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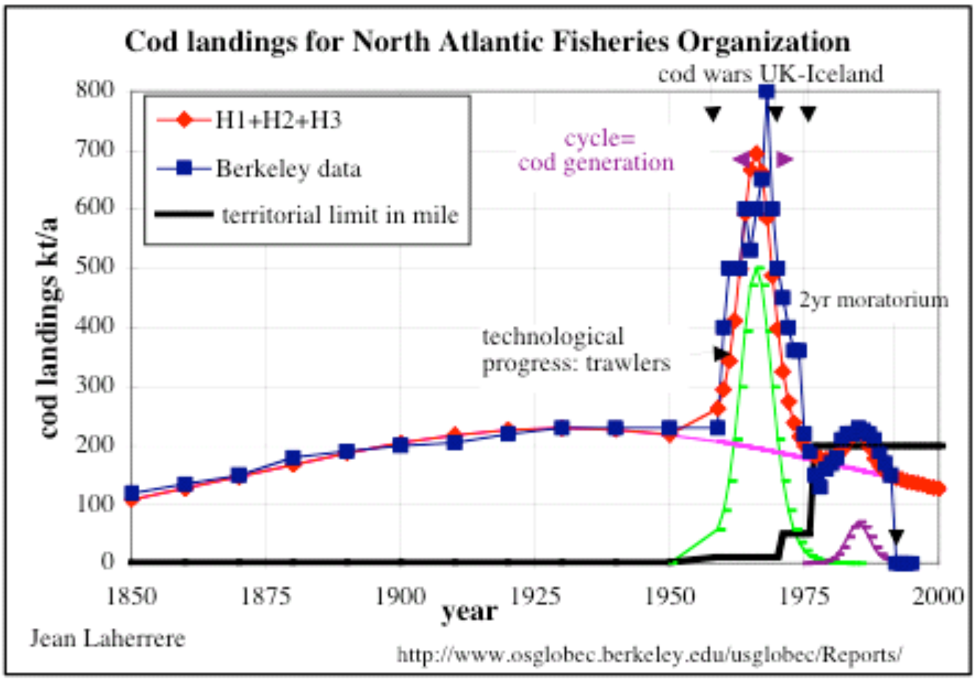
This paper is a long text which is the base of the presentation after reduction to stay within 45 minutes

Advice from an old geologist-geophysicist on how to understand Nature

-Nature is the main driver which reacts to human excess
Present basic facts
-Cycle
-what goes up must come down, life is cycle
-what was born will die: sun, earth, mankind and civilization
-constant growth has no future in a limited world
-most events can be modelled with several peaks and symmetrical cycles
-US oil production peaked in 1970, world production will peak (maximum) one day
-North Atlantic cod landings peaked in 1965 and cod is considered as extinct in most of the Grand Banks

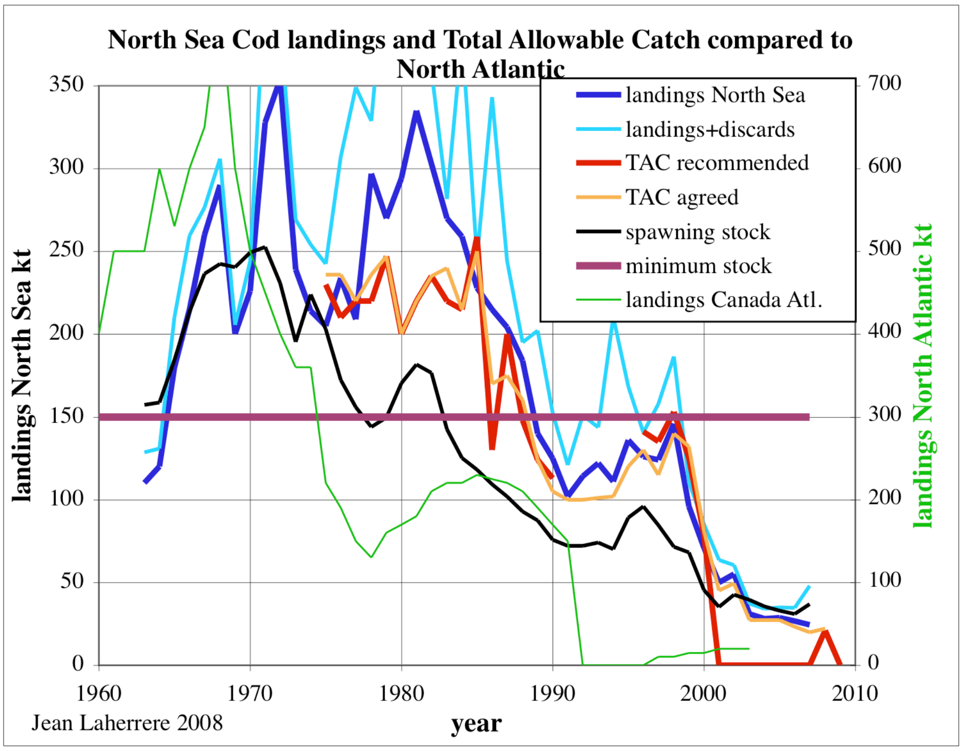
Figure 1: **Cod landings in Northern Atlantic in 2000**



Technology (trawlers) has increased production, but has killed the cod species (believed to be renewable!) after bad estimation of the resources (quotas were designed to fish 20% of the cod resource when in fact they fished 60% of it, plus fishing their food and destroying the breeding grounds) !

North Sea cod fishing is going exactly the same way with 15 years delay

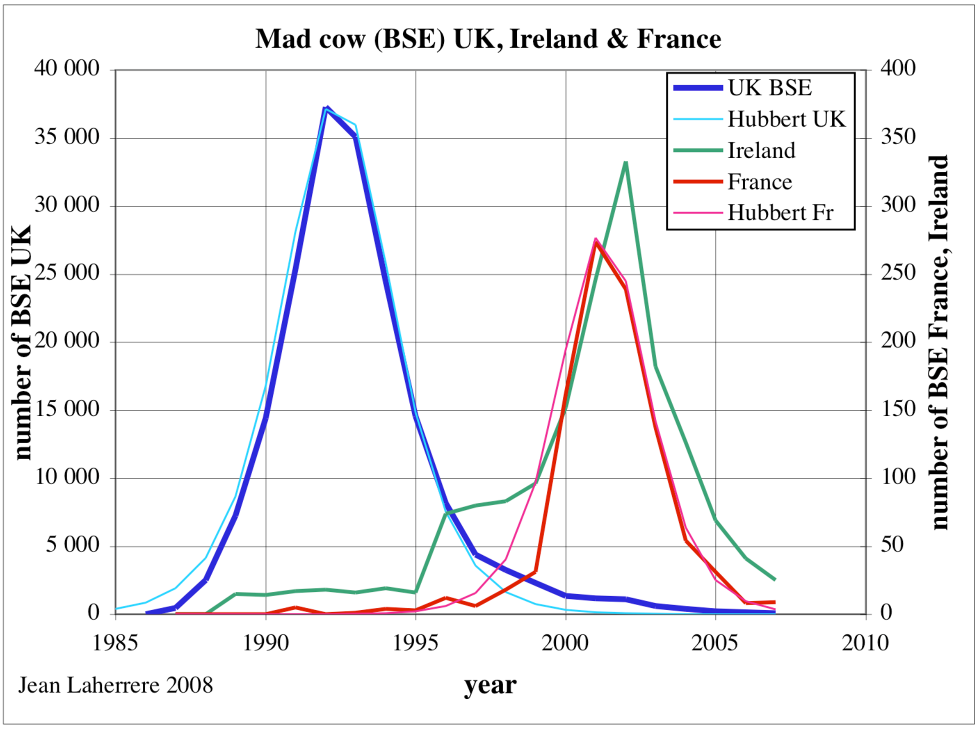
Figure 2: Cod landings in North Sea and Total Allowable Catch (TAC) compared to North Atlantic



-UK mad cows

UK mad cows has peaked in 1992, when mad cow peak is ten years later in France and Ireland

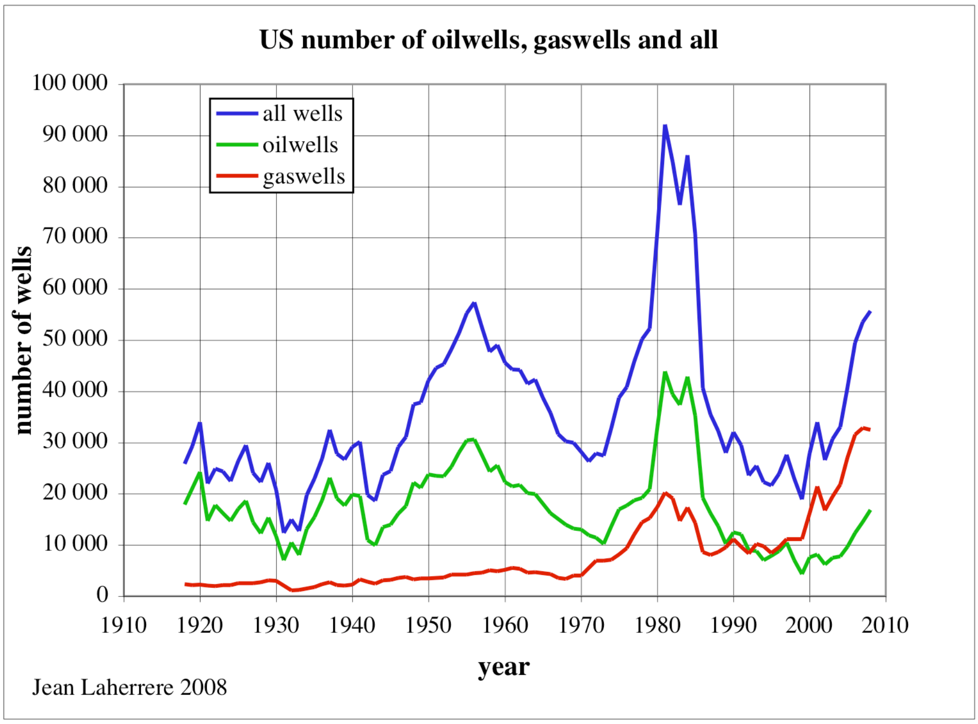
Figure 3: Mad cow (BSE) in UK, Ireland & France1985-2007



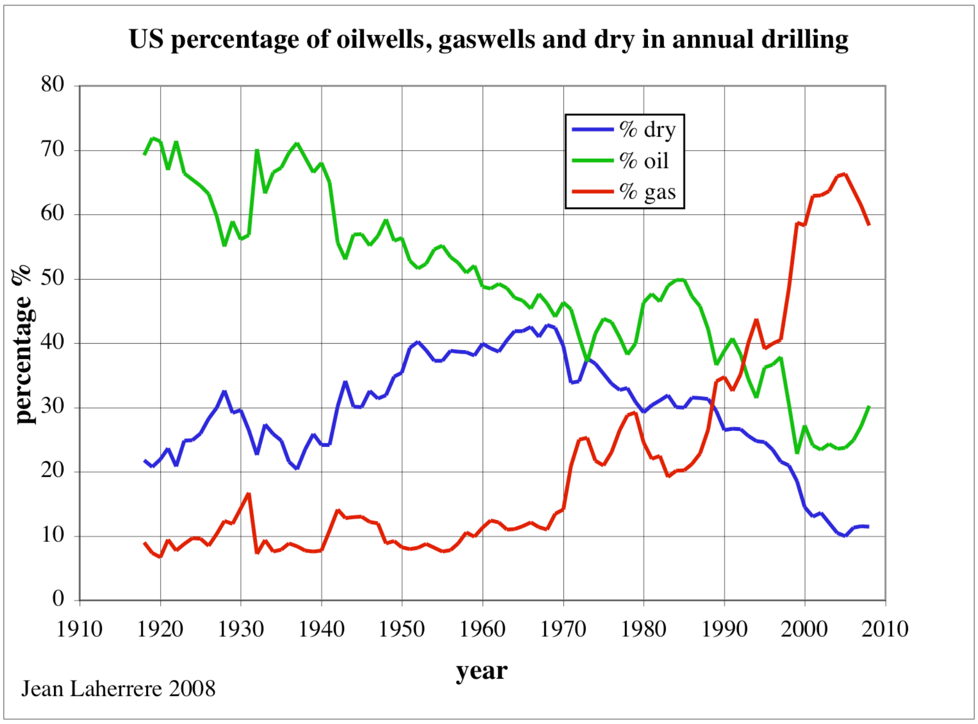
-US annual drilling

Several cycles in the number of wells in US drilling with two peaks in 1956 and 1981, and one coming soon

Figure 4: US annual total number of wells , oilwells & gaswells

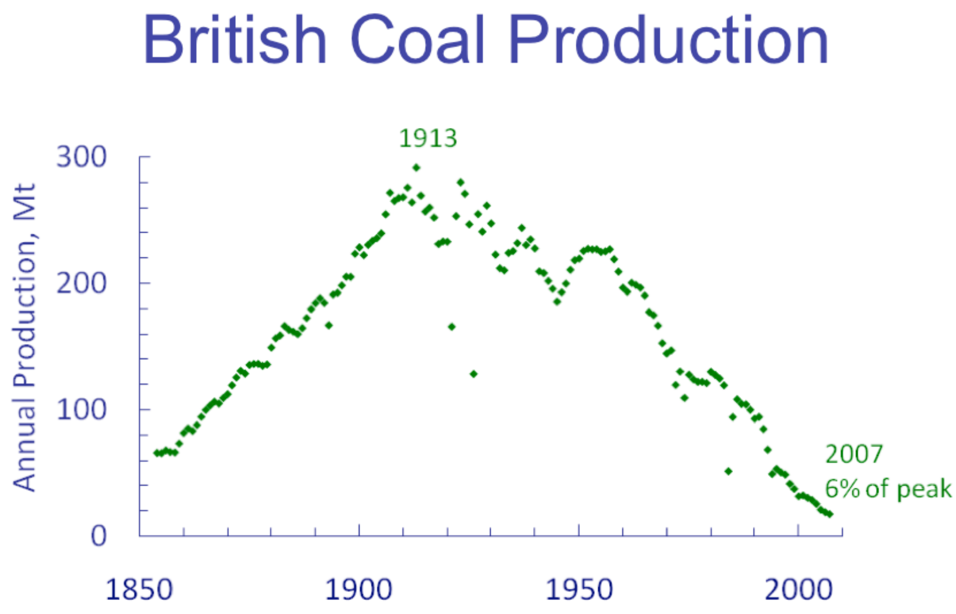


But, it is a different picture when looking at the percentage: dry wells show a peak in 1969 and gaswells in 2005 (rush on the Bakken oil!)
Figure 5: US annual percentage of oilwells, gaswells and dry wells



-UK coal production

British coal production (Rutledge 2008) displays a very long example of bell-shape curve, in fact with several cycles and a bumpy peak (due to the first world war), but globally the slopes are symmetrical
Figure 6: British coal production 1850-2007 from Rutledge

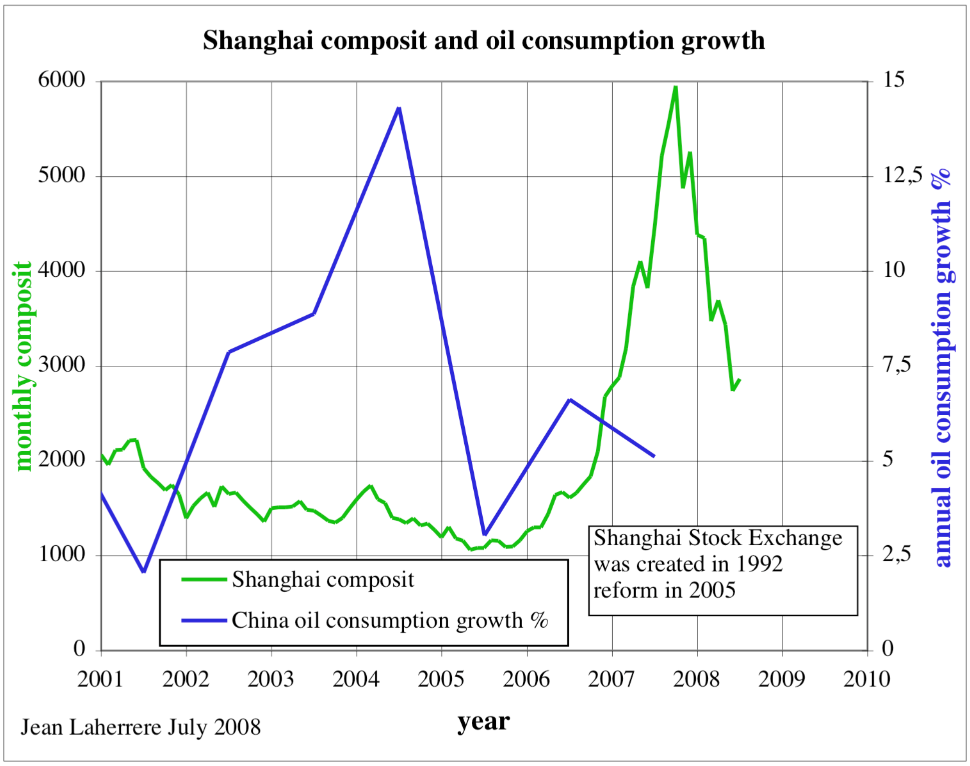


-Shanghai stock exchange

Shanghai composit displays a perfect symmetrical peak centred in October 2007, when oil consumption growth peak was in 2004. How long will the decline of the Shanghai stock exchange be?

I am afraid that China has pushed hard for the Olympic Games and after the Games China will suffer.

Figure 7: Shanghai Stock Exchange peak and oil consumption growth 2001-2008

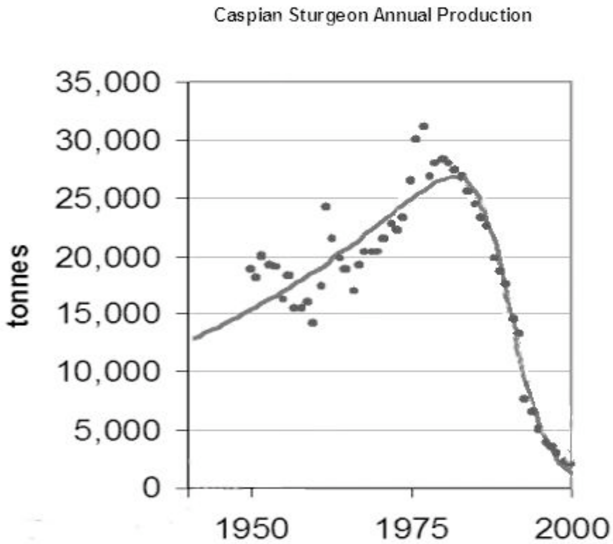


-unsymmetrical cycle = Caspian caviar

The collapse of the FSU aggravated the decline of sturgeon landings which peaked around 1980, and the bell shape is quite unsymmetrical.

Will a new cycle be? Sturgeon needs to be 30 years old to bring caviar.

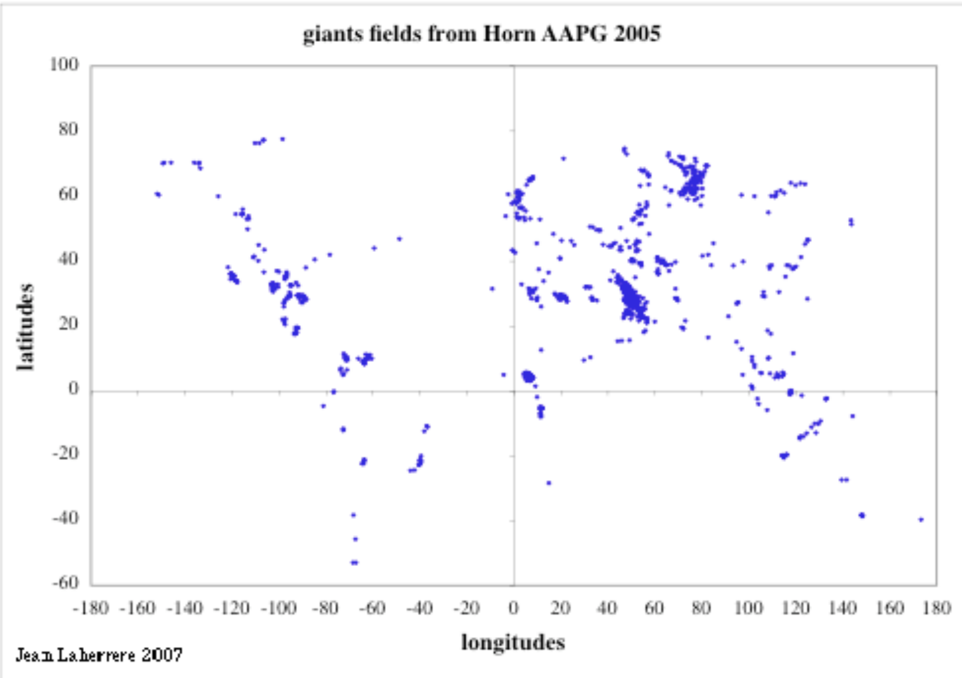
Figure 8: sturgeon (caviar) landings in Caspian from Ugo Bardi TOD August 2008



-inequality
99% of the visible Universe is plasma : being solid is exceptional
If there is equality at the starting gate, there is **only one winner at the finish line**: we were all created with only one spermatozoid out of over 200 millions

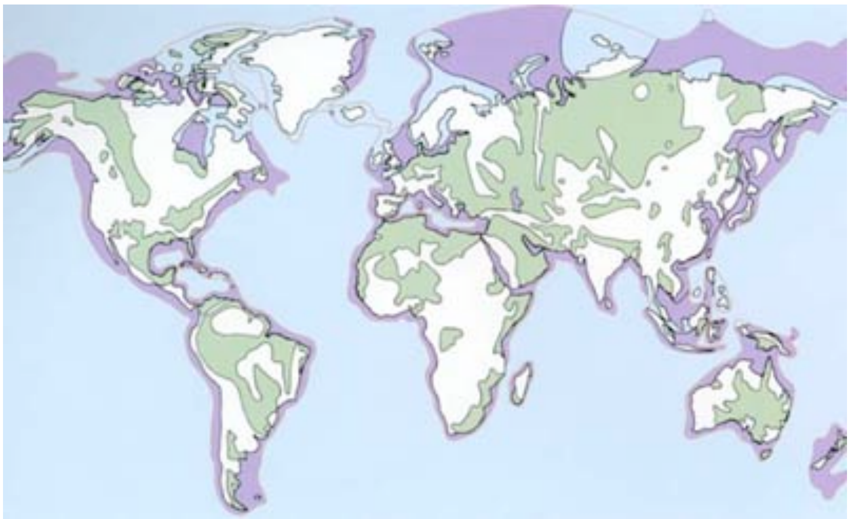
Inequality of accumulations can be seen on the distribution of giants fields (defined as over 500 Mboe). Presently about 50% of the oil production is coming from giant fields. Out of about 600 sedimentary basins only 200 have oil & gas fields and about 20 have the majority of oil & gas reserves.

Figure 9: **location map of giant oil and gas fields from Horn AAPG 2005**



The map of giant oil & gas fields (HORN AAPG 2005) is to be compared with the map of sedimentary basins. Middle East, West Siberia, North Sea and Gulf Coast display high concentration. The South hemisphere contains much less giant fields (less sedimentary basins).

Figure 10: **location map of sedimentary basins from Schlumberger**

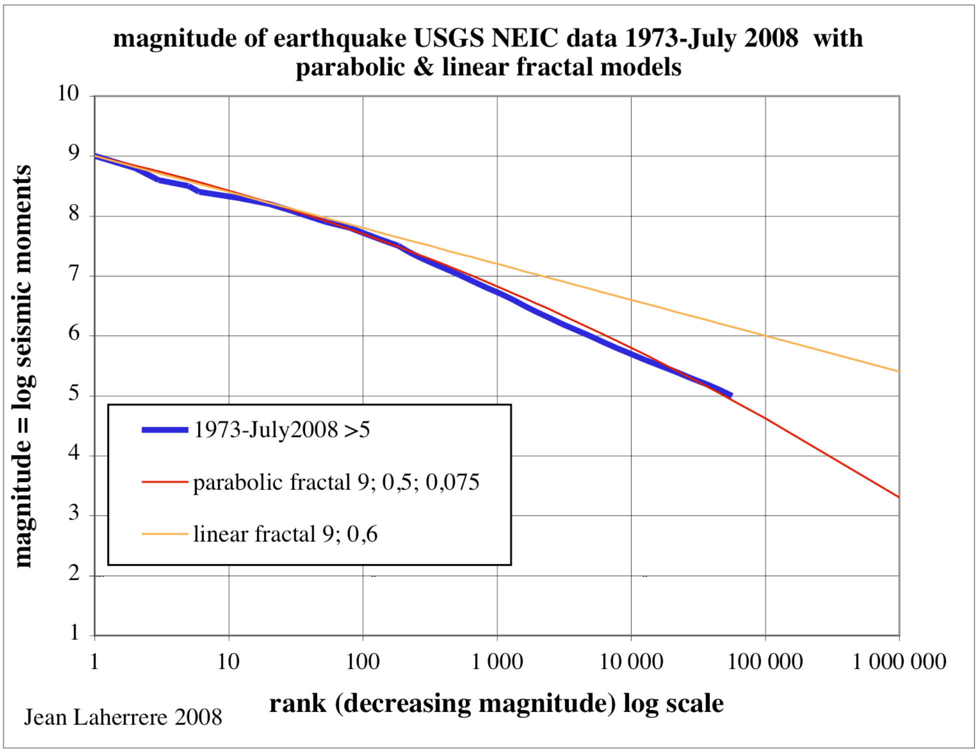


Pareto (1848-1923) has claimed the famous 80/20 ratio on the distribution size-number
80% of the subsidies to farmers go to 20% of the farmers
80% of medical expenditures are for 20% of the patients
In fact the Pareto law corresponds to a fractal distribution

-fractal distribution
-autosimilarity : one part is similar to all = cauliflower = fractal
-perfect = power law = linear in a display log-log rank-size
-limited world = every is curved (by gravity) = parabolic fractal

World earthquakes located by USGS in NEIC database are plotted as magnitude (= log of the seismic moment) versus log of the rank (by decreasing magnitude). The 1973-2008 plot should be linear following the Gutenberg-Richter law (power law) when in fact it is curved and can be modelled by a parabolic fractal (Xo=9; a=0,5, b=0,075).

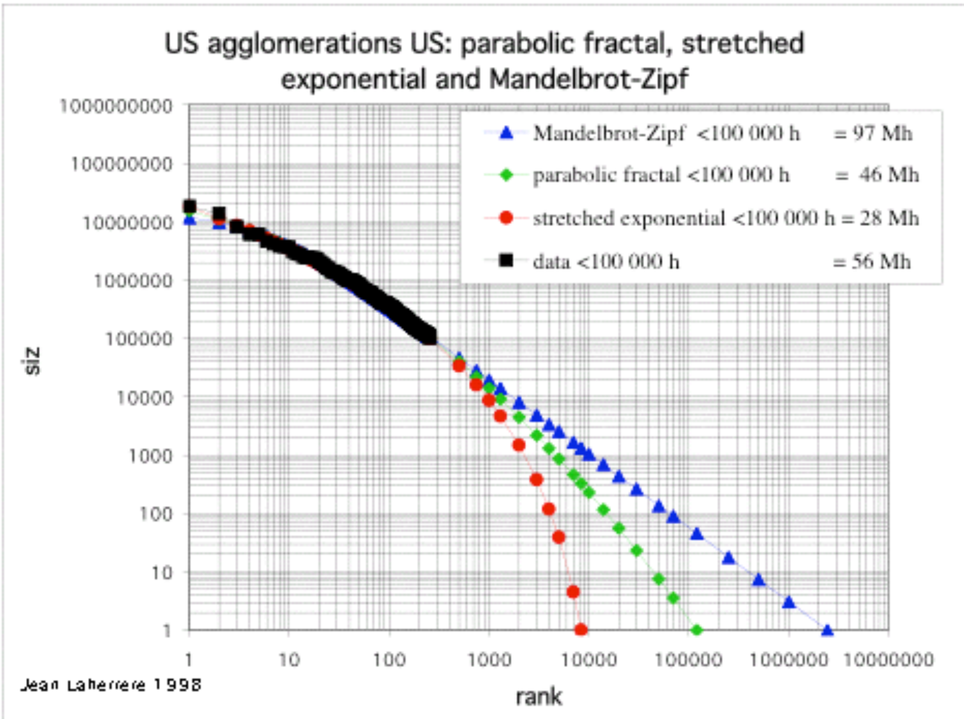
Figure 11: magnitude of earthquakes from USGS with parabolic and linear fractal



-**urban agglomerations** (defined by the continuity of the buildings, different from administrative boundaries)

The US urban agglomerations over 100 000 inhabitants can be modelled with different distribution = parabolic fractal, stretched exponential (Laherrere & Sornette 1998) and Mandelbrot-Zipf (power law: see Gell-Man 1995 " The quark and the jaguar: adventures in the Simple and the Complex").
The best extrapolation of the aggregation from agglomerations below 100 000 to the minimum agglomeration (one people) is the parabolic fractal (46 M against reality of 56) against 96 for Mandelbrot and 28 for stretched exponential

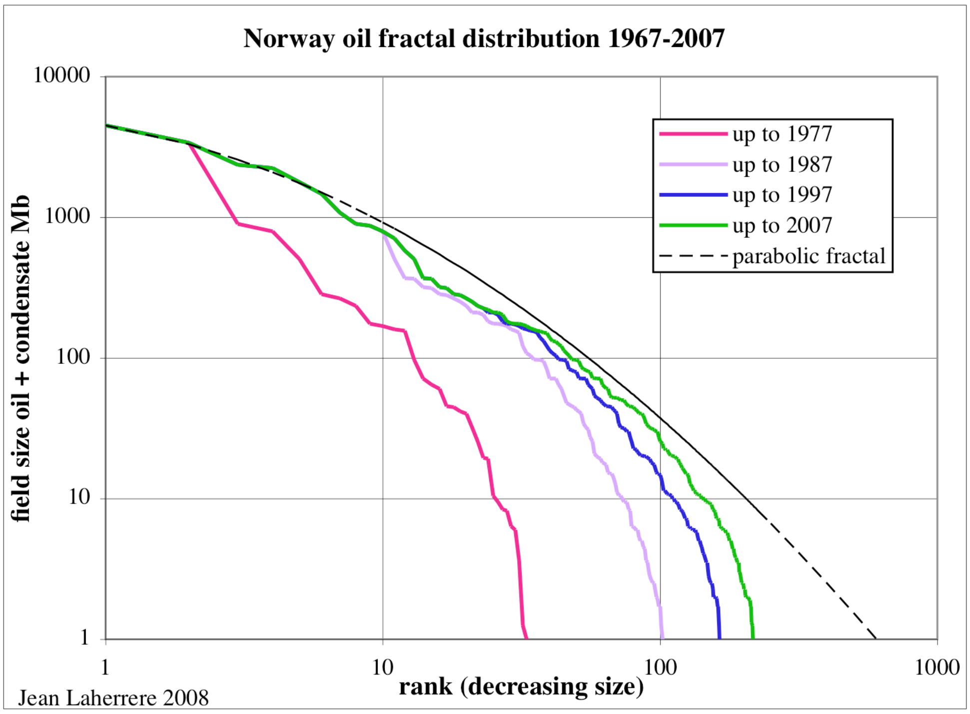
Figure 12: US urban agglomerations: parabolic fractal, stretched exponential and Mandelbrot-Zipf



-oilfield reserves

Parabolic fractal is a good tool to study the habitat of Petroleum Systems, but it works less when used to study country distribution. Norway has several Petroleum Systems and the main one is shared with the UK. Then a parabolic model only for Norway is not supposed to be the best tool. The oilfield distribution in fractal display every ten years shows that the size over 200 Mb was reached in 1997. But there is a lack of fields between 200 Mb and 1000 Mb, likely due to aggregating several PS. A study by Petroleum System should be done.

Figure 13: Norway oilfield parabolic fractal distribution 1967-2007



In fractal distribution the number one (rank one) could be also more than number one of the fractal distribution being much higher than normal distribution from rank 2 and beyond: it is the King effect

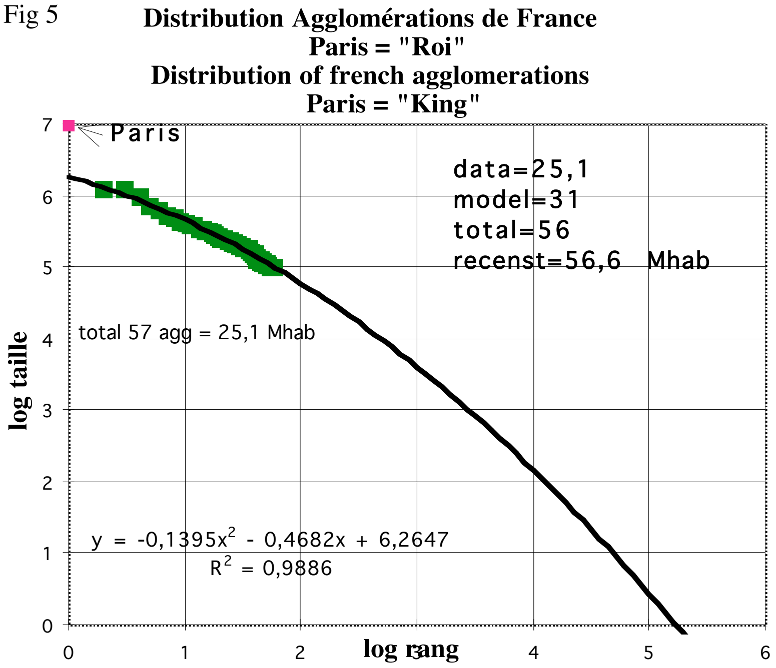
King effect

Plotting the fractal display of France urban agglomerations shows that the first rank is well above the rest of the crowd, like a King arises at the beginning from a bunch of barons by taking their wealth and eliminating them in order to have no competition. It is the case of Paris, as also London and Moscow, but not New York.

In France the display of 57 urban agglomerations above 100 000 inhabitants in 1994 allows by extrapolation to the minimum size of 1 inhabitant to obtain a cumulative population of the country very close to the census

Figure 14: Distributions of French urban agglomerations with Paris= King

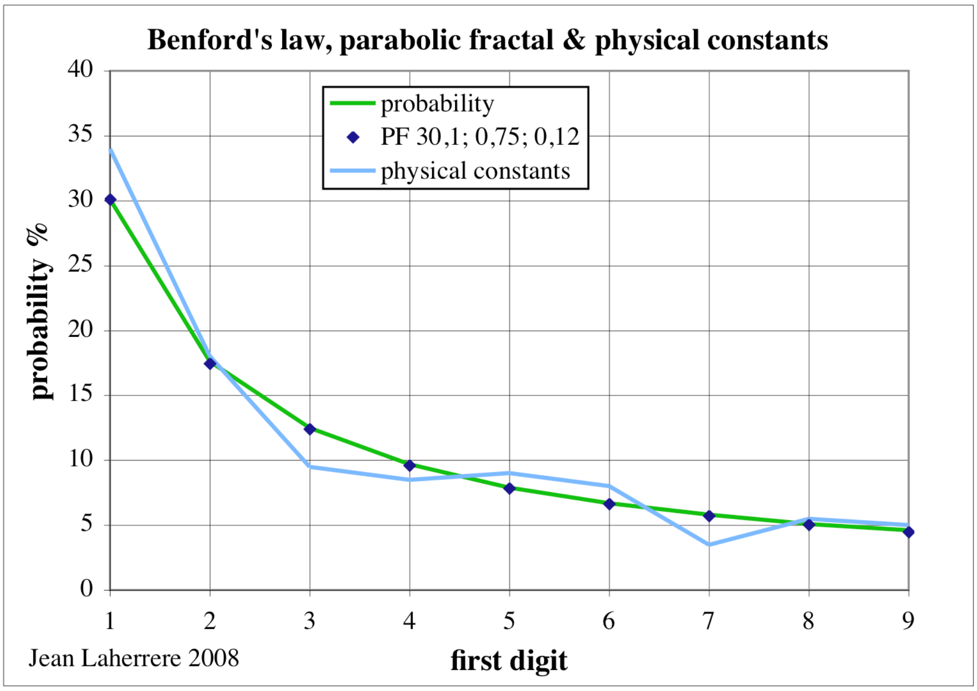
Fig 5



In the Palaeozoic gas system of the Anglo-Dutch basin (UK, Netherlands, Germany) Groningen us a king (Laherrère J.H. , A.Perrodon, C.J.Campbell 1996 "The world's gas potential" Petroconsultants report July, 200p)

-Benford's law = first digit law

Newcomb in 1881, finding that the first pages of the log book were more soiled than the last pages, wrote "*note on the frequency of use of the different digit in natural numbers*".
Benford in 1938 stated that the first digit x of many natural distributions (lake area, river length, number of the street in a telephone book) follows an equation like $P(x=n) = log(1+1/x)$ *for* $n=1,2,...,9$, meaning that 1 is found about 30% (instead of 11%) more often than 9 found about 5% (instead of 11%). The explanation is that small events are more frequent than large events.
Benford's law gives a almost perfect parabolic fractal with b=0,75 and c=0,12.
The first digit of physical constants is close of Benford's law, despite the small number of them
Figure 15: Benford's law, parabolic fractal and physical constants



Benford law is used to find tax fraud (Hill 1988) where cheaters use first digit 1 as often as 9 in false reporting.

-non linearity

Linearity is only one solution, but Universe is non linear and there are often several solutions
Linear is only local, like the bubble level = horizontal or the plumb line = vertical in one point
When you find one solution, do not stop searching for a better one.

How to choose between different solutions

How many solutions for **2, 4, 6, ?, ?, ?, ?**

rank: 1, 2, 3, n-2, n-1, n
value: 2, 4, 6, N-2, N-1, N

There are numberless solutions

2, 4, 6, 8, 10, 12, 14, 16	N =2n or N = (N-1) +2
first degree	
2, 4, 6, 10, 16, 26, 42, 68	N = (N-1) + (N-2)
2, 4, 6, 8, 10, 12, 14, 16	N = 2(N-1) - (N-2)
2, 4, 6, 6, 0, -18, -54,-108	N = 3(N-1) - 3(N-2)
2, 4, 6, 4, -14,-76,-234,-556	N = 4(N-1) - 5(N-2)

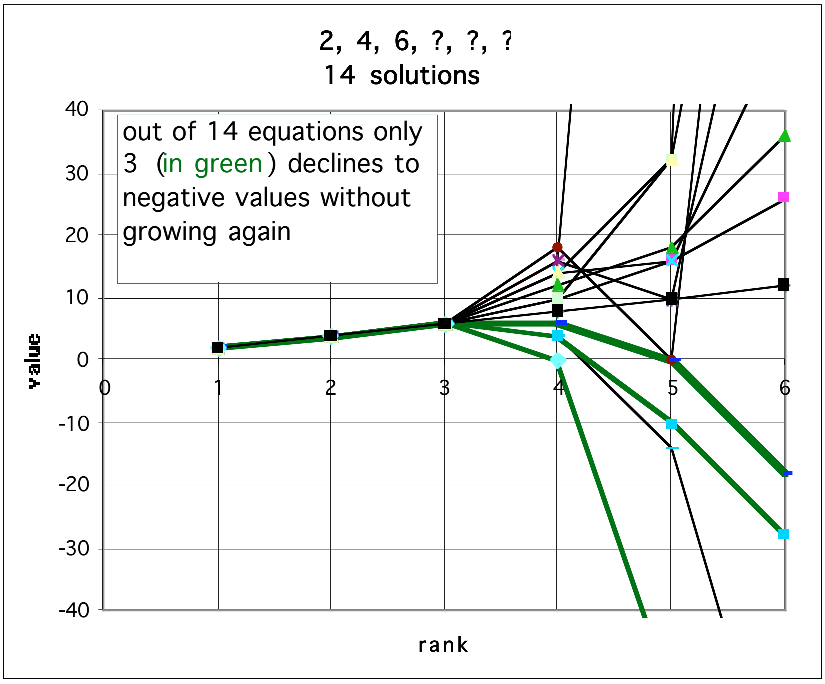
2, 4, 6, 0, -54,-324,-1458,-5832	N = 6(N-1) - 9(N-2)
2, 4, 6, 12, 18, 54, 108, 162	N = 3(N-2)
2, 4, 6, 14, 16, 54, 26, 244	N = 5(N-2) – (N-1)
2, 4, 6, 16, 10, 92, -114, 872	N = 7(N-2) – 2(N-1)
2, 4, 6, 18, 0, 162, -486, 2916	N = 9(N-2) – 3(N-1)
second degree	
2, 4, 6, 14, 32, 130, 642, 9092	$N = (N-1)+(N-2)^2/2$
2, 4, 6, 4, -10, -28,-106,-604	$N = 2(N-1) - (N-2)^2/2$
2, 4, 6, 16, 226, 5 104, 3 109,	$N= (N-1)^2-5(N-2)$
2, 4, 6, 10, 32, 462, 1 105,	$N = ((N-1)^2-(N-2)^2)/2$

Occam razor (1285-1349): the best model is the simplest one
= minimum complexity = 2, 4, 6, 8, 10, , 2n
but in fact the simplest is often wrong, because permanent growth does not exist in Nature
The series 2, 4, 6, ? has a beginning and grows, in Nature it must pass a peak and decline
The simplest (first degree and coefficients <10) natural answer is several:

2, 4, 6, 6, 0 N = 3(N-1) - 3(N-2)

2, 4, 6, 0 N = 6(N-1) - 9(N-2)

Figure 16: some solutions of first degree



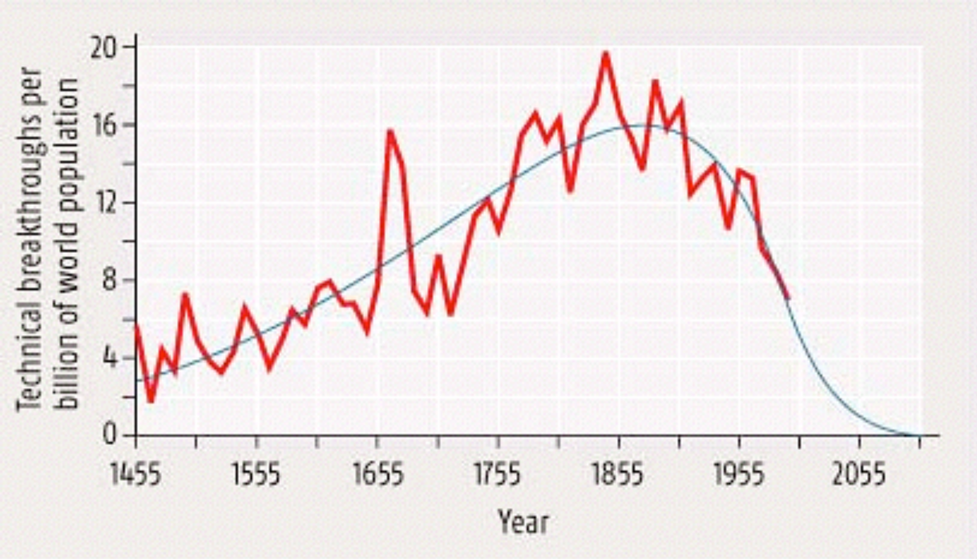
One bacteria which doubles every half-hour, provided with necessary resources, will occupy the solar system in one week and the universe in 11 days!

-Science and technique peak?

Jonathan Huebner, Pentagon physicist, in his 2005 book «*Technological Forecasting and social change* » taking the data from 2004 Bunch & Hellemans « *History of Science and Technology* » with an inventory of 7200 fundamental innovations, claimed that the peak of technique has passed around 1850!

Today's rate is seven important innovations per billion inhabitants per annum, like in 1600.

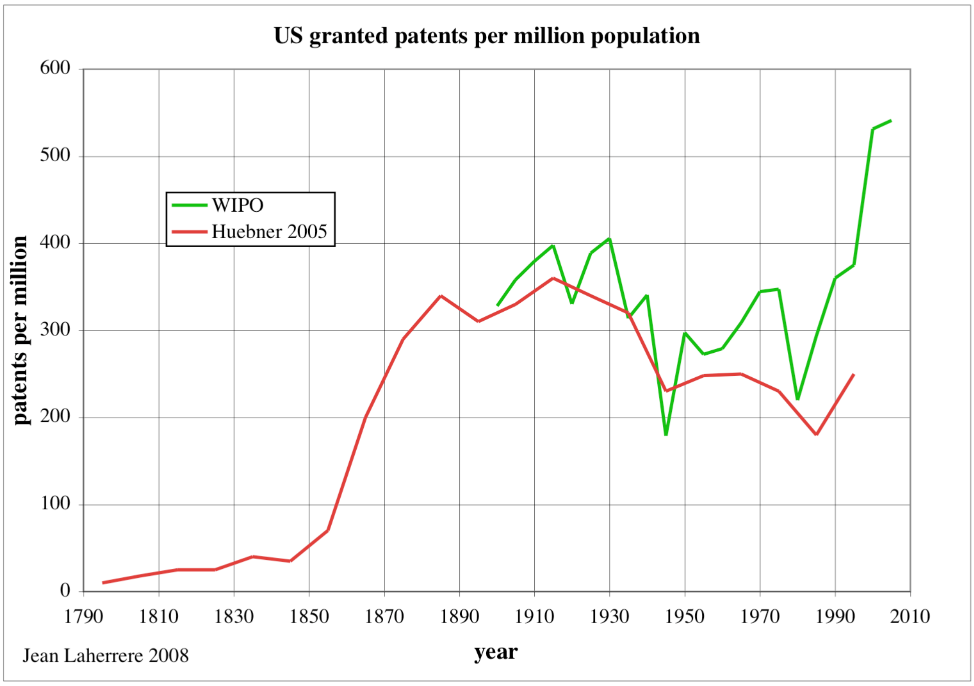
Figure 17: number of innovations per billion inhabitants 1450-2000 from Huebner



Steam engine, internal combustion engine and electricity (end XIX century) are more important than computers, because you can live without a computer but not without water (pump)

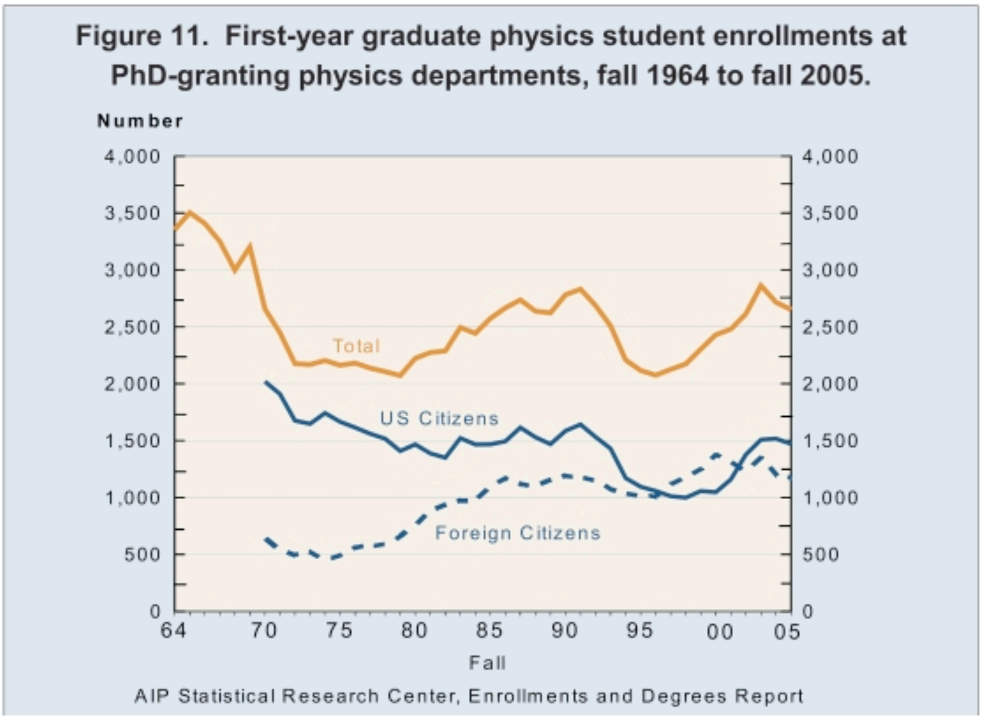
The number of US patents per million inhabitants has peaked around 1920, but it is on the rise since 1980 (oil shock?).

Figure 18: number of US patents per million of inhabitants 1795-2005 from Huebner & WIPO



The number of first-year graduate physics is declining with up and down and foreign students are close to US students.

Figure 19: US: number of first-year graduate physics 1964-2005



-Uncertainty

The more I know, the more I know that I do not know, and the others neither

-science is in need of breakthrough = Lee Smolin L. 2006 "The troubles in physics - the rise of string theory, the fall of science, and what comes next" Houghton Mifflin
-string theory has not achieved anything concrete since 30 years
-quanta mechanics is incompatible with the theory of relativity
-standard model of particles seems to forget that particles are also waves
-I bet that the Higgs boson will not be found in the LHC (starting its experiments this month)
-the electron discovered more than 100 years is badly known (size, location), only its probability : is it a particle, a wave, both or neither?
-it is assumed for 70 years that the Universe is constituted by more than 95 % of unknown dark energy and dark matter (slight change of Newton's law makes dark matter disappear)
-Poincare has shown that the 3 bodies problem cannot be resolved with equations, only computers can approximate the problem with no certainty
-Heisenberg ; uncertainty principle = if a particle location is known with accuracy, its move is unknown, and reciprocally
-Lorentz : a butterfly (it was first a seagull) flipping its wings in Texas can create a tornado in Brazil = chaos and importance of small effects. Uncertainty on initial conditions makes the solar system evolution uncertain in 100 Ma, like a pool ball after ten bounces
-prion (mad cows), AIDS, SARS were unknown 30 years ago, what is next?
-bacteria was the first living creature and will be the last. Human beings dominate the Earth with their size and complexity, but not by their weight or number, and depend upon bacteria for their digestion

-Right to be wrong

In business where there is no risk, there is little profit.
Explorers have a great advantage on producers, because they can drill nine dry holes out of 10 new field wildcats. Having the right to be wrong, they are not afraid to be optimistic in their estimates.
I always refuse to be called expert, because one expert is supposed to be always right, and I want to keep my right to be wrong. Engineers and producers do not have such advantage and it is why they are more pessimistic by taking first the minimum value. Then, they are sure to be right 90% of the times and furthermore, when there is growth, they can claim that the growth is due to their work.

-Good and bad practices :

good: -goal of maximum recovery by wise production: long term goal

-probabilistic approach giving a range minimum, expected value and maximum

-using technology to produce difficult oil (deepwater and extra-heavy)

bad: -favouring the short term with a goal of maximum today to please the shareholders who want fast results and high rate of return (pension funds)

-using technology (horizontal drilling and frac) to increase easy oil production in detriment of ultimate recovery (Yibal, Rabi-Kounga,…), pleasing shareholders but leaving less for their children

-deterministic approach with only one estimate being the minimum to please the banker as required by the obsolete US SEC rules

it is wrong:

-to aggregate proved reserves

The addition of minimum field reserves is not the minimum of the country reserves because it is unlikely that all field values will be at minimum. It is like giving the same probability of getting 1 with one die (1 out of 6) and 6 with six dice (1 out of 36). Only the addition of field means (expected value) gives the mean value of the country. Only the product of mode values (most likely) is the mean of the product.

It is incorrect to aggregate independent proved reserves (as they are in aggregation of countries) and SPE 2006 draft reserve definition shows that it could underestimate the real proved reserves by about 100%

Figure 20: Comparison of arithmetic aggregation and probabilistic aggregation from SPE 2006

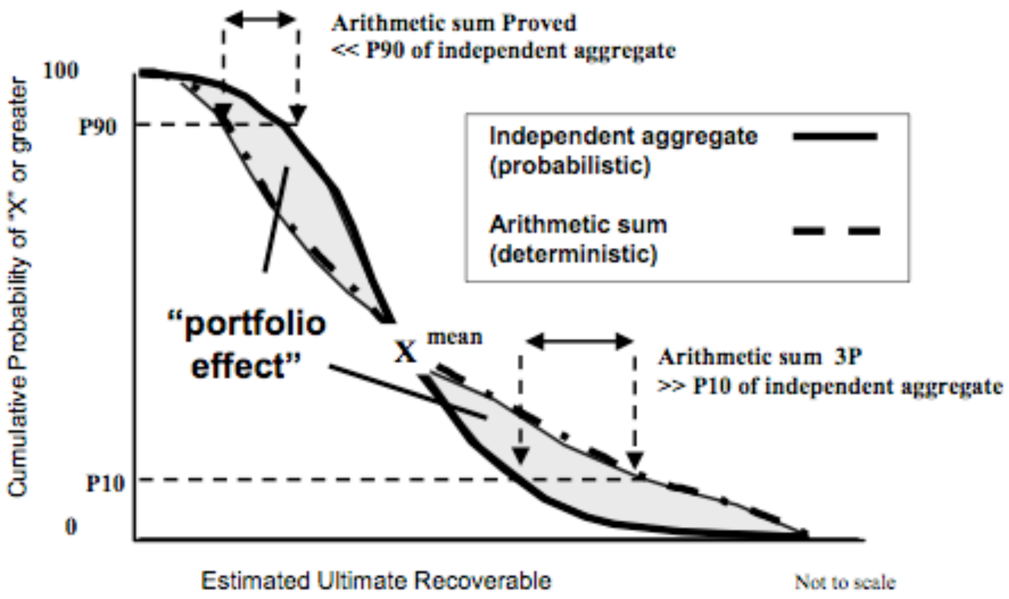


Figure 3-2: Deterministic versus Probabilistic Aggregation

SEC rules should be changed and should allow, in addition to proved data, to provide proven plus probable or expected value. Incorrect aggregation should be emphasized.

Current proved values are no use to be extrapolated for forecasting future production, when backdated mean values allow to plot creaming curves or logistic cumulative plot to assess ultimates.

-to compare and extrapolate different items:

-current proved= 1P = minimum against 2P = backdated proven + probable = expected value.

It is what USGS (Geological Survey) did in 2000 by extrapolating US reserve growth to the rest of the world. It is as comparing New York temperature with Paris temperature without bothering to check that the first is in ° Fahrenheit and the second in ° Celsius.

-millennium average against annual average: it is done for CO2, CH4 over 700 000 years ago from ice cores (millennium smooth of bubbles in the firn before close off and in the sampling) compared with present annual data.

-to present incomplete series, long future against short past

It is done very often, in particular for IPCC data (see climate change)

-to present results with a number of significant digits larger than accuracy

for most people addition of the measures of two items has to be exact

$$1000+1 = 1001$$

no, because rounding, if the accuracy of the measures is 10 %, the addition has to be

$$900\text{-}1100 + 0{,}9\text{-}1{,}1 \approx 900\text{-}1100 \qquad \text{or}$$

$$1000 + 1 \approx 1000$$

Conversion must keep the same number of significant digits, it means showing the same accuracy in the numbers

$$1000 \text{ ft} \approx 300 \text{ m and not } 304{,}8 \text{ m}$$

$$2000 \text{ b} \approx 300 \text{ m}^3 \text{ and not } 318 \text{ m}^3$$

In the oil industry, reporting any data with more than two significant digits is statistically incorrect because the accuracy of the reported values varies over 10% and shows that the author is incompetent.

The oil industry is showing a kind of incompetence by reporting:

World oil production for 2006	definition	Mb/d
OGJ Oil & Gas Journal	oil	72.647
WO World Oil magazine	crude/condensate	73.330 139
BP Statistical Review	liquids (excl BTL. CTL)	81.663 310 979 140 2
USDoE (Depart of Energy)/EIA	crude oil	73.573 844 712 166 8
	all liquids	84.597 461 4
IEA International Energy Agency	oil	85.4

The number of significant digits is ridiculous in front of the accuracy of the data

-to use for unit wrongly prefix with power

Young children learn at school that the prefix is involved when exponent, but many official agencies seems to ignore such simple thing and use Gm^3 (cubic gigametre) for billion of cubic meter which is in fact a cubic kilometre

$$10^9 \text{ m}^3 = \text{km}^3 \text{ and not Gm}^3$$

$$= \text{G.m}^3$$

-to confuse zero and no data

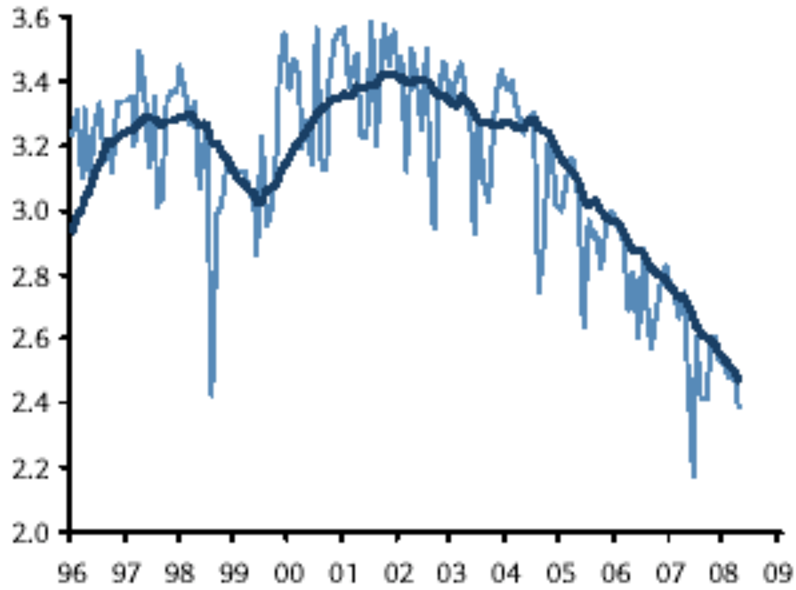
Some sites (such as JODI) reporting data and aggregation seem to ignore that *no data* is not equal to *zero*

-to badly adjust smoothing

It is interesting to compare detailed series with a smooth series, but many adjust the smoothing at the end of the series instead of the middle, making a misleading lag: for example Norway oil production from Barclays

Figure 21: Norway oil production from Barclays

Figure 89: Output and 12 month average (mb/d)



-to badly identify a paper or a graph

Every document should clearly indicate within the text

-the date including the year (many papers on Internet reports the day and the month but not the year)

-the title

-the author

-the legends and units if graph

-the scale if map

-to eliminate data which do not fit with your theory, saying that it is artefact without justification. Noise is often what is unknown.

CO2 data has been censured as artefacts because not in line with the fitting of ice core bubble (questionable dating and smoothed on several thousands years in the firn) analysis from Antarctica with direct measures in Hawaii (see my paper on climate change).

Einstein withdrew the cosmologic constant in his famous equation because it was against the theory of constant universe. After the discovery of universe expansion by Hubble he said that it was his largest mistake.

-to look only at money constraints and to forget EROI (Energy Return On energy Invested)

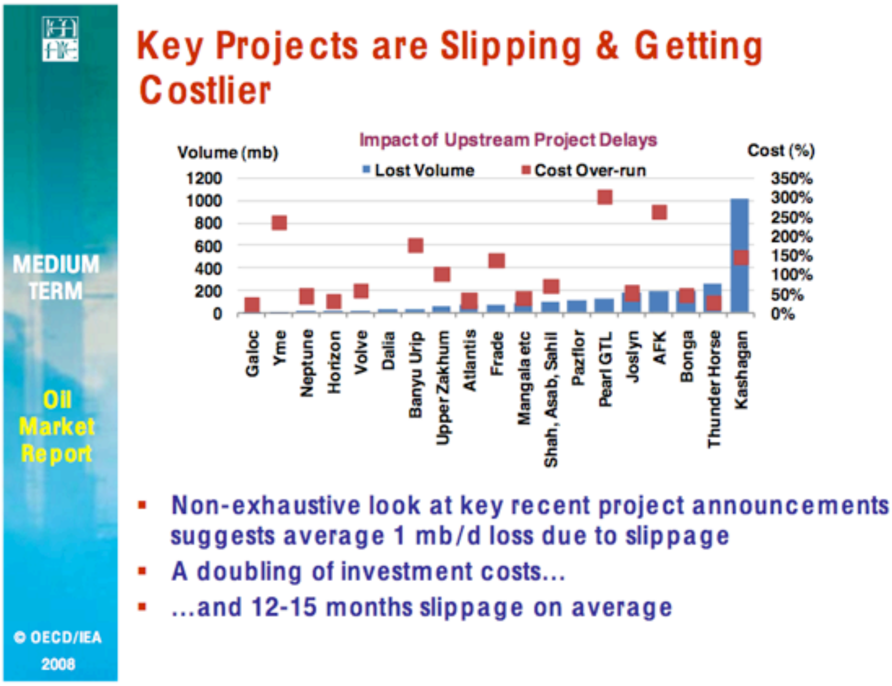
Many believe that oil & gas reserves increase when price increases, as it happens with minerals: gold, copper, coals. But oil is liquid and migrate to field where the concentration is 100% (outside the residual water), when concentration of copper varies from small concentration to large concentration and the reserves are estimated at a certain economical threshold, increasing the threshold increases the reserves. When searching for energy the energy invested should be lower than the energy produced.

Coal is solid but can be concentrated in seams, yet the problem is then the thickness and the depth of the seams. Coal beyond 1500 m depth or offshore is considered as unrecoverable because EROI (waiting for a breakthrough in in-situ gasification).

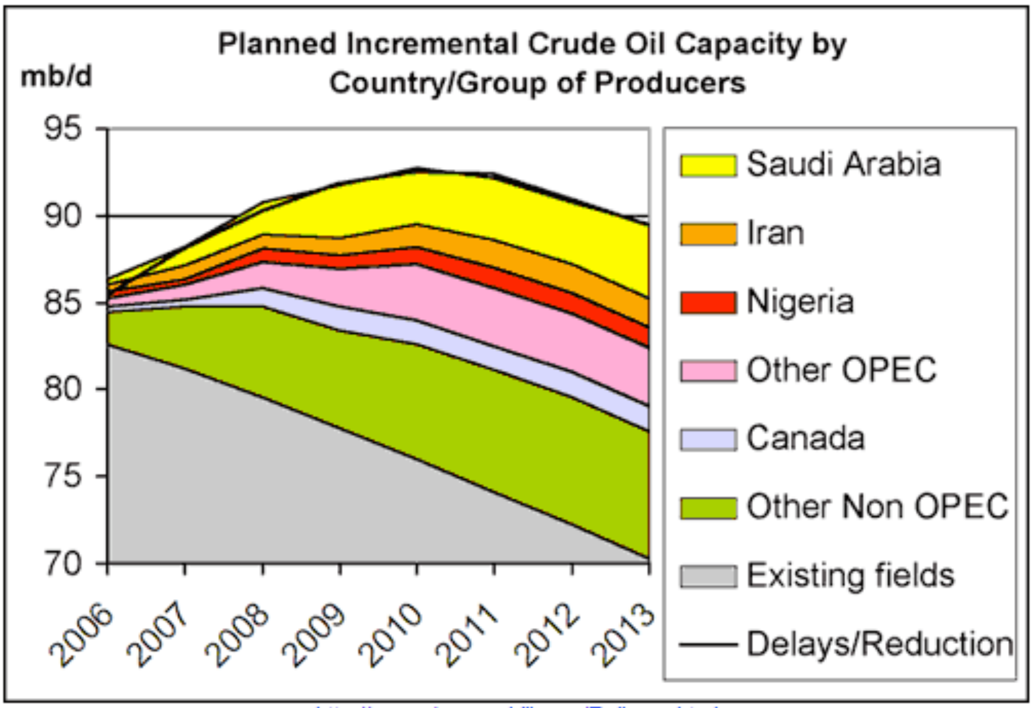
-to forget about time constraints

Time is the most important constraint of Nature (after resources):

there is no way to make a baby in one month with nine women,
Mc Namara law: Mc Namara, after being in charge of NASA, has issued a law where, in frontier areas, the initial project versus reality: cost has to be multiplied by pi and time by e (Euler number = 2,7). This law is verified in many exotic projects such as the Centre Pompidou in Paris, TransAlaska pipeline, presently with Kashagan in the Caspian sea. The problem of cost is usually resolved easily because more money can be found, but lost time is lost for ever. The explanation of such law is that in frontier area the range of uncertainty is as large as cost and, in order to have the project accepted, only the minimum value is given and at the end the expected value = mean occurs and is about 3 times the minimum (see Bourdaire J.M., R.J.Byramjee, R.Pattinson 1985 “Reserve assessment under uncertainty -a new approach” Oil & Gas Journal June 10 - p135-140, where the ratio between minimum and mean is about 3 in a lognormal distribution).
IEA plotted in 2008 the cost over-run of the key project: 300% is reached by some and most of projects are not yet completed
Figure 22: Key projects cost over-run from IEA 2008

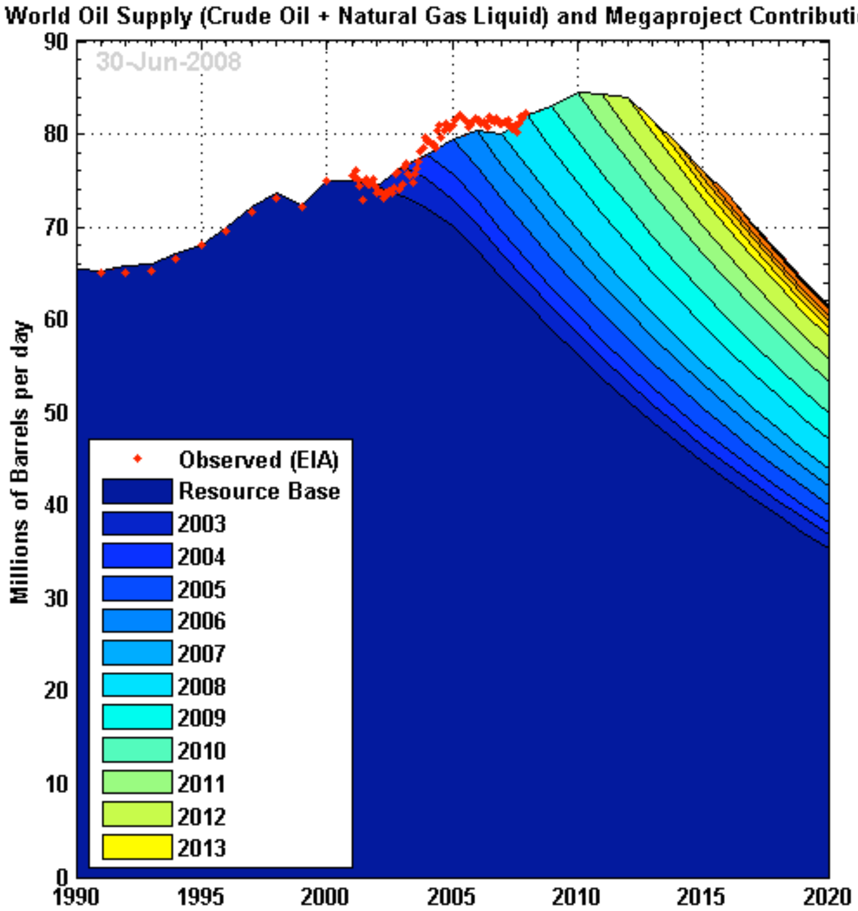


Chris Skrebowski (editor Petroleum Review, Energy Institute in London) has forecasted the peak oil by adding all the planned oil developments for the next 10 years because most of the data is published with cost, peak capacity and time of start. But he has added a certain lag for the start. “Total” reports more than 3 years delay for their oilsands projects; Kashagan over 7 years ; Thunder Horse (BP platform of 1 G$ Gulf of Mexico) over 3 years.
Figure 23: **Skrebowski’s forecasts from megaprojects** April 2006



http://www.durangobill.com/Rollover.html

CERA (subsidiary of IHS) has done a similar study in 2005 with the same data but did not include any correction in time or capacity. They forecasted 101 Mb/d in 2010, and 110 Mb/d in 2015 when Skrebowski sees a peak around 2010-2011 at 94 Mb/d. The other difference is the decline of existing fields. But these forecasts are only for oil projects and do not include synthetic oil.
CERA in 2007 forecasted world oil capacity at 112 Mb/d in 2017, equivalent to a liquids production of 107 Mb/d in 2017. Udall, Andrews and Partners (I was one of them) in February 2008 bet 100 000 $ to CERA that oil production will not reach 107 Mb/d between now and end of 2017. CERA did not answer the bet. It is what I call a win by forfeiture.
The oil drum (TOD) Canada in "Oil megaprojects update (July 2008)" (3958) has plotted the forecast up to 2012 for crude oil and NGL
Figure 24: TOD July 2008 forecast on megaprojects



-to fire staff in downs of short cycles:

It was done by the oil industry under the pressure of new shareholders (pension funds) looking for short term profits. So oil industry has a bad image upon young people. There is a shortage of staff in the oil & gas industry, when problems are more complex and need more brain power. In 2006, there were some 1700 people studying petroleum engineering in 17 US universities compared with over 11 000 in 34 universities in 1993. Yet oil & gas industry needs more and better staff to fight against complex fields

-to believe that the quality of the results of a model depends only of the quality of the model :

GIGO: garbage in , garbage out : whatever the quality of a model, the quality of the results depends mainly upon the quality of the data and hypotheses.
Monte Carlo runs cannot transform wishful thinking into scientific truth.

-to believe in what seems obvious

It is obvious that the sun is turning in the sky around us and in France (and other countries) a majority of people believes that the Sun is turning around the earth despite what they learn at school.

-Human behaviour

If Nature is fairly easy to understand following simple laws, human behaviour is much more complex, following mainly conscious or unconscious motive.
Most statements are motivated by personal beliefs and each statement should be questioned by guessing the motive:
-to report high reserves for OPEC members because quotas depend upon reserves

-to appear rich for bankers and oil companies in front of the stock market
-to appear poor for the tax payer in front of the Income Tax
OPEC is a producer club and IEA is a consumer club. Their motives are different.

People in charge wants to show that he is better than his predecessor and changes completely the message, as it can be seen for the IEA when only the head of the long term analysis is changed.
Figure 25: **IEA 1998 forecast by JM Bourdaire: there is a problem** (unidentified unconventional)

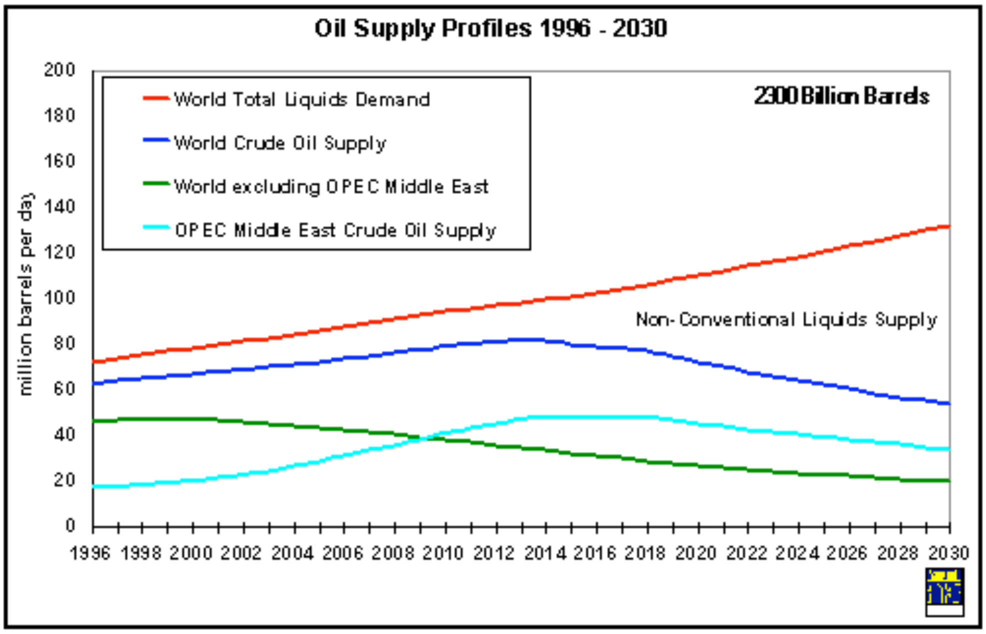


Figure 26: **IEA 2002 forecast by O. Appert: there is no problem**,

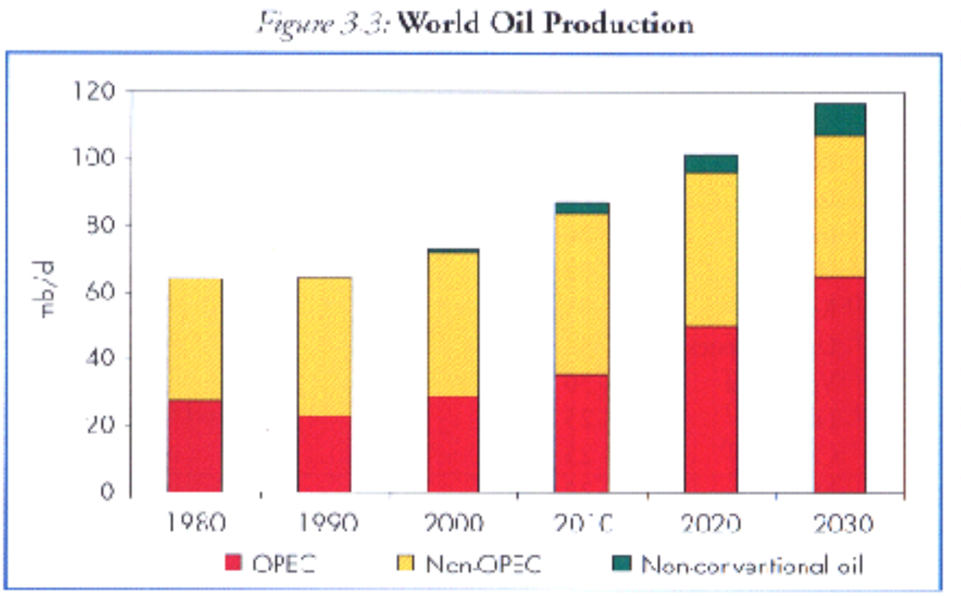
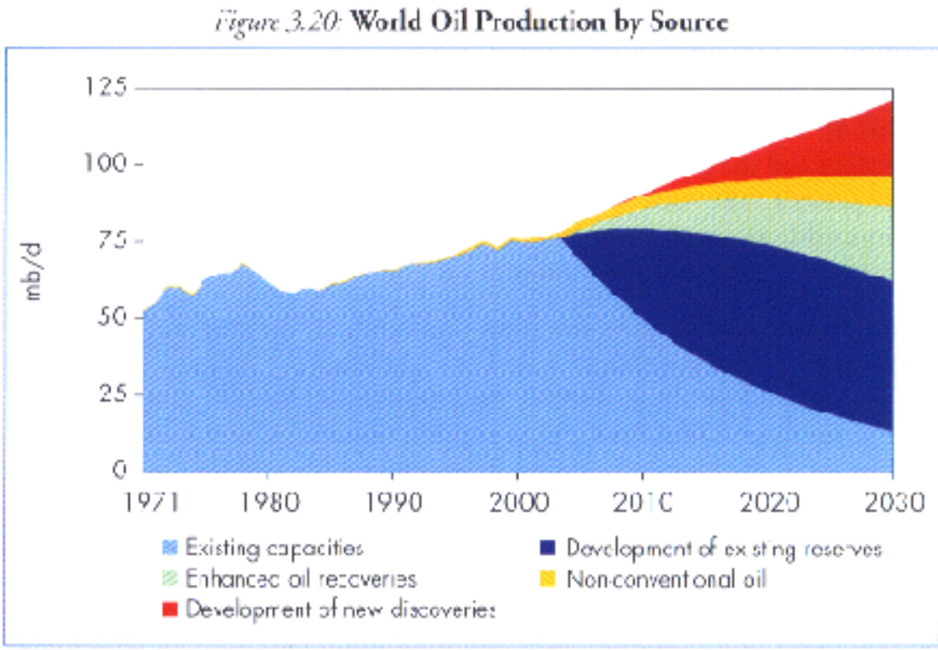


Figure 27: **IEA 2004 forecast by F.Birol: there could be a problem**



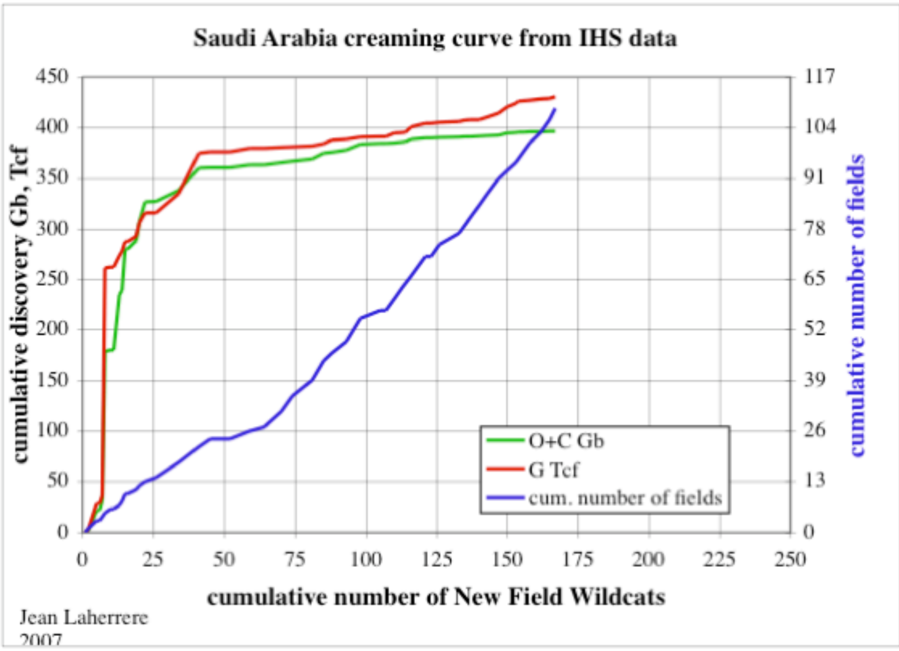
Fatih Birol is preparing a new WEO 2008 for November. What will the message be?

Most of recent big failures seem to come from lack of common sense:
-Chernobyl = operations against every security rules and absence of container for the plant
-Bug Y2K = why to use only two digits for year
-Katrina damage to New Orleans levee= levees were maintained only for power 3 hurricane
-Airbus 380 electric wire= different softwares in Toulouse and Hamburg
-Minneapolis bridge 2007 collapse = lack of maintenance
-US Subprimes = assumption of permanent rise in housing prices
-Dubai artificial islands counting on limitless energy??

-Myths to be rejected
To avoid showing decline, all means are used, in particular myths.
Myths are very hard to fight and there are many in the oil industry

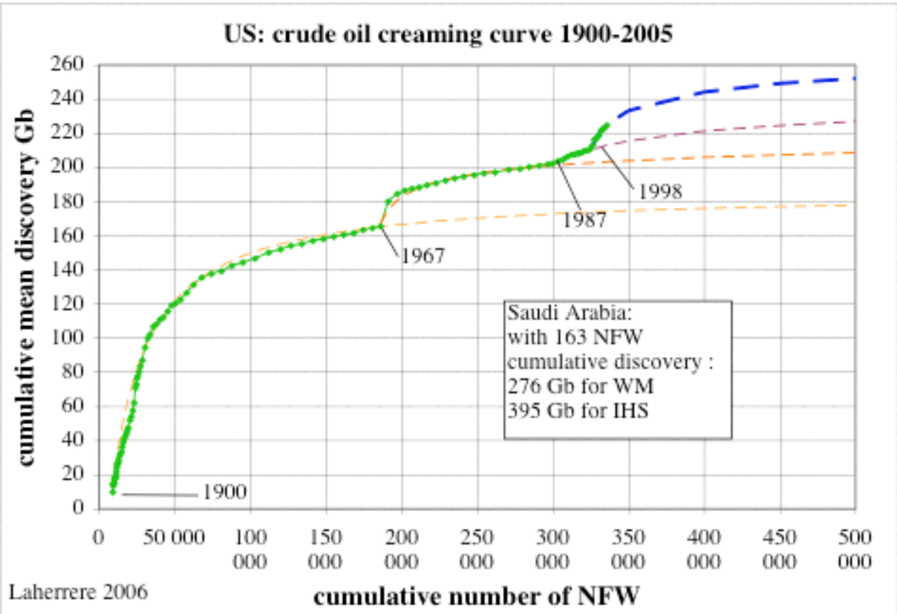
-Myth 1: Middle East is under explored

Saudi Arabia has found 80% of the present discoveries with the first 20 NFW (new field wildcat) from 1935 to 1965 within 12 fields and only 1% with the last 20 NFW from 1997 to 2005 within 16 fields. The country is not under explored, it is finding more fields, but much smaller fields.
Figure 28: **Saudi Arabia creaming curve = cumulative oil discovery versus cumulative number of New Field Wildcats**



It is not the number of NFW that counts, but the maturity of the exploration. US has only discovered 225 Gb with 335 000 NFW and over 30 000 oilfields. The US oil creaming curve shows several cycles, the last one being deepwater, but the curve is going towards the ultimate if there is no more cycle, but Saudi Arabia looks more mature than the US if no new cycle is found: there is no deepwater and Rub al Khali seems more gas prone than oil prone.

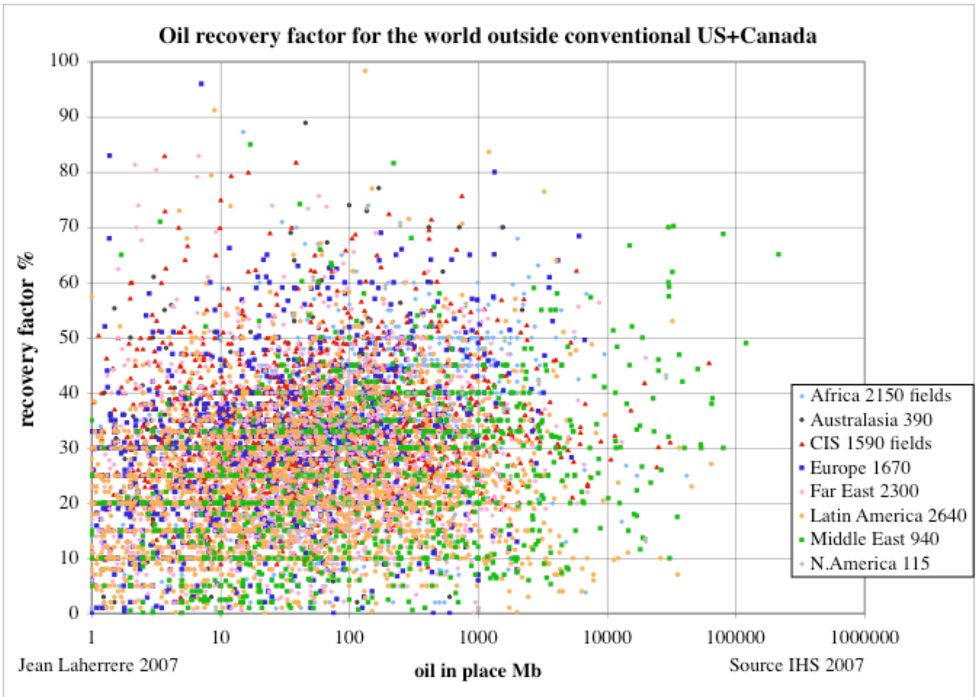
Figure 29: **US oil creaming curve**



Myth 2: oil recovery (RF) is about 35% in the world and 50 % in North Sea, so world reserves can be increased worldwide.

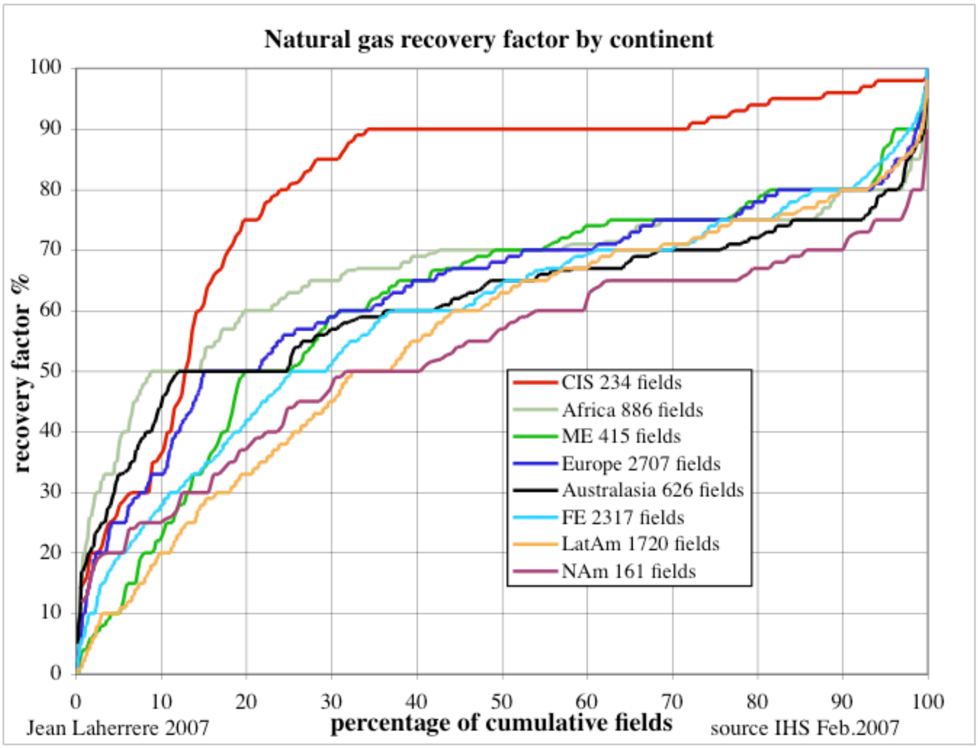
Statistics on oil recovery are meaningless because the reported range is from almost 0% to almost 100%! Average value is quite different when computed with number of fields or with volume of oil reserves.

Figure 30: oil recovery factor for the world outside US & Canada



Recovery factor for conventional oil depends mainly upon the geology of the reservoir: from 1% for tight reservoir to 85% for very porous and permeable reservoir.
Technology cannot change the geology of the reservoir.

Russian classification ABC1 presented by Khalimov in 1979 was described in 1993 by the same Khalimov as grossly exaggerated, because taking the maximum theoretical recovery: it is obvious by comparing FSU values to the rest of the world.
Figure 31: natural gas recovery factor by continent



FSU reserves should be corrected (reducing by about 30%), going from 3P to 2P.

Every major oil and gas field production should be plotted to have a quick estimate of reserves, but it works only when the decline is significant and when production is not constrained by quotas.

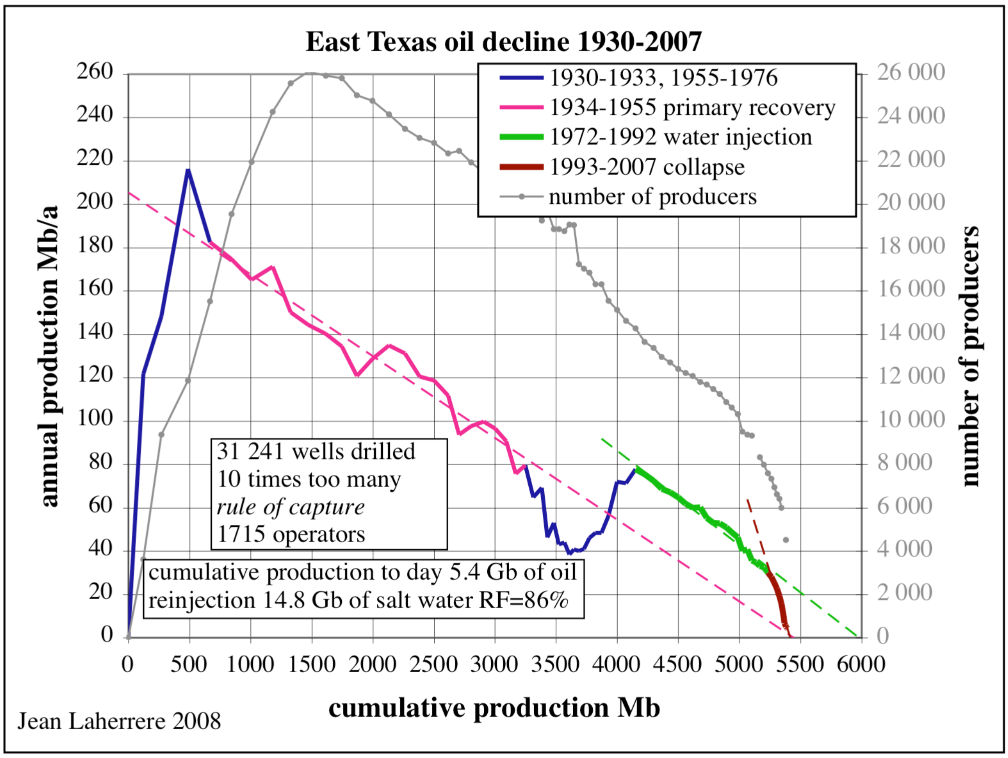
-Myth 3: technology increases reserves

Reserve growth is claimed by USGS 2000 report by extrapolating the current proved reserve growth in the US fields to the backdated proven+probable reserve in the rest of the world. It is a non-scientific extrapolation as there are two completely different objects. Previous USGS assessments (Masters) denied reserve growth when using inferred estimates.

Reserve growth due to technology should be shown on the decline of annual production versus cumulative production

Field reserve growth is often negative at the end, contrary to genuine expectations before, as the largest oilfield in the US Lower 48, East Texas, which was estimated for a long time to hold 6 Gb when decline was only 5%/a, but now, with decline increase to 10%/a, near exhaustion, ultimate recovery is only 5.4 Gb, with a negative reserve growth of -10%. The last decline (brown) is in agreement with the first decline (pink) using only primary recovery: it is a surprising fact!

Figure 32: **Oil decline of East Texas, largest US L48 oilfield 1930-2007**

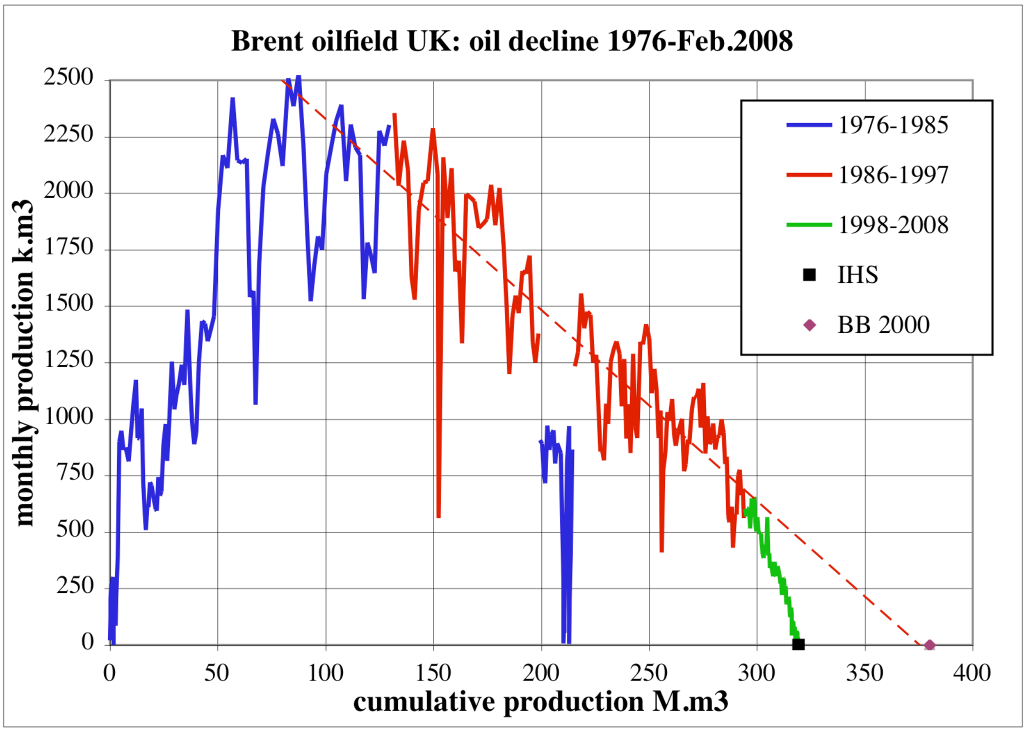


In this field, over 30 000 wells have been drilled (by over 1700 different operators) 10 times too many (spacing of 4 acres per well, when 40 acres/w was largely enough), because of the *rule of capture*! There is a very active water drive and **the recovery is estimated at 86 %**. **Present water cut is over 98%** =14 000 b/d of oil with 1 000 000 b/d of water from 4500 wells! = 3 bo/d/w and 220 bw/d/w. The amount of oil produced (5,4 Gb) is 37% of the water reinjected (14,8 Gb).

The decline of annual production versus cumulative production is most of the times close to a straight line, but some show, such as East Texas, a collapse at the end, making the straight line extrapolation an optimistic estimate, like in the Brent decline (outside the trough in 1989-91 for works on gas repressuring).

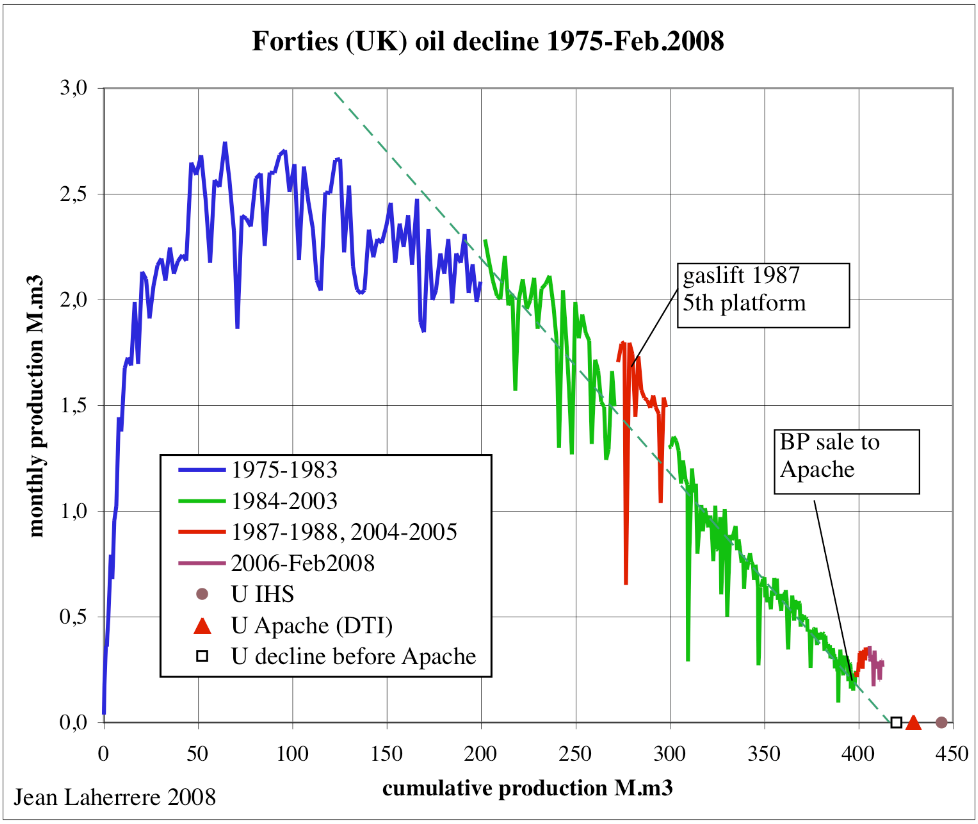
Up to 1997 Brent oil ultimate was estimated to be around 350 to 400 M.m3 with a decline of 8%/a, but production from 1998 to 2006 (green curve) with a decline of 20 %/a shows that the ultimate will be around 320 M.m3. Again negative reserve growth.

Figure 33: **Brent oil decline showing a late collapse Nov.1976-Feb.2008:**

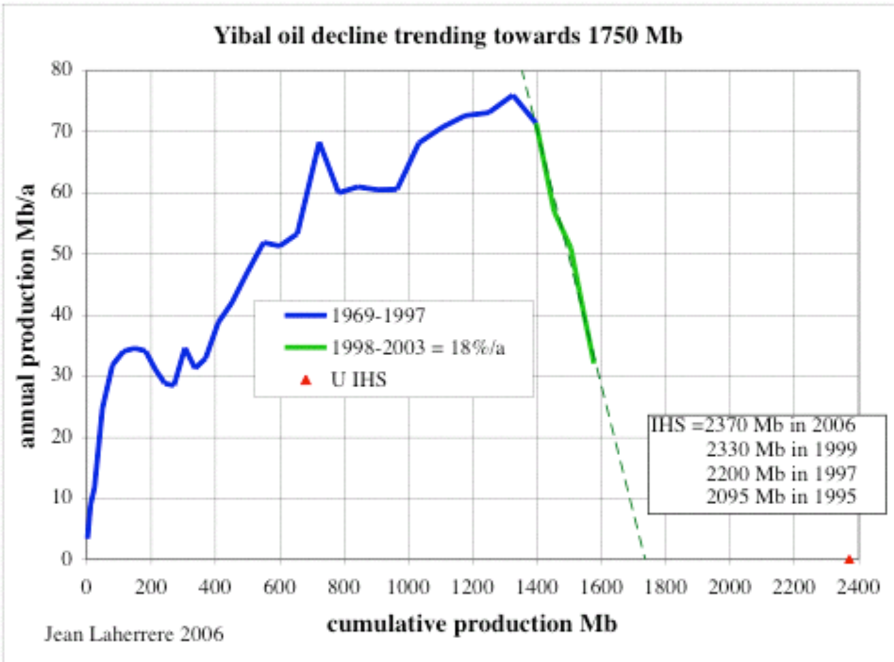


Another good example of oil decline is Forties in the North Sea where the decline was straight since 1984 but in 1987-1988 a fifth platform with gaslift allows to produce a little more, but quickly the decline has returned to previous trend. BP sold this mature field to Apache a small independently who can produce cheaper being smaller. In Apache since the end of 2004 has drilled more than 50 wells, increasing the production but will the ultimate recovery be increased? The future will tell. Apache claimed to have increased the oil in place by 800 Mb but barely the reserves by 30 Mb (5 M.m3), hardly seen on the graph.

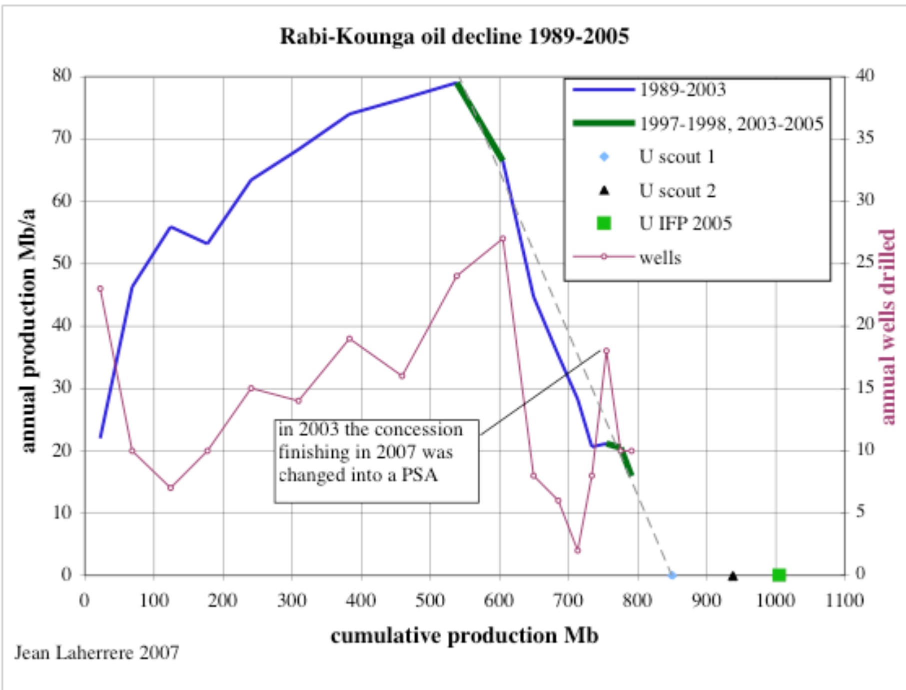
Figure 34: **Forties oil decline 1975-Feb2008**



Modern production aims at maximum daily production to get maximum profit (pushed by new shareholders such as pension funds asking short-term large rate of return).
Using multi-branch horizontal wells increases the production, but not the total recovery as shown by Yibal, the largest oilfield in Oman, when the decline is about 18%/a and the ultimate is likely to be around 1750 Gb and not 2370 Mb as reported by IHS in 2006, but 2200 Mb in 1997 and 2095 Mb in 1995: the IHS reported reserve growth of Yibal from 1995 to 2006 is wrong!. Oil production is not reported since 2004!
Figure 35: **Oil decline of Yibal, largest field in Oman 1969-2003,** operated by Shell

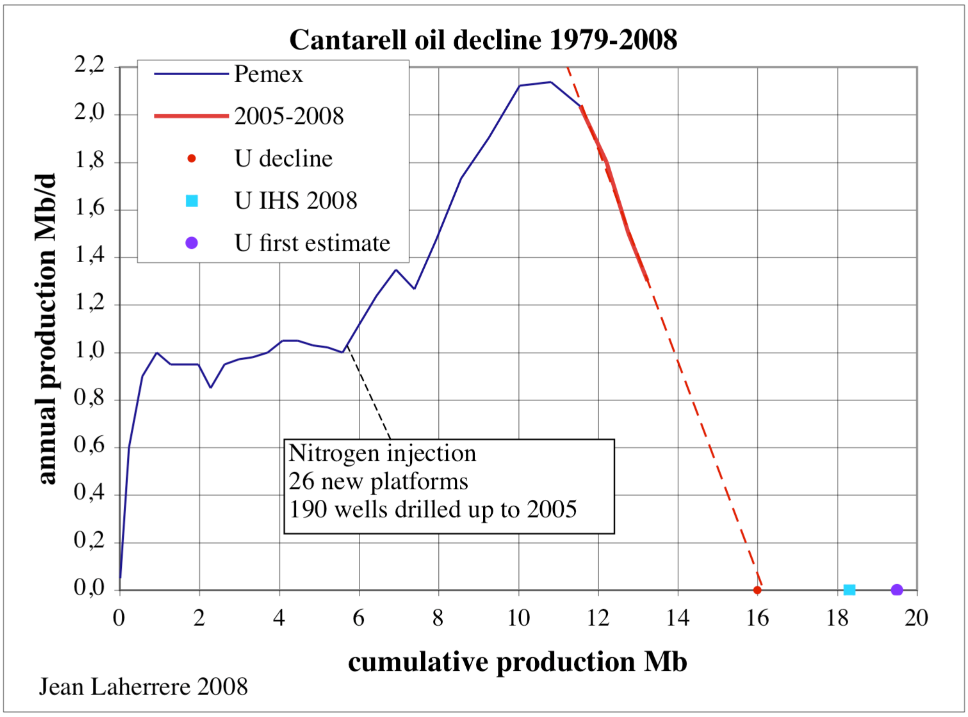


Same pattern and same operator for Rabi-Kounga largest field in Gabon.
Figure 36: **Oil decline of Rabi-Kounga, largest field in Gabon,** operated by Shell



The largest Mexican oilfield, Cantarell, discovered in 1977 was reported by IHS as 15,3 Gb in 1995 and 18,7 Gb in 2006. In 1995 when annual production was at 1 Mb/d, Pemex started a very expensive nitrogen injection and production raised quickly as they installed 26 new platforms and drilled up to now 190 wells, but it peaked at 2,1 Mb/d in 2003 & 2004 and starts declining sharply in 2005 with a decline of 14%/a

Figure 37: **Oil decline of Cantarell, largest field in Mexico 1979-2008**



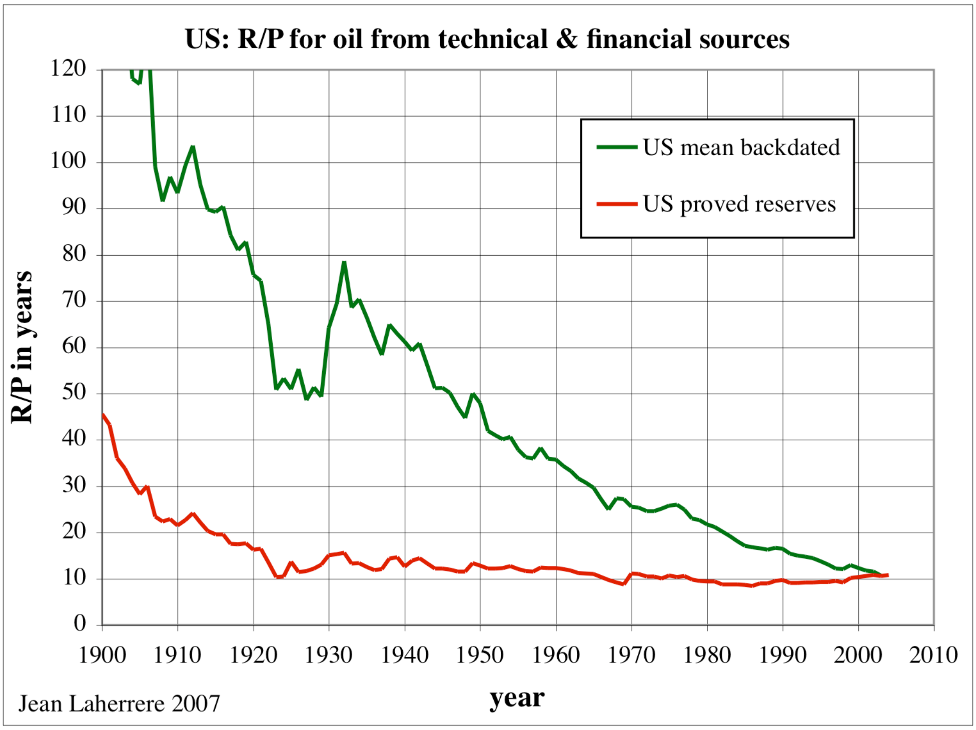
Cantarell pattern is similar to Yibal: slow start, large increase and steep decline (14%); all thanks to new technology and an ultimate about 16 Gb compared to more than 18 Gb for IHS. Again a negative reserve growth!

There are many negative reserve growth examples in the world, and in my review of all major (>100 Mb) oilfields of the world I found few examples of decline showing a real positive reserve growth and all those examples are due to an exceptional geologic case. The best examples are Ekofisk, which has seen its chalk reservoir compacted with the decrease of pressure, so that the seafloor has fallen by 8 meters (platforms had to be raised) and the compaction has increased the reserve from 160 (Roadifer 1985) to 550 M.m3.
There is another example of exceptional positive reserve growth, which is Eugene Island 330 in the Gulf of Mexico. The largest fault in the area called the Red Fault (studied on the web by several universities) allows the reservoir to be directly in communication to the source rock and when the pressure dropped, the reservoir was fairly quickly recharged by the source-rock. In 1999 Wall Street Journal (Cooper) stated from this example that oil was coming from the mantle making oil renewable and almost unlimited.

-Myth 4: reserves represent 40 years for oil, 60 years for gas and 250 years for coal!

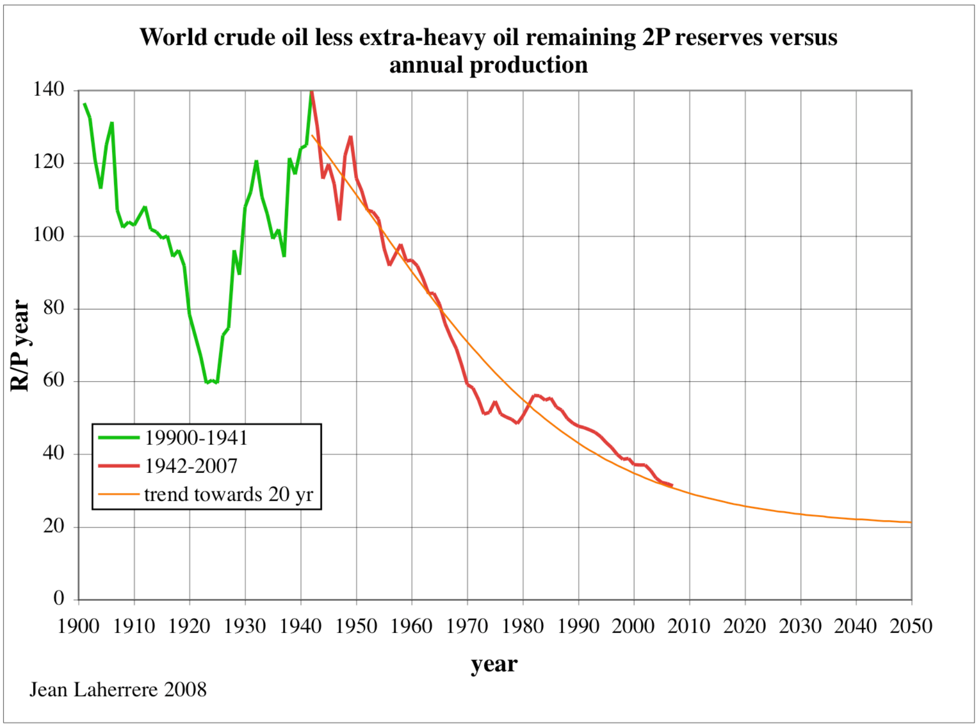
R/P from US proved reserves has been about 10 years for the last 80 years, showing that this ratio is useless for forecasting, in fact it is used to estimate reserves as a thumb rule (even used by USGS). Using backdated proven + probable (mean reserves) gives a complete different decreasing trend, but R/P trends towards an asymptote about 10 years and this ratio will stay until the last barrel (the 9 barrels left will return to resource statute!)

Figure 38: US R/P from proved reserves and mean backdated reserves 1900-2006



For the world R/P (crude oil less extra-heavy) decreases from 140 years in 1950 to 35 years to day and trending towards a 20 years asymptote.

Figure 39: World crude less EH oil R/P 1900-2007



R/P is a very poor indicator for forecasting the future, but used by many.

The world is using many indicators which are very poor, such as proven reserves, recovery factor, R/P, single cycle (Hubbert peak), GDP.

They please because they are simple but Paul Valery wrote: *All that is simple is false and all that is not is useless,* but they are also flawed.

-Myth 5: reserves increase with technology

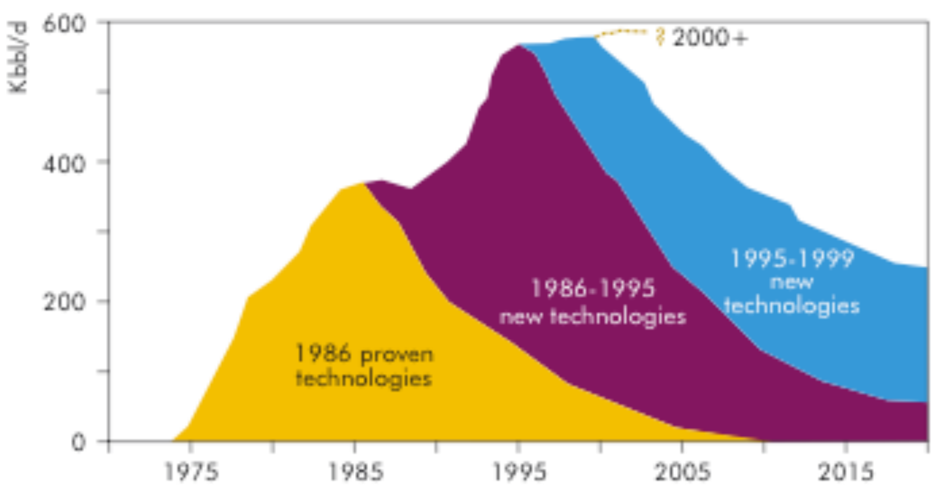
It is interesting to find that major companies or official agencies that claim that peak oil is decades away, always quote old works by others, never their own.

Exxon-Mobil 2006 quotes USGS 2000 (10 years old as being at end of 1995), Shell in 2002 quoted EneRG (1999), IEA in 2005 quoted Shell 2002! IFP quotes Wood Mac! Is it to say, if found wrong, that it is not their work?

IEA in May 2005 *Resources to reserves* claims that reserve growth is due to technology, justified by a flawed North Sea old graph published by Shell 2002 coming from *European Network for Research in Geo-Energy* (unknown report 1999?), and badly drafted (wrong scale: 0.6 Mb/d instead of 6 Mb/d)

Figure 40: May 2005 IEA graph titled *Impact of technology on production from the North Sea* quoting Shell

Figure 1.20 • *Impact of technology on production from the North Sea, in thousand barrels per day*



Source: European Network for Research in Geo-Energy - ENeRG - courtesy of Shell.

There is a curve suggesting that 2000 will add more production but in fact the blue line to 2005 represents the reality as shown by figure 28

1988 trough is partly due to Piper Alpha oilfield blow out (160 dead) and Brent oilfield works for gas repressuring as shown in Tzimas et al "Enhanced oil recovery using carbon dioxide in the European Energy System" 2005

Figure 41: North Sea oil production from Tzimas 2005 showing that the trough is mainly due to the collapse of two UK fields (in brown and light blue)

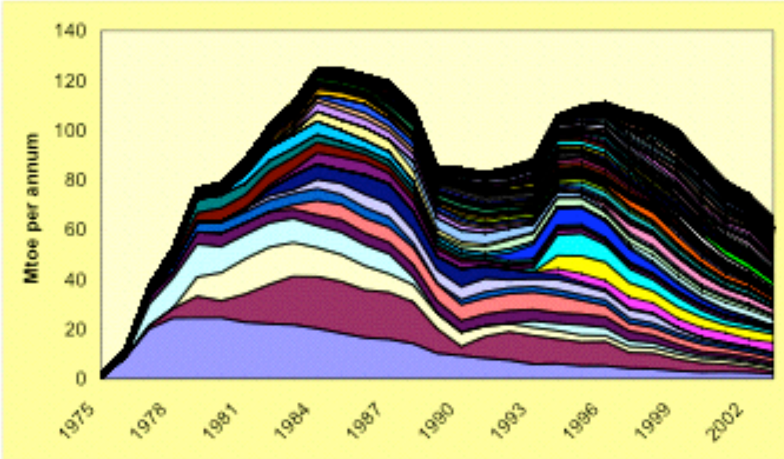


Figure 4.2 : North Sea oil production, UK sector excluding West of Shetland. Different colours represent different fields.

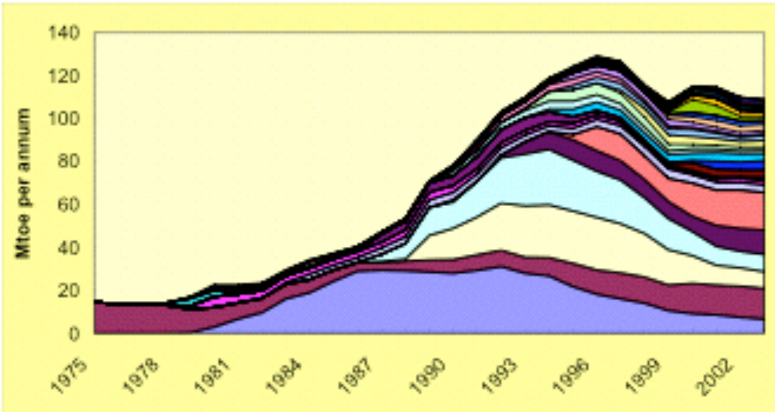
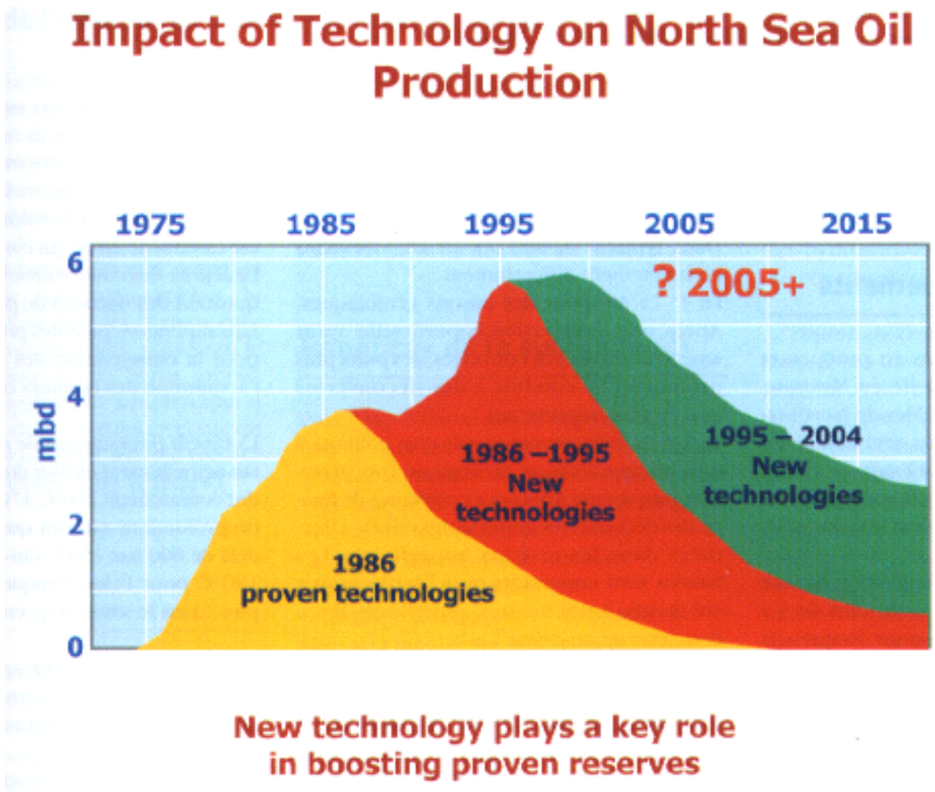


Figure 4.3: North Sea oil production, Norwegian sector excluding Norwegian Sea. Different colours represent different fields.

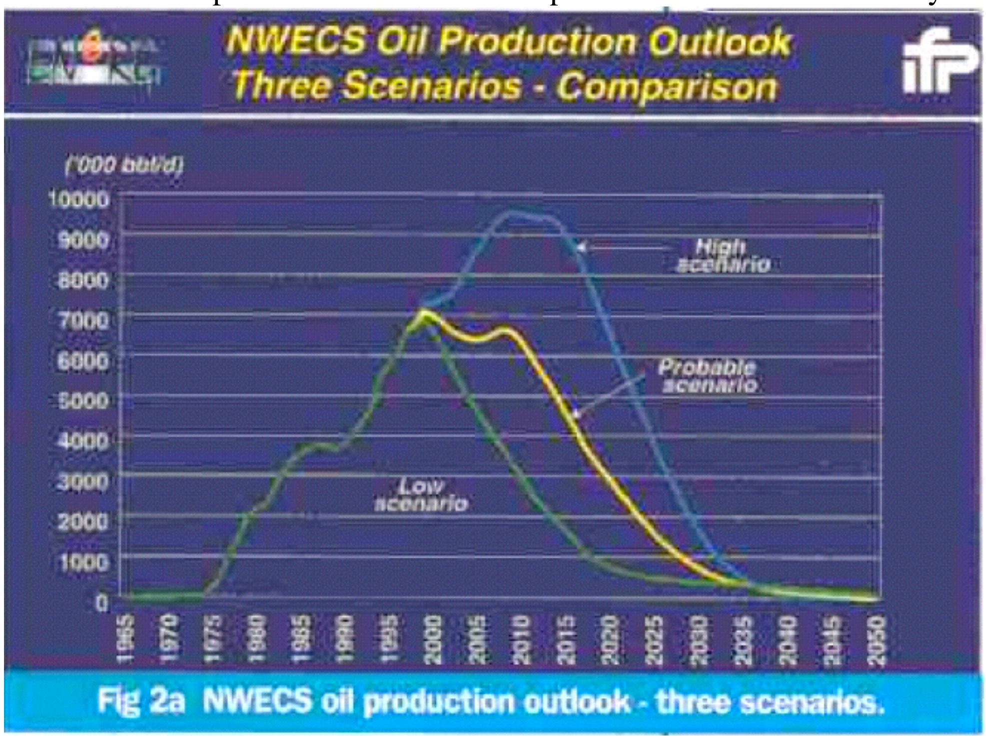
IEA shows in October 2005 (*Jan. 2006 Petrole & Gaz Information p.19)* the same May 2005 graph but redrafted by replacing 1999 by 2004 ! and suggesting a good surprise thanks to 2005+?
In the same bulletin p.84, Shell (Rodriguez) displays exactly the same graph than IEA but without the IEA change of 1999 by 2004 and 2000 by 2005.
It is amazing to see such swindle of changing date and removing references of an old graph!
Figure 42: October 2005 IEA (Pochettino) graph titled *Impact of technology on production from the North Sea,* but Shell is not quoted anymore.



North Sea oil production has peaked in 1999 and the green line is right down to 2005 as shown on figure 28! It is hard to see what is bringing 2005+

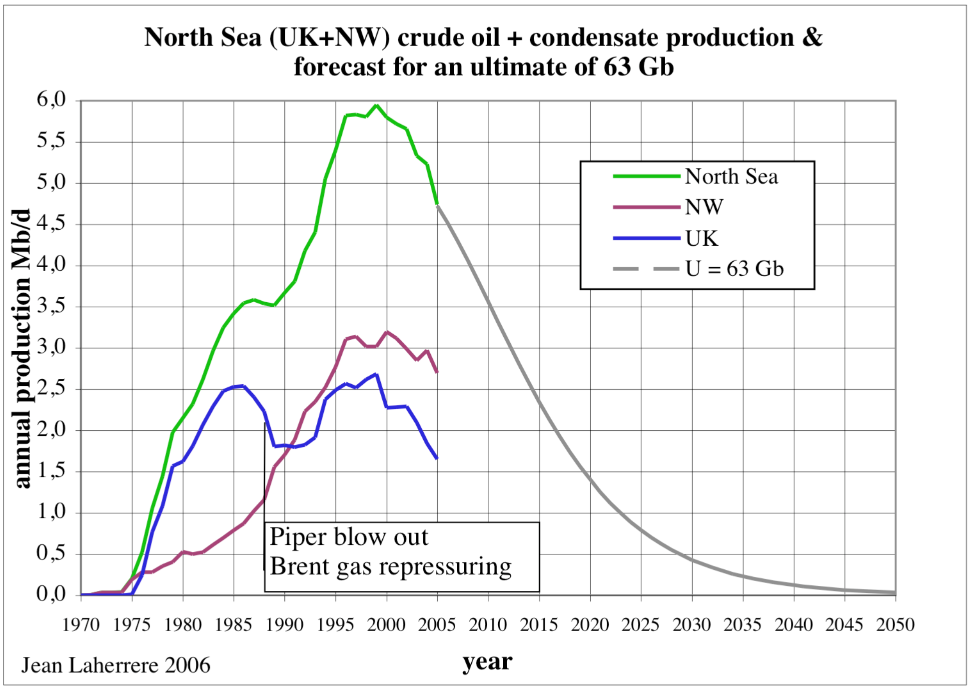
European Network for Research in Geo-Energy newsletter Feb 1998 claims "North Sea oil and gas production outlook- a major challenge" production decline will be delayed by 10 years and the probable scenario has a second peak in 2010

Figure 43: North West European Continental shelf oil production with 3 scenarios by IFP 1998



The real data up to 2005 follows the 1998 low scenario and the 1998 probable scenario was pure wishful thinking!

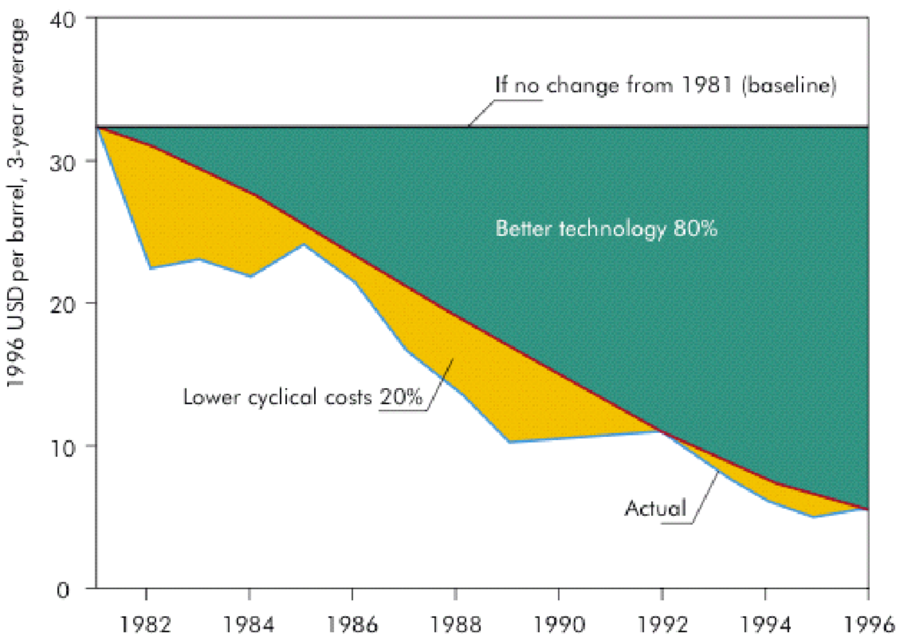
Figure 44: North Sea oil production showing that the IFP low scenario occurs



-Myth 6: cost decreases with technology

Figure 45: **unjustified claim of technology impacts on costs for US offshore**

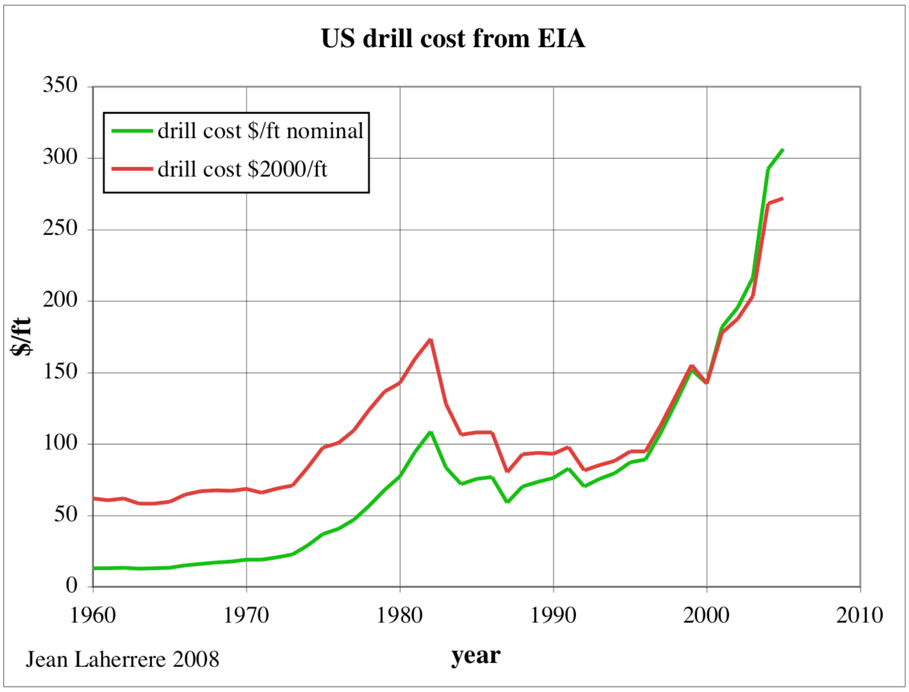
Figure 2.5 • *Technology impact on costs for offshore USA*



This graph is typical of lying publicity.

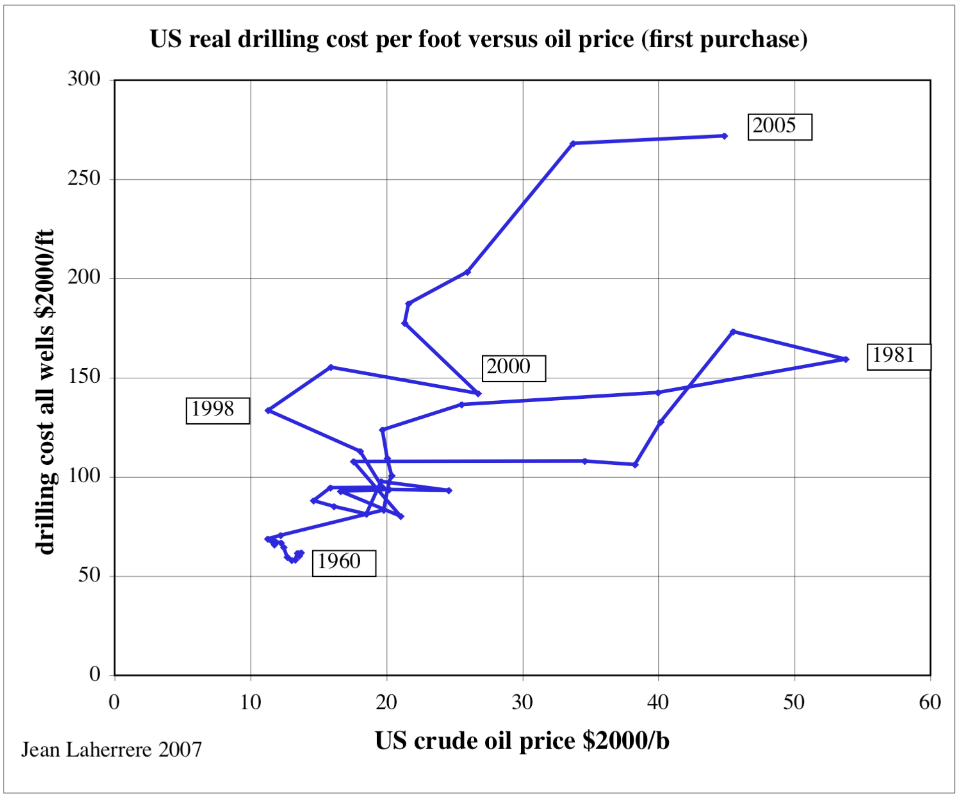
First the data starts only in 1981 when reality looks different with drilling cost for the period 1960-2004, drilling cost is more reliable data than cost per barrel (gathering badly defined items in exploration and development). Drilling cost displays completely different trends before 1982 and after 1996, a short episode was chosen to see the decrease, hiding the increase before and after

Figure 46: **US drilling cost per foot 1960-2005 in $2000 & nominal**



In reality US drilling cost depends mainly upon the oil price. From 1960 to 1997 cost in dollar per foot varies roughly as a linear function of oil price. So cost per foot in 1977 is equal in $2000 to cost in 1997. Technology progress has done nothing to decrease cost, in contrary technology pushing towards deepwater since 1997 as drilling goes to deepwater, cost per foot has exploded!

Figure 47: **US drilling cost 1960-2005 versus oil price in $2000**



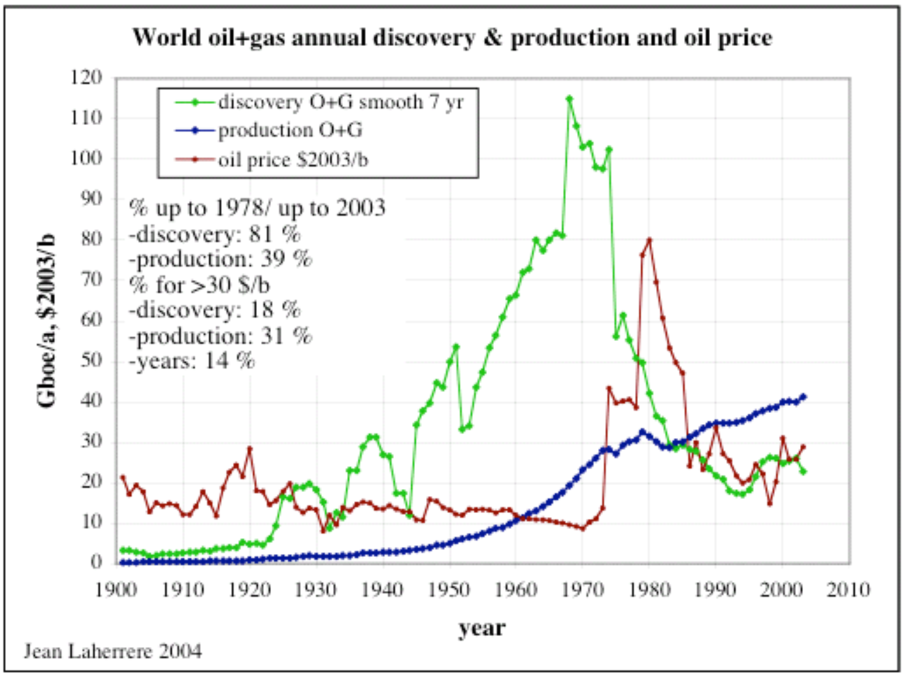
Drilling costs have also increased sharply lately because the lack of available rigs when producers in particular Saudi Arabia are increasing drilling to keep their production steady or to increase a little. Daily rate for deepwater is now about 0,5 M$/d and total cost about 150 M$ in deepwater exploration (240 M$ for Tupi).

Development costs have also doubled for Sakhalin 2 and multiplied by ten for Kashagan.

-myth 7: discoveries increase when prices increase

Oil and gas discoveries peaked around 1965 when oil price was low and they declined sharply with oil shocks because every poor prospects discarded before were then drilled. But oil production dropped by lack of demand because consumers went to energy savings convinced that prices will triple in the near future: this forecast was quite wrong, instead, counter shock of 1985 occurred !

Figure 48: **World oil & gas discoveries and production with oil price**



Discoveries pop up again in 1995 because going towards deepwater by lack of easy prospects and it is later after 1999 that oil price raises again. Oil price is not the driver for discoveries.

-myth 8: oceanic hydrates represents more resources than all fossil fuels

Hydrates of methane (solid which contains 160 times more methane in volume) are reported by some to have more reserves than all other fossil fuels. It is completely wrong because oceanic hydrates in sediments of less than few millions years cannot match fossils fuels issued of sediments of more than 600 Ma. These unrealistic estimates were divided by 100 (Soloviev V.A. 2004 "On gas hydrate mythology" IGC).

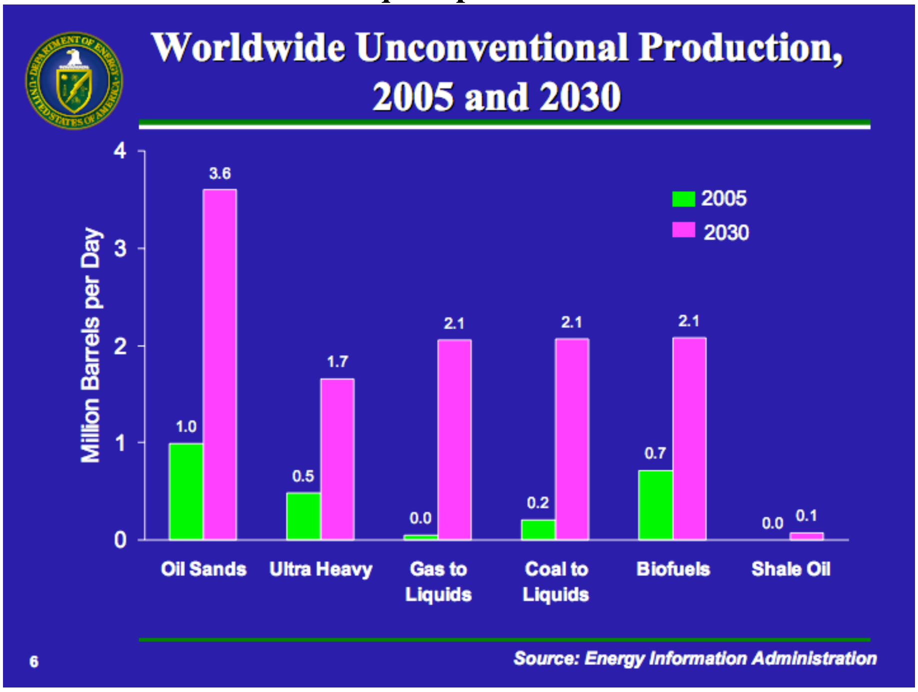
Out of thousands of holes drilled by JOIDES only 3 found hydrates thicker than 15 cm and the last thick occurrence (leg 164) has shown no continuity in a hole drilled 20m apart. Oceanic hydrates are heterogeneous and of limited extent : few millimetres vertically and few meters horizontally. No method is known to produce them. Japan, India has drilled since 1999 many wells to core oceanic hydrates and despite their needs of gas, there is no plan to produce them. There is no known technology to produce oceanic hydrates. Continental hydrates in permafrost were found, but they are accumulated in conventional gasfields which were before the glaciations 2 millions years ago trapped as free gas. Now in permafrost they do not add anything to conventional reserves except problems!

-myth 9: oil shale have reserves of >2 Tb at a cost of 30-70 $/b

Oil shale in fact is immature kerogen (needing pyrolysis to be converted into oil in what is called the oil kitchen) and is classified with coal as lignite. It is often confused with oilsands which in contrary is at the other end of the oil generation being degraded oil.

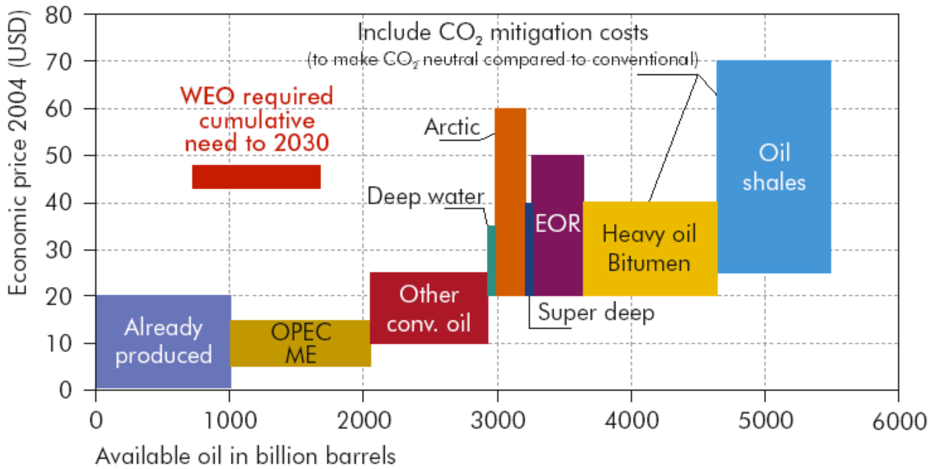
Oil shale were produced in France from 1837 (schistes d'Autun) and closed in 1957. Oil shales occur in many places but most of resources are in the US. In some place oil shales are burnt in power and cement plants, like in Estonia. But Estonia was obliged, in order to join the UE, to stop burning oil shales because of pollution. During the oil shocks of the 70s, billions of dollars were spent in the US on mining oil shales and making oil by pyrolysis (600°C) = retorting. Towns were

built, but too many problems (water, large volume of fines impossible to store, EROI) leads to a complete and sudden stop at the 1985 counter shock. Australia had for few years a pilot of 4000 b/d for phase 1 (hoping 200 000 b/d in phase 3): the Stuart plant built by Suncor (large producer of Canadian oilsands) was stopped after bankruptcy in 2004, having never reached a constant level of phase 1. Almost every one has stopped thinking about mining and retorting oil shales (only Brazil with about 4000 b/d and China with <2000 b/d did not close their plants) and the hopes are in situ (China?). Shell has been working for 20 years on ICP (In-situ Conversion Process) which creates a slow pyrolysis by heating the oil shale (3-4 years) with electric heaters in holes few meters apart. To prevent water from upsetting the heating, a wall of sediments is frozen around the heating place. Shell is rumoured to have produced for the last few years 10 b/d with an electric monthly bill of 60 000 $. Shell claims a EROI of 3,5, without giving the detail: it is unlikely that this number covers the full process including freezing. Shell said that that they will decide or not in 2010 to build a commercial pilot plant in order later to go eventually for a full plant.
It is likely, as Youngquist said: *oil shale will be the energy of the future for ever*
USDOE has issued last year several leases of 160 acres for pilot but they forecast only 0.1 Mb/d of shale oil for 2030 compared to 3.6 Mb/d for oilsands
Figure 49: **USDOE non-conventional liquids production forecast for 2030**



Huge volumes of shale oil reserves are estimated but it is more likely that they will stay as resources for ever, even with oil price over 70 $/b.
Figure 50: oil resources versus oil cost from IEA 2005

Figure ES.1 • *Oil cost curve, including technological progress: availability of oil resources as a function of economic price*



This graph is mainly wishful thinking and wild guess to promote the peak oil deniers' idea of abundance. Only deepwater estimate seems reasonable. Heavy oil is not defined.

-Conventional and unconventional

There is no consensus on the definition of unconventional and the practice has changed with time. Presently the head of EIA Guy Caruso (June 2008) defines conventional when production flows readily from a vertical wellbore.

We use the term "oil" to refer to the first four of those categories: conventional crude oil and lease condensate, natural gas plant liquids, refinery gain, and unconventional crude oil. We use the term "liquids" to refer to "oil" plus biofuels and liquid fuels manufactured using coal (CTL) or natural gas (GTL) as a feedstock. We also make a distinction between conventional and unconventional crude oil. ***Conventional crude oil comes from underground reservoirs for which the geophysical properties of the reservoir rock and characteristics of the crude oil permit the oil to flow readily to a vertical wellbore****. Unconventional oil is oil which, due to the characteristics of the reservoir rock or the fluid, is not easily extracted using vertical wells, including Canadian oil sands, shale oil, and very heavy crude oil (e.g., Orinoco crude oil from Venezuela). These distinctions are important because the conventional crude oil share of total liquid fuel supply, which was 84 percent in 2006, is expected to decline to between 62 percent and 74 percent of total global liquids supply in 2030 in the two analysis cases discussed later in this testimony*

In contrary USGS since 1995 has defined unconventional as the **continuous-type accumulations.**

Conventional oil and gas accumulations are defined as discrete fields with well-defined hydrocarbon-water contacts, where the hydrocarbons are buoyant on a column of water. Conventional accumulations commonly have relatively high matrix permeabilities, have obvious seals and traps, and have high recovery factors. In contrast, continuous accumulations (also called unconventional accumulations) commonly are regional in extent, have diffuse boundaries, and are not buoyant on a column of water. Continuous accumulations have very low matrix permeabilities, do not have obvious seals and traps, are in close proximity to source rocks, are abnormally pressured, and have low recovery factors. The USGS assessment focused on understanding the geology and occurrence of continuous hydrocarbon accumulations, as the resource potential of these accumulations may be greater than that for conventional accumulations in the U.S. Included in the category of continuous accumulations are hydrocarbons that occur in tight reservoirs, shale reservoirs, unconventional reservoirs, basin-centered reservoirs, fractured reservoirs, coal beds, and oil shales

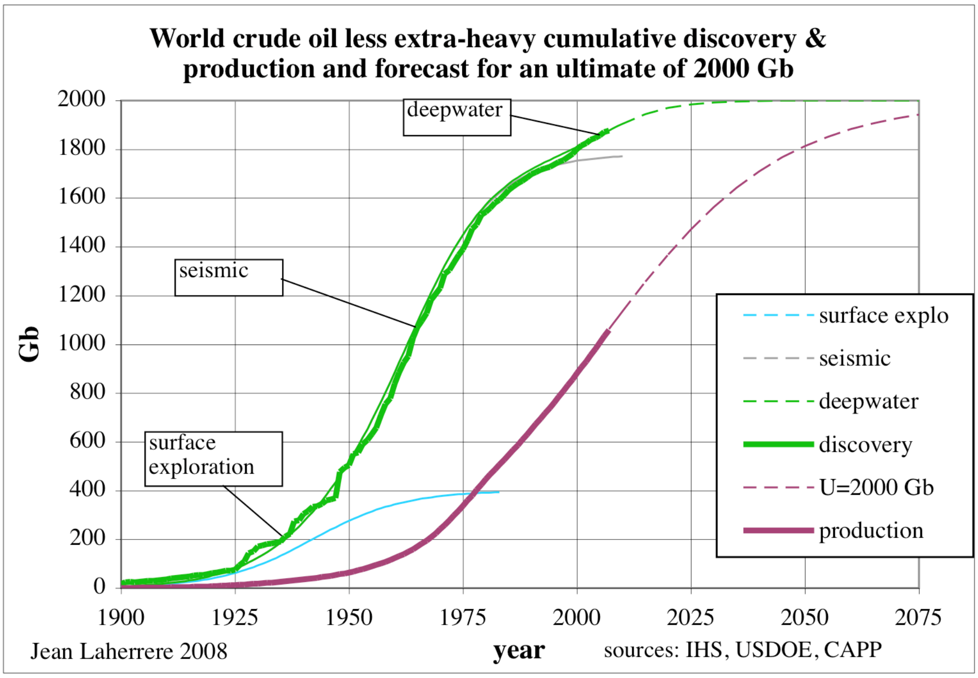
It means that USGS estimates conventional ultimates as discrete fields to be guessed for number and sizes, but unconventional ultimates by assuming that oil and gas is present everywhere and the recovery is assumed globally.
The problem is that the recovery of conventional ultimate versus the amount generated in the Petroleum System (efficiency factor) is very low. The estimate of the amount of oil generated in the kitchen of a Petroleum System needs to be measured using elaborated equipment such as RockEval in few key wells, measures which hard to get. We (Laherrère J.H., A.Perrodon, G.Demaison 1994 "Undiscovered Petroleum Potential" Petroconsultants report, 383p) estimated that the efficiency factor is 0.03 % for Paris Basin,0.4% for Gippsland, 0.6 % for Niger Delta, 0.8 % for Saharan Triassic, 1% for North Sea and 1.4 % for Arabo-Iranian PS.
The oil in place in conventional field is mainly a guess because depending on discrete few values from wells fitted to seismic surveys. Oil in place in continuous-type (source & reservoir rock) is more difficult to estimate. Recent successes in tight reservoirs come mainly from increase in oil & gas price, horizontal drilling and frac. But the example of Bakken in Montana shows that the largest field Elm Coulee is in fact a stratigraphic field due to better porosity, with definite boundaries, not to be extrapolated to the rest of the basin.
Having spent 5 years exploring Canada, I was very interested by the discovery of Elmworth in the deep basin, in an area where already 200 wells had penetrated the tight reservoir. John Masters who led the discovery by Canadian Hunter Exploration wrote a book in 1980 "The Hunters" stating that the potential recoverable resources of the Deep basin is 440 Tcf (page 77). Elmworth ultimate is now estimated around 5 Tcf. The Britannica Riva site gives 560 Tcf for Elmworth discovered in 1976. In OGJ 15 Nov.1993 Elmworth is stated as Canada's largest gas field.
In the 2006 NRC report "Canada's energy outlook" only CBM is considered in unconventional gas.
The USGS in its last estimates of continuous-type accumulations has neither released the detail of the volume in place nor the used recovery factor: it should be very low, but no one is able to give the right answer

-Modelling of future "*oil*" production

Future production is modelled by drawing a curve with several cycles and the area below the complete curve from start until the end of production represents the ultimate. The model has to fit past data with value and slope.

-**Cumulative discovery & production**

We start with cumulative crude oil less extra heavy (or cheap oil) with 2 Tb (2000 Gb) ultimate. With 3 cycles for exploration (surface exploration, seismic, deepwater) and 2 cycles for production (pre-shock and after shock), the oil midpoint production is in 2005 and the oil peak in 2012 .
Figure 51: **World cumulative crude oil (less extra-heavy) mean discovery & production with forecast for an ultimate of 2 Tb 1900-2075**

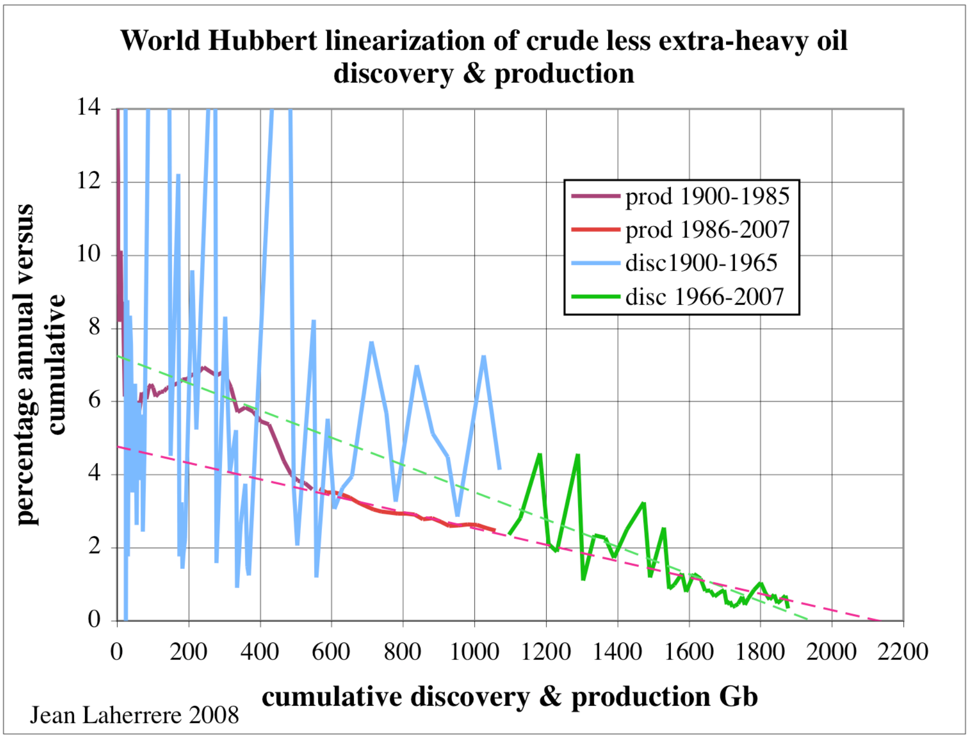


Present cumulative discovery is over 1800 Gb, leaving less than 200 Gb for yet to find, which is less than the accuracy of the ultimate (taken with only one significant digit to clearly show its inaccuracy).

Hubbert linearization (percentage of annual versus cumulative plotted against cumulative and extrapolated with a linear trend) of oil production is used by many to get the oil ultimates. The plot is usually not straight (only if the pattern is logistic) and the extrapolation depends upon the chosen period. It should be used carefully and combined with the discovery (which should be the backdated mean)

The plots for crude less extra-heavy oil discovery and production trend towards roughly 2000 Gb.

Figure 52: **World Hubbert linearization of crude oil (less extra-heavy) mean discovery & production**

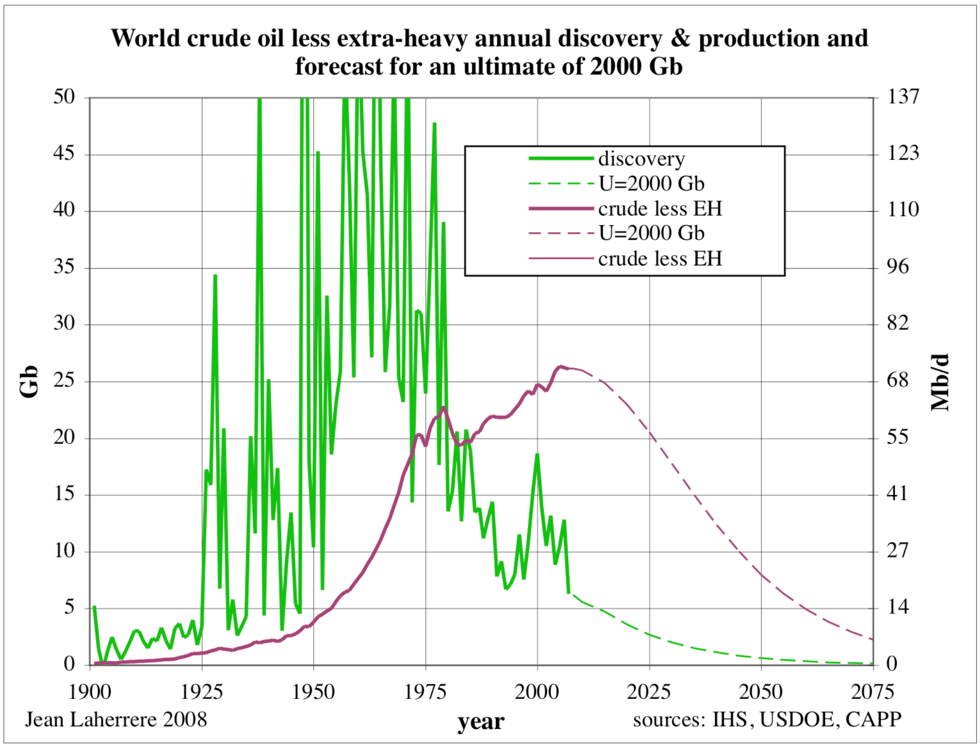


- **-World annual “oil”**

-Crude oil less extra-heavy discovery & production

Annual crude oil less extra-heavy discovery peaked around 1960 and production may peak in 2012. The model represents the best that Nature can offer, if there is no above ground constraints. It is likely that there will be not a peak, but a **bumpy plateau** (with chaotic prices) because constraints from demand or investments or politics. Paul Volcker (former head of the Fed) forecasted in 2004 75% chances to have an economic crisis in the next 5 years. Last year his successor Alan Greenspan, now retired, stated that there is a 33% chances of a depression in 2007. The housing price bubble, which has allowed consumers to borrow and consume more than necessary, is ending. It is funny to see top position managers expressing their belief as soon as they retire: Bernabe ENI in 1998; Bowling ARCO in 1999, Volcker, Greenspan.
Claude Mandil, just before retiring last year, said that IEA 2006 reference forecast is unsecured, unattainable, unrealistic and unsustainable.

Figure 53: **World annual crude less extra-heavy oil mean discovery and production with logistic model for U = 2000 Gb** (no above ground constraint) 1900-2075



-liquids production: peak or bumpy plateau?

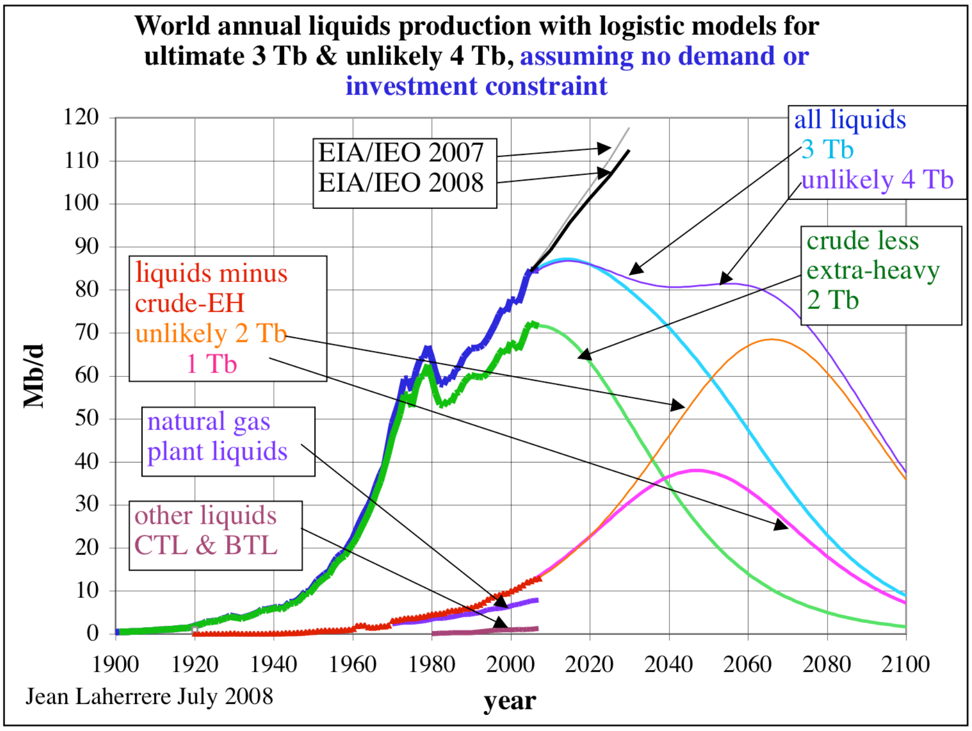
The oil demand, as it is published by USDOE/EIA and IEA, includes all liquids even synthetic oil as GTL (gas-to-liquid), CTL (coal-to-liquid) and BTL (biomass-to-liquid).,
All liquids ultimate is estimated at 3 Tb being the sum of

-crude less extra-heavy	2000 Gb
-extra-heavy	500 Gb
-natural gas liquids and GTL	250 Gb
-synthetic oil (BTL, CTL) & refinery gains	250 Gb

Crude oil less extra-heavy (cheap oil) is modelled in the previous graph with an ultimate of 2 Tb. The rest (being **expensive oil)** is modelled (red curve) with an ultimate of 1 Tb with a peak around 2050. The all liquids (2 Tb +1 Tb ultimate) peak is around 2015 and over 90 Mb/d, but this is theoretical assuming no constraint from demand or from investments. Skrebowski (Petroleum Review 2006) has forecasted an oil peak in 2010 at 94 Mb/d looking only at all planned *megaprojects*.

Doubling the ultimate of expensive oil (red curve), making the all liquids ultimate at 4 Tb, **will not change the oil peak date**, changing only the slope after the peak.

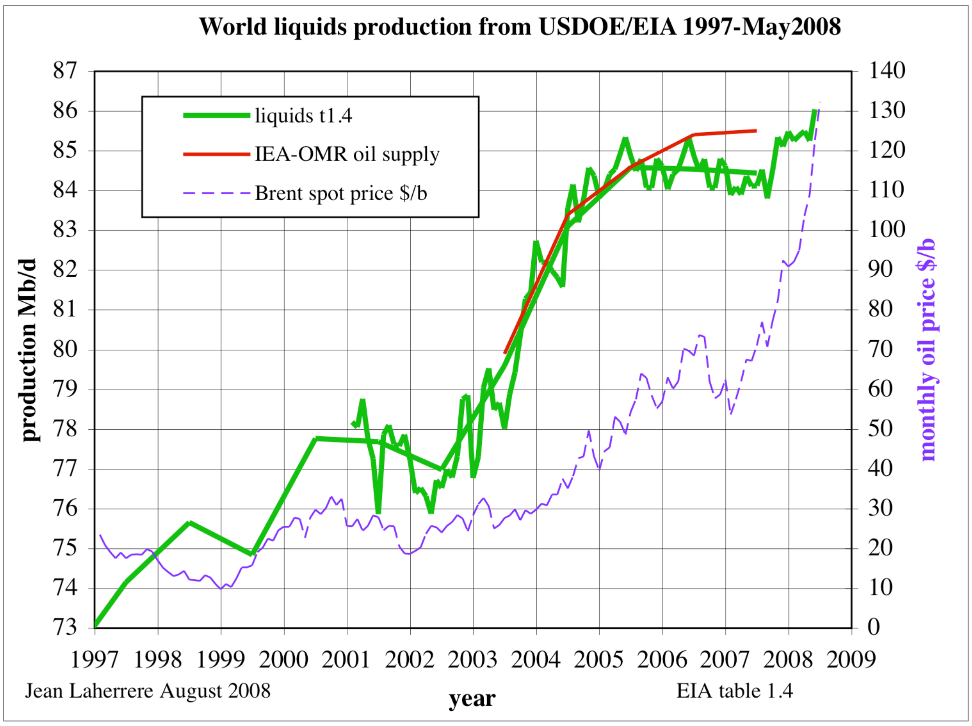
Figure 54: **World liquids production** (no demand or investment constraint) **1900-2100 for an ultimate of 3 & 4 Tb**



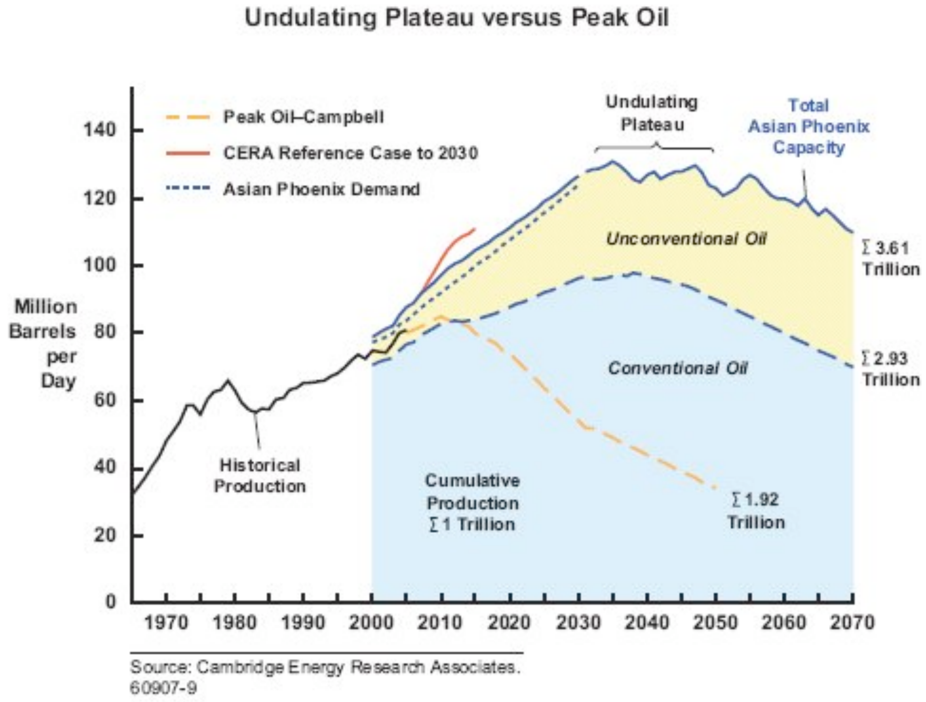
This graph is drawn as the previous one with the assumption that the constraints are only from the resources, but that above ground constraints from the demand, investments or politics will not occur that is unlikely. That is why since 2001 that I forecast a bumpy liquids plateau with chaotic oil price.

On the last monthly data from USDOE on liquids, what do we see: a plateau? or just one more step as in 2001?

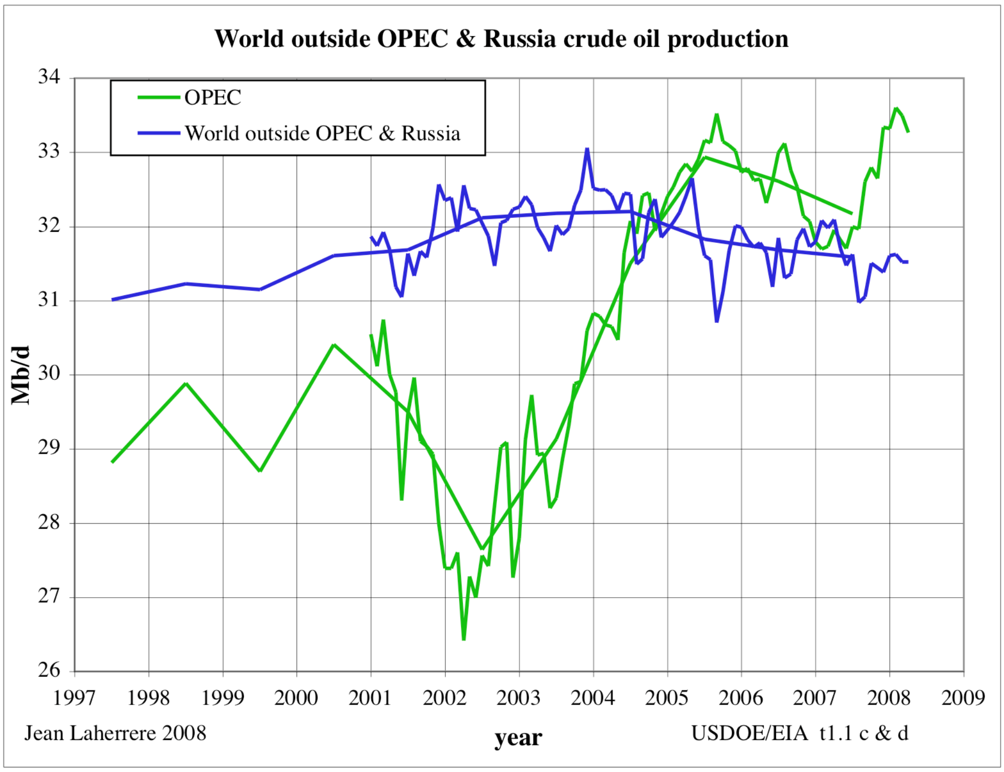
Figure 55: **World liquids production 1997-May 2008**



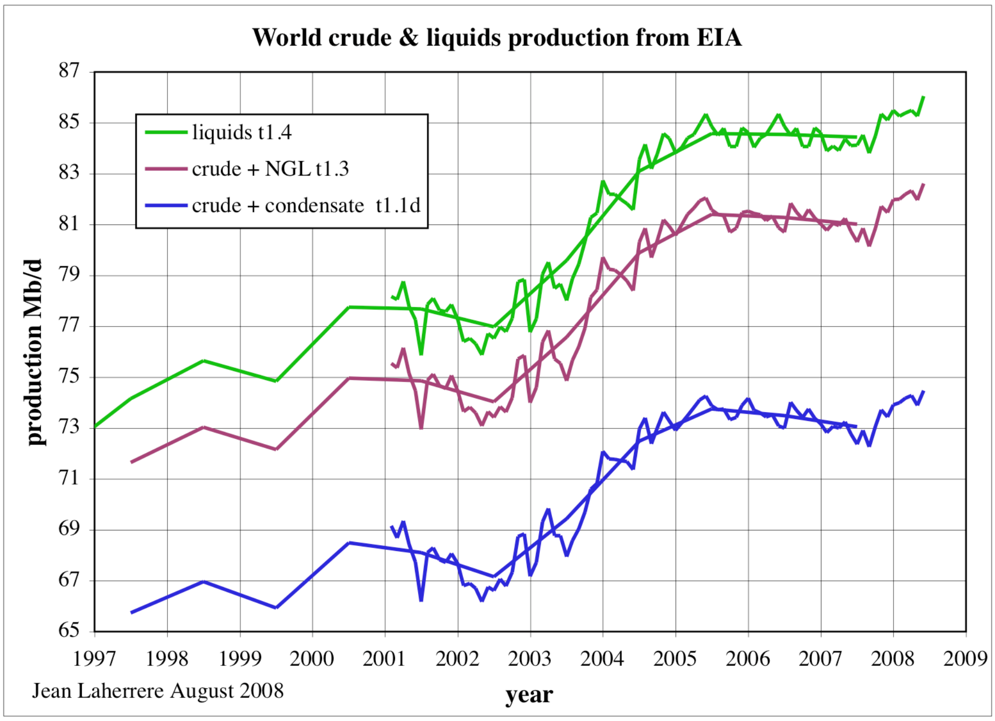
The liquids production seems to be entering a bumpy plateau.
CERA has not said anything new, but its undulating plateau is for the period 2030-2050 and for a volume described by Total CEO de Margerie as almost impossible!
Figure 56**: CERA 2007 forecast for world liquids production**



Crude oil production outside OPEC (now including Angola) and outside Russia seems to have peaked in 2004.
Figure 57: **Non-OPEC, Non-Russia crude oil production 1992-2008**



But the claim made by some for a 2005 peak for crude oil (which includes condensate in USDOE report) seems to be contradicted by the production of February 2008
Figure 58: **World crude oil & liquids production 1997-May 2008 from EIA**



-Conclusions

Human behaviour is often irrational, when Nature is easier to understand.

Nature is mainly cyclic and can be modelled often with few cycles, the problem is how to guess the next one

The main rules are:

-what goes up must down

- linear is only local and tangent to a curve

The main advices:

-understand the accuracy of your estimate and never use more than 2 significant digits in the oil industry

-understand the motive of any statement and ask for definition of terms & for technical data

-be aware that most published data is political or financial, most technical data being confidential

-do not underestimate time

-always display the full historical series and refuse statement based on selected short period

The more I know and the more I know that I do not know, and the others neither.

Keep asking and searching: if the earth is limited, the yet to find in science is huge.