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Uncertainty of data and forecasts for fossil fuels

by Jean Laherrere jean.laherrere@wanadoo.fr
ASPO (Association for the Study of Peak Oil) and ASPO France

The publishing of data is a political act, one depending largely upon the image the author would like to portray i.e. rich in front of the banker, the shareholder, or alongside quotas; poor in face of taxes. The range of uncertainty allows to show different images.

-Motive and language

We live in a society of consumption where growth is the Santa Claus who will cure all future problems and where managers and politicians are judged by the growth of the stock market or the GDP. Growth has to be shown what so ever.
Always try to find the motive of an author speaking about a subject
Ambiguity of term is often used to present what is wished without giving an accurate definition or reference.
Petroleum = *an oily flammable bituminous liquid in upper strata of the earth*
Oil = *any of numerous unctuous combustible substances that are liquid*
Oil is an ambiguous term and includes biofuels (olive oil) and alcohols
Oil should not be confused with petroleum or hydrocarbons
Gas means gasoline for some, but natural gas for others.
M means thousand for the US industry (outside computers) but million (= mega) in metric countries.
Billion is thousand millions in the US, but million millions (square million) in Europe.
Webster's definition for billion is a very large number, which is not very precise!
Decimals are indicated by a dot for some and by commas by others
Dot countries
Countries where a dot is used to mark the radix point include:
Australia, Brunei, Botswana, Canada (English-speaking), Dominican Republic, El Salvador, Guatemala, Honduras, Hong Kong of the People's Republic of China, India, Ireland, Israel, Japan, Korea (both North and South), Malaysia, Mexico, New Zealand, Nicaragua, Nigeria, Pakistan, Panama, Philippines, Peru, Singapore, Sri Lanka, Taiwan, Thailand, United Kingdom, United States (including insular areas)
Comma countries
Countries where a comma is used to mark the radix point include:
Albania, Andorra, Argentina, Austria, Azerbaijan, Belarus, Belgium, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Cameroon, Canada (French-speaking), Costa Rica, Croatia, Cuba, Chile, Colombia, Cyprus, Czech Republic, Denmark, Ecuador, Estonia, Faroes, Finland, France, Germany, Greece, Greenland, Hungary, Indonesia, Iceland, Italy, Latvia, Lithuania, Luxembourg (uses both separators officially), Macedonia, Moldova, Netherlands, Norway, Paraguay, Poland, Portugal, Romania, Russia, Serbia, Slovakia, South Africa (officially, but decimal point is commonly used in business), Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, Uruguay, Venezuela, Vietnam, Zimbabwe
Grouping of numbers
Commas or dots are used to separate digits into groups of three, counting from the decimal marker, adding confusion and they should be replaced by a space

-Reporting data

-OPEC productions are ruled by quotas, but because OPEC members were cheating on quotas, OPEC oil productions are flawed and unreliable. Real data on oil transported by tankers have to be bought from spy companies (Petrologistics in Geneva).
-words such as **energy, oil, reserves, resources, conventional, proved, probable, light, heavy, reasonable, sustainable, dangerous are badly or not defined on purpose**

Data are flawed by finance (stock market) or politics (quotas), or they are missing
Ambiguity is often favoured by purpose:
• Oil and liquids: oil can vary from regular (former conventional) oil of Campbell (66 Mb/d) to crude oil (73 Mb/d) and finally to all liquids including NGLs, synthetic oils from coal (CTL), biomass (BTL), and refinery gains (85 Mb/d in 2005).

World oil production is reported for 2005 with many ridiculous significant digits going down to 10^{-7} b/d (?) when current revisions is about 10^{5} b/d, which is 10^{12} more = difficult to understand such crazy practices, leaving the computer giving unreal accuracy!

World oil production for 2005	definition	Mb/d
OGJ Oil & Gas Journal	oil	72,361 6
WO World Oil magazine	crude/condensate	72,112 9
BP Statistical Review	liquids (excl CTL)	81,087 544 356 164 4
USDoE (Depart of Energy)	crude oil	73,653 375 786 794 6
/EIA energy information agency	all liquids	84,563 799 689 834 3
IEA International Energy Agency	oil	84,45

• The term “liquids” may be restricted to hydrocarbons (Campbell) or to all liquids including everything that burns (olive oil).
• Oil production in the US includes condensate produced at the wellhead, but excludes NGL production totals. OPEC oil production excludes condensate. The UK reports only condensate while Norway reports condensate in cubic meters and NGL in tonnes
• Conventional versus unconventional: there is no consensus. In the past, conventional was primary and secondary recovery, with the rest being unconventional. Some exclude heavy oil such as arctic and deepwater. USGS and SPE define conventional as field having water-contact with dynamic aquifer.
• Peak oil is often discussed without defining the product, and oil peak dates (as ultimate reserves) are compared when they are not dealing with the same “oil.”

Reserves Definitions

There are currently several reserve definitions in use:

- **US:** all energy companies listed on the US stock market are obliged by the SEC to report only proved reserves (**1P**), assumed to be the **minimum;** these reserves are audited.
- **OPEC:** because quotas depend upon reserves, OPEC members report proved reserves (**1P**), which is their wish being non-audited.
- **FSU classification**: ABC1 (1979) reports **maximum** theoretical recovery, being equal to proven plus probable plus possible (**3P**).
- **Rest of the world:** SPE/WPC (1997) regulations (I was a member of the task force) report reserves as proven plus probable (**2P**), close to the **expected value**.

Proved reserves (1P) tell bankers that the company will not go into bankruptcy, but development decisions are taken on mean reserves (2P). The aggregation of proved reserves is incorrect, as it underestimates the total. Thus, national proved reserves are more than the addition of field proved reserves, and therefore world proved reserves are more than the addition of all national proved estimates.

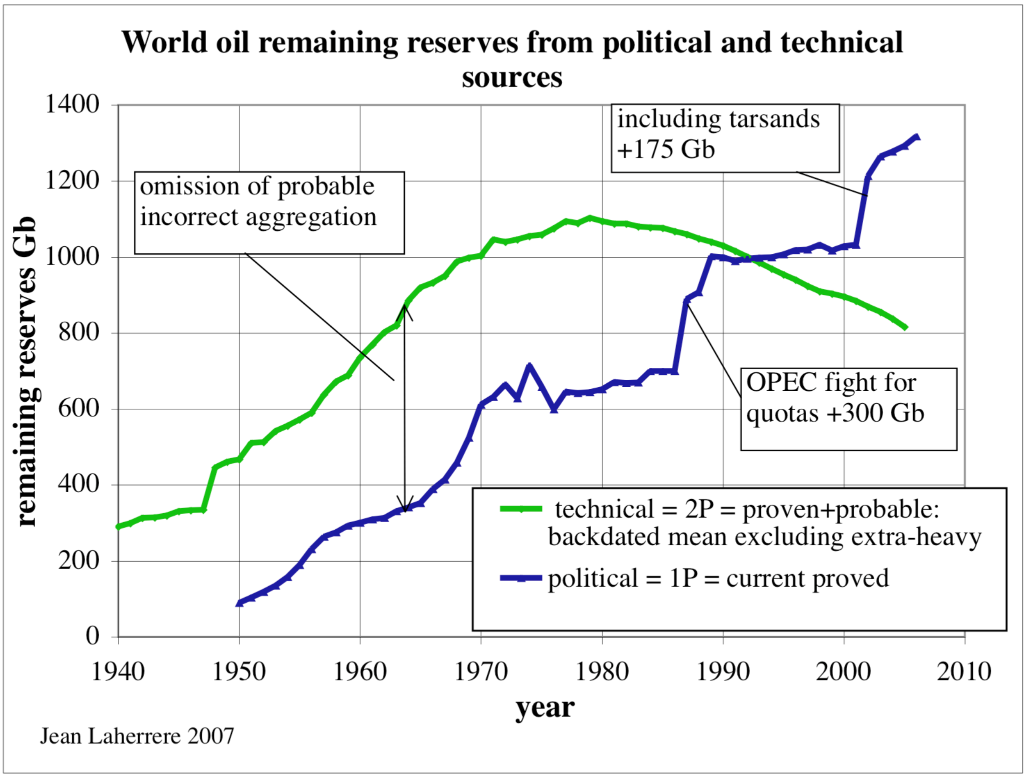
Proven plus probable reserves estimates are confidential in all countries except the UK (DTI), Norway (NPD), and federal US (MMS). In Russia, divulging oil (but not gas) reserves can be punished by 7 years jail!
Scout companies sell reserve databases but they are very expensive, dealing with huge quantities of data (about 24 000 fields outside the US and Canada non-frontier provinces) and need constant updating and correction.

US DOE/EIA proved reserves as end of 2005; posted October 5, 2006:
US federal agencies are obliged since 1993 to use the International System (SI) of units, and under SI, thousands have to be indicated by a space and not a comma (which is used in some countries to indicate the decimal point).

Oil (Billion barrels = Gb)	**Oil & Gas Journal**	**BP Stat Review**	**World Oil**	**Cedigaz**
World	1 292,935 5	1 201,331 538 509 4	1 119,615 3	
Canada	178,792 4	16,500	12,025	
Africa	102,580	114,268	109,759	
Gas (Tcf)				
World	6 124,016	6 359,172	6 226,554 6	6 380,625
Norway	84,26	84,896 5	83,272 1	109,759 02
Africa	485,841	507,826	490,882	508,819

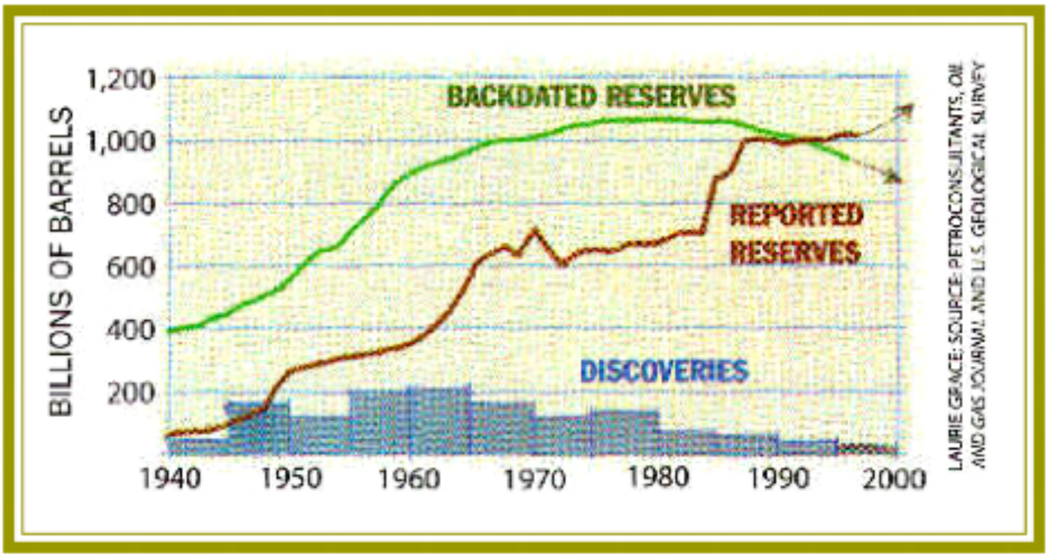
This inventory is misleading because it is incorrectly aggregated, yet it is repeated every year without any objection.

One of my most important graphs displays the technical (backdated mean) and the political (current proved) remaining reserves at the end of 2005.
Figure 1: World oil remaining reserves from political and technical sources



The same graph was presented eight years earlier in the *Scientific American*, March 1998, Campbell and Laherrere, "The end of cheap oil."

Figure 2: same graph presented in 1998 in Scientific American



The 2006 graph is identical to the 1998 one, showing that ASPO (The Association for the Study of Peak Oil) does not change as often as some say.

Proven reserves are only financial data and should never been used for forecasting future production.

Unfortunately technical (2P) data are not usually published (except in the UK (DTI), Norway (NPD), and US federal (MMS)), but they can be bought by scout companies such as IHS or Wood Mackenzie, so it is wrong to say that they are confidential; they are only expensive and anyone can buy them.

-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

use 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)

use technology (horizontal drilling) to increase present easy oil production in detriment of ultimate recovery, pleasing shareholders but leaving less to 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 as 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 mean (expected value) field give 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 by about 100%

Figure 3: Comparison of arithmetic aggregation and probabilistic aggregation from SPE 2006

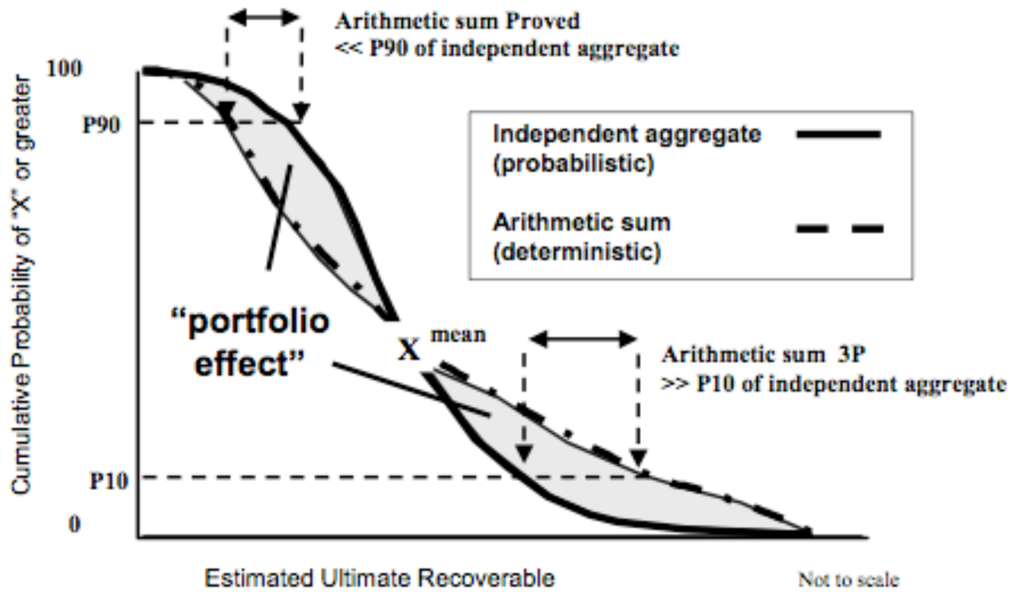


Figure 3-2: Deterministic versus Probabilistic Aggregation

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 form 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 :

1P = current proved= minimum against 2P = backdated proven + probable = expected value. It is what USGS (Geological Survey) did in 2000 by extrapolated 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 et temperature over 100 000 years ago from ice cores 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.

-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

$$10^9 \text{ m3} = \text{km}^3 \text{ and not Gm}^3$$

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

-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 have been censured as artefacts because not in line with the fitting of ice core bubble analysis from Antarctica with direct measures in Hawaii (see climate changes). 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 he was his largest mistake.

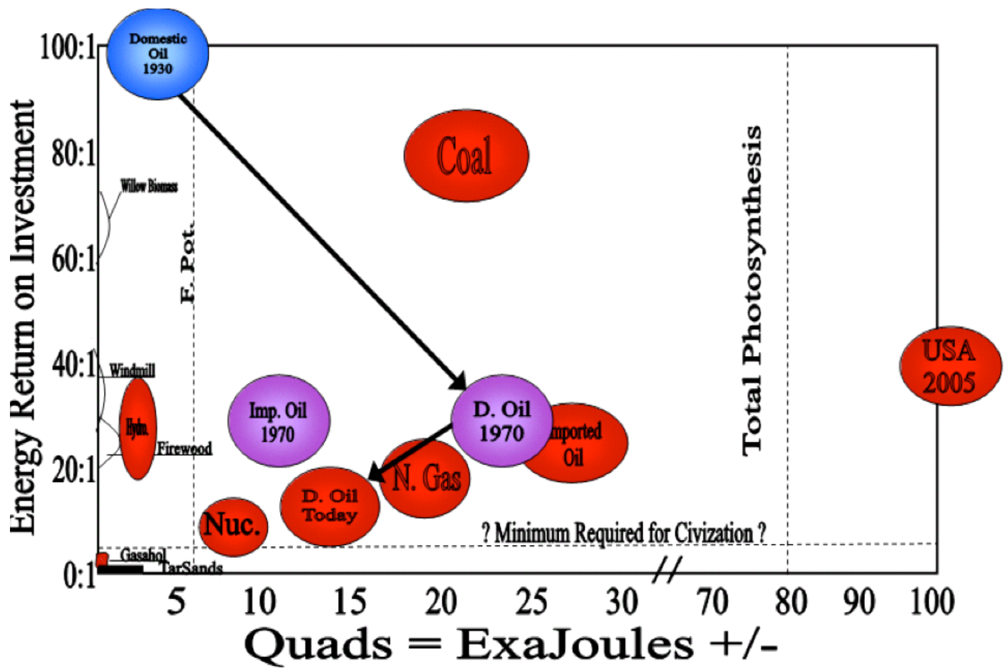
-to look only at money constraints and not EROI

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. Coal is solid but can be concentrated in seams but the problem is then thickness of the seams.

Concentration for oil and gas in conventional field allows to produce at 100% just by opening a valve. Furthermore oil is mainly produced as energy source (outside petrochemicals) and what is important to decide development is not the cost of production but the EROI (energy returned on energy invested). It takes more energy to produce coal in depth over 1500 m than the energy of such deep coals. In contrary gold can be mined down to 4000 m if the price of gold is more than the cost. For ethanol from US corn, Pimentel & Patzek claim that the EROI is about 0,7 when USDA claims that it is 1,3, but subsidies for corn (at production, transport and plant) allows to make money in this losing energy business.

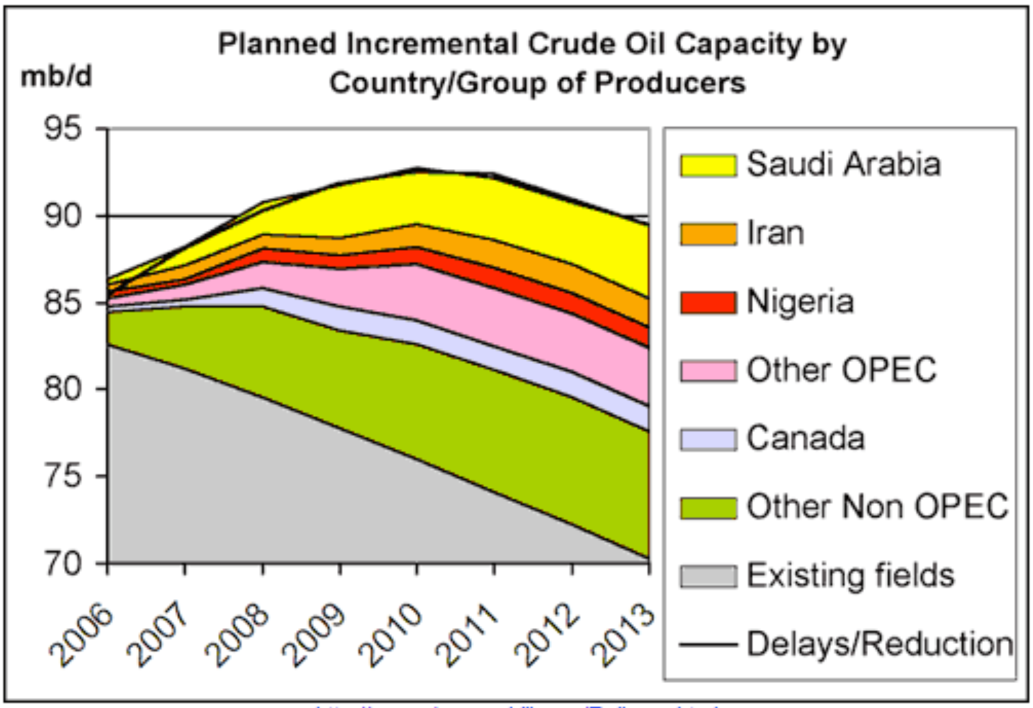
Charlie Hall who started studying the EROI of fish in river estimates that EROI for US oil was about 100 in 1930, 30 in 1970 and about 10 today

Figure 4: EROI from Hall ASPO 2006 Pisa



-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 the NASA has issued a law where, in frontier areas, the initial project against reality : cost has to be multiplied by pi and time by e (Euler number = 2,7). This law is verified in many exotic projects as Centre Pompidou in Paris, TransAlaska pipeline, presently with Kashagan in Caspian sea. The problem is 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 large as cost and in order to nave the project accepted only the minimum value is given and at the end the expected value = mean occurs which 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. The ratio between minimum and mean is about 3 in a lognormal distribution.
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 for their oilsands projects ; Kashagan over 5 years ; Thunder Horse (platform of 1 G$ Gulf of Mexico) over 3 years.
Figure 5: **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 put any correction in time. 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 forecast are only for oil projects and do not included synthetic oil.

-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 needs more brain power. Today, there are some 1700 people studying petroleum engineering in 17 US universities compared with over 11 000 in 34 universities in 1993. But oil & gas industry needs more and better staff to fight against complex

-to believe that the quality of the results of a model depends only of the quality of the model : **GIGO: garbage in , garbage out** : what so ever is the quality of a model, the quality of the results depends mainly upon the quality of the data and hypotheses.

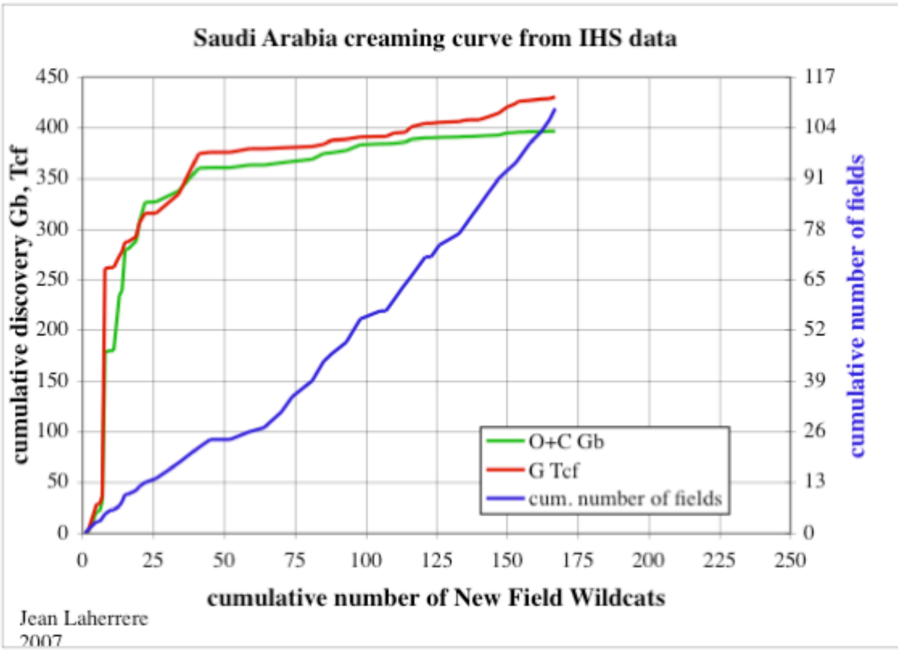
-Myths to be rejected

To prevent showing decline, all means are used, in particular myths.

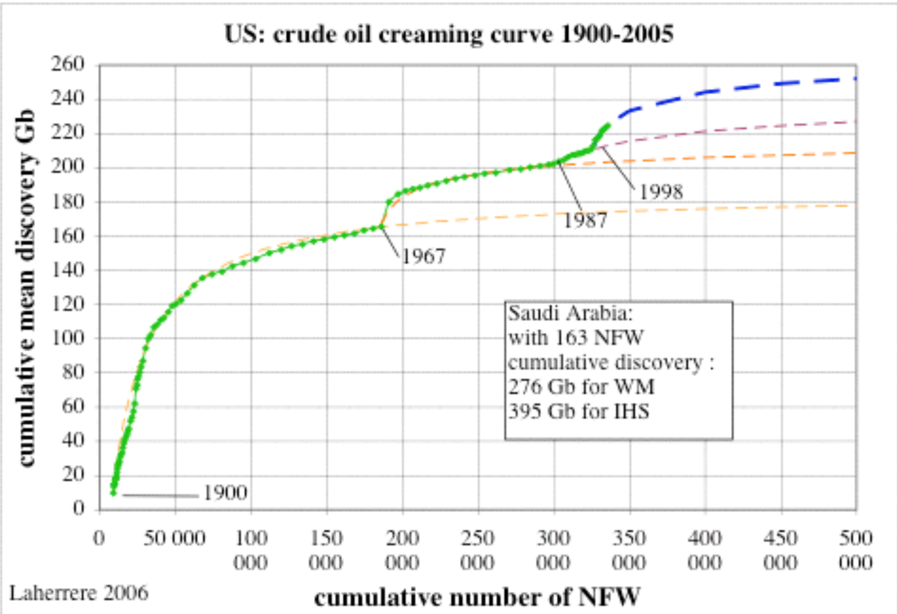
-Myth 1: Middle East is under explored

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 6: **Saudi Arabia creaming curve = cumulative oil discovery versus cumulative number of New Field Wildcats**



It is not the number of NFW which 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 to 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 7: **US oil creaming curve**

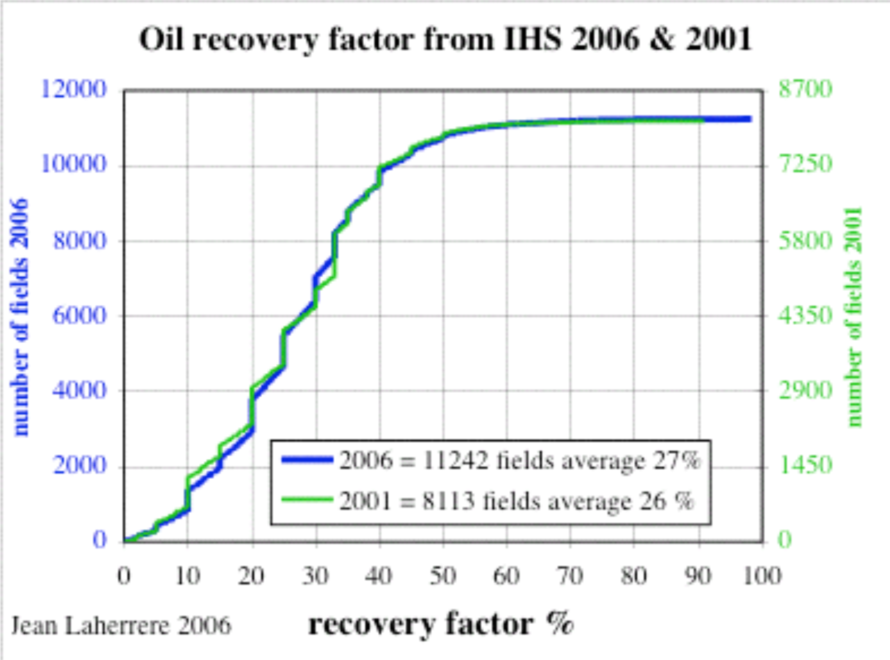


Myth 2: oil recovery (RF) is about 35% in the world and 50 % in North Sea, so world reserves can be increased worldwide.

The most detailed database of IHS reports for 2006 about 11500 fields for the world outside the US onshore with oil recovery factor ranging from 0,1% to 98 % with an average (by number) of 27%. In 1997 the database was less documented, reporting only 787 fields with an average of 36%. Raw incomplete data could lead to the wrong conclusion that recovery rate is decreasing statistically with time.

In 2001, only 8113 fields (109 fields in FSU compared to 1399 in 2006) are reported with RF with an average of 26%.
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.

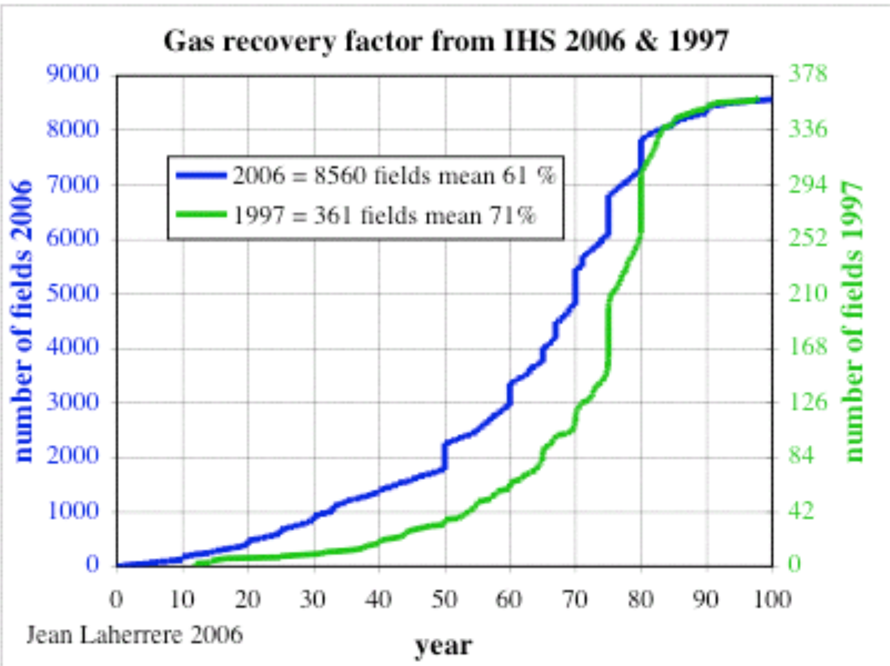
Figure 8: **Oil recovery factor from IHS (world outside US onshore) 2006 & 2001**



Recovery factor 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.

For gasfields, 8560 fields are reported in 2006 with RF with a mean of 61% when in 1997 only 361 fields were reported with a mean of 71%

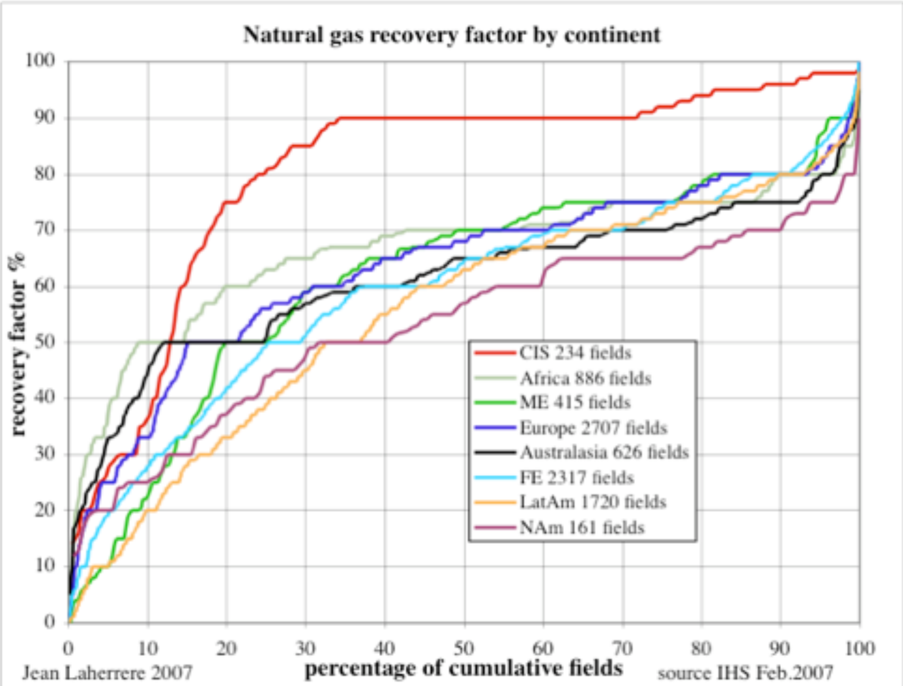
Figure 9: **Gas recovery factor from IHS (world outside US onshore) 2006 & 1997**



It is obvious that in the past only large fields were reported with RF, when now small fields are reported.
There is no indication from the statistics that recovery factor increases with time as suggested by many. However in 2001 RF for Ghawar was only 47% when in 2004 RF was increased to 60% and in 2006 to 70%. It is obvious that these reports are political. It is very difficult to improve the estimate of the oil in place without new wells or new seismic, when reserves estimate improves with more production data. At the end of production, reserves are exactly known when oil in place is still a guess!, so the RF!.
In World Oil December 2005, CEO Statoil T.Overvik stated that Statfjord has recovered **64 % of 8 Gb oil in place** (OIP), compared to 48 % in 1979, hoping to reach 70% in the future. But in WO December 2004 Overvik stated having produced **63 % of 6 Gb OIP**. Is the change of OIP a typing mistake or is OIP a wild guess? IHS reported, in 1998, an OIP of 6.3 Gb with oil+condensate (O+C) 2P= 4,60 Gb giving a recovery factor of 73 % and, in 2005, an OIP of 6.1 Gb with O+C 2P=4,36 Gb giving a RF of 72 %. IHS does not see any improvement in recovery factor, being already very high in 1998!

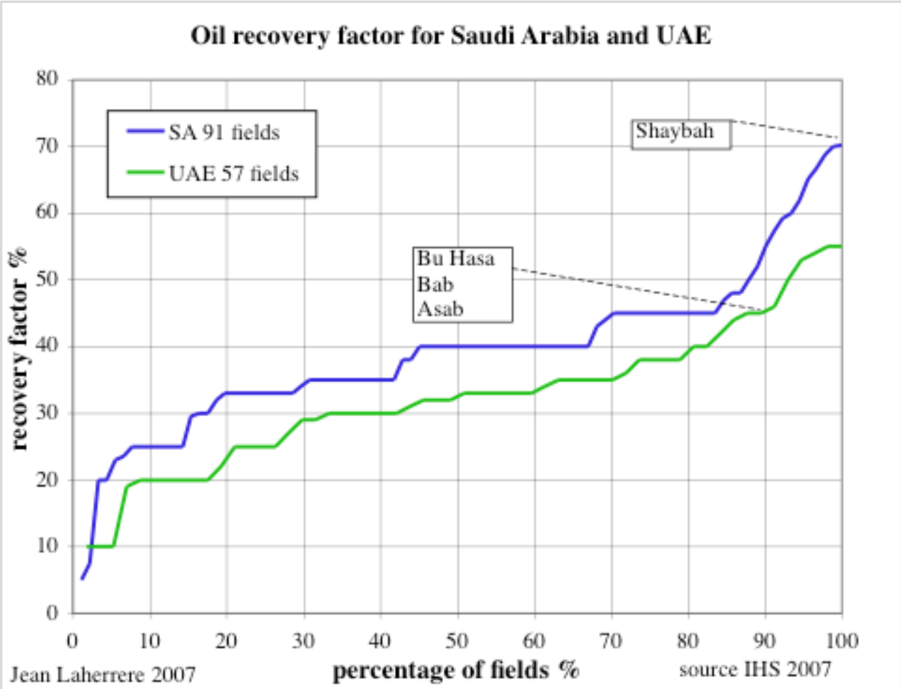
Recovery factor depends mainly upon the geology of the reservoir : 1% for tight reservoir and 85% for very porous and permeable reservoir.
Technology cannot change the geology of the reservoir.

However RF is useful when comparing different oil classification as FSU reserves compared to the rest of the world or Saudi Arabia compared to UAE
FSU ABC1 reserves (used also in India) were assessed using the maximum theoretical recovery (Khalimov 1993) and it is obvious when comparing recovery rate for natural gas that FSU is far above the other continents, proving that it is 3P reserves.
FSU reserves should be corrected (reducing by about 30%) to come from 3P to 2P.
Figure 10: distribution of natural gas recovery factor by continent



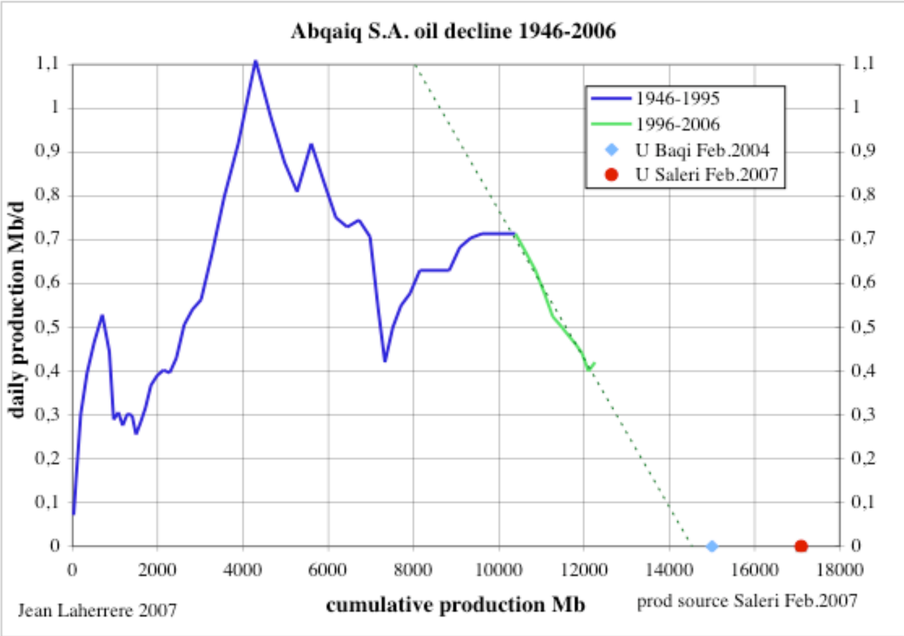
Saudi Arabia oil estimate seem also too optimistic when comparing oil recovery factor distributions with UAE and in particular for Shaybah field (70 %), which belongs to the Petroleum System of Abu Dhabi, with Bu Hasa, Bab and Asab fields (about 45 %).
Shaybah was developed later in difficult conditions (over 5000$/b/d) for Aramco far from their bases, when Bu Hasa and others were developed sooner close to ADNOC bases: it is why Shaybah is presented more optimistically!

Figure 11: distribution of oil recovery factor for Saudi Arabia and UAE



The best way to check the reliability of scout databases is to plot the declines of mature major fields. The only necessary data is a complete annual production series.
Despite the political constraints on OPEC production, ultimate from oil decline of Abqaiq (looking to be produced at full rate) in Saudi Arabia (Saleri Feb2007) using straight extrapolation can be compared to Aramco (17 Gb in 2004, 15 Gb in 2007), keeping in mind the collapse at the end shown by most giant fields due to the use of best technology (the goal is maximum profit and not maximum recovery). Aramco Baqi in 2004 reported 15 Gb but Aramco Saleri I in 2007 reports 17,1 Gb hoping EOR (unconventional recovery)

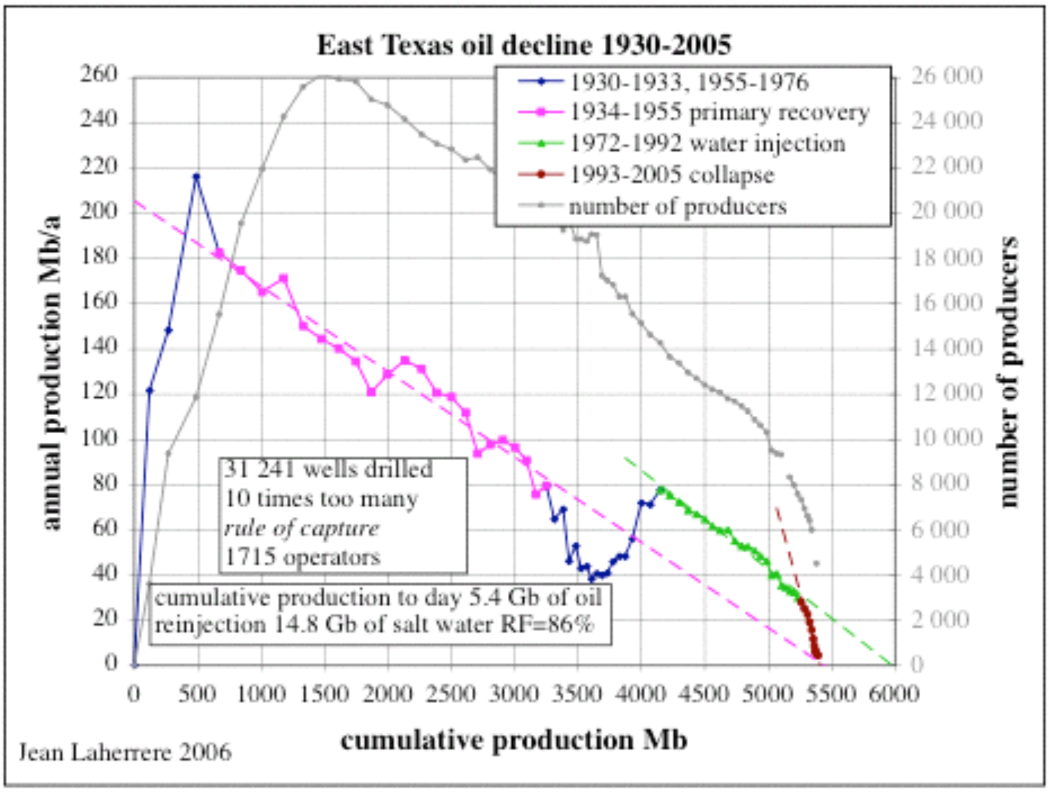
Figure 12: Abqaiq oil decline 1946-2006



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 because quotas.

-Myth 3: technology increases reserves

Reserve growth is claimed by USGS 2000 report by extrapolating the current proved reserve growth in the US old 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 13: **Oil decline of East Texas, largest US L48 oilfield 1930-2005**

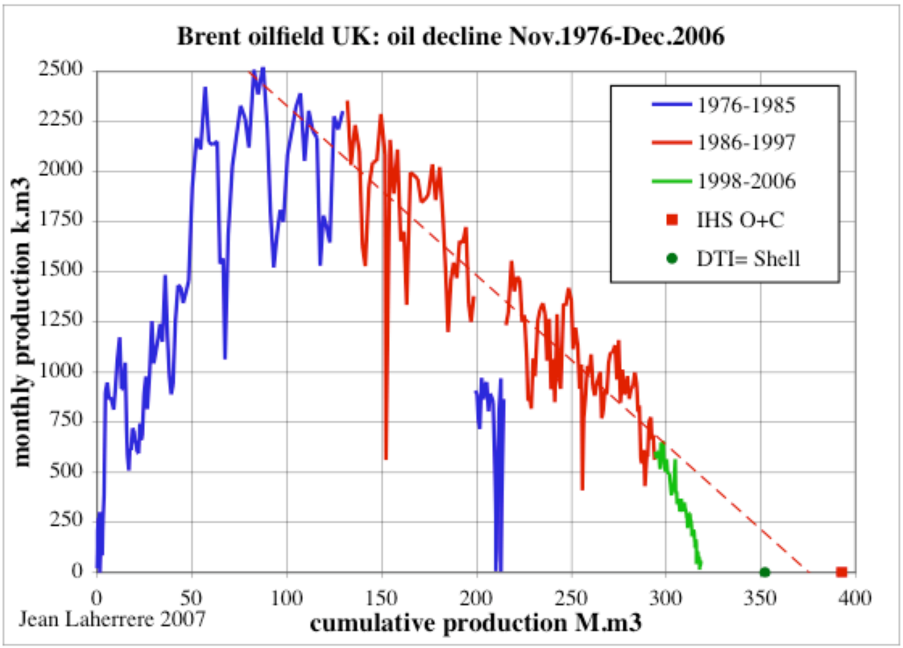


In this field, over 30 000 wells have been drilled (by over 1700 different operators) 10 times too many (spacing of 4 acres per well, when 40 acres/w was largely enough), because of *rule of capture*! There is a very active water drive and **the recovery is estimated at 86 %**. **Present water cut is 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 shows, as East Texas, a collapse at the end, making the straight line extrapolation an optimistic estimate, as in the Brent decline (outside the trough in 1989-91 for works on gas repressuring).

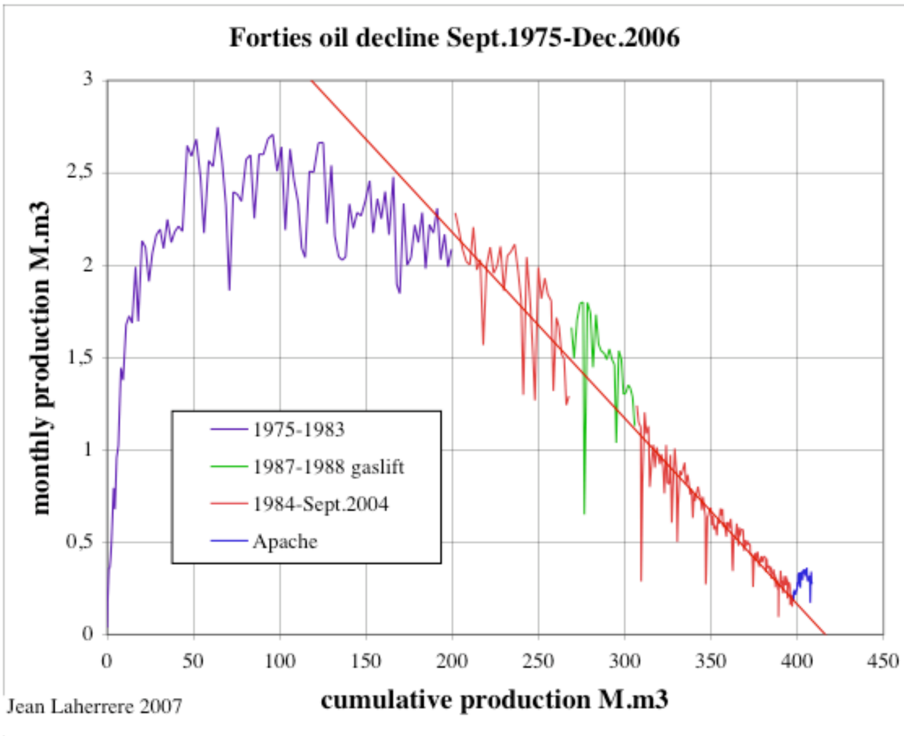
Up to 1997 Brent oil ultimate was estimated to be around 350 to 400 M.m3 with a decline of 8%/a, but production from 1998 to 2006 (green curve) with a decline of 20 %/a shows that the ultimate will be around 320 M.m3. Again negative reserve growth.

Figure 14: **Brent oil decline showing a late collapse Nov.1976-Dec.2006:**

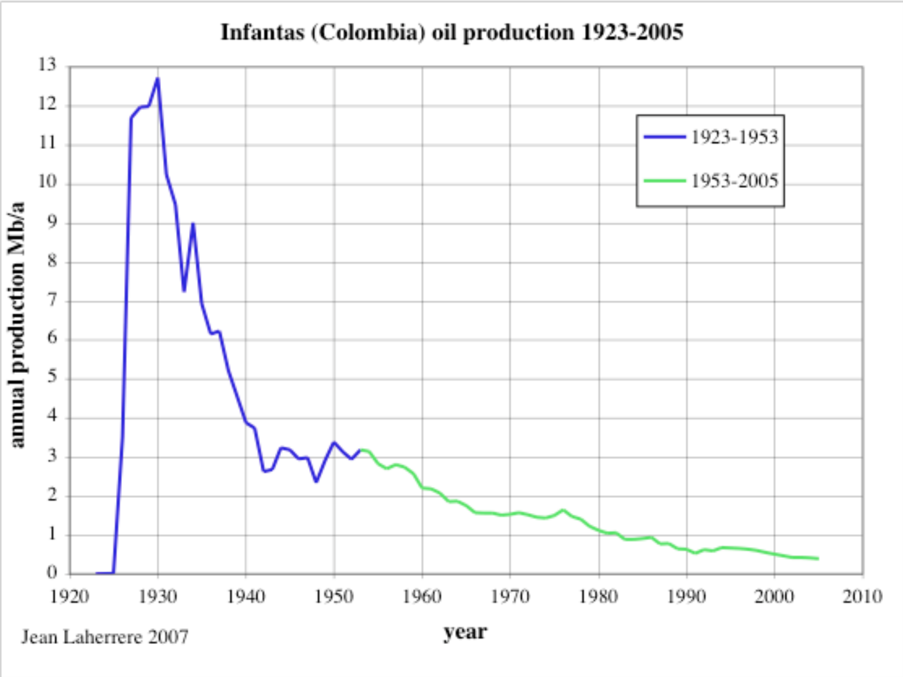


Another good example of oil decline is Forties in North Sea where the decline was straight since 1984 but in 1987-1988 a fifth platform with gaslift allows to produce a little more, but quickly the decline has returned to previous trend. BP sold this mature field to Apache a small independently which can produce cheaper being smaller. In Apache since end of 2004 has drilled more than 50 wells, increasing the production but will the ultimate recovery be increased? 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.

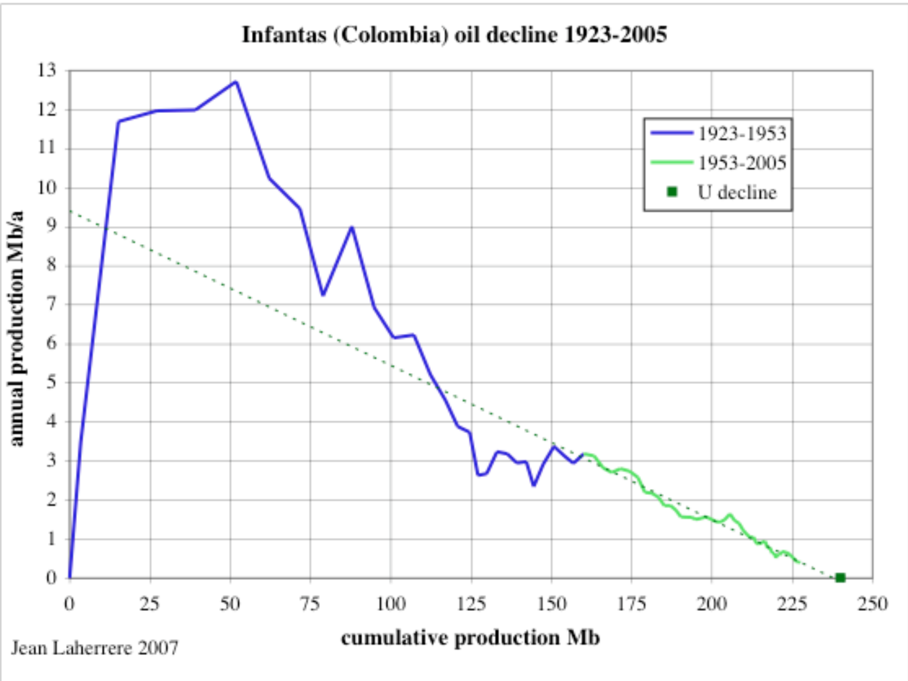
Figure 15: **Forties oil decline**



One of best example of straight long oil decline on annual versus cumulative production is Infantas in Colombia;
Infants has been in production since 1923, quick raise up to 1930 and than sharp decline but slow decline in time since 1950
Figure 16: **Infantas (Colombia) oil production**

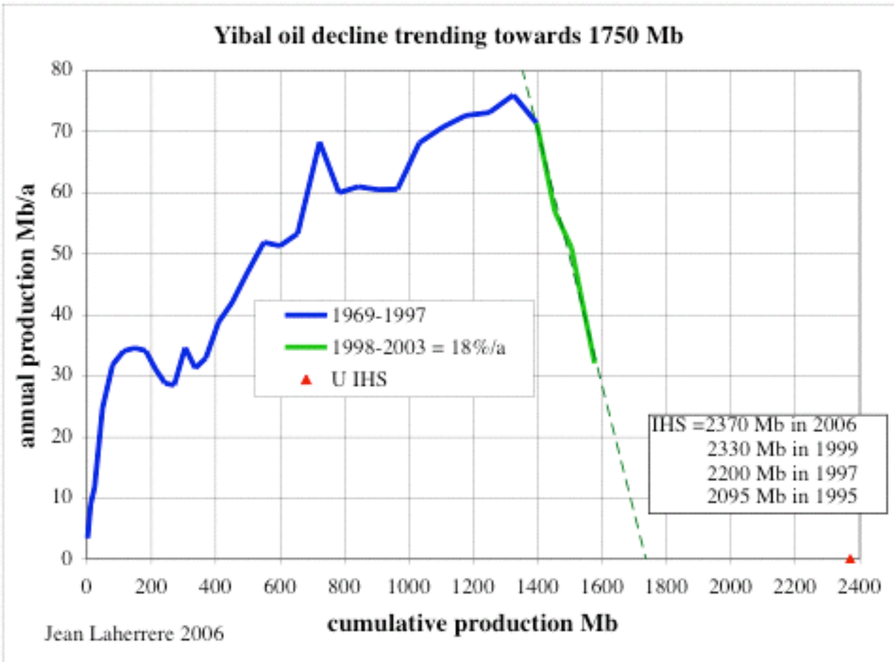


The decline versus cumulative is straight since 1953 and provides a good estimate for ultimate recovery at 240 Mb
Figure 17: **Infantas (Colombia) oil decline**

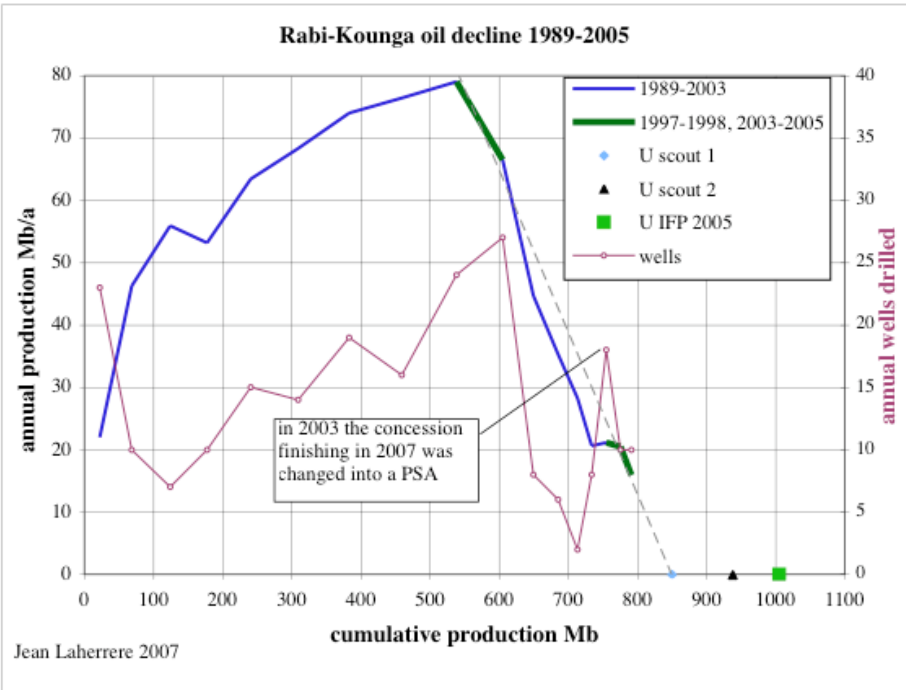


But this kind of slow decline is old practice. IOCs are now in a hurry to produce.

Modern production aims to get maximum production to get maximum profit (pushed by new shareholders as pension fund 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!.
Figure 18: **Oil decline of Yibal, largest field in Oman 1969-2003,** operated by Shell

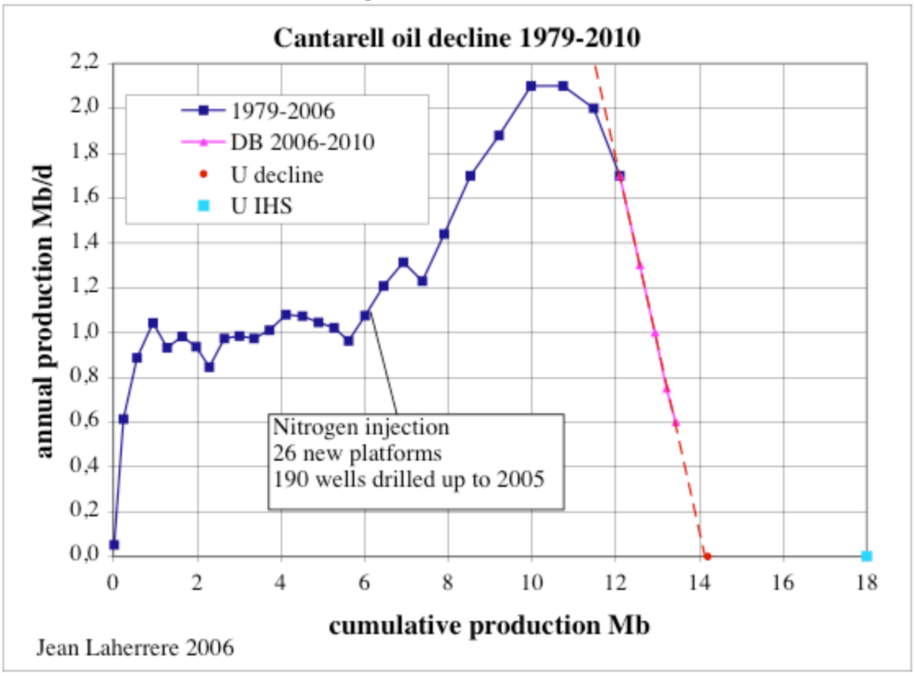


Same pattern and same operator for Rabi-Kounga largest field in Gabon.
Figure 19: **Oil decline of Rabi-Kounga, largest field in Gabon,** operated by Shell



The largest Mexican oilfield Cantarell discovered in 1977 (aggregation of several fields as Akal, Chac, Kutz, Sihil and Nohoch) 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 an 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

Figure 20: **Oil decline of Cantarell, largest field in Mexico 1979-2010**

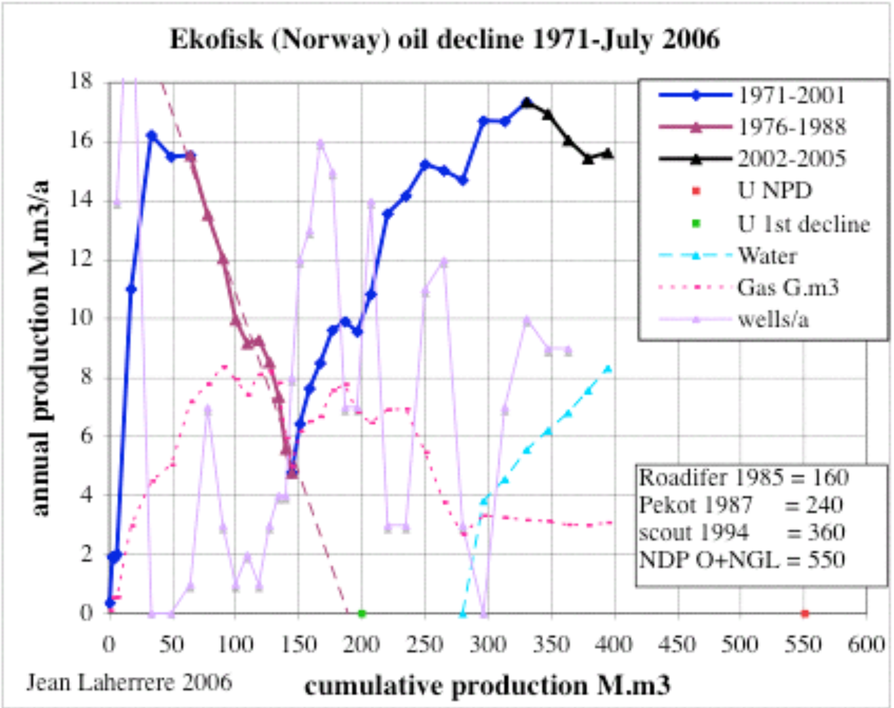


Cantarell pattern is similar to Yibal, slow start, large increase and steep decline; all thanks to new technology

The ministry of energy has reported that Cantarell is declining and will produce only 1,4 Mb/d in 2008, meaning a decline of 12%/a (14 %/a was also reported) and an ultimate about 16 Gb compared to more than 18 Gb for IHS. Again a negative reserve growth !.

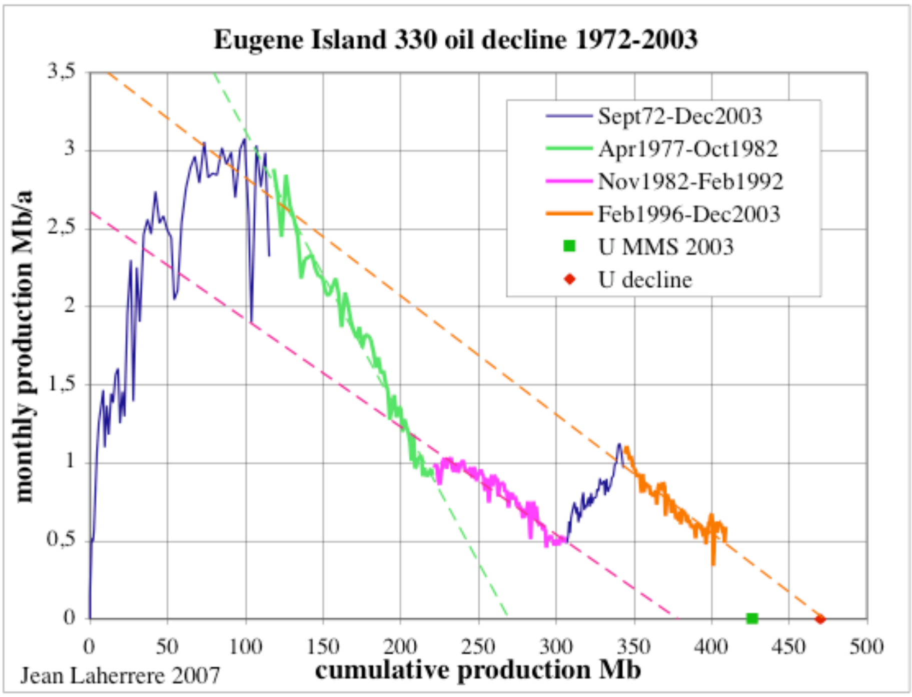
There are many negative reserve growth examples in the world, and in my review of all major (>100 Mb) oilfields of the world I found few examples of decline showing a real positive reserve growth and all those examples are due to an exceptional geologic case . The best examples are Ekofisk, which have seen its chalk reservoir, compacted with the decrease of pressure as such as the seafloor has fallen by 8 meters (platforms had to be raised) and the compaction has increased the reserve from 180 to 560 M.m3.

Figure 21: **Oil decline of Ekofisk (Norway) 1971-July 2006**



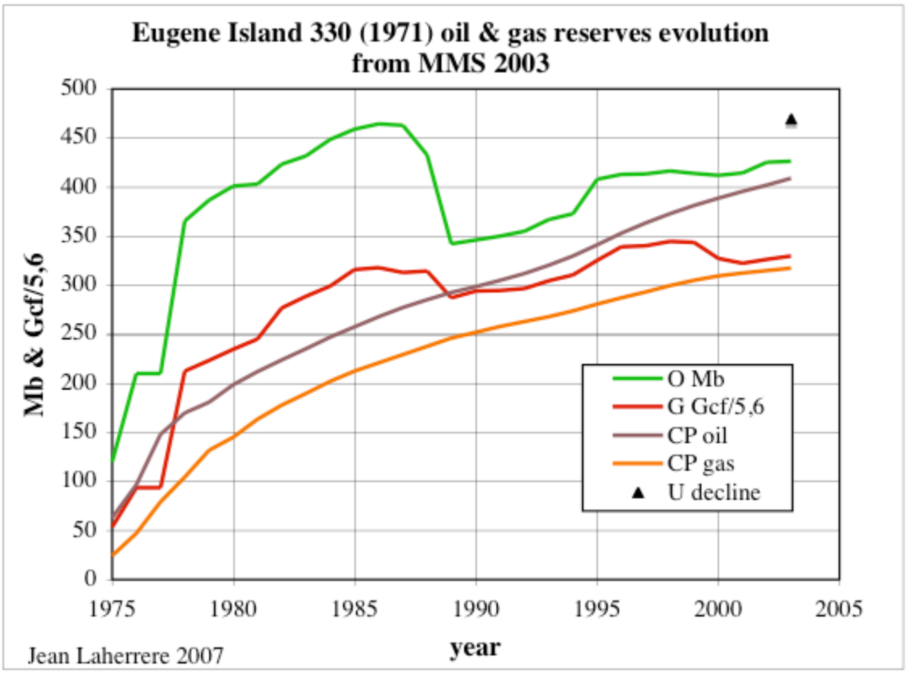
There is another example of exceptional positive reserve growth, which, is Eugene Island 330 in the Gulf of Mexico. The largest fault in the area called the Red Fault (studied on the web by several universities) allows the reservoir to be directly in communication to the source rock and when the pressure 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.

Figure 22: **Oil decline of Eugene Island 330 (US Gulf of Mexico) 1972-2003**



So oil decline displays an increase of reserve but official proved reserves show a decrease from 1987 to 2003!

Figure 23: **Eugene Island 330: oil & gas reserves, cumulative production evolution**



On the plot of annual production versus cumulative production, there are many example of negative reserve growth and few of positive reserve growth, so it is likely that the final **proven +probable** reserve growth would be negative, at the most nil when using mean values (by definition mean values are statistically assumed to not change as it is the expected value), but not positive as claimed by USGS.

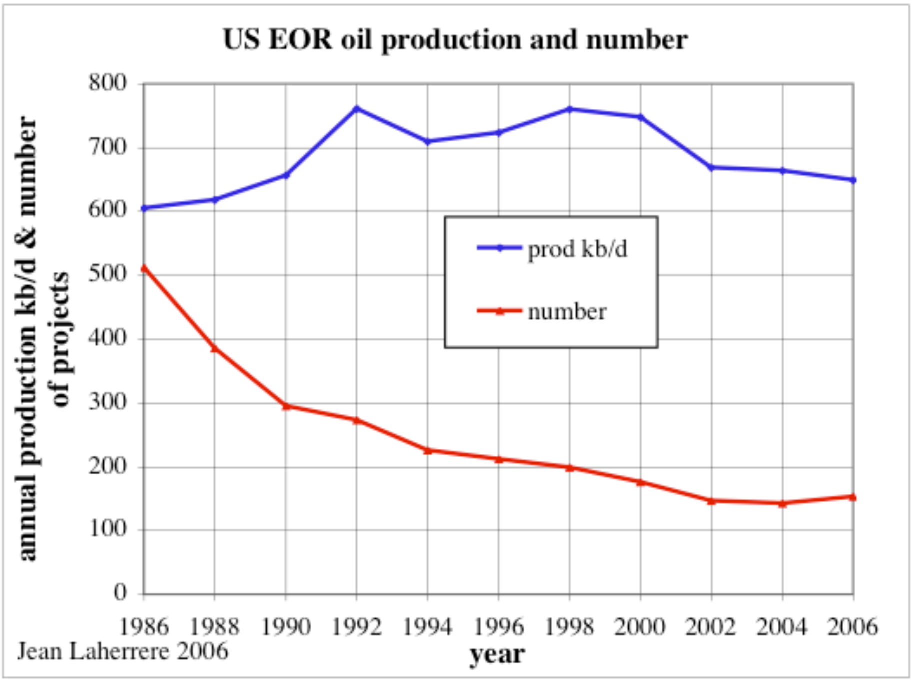
All tricks are used to show how good is the new technology.

It is surprising to read the statement of Lord Browne BP on World Energy vol. 9 n°2 2006 « *the last 30 years the limits to the depth of water in which drilling is possible has increased from **around 100 feet to more than 6000 feet*** » In fact the truth is quite higher for both limits. In the Gulf of Mexico 100 feet was reached in 1956 (GI043) and in 1975 31 years ago Cognac field (MC194) was discovered by 1024 feet. In 1977 30 years ago Total drilled Habibas in Algeria offshore by 3028 feet of water (TD 14752'). Today wells have been drilled by more than 10 000 feet of water (Chevron 10 011 feet at Toledo in 2004).

Why to give such wrong statements to praise the impact of technology? It is the case of IEA in May and October 2005 showing a manipulated 1998 Shell graph on North Sea (Laherrere 2006).

Many expects EOR (enhanced oil recovery = unconventional oil as stream, miscible gas or chemicals) to add a huge volume of oil. But EOR has been in practice since many years and in US EOR volume has decreased since 1998 despite that oil price has been multiplied by more than 5 since 1999.

Figure 24: **US EOR production & number 1986-2006**



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

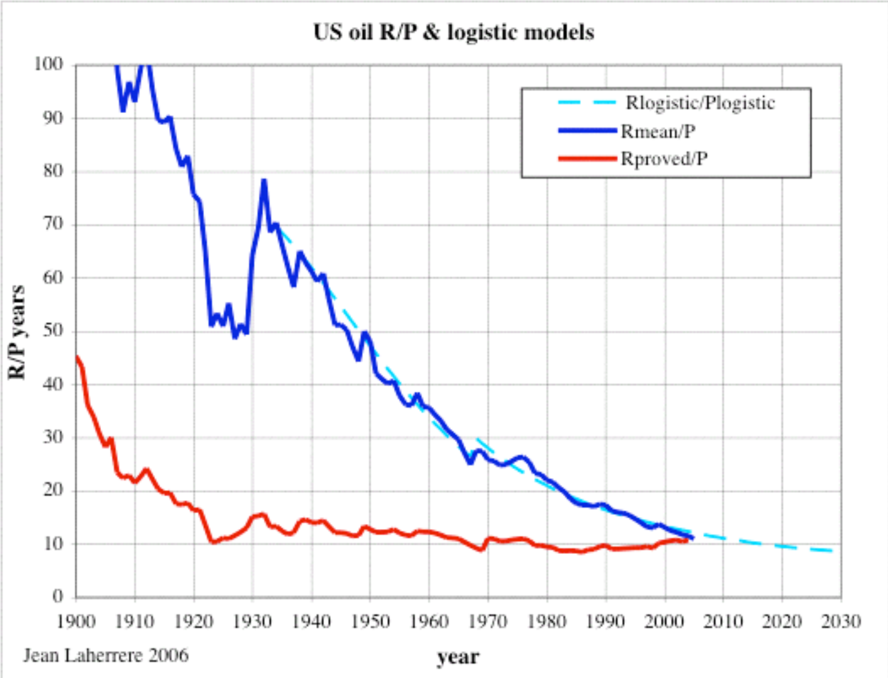
In France coal reserves and R/P are reported by BP Review

	Reserves Mt	R/P years
2000	116	32
2001	36	15
2002	36	17
2003	36	16
2004	15	17
2005	15	25

But in France the last coal mine was closed in 2005 and local authorities refuse surface mining proposals (in Aveyron and Nievre), so no new production is anticipated, so reserves are nil but resources still high . Unfortunately most of the times**, reserves are confused with resources, mainly for coal**.

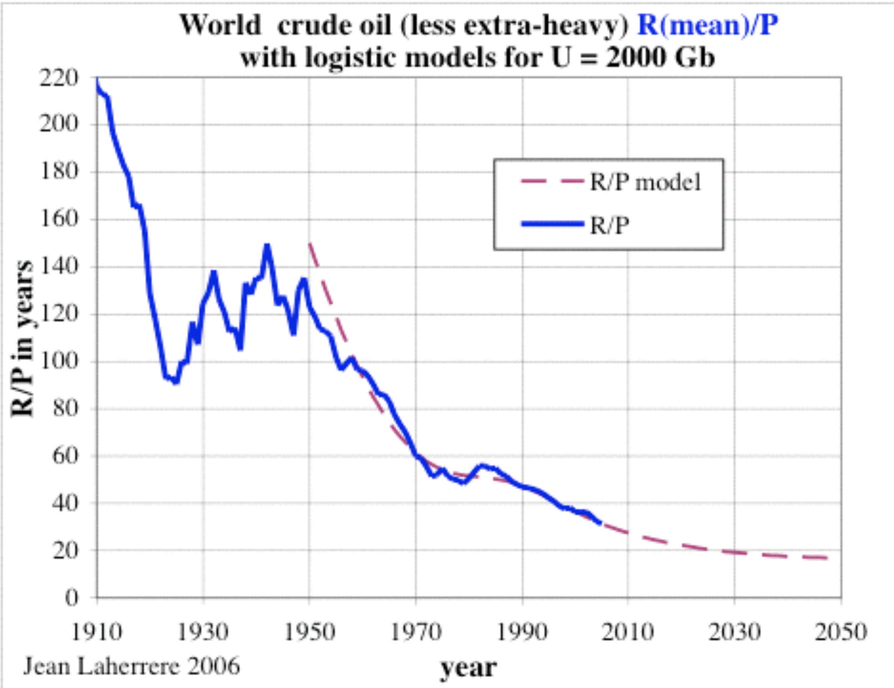
R/P from US proved reserves is about 10 years since the last 80 years, showing that this ratio is useless for forecasting, in fact it is used to estimate reserves as a thumb rule (even used by USGS). Using backdated proven + probable (mean reserves) gives a complete different decreasing trend, but R/P 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 25: **US R/P from mean backdated reserves and from proved current**



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 26: **World R/P from my technical database with logistic models 1910-2030**

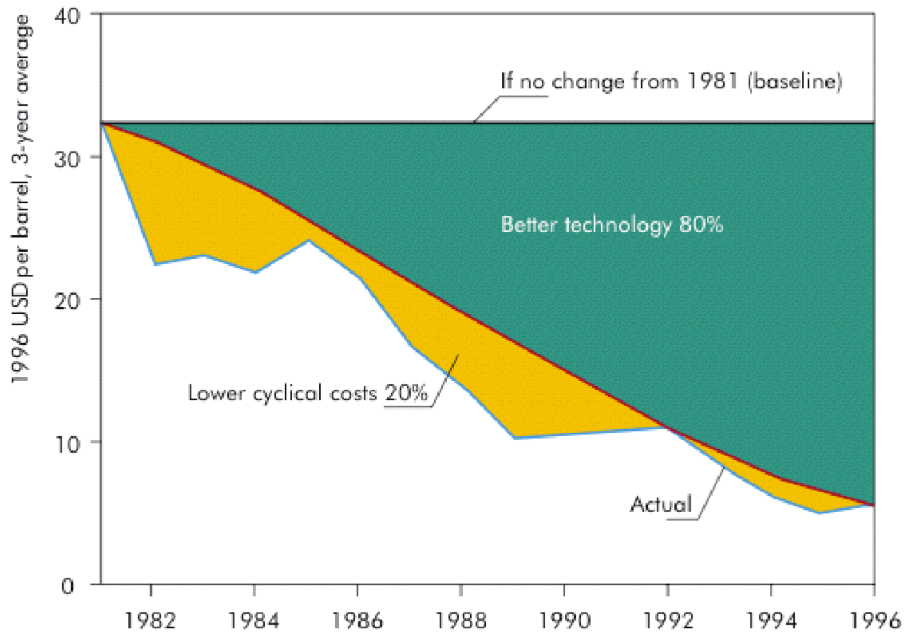


R/P is a very poor indicator for forecasting the future, but used by many.

-Myth 5: cost decreases with technology

Figure 27: **unjustified claim of technology impacts on costs for US offshore**

Figure 2.5 • Technology impact on costs for offshore USA



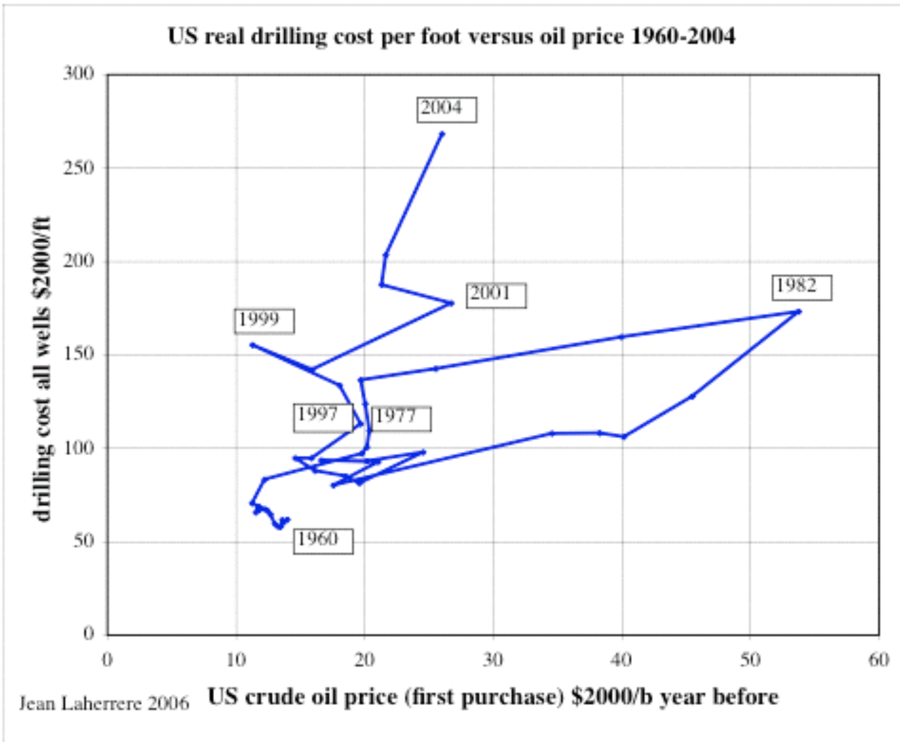
This graph is typical of lying publicity.
First the data starts only in 1981 when reality looks different at drilling cost for the period 1960-2004, drilling cost is more reliable data than cost per barrel (gathering badly defined items in exploration and development). Drilling cost displays completely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

Figure 28: **US drilling cost per foot 1960-2004 in $2000**

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 29: **US drilling cost 1960-2004 versus oil price in $2000**



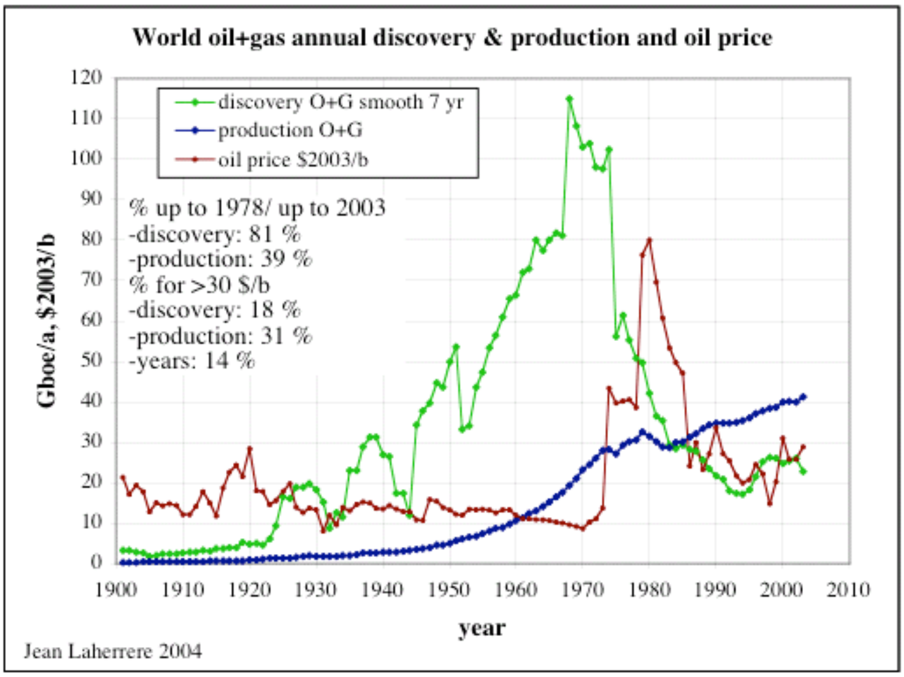
Drilling costs have also increased sharply lately because the lack of available rigs when producers in particular Saudi Arabia are increasing drilling to keep their production steady or to increase a little. Daily rate for deepwater is now about 0,5 M$/d and total cost about 150 M$ in deepwater exploration.

Development costs have also doubled as Kashagan (30 M$ for 1 Mb/d ?) and Sakhalin 2 with 20 G$.

-myth 6: 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 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 30: **World oil & gas discoveries and production with oil price**

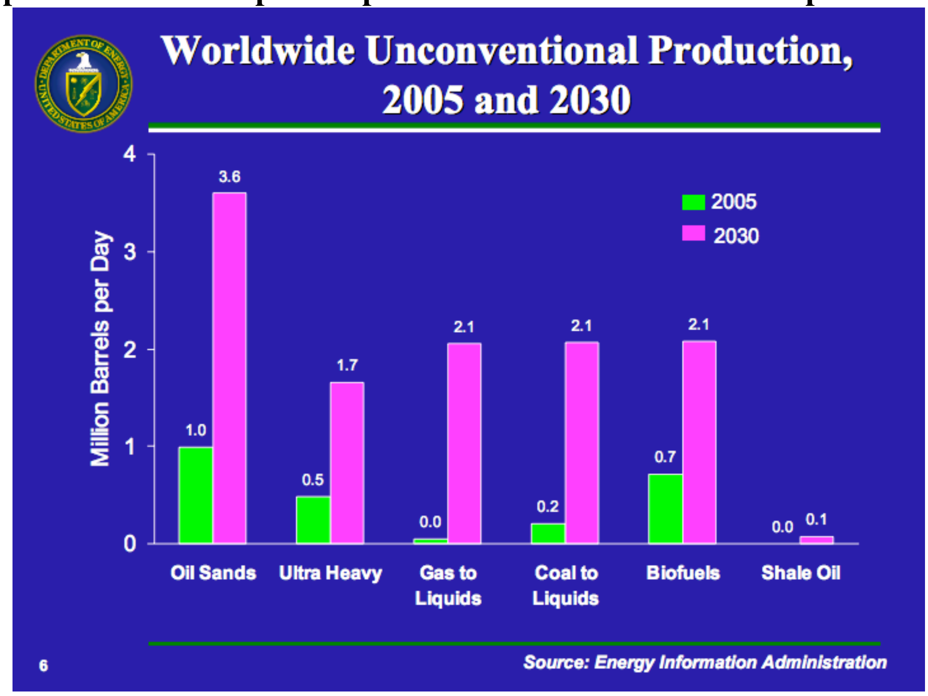


Discoveries pop up again in 1995 because going towards deepwater by lack of easy prospects and it is later after 1999 that oil price raises again. Oil price is not the driver for discoveries.

-myth 7 :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 having 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 have been 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 are 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 have been 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!

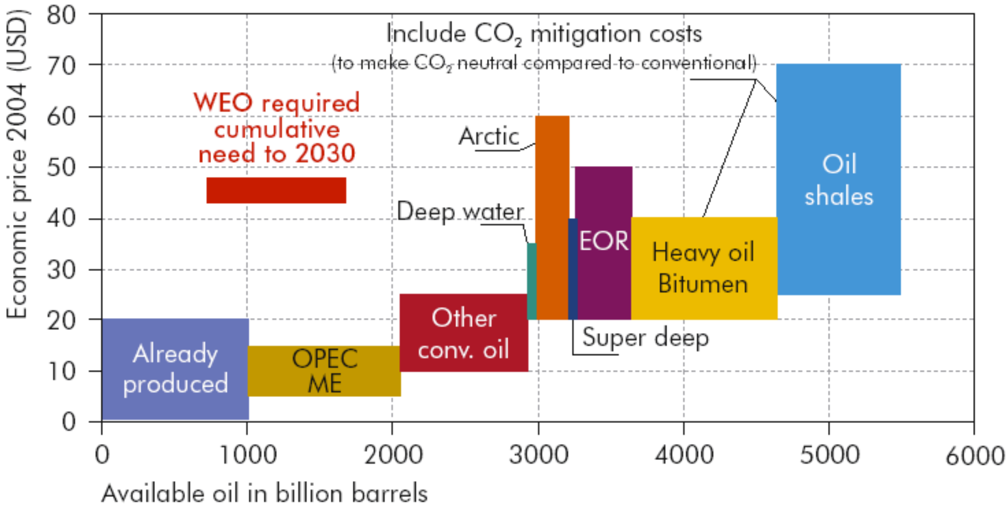
-myth 8 : oil shale have reserves of >2 Tb at a cost of 30-70 $/b
Oil shale in fact is immature kerogen (needing pyrolysis to be converted into oil in what is called the oil kitchen) and is classified with coal as lignite. It is often confused with oilsands which in contrary is at the other end of the oil generation being degraded oil.
Oil shale were produced in France since 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, as in Estonia. But Estonia was obliged joining the UE to stop burning oil shales because pollution. During the oil shocks of 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 (except Brazil with about 4000 b/d and China with <2000 b/d did not 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 to upset the heating, a wall of sediments is frozen around the heating place. Shell is rumoured to produce 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 as 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 said Youngquist: *oil shale will be the energy of the future for ever*
USDOE has issued last years several leases of 160 acres for pilot but they forecast only for 2030 shale oil as for memory for only 100 000 b/d compared to 3,6 Mb/d for oilsands
Figure 31: **prevision USDOE pour la production de non-conventional pour 2030**



Huge volume 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 32: 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*



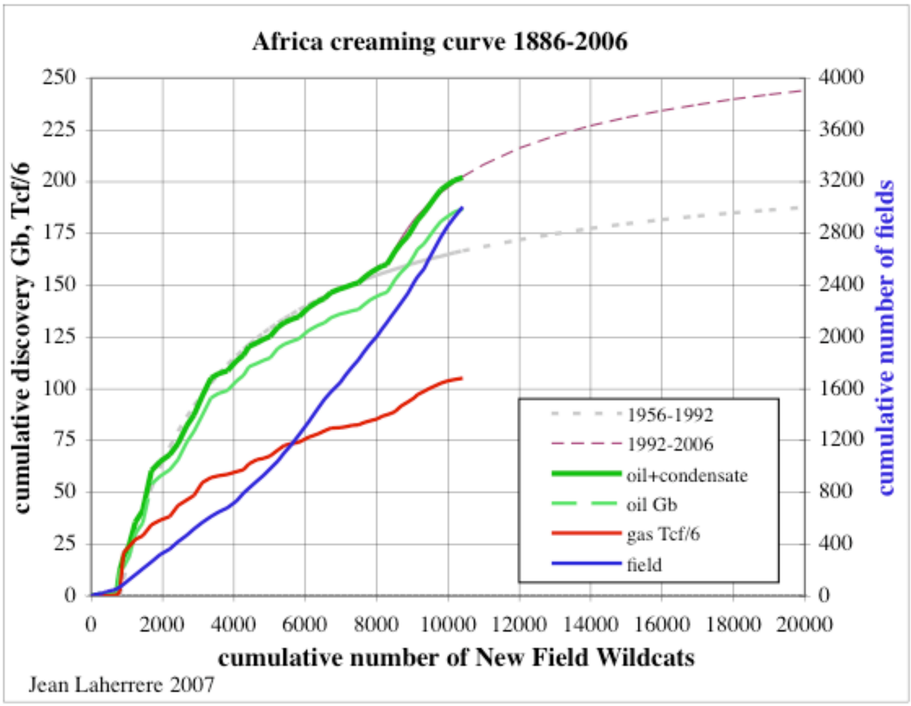
This graph is mainly wishful thinking and wild guess to promote the idea of abundance of peak oil deniers. Only deepwater estimate seems reasonable. Heavy oil is not defined.

-poor indicators :

The world is using many indicators which are very poor, as proven reserves, recovery factor, R/P, single cycle (Hubbert peak), GDP.
They please because they are simple but Paul Valery has written : *All that is simple is false and all that is not is useless.*

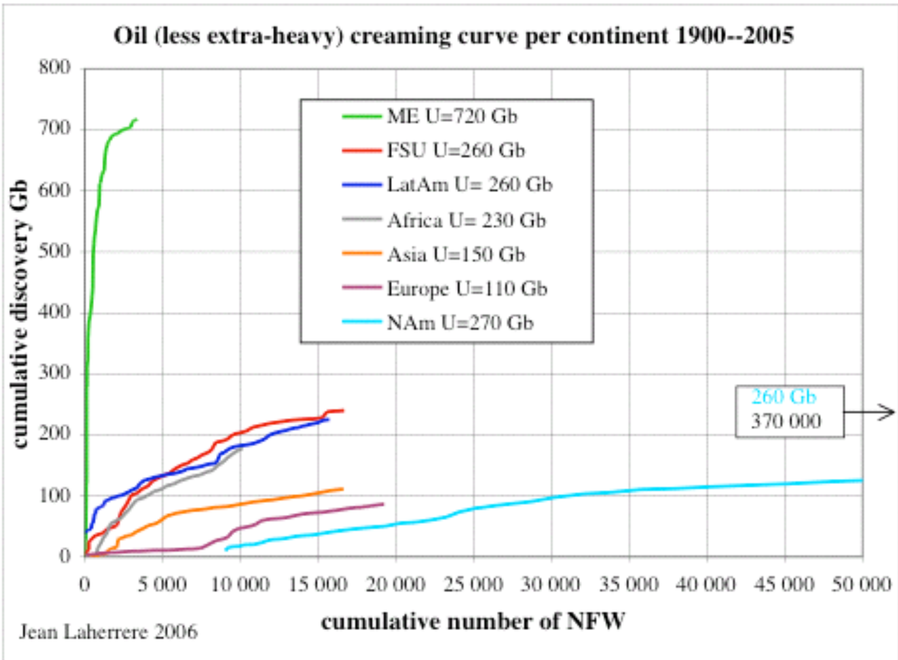
-Ultimate estimation

Creaming curve is the plot of cumulative mean discovery versus the cumulative number of exploratory wells (NFW= New Field Wildcat). It is modelled easily with several hyperbolic cycles.
Africa displays two oil cycles which can be modelled with hyperbolas and the oil ultimate can be estimated at 250 Gb (less than the asymptote because the amount of NFW will be limited and estimated at the double of present value. Gas in Gtoe +Tcf/6 is about half of the oil . The cumulative number of fields shows in contrary an increase, first around 4000 NG FW =1956 beginning of Sahara exploration with modern seismic and around 8200 NFW = 1993 beginning of deepwater discovery (as also Berkine in Algeria and Mursuk in Libya)
Figure 33: **Africa oil & gas creaming curve**



The display by continent shows the huge inequality of endowment. The ultimate by continent is shown in the next graph totalising 2000 Gb. My ultimate in 2005 was 2150 Gb but I decrease it to a round value because the uncertainty of data being more than 10 %. I will change it to a more precise number only when I am sure that the accuracy may allow it.

Figure 34: **Crude oil less extra-heavy creaming curve by continent**



Creaming curves are rarely used because few have the detailed and complete data of NFW..

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 giants fields. Out of about 600 sedimentary basins only 200 has oil & gas fields and about 20 has the majority of oil & gas.

The map of oil & gas fields(HORN AAPG 2005) is shown in the following world map. Of giants and the next of sedimentary basins. Middle East, West Siberia, North Sea and Gulf Coast display concentration. South hemisphere contains much less giant fields (less sedimentary basins).

Figure 35: **location map of giant oil and gas fields from Horn AAPG 2005**

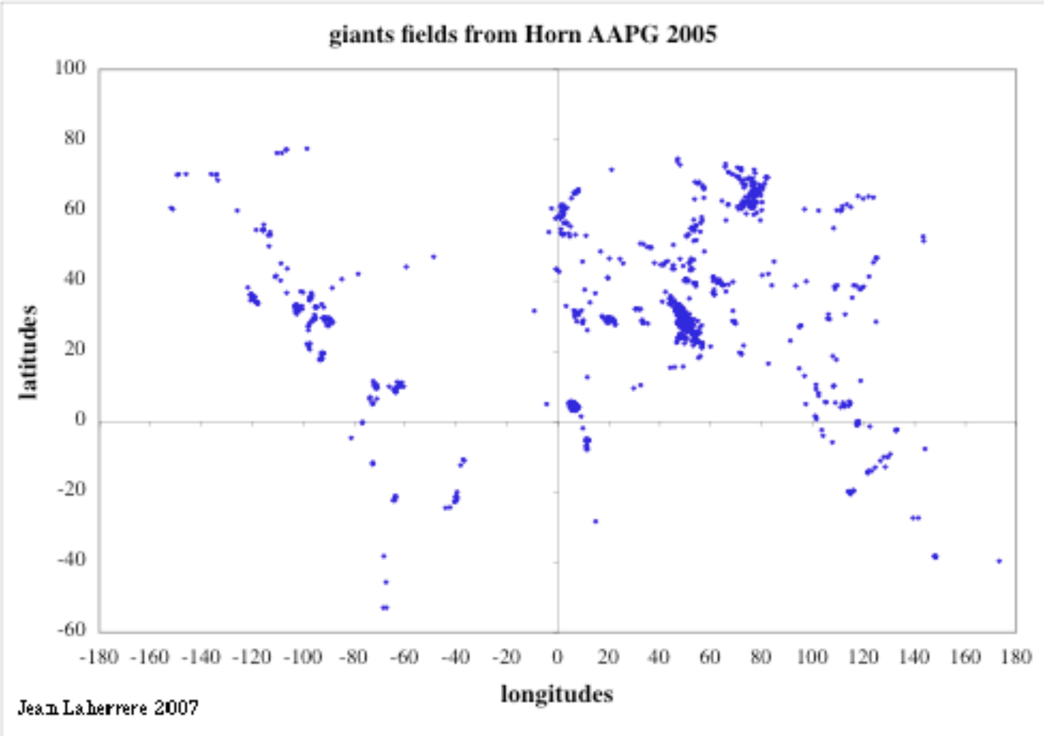


Figure 36: **location map of sedimentary basins from Schlumberger**

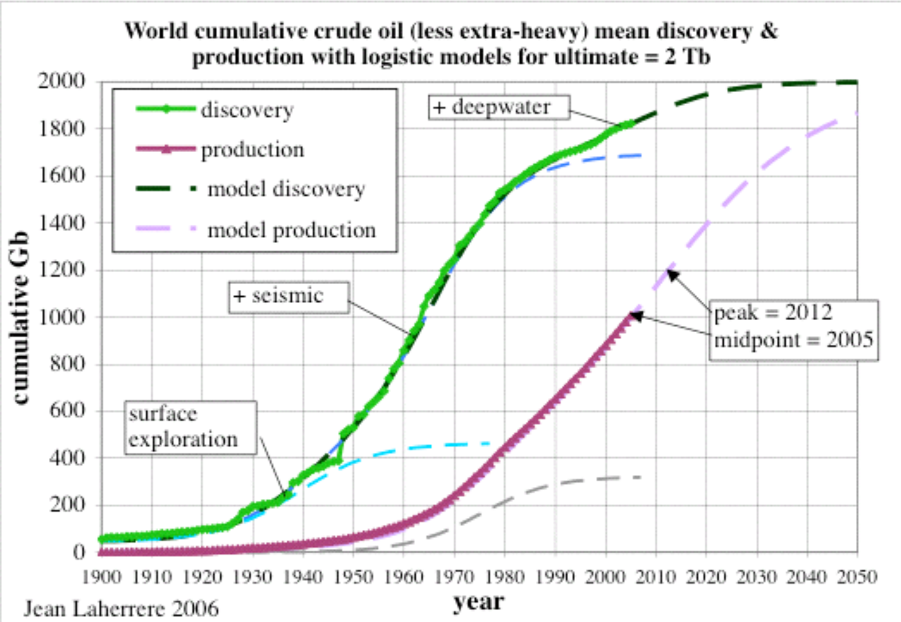
-Modelling of future "*oil*" production

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 at 2005 and the oil peak at 2012 .

Figure 37: **World cumulative crude oil (less extra-heavy) mean discovery & production with forecast for an ultimate of 2 Tb 1900-2050**



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 for well showing its inaccuracy).

- **-World annual "oil"**

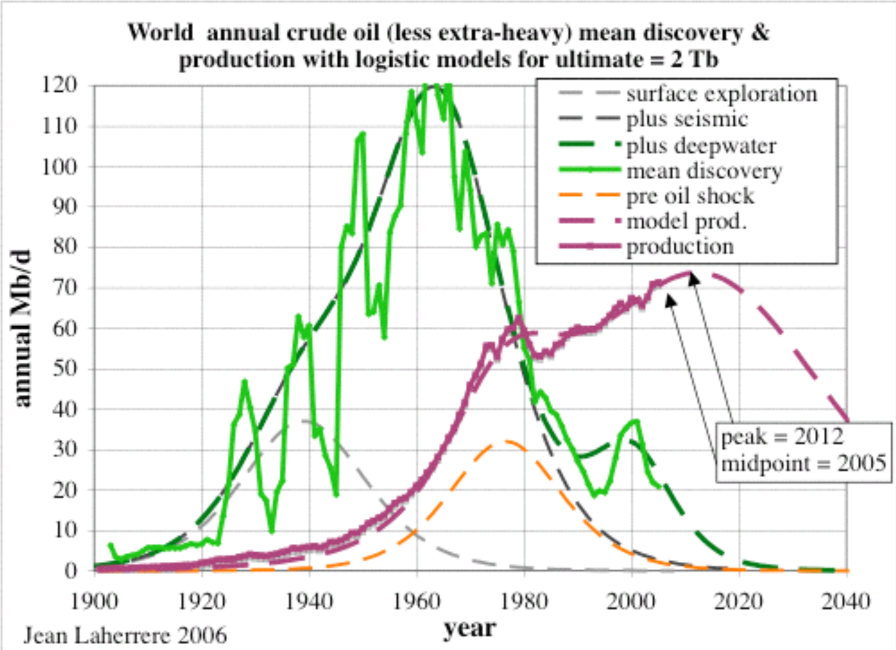
-Crude oil less extra-heavy discovery & production

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 constraint from the demand or from investments. It is likely that there will be not a peak but a **bumpy plateau** (with chaotic prices) because constraints from the depends or investments, following 2004 Paul Volcker (former head of the Fed)'s forecast of 75% chances to have in the next 5 years an economic crisis. This year his successor Alan Greenspan now retired added that there is a 33% chances of a depression in 2007. The house price bubble, which has allowed consumers to borrow and consume more than necessary, is ending.

It is funny to see top position managers saying their belief as soon as they retire: Bernabe ENI in 1998; Bowling ARCO in 1999, Volcker, Greenspan.

Claude Mandil will do the same when he retires in the fall; he is already saying that IEA 2006 reference forecast is unsecured, unattainable, unrealistic and unsustainable.

Figure 38: **World annual crude less extra-heavy oil mean discovery and production with logistic model for U = 2000 Gb** (no demand or investment constraint)

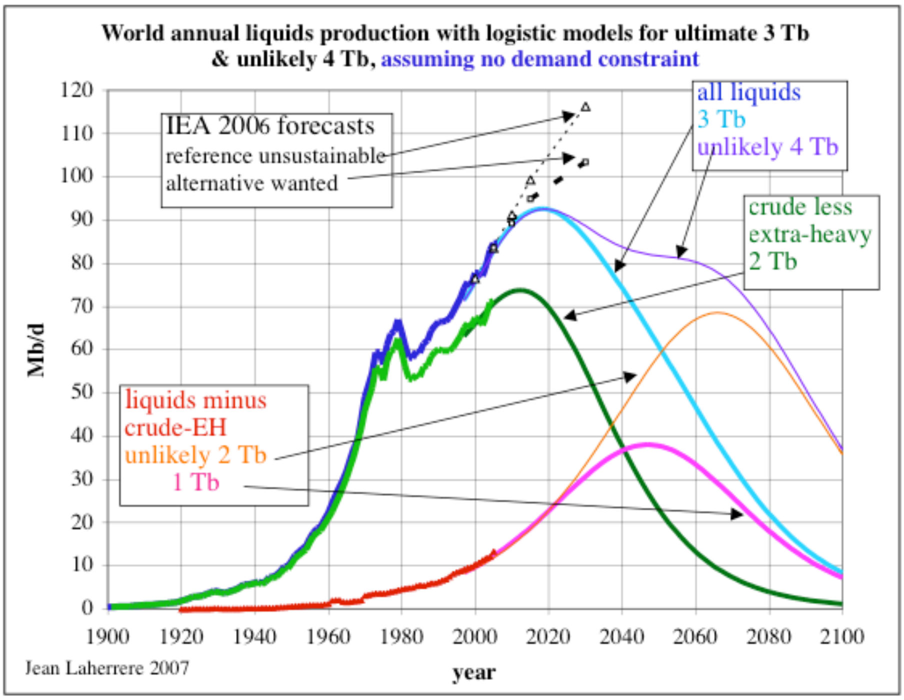


-liquids production

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 the 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 39: **World liquids production** (no demand or investment constraint) **1900-2100 for an ultimate of 3 & 4 Tb**

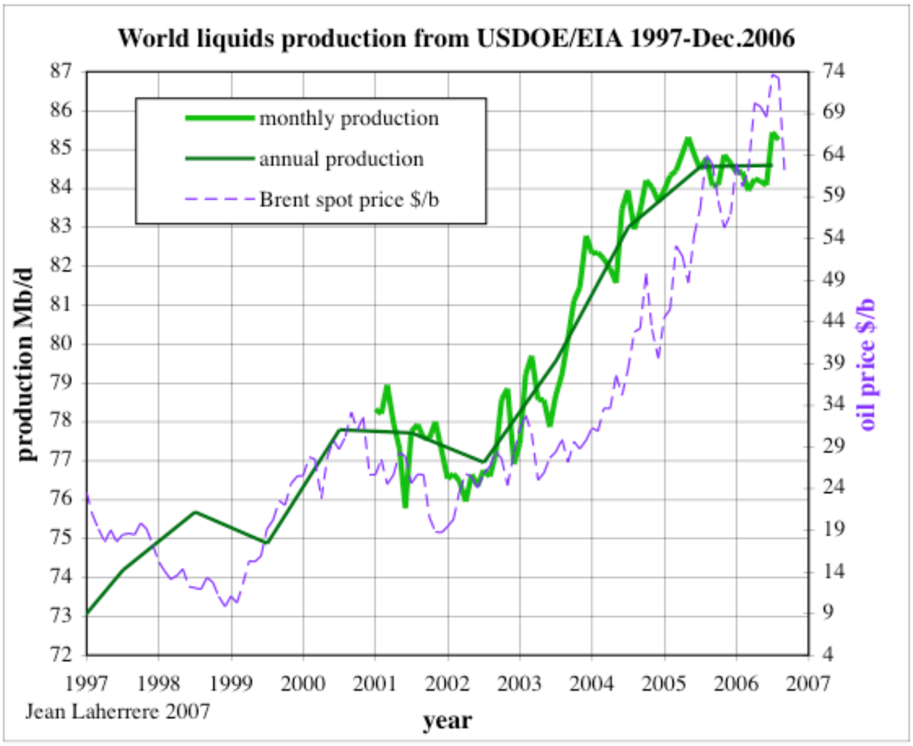


This graph is drawn as the previous one with the assumption that the constraints are only from the resources but that constraints from the demand, investments or politics will not occur that is unlikely.

On the last monthly data from USDOE on liquids, what do we see?

a plateau? or just one more step as in 2001?

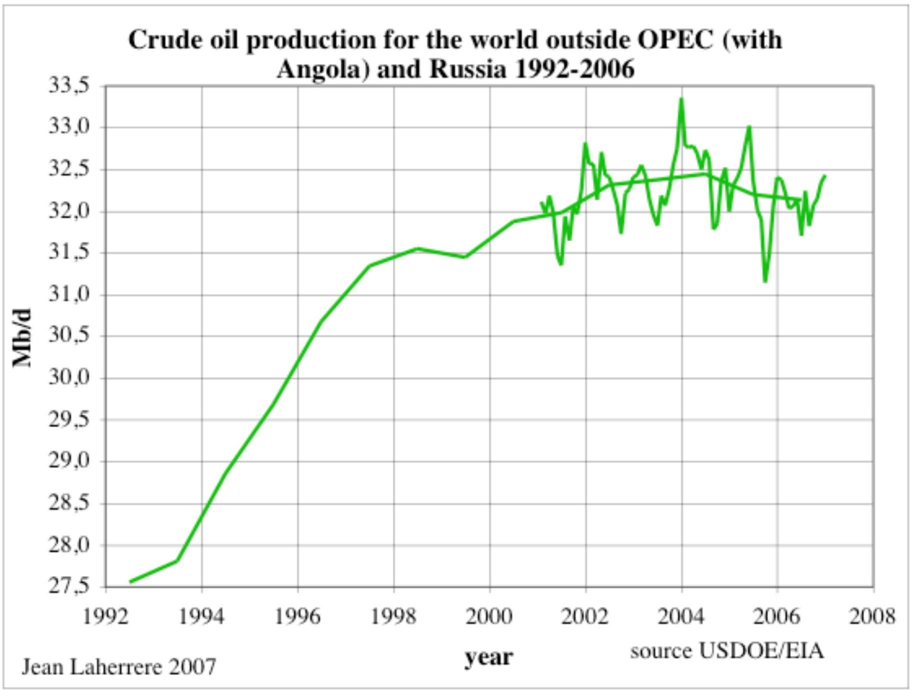
Figure 40: **World liquids production 1997-2006**



The liquids production seems to be entering a bumpy plateau that I forecasted years ago (CERA has not said anything new) because of the constraints.

The crude oil production outside OPEC (now including Angola) and outside Russia seems to have peaked in 2004.

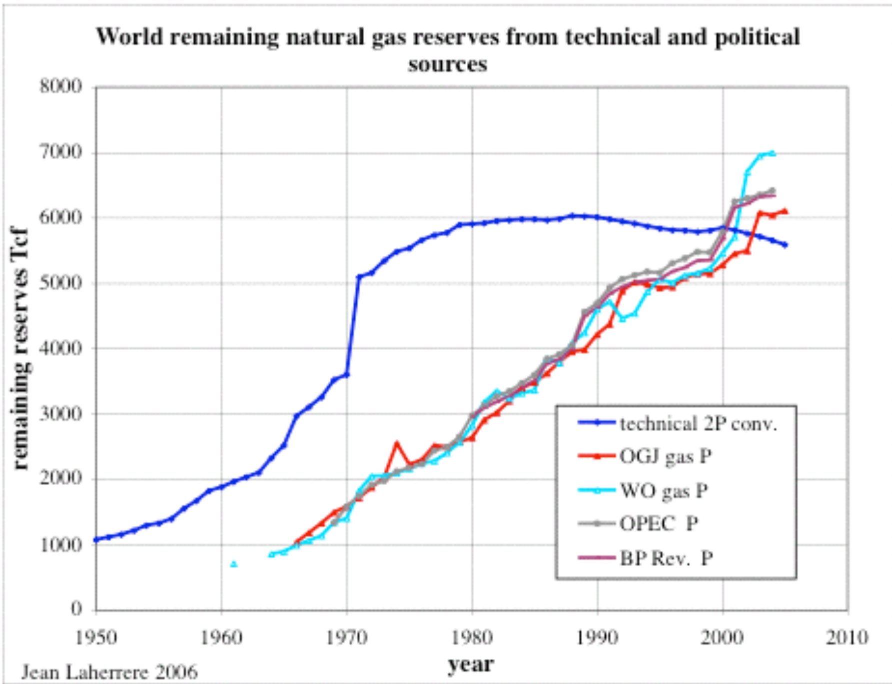
Figure 41: **Non-OPEC, Non-Russia crude oil production 1992-2006**



-Natural gas

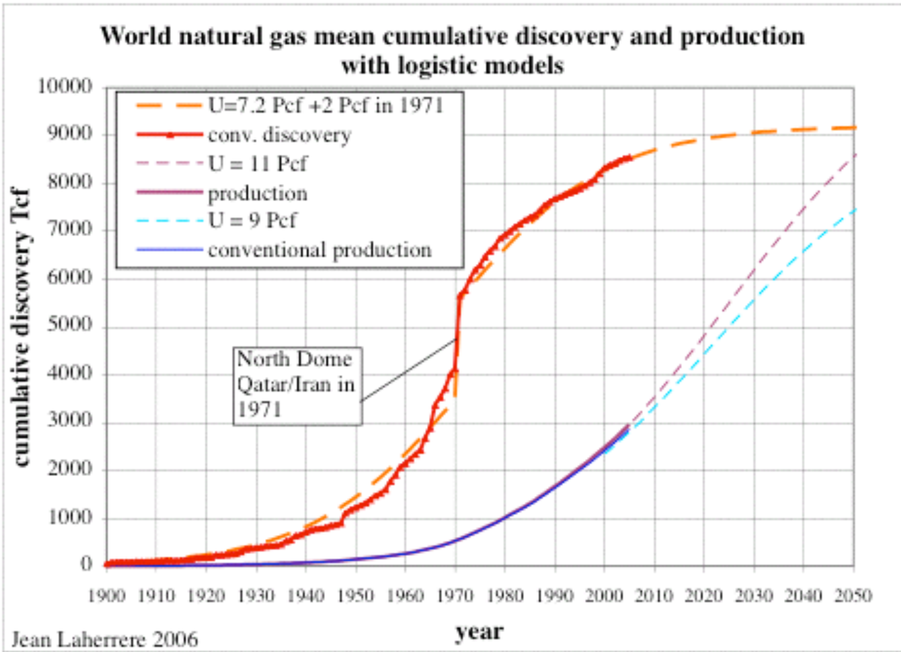
The political remaining natural gas reserves reported as proved by nations display the same divergence with the technical data. The problem is that technical database is more difficult to obtain, because the difference between there is a lot of stranded gas (reserves or resources?). Technical data has peaked since 1980

Figure 42: **world remaining NG reserves from different sources**.



World cumulative discovery and production is modelled with a logistic curve but the largest gasfield (North Dome found in 1971 being North field in Qatar and South Pars in Iran reported as 1991 by IHS) represents about 15 % of the ultimate (Ghawar represents only 6%) and upsets the curve, so it is separated from the curve

Figure 43: **2006 forecast: World conventional cumulative gas conventional discoveries and production with logistic models**



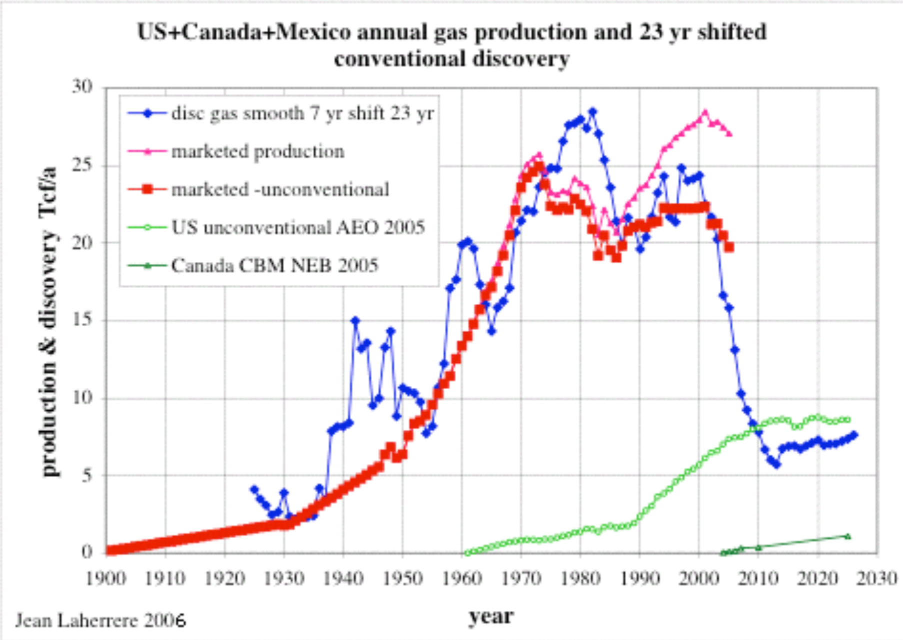
The ultimate NG was estimated at 10 000 Tcf (10 Pcf) 10 years ago (Laherrere, Perrodon, Campbell 1996) for conventional and 12 Pcf including non-conventional. We keep these values, as updated data confirm these round values, but if in-situ gasification of coal works, the ultimate can increase, but it will not change the peak, only the later decline.

Global gas will peak around 2030, but as gas is ten times more expensive to transport than oil, there are several natural gas local markets: North America, Europe, Asia Pacific and now South America.

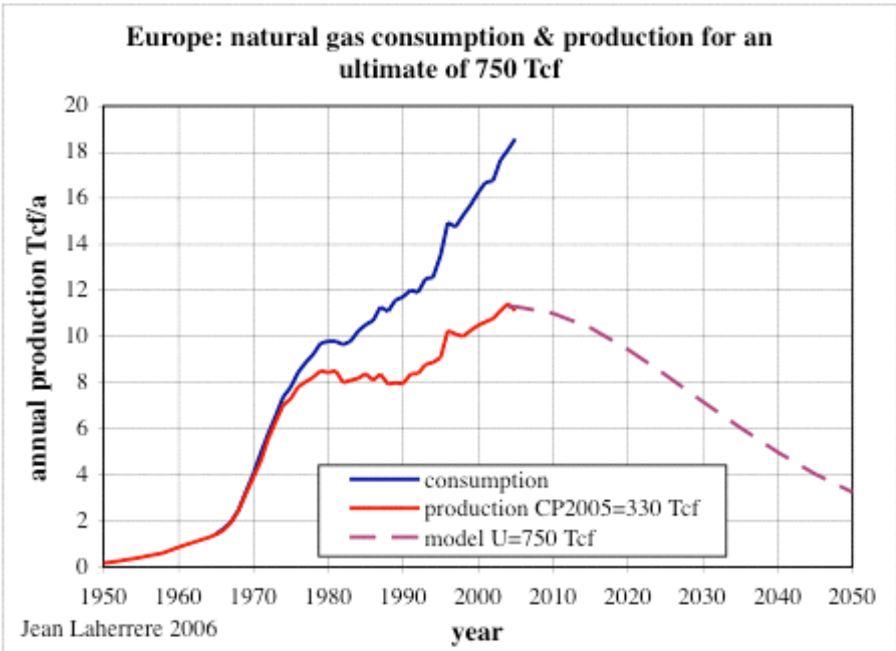
There is still flared gas because too far from consumption centres and there is large amount of unconventional gas with tight reservoirs, gas shales, CBM (coalbed methane). But unconventional gas needs a very large amount of drilling and growth will be slow. The attempts in the 70s to produce dissolved gas in geopressured aquifers (Gulf Coast) demonstrate that problems are almost insurmountable. Hopes in oceanic hydrates are dreams as these hydrates are too dispersed (decimetric or metric accumulation) to be one day produced if a way to produce them is found = again a myth as mentioned above!

Gas shortage will occur soon in North America and it is why they are rushing to build LNG terminals. Conventional natural gas production will decline sharply when comparing to the discovery shifted by 23 years.

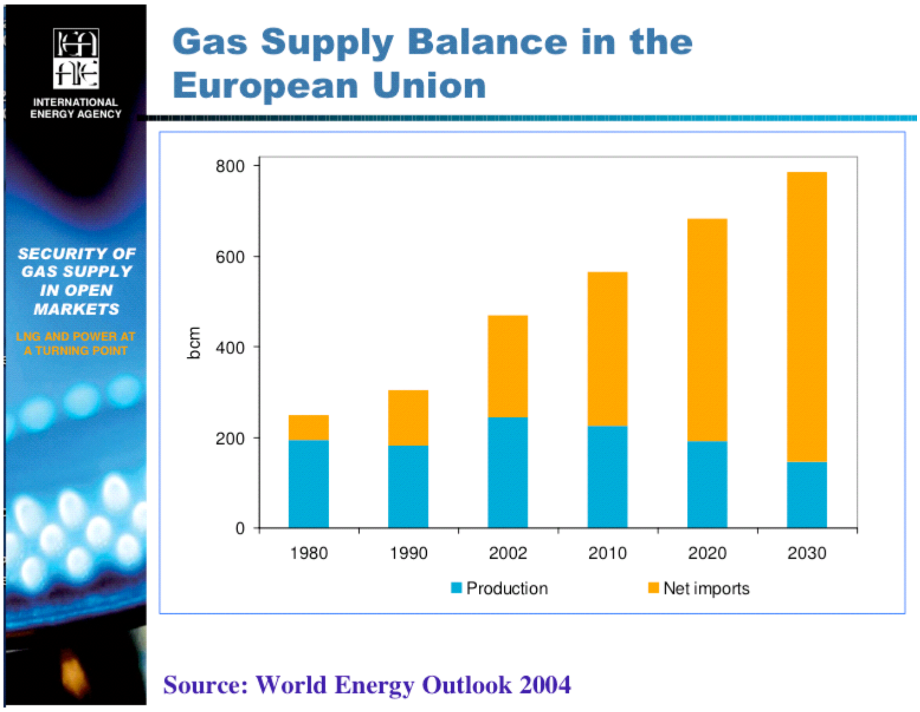
Figure 44: **US + Canada + Mexico: conventional gas production & shifted discovery by 23 years: 1900-2030**



Natural gas production in Europe is peaking but consumption is rising sharply. Europe is counting too much on Russia gas. Europe will suffer soon of gas shortage and high prices.
Figure 45: **Europe: natural gas consumption & production for an ultimate of 750 Tcf: 1930-2050**



IEA recognizes that the European Union gas supply balance will need to import (mainly from Russia and Algeria) in 2020 about 500 G.m3 (18 Tcf)
Figure 46: Supply and demand of natural gas for European Union from IEA

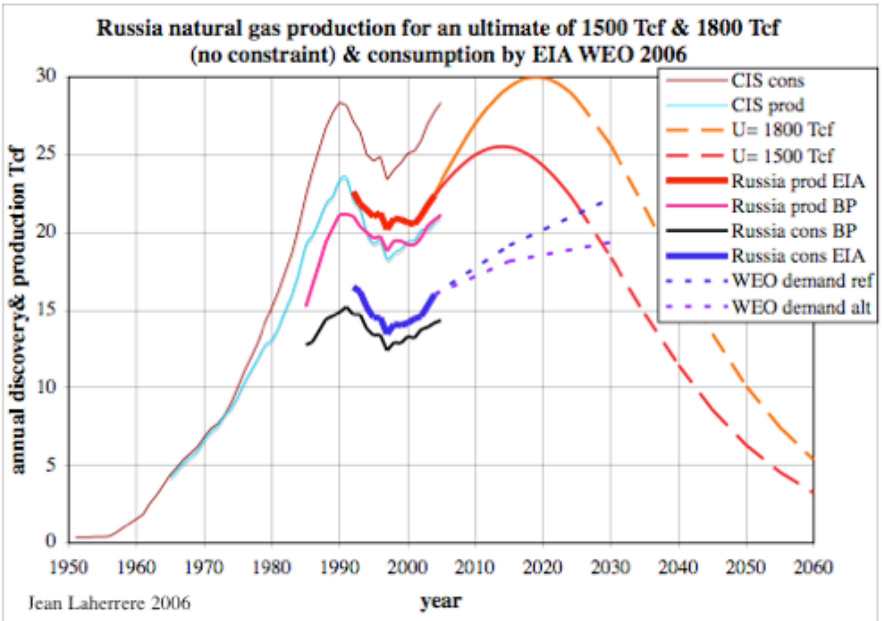


Europe is counting on Russia gas reserves, which are overestimated because the FSU 1979 classification (Khalimov 1979, 1993) is dealing with the maximum theoretical recovery (3P). The largest West Siberia gasfield Urengoi (for many still the world largest!) is sharply declining (Milov 2005, Stern 2005) and its likely ultimate is about 240 Tcf when reported as 370 Tcf by

My estimate of FSU ultimate is about 2000 Tcf and FSU gas production should peak (no investment constraint) about 2020 at less than 35 Tcf/a (presently 27), with a potential of export less than 10 Tcf. But if Russia is making a lot of money from oil and gas export; Gazprom finance is used by the government leaving no enough to invest in the very expensive development large gasfields (over 100 Tcf) of Yamal peninsula (Bovanenko discovered in 1971) and Barentz sea (Shtokman discovered in 1988). Yamal gaspipeline has been planned for decades and still not completed.

Russia is also promising to export gas to US and Asia (3 Tcf/a for China in 2011 signed in March 2006). Putine (rumoured as the next Gazprom head when obliged to quit Russia presidency in 2008) is making alliance with Sonatrach to squeeze Europe gas needs. But FSU was used to waste gas because it was considered in the past as unlimited (Moscow flat rents include gas heating and there is no meter). Large savings could be realized. January 2006, Gazprom shut gaspipeline not only for Ukraine and Europe but also for all Russian consumers as it was very cold and production was not able to supply the demand (Milov 2006).

Figure 47: **Russia gas production for ultimates 1500 & 1800 Tcf (no constraint) and consumption by EIA**



Europe gas needs are unlikely to be filled, if the demand continues as in the past (business as usual), by the present exporters. More LNG terminals and gas pipelines will be then necessary.

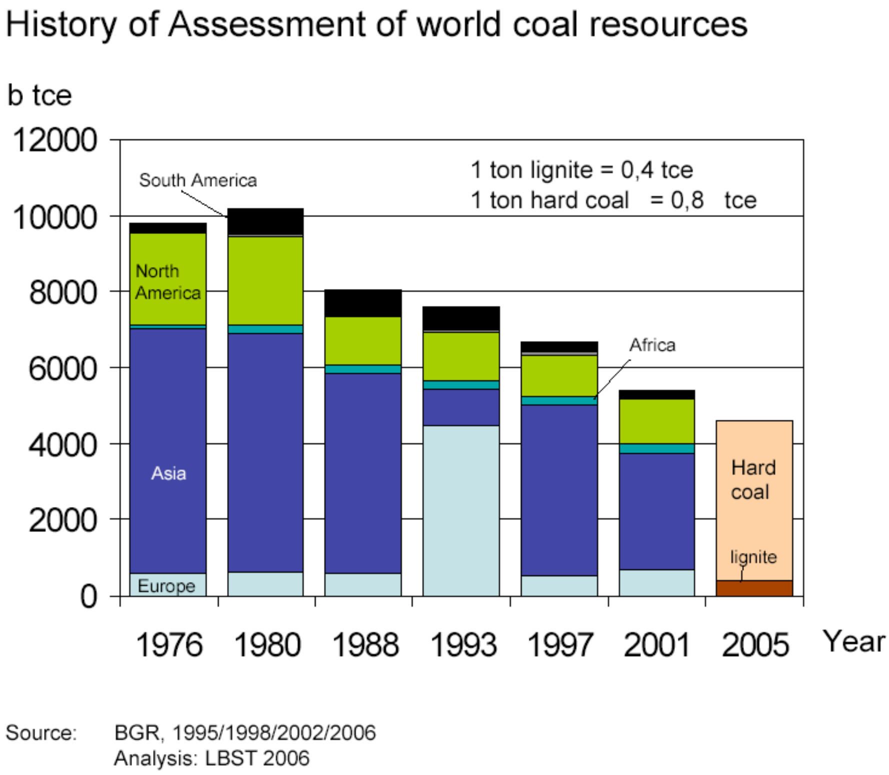
-coal

For coal it is more difficult because there is no coal scout company selling technical data and reserves published as those from national agencies which use different definition and play on the ambiguity between reserve and resources; The only agency doing periodically and from their own estimates the inventory of the world resources is the BGR (Federal institute for geosciences & natural resources) in Germany, but BGR assessments of coal reserves have increased from 1997 to 2005 when coal resources have decreased

BGR	reserves			resources		
Gtoe	1997	2001	2005	1997	2001	2005
hard coal	340	421	437	3503	2474	2489
soft brown coal	50	47	49	760	291	242
coal	389	467	487	4262	2765	2731

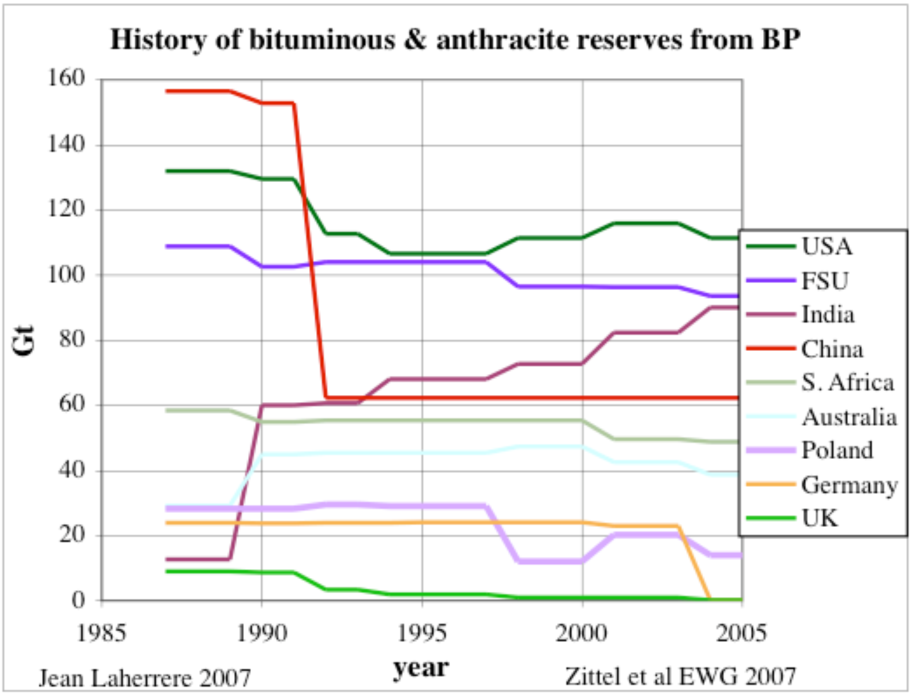
In fact BGR coal resources have been in the decline since 1980 from Zittel et al 2007 Energy Watch Group 2007 (« Coal : resources and future production » EWG-series n°1/2007 March) Europe resources display an erratic spike in 1993 and the world resources have been divided by half !

Figure 48: **History of assessment of world coal resources from Zittel et al 2007**



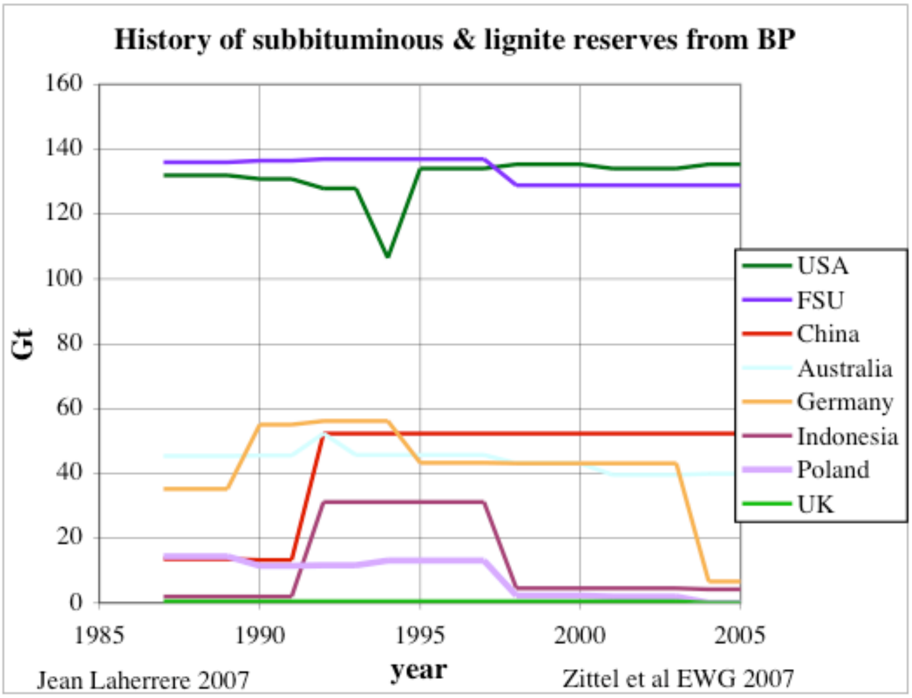
BP Statistical Review reports WEC estimates where German proved hard coal reserves stated as 23 Gt in 2003 was downgraded to 0,183 Gt in 2004 and 0,161 in 2005, without any explanation.
The history of remaining reserves for main producers from BP data (reported by Zittel et al 2007) shows severe revisions for hard coal = decreases for China, Germany and increases for India

Figure 49: **History of bituminous & anthracite reserves from BP**



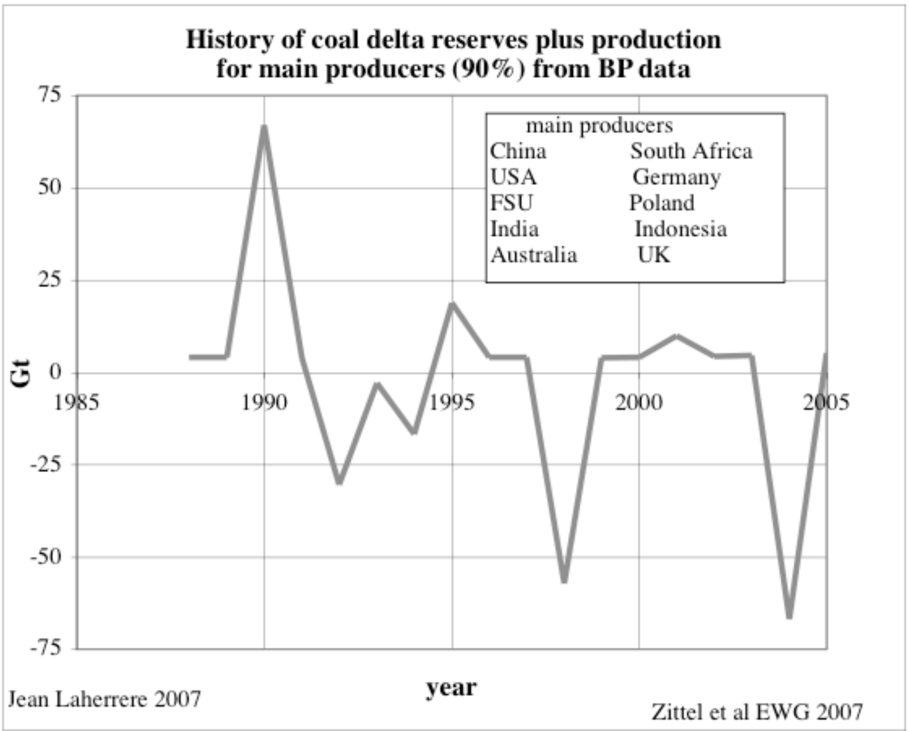
same for brown coal

Figure 50: **History of sub-bituminous & lignite reserves from BP**



Such large variation up and down shows the poor quality of the estimate.

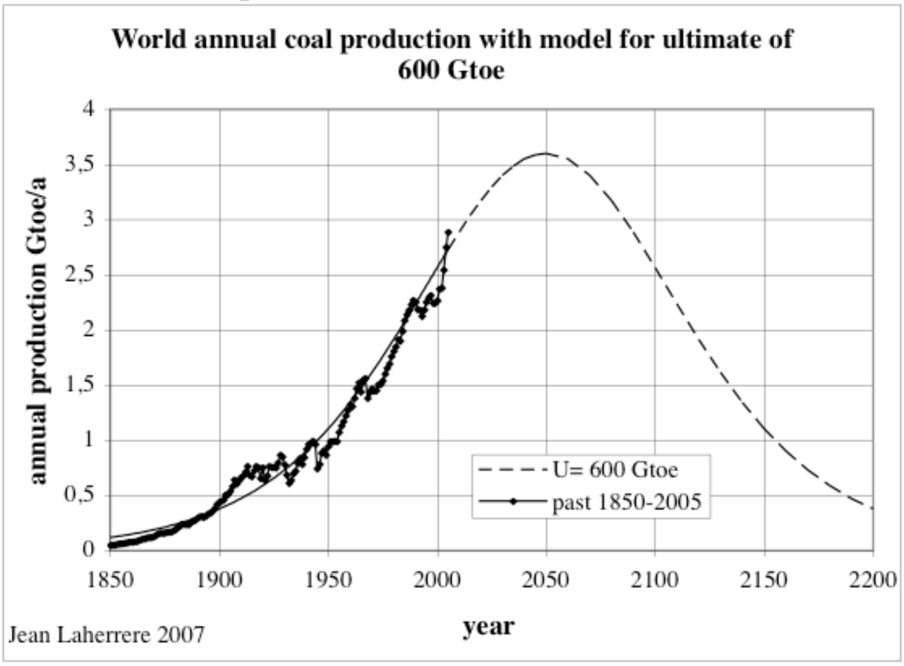
The delta of BP remaining reserves plus annual production for the main 10 producers (90% production) represents the variation in ultimate recovery and it is trending downwards.
But again the spikes indicate the poor quality of the data ;
Figure 51: **History of coal growth of reserves plus production for main producers from BP**



Zittel rightly insists on the poor quality of coal reserves and resources.

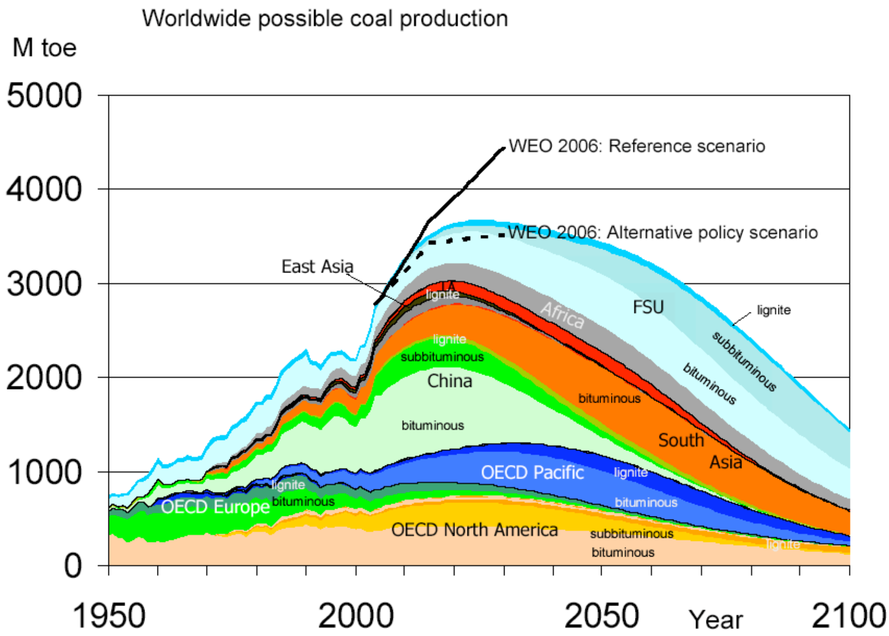
Assuming an ultimate of 600 Gtoe world production should peak around 2050.

Figure 52: **world annual coal production 1850-2200 for an ultimate of 600 Gtoe**



Zittel forecasts a coal peak around 2030 at 3,6 Gtoe/a, close to IEA/WEOP 2006 alternative scenario, sooner and higher than my peak (3,6 2050), but their decline is sharper than mine (1,5 Gtoe for 2100 against 2,5 for mine).

Figure 53: **world annual coal production 1950-2100 from Zittel et al**



EWG coal peak is forecasted at 3,6 Gtoe around 2030 and not far from my forecast 3,6 Gtoe around 2040, but their decline is steeper with only 1,5 Gtoe in 2100 against 2,2 Gtoe for mine They comment on the decreasing evolution of BGR world reserve estimates

-forecasting fossil fuels FF

BGR annual report 2005 displays the reserves of non-renewable at end 2005 for the top 10. US is well ahead followed by Russia , China and India, Australia, Saudi Arabia is only sixth ! It shows the obvious importance of coal, but coal is badly estimated.

Figure 54: **top ten countries for non-renewable reserves at end 2005 from BGR**

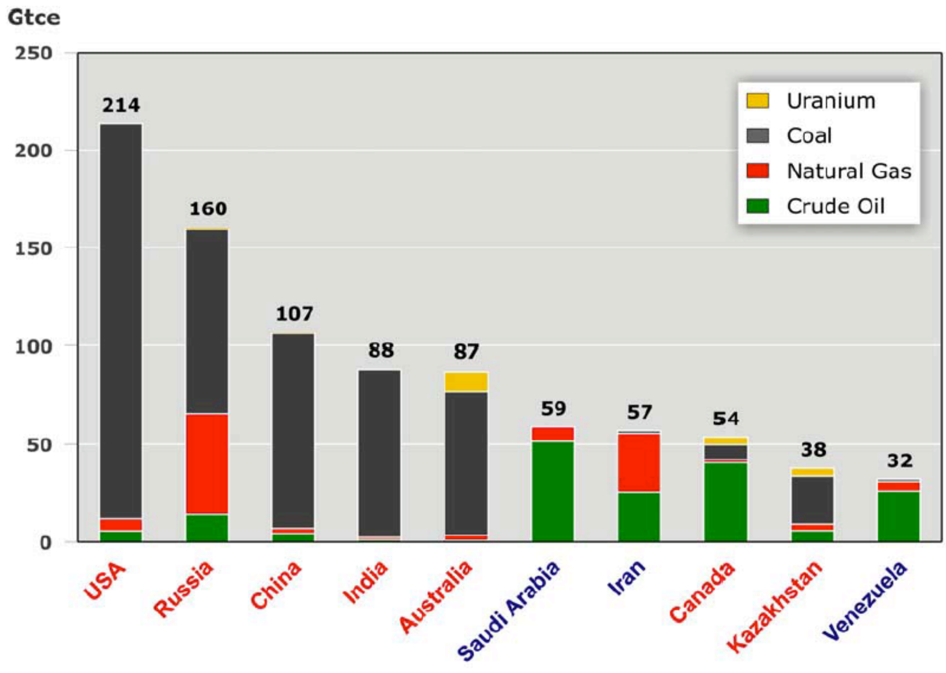


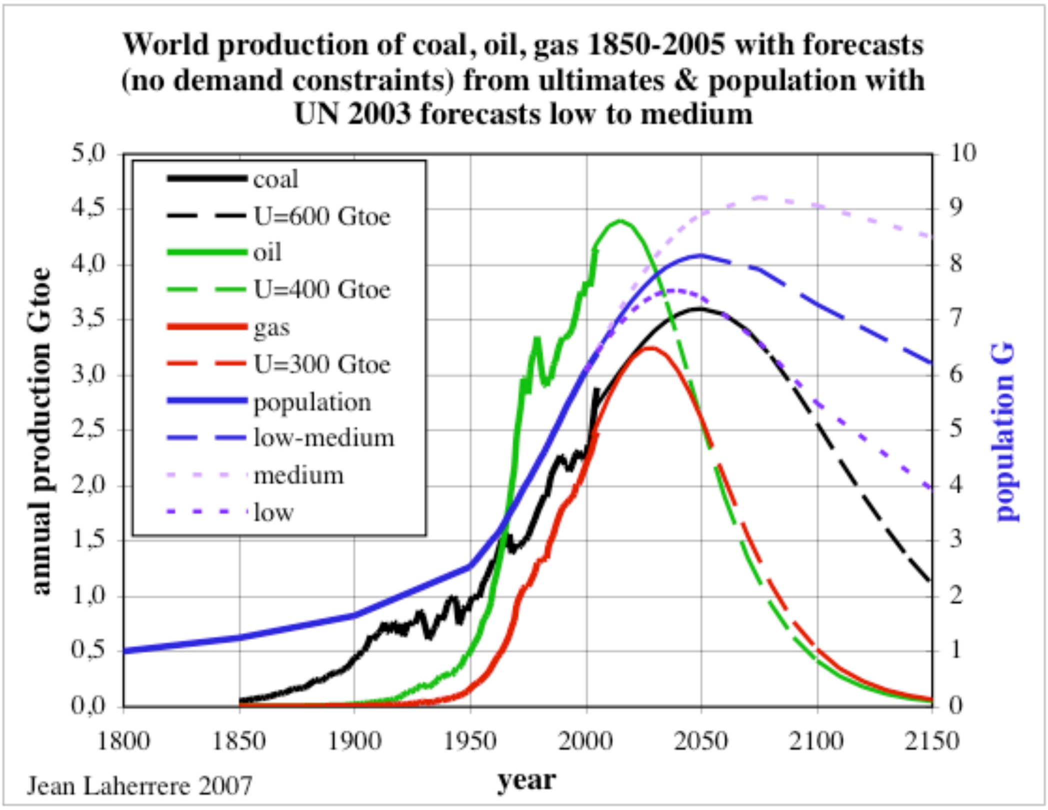
Fig. 7: Top ten countries with regard to reserves of non-renewable fuels in 2005
(OPEC countries are given in blue)

The main problem for forecasting production is to estimate the ultimates, for oil and gas it is from creaming curves leading to 400 Gtoe for oil and 300 Gtoe for gas and for coal it is from BGR past estimates trend at 600 Gtoe.

Using the cumulative coal production (145 Gtoe end 2005) and remaining reserves estimated by BGR (487 Gtoe) we have taken coal ultimate at 600 Gtoe
FF production is modelled with these ultimates to reach a peak

	Ultimate Gtoe	peak year	peak volume Gtoe/a
-oil	400	2015	4,3
-gas	300	2025	3,2
-coal	600	2050	3,6

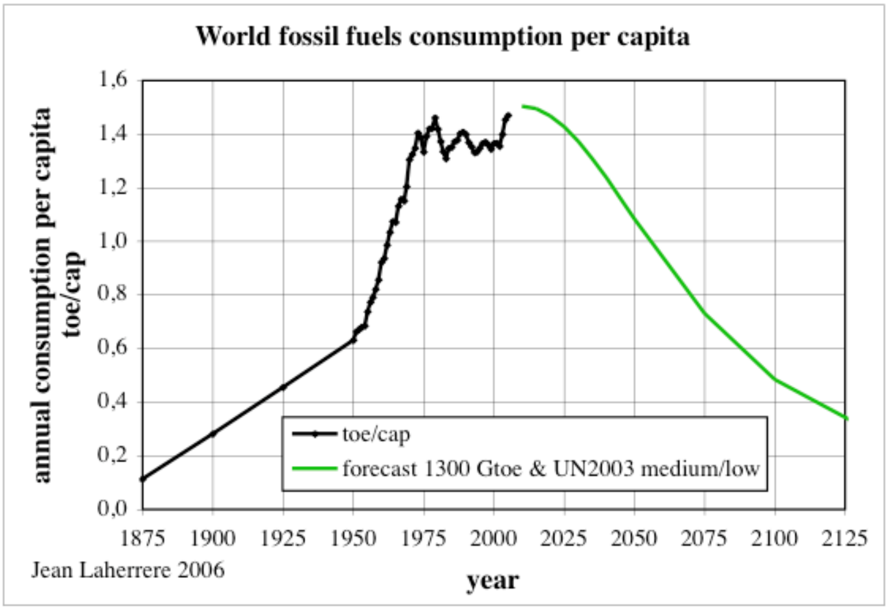
Figure 55: **world annual production of oil, gas & coal and population 1800-2200**



UN 2003 forecast for world population up to 2300 is plotted with the medium, low/medium and low fertility scenario. Past UN forecasts show that the low/medium is the best forecast as the medium was always too optimistic

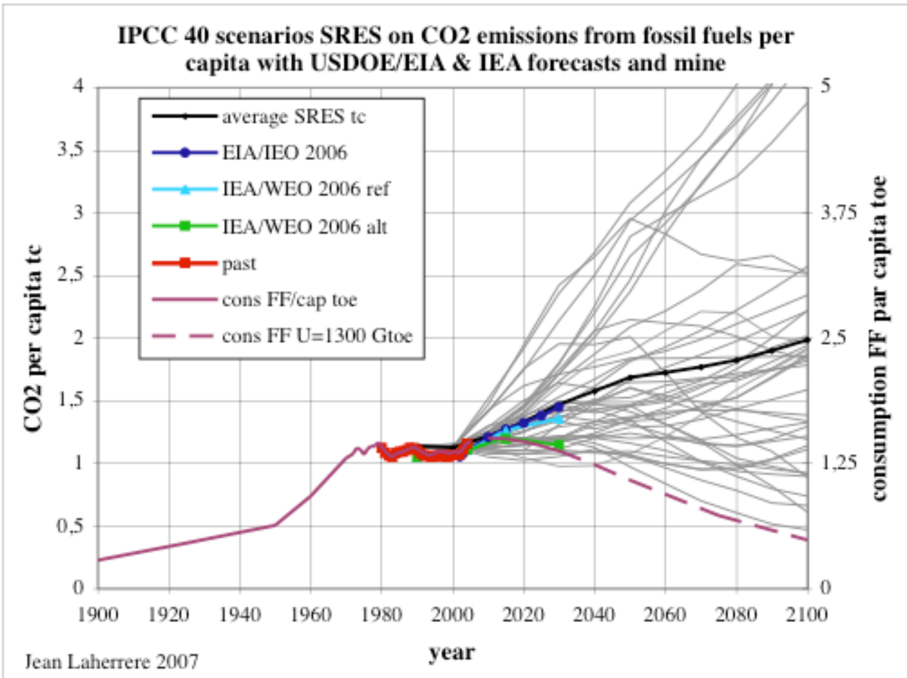
Form the previous data, the plot of the world annual FF consumption (= production) per capita shows that, after a sharp raise from 1945 to 1973, the consumption per capita has levelled and stayed around 1,4 toe/cap for the last 30 years, the forecast will stay at this level until 2025 and then decline.

Figure 56: **world fossil fuels consumption per capita 1875-2125**



If the fossil fuels consumption per capita will decline after 2025, the CO_2 emissions from fossil fuels per capita will decline too, if no CO_2 sequestration is not performed, and decline more if CO_2 sequestration is carried out. The Intergovernmental Panel on Climate Change IPCC 40 scenarios (called SRES) are plotted in the next graph displaying a huge range with an average which is, in line up to 2030 with USDOE/EIA forecasts, above the IEA/WEO 2006 reference scenario (being Business as usual) described in 2007 by the head of IEA Cl. Mandil as « unsecured, unattainable, unrealistic and unsustainable ». The favoured scenario is the alternative scenario in green in line with my forecasts. But my forecast for 2100 at 0,4 tc/capita is below the smallest of the scenarios which varies from 0,5 (B1T MESSAGE) to 5,2 (A1C AIM) tc/cap. Despite such this huge range they are outside the real world from technical reserves.

Figure 57: **IPCC scenarios on CO2 emissions from fossil fuels per capita** with EIA, IEA and my forecasts



It is obvious that IPCC scenarios for CO2 emissions are much too high !

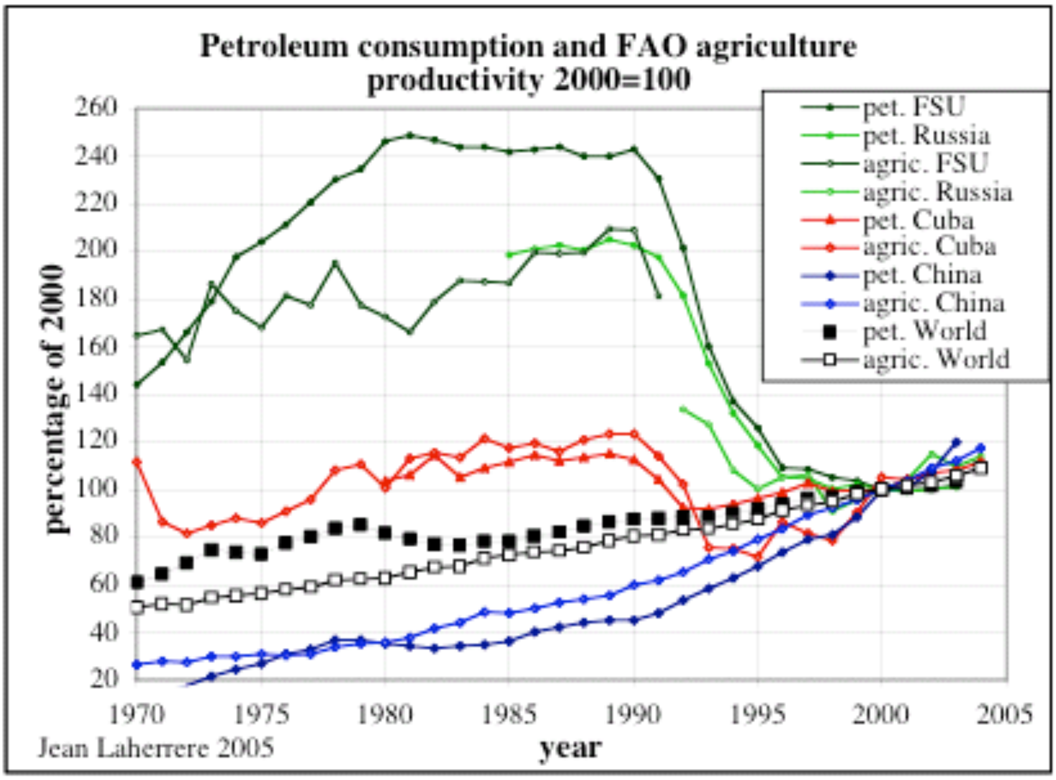
-nuclear = fossil fuel?

nuclear energy is obviously a non-renewable energy, uranium was formed about 6 Ga before the creation of earth, and losing radioactivity is transformed slowly into lead.
Present fission plants use only U235 which is only 0,7% of the uranium and being fissile, when U238 represents 99,3 % and not fissile (a very small part is transformed into plutonium). With present techniques there is enough uranium (4 Mt proven and 15 Mt expected) to fill the demand until only 2035-2040. Fast breeders (IVth generation) are needed to use U238 and thorium (not fissile but with resources higher than uranium). It is why there is little time left to make the IVth generation workable. The stop of research by some countries is damaging the future of next generations because after the peak of fossil fuels, only nuclear may manage with fast breeders to provide enough energy that renewables will be unable to fill the lack of fossil fuels in enough quantities.

-food =energy

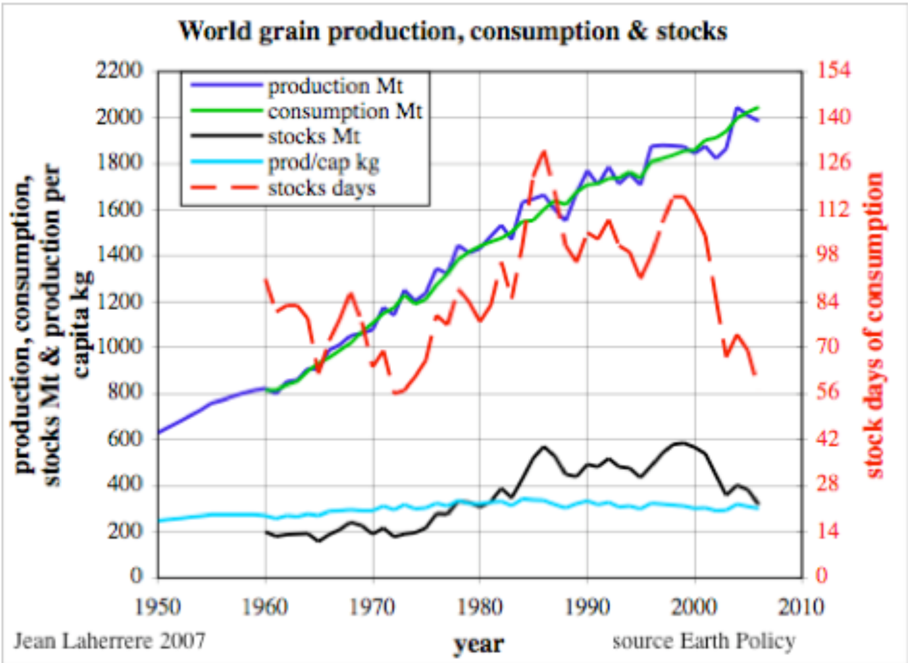
In 1960 BP in Lavera transformed oil into proteins but this food was not accepted. Today food is transformed into ethanol and biodiesel. But for the last decades the green revolution has transformed agriculture into a way to make food out of oil and gas through mechanisation, irrigation, fertilizers (from natural gas) and pesticides. The correlation between petroleum s consumption and agriculture productivity is striking in particular for Cuba and FSU.

Figure 58: **petroleum consumption and agriculture productivity 1970-2004**



Since 1985 stocks of world grain has stopped to grow and since 2000 they decrease as production grew less than consumption.

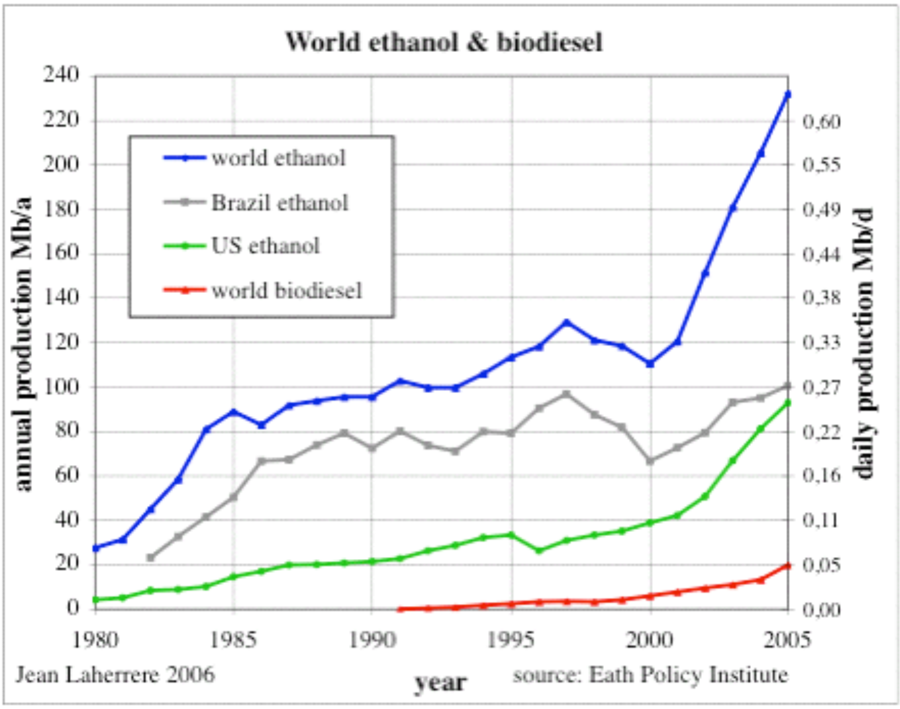
Figure 59: **world grain production, consumption and stocks 1950-2006**



It is obvious that agriculture will not in the future feed the world and fill the tanks of the cars.

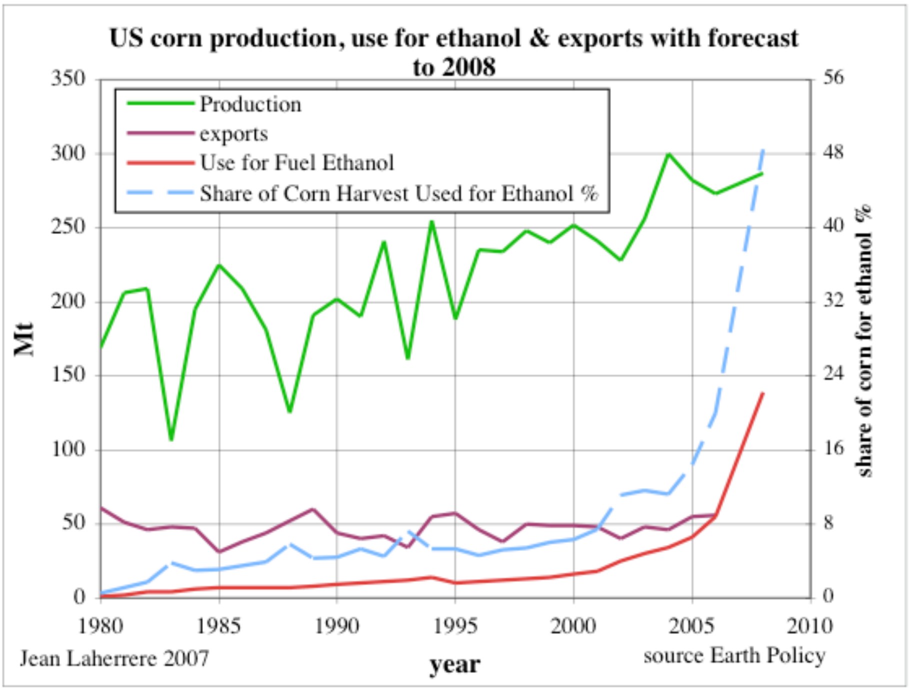
But under the pressure of US farmers, bioethanol is booming as also prices for corn and then foods.

Figure 60: **World biofuels production 1980-2005**



The US production of corn has been increasing since 1980 with up and down, but the use for ethanol is raising from 10 % in 2003 to 50 % in 2008

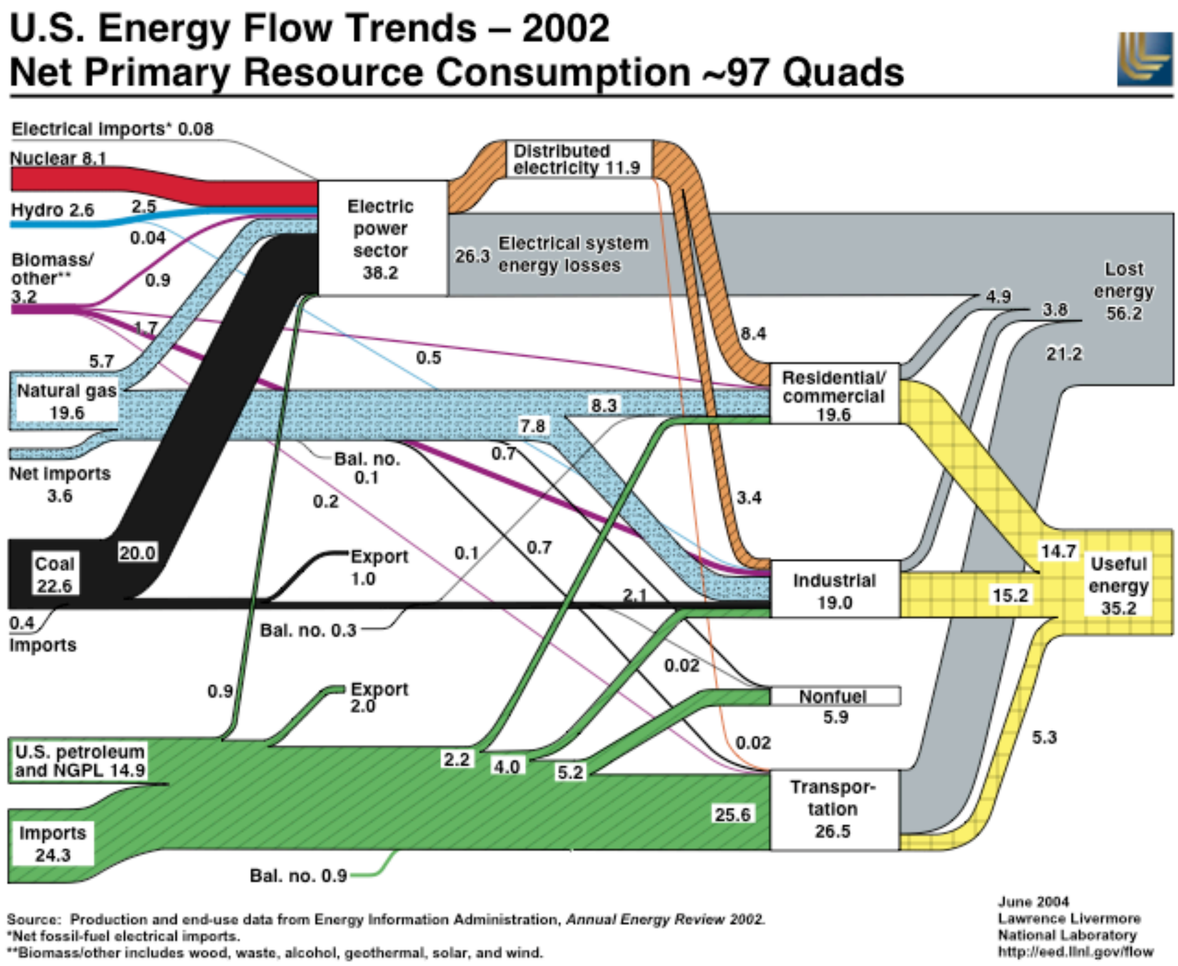
Figure 61: **US production of corn and use for ethanol 1980-2008**



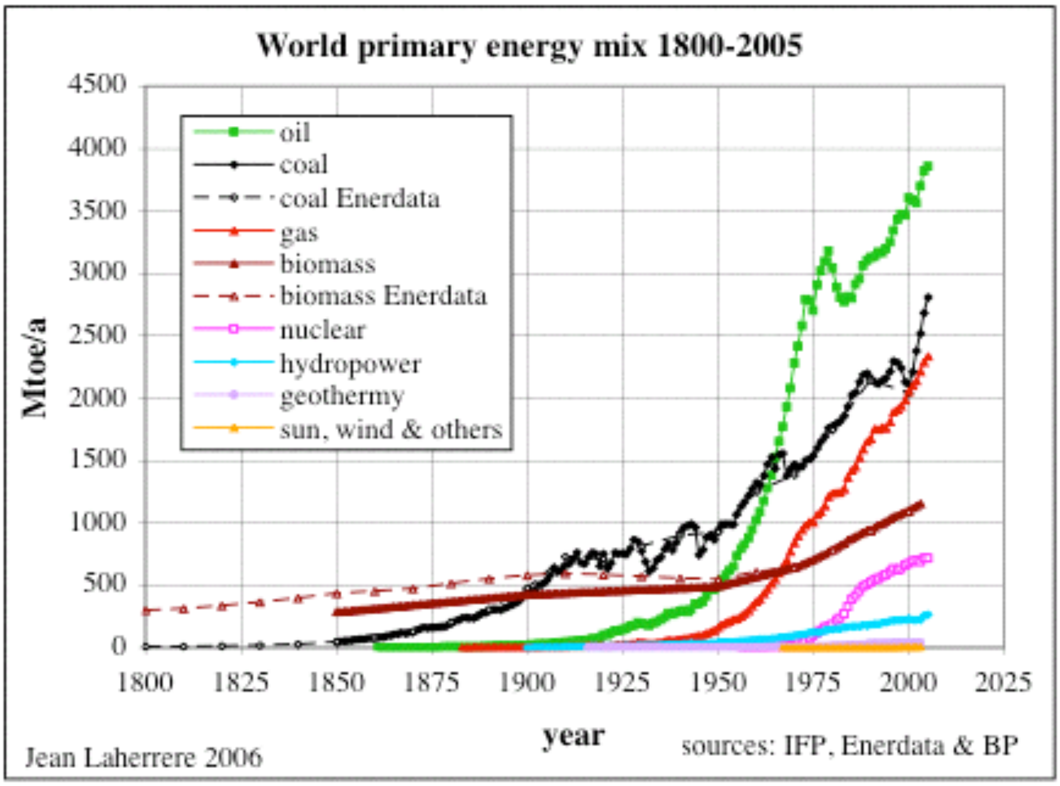
US corn is subsidized as also the transport and conversion into ethanol. The EROI of US corn into ethanol has been debated for the last 10 years between university as Pimentel and Patzek who claim 0,7 and the USDA which claim 1,3. The main argument is on the by products, if they are used to increase EROI, Pimentel & Patzek claim that it is necessary then to add fertilizers. EROI is completely overrun by the subsidies which make ethanol very profitable

economically for the farmers, if not energically for the country. Top soil has been eroded in US and fossil aquifers are dangerously depleted.
Ethanol in Brazil from sugar cane is completely different because fertilizers, irrigation are not necessary.

-energy, energy per capita
Primary energy has to be distinguished from final energy, because the large loss in loss : for US 2002 56 quads (10^E15 BTU) lost for 35 quads used = 61% loss. So much loss is shown that USDOE has stopped showing this graph and uses now a flux graph where losses are not shown
Figure 62: **US energy flow 2002**

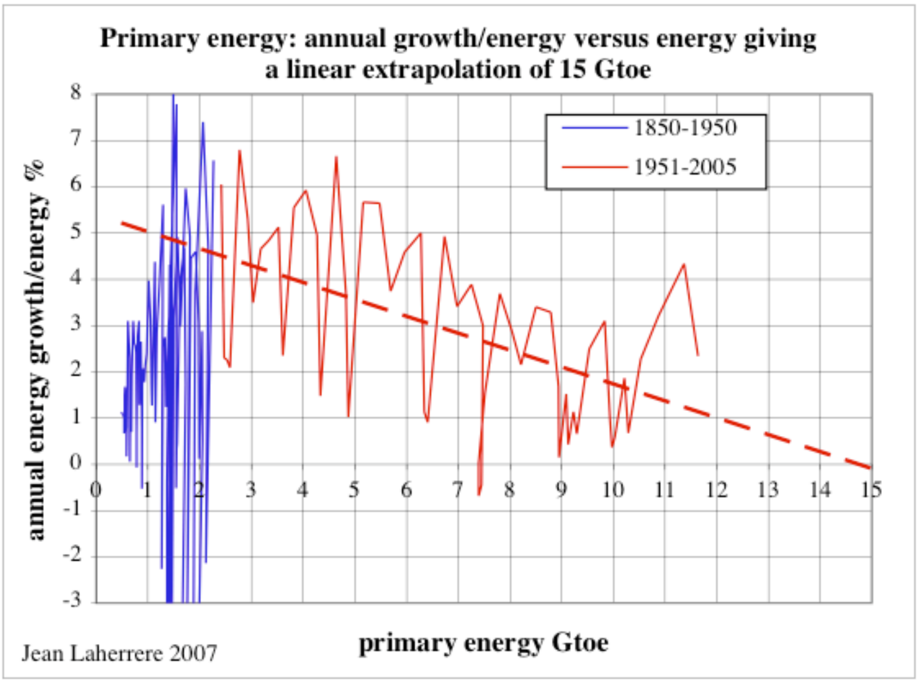


Primary energy historical series are hard to find and transforming each energy in a reference unit (Quad, Joule, toe) is hard. There are several conventions for energy equivalences.
Primary energy historical evolution is hard to get because non-commercial energy (wood & dung, energy from muscle: human and animals) are badly or not reported. Also equivalences to convert each energy in a single unit (joule or toe) are arbitrary conventions which are not changing with progress: nuclear is taken as 33% efficiency (why not higher?), geothermal as 10%.
Figure 63: **World annual primary energy mix 1800-2005**



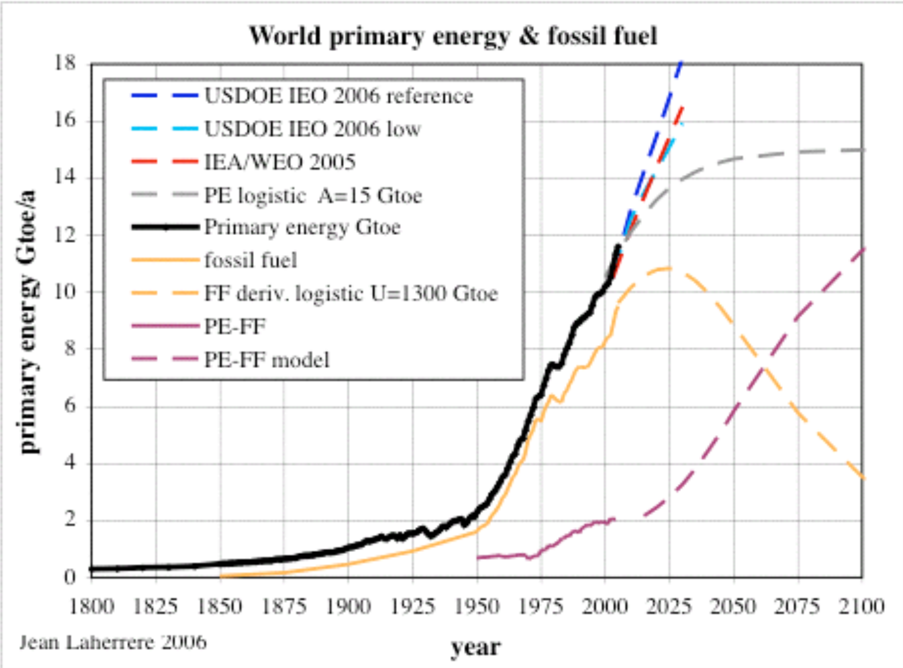
World primary energy displays an obvious concave curve from 1800 to 1973 first oil shock and beyond up to now (11,6 Gtoe in 2005) a fair (not for all, in particular in the last few years) convex curve. Extrapolation (Hubbert linearization) of the past 50 years leads towards an asymptote at 15 Gtoe.

Figure 64: **World primary energy annual growth versus energy giving an asymptote at 15 Gtoe**



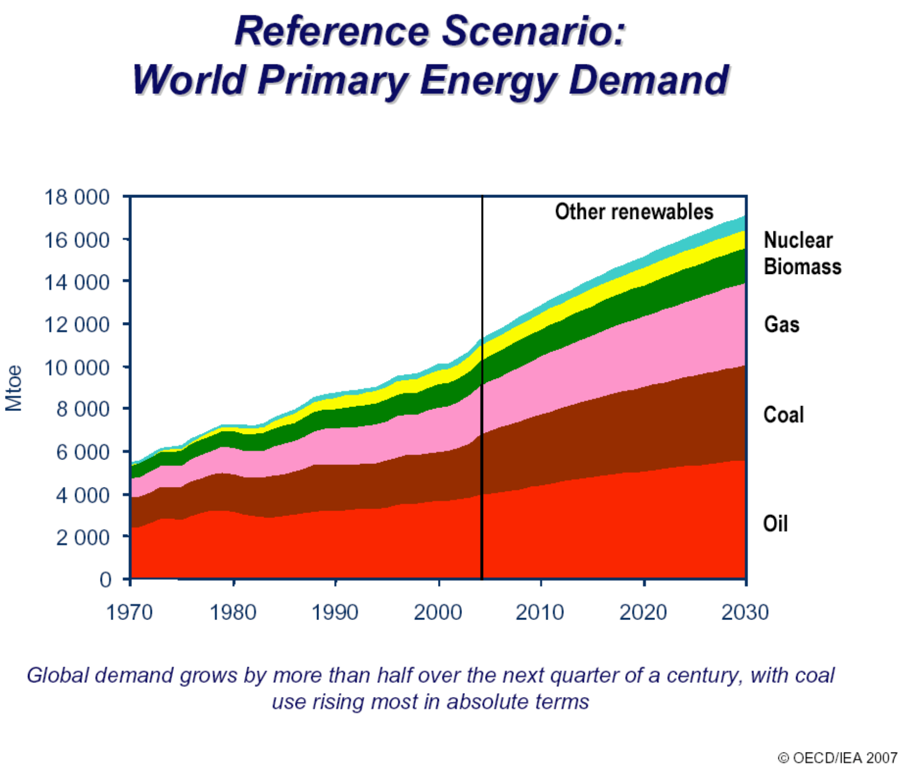
Fossil fuels forecast is plotted and the gap between primary energy and fossil fuels (being nuclear and renewable) was 2 Gtoe in 2005 and is likely to be 6 Gtoe in 2050. It is doubtful that renewable can fill this gap without the help of nuclear plants.

Figure 65: **World annual primary energy 1800-2100 with asymptote at 15 Gtoe and EIA & IEA forecasts**



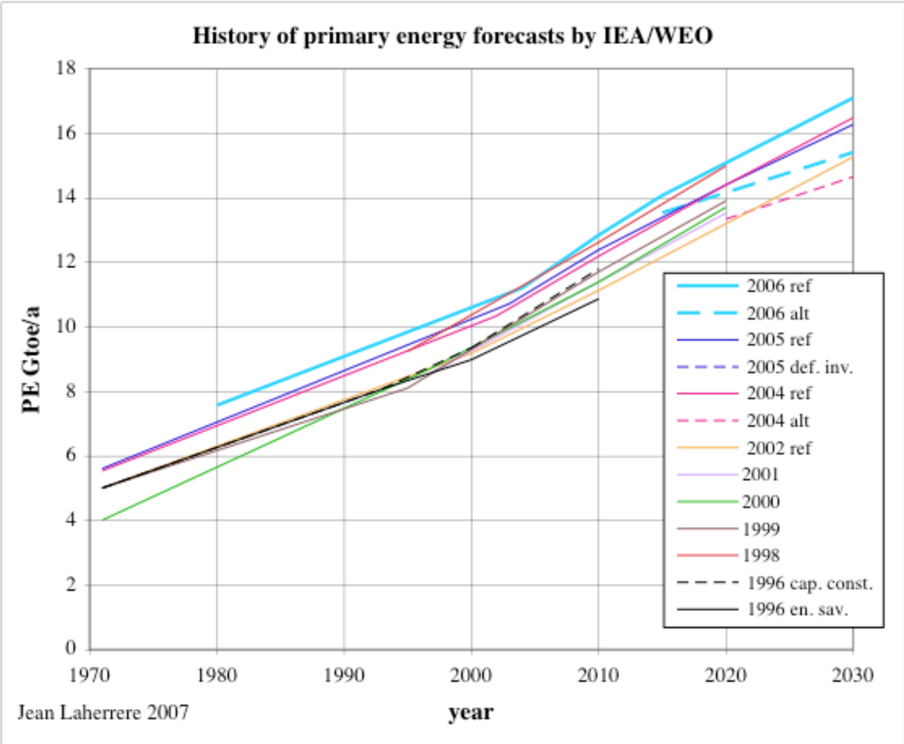
Official (USDOE and IEA) forecasts being the wishes of *business as usual* (continuing to have a over 3%/a growth for the next 30 years) lead to 17 Gtoe in 2030.

Figure 66: **World IEA/WEO 2006 primary energy reference scenario (BAU = unsustainable)**



The history of IEA/WEO forecasts from 1996 to 2006 displays a poor evaluation of past data. This graph shows the heterogeneity of the data for the past where PE 1980 varies from 5,5 Gtoe to 7,5 Gtoe, due likely to different authors, different references, poor data, poor definition of primary energy and changing energy equivalences.

Figure 67: **history of IEA primary energy forecasts 1996-2006**



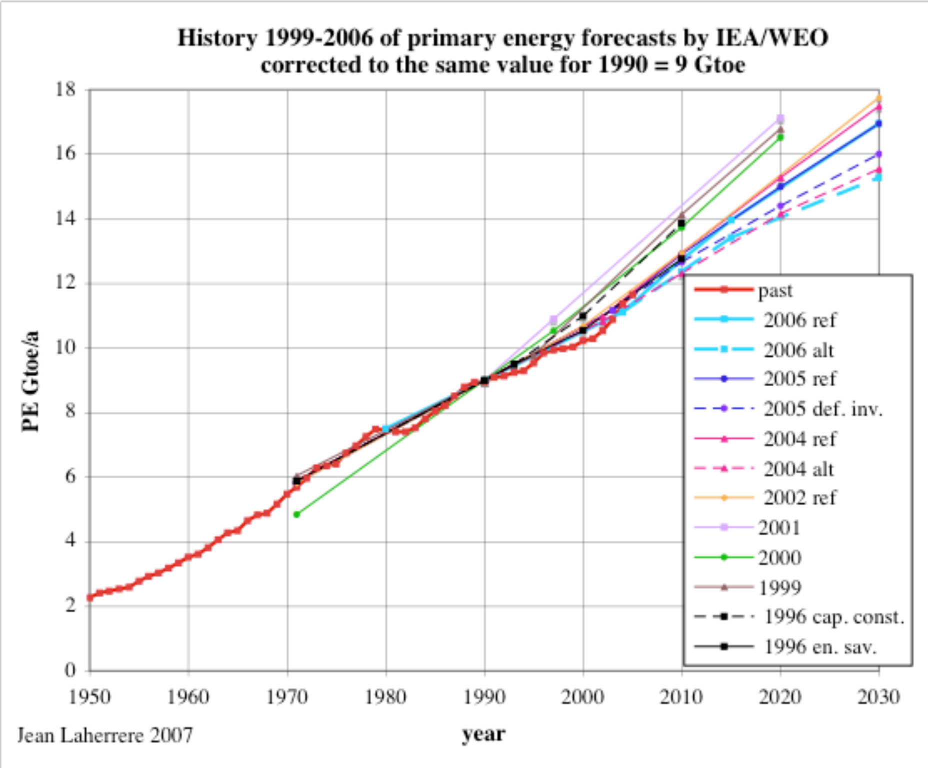
If the world energy agency reports such erratic past values, it means that primary energy is an ambiguous measure and that this measure must be improved.

Primary energy is reported for 2004 in Gtoe

IEA	11,2
EIA	11,2
BP	10,5

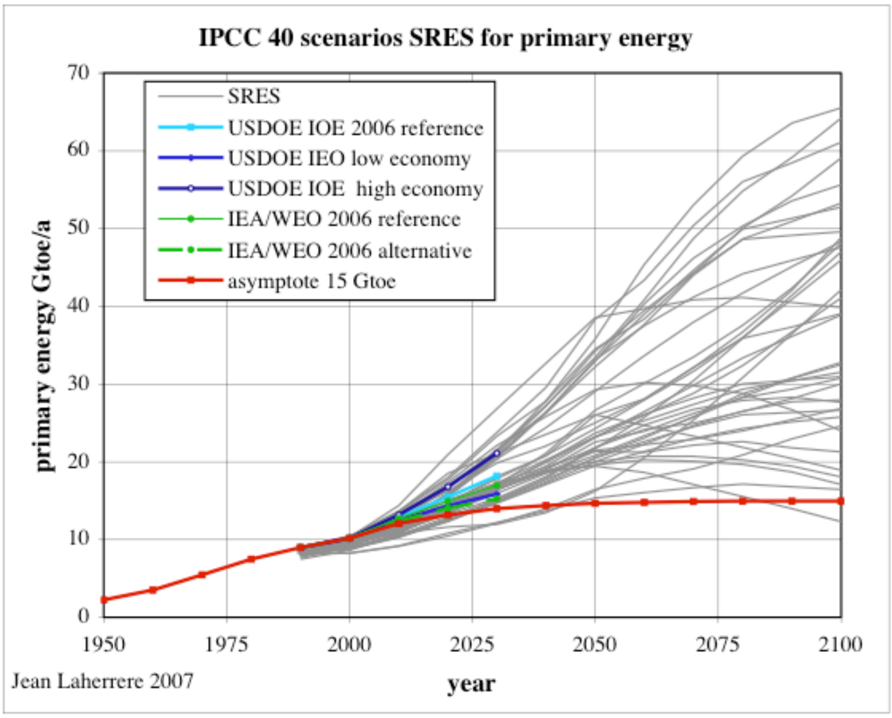
The same IEA forecasts corrected to have the same value of 9 Gtoe in 1990 shows a decrease with time with the 2006 wanted alternative scenario being the smallest.

Figure 68: **IEA primary energy forecasts 1997-2006 corrected to same value in 1990**



This history shows that IEA was always too optimistic, except maybe for the last alternative 2006 scenario.!
But there is a big change, in past IEA scenarios, the reference was the Business as Usual (BAU) and was wanted , other alternative was indicated in case lack of investments or other cause. But for 2006 the alternative scenario was the one wished because the reference was quoted by his head Cl. Mandil as unsecured, unattainable, unsustainable and unrealistic (Petroleum Review march 2007)
But my forecast for oil is less than IEA alternative scenario because they believe in increase from OPEC.

-IPCC energy scenarios
As already mentioned, IPCC energy scenarios are unrealistic and unchanged since 1998: 2007 report is as poor as 2001 report because the quality of the output of a model depends upon first the quality of the input (SRES) and second the quality of the model. SRES are obsolete (1998 where oil was at 10 $/b) and should be changed to reflect the present situation and the coming peaks of fossil fuels. They were designed by IIASA on mostly unrealistic grounds that I described already in an IIASA workshop in 2001, in particular for gas dreaming of methane hydrates. These 40 scenarios for 2100 range from 12 to 66 Gtoe, with an average of 37 Gtoe, meaning that the gap to fill beyond fossil fuels (at 4 Gtoe/a) could be 33 Gtoe (3 times primary energy of today!)!
Figure 69: **World IPCC scenarios for primary energy 1990-2100**

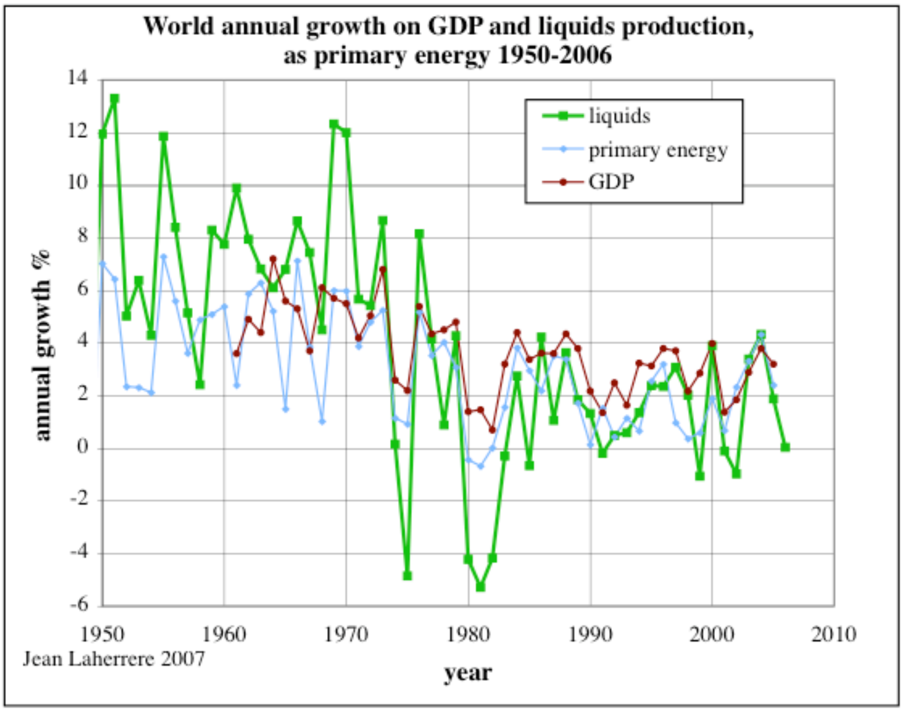


The result of a model depends upon the quality of the model but also of the hypotheses. As said the Americans GIGO and it can be modified for the 2007 IPCC report as SGISGO: same Garbage In, same Garbage Out.

-energy and GDP growth

For many GDP should always grow, despite that it was not always the case in the past. For many GDP is wealth when in fact it is expenditures. More drugs, terrorisms, Aids, wars, catastrophes, higher is the GDP. The growth of world GDP is compared with growth of liquids production as primary energy and the correlation looks good since 1970. Coming peaks (zero growth followed by negative growth) of liquids and primary energy will lead also to zero growth for GDP.

Figure 70: **world annual growth on GDP, liquids production and primary energy 1950-2005**



The most astonishing point that I have found few years ago in economy is that the **cost** of energy for the last 40 years has been only about **5%** of world GDP when experts (Kummel, Ayres) estimate that the **contribution** of energy is about **50%** (35% for capital and only 15% for labour).

Energy prices are largely undervalued. Energy is cheap because it was abundant but with coming peaks this situation has to be changed

Everyone knows that to morrow without oil all industrial countries would stop but everyone complains that oil is expensive. But it represents only 85 Mb/d x 65 $/b = 2 T$ per year compared to GDP being more than 50 G$ (PPP) = 4%.

Saying that 4% of GDP for oil is expensive, when without it, all transports will be stopped, shows the lack of knowledge of all consumers.

Energy being cheap (as water) is considered as a right which should stay this way for ever, mainly in the US.

But looking at the past and the difference of consumption of energy between US and Europe (twice) that the best solution for saving energy is high energy price, by taxes or by simply itself.

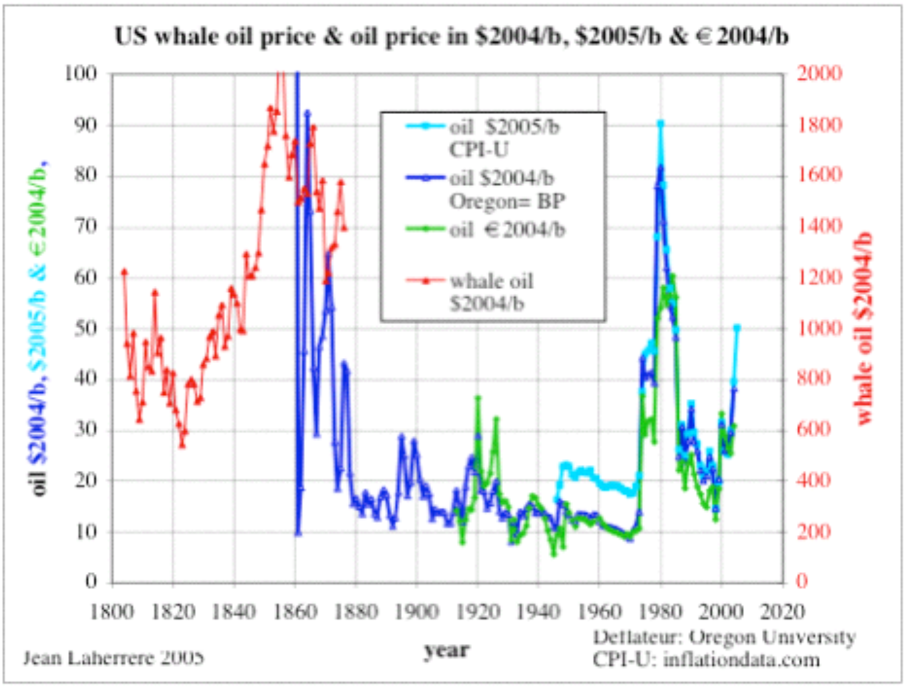
GDP was pushed by the house price bubble and US debt is deepening and US savings negative. What is coming next?

-prices

-oil prices

Many believe that oil is more expensive than before. In 1840 whale oil (for lighting) was about 2000 $2005/b ; in 1860 oil was about 100 $2005/b ; in 1980 80 $2005/b, so today oil price at 60$/b is cheap !

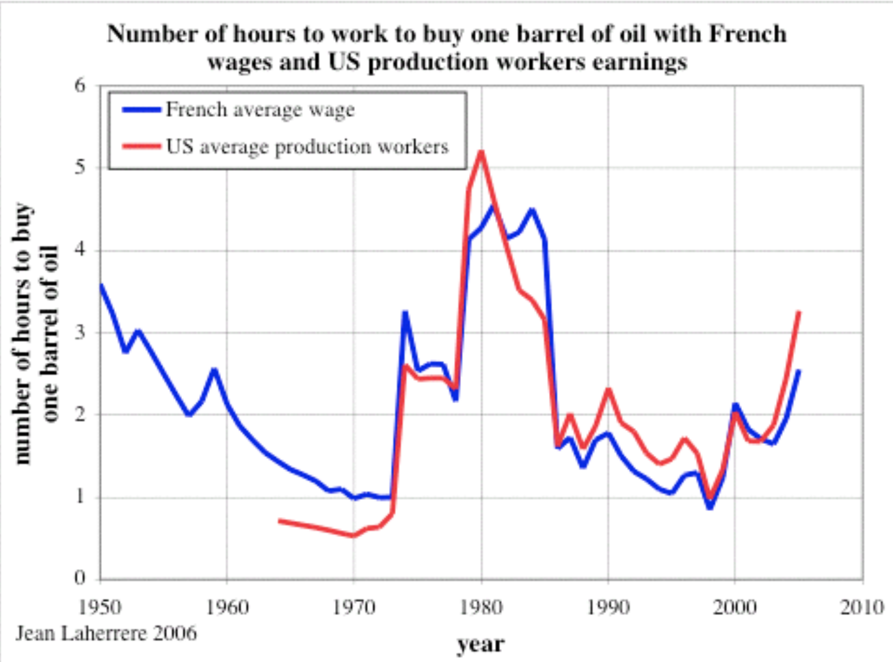
Figure 71: **US oil whale price and oil price in $2005**



The number of hours (average wage) to buy one barrel of oil was in France 3,5 hours in 1950, 4,5 hours in 1981 and only 2,5 hours in 2005

It is interesting to notice that the number of hours for the American worker is very close to the French worker, but the American can buy 20% more oil because he works 2000 hours per year when the Frenchman works only 1600 hours !

Figure 72: **number of hors to work to buy one barrel of oil with French & US wages.**



-fossil fuels prices

The nominal prices for fossil fuels from BGR 2005 show relative different trends, but all a sharp increase since 2003.

Figure 73: **nominal fuel prices 1940-2005 from BGR**

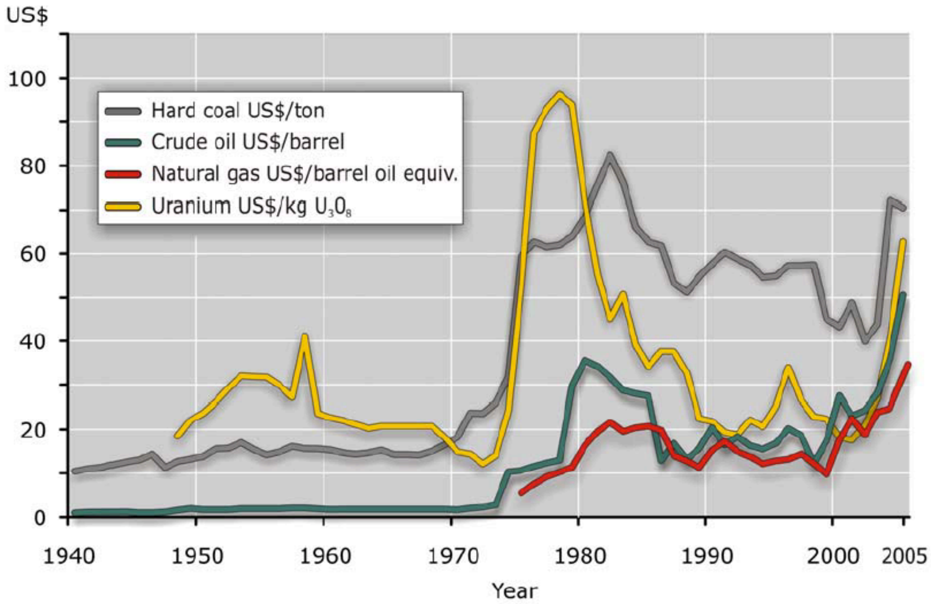


Fig. 3: Development of nominal fuel prices from 1940 to 2005 (annual average)

Most of consumers accuse the Euro to be the cause of increase of cost of living since its introduction in 2000, but the cause is the increase in energy and minerals (cooper & others)
But what is important is the consumer belief in future price: up or down?
EIA was always wrong on oil price forecasts
Figure 74: **world oil price past forecasts 2000-2004**

Figure 1: Oil prices & forward curves 2000-04

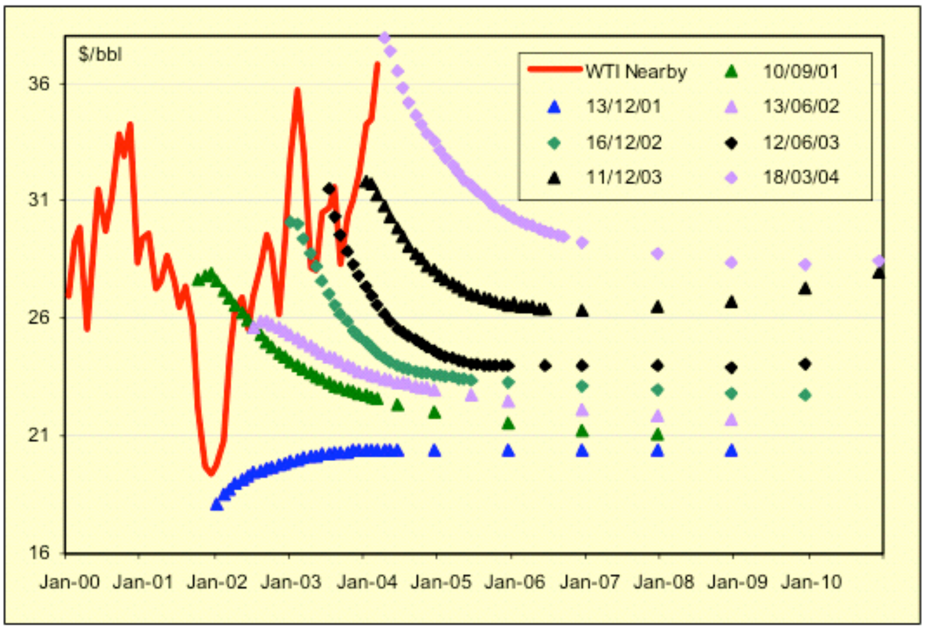


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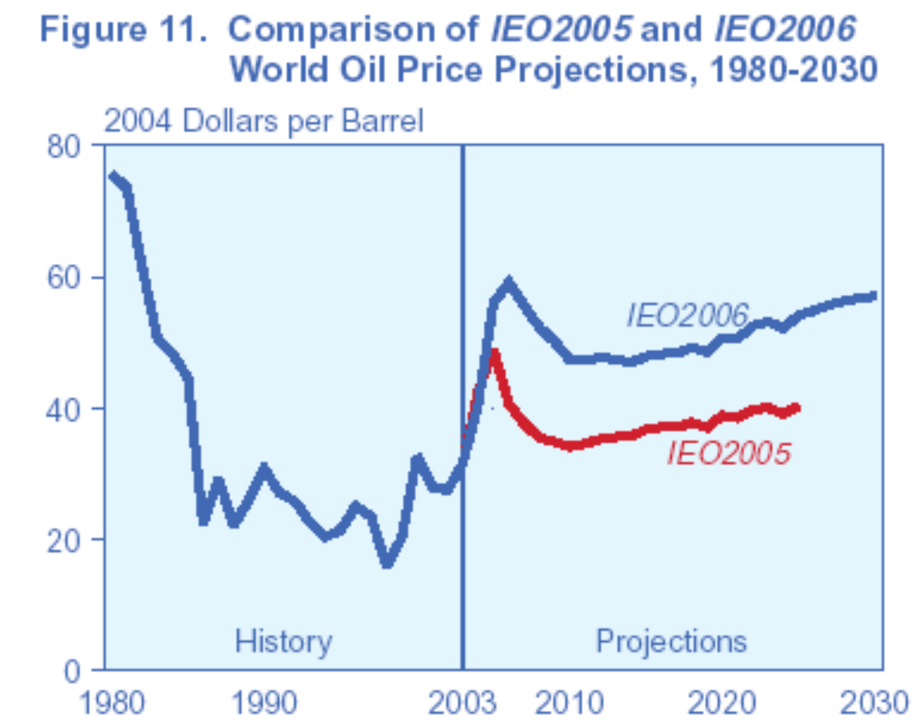
Figure 75: **world oil price forecast from USDOE/EIA 2006**

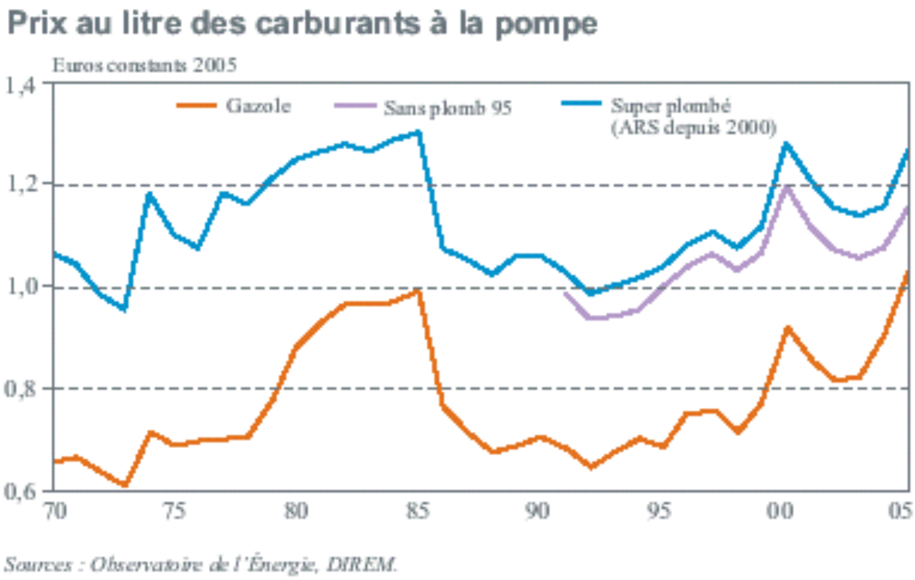


Official agencies forecast for the next 30 years (one generation) oil prices less than now, preventing any will to save oil.

Frenchmen have convinced that gasoline is more expensive than ever: they are wrong. Diesel is about the price of 1986, but diesel, being 12% more efficient per litre, should be taxed in France more than gasoline (as it is in Switzerland).

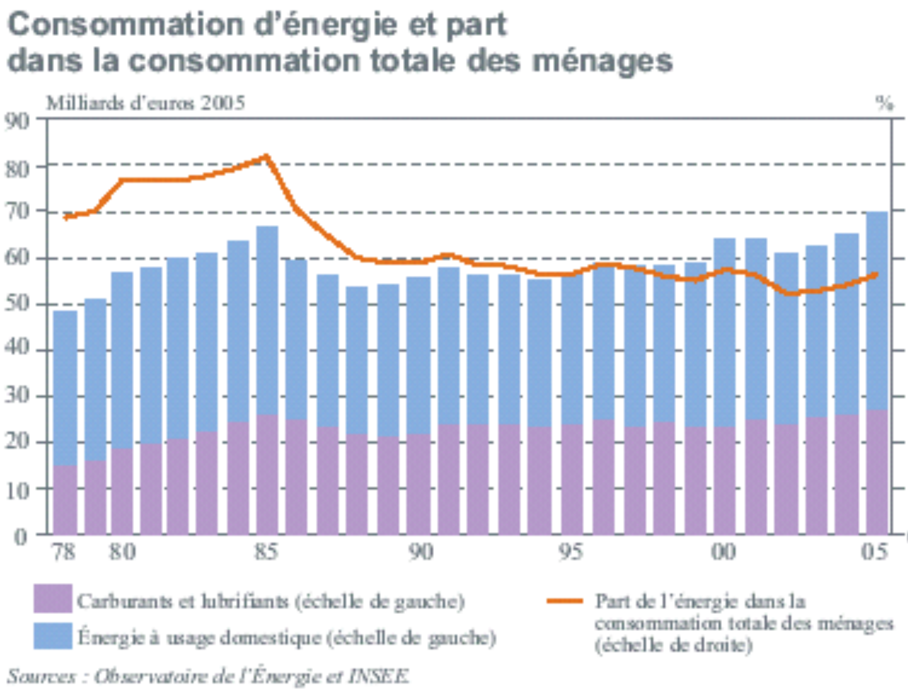
-gasoline and diesel prices

Figure 76: **French gasoline price**



Consumers complain about the cost of energy, but in France the percentage of energy for a household was 8% in 1986 and in 2005 only 5,5 %.

Figure 77: **French household energy consumption**

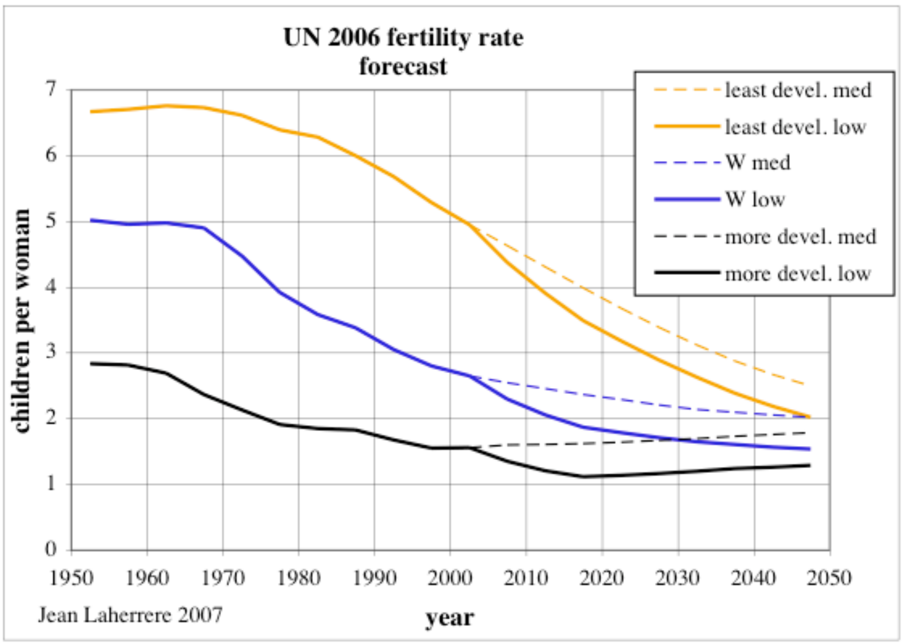


-population peak in 2050

Forecasting energy implies to forecast population to get per capita. UN forecasts are exactly as for IPCC, mainly wishful thinking. Population forecasts are based on fertility rate and political aims are triggered. The goal is to have equality and everyone with about the same fertility rate in 2300 (2003 revision). But Nature does not like equality: life is a race and there is a winner (only one out of 300 millions spermatozoa)

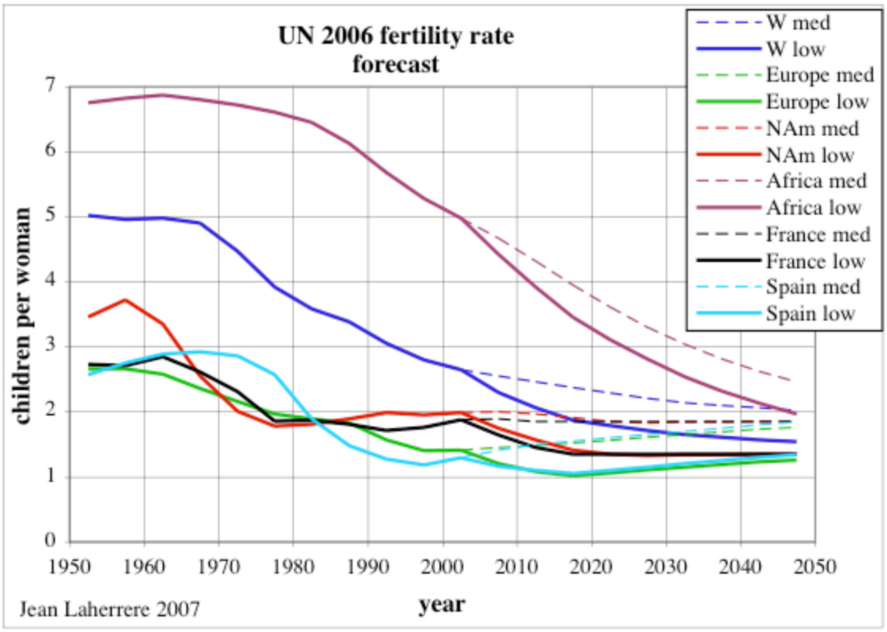
So because industrial countries fertility rate are down below the replacement level, the rate is assumed to raise and to catch developing countries rate : is it a nice social wish, hoping that old civilisation will change or is it more realistic assumption that new that immigration will completely change the old civilisation?

Figure 78: **UN 2006 fertility rate forecast to 2050 for the world**



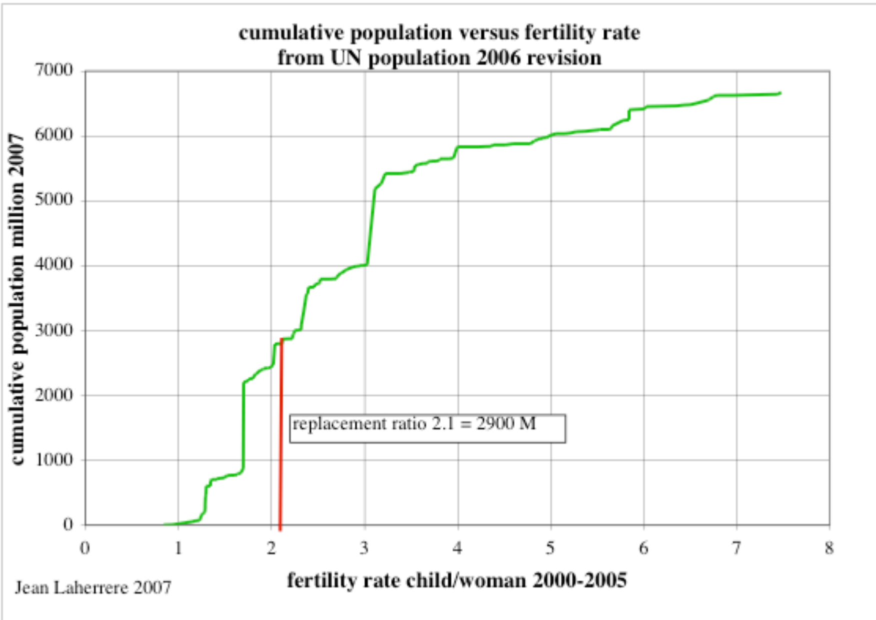
Spain fertility has decreased sharply: is it to increase again?

Figure 79: **UN 2006 fertility rate forecast to 2050 for Europe, Africa, North America, France and Spain**



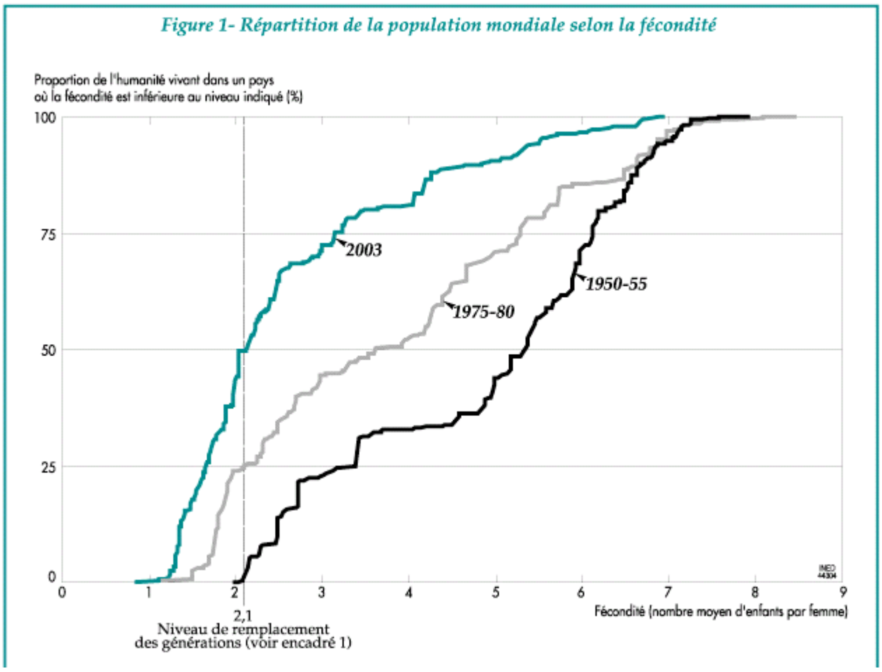
Presently about 2,9 billion people have a fertility rate below 2,1 child per woman (replacement rate) from UN data.

Figure 80: **cumulative population versus fertility rate from UN 2006 revision**



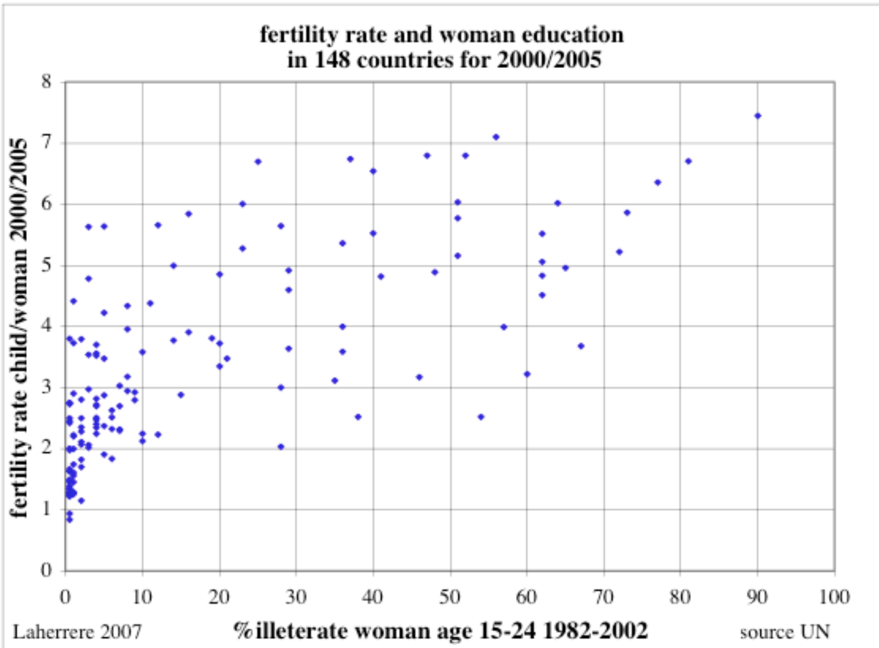
In 2004 INED (French institute of demography) had plotted the percentage of the world population versus fertility rate from 1950 to now and found that in 1950 no country was below 2,1, in 1975 one quarter of the world was below 2,1 and in 2003 one half was below 2,1. The evolution was fast.

Figure 81: **Evolution of world fertility rate in time and percentage of the world population from INED 2004**



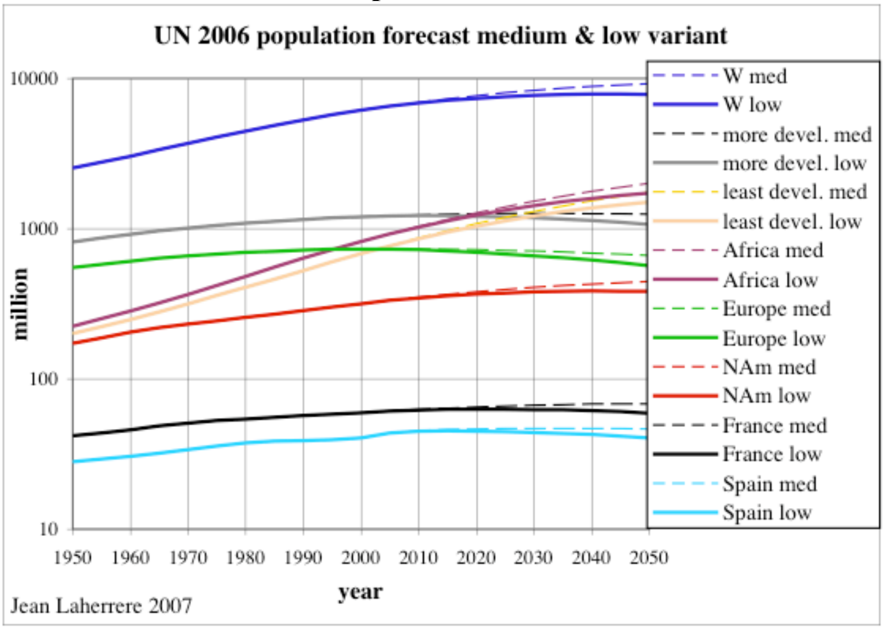
2006 UN revision fertility data is for the same period 2000-2005 as INED, but the percentage is little less, about 45 % below 2,1. Fertility rate data is very unreliable and the best proof is that USCB reports fertility value with 4 significant digits because many data are coming from equations and not census. For example there is no census in Somalia since 1980 but detailed annual fertility are reported (but no education)!

What is the cause of high fertility rate ? Religion and education seems the most likely. Education (% illiterate of the young women age 15-24) plotted versus fertility rate confirms that high fertility is found in countries where women are uneducated.
Figure 82: **Fertility rate and woman education in 148 countries**

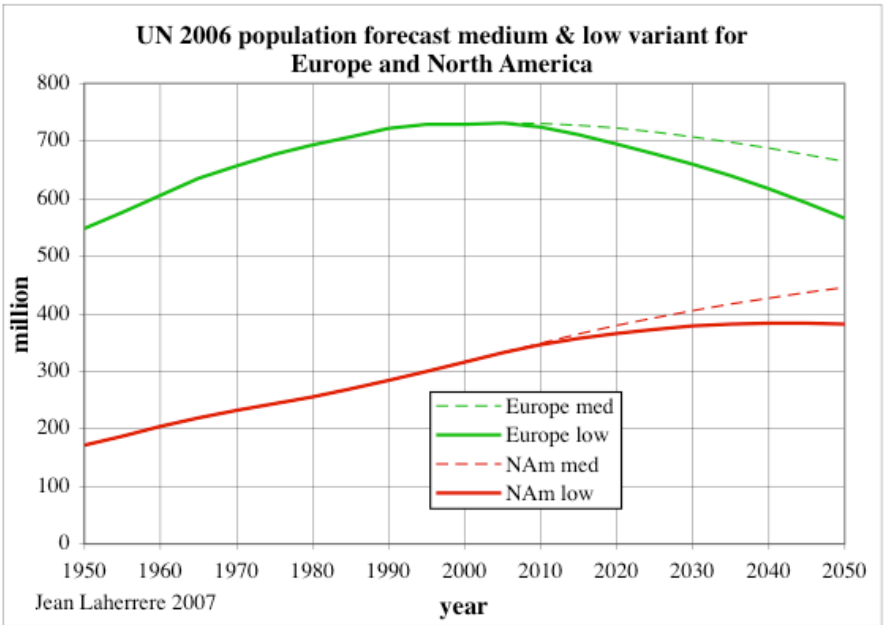


With such correlation and the fact that high fertility rate countries are staying in an high level when other decrease, means that the UN wish for fertility equality in the future seems unlikely!

Population forecasts are plotted on a log scale to see parallel growth or decline.
Figure 83: **UN 2006 forecast for world, developed, less developed, least developed, Africa, Europe, North America, France and Spain 1950-2050**

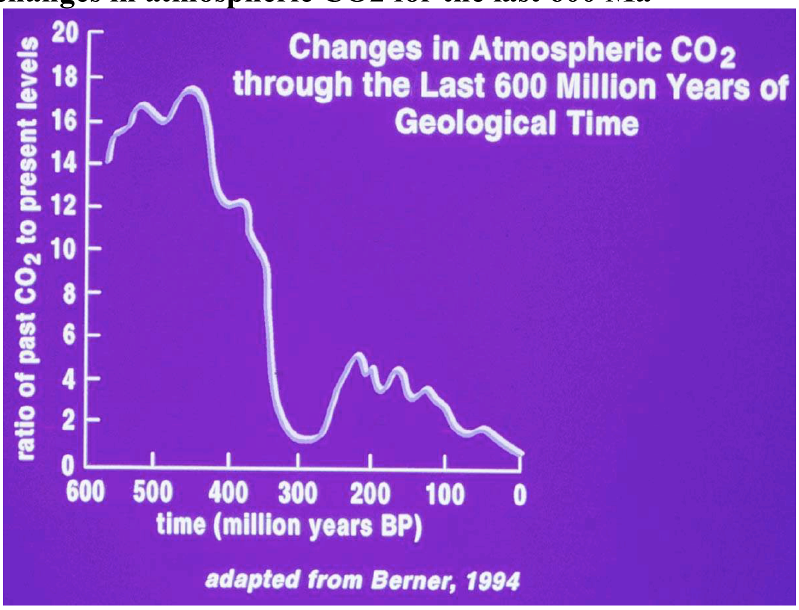


On a regular scale, Europe will lose 100 millions in 2050, but North America will gain 100 millions. Both have a very different future !
Figure 84: **UN 2006 forecast for Europe and North America 1950-2050**



-climate change (see Annex on Climate change)
There is a lot of arguments between scientists on global warming, in particular with geologists who know the history of the earth better than climatologists. The hockey stick graph of temperature of the last millennium in the IPCC 2001 report denying the Little Ice Age is hard to believe. Global warming is real, but is it only due to human activities or both natural and human activities? Global cooling as it was feared in 1975 can return in decades.
Believing that climate can be stabilized in the future is also utopia, climate has changed since earth birth and will continue to do so. For the last 2 millions years, earth is in glaciation and

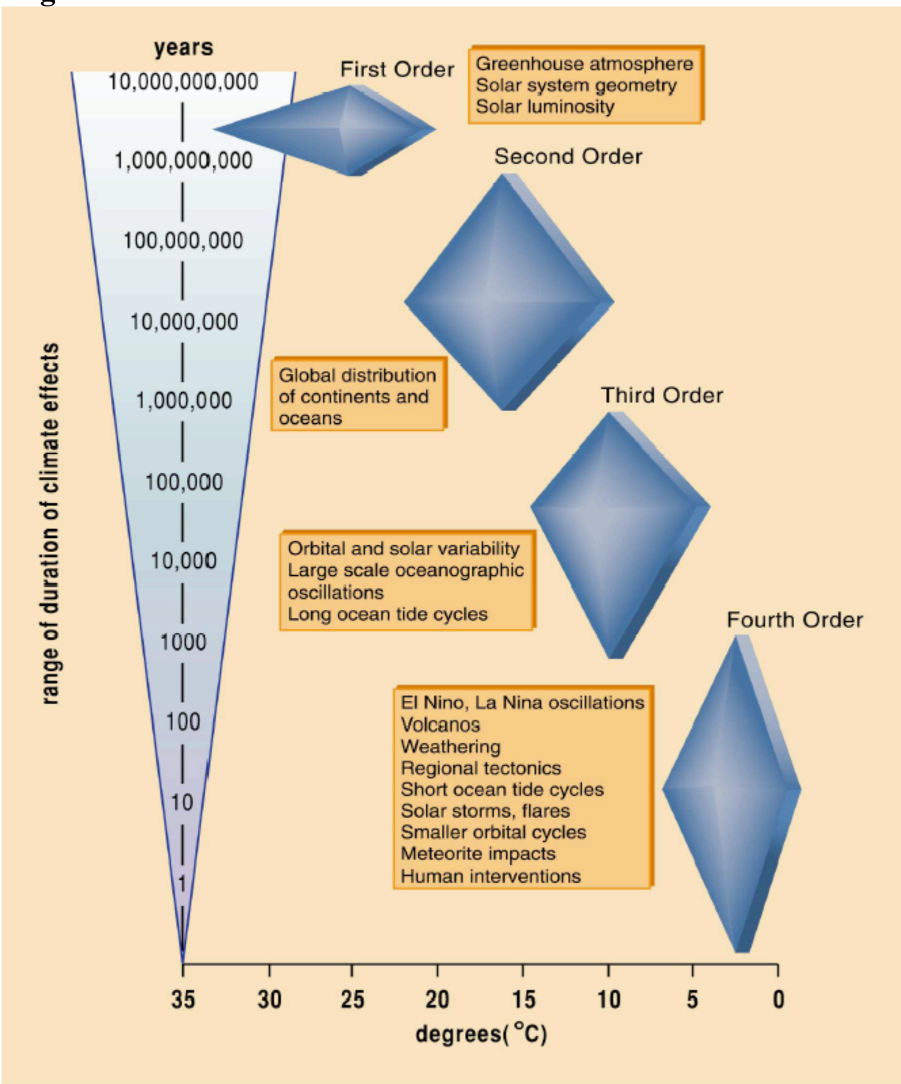
today we are in a interglacial period and we are going towards a new glaciation in few millennia. During Eocene 50 Ma ago, temperature were much higher and mammals did prosper.
Climate will continue to change, as earthquakes will continue to occur and as continent will continue to drift, which is the cause of glaciation in the poles (no continent no ice as in Cretaceous time).
Mankind in the past was exposed to temperature change (larger than 2 degrees considered as many as catastrophic) and succeeded to survive by being mobile. Some areas will gain some areas will lose but with a not so heavy worldwide the balance-sheet.
Dansgar-Oeschger events (21 between -75 ka and -15 ka) occur with warming of 10°C in few decades (Deconinck "Paleoclimats 2006) and Homo Sapiens survived.
I have worked (under tents) in several hot and cold deserts as Sahara, Simpson desert and Canadian Northern Territories ranging from -45°C to +45 °C. Human beings live in very different climates and must be able to adapt to a change small compared to the range.
Today problem is the lack of mobility and aversion to change.
The problem will that people does not like to change: it is like the physical principle of Fermat or Maupertuis: the *least effort* or the least change. But evolution is the key of life. Only the mobile have survived!
CO2 is the wrong bad guy and post-carbon goal is against nature. CO2 is the food of plants with sun and water. Flowers are growing better in Holland in greenhouses by injecting more CO2 !
CO2 had about 20 times higher concentration 500 Ma than now, but about the same 300 Ma ago and then CO2 increased to 5 time 200 Ma to peak again and go down to present level. Life did continue to grow and to evolve ;
Figure 85: **changes in atmospheric CO2 for the last 600 Ma**



CO2 and temperature are moving together and it is as egg and chicken. Which is the driver? The best answer is from the ice cores: temperature starts to move first and CO2 follows with a gap of about 800 years. As solubility of CO2 decreases sharply with temperature, when temperature increases, solubility of CO2 in sea water decreases and CO2 is released into the atmosphere and concentration increases with a certain lag related to the 1000 year cycle of oceans. But there are also examples of cases where CO2 did increase the temperature of the earth: it was during the so called snowball earth where CO2 from volcanoes succeeded happily in warming the earth (Proterozoic).

Human activity is in the range of climate effects is on the fourth order as shown in this graph by Gerhard 2006.

Figure 86: **range of climate causes from Gerhard 2006**



Sequestration of CO_2 is not the solution because it will use more energy. Most consumers like Kyoto Protocol because it involve governments taxes and they do not feel involved in doing anything.

The best solution is saving energy and this saving involves every consumer and energy saving will decrease CO_2 emissions.

We have seen above the poor scenarios of IPCC for CO_2 fossil fuels emission per capita IPCC energy scenarios are obsolete dating from 1998 (from IIASA) where oil price was at 10 $/b and are wishful thinking scenarios not based on reality and past.

I presented in 2001 in IIASA (the paper is on their site) graph showing that the IPCC energy scenarios were unrealistic and they kept the same for 2007 IPCC report . As I told last year before the report Same Garbage In , Same Garbage Out.

The catastrophism found in the last IPCC 2007 report is not justified by the coming peaks of oil, gas and coal.

The main goal is first to save energy instead of fighting emissions without bothering to stop wasting food and energy, in contrary spending more energy to reduce CO_2.

-reason and faith, **funds and politics**

In the past century science was favoured as the main source of progress in life and education. But science seems to have peaked for the layman. Science has accomplished real progress in molecular biology and medicine, but little in physics, because of the incompatibility between quantum mechanics and theory of relativity. Since 1930 only 5% of what is seen in the universe is explained. For long 95% of the Universe was believed to be unknown dark matter. Since 10 years the unknown is about 75% dark energy and 20 % dark matter. Or the gravity equation has to be slightly modified. The standard model of particles is assumed to explain the world as long as the coming LHC in Geneva will find the Higgs boson (I doubt that they will as I told them in a presentation at the CERN)! Electron is known since one century but no one knows its size, because electron is both particle and wave.

Who is guilty of the fact that science is losing ground : education or other?

July 2006 in French TV *who wants to earn millions*: at the question : *what is turning around the earth: sun, moon, mars ?* Answer 56% the Sun! 42% moon, 2% Mars: failure of education?

Scientists are under pressure of funding funds and efficiency is often preferred to honesty. Lying by omission (used by Jesuits) is often found. Omitting data by calling them noise or artefacts, correcting data and graph is now frequent to achieve better results. I have shown several cases in this paper.

Getting funds seems to be sometimes the goal of scientists, or getting in line with politics or medias. In our consumption society, decline is a politically incorrect word.

IPCC scenarios were not forecasts but free thinking, but what comes out of the models are taken as real forecasts and sometimes compared to the past as they were reality of today.

IPCC fourth report was published first on Feb.2007 in Paris as *Summary for Policymakers* where scientists met with politicians (Chirac was leading the show). But the scientific report will be issued only in May 2007, as if it has to fit the political decisions of February! It is strange to publish the political summary before the scientific report!

Managers and politicians are judged on the growth of their company and country, so growth is the only goal to show. It is why GDP, inflation, are flawed by many factors, as the hedonic factor for GDP.

Catastrophism is favoured to be efficient.

Faith is often preferred to reason. Some debates between scientists remind now of religious or political debates, where looking at facts is not the goal, but attacking his opponent or his idea under consideration other than scientific.

-conclusions

more I know more I know that I do not know & the others neither, but being old I can give some **advices to**

-students

live is cycle, what goes up must go down, denying peak is denying life and we are all mortal

always define clearly what you are talking about and give a number with date as reference

the number of significant digits should be in line with accuracy of the estimate

do not compare apple with orange and extrapolate one from the other

time is important but always minimized

inertia is the enemy, status quo is often preferred to action, evolution is live, inaction is decline

-consumers

stop wasting energy and food and think to your grandchildren, climate is not the problem, but the limit of the earth

-educated citizens

do more children, if not, only Taliban will survive, educated civilisations are dying with a low fertility rate

-scientists

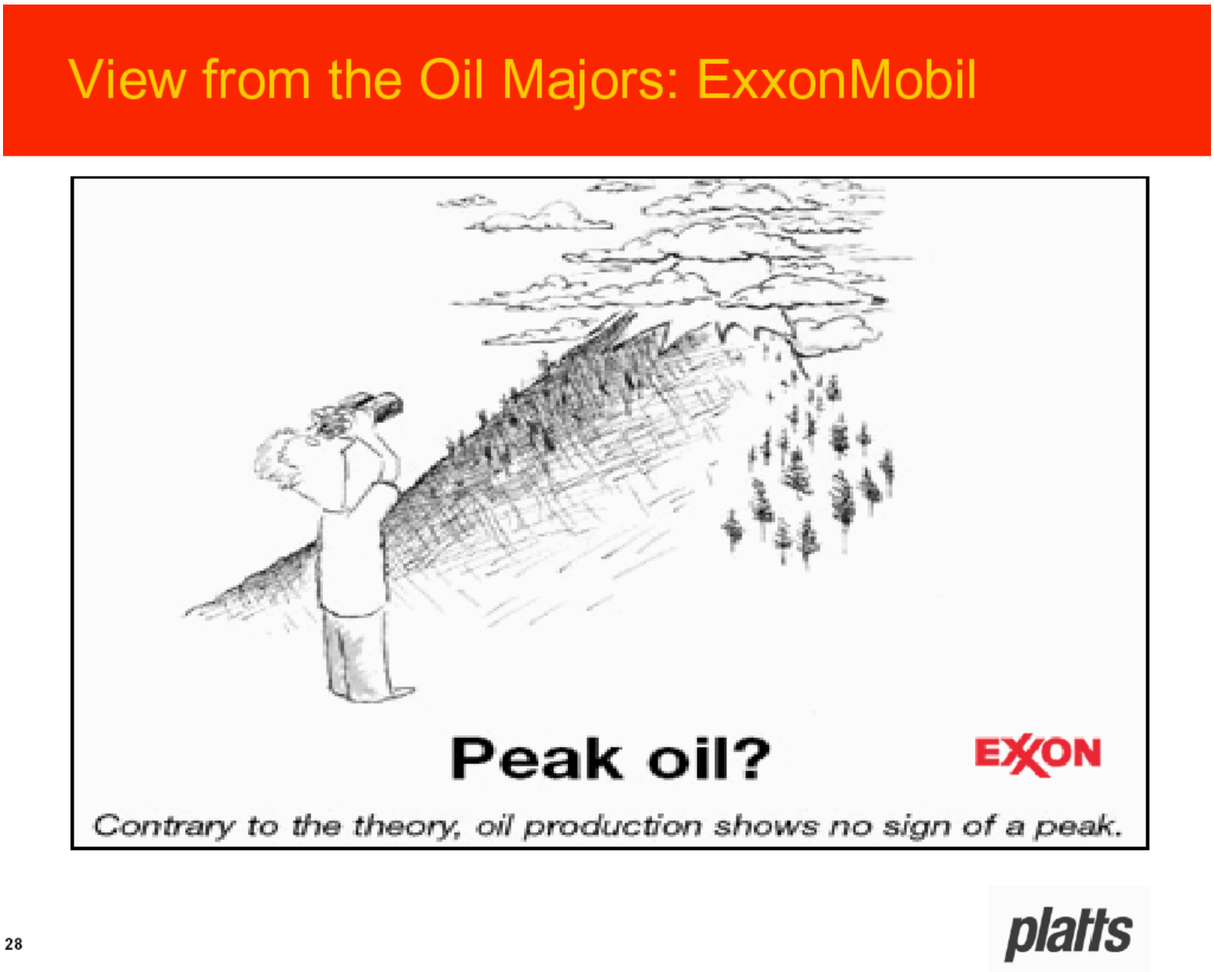
defend reason against belief

95% of the Universe is assumed unknown with 75% of dark energy and 20% of dark matter, a huge part of the Universe is still to be understood, keep searching, keep being in doubt,

finding a solution, keep searching a better solution because Nature is not linear with several solutions

in exploration 9 dry holes are drilled to find one discovery, do not stop at dry holes, keep drilling

Being a member of ASPO I conclude with this cartoon on peak oil



Exxon seems to ignore that US oil production has peaked in 1970

Annex : Climate changes graphs and doubts

Sorry for my broken English.