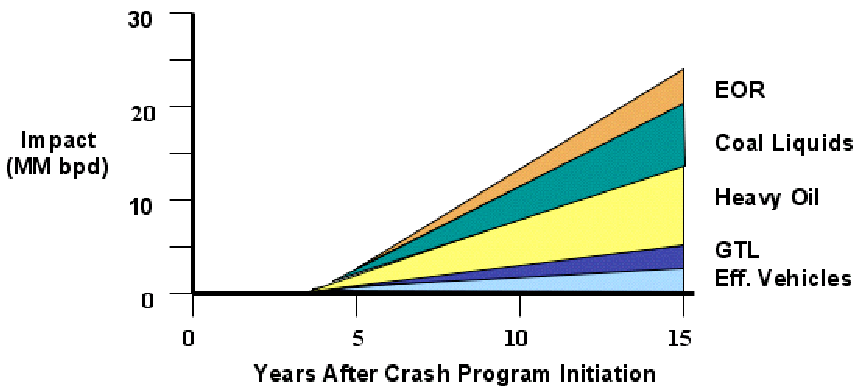


Figure A-5. The total of the wedge estimates

The conventional oil is assumed to decline symmetrically. The mitigation of the unconventional items (if the crash program starts at peak time) will reduce only partly the supply shortfall (constant demand growth) 20 years later, leaving a shortage of about 40 Mb/d.
Figure 40: **Hirsch's forecast of supply shortfall if mitigation crash programs start at peak for 100 Mb/d**

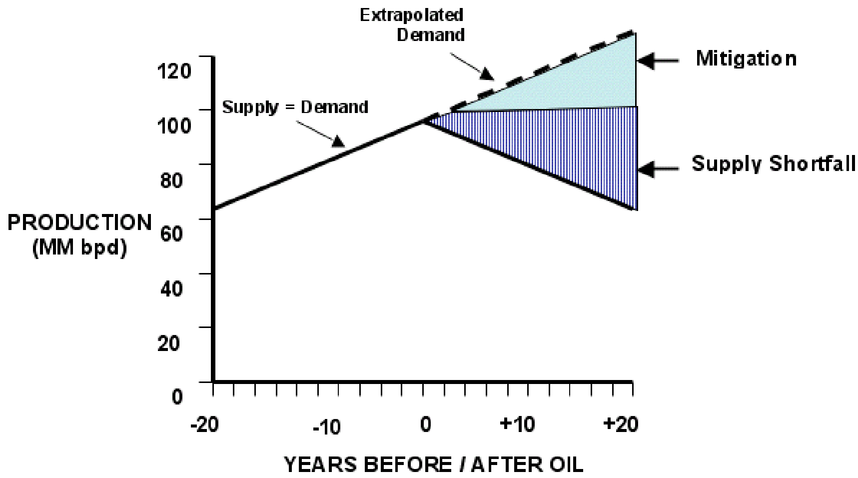
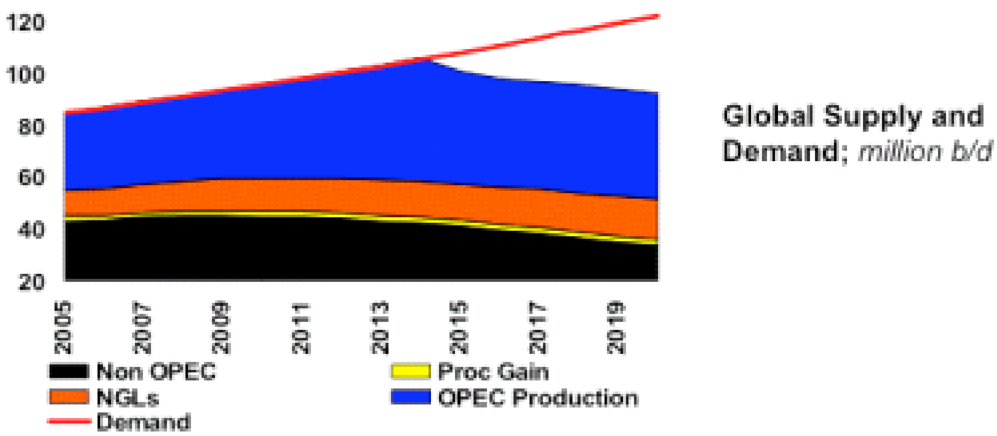
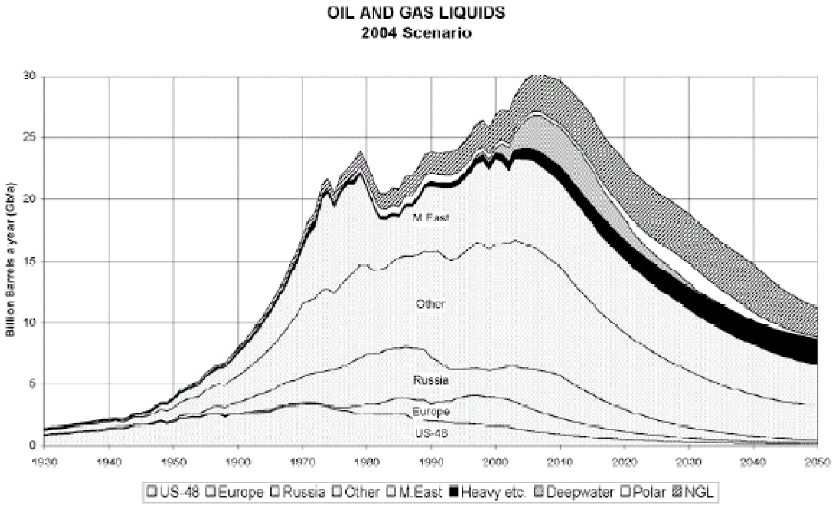


Figure VIII-4. Mitigation crash programs started at the time of world oil peaking: A significant supply shortfall occurs over the forecast period.

PFC Energy, in a 2004 presentation to CSIS (Center for Strategic & International Studies) at Washington, forecasts a peak:
in 2014 at 100 Mb/d if the demand grows at 2.4 %/a
in 2018 at 105 Mb/d if the demand grows at 1.8 %/a
in 2025 at 105 Mb/d if the demand grows at 1.1 %/a
Figure 41: **PFC forecast for a high demand of 2.4 %/a with a peak in 2014 at 100 Mb/d**



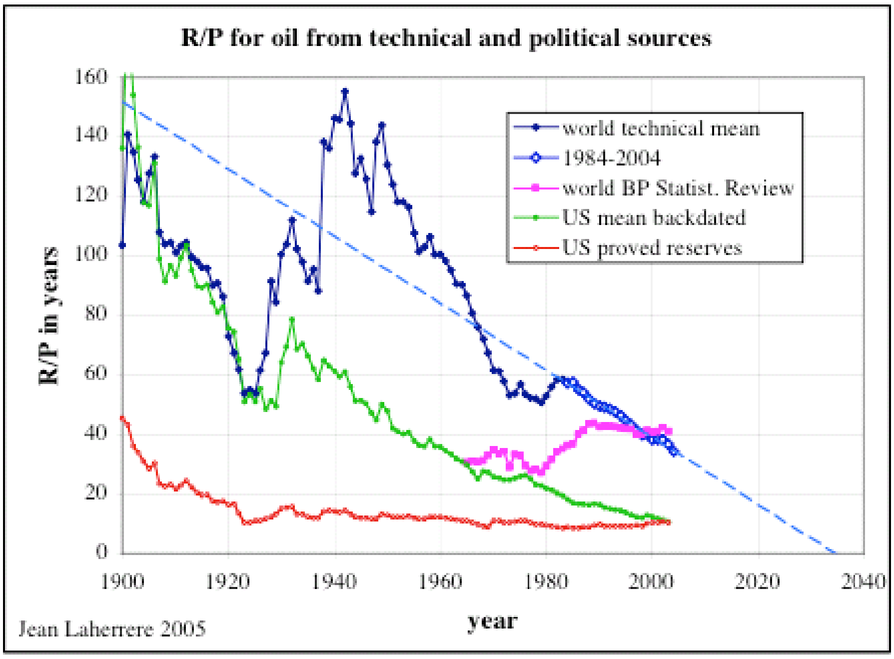
In the ASPO newsletter of March 2005, Colin Campbell forecasts a peak in 2006 with an ultimate of 1.8 Tb for regular oil (excluding heavy oils (<17°API), deepwater and arctic) (66 Mb/d in 2005) and in 2007 at 83 Mb/d with an ultimate of 2.4 Tb for liquids (but excluding refinery gains and other liquids) (82 Mb/d in 2005).
Figure 42: **ASPO 2005 forecast for regular oil, heavy, deepwater, polar and natural gas liquids**



-medias forecasts in R/P

One of the most used parameter for oil future is the R/P ratio, being the remaining reserves over the present annual production given in years. It is often said that oil R/P is 40 years, suggesting that there is enough oil for the next 40 years. But first production is assumed to grow and the physics of production cannot allow a constant plateau during 40 years and no production on the 41st year. For the US proved reserves, R/P has been around 10 years since 1920 and shows that this R/P has no meaning, in fact it is a rule of thumb to compute reserves (even used by USGS)! Taking the technical reserves R/P for the world was at 140 years in 1900, went down to 50 years in 1925, up to 150 years in 1945 and presently at 35 years trending linearly to zero reserves in 2035; and for the US R/P was at 160 years in 1900 declining slowly (except during the 30s) to 10 years now, with no linear trend.

Figure 43: **R/P for world & US oil from political and technical sources**



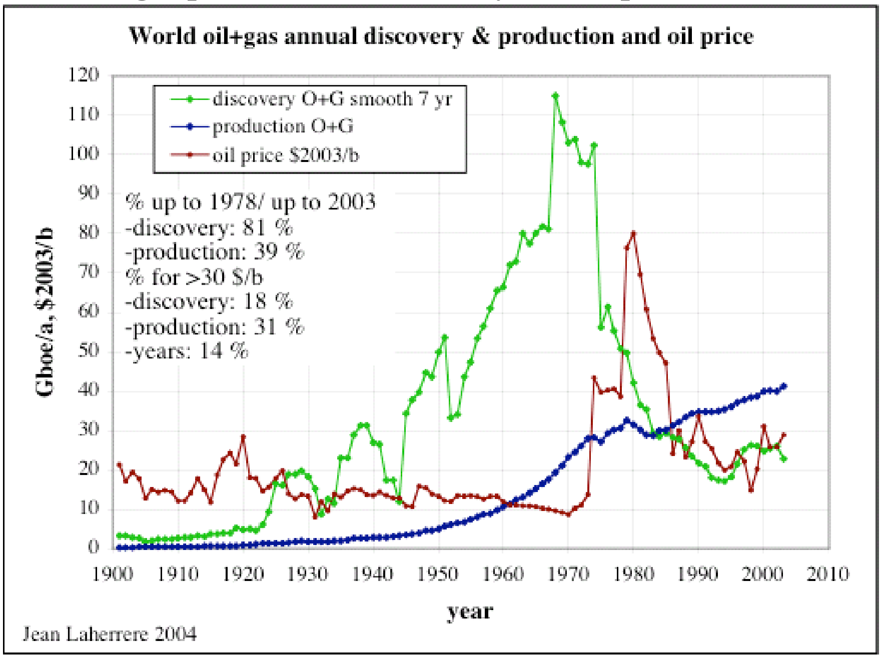
R/P is a bad parameter but it is used by most!

-Oil + gas discovery versus oil price

Some believe that high price leads to more discoveries, but it is not what the past shows, because the oil shock (1979) corresponds to a fall in discovery and the trough of price in 1999 corresponds to the peak of deepwater

The annual discovery of conventional oil + gas (smoothed on a 7 year period) shows that 81 % of the discovery occurs before 1979 (but only 39% of the production).

Figure 44: **World oil+gas production & discovery and oil price**

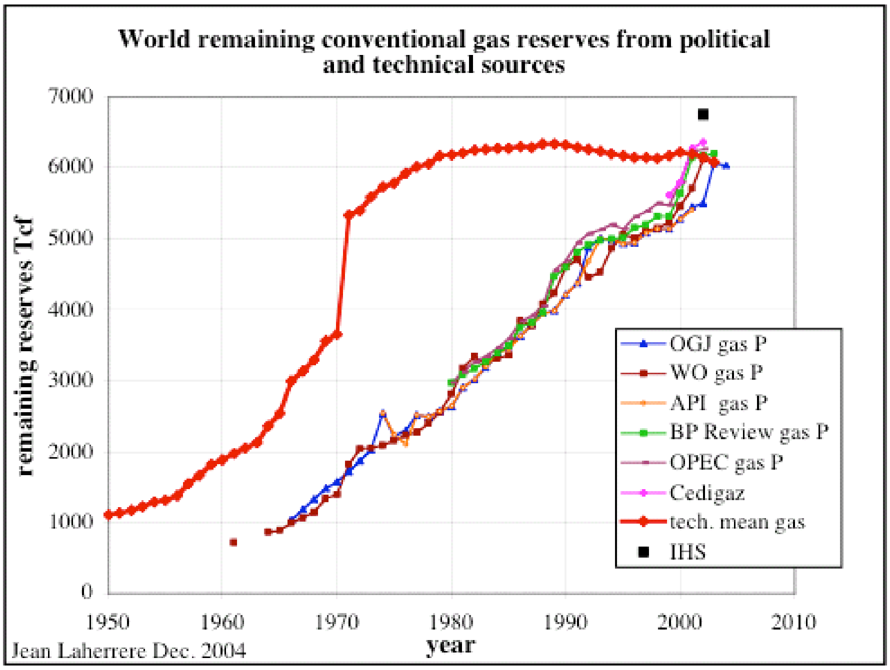


-Natural Gas

As for oil, natural gas reserves are political when reported globally by government and technical when reported field by field by scout companies. But since there is not OGEC and no quotas, gas reserves are less political. In Russia gas reserves are not State secret.

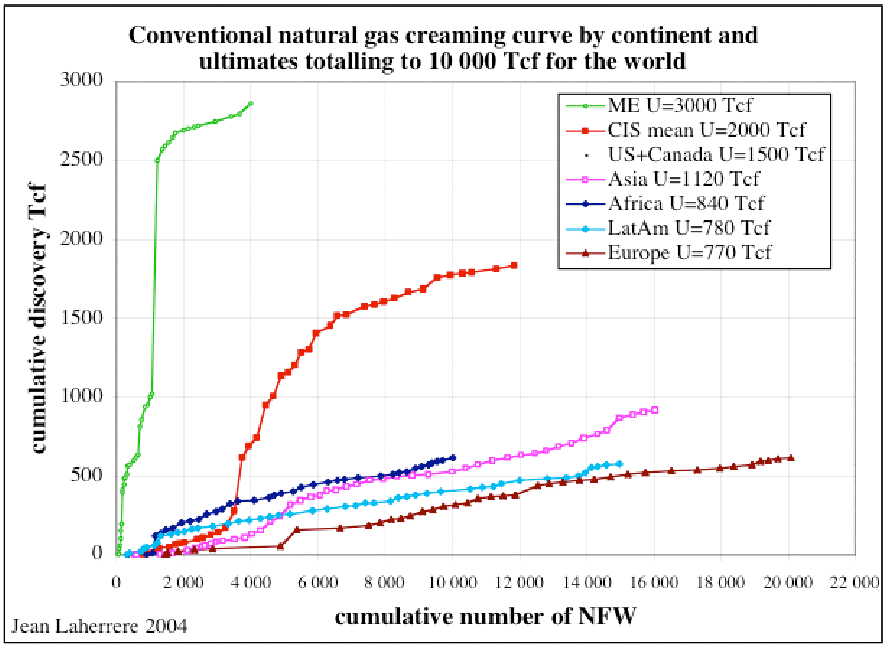
As shown in figure 21, technical discovery has been about equal production since 1980 and the remaining technical reserves stay flat except for the last 2 years.

Figure 45: **World remaining natural gas reserves from political and technical sources**



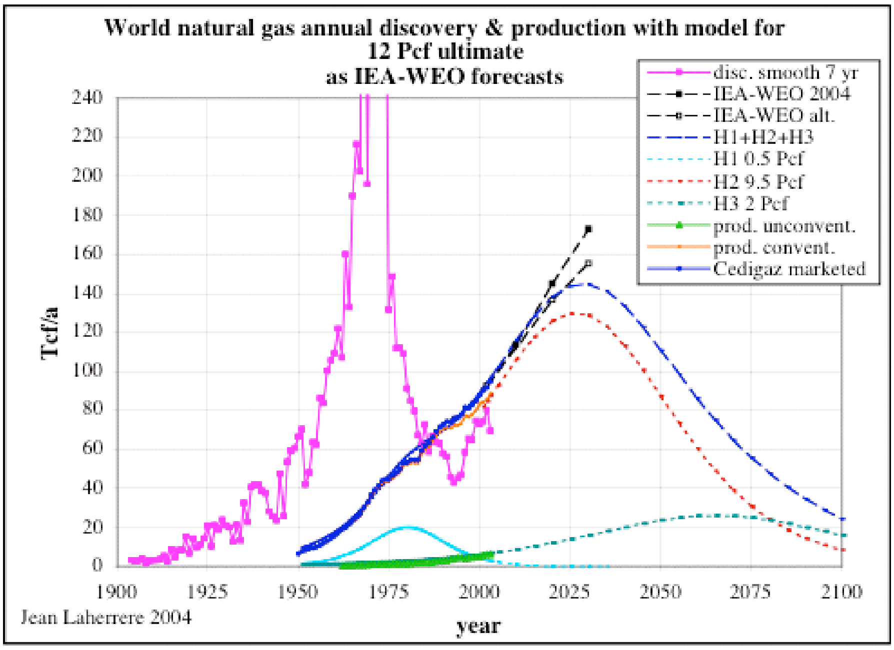
The creaming curve shows also the great inequality of gas distribution, the ME having the largest endowment, then the FSU in between with the other continents below.

Figure 46: **Natural gas creaming curves by continent & ultimates**



As for oil, we model the future production with a Hubbert curve, using an ultimate of 10 Pcf for conventional gas and 2 Pcf for unconventional gas (adsorbed gas in CBM as shale gas, and tight reservoirs). We consider hydrates as having no potential for reserves, for being too dispersed (Laherrere 2000). Geopressured aquifers were considered 30 years ago to be holding a huge potential, just like now hydrates are by some academic searchers, but no one talks anymore about dissolved gas in aquifers !

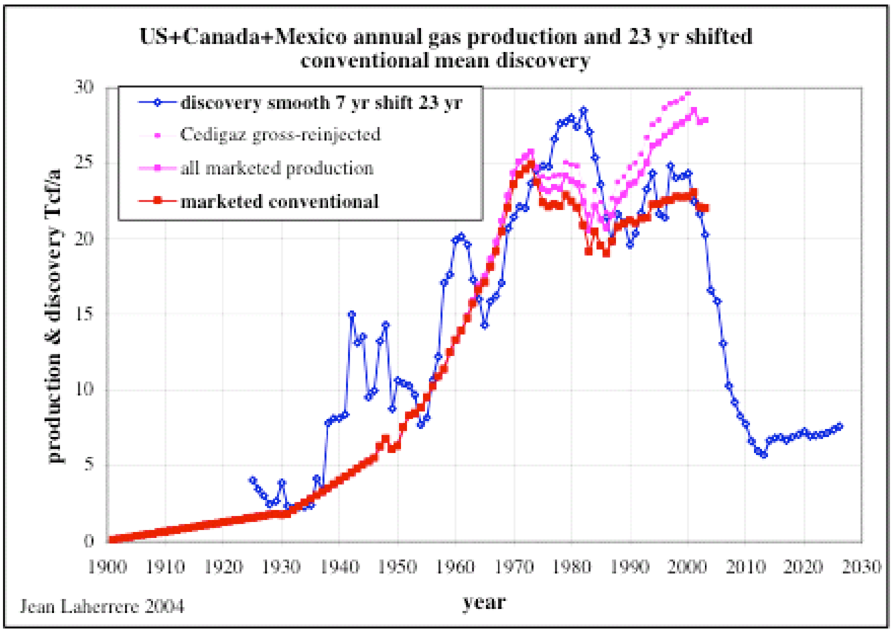
Figure 47: **World natural gas discovery and production modelled with 12 Pcf ultimate as IEA 2004 forecasts**



This gas peak is global and forecasted in 2030 at less than 150 Tcf/a when IEA forecasts 173 Tcf/a in 2030, but if oil is one global market being transported very cheap around the world, gas is much more expensive to transport (over 5 times) and many discoveries are still stranded, though many LNG plants were built. But shipping could be a problem if LNG volumes increase too much. Local gas shortages could occur sooner than the global oil shortage and this will start soon with North America

Up to now, North America gas consumption was supplied locally, but production is peaking. The annual conventional natural gas discovery (smooth on 7-year period) is shifted by 23 years to fit the past annual conventional production (red curve) and it is easy to see that soon the decline will be a waterfall, as claimed by Matt Simmons (ASPO Berlin 2004).

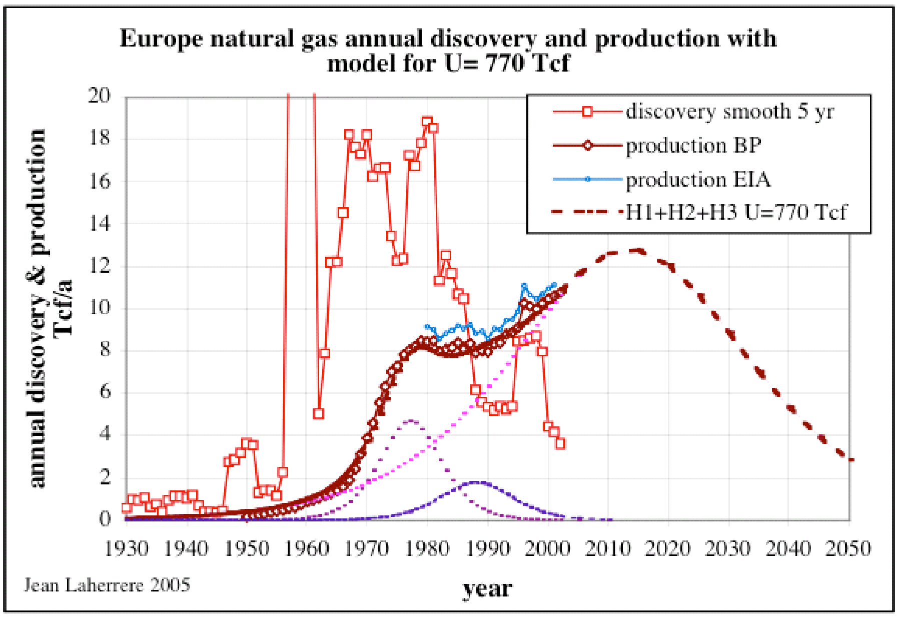
Figure 48: **US+Canada+Mexico natural gas production and conventional « mean » discovery shifted by 23 years**



North America conventional gas production will decline sharply soon, and unconventional is flattening as stated also by Matt Simmons (2004). Natural dry gas consumption has been declining in the US since price has doubled, and most fertilizer plants have closed. Only LNG can solve the problem of declining production, and many terminals are in project but few will be authorized.

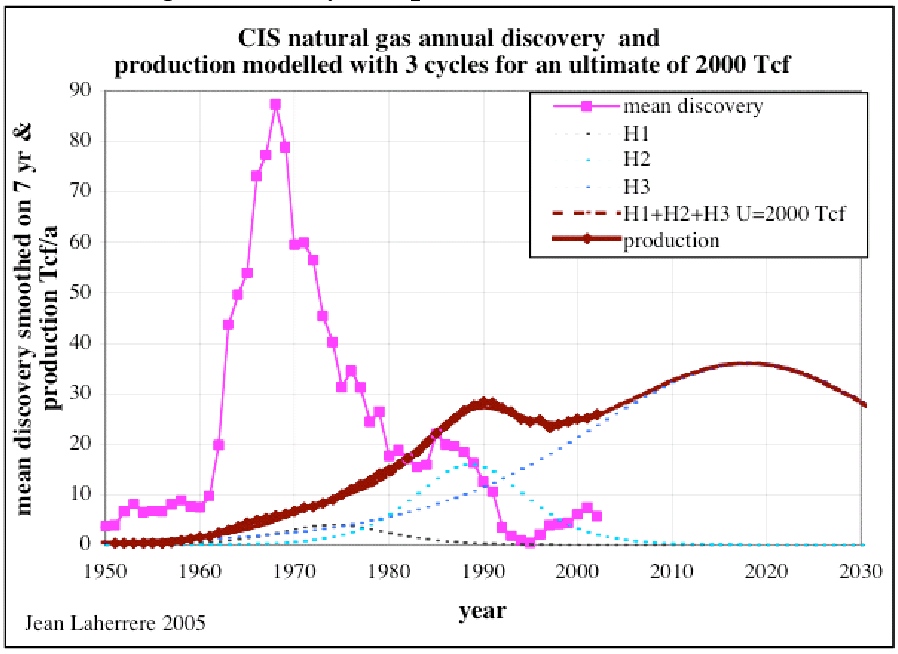
Europe gas production is peaking soon and will start to decline in the 2010s.

Figure 49: **Europe natural gas discovery and production modelled with a 770 Tcf ultimate**



Many count on gas imports from Russia as well as Africa.
But FSU natural gas reserves are overestimated (in particular the largest gasfield Urengoi which has been declining since 1987, and sharply since 1999) needs to be reduced by 30 % (Laherrere 2004 ASPO & IIASA) to represent the mean value. The ultimate is about 2000 Tcf and gas production will peak at less than 35 Tcf/a before 2020. This future production is not enough to satisfy gas consumption growth in Europe and in Asia Pacific, as planned by both

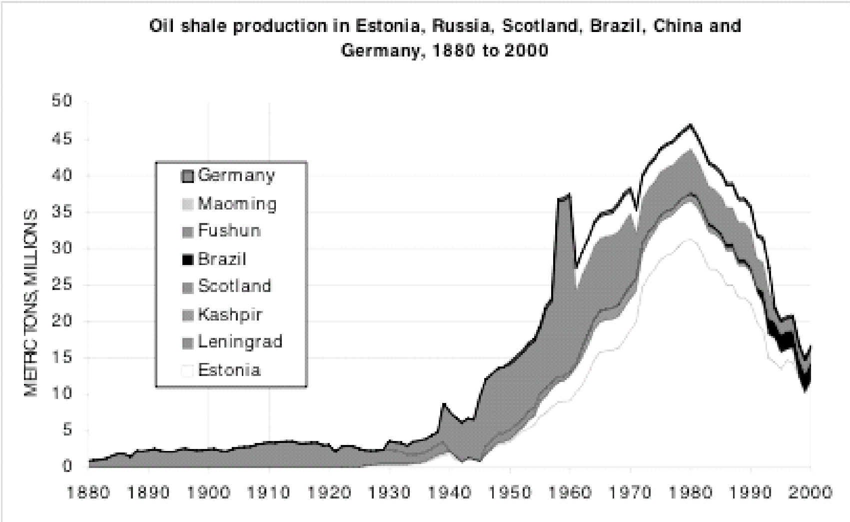
Figure 50: **FSU annual gas discovery and production modelled for a 2000 Tcf ultimate**



-Oil shales

Oil shales are in fact an immature source-rock which has not yet generated any oil and needs to be heated at 600 °C to yield oil by pyrolysis. In fact they should be classified with coal and peat. And most oil shale in Estonia was burned in electric or cement plants. They are completely different from oilsands, which are at the end of the oil cycle before being entirely degraded.
Oil shale has a long past of production, starting in 1837 in France (Autun mines, which were closed in 1957), Scotland 1850-1963, Australia 1865-1952, 1998-2004, Brazil 1881-1900,1941-

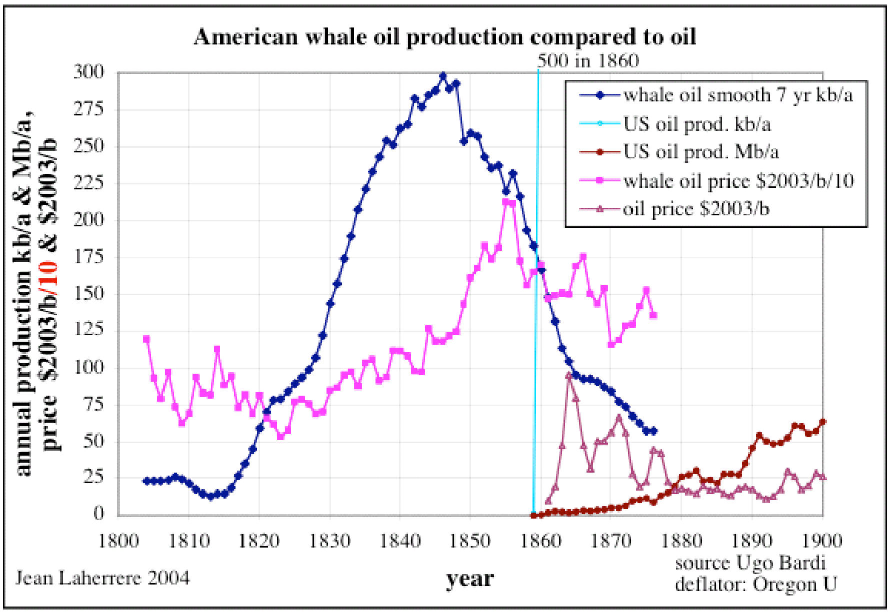
1957, 1972-, Estonia 1921-, Sweden 1921-1965, Switzerland 1921-1935, Spain 1922-1966, China Manchuria 1929-, South Africa 1935-1960.
The peak of oil shale was in 1980 at 50 Mt/a followed by a symmetrical decline (Hubbert curve).
Figure 51: **World oil shale production 1880-2000**



source: Illustration #21 from paper: Origin and resources of some world oil shale deposits, by John R. Dyni, U.S. Geological Survey, Denver, CO, USA, presented at the Estonian Oil Shale Symposium, Tallinn, Nov. 18-20, 2002.

Cumulative production is in the order of 1.5 Gt equivalent to 1.5 Gboe, being about 0.1 5 % of the oil production. During the oil shock of 1973, many pilots were built in the US (together with towns), spending billions of dollars to produce few millions of barrels. The US is reported to contain 2000 Gb out of the 2600 Gb of world resources (USDOE 2004 (Rapport USDOE March 2004 Strategic Significance of America's Oil Shale Resource), mainly in the Green River oil shales.
But to extract oil from the mines, shales must be broken into small pieces, and after heating, the waste is very small fines with a double volume, which are very difficult to store. A very large volume of water is necessary and out of the potential of this dry area. In fact environment problems and furthermore investing more energy than the energy return has killed the production. It was said to be a question of oil price but it is a problem of energy count. Suncor the Canadian oilsand producer built in 1998 a plant using its oilsands technique in Australia (Stuart oil shale which are very rich with 2.6 Gb reported reserves) with two Australians partners (deal already signed by Exxon in 1980 but abandoned). The plant has three phases, with the first one at 4000 b/d and the last one at 200 000 b/d (reduced at 65 000 b/d). The plant was unable to reach the 4000 b/d level. Suncor left in 2000, writing off the plant investment. The Australian partners having only to take care of the operational cost were unable to finance the plant and the plant was closed last year.
Oil shale has a very disappointing past and an unlikely future!

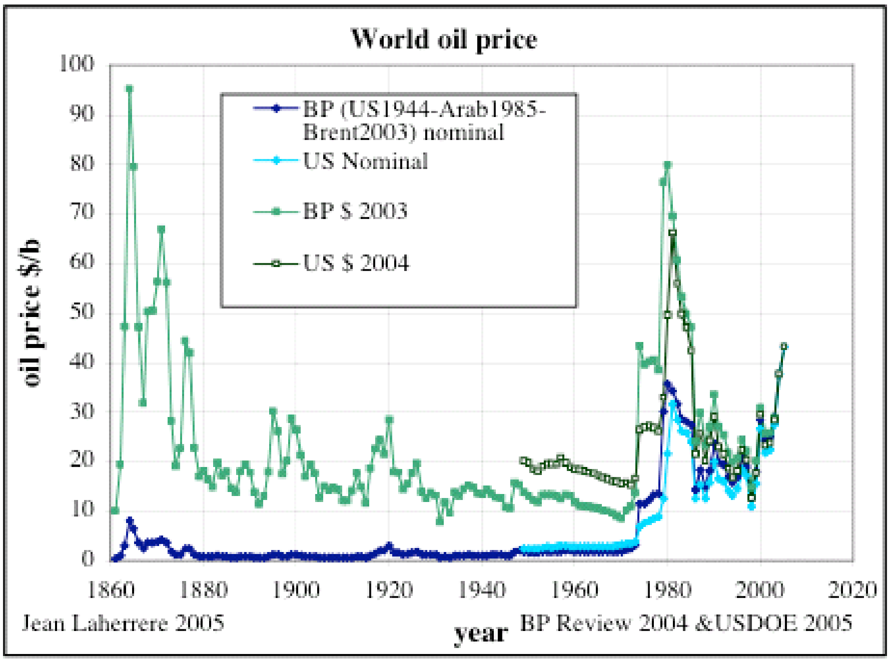
-Oil price
Oil from whale was used for lighting before being replaced by crude oil.
Figure 52: **US whale oil production compared to crude oil 1800-1900**



US whale oil production displays a perfect Hubbert curve and its price jumped after the peak occurrence, reaching 2000 $2003/b in 1855 . It was, in 1875, 30 times more expensive than crude oil.

Oil price has varied considerably in the past, with large discoveries and great political events. Oil price has to be compared in constant money but there is no consensus on the deflator.

Figure 53: **Oil price 1860-2005 from BP Review & USDOE**

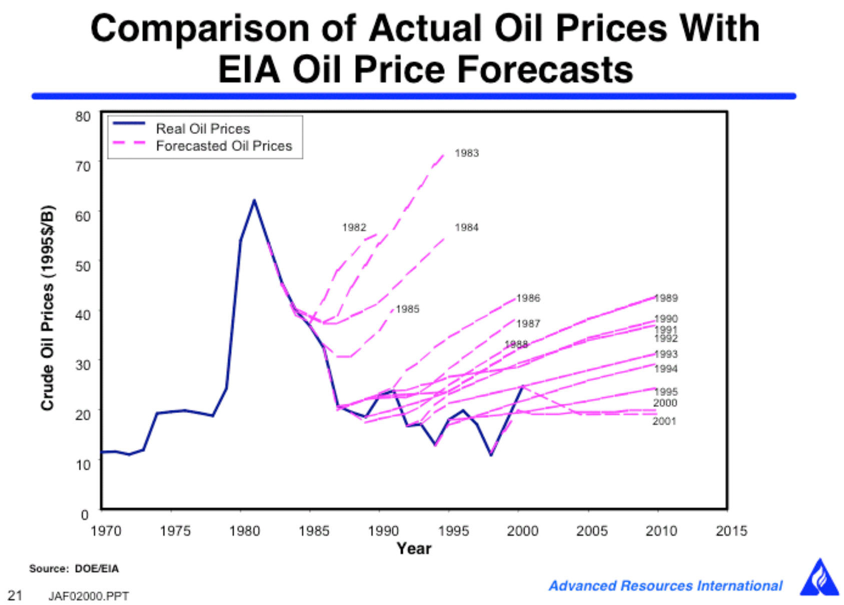


The present price is only half of the real value in 1980 or even 1865!

-Oil price forecasts

I refuse to forecast oil price, except to say that the cheap oil is gone and a possible range of 20-100 $/b. Oil price is quite irrational or led by wrong data (the 10 $/b in 1990 due to IEA missing barrels) and every forecast in the past was wrong. The 50 $/b of 2004 was not forecast by any economist!

Figure 54: **Comparison of actual oil prices with EIA forecasts 1970-2000**



USDOE and IEA forecasts are about 25 $/b in 2030!

Bauquis 2004 wishes a new oil shock with 100 $/b to allow renewable and energy savings to solve the coming shortage of fossil fuels before 2050. If an economic depression occurs and demand falls, all very expensive investments (extra-heavy oils, deepwater) will be obliged to produce even if losing money, as these equipments cannot be stopped and the price fall will be harder. It is why chaotic oil prices may occur.

PIW 050214 reports14 latest oil price forecasts by analysts which look optimist!

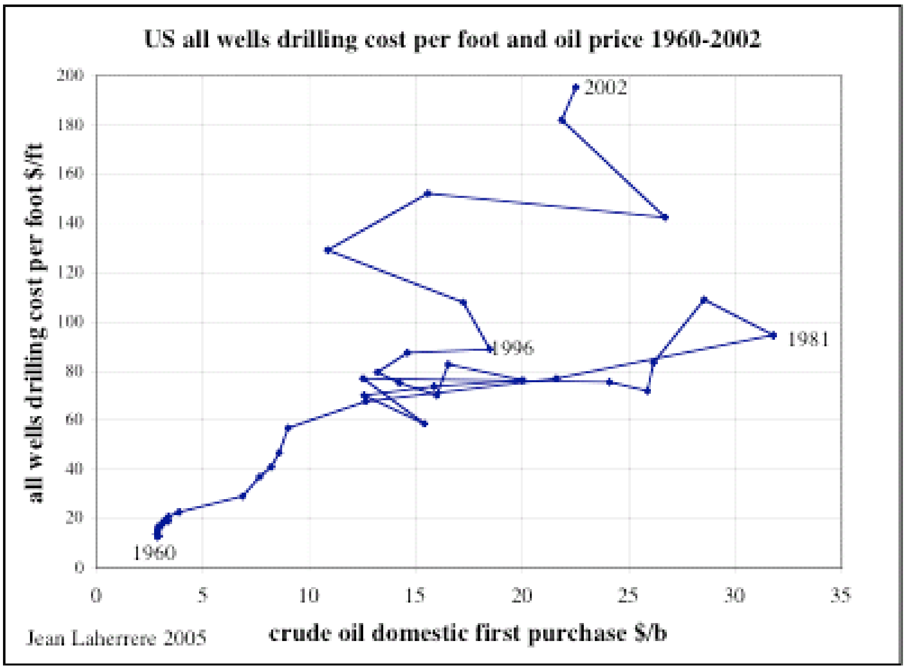
	Q1 ’05	Q2 ‘05	2005	2006
Average	44.66	42.40	41.30	37.72
High	47.50	47.00	46.50	43.20
Low	41.00	36.25	35.00	30.00

The recent change is that, for long, OPEC was afraid that high oil price will kill the demand such as in 1979 and OPEC goal of 25 $/b was still stated few months ago, despite the fall of the dollar. But now OPEC is convinced that high price does not damage demand and the new goal is about 40-50 $/d and OPEC mentions a possible 80 $/b soon.

-Drilling cost

For many, technology decreases drilling costs, but reality is different ,as the US cost of drilling all wells per foot plotted versus the wellhead oil price displays a almost linear trend from 1960 to 1996, where oil price moves from 3 $/b to 32 $/b and the drilled foot from 10 to 100 $. But in 1997, because of deepwater drilling cost has increased drastically up to 200 $ in 2002.

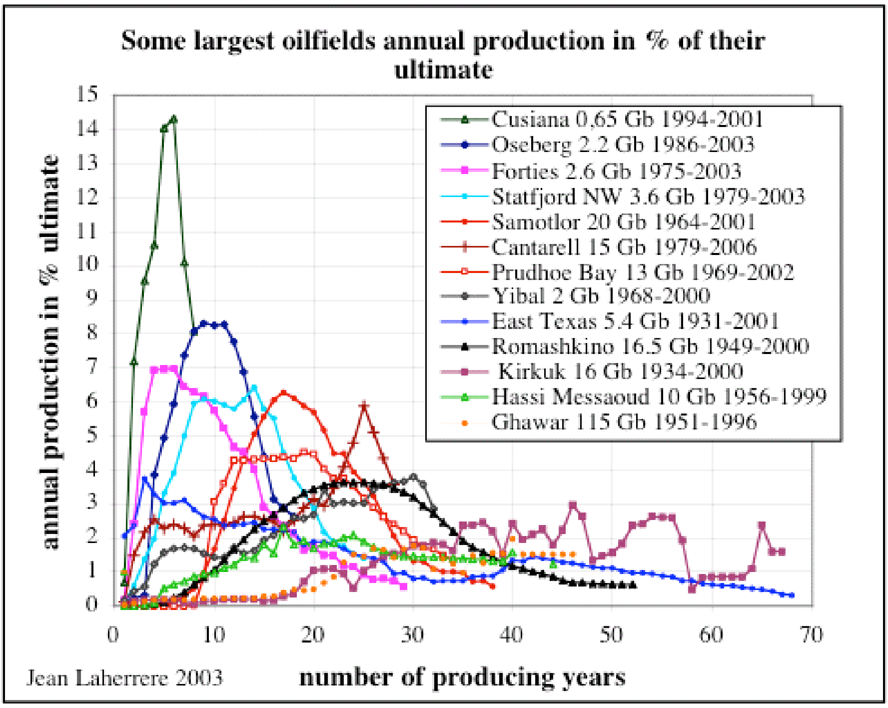
Figure 55: **US drilling cost per foot versus oil price**



-Oilfield production pattern for some giant oilfields

The display for the largest oilfields of the percentage of annual production to their ultimate versus years of production

Figure 56: **Annual percentage of production to the ultimate for some of largest oilfields**



The maximum annual production varies from 3 to 14 % of the ultimate. Offshore or insecure fields are produced much faster than onshore fields

-Fossil fuels

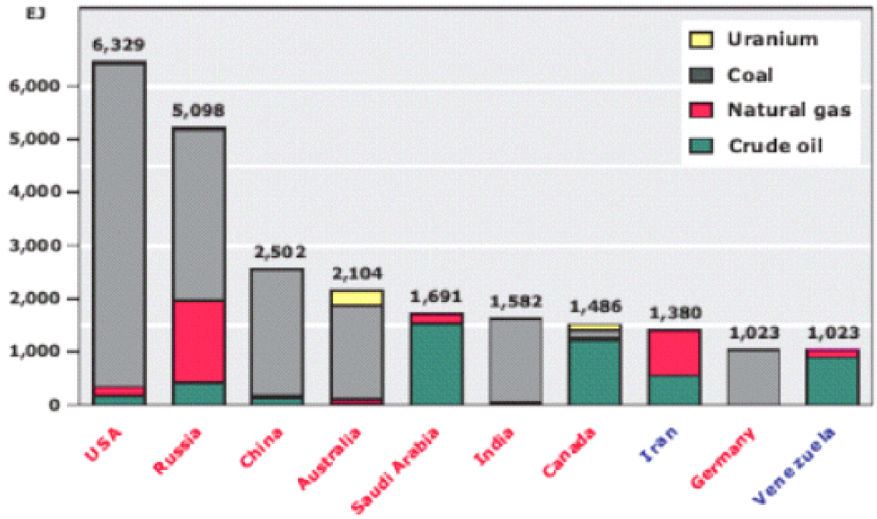
-Resources assessment

The most important item to deal with energy is to assess world resources. In the past, many agencies were involved but now only one, BGR in Germany, is making a complete inventory of

the earth and updating it often. The WEC (World Energy Council), gathering almost every country in the world (in contrary to the limited number of countries in IEA or OPEC), reports the individual assessment by each member but does not aggregate the total by lack of homogeneity.
Remaining reserves at estimate year

BGR- Germany	reserves Gtoe		resources Gtoe	
estimate year	1997	2001	1997	2001
conventional oil	151	152	76	84
non-conventional oil	134	66	574	250
conventional natural gas	116	122	172	165
non-conventional gas	2	2	2458	1163
hard coal	341	423	3519	2486
soft brown coal	50	47	763	292
uranium	24	15	179	174
thorium	22	22	23	23

BGR displays this interesting graph of the fossil fuels richest countries.
Figure 57: **Fossil fuels remaining reserves for the 10 richest countries**



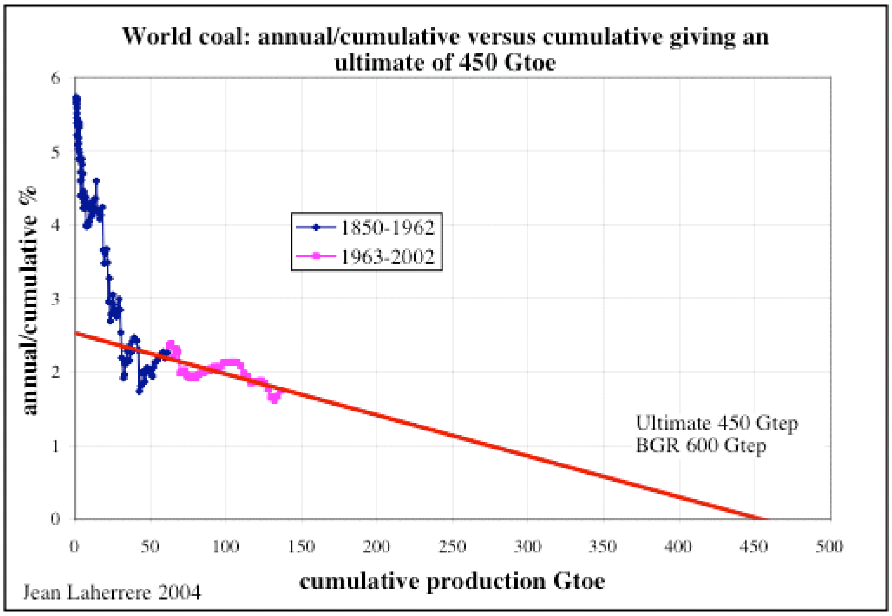
Given in reserves per capita, the ranking is different for these 10 richest countries, adding the number of year at 2003 consumption

country	popul M	res Gtoe	**res. toe/cap**	cons. Mtoe	year consumption.
Australia	20	50	**2505**	116	432
Saudi Arabia	25	40	**1610**	122	330
Canada	32	35	**1106**	291	122
Venezuela	26	24	**937**	64	381
Russia	144	121	**843**	671	181
US	294	151	**513**	2298	66
Iran	67	33	**490**	129	255
Germany	83	24	**293**	332	73
China	1300	60	**46**	1178	51
India	1087	38	**35**	345	109

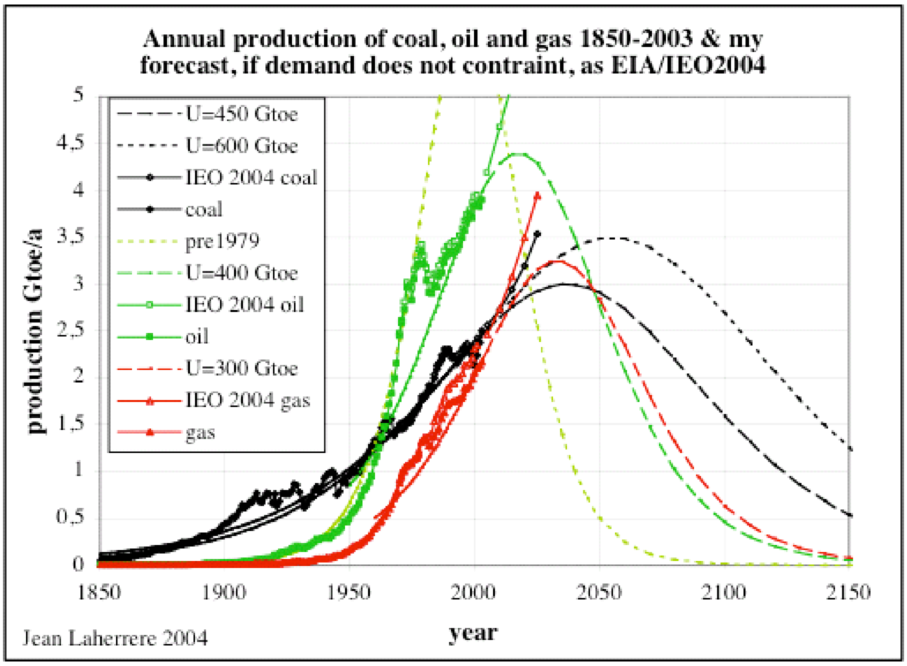
But Qatar has 0.7 million people and 200 Gboe (North Field gasfield) or 27 Gtoe and 39 000 toe/cap! 15 times more that in Australia !

-Fossil fuels production

Coal resources are badly reported and known, as there is no scout company reporting coalmines. Ultimate can be estimated by extrapolating the past production (annual/cumulative versus cumulative) and for coal we have a value of 450 Gtoe compared to 600 Gtoe from the BGR 2001.
Figure 58: **World coal annual/cumulative versus cumulative production giving an ultimate of 450 Gtoe**



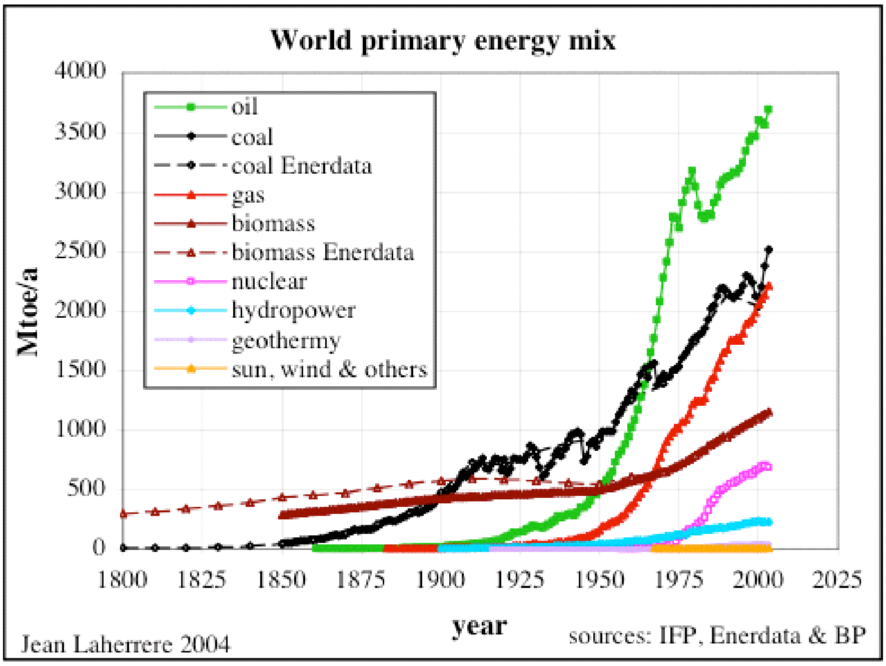
Coal is modelled with Hubbert curve for two ultimates (450 and 600 Gtoe), as the oil for 400 Gtoe (3 Tb) and gas for 300 Gtoe (12 Pcf). If the demand has no political or economical constraint, coal peak is reached in 2035 (U=450 Gtoe) or 2055 (U= 600 Gtoe), far from the reported 250-year life in most medias. In brief, oil peak around 2015, gas peak around 2030 and coal peak around 2050.
Figure 59: **World annual production of coal, oil and gas with models and USDOE forecasts 1850-2150**



-Primary energy

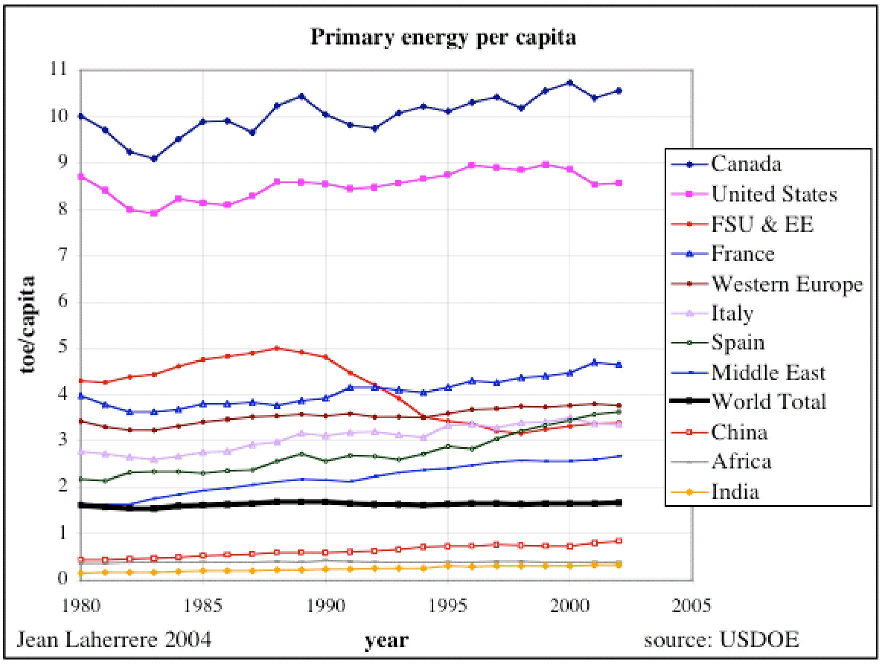
The primary energy mix displays a continuous increase for coal, a sharp increase for oil from 1950 to 1979, a significant increase of biomass after 1980, a slow increase of hydropower and insignificant amount of sun; wind and others.
Energy mix requires to convert it all in the same unit being Joule or oil equivalent, and it is not easy for electricity. It is necessary to make conventions on the energy equivalence depending upon the average efficiency of each source, but these conventions are hardly discussed and should be updated from time to time. Most agencies now use IEA conventions (geothermal efficiency of 10% ?). France changed its conventions in 2001, where final energy decreased from 232.1 Mtoe to 175.1 Mtoe and the percentage of oil in final energy increased from 39,8 % to 51,3 %: drastic change and again too many significant digits!

Figure 60: **World primary energy mix 1800-2003**



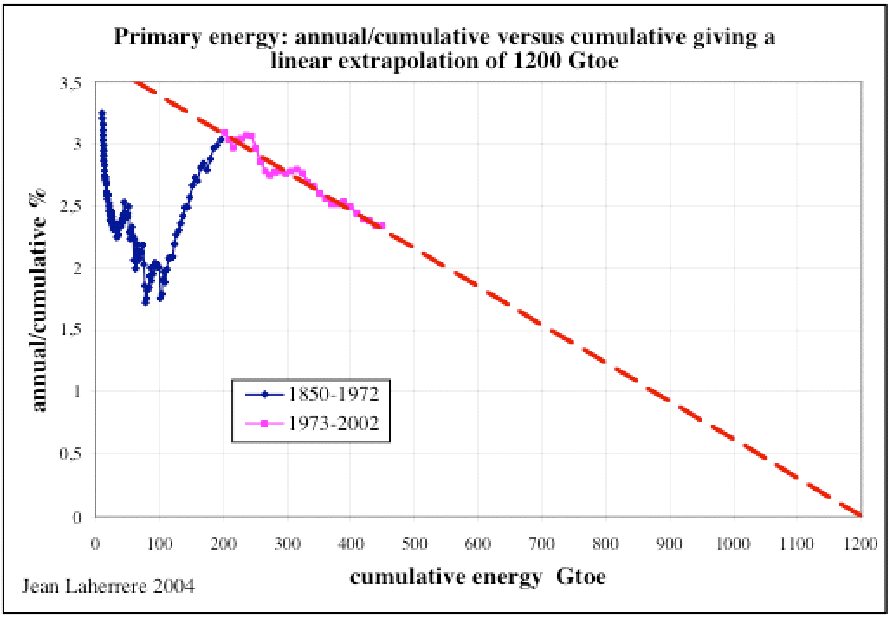
The primary energy per capita is almost constant for the world average at 1,7 toe/cap, but the range in 2002 is huge between Canadian (over 10 and up) US (8.5 and up) Europe (3,8 and up), Africa (flat 0.4), India (0.35 but up)

Figure 61: **Primary energy per capita 1980-2002**



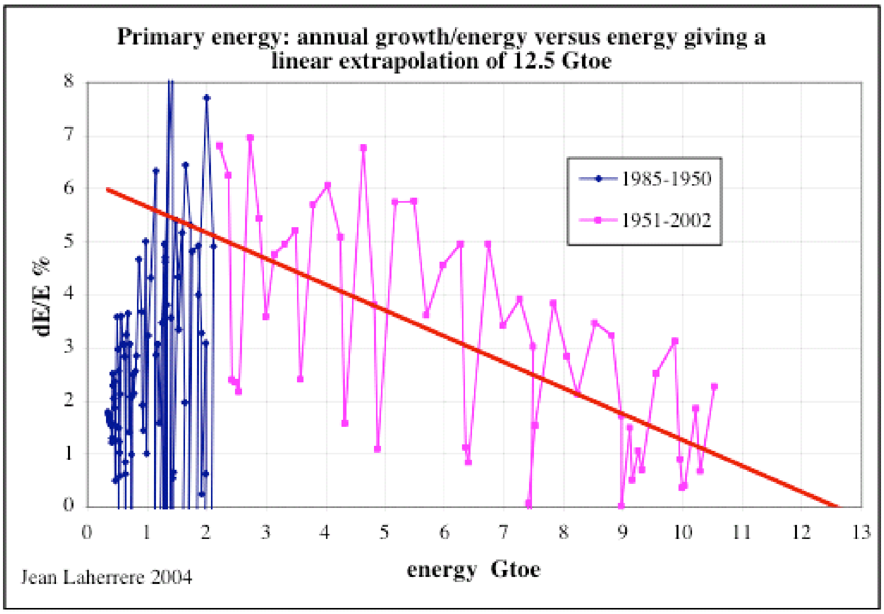
The forecast for primary energy has to be tied to the past and the display annual/cumulative versus cumulative energy shows a linear trend since 1973 towards 1200 Gtoe (no energy), meaning that the primary energy could be fitted with a Hubbert curve, with an ultimate of 1200 Gtoe.

Figure 62: **World primary energy annual/cumulative versus cumulative energy giving an extrapolation of 1200 Gtoe**



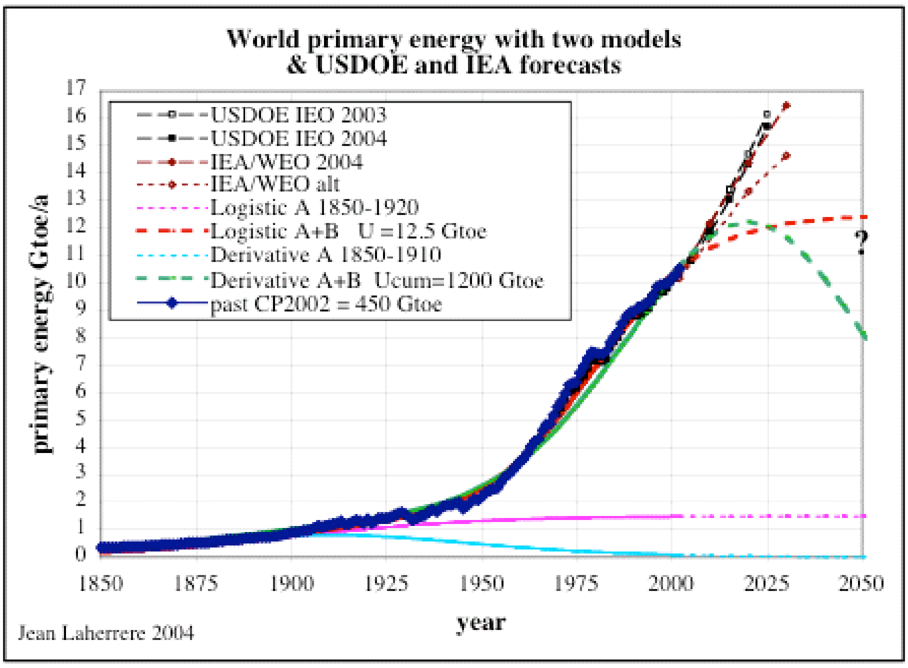
But the display of annual growth / annual energy versus annual energy shows also a linear trend (more chaotic) towards 12.5 Gtoe for no growth, meaning that the primary energy could be fitted with a logistic curve with an asymptote at 12.5 Gtoe.

Figure 63: **World primary energy annual growth/energy versus energy giving an extrapolation of 12.5 Gtoe**



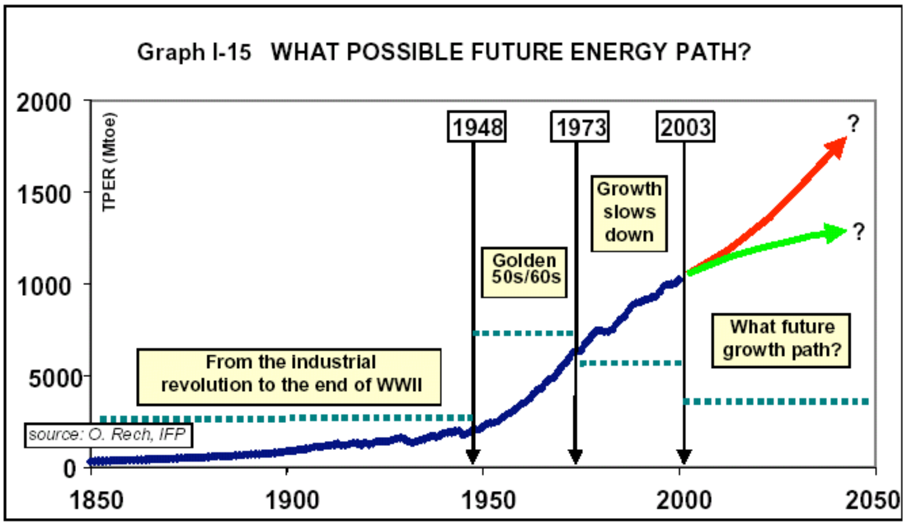
The Hubbert and logistic models are a good fit to the past, but we are unlikely to see a peak around 2025 (unless a sharp depression) and the flattening towards 12.5 Gtoe is more likely. The USDOE 2004 forecast, with 16 Gtoe in 2025 (IEA 2004 is 16.5 Gtoe in 2030), is quite far from these flattening models, and as we said "what goes up must come down!" because the world population will come down this century, the fossil fuels will be lacking in few decades and the renewables are limited by space. The only uncertain future is nuclear, with high potential if consumers accept fusion or fast breeders.

Figure 64: **World primary energy with two models and EIA & USDOE forecasts 1850-2050**



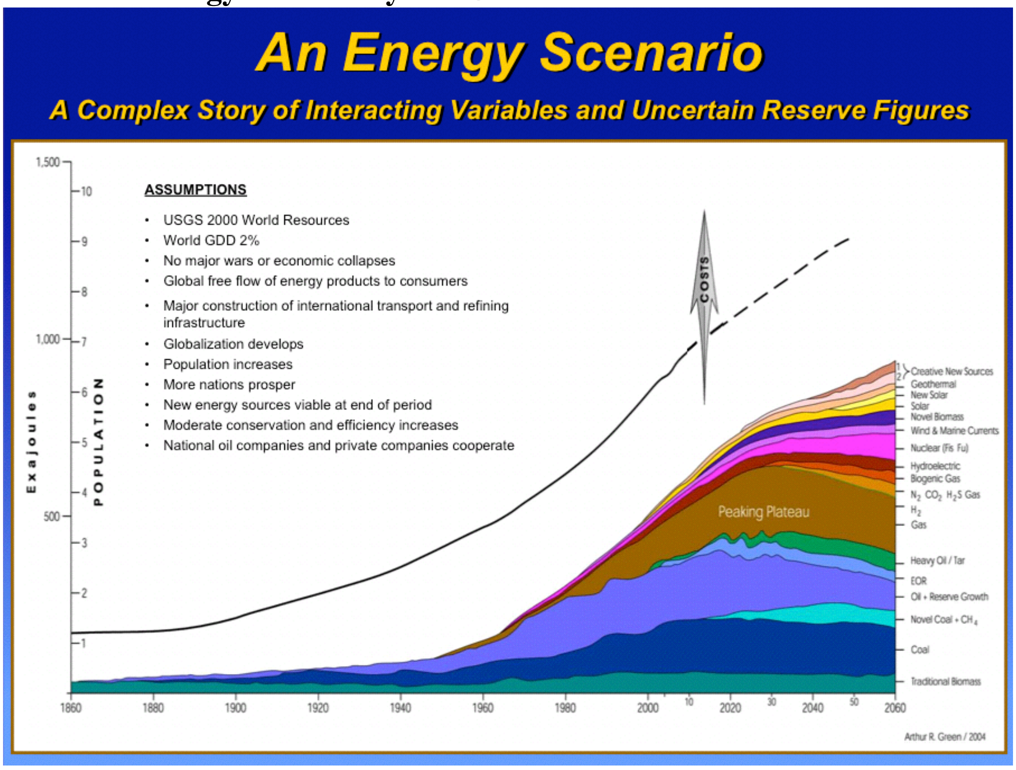
The WEC 2003 report suggests either a slow down of growth in a S curve or an increase in line with IEA

Figure 65: **WEC 2003 forecast for world primary energy 1850- 2050**



The Exxon-Mobil chief geoscientist Art Green forecast energy (with the break down of each energy) as a logistic curve but the slow down starts in 2030 when the WEC and myself sees it much sooner.

Figure 66: **World energy scenario by Art Green 1860-2060**

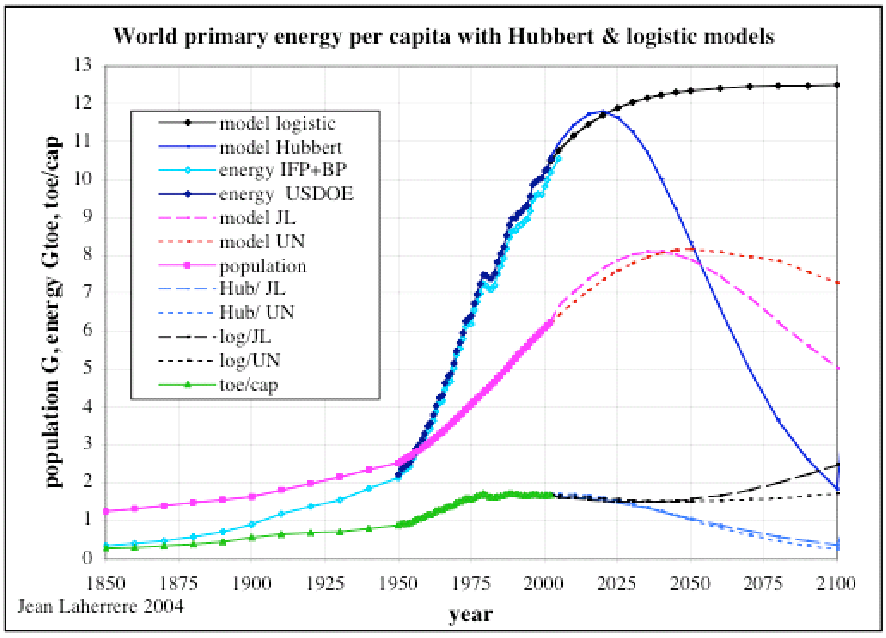


-Primary energy per capita

The energy forecasts (Hubbert & logistic) are associated with the population forecasts (UN and mine) to obtain the primary energy per capita.

Despite the large range of the models, the energy per capita, which was flat around 1.7 toe/cap from 1975 to 2003, will stay at this level for the next 25 years for all models and will diverge only after 2025.

Figure 67: **World primary energy per capita with Hubbert & logistic models 1850-2100**

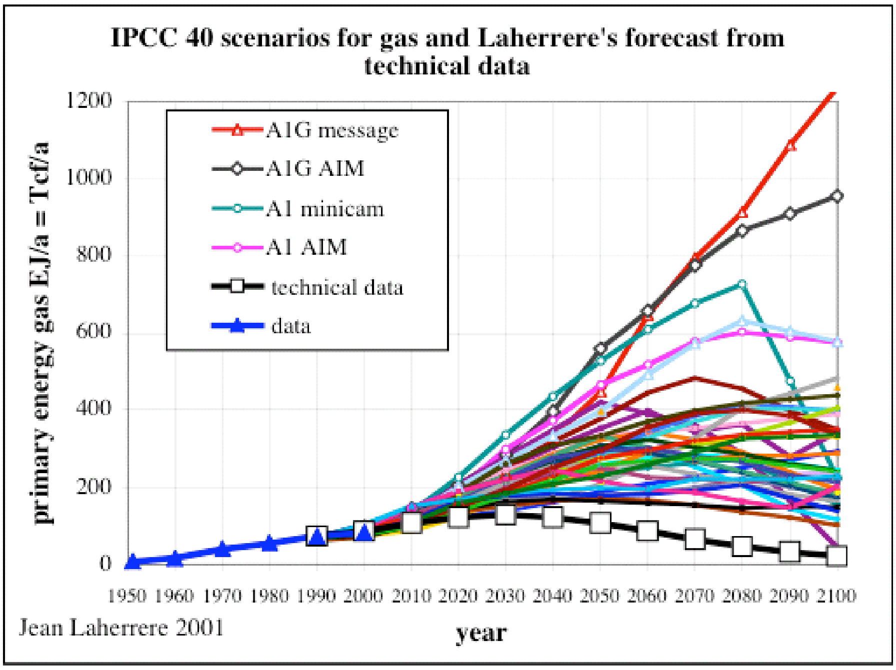


It means that for the next 25 years it is likely that the world average primary energy per capita will stay about the same and with energy savings, it should be easy to manage the world. The problem will be to satisfy the wishes of developing countries to increase their low level of energy. It should be possible only if developed countries, and in particular North America, decrease their high level of energy consumption.

-IPCC energy scenarios

The IPCC 2000 third report (used by Kyoto Protocol) is based on 40 scenarios of energetic consumptions done by academic scientists (IIASA) with little knowledge of industrial realities. IIASA forecasts a « Methane age » based on a huge potential of oceanic methane hydrate, but the last estimate (Soloviev 2000, Milkov 2004) divides the old estimates by a hundred!
The huge range of IIASA gas scenarios (based on theoretical concepts) is outside of my forecast based on technical data.

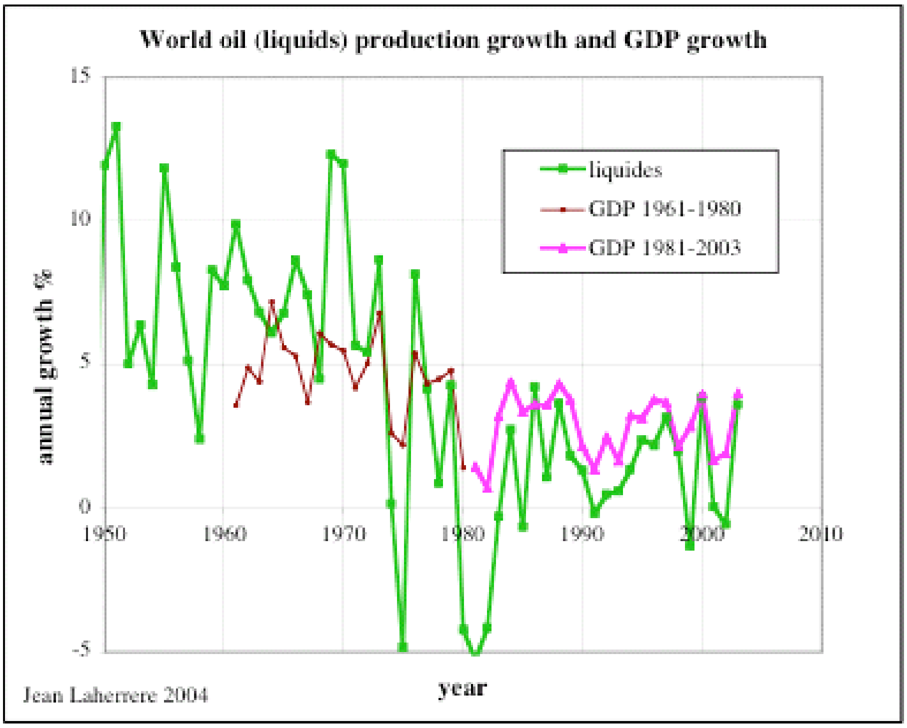
Figure 68: **IIASA scenarios (IPCC report) for gas consumption compared to mine 1950-2100**



The result of IPCC 2001 modelling is worth the quality of its assumptions, it means very poor! But it is dismaying to read that the 2007 IPCC report will use the same unrealistic scenarios!

-GDP and oil demand

Figure 69: **growth in world BDP and oil demand :**



Energy cost represents on the last 40 years less than 5% of the GDP, when experts (Ayres 2002, Kummel et al 1998) believe that energy contributes to 50 % of the GDP. Energy is largely undervalued. US core inflation excludes food and energy as if the US consumer lived on computer without plugs, cars without tanks and Chinese gadgets!

Conclusions

-what is born will peak and later die, there is no example of the contrary
-any natural event can be modelled fairly well with several symmetrical cycles
-constant growth has no future in a limited world
-forecasting production requires good data on the past and good geological assessment of the resources
-reserve uncertainty is large because of the geological complexity and the very limited amount of measures (wells and seismic cover few % of the field area). Reserves are accurately known only when the field is abandoned
-publishing production, reserves and population data is a political act because it depends upon the image the author wants to give and he chooses within the large range of uncertainty the value he prefers (where he puts many decimals!)
- estimate should be given as a range, and not as a single value; only two digits should be used
-quality of data is poor, like the definition of the product, because of its political implication, and very few wish to improve it because of confidentiality and competition
-as long as the OPEC members (80% of world reserves) fight for quotas (as long as spare capacity will exist), data will not improve.

-oil production mimics oil discovery with a certain lag (7 to 50 years), but is constrained also by demand and the first oil peak of 1979 was due to lower demand in front of high oil price expectancy.
-US discovery peaked in the 30's, and US oil production peaked in 1970. World oil discovery peaked in the 60's and production could peak within the next decade or so
-the coming oil peak could be in fact a bumpy plateau if economic depression constraints the demand and delays the peak
-world gas peak will come (2030) later than oil peak, but a gas shortage could occur soon in North America because local production is declining and LNG could not be brought within enough volume by lack of ships and terminals.
-coal resources seem to be less than reported by lack of good inventory and good definition; coal could peak much sooner than expected, around 2050
-fossil fuels will peak around 2030, but the production per capita, which was flat for the last 25 years, will stay flat for the next 25 years, and the problem is sharing this limited energy between rich and poor countries.
-primary energy extrapolation of the past (10 Gtoe in 2003) leads to flattening about 13 Gtoe
-limits in water, agriculture and fishery will likely occur sooner than for fossil fuels
-oil and gas IIASA scenarios of IPCC last report are unrealistic, making IPCC conclusions unreliable
-high-energy price is the best solution to save energy and save future demand problems
-societies of endless consumption and growth have to change behaviour soon
-the sooner consumers know about the oil peak and change their way of live, the later and softer will be the oil peak and decline

More graphs and papers are on the site www.oilcrisis.com/laherrere

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