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Why are remaining oil & gas reserves from political/financial sources and technical sources so different?

Jean Laherrere ASPO France

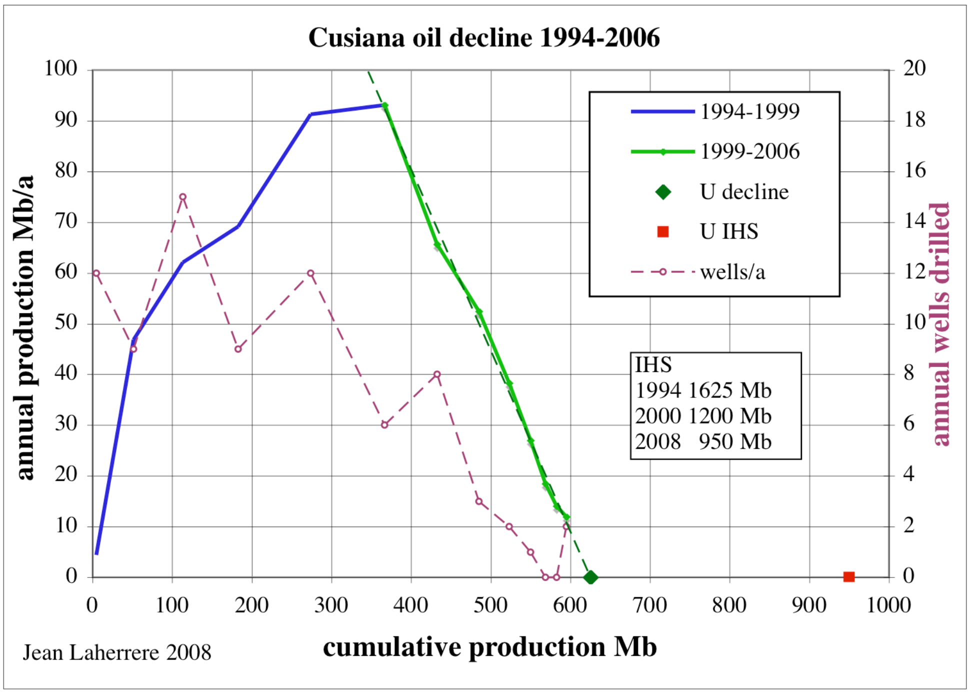
Part 3

-Colombia

-Cusiana

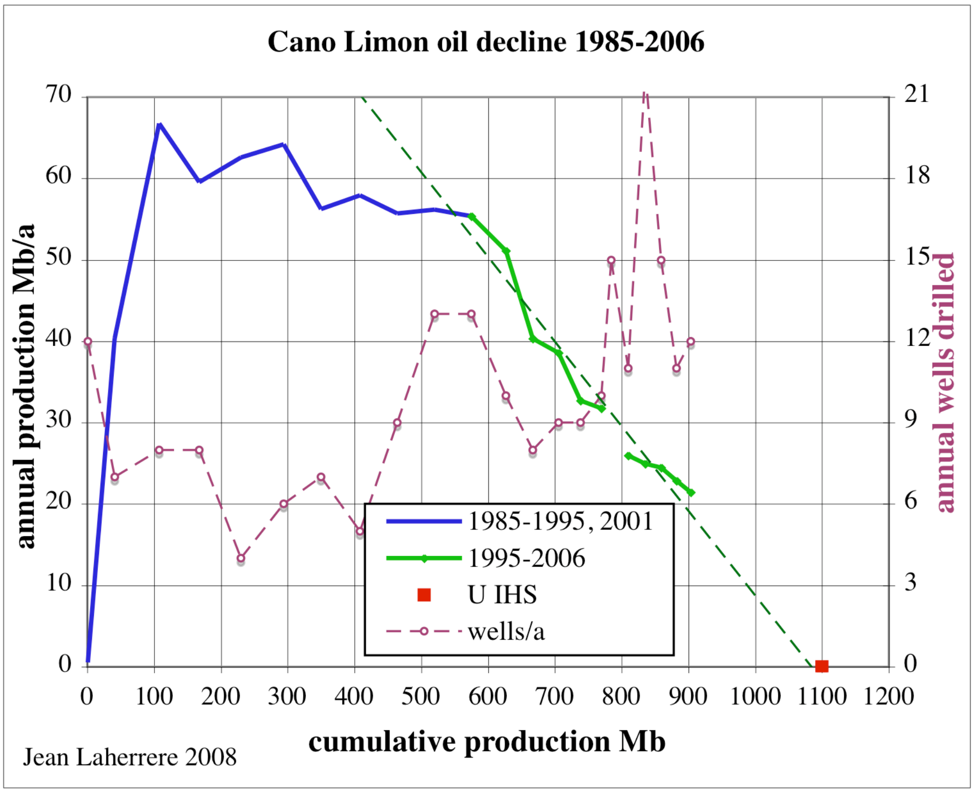
I was in charge of the Total worldwide exploration techniques when Cusiana was proposed to the management and was discovered. I was directly involved in the recommendation to continue drilling and testing when the operator proposed twice (after a VSP and a log) to stop the well. When discovery was released in the media, partners reported different ultimates: Triton 3 Tb, BP 1.5 Gb and Total 1 Gb. Now decline is trending towards less than 0,65 Gb, when IHS is still reporting 0.95 Gb. The operator was too optimistic.

Figure 68: Cusiana oil decline 1994-2006



In the same basin, Cano Lemon displays a different decline pattern (disturbed by multiple bombing of the pipeline) in line with the reported ultimate of 1.1 Gb.

Figure 69: Cano Limon oil decline

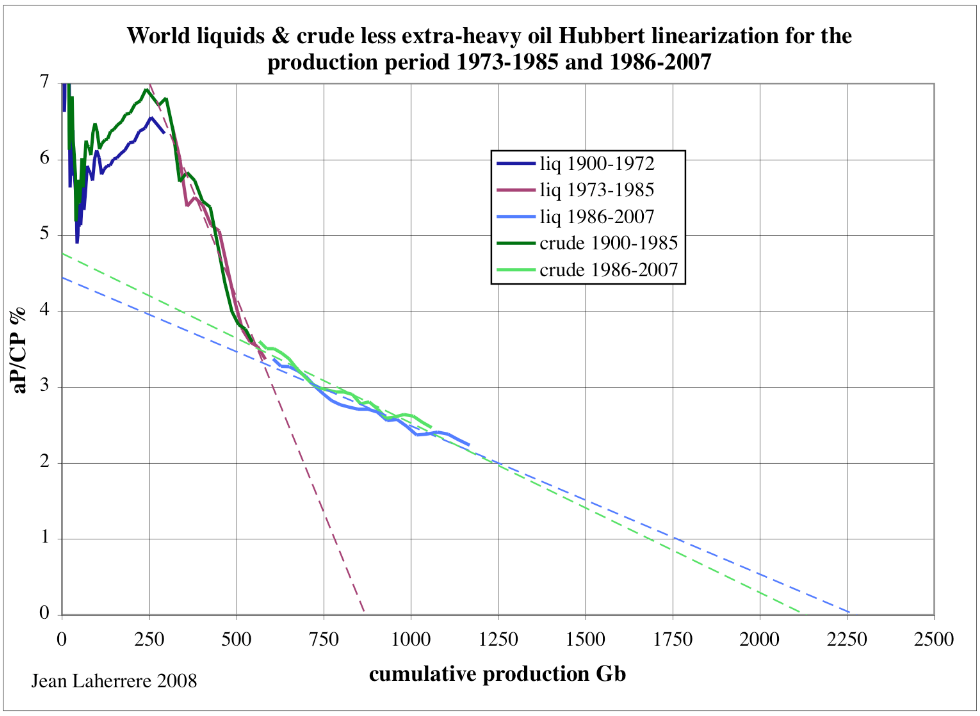


-Ultimate and Hubbert linearization

Hubbert linearization is used by many to estimate ultimate from production, but linear extrapolation works only if production follows a logistic curve (in fact derivative). Some portions are linear, but not all the curve, so it is hard to believe that the last linear portion will be the last one.

World liquids production or crude oil less EH displays a Hubbert linearization far from being one simple linear trend. There is a roughly linear portion from 1973-1985 (first oil shock to the oil counter shock) and another rough linear portion from 1986 to 2007. The coming depression could change this trend as 1985 did.

Figure 70: World liquids and crude oil less extra-heavy Hubbert linearization for 1973-1985 and 1986-2007



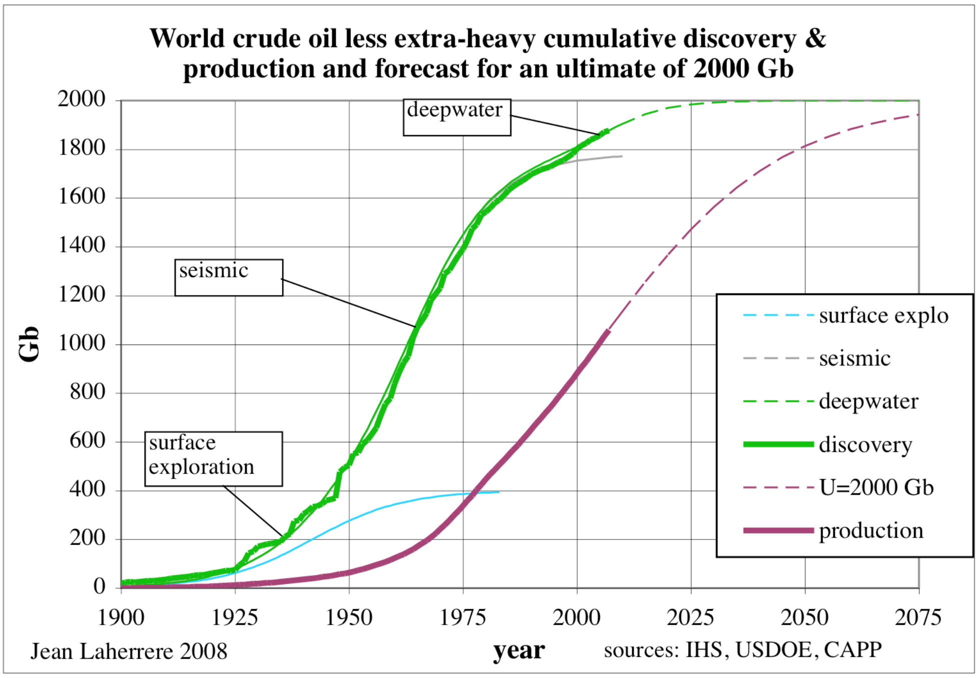
For crude less extra-heavy (EH) oil the Hubbert linearization (green trend) for the period 1986-2007 is about 2100 Gb, but the extrapolation of the cumulative discovery fits better with a 2000 Tb, yet the accuracy is not good enough to exclude 2100 Gb. But it is obvious that the linearization for liquids trending towards 2250 Gb is wrong, because the difference between *liquids* and *crude less EH oil* is much higher than 250 Gb including EH (about 500 Gb), NGL (about 250 Gb) and refinery gains + synthetic oils (= GTL, CTL and BTL) that are difficult to estimate. We believe that the *crude less EH oil* ultimate is about 2 Tb = 2000 Gb and *liquids* ultimate about 3 Tb. The accuracy of such an estimate is less than 10 %, so 100 to 200 Gb can be added (or subtracted) in the future without changing much this rounded estimate

Hubbert linearization of oil production is a poor way to estimate ultimate. It is done by many because it is the only data they have.

Extrapolation of discovery data (in particular the creaming curve) is a much reliable tool, when reserves estimates are close to the mean (expected value) and are backdated. Current proved values are useless as shown in the first graph.

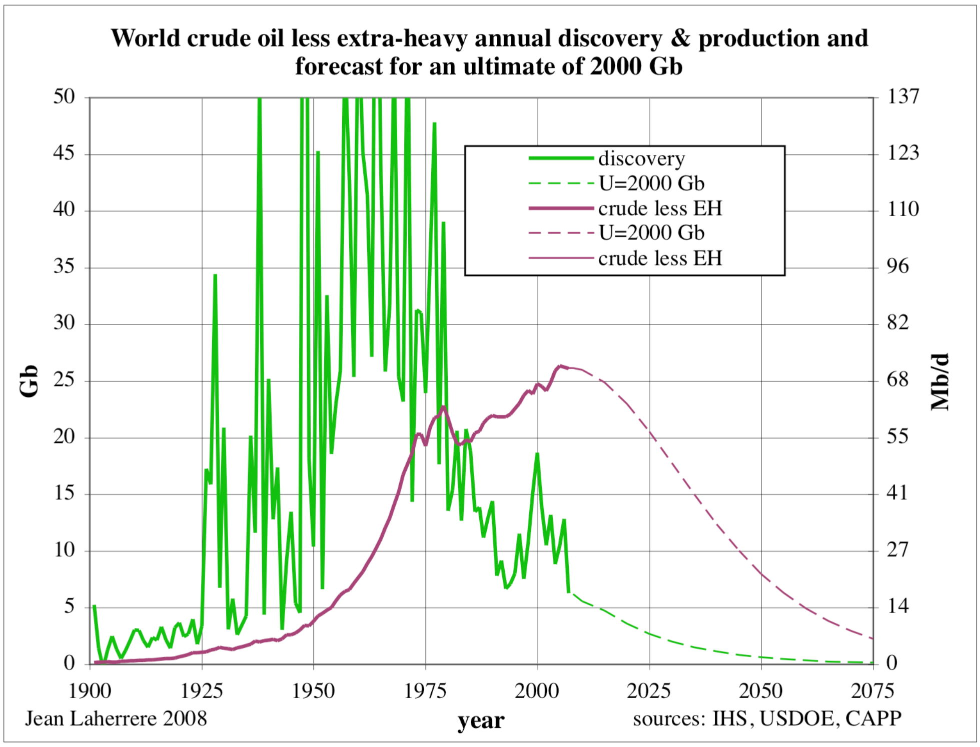
Cumulative mean backdated discovery can be easily modelled with a S curve (logistic curve) or in more detail with three S curves, the first one corresponding to the surface exploration up to 1945, the second with seismic exploration up to 1995 and the last one being deepwater. If there is no new cycle (most of the petroleum systems have been drilled (even Antarctica with JOIDES) and their potential evaluated looking a t the possible source-rocks: a few wells are enough for that). The yet to find YTF can be deducted from the known cumulative discovery (about 1,9 Tb) and the rounded 2 Tb ultimate. YTF is less than 200 Gb for easy oil.

Figure 71: World *crude less extra-heavy oil* **cumulative** discovery and production with forecast for an ultimate of 2 Tb



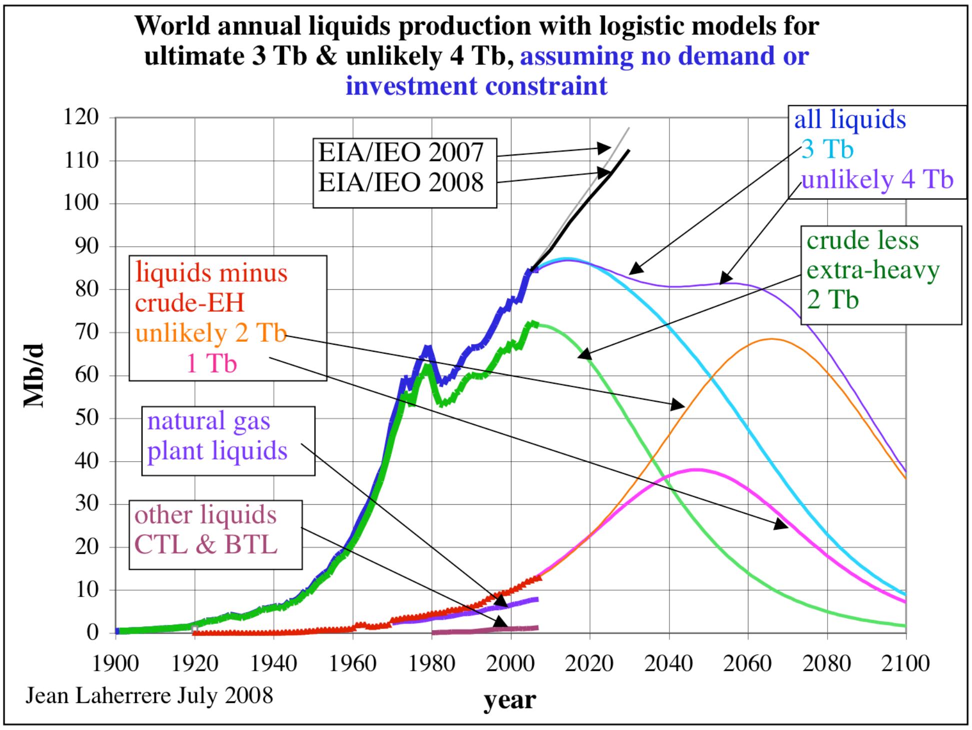
The annual production forecast with the same ultimate shows that the *crude less EH oil* has peaked in 2006 at 71 Mb/d and the 2 Tb ultimate forecasts a production of 55 Mb/d in 2025.

Figure 72: World *crude less extra-heavy oil* **annual** discovery and production with forecast for an ultimate of 2 Tb



But *liquids* is the aggregation of "*cheap oil*", "*expensive oil*", *NGL*, *refinery gain* and "*synthetic oils*". The difference between the *liquids* and the *crude less EH oil* represents the *expensive liquids* and can be modelled (in red) with an ultimate of 1 Tb (likely) or even 2 Tb, but the peak is not changed because expensive liquids need time. A *liquids* ultimate of 4 Tb could provide a plateau.

Figure 73: World *liquids* production for ultimate 3 & 4 Tb assuming no surface constraint



Also time of development is always considered too optimistically, hoping that everything will be all right. But there is the Murphy's law! In Nature it is not possible to make one baby in one month with nine women!

Time is an important factor which is usually underestimated.

The Mc Namara law (from NASA experience) said for frontier projects that the ratio between initial proposals and reality is about pi for cost and e (Euler number = 2,7) for time.

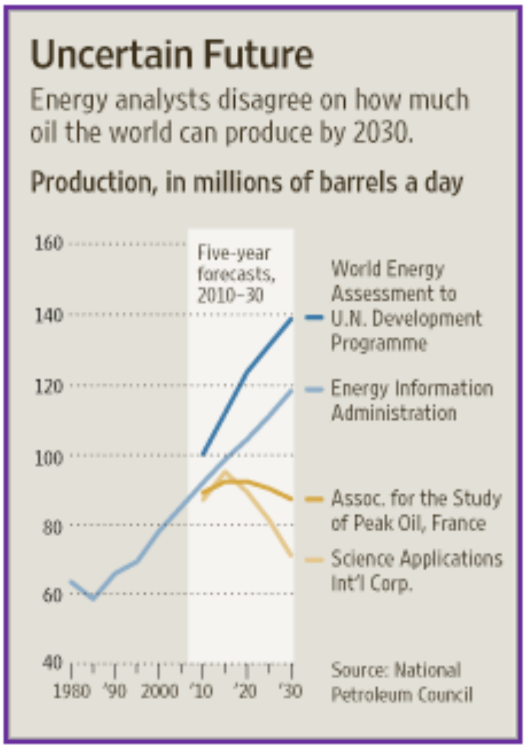
Furthermore this modelling assumes that constraint *under the ground* is only geological, but constraint *above the ground* that is political (civil war in Iraq and Nigeria, nationalisation in Russia and Venezuela), financial (investment on supply, depression on demand) could also change the curve, still the area below the curve has to stayed the same being equal to the ultimate.

The forecast by USDOE/IEO 2008 (as IEA 2007) is mainly political called Business as Usual (BAU) to please our society of consumption addicted to growth.

But constant growth is impossible in a limited environment and what goes up has to come down one day!

National Petroleum Council 2007 Hard truths was taking ASPO France forecasts (as shown above) as reference

Figure 74: World liquids production forecasts by NPC from WSJ 19 Nov 2007



-Creaming curve

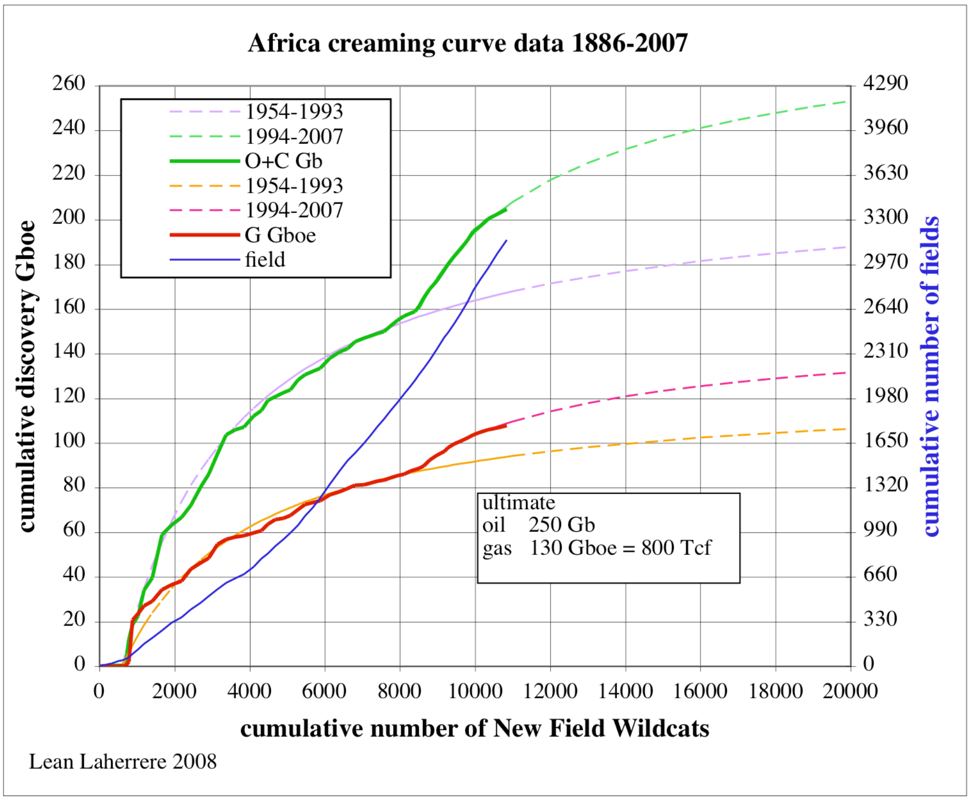
Creaming curve (invented by Shell in the 80s) is the cumulative discovery versus the cumulative number of New Field Wildcats (NFW). It should use backdated mean value to be reliable. It is rarely used because the number of NFW is often confidential and difficult to get. The cumulative discovery versus time is much more difficult to model because the stop and go of exploration.

I am always amazed how easy it is to model a creaming curve of a continent or a country with several cycles, each cycle with a hyperbolic curve. This hyperbola corresponds to the well known law of diminishing returns in minerals exploration. The large ones, easy to find as large, are found first and the small ones are found later.

Africa can be modelled with two cycles: the first 1954-1993 is the conventional and the second 1994-2007 is deepwater (as also the Berkine basin in the Sahara).

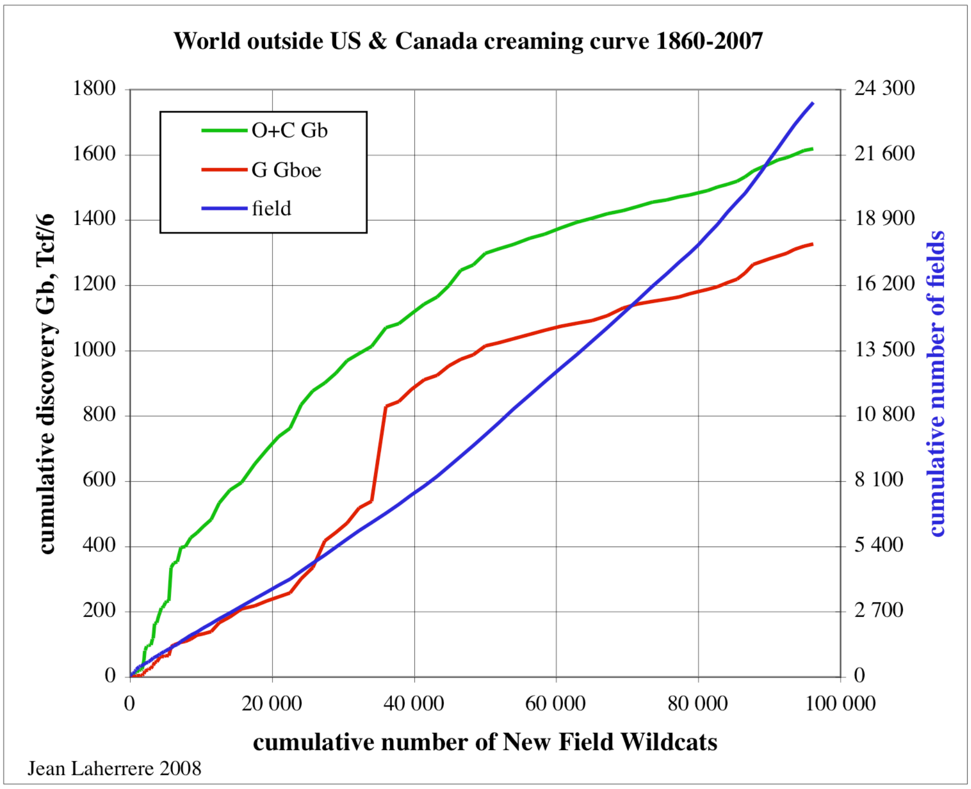
It is also fascinating to see that a new cycle occurs without changing the slope of the cumulative number of fields (blue curve) (corresponding to success ratio)

Figure 75: Africa creaming curve 1886-2007



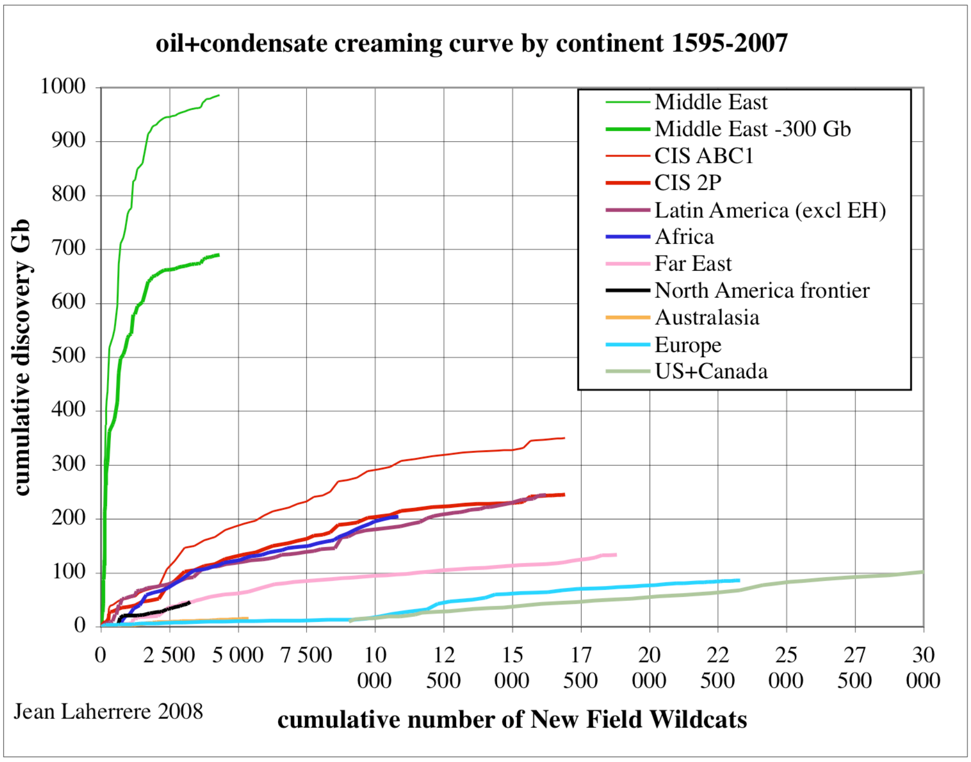
The creaming curve of the world outside US & Canada is more difficult to model being an aggregation of too many geological basins

Figure 76: World outside US & Canada creaming curve 1860-2007



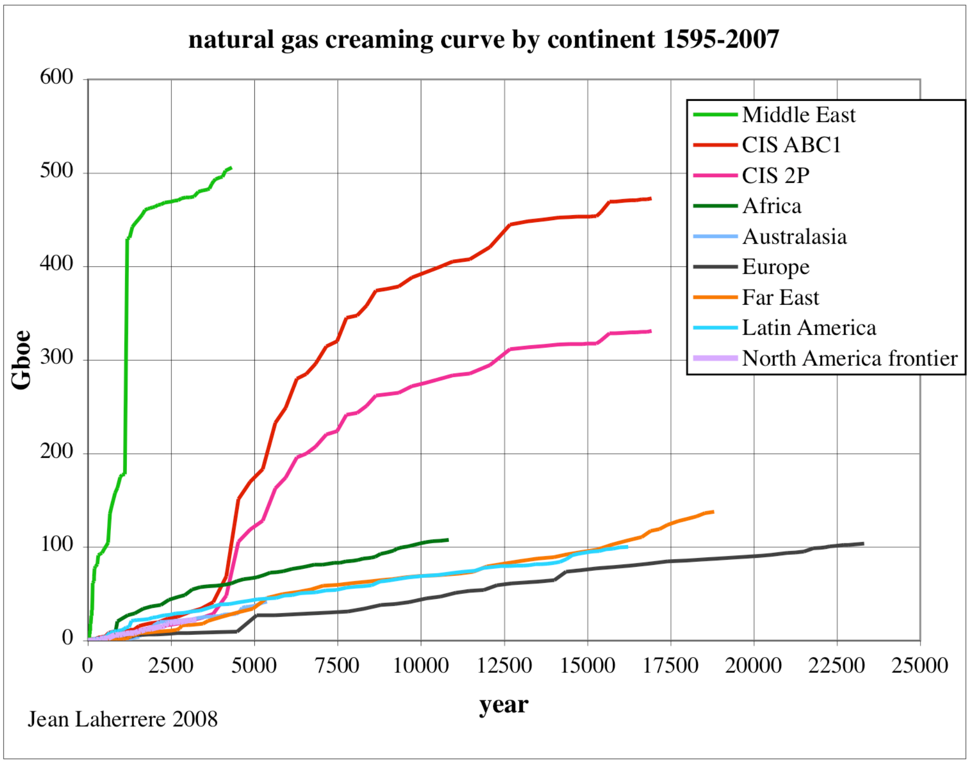
The oil+condensate creaming curves by continent (before and after correction for ME and CIS) display a wide range of endowment, first ME being largely gifted, second CIS, Latin America and Africa are similar with good endowment, third North America frontier and Far East with fair, and last Europe and US+Canada with poor endowment, needing lot of drilling.

Figure 77: oil+condensate creaming curve by continent 1595-2007



For natural gas, again first ME is largely gifted, second CIS and third the rest

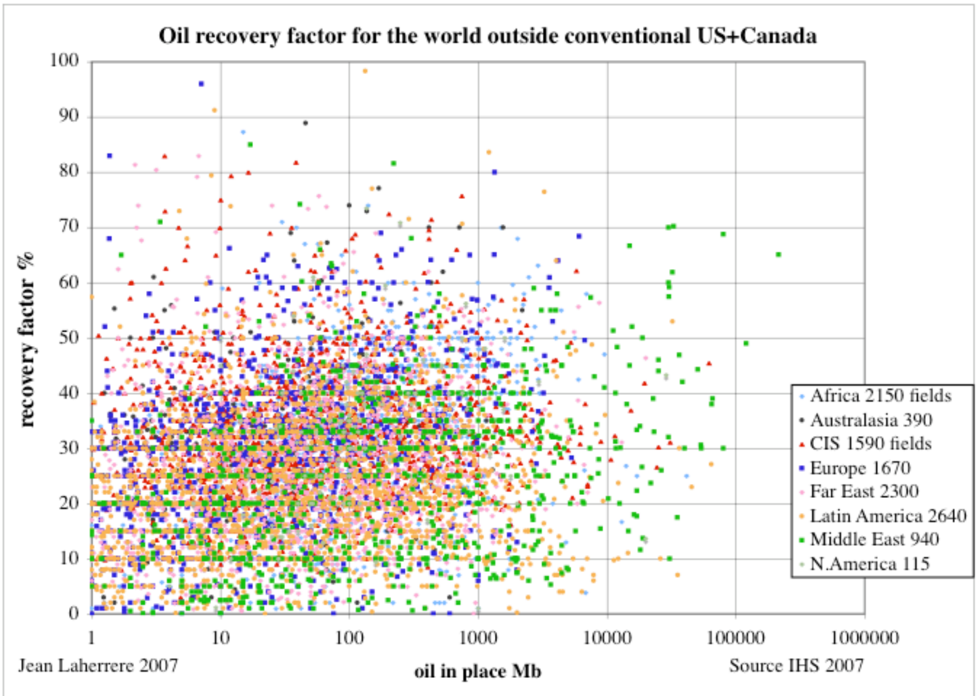
Figure 78: natural gas creaming curve by continent 1595-2007



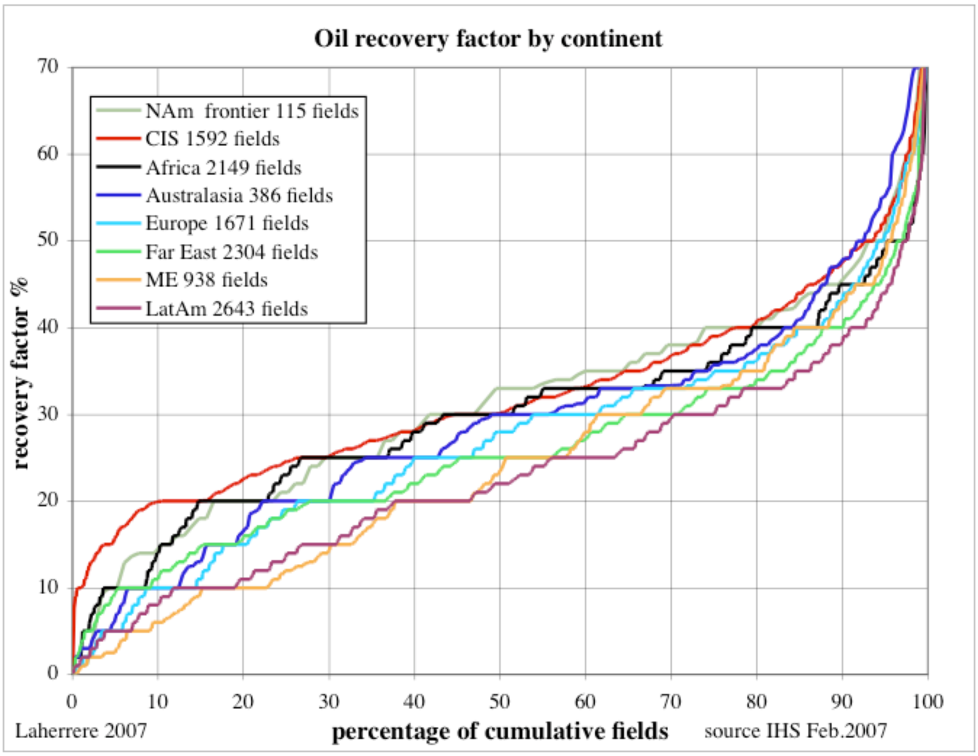
-Recovery Factor (RF)

Recovery factor was used in the past to estimate reserves by computing first the oil in place from the seismic structure area, net pay, porosity, saturation, volume factor and oil in place multiplied by

recovery factor gives the reserves. Recovery factor was mainly guessed and often using a round number (multiple of ten or five).
Computing an average is useless because the average varies when computed from the number of fields or from the volume of reserves.
RF as guessed and oil in place estimate can be improved only with new wells or new seismic. In contrary reserves estimates improve with time with new production data When a field is abandoned, reserves are exactly known but oil in place still guessed.
Now reserves are estimated through modelling using Monte Carlo runs to simulate the life of the field, assuming a certain development (producers and injectors) and data from seismic, logs and tests. The number of cells for simulation can reach 100 millions. The cumulative production of the model at the end represents the reserves and oil in place or recovery factor are not used.
The plot of oil RF versus oil in place log scale displays a large cloud, because RF varies from almost zero to 90%, but concentrated below 50%
Figure 79: oil recovery factor for the world outside US & Canada

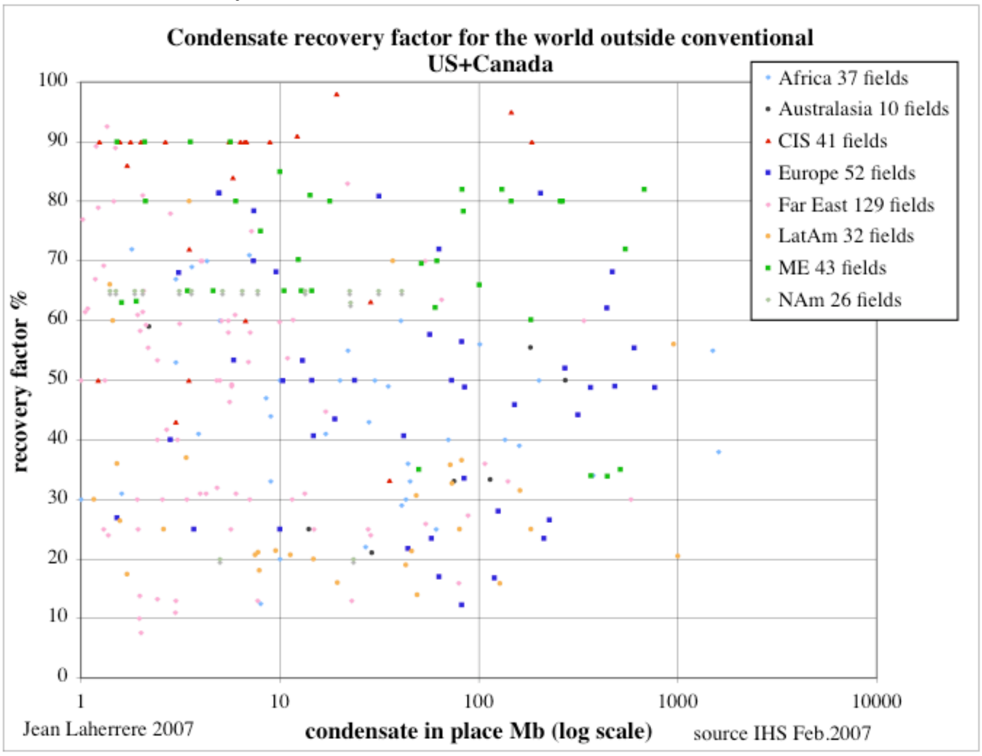


If world average RF has little interest in absolute, it is interesting to compare by continent the RF versus the percentage of cumulative number of fields.
For oil CIS is at the top confirming overestimation.
Figure 80: oil recovery factor by continent



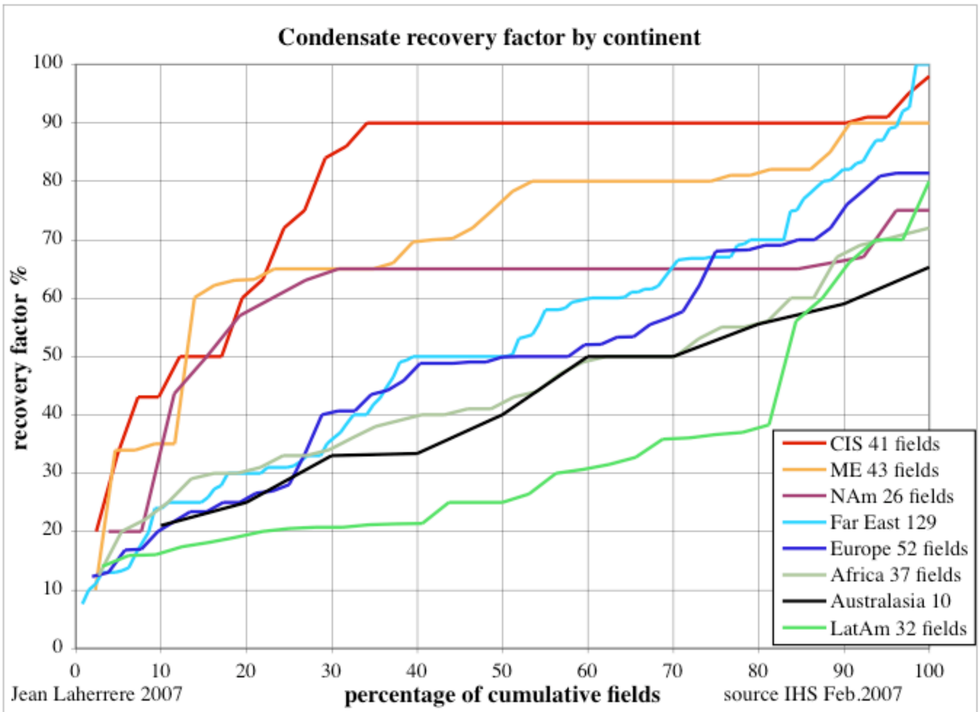
For condensate there are less values, but the cloud is also very large from 10% to 90%

Figure 81: condensate recovery factor for the world outside US & Canada

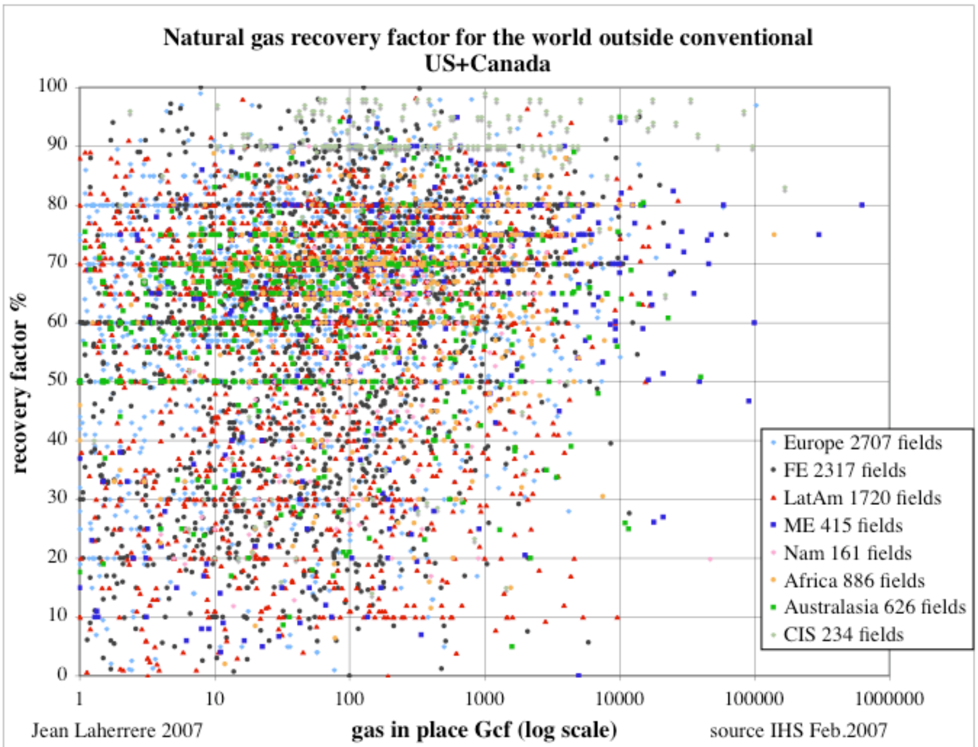


CIS is without any doubt too high, but Far East too low compared to others.

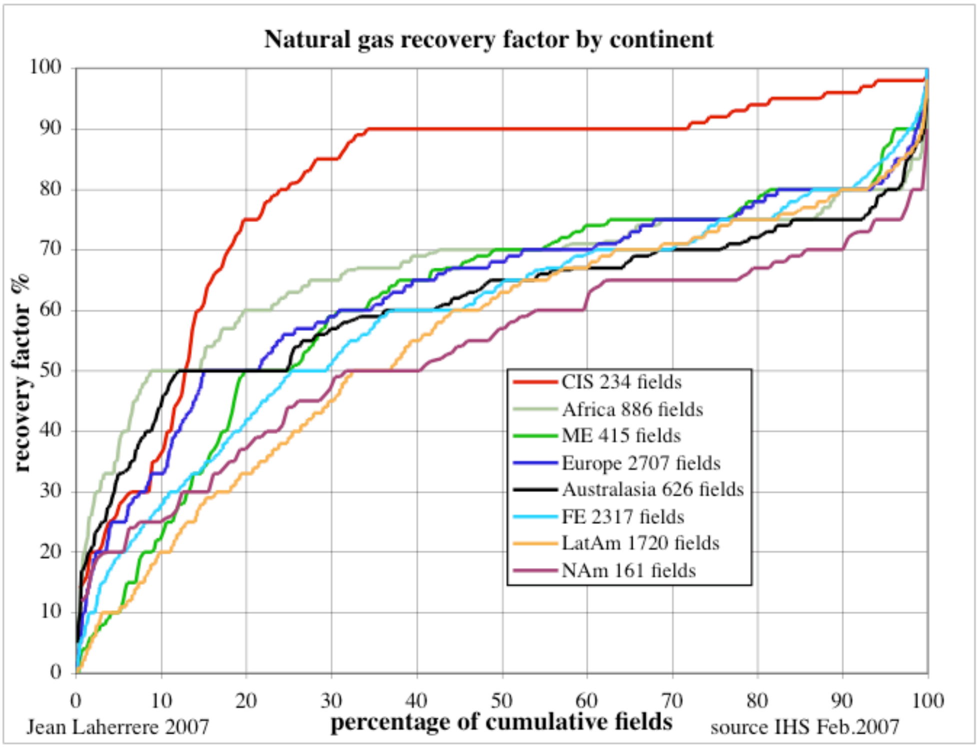
Figure 82: condensate recovery factor by continent



For natural gas the cloud is also very large but the concentration is of course higher than for oil
Figure 83: natural gas recovery factor for the world outside US & Canada



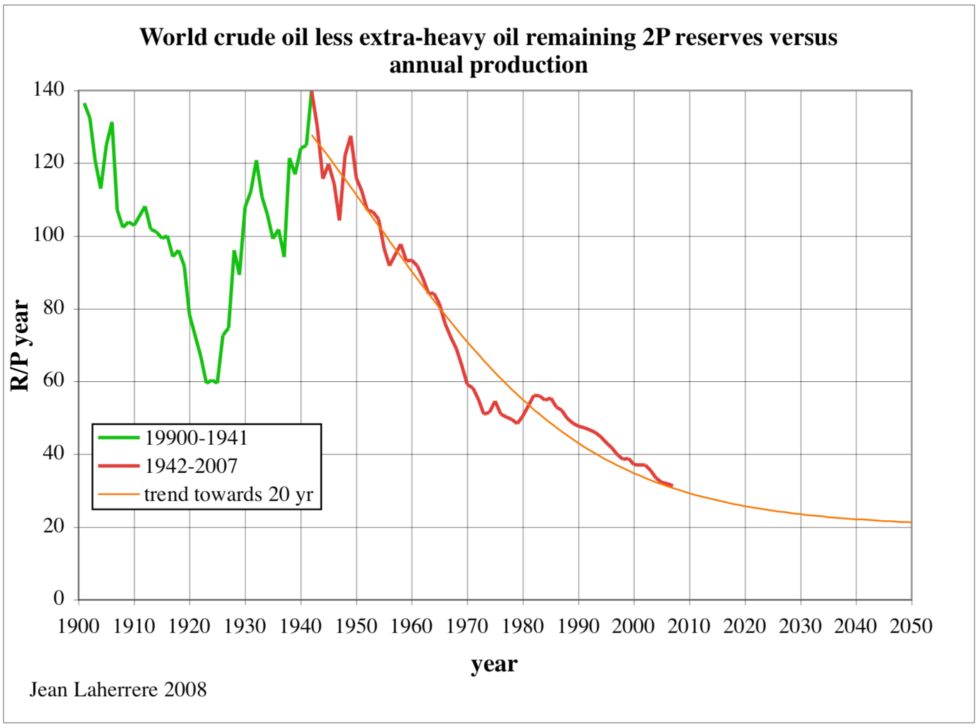
In the display by continent, CIS is by far above other continents, confirming a different classification (ABC1) and overestimation.
Figure 84: natural gas recovery factor by continent



-R/P

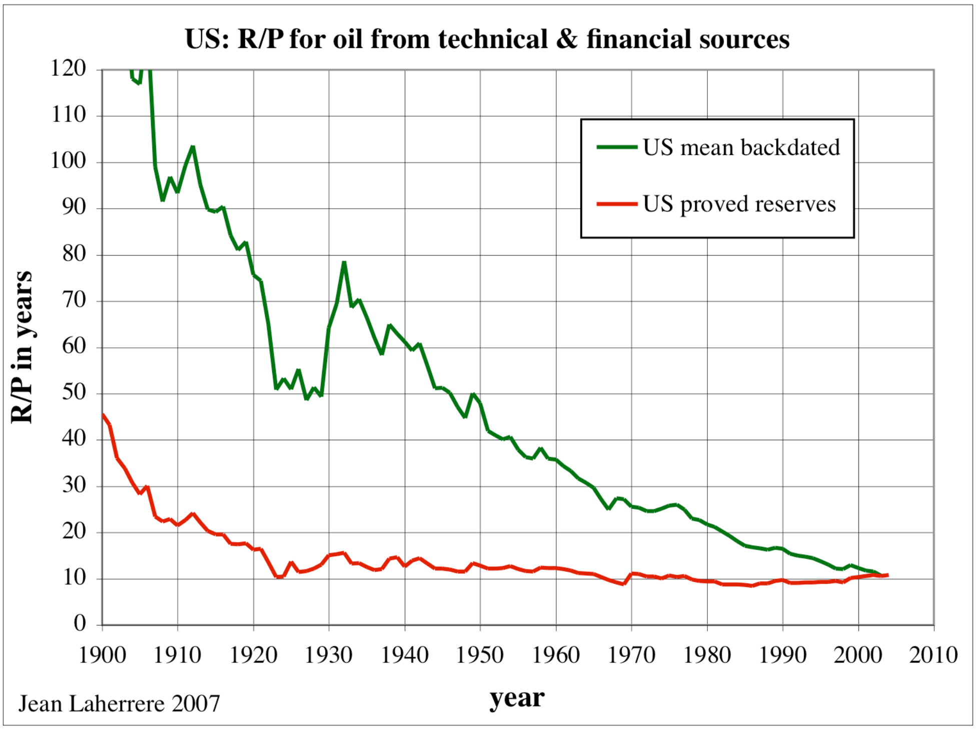
Most of the media use R/P (remaining reserves versus annual production) in years to qualify the remaining potential of fossil fuels: 40 years for oil, 60 year for gas and 200 years for coal. This indicator is a poor one, first because based on political wrong data and second because the production does not stay flat until exhausted to drop the following year to zero. The best proof of poor indicator is that US R/P has been 10 years for the last 80 years and likely it will stay at 10 years until the last produced barrel (the last remaining 9 barrels reserves will go back to resources)
Using technical data the world R/P was up and down, presently declining from 140 years in 1940 to 30 years now and trending towards 20 years.

Figure 85: World crude less EH oil R/P 1900-2007



For the US, R/P from proved reserves has been around 10 years since 1920 and likely will stay until the end. It corresponds to a rule of thumb (sometimes used by USGS) where reserves are estimated at 10 times annual production. R/P from backdated mean reserves was over 100 years in 1900 and from 1930 at 80 years decreases slowly to 10 years.

Figure 86: US R/P from proved reserves and mean backdated reserves 1900-2006



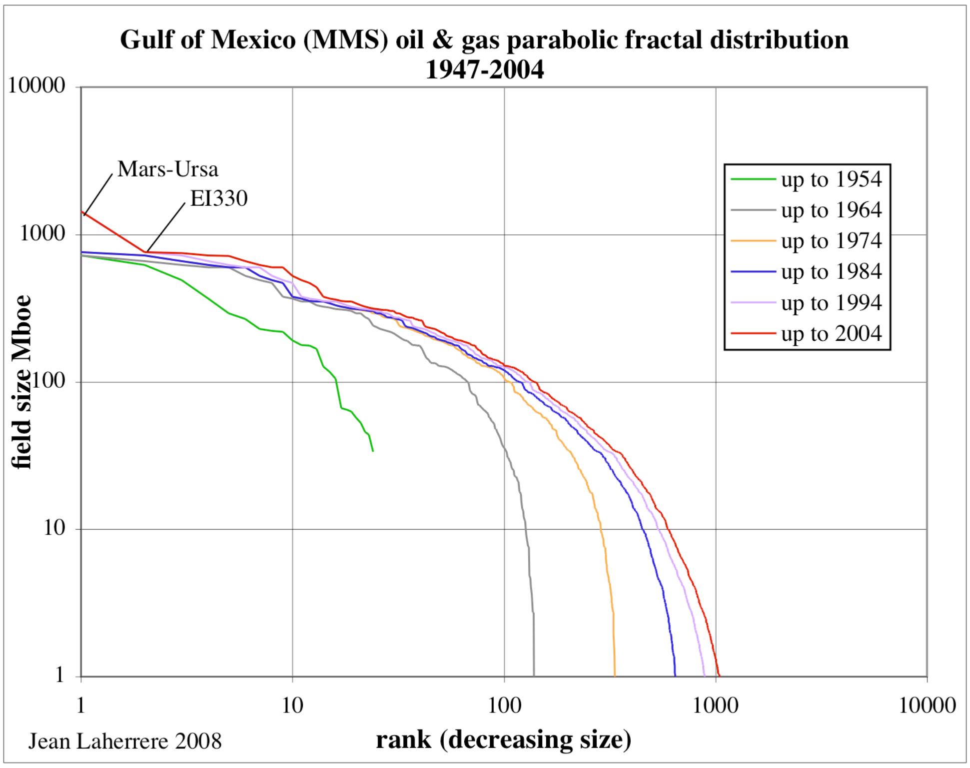
R/P is a poor indicator and should not be used; for forecasting the future.

-GOM

GOM MMS database is the most complete reliable database, but slow to update, presently end 2004.

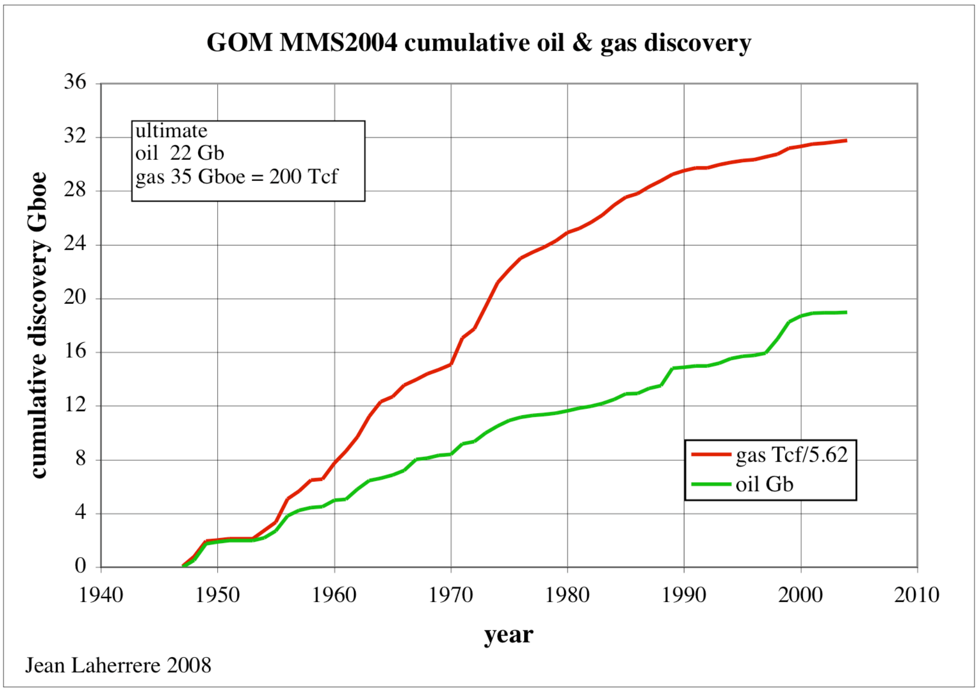
GOM field discovery could be displayed with a fractal distribution with evolution every 10 years. The large oilfields are found first. Unfortunately Mars and Ursa are grouped being the largest field, disturbing the field fractal distribution.

Figure 87: GOM (MMS 2004) oil & gas parabolic fractal distribution



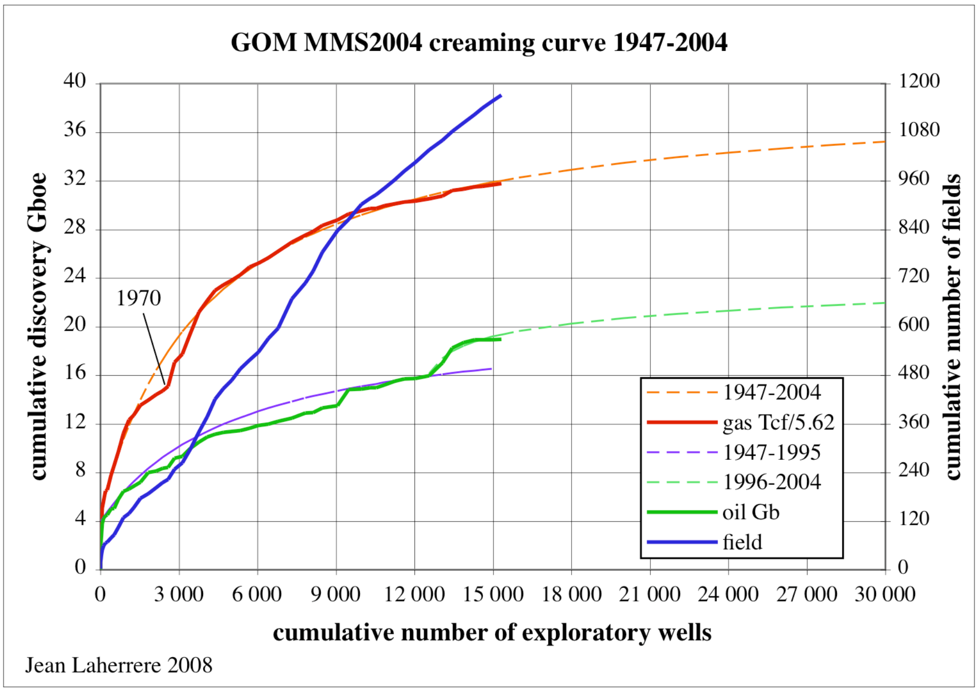
The cumulative discovery of oil and gas in Gboe shows that gas is more frequent than oil, but extrapolation versus time is not easy, better go to creaming curve.

Figure 88: GOM (MMS 2004) cumulative oil & gas discovery



The creaming curve can be easily modelled with two cycles for oil and one for gas. Ultimates is estimated at 22 Gb for oil and 35 Gboe = 200 Tcf for gas.

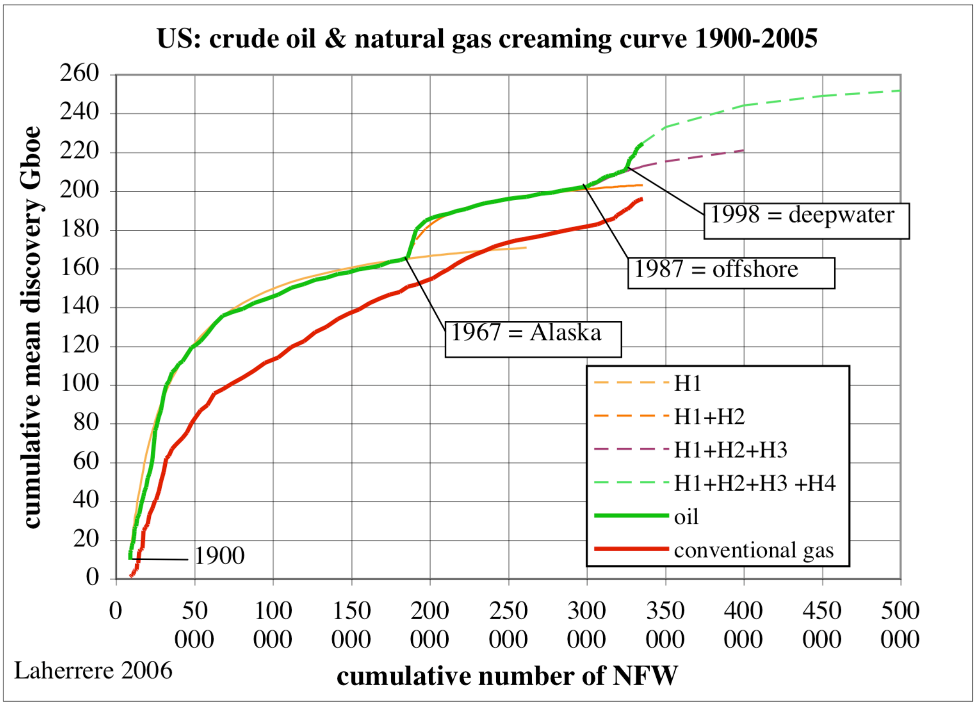
Figure 89: GOM oil & gas creaming curve 1947-2004



-US

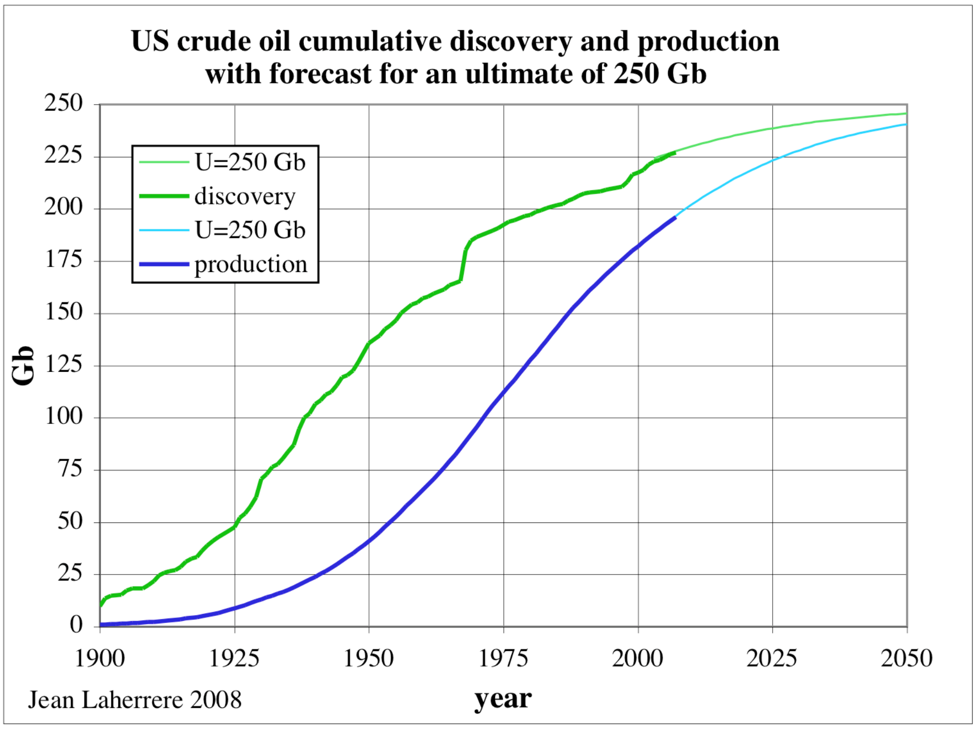
The US oil creaming curve was in 2006 modelled with different cycles: 1900-1967= Lower 48, 1967-1987 adding Alaska, 1987-1998 adding offshore 1998-2005 adding deepwater towards an ultimate of 250 Gb.

Figure 90: US crude oil & natural gas creaming curve 1900-2005



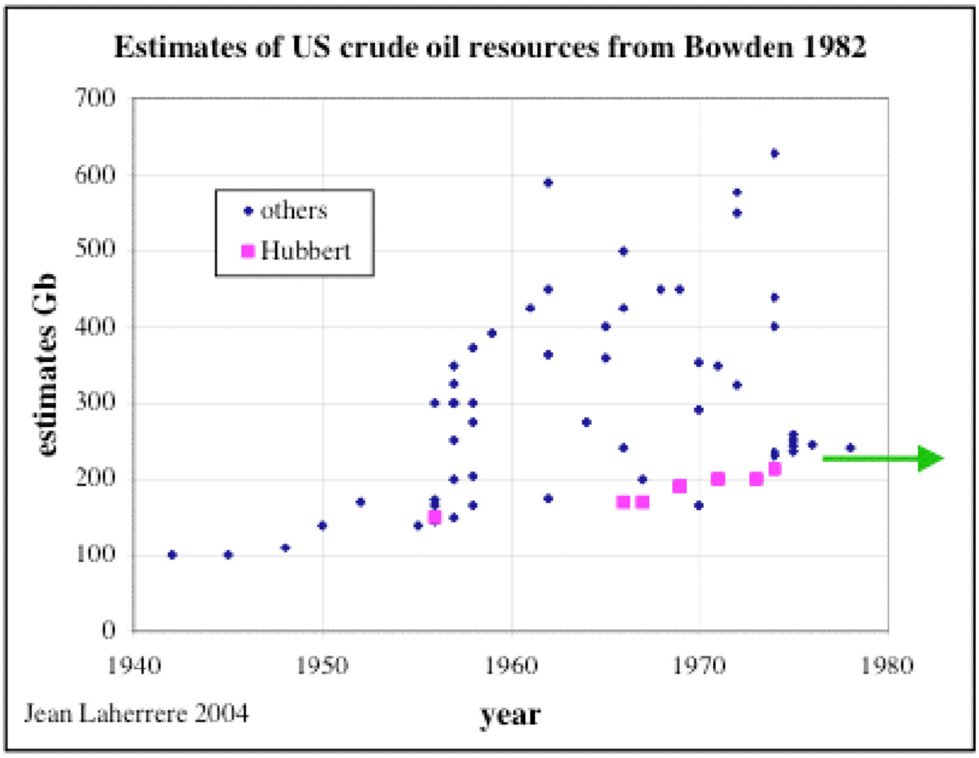
US cumulative discovery and production versus time are extrapolated for an ultimate of 250 Gb

Figure 91: US crude oil cumulative discovery & production 1990-2007 for an ultimate of 250 Gb



This 250 Gb ultimate should be compared to the old estimates (called resources?) as reported by Bowden in 1982. USGS was hoping about 600 Gb in comparison with Hubbert which was around 200 Gb

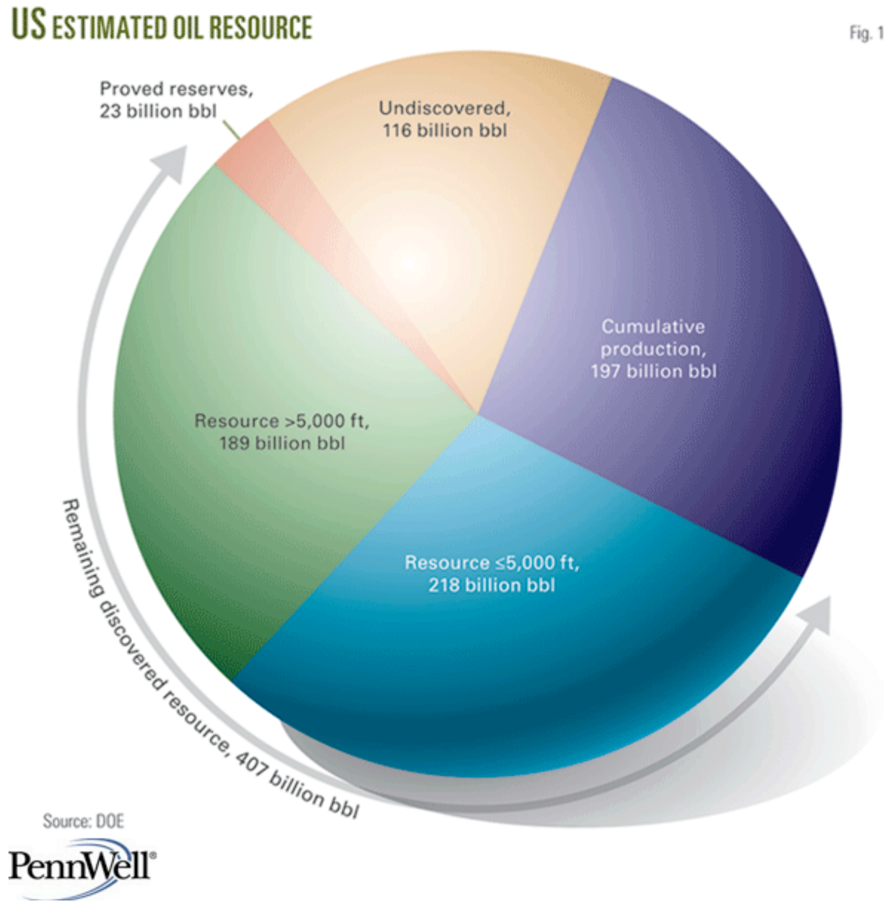
Figure 92: US oil ultimates from Bowden (1982)



The USDOE misleading graph (no date for cumulative production and remaining reserves) confuses reserves (what will be produced) and resources (what is in the ground).

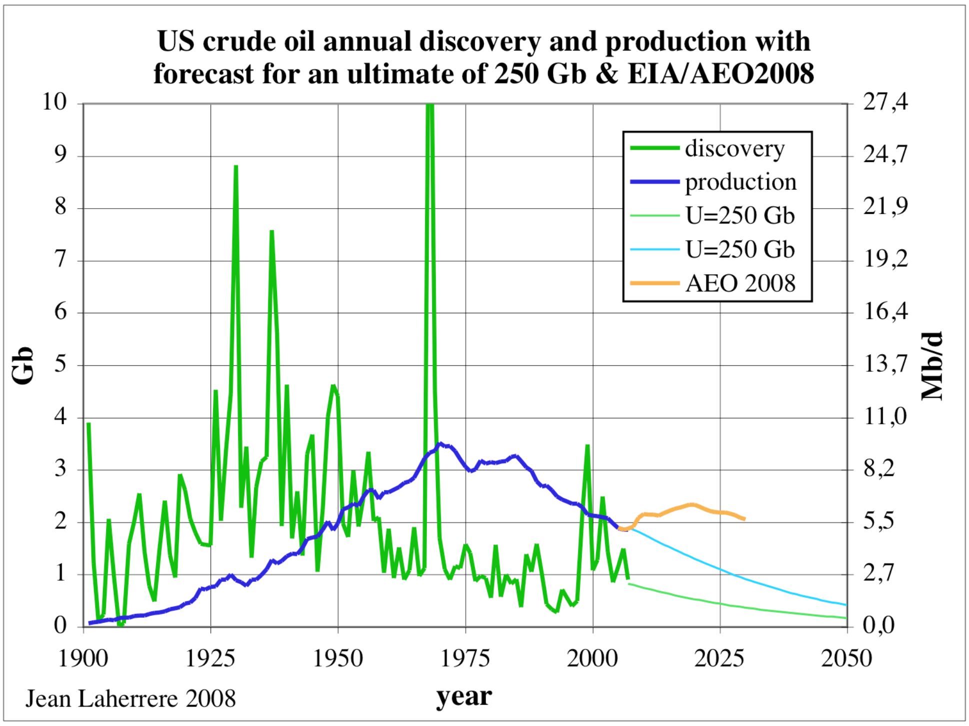
US cumulative oil discovery is 220 Gb out of resources of 743 Gb. But how much resources will stay in the ground?

Figure 93: US oil ultimates from USDOE : OGJ 14 April 2008 p45



The US annual discovery and production is extrapolated for a 250 Gb ultimate, giving a forecast for 2030 of 2.5 Mb/d to compare to EAI/AEO 2008 of 5.6 Mb/d, more than the double!

Figure 94: US crude oil annual discovery & production for an ultimate of 250 Gb & EIA/AEO 2008

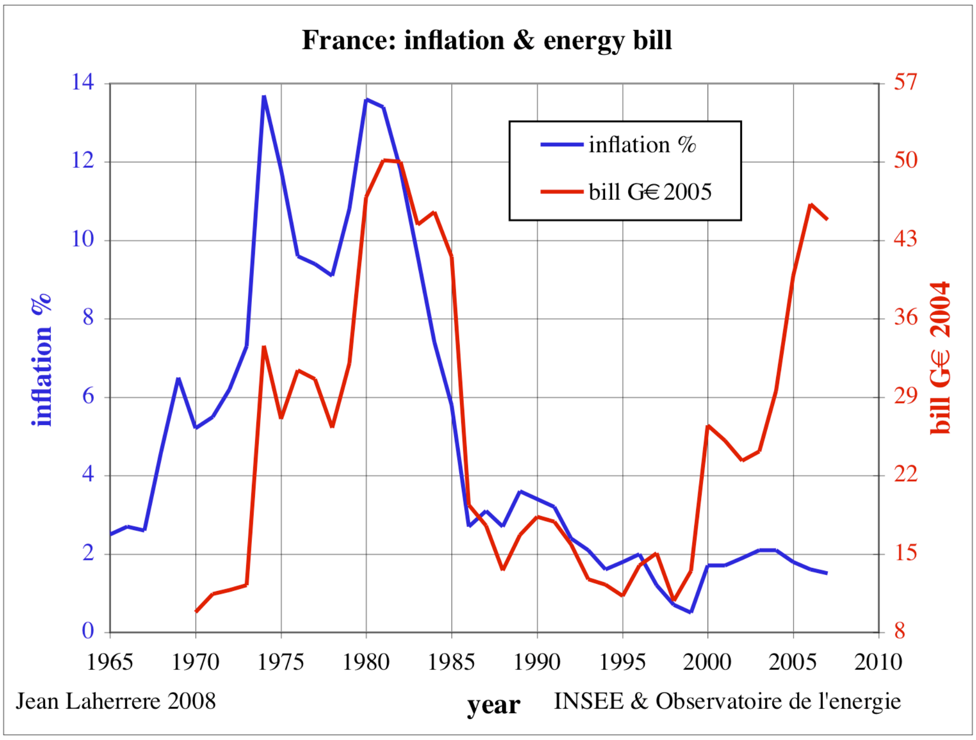


-inflation, energy bills & oil price

Inflation is manipulated, like oil reserves, because in our consumption society decline is a politically incorrect term.

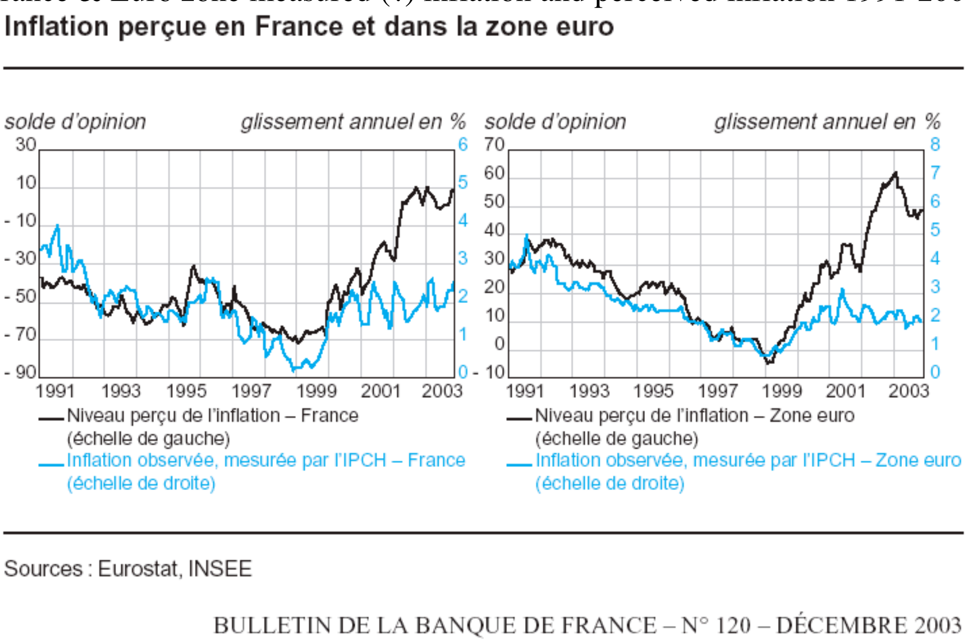
In France the energy bill correlates roughly with inflation from 1970 to 1998, but since 1999 inflation (almost flat) differs strongly from energy bill which shots up.

Figure 95: France: inflation & energy bill 1970-2007



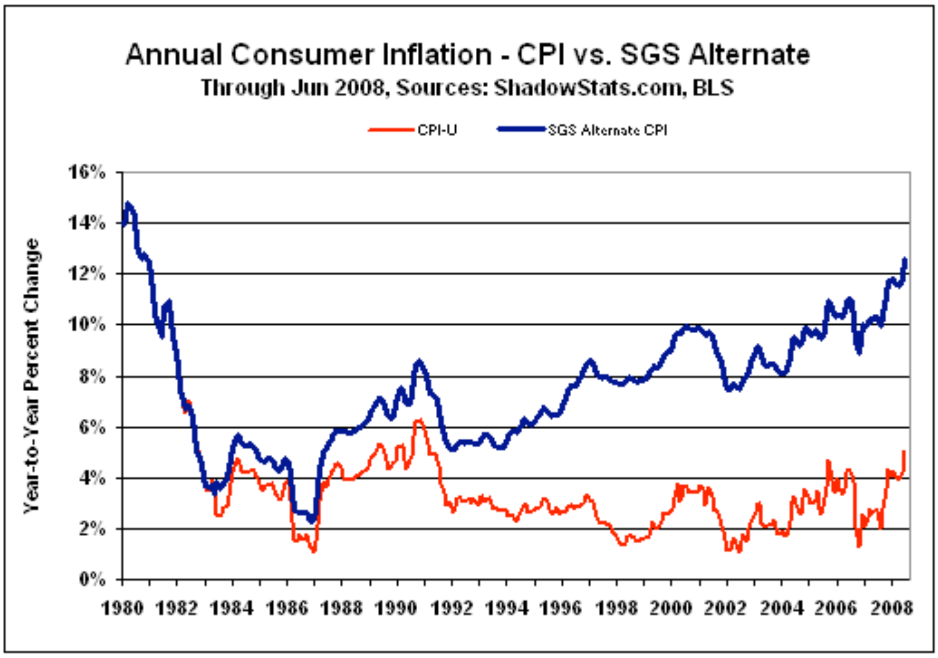
There is the same divergence between inflation measured by HICP and the perceived level starting in 1999.

Figure 96: France & Euro zone measured (?) inflation and perceived inflation 1991-2003

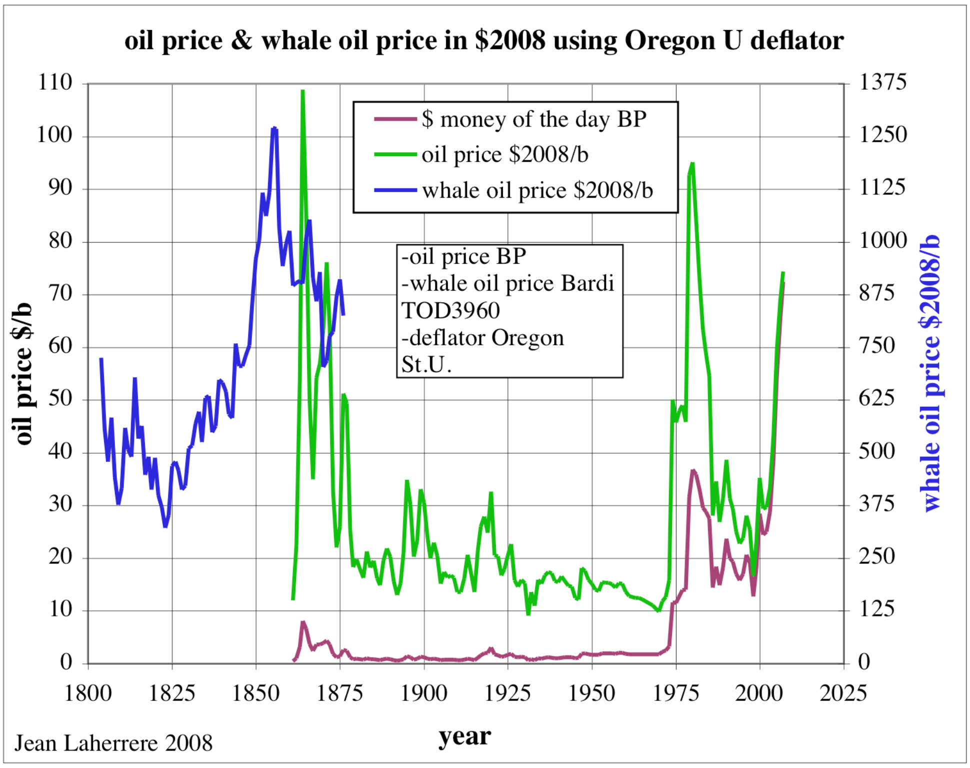


SGS (shadow government statistics http://www.shadowstats.com/alternate_data) is reporting an alternate CPI (Consumer products index) where inflation diverges form official inflation much sooner than in the previous graph

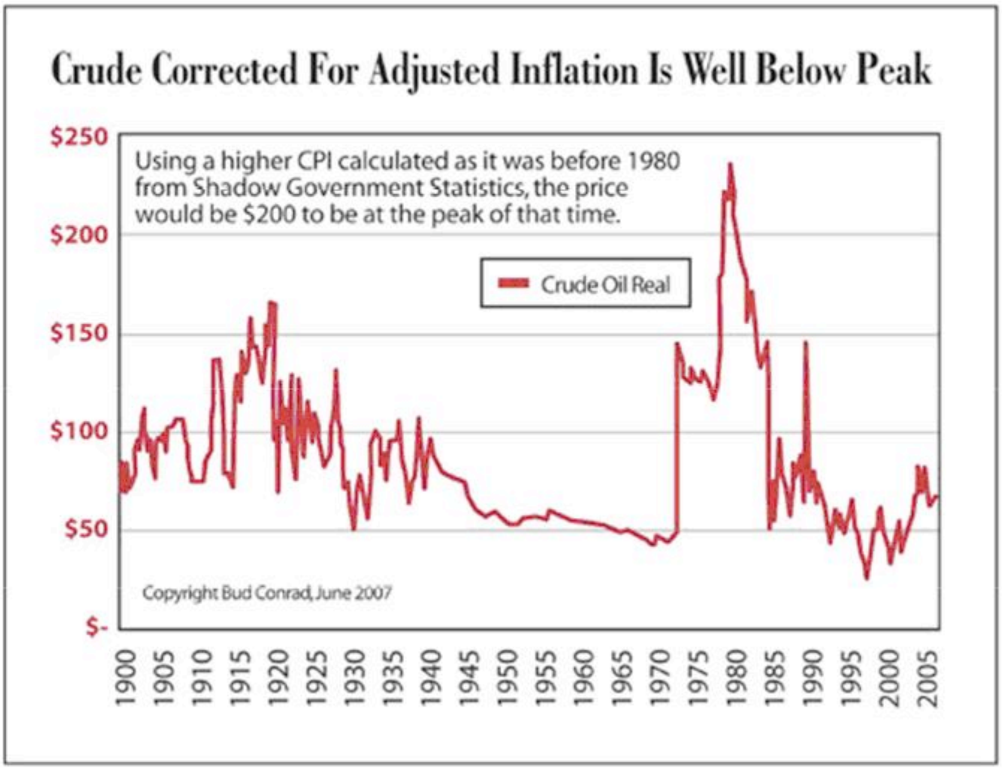
Figure 97: inflation from official CPI and alternate CPI by SGS



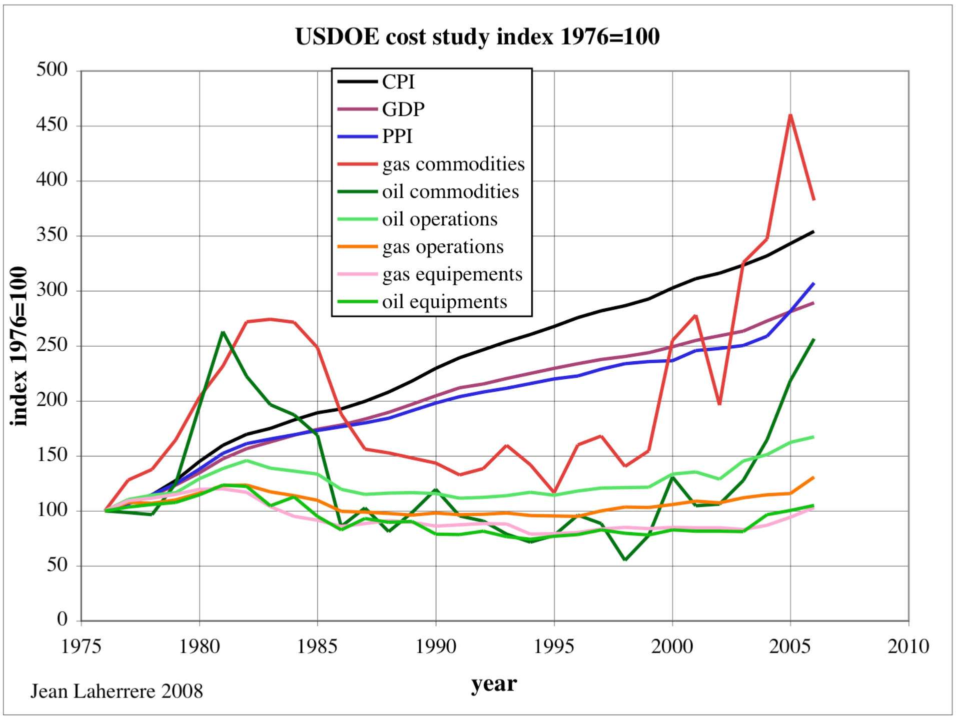
Whale Oil price (from Bardi TOD 3960) and oil price (BP Review 2008) since 1800 are converted in $2008 by using the CPI from Oregon State University.
Whale oil (used for lighting) was worth over 1200 $2008/b in 1855 and oil over 100 $2008/b in 1864, again 100 $2008/b in 1980. Today oil is very cheap compared to whale oil.
Figure 98: whale oil price & oil price in $2008/b



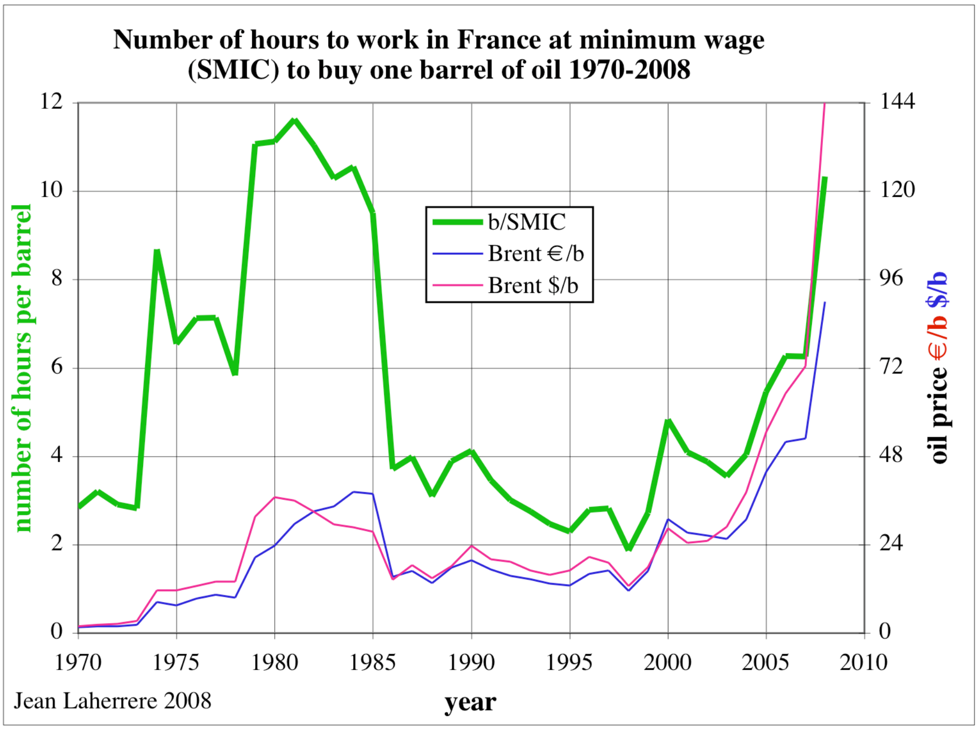
Using the SGS unofficial CPI, Bud Conrad computed that 1980 oil price is higher than 200 $2007/b, oil today at 145 is cheap!
Figure 99: US crude oil corrected for SGS alternate inflation



But price index varies between consumers products (CPI), producers products (PPI), GDP and oil & gas commodities, operations and equipments in USDOE cost study for 100=1976
The difference can be huge, more than 4 times
Figure 100: US cost study index = 1976

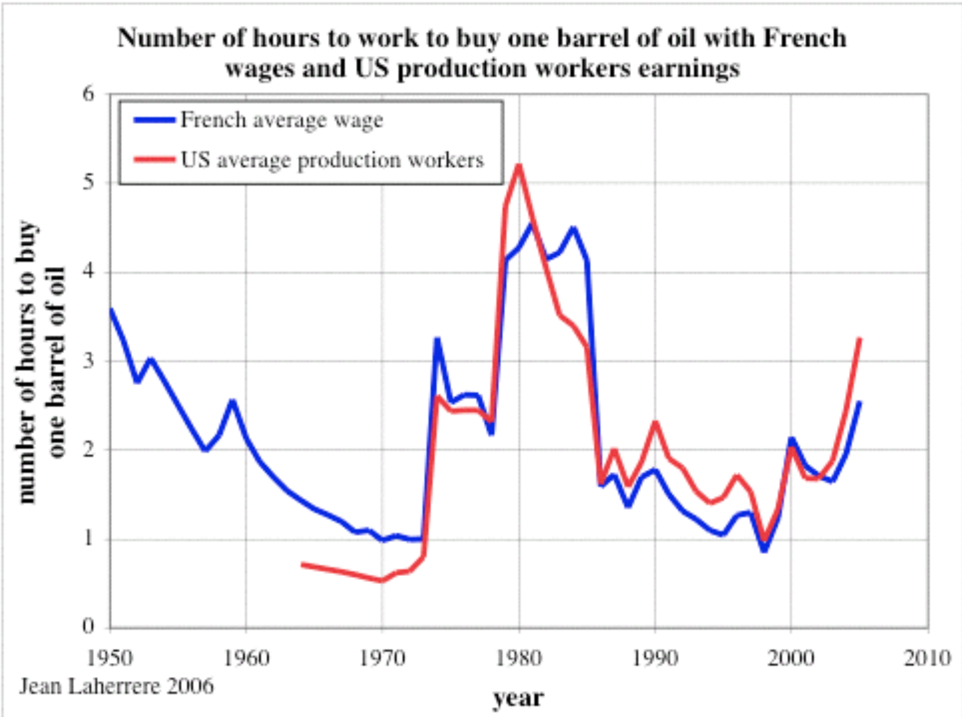


The best way to compare historical oil prices is to measure it in number of hours to work to buy one barrel. Using the minimum wage in France (SMIC) over 11 hours were needed in 1980 compared to 6 hours in 2006 and 10 hours in 2008 (assuming July being the average and not a peak).
Figure 101: number of hours in France at minimum wage (SMIC) to buy one barrel of oil 1970-2008



Using average wage in France and US, the number of hours is less, but it is interesting to find that American workers have to work as long as French workers, yet American can buy more because they work 2000 hours per year when French work only 1600 hours.

Figure 102: number of hours in France and US (average wage) to buy one barrel of oil



In TOD 4315, they tried to estimate the human energy and it seems that a man needs about 11 years to make as energy as a barrel of oil, compared to about 10 hours to work at minimal wage to buy it. Oil has replaced hundred of slaves!

-Conclusions

Most published data is politically (OPEC) or financially (SEC) motivated and differs widely from confidential technical data.

Reserve growth in the US is due mainly to the omission of probable reserves because of the SEC rules (about to be changed in 2009) and incorrect aggregation of proved reserves.

US negative reserves revisions are now as large as positive reserves revisions, meaning that the probability of estimates is about 50% far from the assumed P90.

Plotting the decline of major fields shows that often new technology (horizontal well+ frac) increases the peak but also the future decline in the detriment of ultimate recovery (but higher net present value when using 15% discounting)

Reserve growth was found mainly in unconventional fields as Midway-Sunset when production did increase with drilling and took 100 years to reach peak. Such growth cannot be extrapolated to new offshore fields.

The OPEC increase of 300 Gb in the second half of the 80s, claimed by ASPO to be political, is now described as speculative resources by Sadad al-Husseini, former EP Aramco.

FSU reserves are still under ABC1 definition, using maximum theoretical recovery, and should be reduced by 30% to represent 2P as indicated by DGMN Gazprom audit.

Ultimate of crude less extra-heavy oil is about 2 Gb with a peak in 2006.

Ultimate of liquids is likely to be 3 Tb and production, assuming no above the ground constraint, will peak between 2010 and 2015.

But an ultimate of 4 Tb will no change the date of the peak, but only will slow the decline.

Constraints *above the ground* will convert the peak into a plateau.

Decline in present fields is difficult to assess because of poor data and constraints.

Future reserve growth in conventional oil is likely to be zero and even negative

Future reserve growth in unconventional oil is not important because for production what matters is the size of the **tap**, and not the size of the **tank**.

Better data and complete annual field production are needed in order to better estimate the ultimate recovery. It is far from being the case because of politics and lack of consensus on definitions.