Oil and gas: what future?

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-Problems of wording

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

-Reporting data

-publishing data is a political act and depends upon the image the author wants to give (rich in front of a banker or for quotas, poor in front of a tax collector).

-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).

-oil field reserves are confidential except in UK, Norway and US federal lands.

-words such as **energy, oil, reserves, resources, conventional, proved, probable, light, heavy, reasonable, sustainable, dangerous are badly or not defined on purpose**

-reporting any data with more than 2 significant digits shows that the author is incompetent

Reserves end of 2004, publication USDOE/EIA 31 May 2006

	Oil & Gas journal	World Oil	OGJ/WO
Crude oil Gb			
world	1 277,181 992	1 081,813	*1,2*
France	0,146 49	0,160 1	*0,9*
Russia	60	67,137 9	*0,9*
Natural gas Tcf			
world	6 043,677	6 997,767 4	*0,9*
France	0,451	0,377 5	*1,2*
Russia	1 680	2 361,053 2	*0,7*

End of 2005	OGJ	BP	OGJ/BP
Oil Gb			
World	1 292,549 534	1200,708 502 619	*1,1*
Russia	60,000	74,436 476 05	*0,8*
Norway	7,705	9,672 727 8	*0,8*
Canada	**178,7924**	**16,5**	***11***
China	18,25	16,038 12	*1,1*
Gas Tcf			
World	6 112,144	6 348,068 437 8	*0,96*
Russia	1 680.000	1 688,046	*1*
Norway	84,26	84,896 5	*1*
Canada	56,577	55,950 5	*1*
China	53,325	82,955	*0,6*

-Reserves

Reserves represent the expected cumulative production to be recovered at the end when the field is abandoned.

There is no consensus on how to assess reserves and there is no world organisation to impose one. The oil industry has issued some rules (SPE/WPC 1997), but they are used only in internal estimates.

UN Framework Classifications (1997, 2004) were completely ignored by the industry.

Reserves estimates are uncertain (except when the field is abandoned), but many definitions, as the SEC (US Securities and Exchange Commission) 1977 obsolete rules (coming from very old SPE rules), deal with "*reasonable certainty* " and refuse the probabilistic approach because the risk aversion of bankers and shareholders.

Russian oil reserves are a State secret (disclosure = 7 years jail) .

Field reserves are confidential because competition in exploration in most countries, except Norway, UK and US federal lands. It is surprising to see so many countries where oil belongs to the country accepting that field data is kept confidential (as in France!).

Reserves represent what will be recovered in future, in a probabilistic approach it has to be the expected value, but it is better to give a range (mini, mean, maxi) or (low, best, high)

Resource is what is in the ground; reserves are only a small part of resource.

There are several reserve definitions in use:

-US = all companies listed on the US Stock Market are obliged to report only proved =1P ≈ assumed to be the minimum?, but SEC rules = reasonable certainty: what is reasonable?: probability of 51 or 99 %?

-FSU classification = maximum theoretical recovery ≈ proven + probable +possible = 3P ≈ maximum

-Rest of the world = SPE/WPC 1997 rules (I was a member of the task force) = proven + probable = 2P ≈ expected value (should be the mean ≈ P40, when given as the median P50, but often confused with the mode (most likely) ≈ P65); range 1P=90%, 3P=10%

Proved reserves (1P) tell bankers that the company could not be bankrupted, but development decisions are taken on mean reserves (2P)
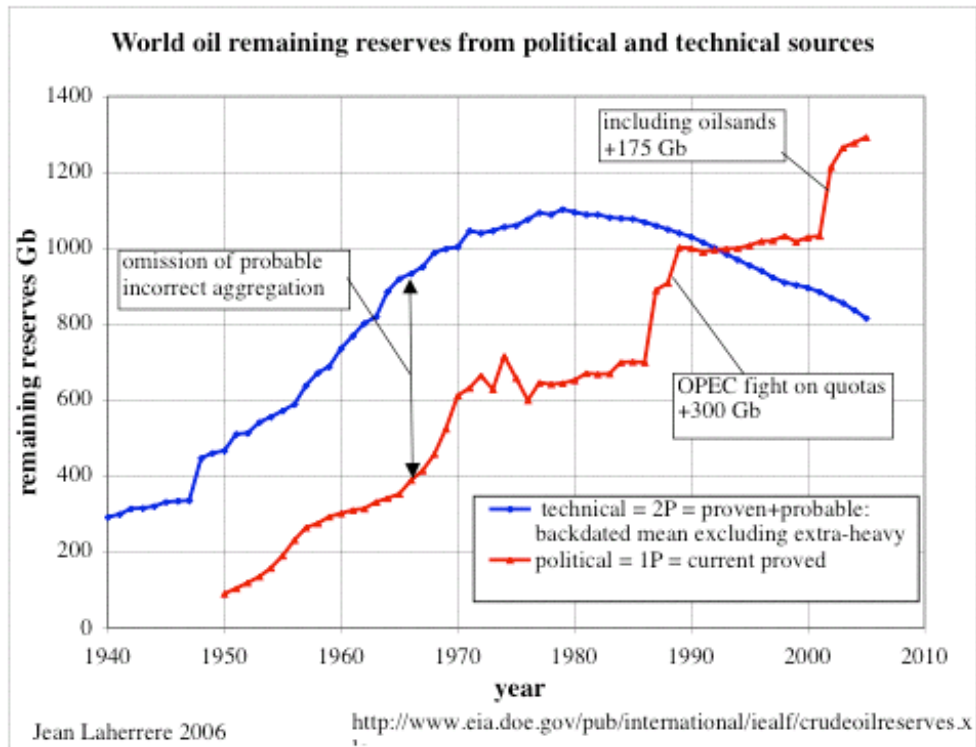
All the attempts to improve the data have failed, despite all the claims of good will by governments and agencies, in particular the JODI (Joint Oil Data Initiative) gathering seven international agencies under the UN since 2000, providing only some incomplete production data.

Reserve growth occurs when reserves are reported as the minimum (proved), but does not occur statistically when reported as proven+probable ≈ mean (expected) value.

-Political and technical data

Oil remaining reserves (known discoveries minus cumulative production) can be compared from political sources giving current proved values and from technical sources after correction of US Lower 48 and FSU to obtain the backdated mean (expected) crude oil (less extra-heavy) value.

The following graph display my technical data, which is the compilation of several heterogeneous databases, corrected to best represent the world mean reserves from field, backdated to the year discovery. The best way should be to backdate to the year where investment are made but it is impossible to obtain it worldwide by lack of data.

Figure 1: **World remaining conventional oil & gas reserves from political and technical sources**

World oil remaining reserves from political and technical sources

Jean Laherrere 2006   http://www.eia.doe.gov/pub/international/iealf/crudeoilreserves.x

Political data is always rising from 1950 to now, when from the technical sources, oil remaining reserves has peaked in 1980! It is well recognized by almost every IOC that, since 1980, oil discovery is less than oil production

From 1950 to 1979 (oil shock) proved reserves were roughly half of the mean value, the difference representing the omission of the probable reserves and the incorrect aggregation.

The same data **annually** shows very well the artefacts of political reporting, compared to the truth, which is that finding new reserves is a nightmare for oil companies (Scaroni 2006) and that since 1980 the world oil production is much higher than oil discovery.

Figure 2: **World annual crude oil (less extra-heavy) mean discovery & production and political additions (so-called proved)**

World oil annual discovery (smooth) and production, as political additions (so-called proved)

Jean Laherrere 2006
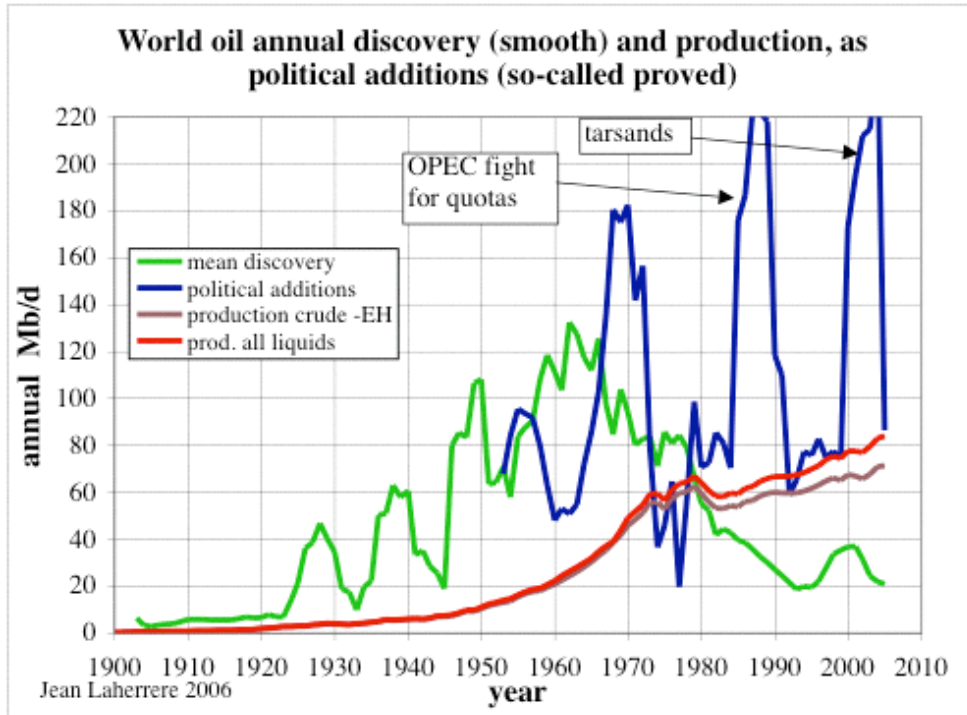
Every study based only on the so-called proved reserves should be discarded as useless following the principle GIGO: **Garbage In, Garbage Out**.

-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 3: **Saudi Arabia cumulative oil discovery from IHS and WM in percentage of the last cumulative versus cumulative number of New Field Wildcats**

Saudi Arabia oil creaming curve 1935-2005 in percentage of total discovery from IHS & WM 2006 & 2004

Jean Laherrere 2006
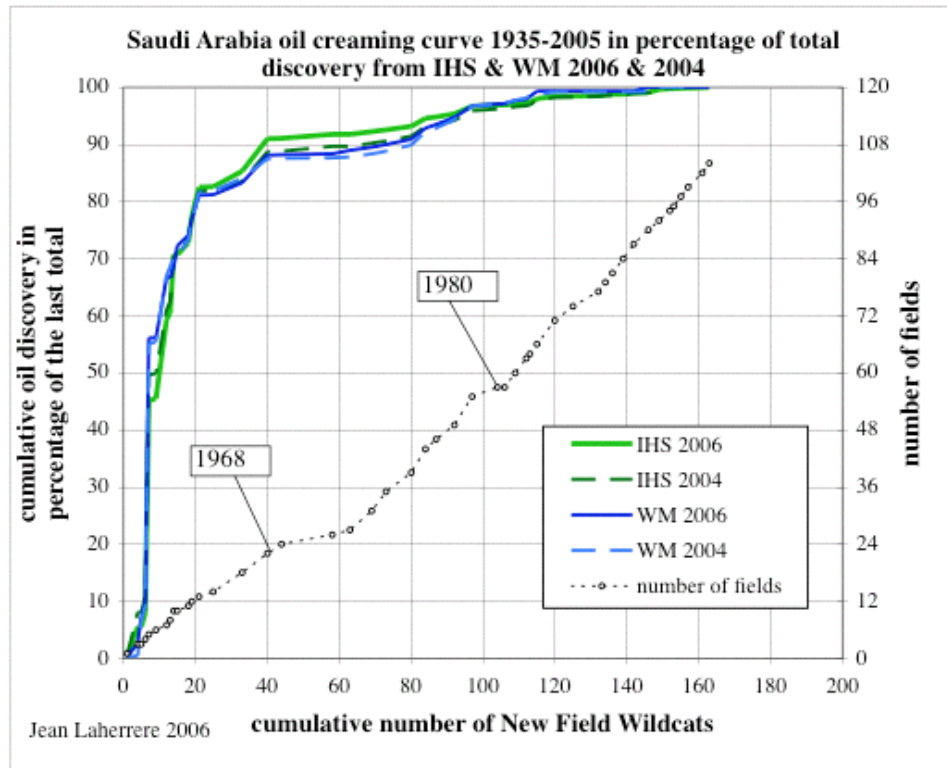
-Myth 2: oil recovery factor (RF) is about 35% in the world and 50% in North Sea, so world reserves can be increased widely

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 oil reserves.

Figure 4: **Oil recovery factor from IHS (world outside US onshore) 2006 & 2001**

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Oil recovery factor from IHS 2006 & 2001

Jean Laherrere 2006
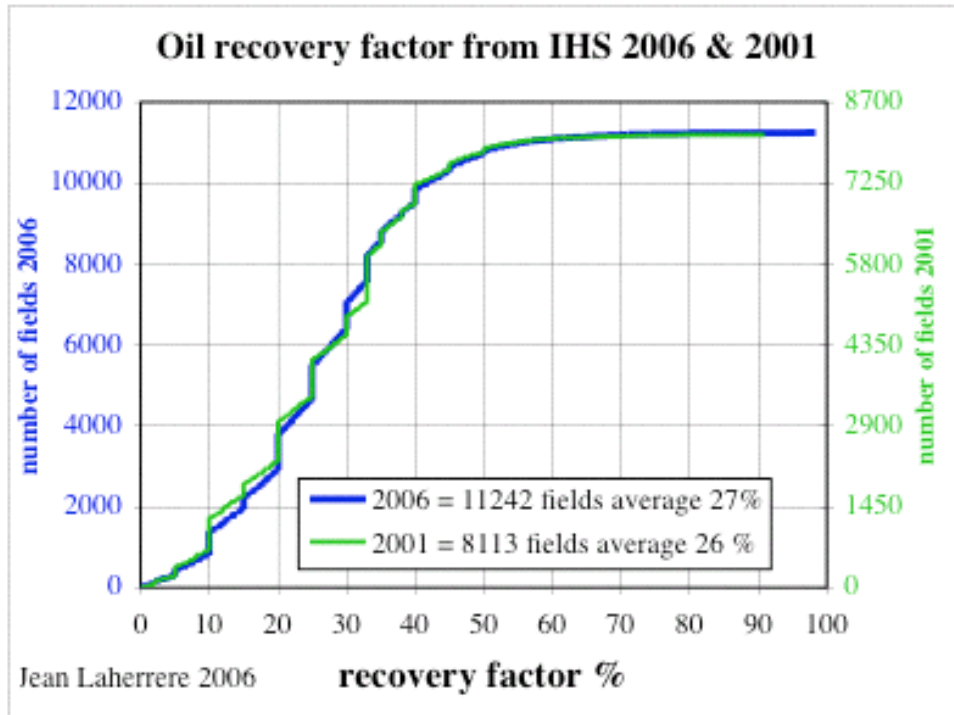
Recovery factor depends mainly upon the geology of the reservoir : from 1% for tight reservoir to 85% for very porous and permeable reservoir. Technology cannot change the geology of the reservoir.

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

Gas recovery factor from IHS 2006 & 1997

Jean Laherrere 2006
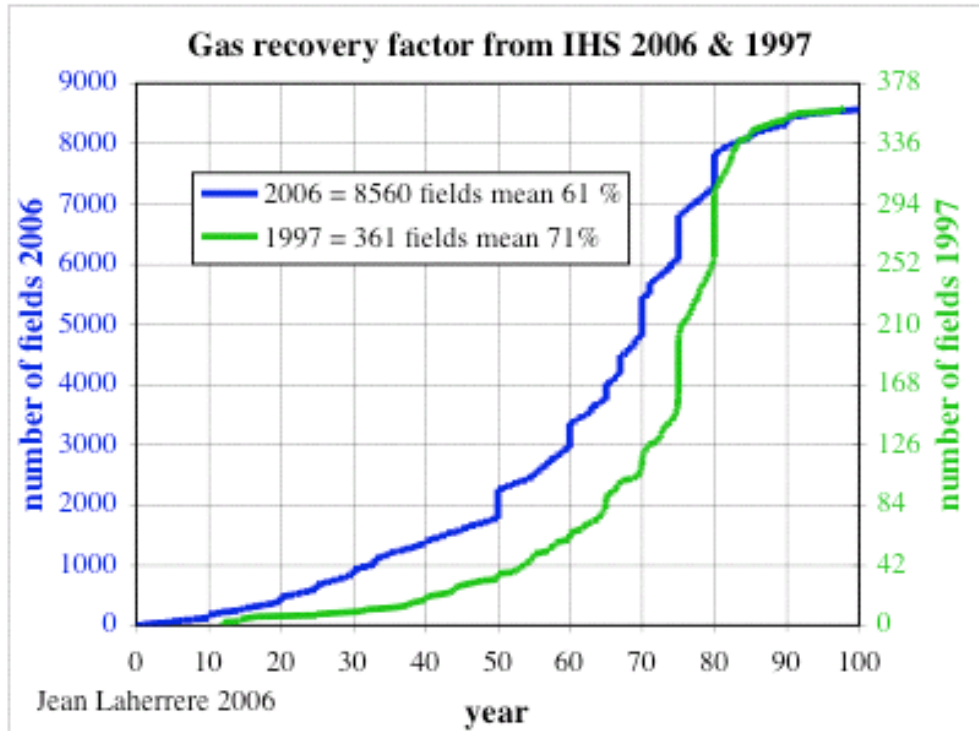
It is obvious that in the past only large fields were reported with RF, when now less productive fields are reported.

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 the reserves are exactly known when oil in place is still a guess!.

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

-Myth 3: technology increases reserves

Reserve growth is claimed by USGS 2000 report 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 nonsciential extrapolation as there are two completely different objects. It is as comparing the temperature in Paris with those in New York without bothering to mention that the first is in Celsius and the second in Fahrenheit. 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%.

Figure 6: **Oil decline of East Texas, largest US L48 oilfield 1930-2005**

**East Texas oil decline 1930-2005**

Jean Laherrere 2006
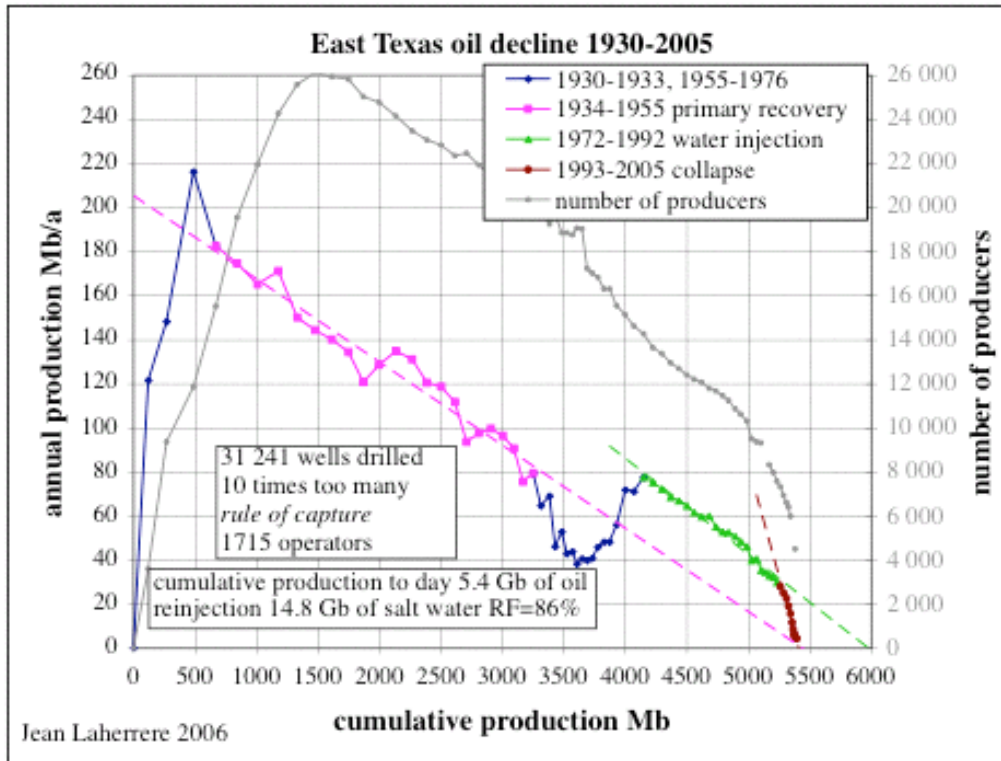
Over 30 000 wells have been drilled (by over 1700 different operators) 10 times too many (spacing of 4 acres per well, when 40 acres/w was largely enough), because of *rule of capture*! There is a very active water drive and **the recovery is estimated at 86 %. Present water cut is over 98%** =14 000 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 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 2005 (green curve) with a decline of 20 %/a shows that the ultimate will be around 320 M.m3. Again negative reserve growth.
Figure 7: **Brent oil decline showing a late collapse Nov.1976-Apr.2006:**

Brent oilfield UK: oil decline Nov. 1976-Apr. 2006
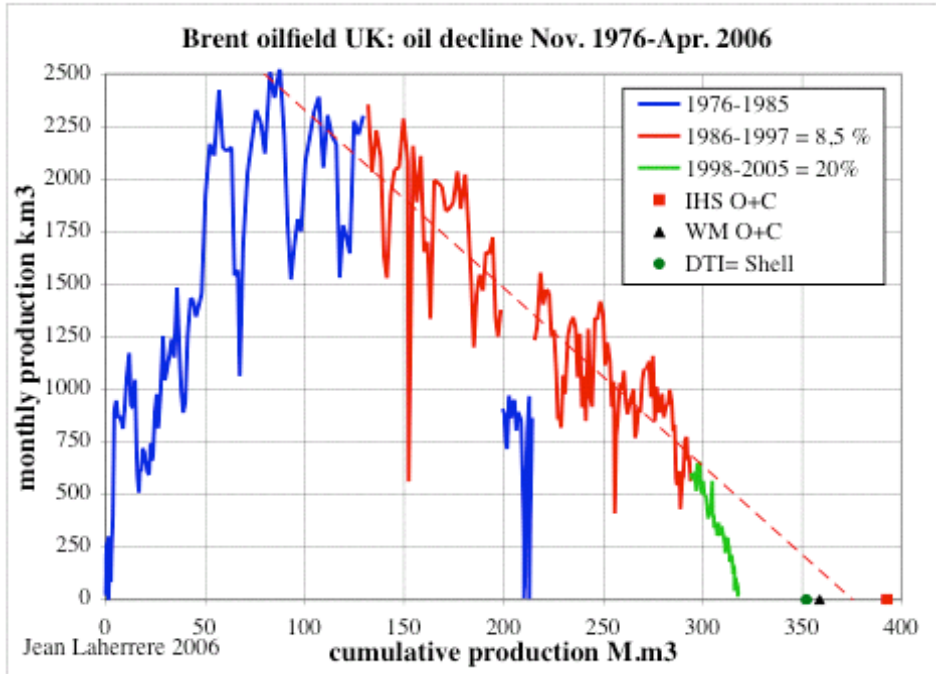
Modern production aims to get maximum production to get maximum profit (pushed by new shareholders as pension fund asking short-term large rate of return.

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 8: **Oil decline of Yibal, largest field in Oman 1969-2003,** operated by Shell

Yibal oil decline trending towards 1750 Mb
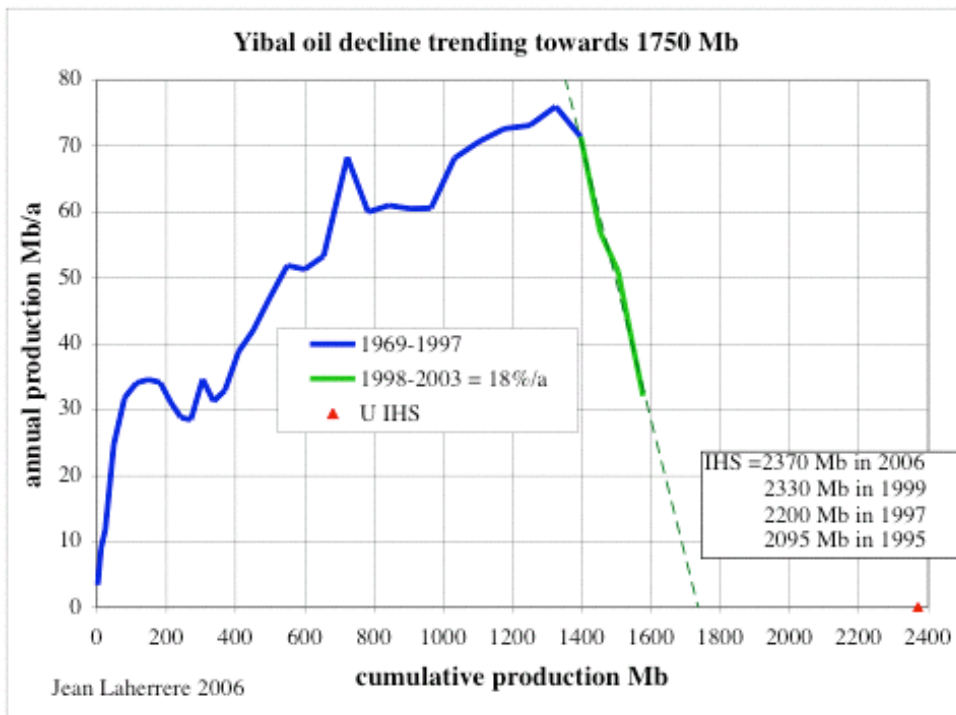
The largest Mexican oilfield Cantarell discovered in 1977 (aggregation of several fields as Akal, Chac, Kutz, Sihil and Nohoch) was reported by IHS as 15,3 Gb in 1995 and 18,7 Gb in 2006. In 1995 when annual production was at 1 Mb/d, Pemex started an very expensive nitrogen injection and production raised 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 in 2005

Figure 9: **Oil decline of Cantarell, largest field in Mexico 1979-2008**
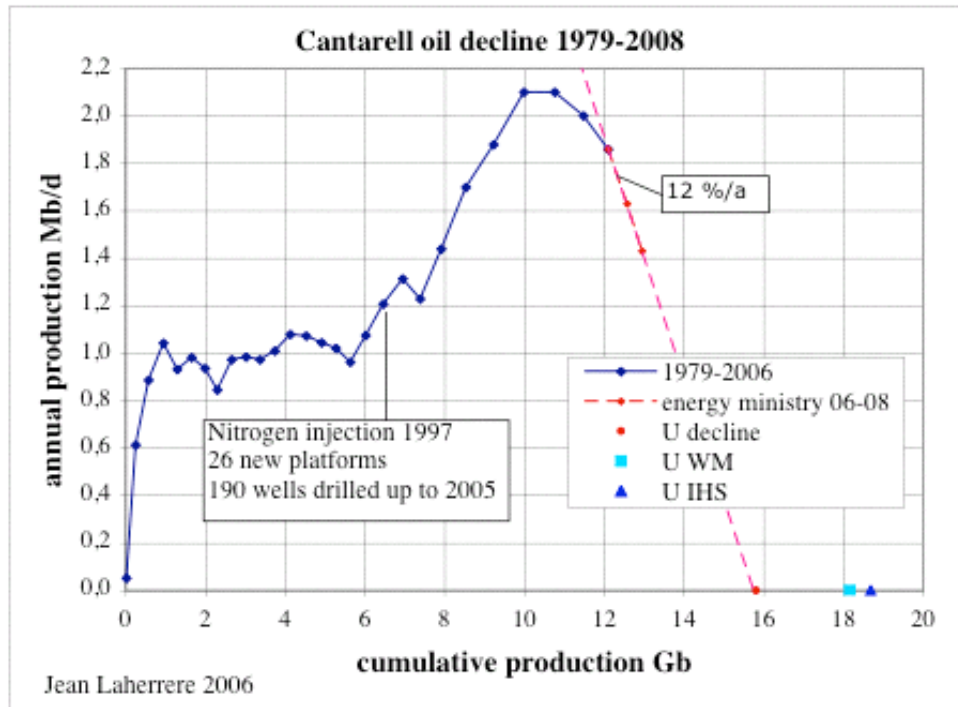
The ministry of energy has reported that Cantarell is declining and will produce only 1,4 Mb/d in 2008, meaning a decline of 12%/a (14 %/a was also reported) and an ultimate about 16 Gb compared to more than 18 Gb for IHS and WM. Again a negative reserve growth !.
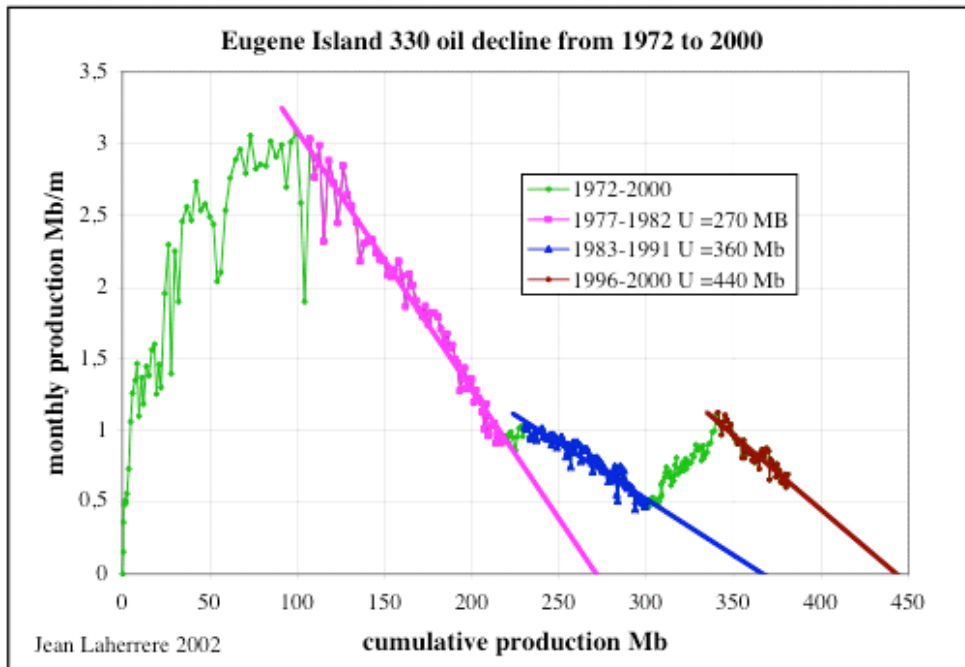
There are many negative reserve growth examples in the world, and in my review of all major (>100 Mb) oilfields of the world I found few examples of decline showing a real positive reserve growth and all those examples are due to an exceptional geologic case . The best examples are Ekofisk, which have 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 10: **Oil decline of Ekofiisk (Norway) 1971-July 2006**

Ekofisk (Norway) oil decline 1971-July 2006

Jean Laherrere 2006
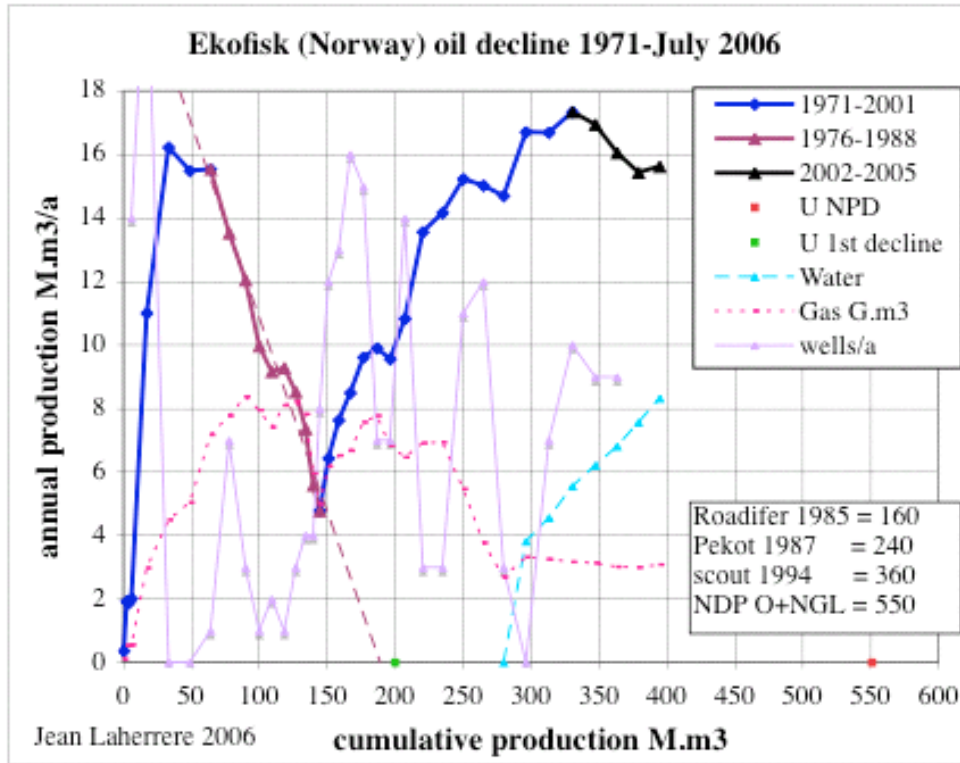
There is another example of exceptional positive reserve growth, which, is Eugene Island 330 in the Gulf of Mexico. The largest fault in the area called the Red Fault (studied on the web by several universities) allows the reservoir to be directly in communication to the source rock and when the pressure 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 11: **Oil decline of Eugene Island 330 (US Gulf of Mexico) 1972-2003**

Eugene Island 330 oil decline from 1972 to 2000

Jean Laherrere 2002

On the plot of annual production versus cumulative production, there are many example of negative reserve growth and few of positive reserve growth, sot 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.

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 29 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).

    -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 from 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!
Figure 12: **US R/P from mean backdated reserves and from proved current**
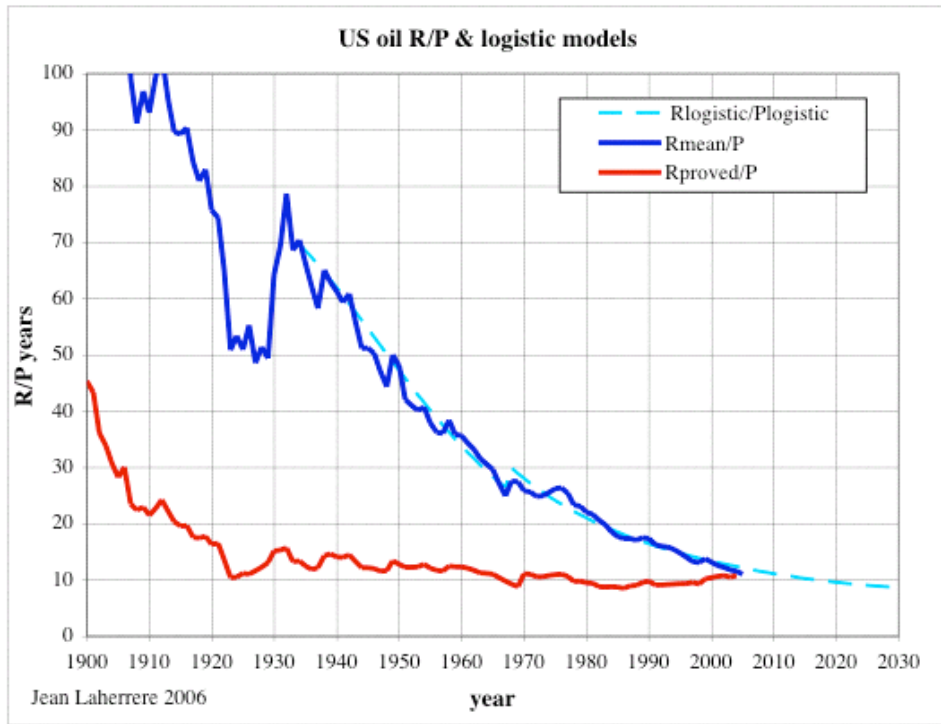
For the world R/P (crude oil less extra-heavy) decreases from 140 years in 1950 to 35 years to day and trending towards a 20 years asymptote.

Figure 13: **World R/P from my technical database with logistic models 1910-2030**
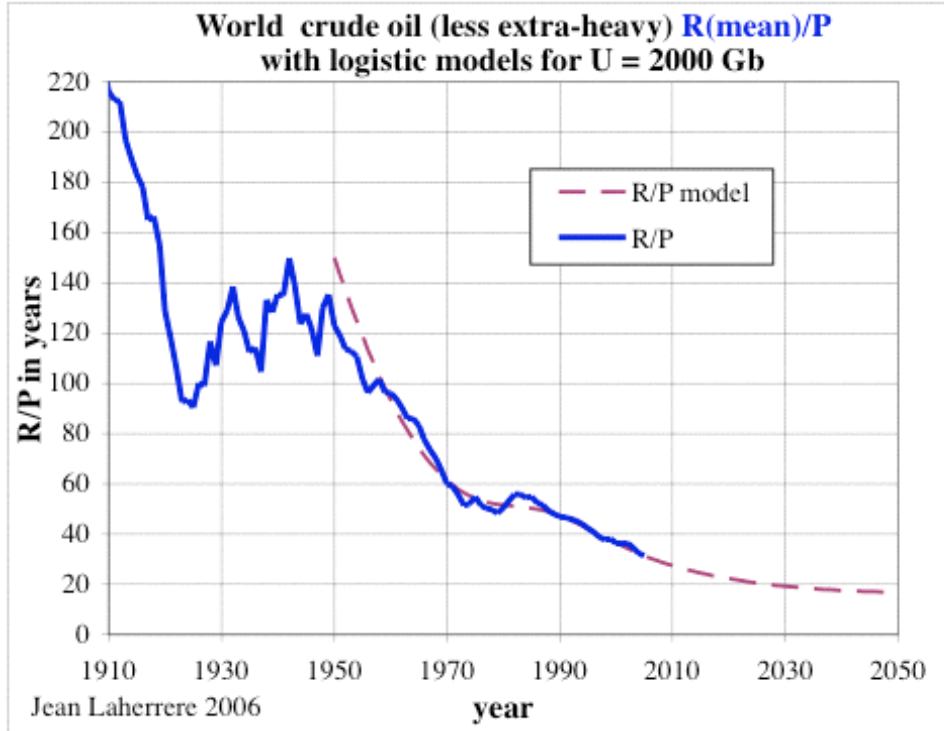
R/P is a very poor indicator for forecasting the future, but used by many.

-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. 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 when getting WM (Wood Mackenzie) worldwide (almost) database

Figure 14: **Crude oil less extra-heavy creaming curve by continent**
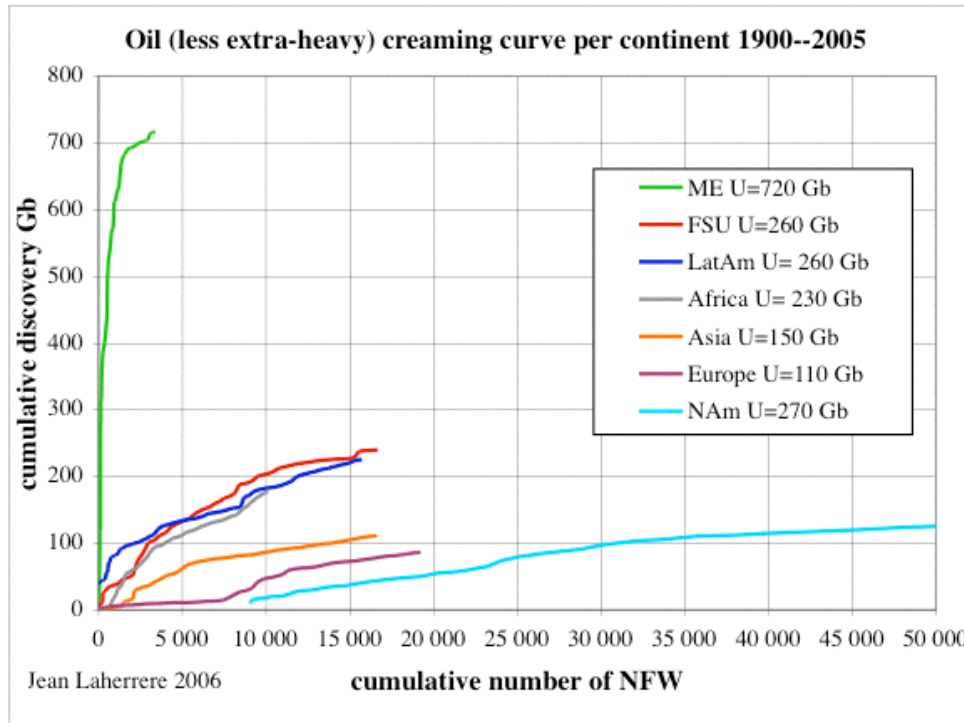
Creaming curves are rarely used because few have the detailed and complete data of NFW..


-Modelling of future » *oil* » production
Future production is modelled by drawing with several cycles a curve which the area below it until the end of production represents the ultimate. The model has to fit past data with value and slope. The model will represent 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) following 2004 Paul Volcker's forecast of 75% chances to have in the ,next 5 years an economic crisis.

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

World cumulative crude oil (less extra-heavy) mean discovery & production with logistic models for ultimate = 2 Tb

Jean Laherrere 2006
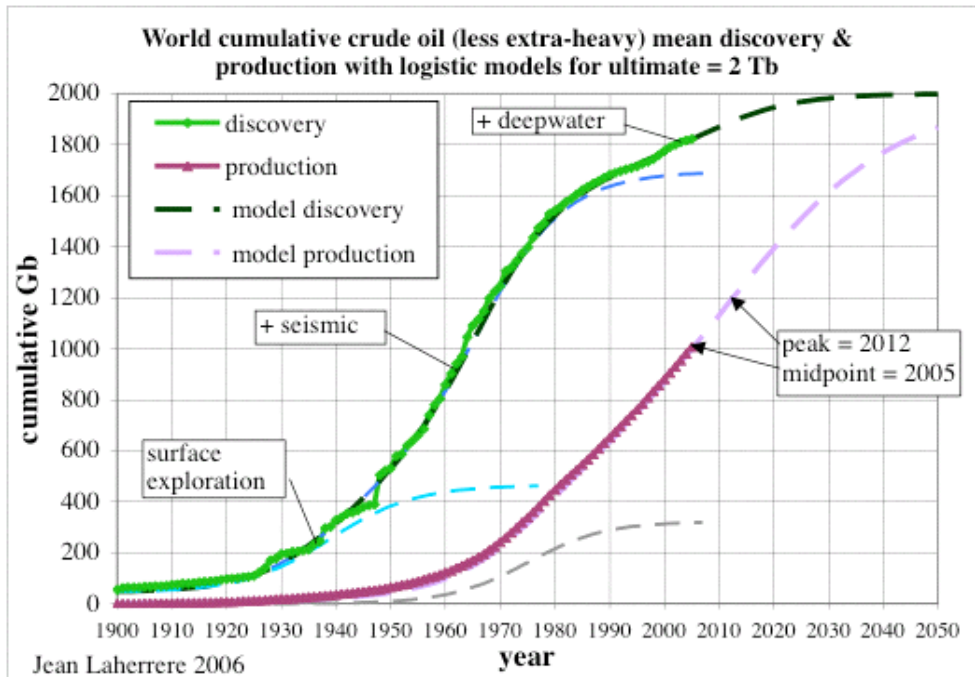
Present cumulative discovery is over 1800 Gb, leaving less than 200 Gb for yet to find, which is less than the accuracy of the ultimate (taken with only one significant digit for well showing its inaccuracy).

- **-World annual "oil"**
    -**Crude oil less extra-heavy discovery & production**

Annual crude oil discovery peaked around 1960

Figure 16: **World annual crude less extra-heavy oil mean discovery and production with logistic model for U = 2000 Gb** (no demand or investment constraint)

World annual crude oil (less extra-heavy) mean discovery & production with logistic models for ultimate = 2 Tb

Jean Laherrere 2006
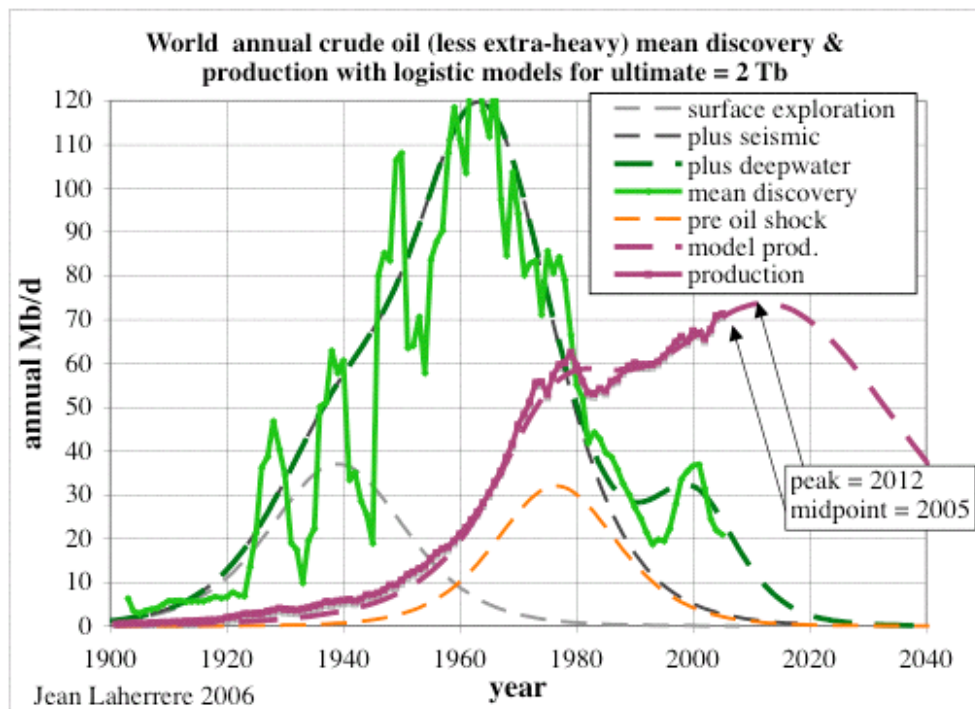
-liquids production

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, making an all liquids ultimate of 3 Tb, with a peak around 2050. The all liquids peak is around 2015 and over 90 Mb/d, but this is theoretical assuming no constraint from the demand or from investments. The all planned *megaprojects* up to 2010 are well known for oilfields with estimates of cost, maximum plateau and timing despite most are optimist (McNamara law saying that the ratio for frontier projects between initial estimate and reality is pi (3,14) for cost and e (Euler number = 2,8) for time. Skrebowski (Petroleum Review 2006) has forecasted an oil peak in 2010 at 94 Mb/d. This detailed forecast is in line with our theoretical forecast from ultimate 3 Tb. But CERA (OGJ 14 Aug. 2006) forecasts, using the same *megaprojects*, that oil production in 2015 will be 110 Mb/d (but from 88.74 Mb/d in 2006?), forgetting to allow a likely lag and reduction in the realization of the projects as did Skrebowski. But these forecast are only for oil projects and do not included synthetic oil. 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 17: **World liquids production** (no demand or investment constraint)
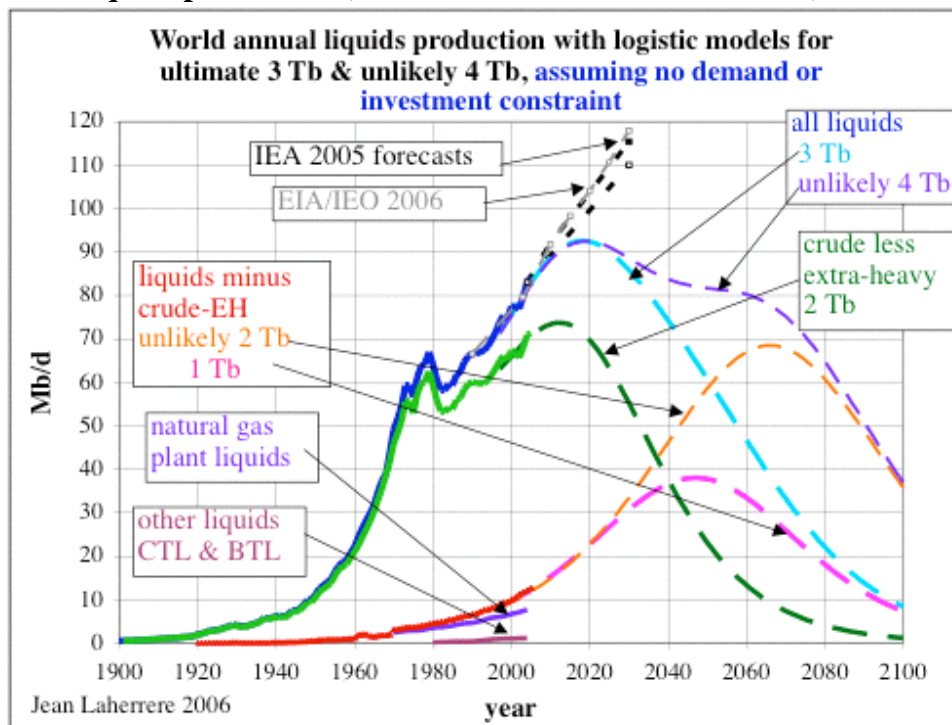

IEA 2005 forecast is plotted with 115 Mb/d in 2030.
Al-Husseini former VP Aramco E&P stated that IEA forecasts are much too high for Middle East and for Russia
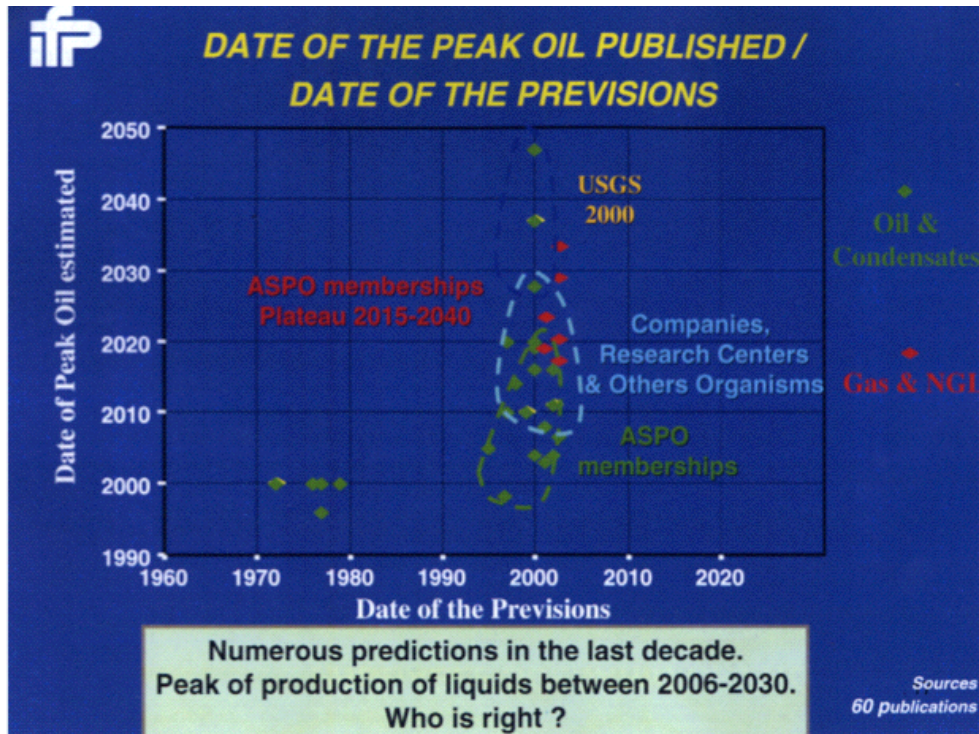
Skinner (WEC 2006) has forecasted unconventional oil as GTL and BTL up to 2015 .He foresees only a moderate increase of 4 Mb/d from 2005 to 2015 when I foresees more than the double; but including NGL and refinery gains

Figure 18: **Unconventional oil supply 2002-2015 Skinner WEC 2006**

Figure 1: Forecast unconventional oil supply
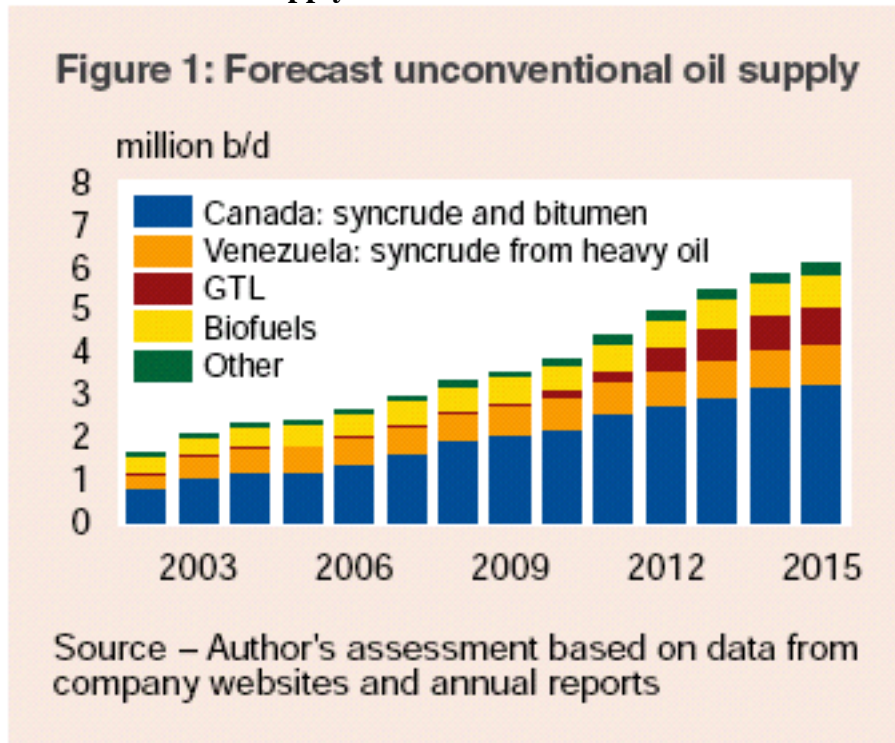
IFP (Champlon Brussels workshop 7 Sept. 2006) has gathered numerous predictions on oil peaks and has delimited ASPO (green curve) and companies, research centers (light blue curve) and these two groups overlap for over half when USGS(yellow) looks out of range

Figure 19: **date of oil peaks from IFP**

Numerous predictions in the last decade.
Peak of production of liquids between 2006-2030.
Who is right ?

Sources :
60 publications

-**US & FSU-Russia forecast**

FSU has peaked in 1988, then collapsed drastically, but Russia recovered from 1997 up to now . But Russian estimates are overestimated, using FSU classification (Kalimow 1979 & 1993) with a maximum theoretical recovery (3P). My estimate as Leonard 2003 (former Yukos VP) is that Russia is presently peaking, despite CERA and USDOE optimistic forecasts.

Figure 20: **Oil production for US, FSU & Russia with several forecasts 1900-2030**
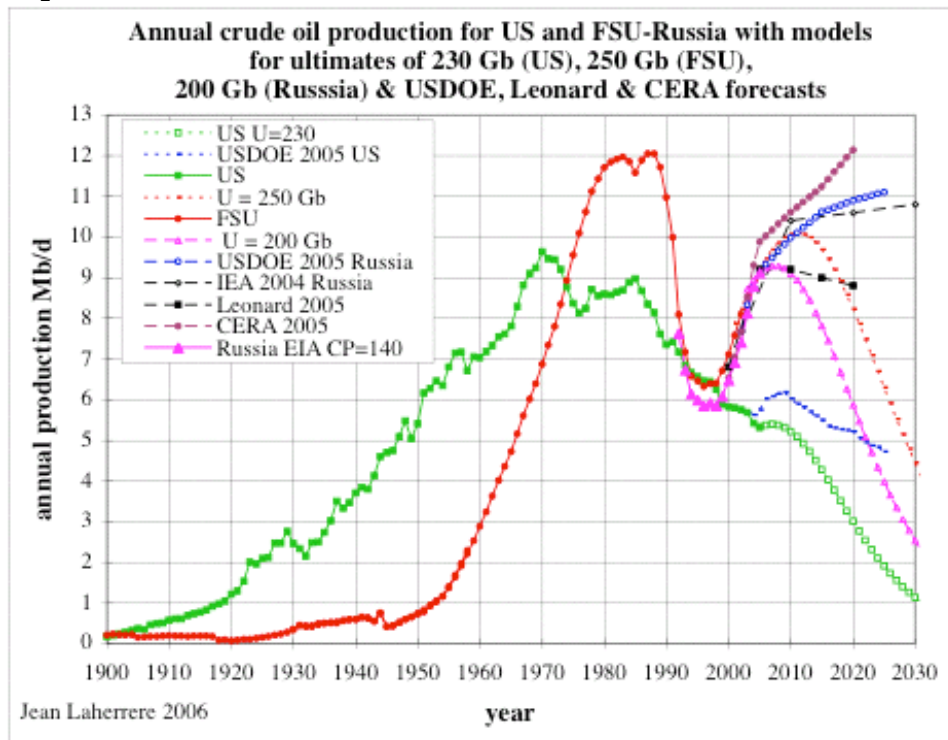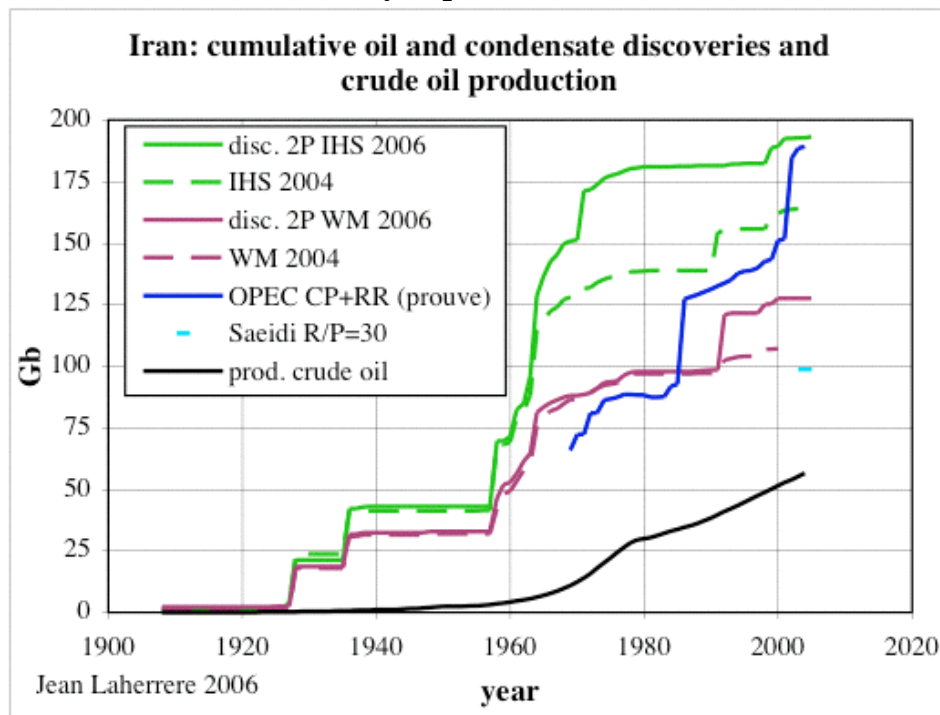
-Iran

M. Saeidi (VP of Iranian Atomic organization) stated (Guardian 27 Aug. 2006) that Iran has only 25 to 30 years of oil, contrary to NIOC reports of 132 Gb with a R/P of 93 years (2004 OPEC report & BP Review) or more than 3 times more. Ali Bakhtiari (ASPO & former NIOC) has already declared that NIOC estimates were exaggerated when reality is close to 40 Gb (from estimates of M.A.Saidi (geologist and former NIOC head). In 2005 Iran has produced 4 Mb/d with a cumulative production of 58 Gb. R/P of 25-30 means that remaining reserves are close to 40 Gb, giving a total discovery about 100 Gb.
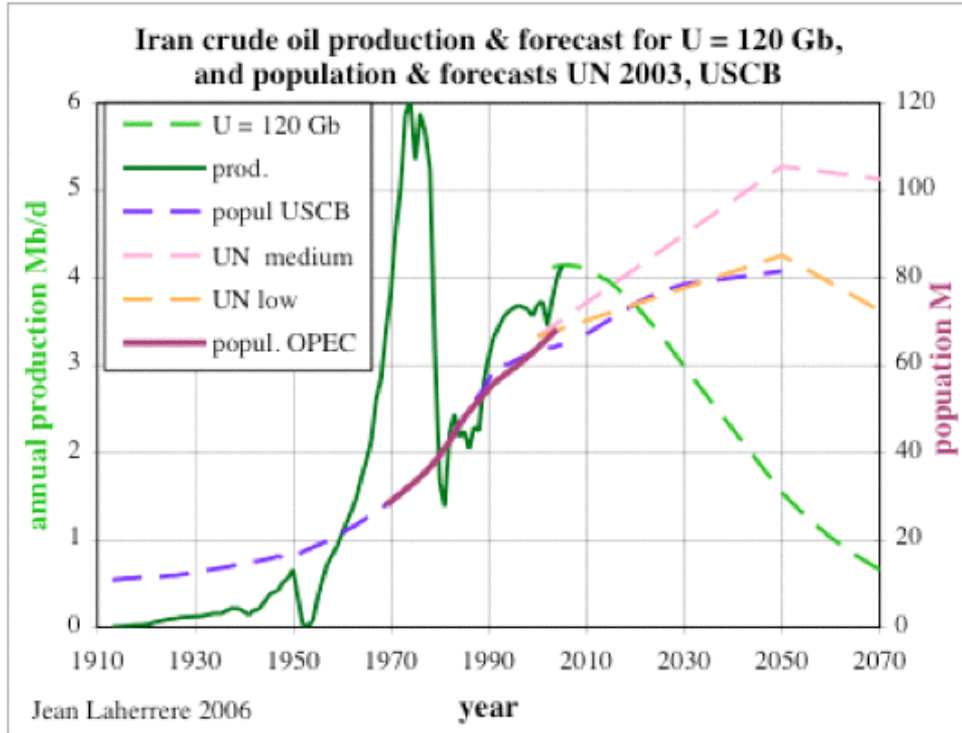
Spy companies (IHS, WM), which sell technical data do not want anymore to upset NOCs (National Oil Company), which are now becoming their clients. They have recently increased their estimates as shown in the following graph, to match official reports, totalling at end of 2005 190 Gb for IHS 2P (against 165 for IHS 2004), 190 for NIOC 1P and 125 Gb for WM 2P (against 105 for WM 2004)

Figure 21: **Iran: cumulative oil discovery & production from different sources 1908-2005**


Last year in ASPO Lisbon I plotted future production with two ultimates: 120 Gb (my guess) and 200 Gb (NIOC estimate) and I concluded that Iran need quickly nuclear plants. Saeidi and Saidi confirm that 120 Gb is a likely ultimate, which leads to an oil peak right now. The claimed last large discoveries as Azadegan found in 1999 (reserves are reported as 6 Gb for IHS, 3.5 Gb for WM, 2.6 to T Gb for Salameh 2005 and 26 Gb (oil in place?) by the medias for a production of only 260 000 b/d), which is not yet developed despite the Japanese signed a contract in 2004 and they are now withdrawing under US pressure; or Yadaveran (Koushk + Hosseinieh) discovered in 2002 (reserves of 3 Gb for IHS , 1.7 Gb for WM and 30 Gb (?) for some medias) which is negotiated with the Chinese and the Indians. But Iranian oil contracts are very poor, and US oil companies are forbidden to operate. Such fields will only impact the decline and not the Iranian oil peak.

The 2003 UN population scenarios (low, and medium which in the past were always too high) is compared to USCB forecast leading to a likely population peak at 80 millions around 2050.

Figure 22: **Iran: forecast of oil production and of population 1910-2070**

Iran crude oil production & forecast for U = 120 Gb, and population & forecasts UN 2003, USCB

Jean Laherrere 2006

The oil production per capita shows a spike around 1970 and a plateau from 1990 to 2010 with a sharp decline beyond.

Figure 23: **Iran: forecast of oil production per capita 1910-2050**

Iran crude oil production & forecast (U = 120 Gb and UN 2003) per capita

Jean Laherrere 2006
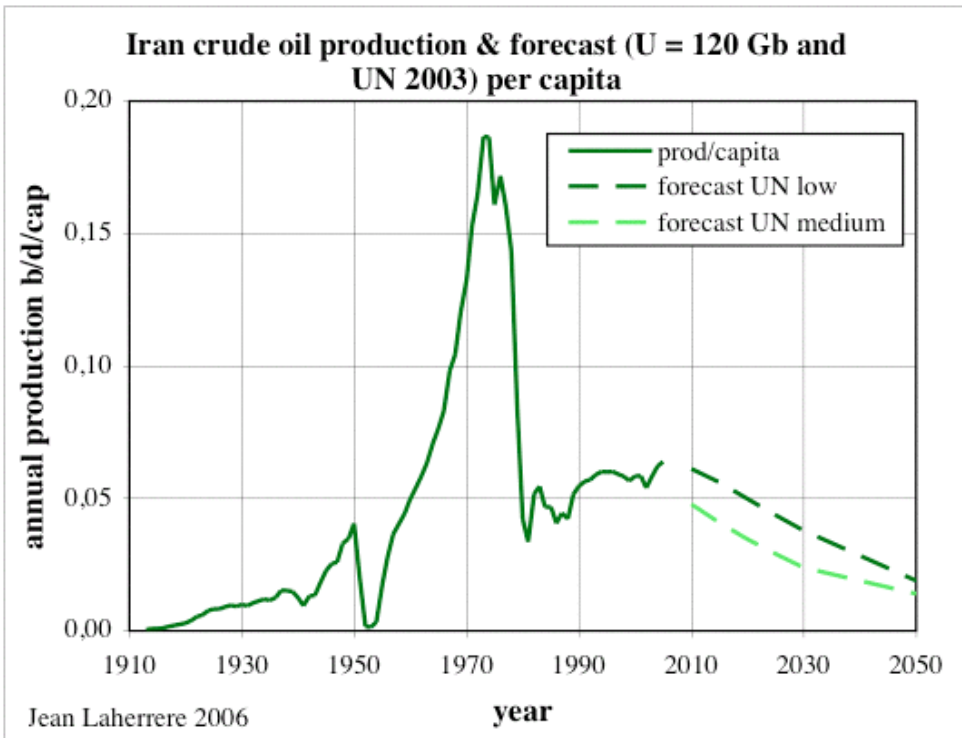
Iran has large reserves of gas but not enough to provide exports for earning money and national consumption and replacing declining oil. They will need nuclear plants quick and should start now to build them.

-Denial of signed contracts
Our forecast is based on ultimate reserves but as already stated it assumes that there is no constraint from the demand or from the investments. A recent trend of denial of signed contracts in Bolivia, Russia and Venezuela is a bad sign for investors, but foreign investment and technology are needed in these countries, which are spending oil money for social uses.
All these constraints will make the oil peak a bumpy plateau and will lead to chaotic prices.

-Natural gas
The 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 IHS and WM is wider than for oil as WM reports only so called technical gas, which can be produced when IHS reports discovery, including a lot of stranded gas. Technical data has peaked since 1980
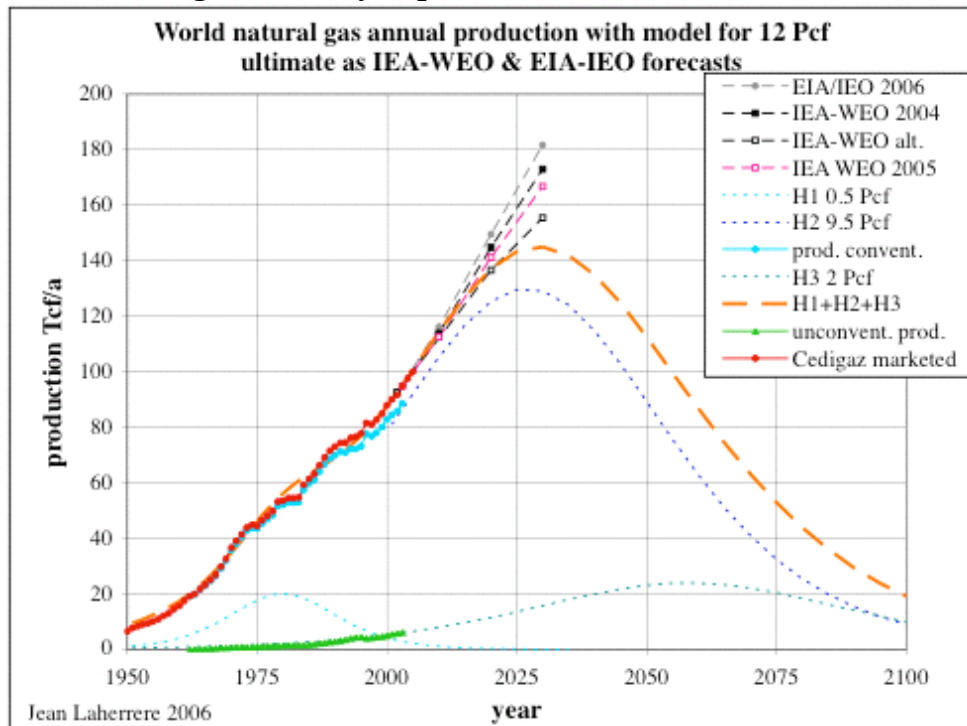Figure 24: **world remaining NG reserves from different sources**.
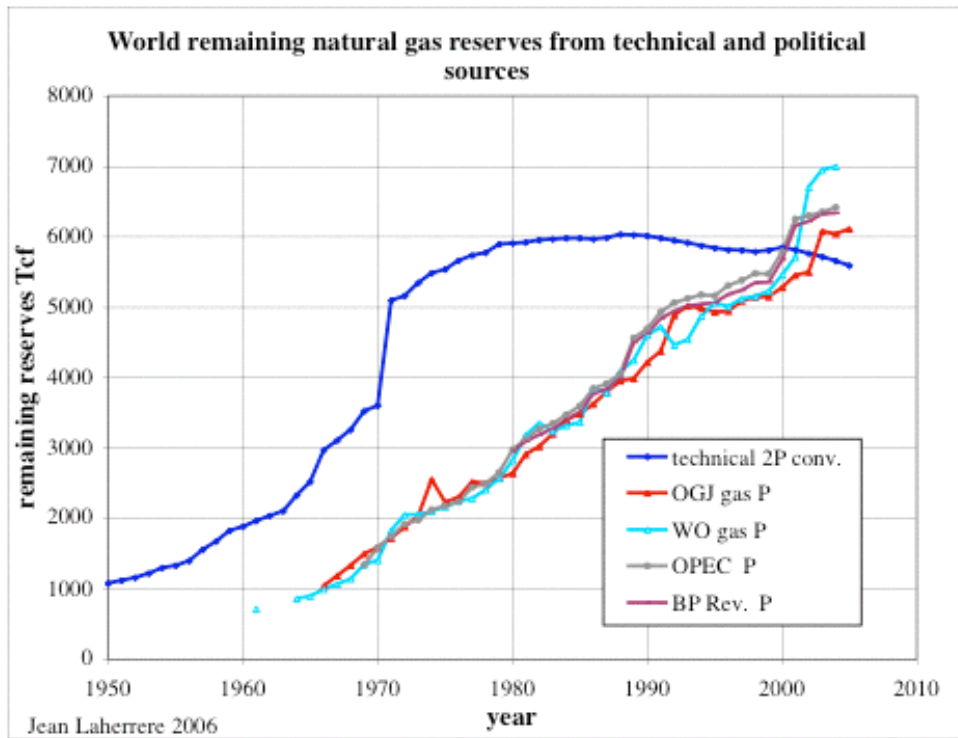
World cumulative discovery and production is modelled with a logistic curve but the largest gasfield (North Dome found in 1971 being North field in Qatar and South Pars in Iran reported as 1991 by IHS) represents about 15 % of the ultimate (Ghawar represents only 6%) and upsets the curve, so it is separated from the curve
Figure 25: **2006 forecast: World conventional cumulative gas conventional discoveries and production with logistic models**

World natural gas mean cumulative discovery and production with logistic models

Jean Laherrere 2006
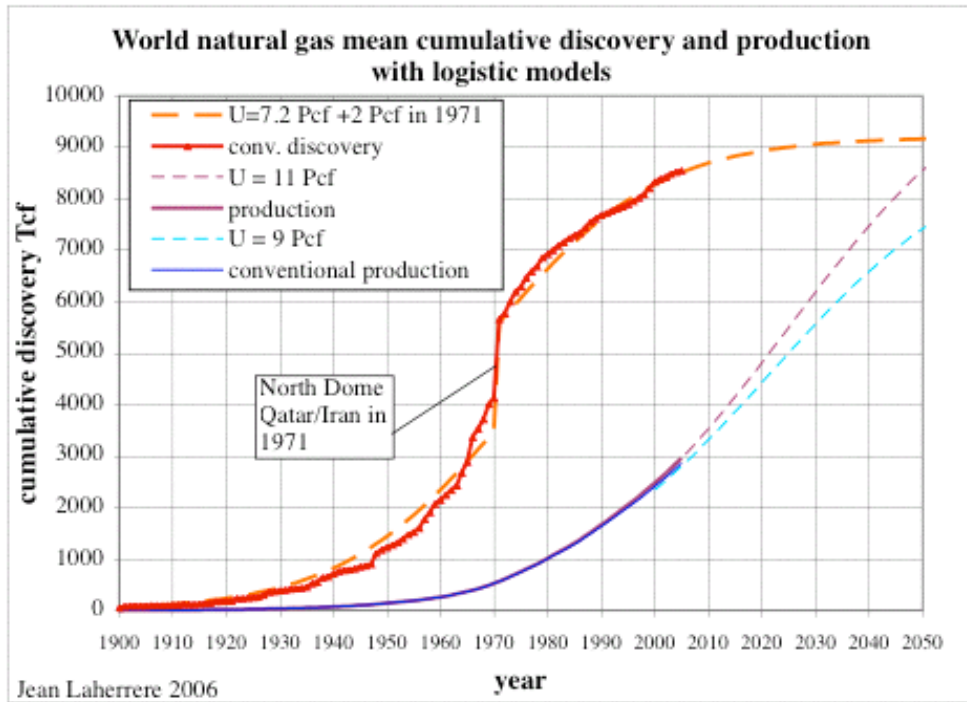
The ultimate NG was estimated at 10 000 Tcf (10 Pcf) 10 years ago (Laherrere, Perrodon, Campbell 1996) for conventional and 12 Pcf including non-conventional. We keep these values, as updated data confirm these round values, but if gasification of coal works (problem of sequestration of CO_2), the ultimate can increase but it will not change the peak only the later decline.

The world NG production will peak in 2030 about 140 Tcf/a when USDOE 2006 forecasts for 2030 182 Tcf/a and rising, but IEA 2005 has decreased from 2004 the value to 165 Tcf/a.

Figure 26: **World annual gas discovery & production as forecasts**

World natural gas annual production with model for 12 Pcf ultimate as IEA-WEO & EIA-IEO forecasts

Jean Laherrere 2006

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 centers 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!

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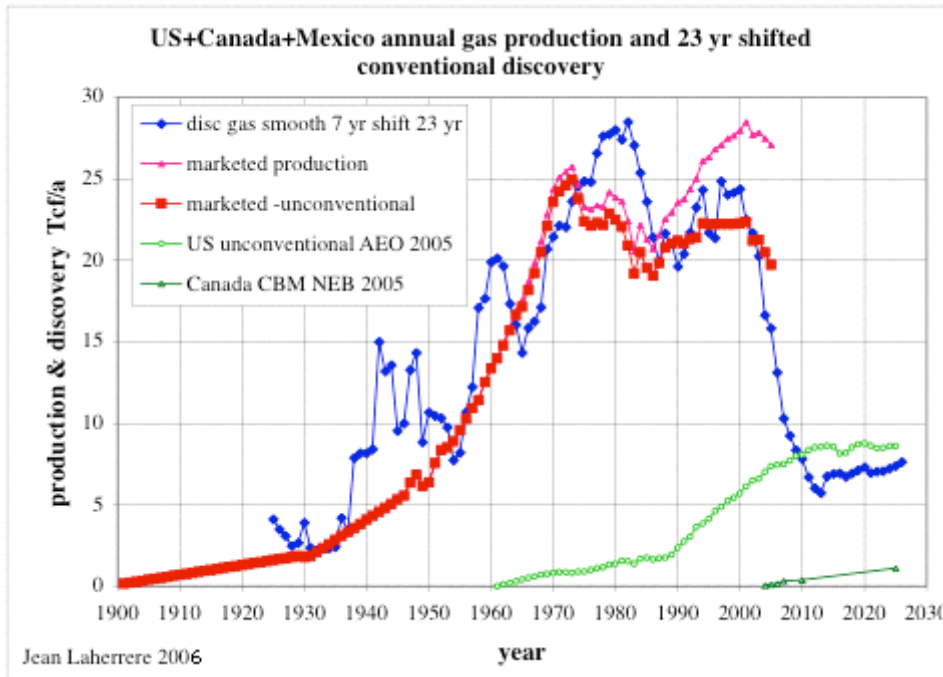

Natural gas production in Europe is peaking but consumption is rising sharply. Europe is counting too much on Russia gas. Europe will suffer soon of gas shortage and high prices despite recent studies by WM.

Figure 28: **Europe: natural gas consumption & production for an ultimate of 750 Tcf: 1930-2050**

Europe: natural gas consumption & production for an ultimate of 750 Tcf

Jean Laherrere 2006
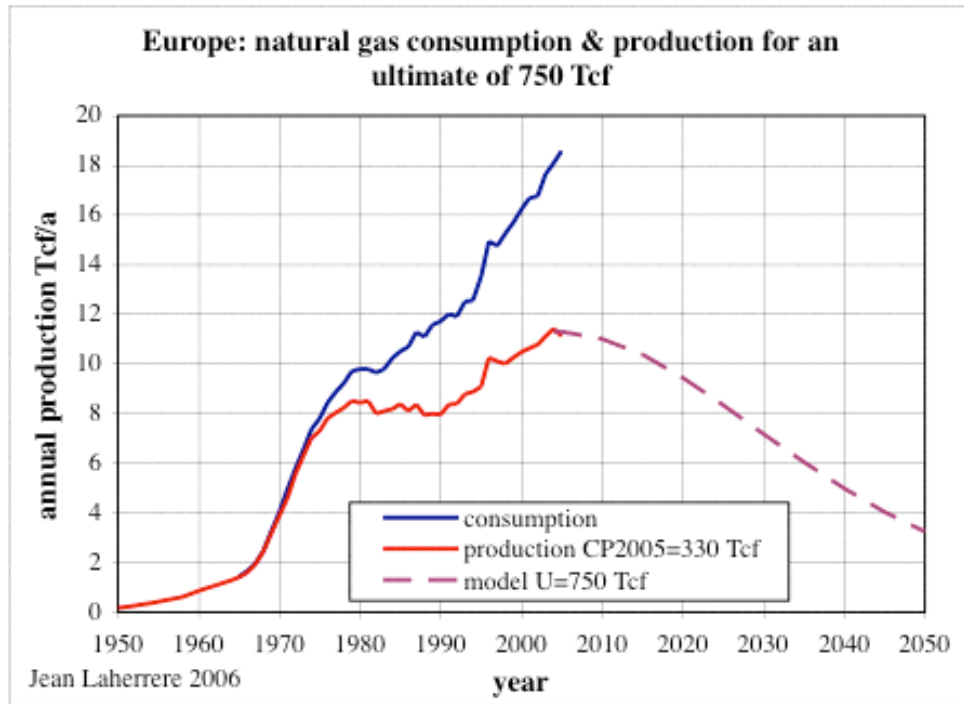
IEA recognizes that the European Union gas supply balance will need to import (mainly from Russia and Algeria) in 2020 about 500 G.m3 (18 Tcf)

Figure 29: Supply and demand of natural gas for European Union from IEA

Gas Supply Balance in the European Union

Source: World Energy Outlook 2004
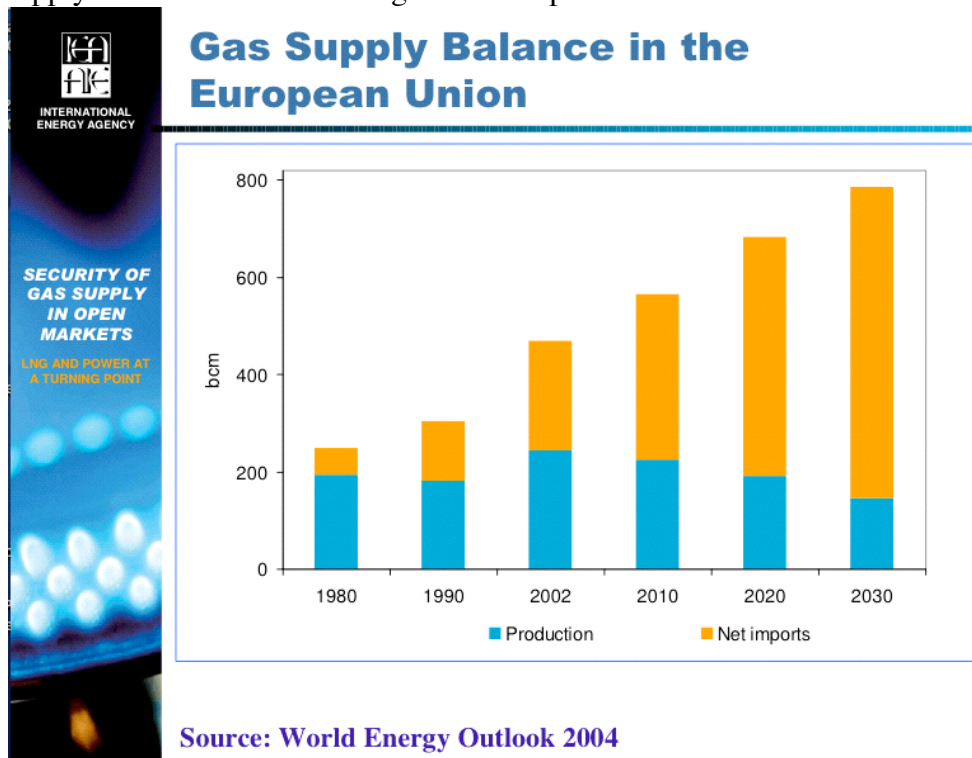
Europe is counting on Russia gas reserves, which are overestimated because the FSU 1979 classification (Khalimov 1979, 1993) is dealing with the maximum theoretical recovery (3P).

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 IHS and 267 Tcf by WM.

Figure 30: **Urengoi gas decline 1979-2020**
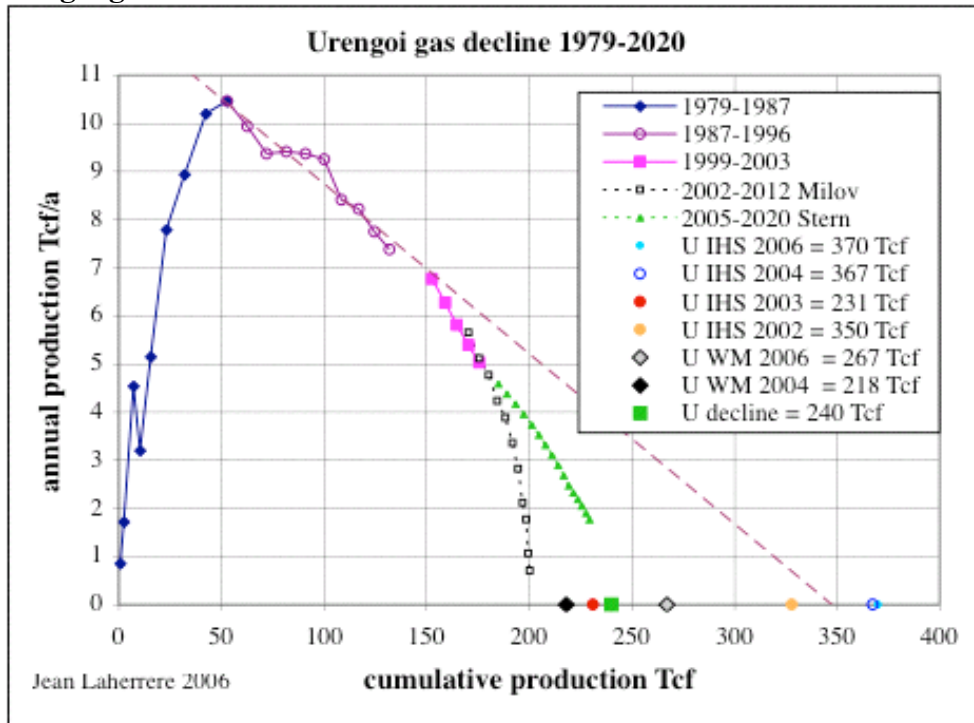
My estimate of FSU ultimate is about 2000 Tcf and FSU gas production should peak (no investment constraint) about 2020 at less than 35 Tcf/a (presently 27), with a potential of export less than 10 Tcf. But if Russia is making a lot of money from oil and gas export; Gazprom finance is used by the government 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 (reported 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 fees include gas heating and there is no meter). Large savings could be realized. Last winter 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 31: **FSU: annual consumption & production of natural gas with an ultimate of 200 Tcf (no investment constraint) 1950-2030**

FSU: natural gas consumption & production for an ultimate of 2000 Tcf

Jean Laherrere 2005   year   source: BP Review
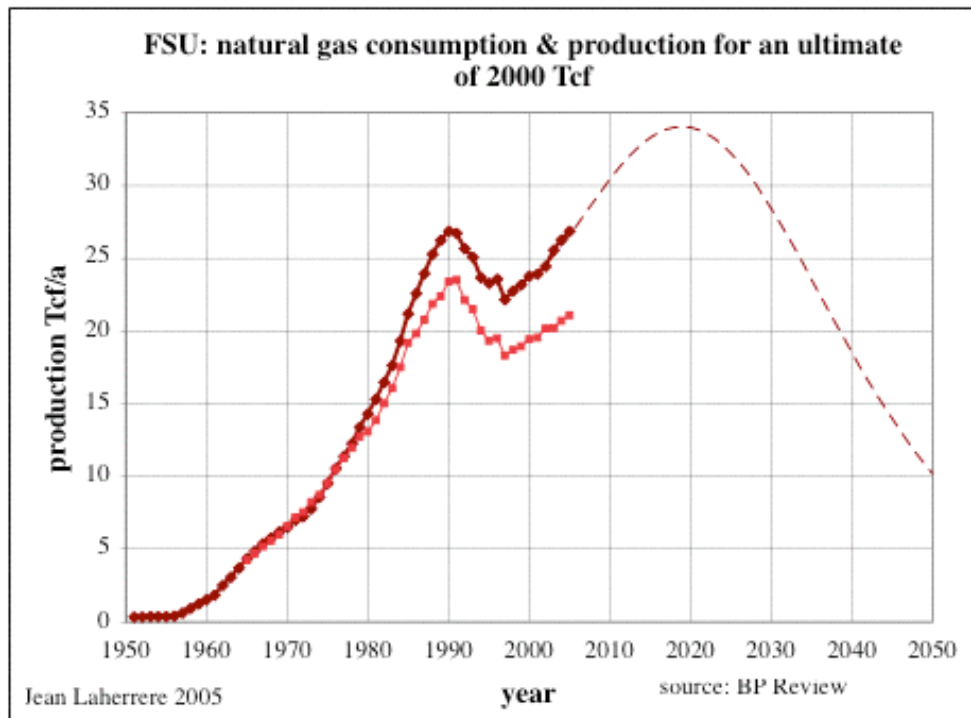
Europe gas needs are unlikely to be filled, if the demand continues as in the past (business as usual), by the present exporters. More LNG terminals will be then necessary.
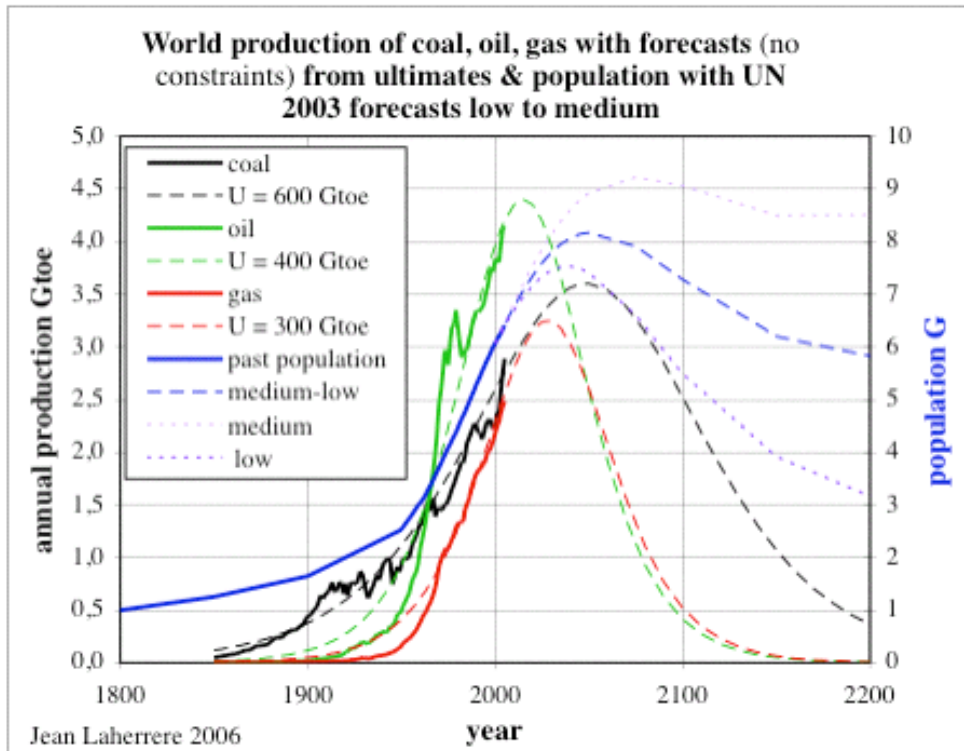

-Fossil fuels forecasts
Fossil fuel production can be easily forecast when ultimates are well estimated. But there are very few inventories of fossil fuels resources (the best and only homogeneous being BGR in Germany). And when done resources are confused with reserves.
My ultimate estimate is as follows, leading to peak (if no demand or investment constraint)

|	Ultimate in Gtoe	peak
-oil	400	2015
-gas	300	2030
-coal	600	2050

The UN 2003 population forecast (medium; low/medium, low) is added, but the medium/low is g- for me the most likely.
Figure 32: **World annual production of coal, oil and gas** & population **1800-2200**

World production of coal, oil, gas with forecasts (no constraints) from ultimates & population with UN 2003 forecasts low to medium

Jean Laherrere 2006

Population peak coincides happily with coal peak, around 2050
The combined fossil fuels will peak around 2030 (no demand constraint

Figure 33: **World annual fossil fuel production 1850-2150**

Fossil fuels production and forecast for an ultimate of 1300 Gtoe
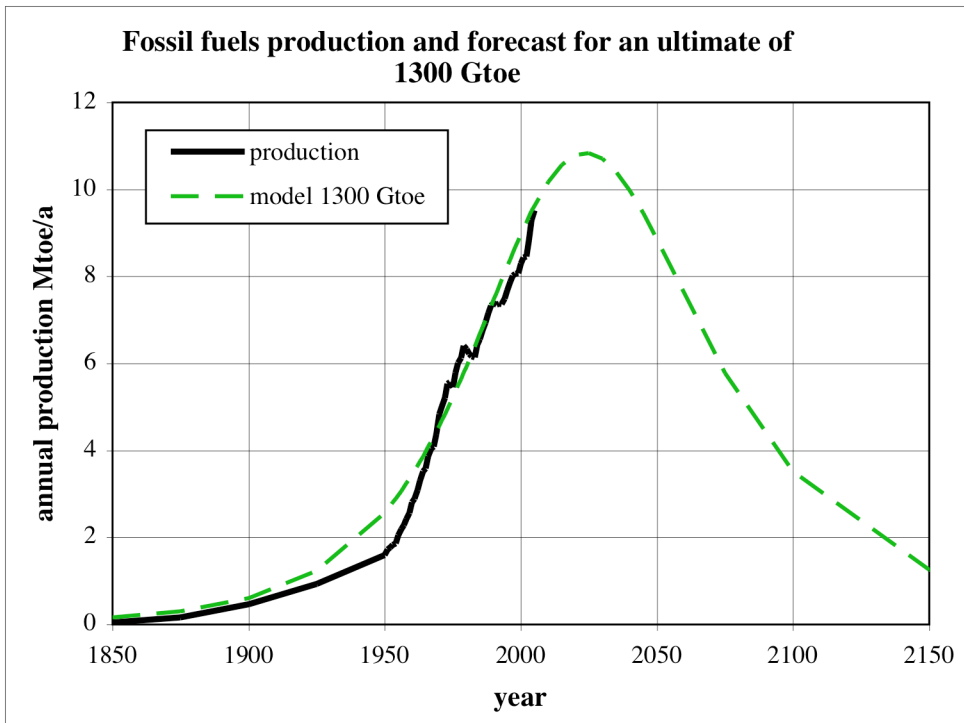
The world fossil fuel consumption (=production) per capita shows that after a sharp rise from 1950 to 1973 (oil shock) it is flat around 1,4 toe/cap since the last 30 years and it will stay at its level

27

until 2025. But from 2025 to 2050 consumption per capita will fall with a slow decline of about 1 %/a.

Figure 34: **World annual fossil fuel production per capita 1875-2125**
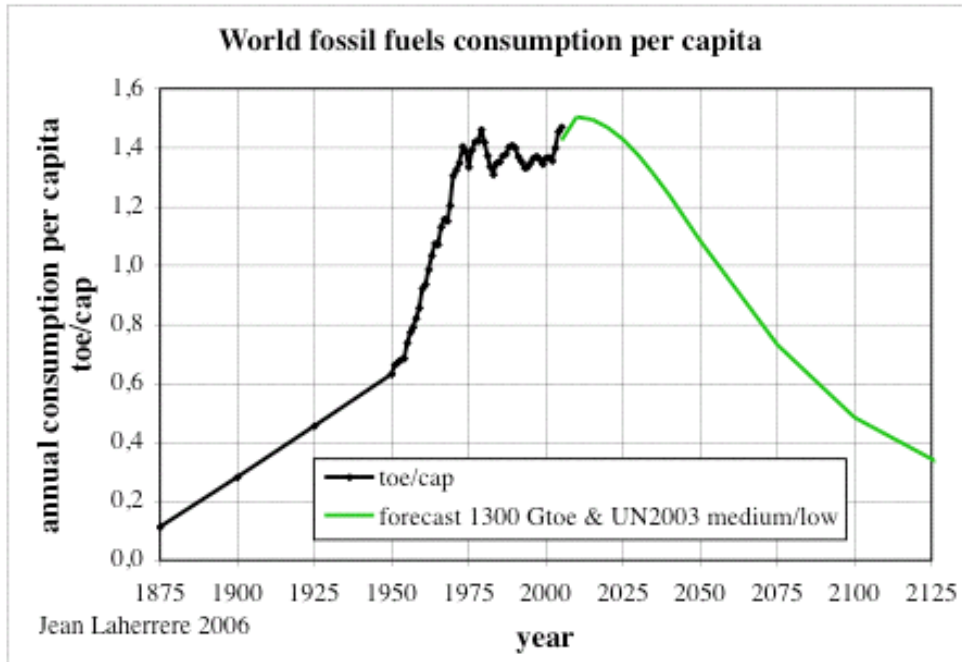

More nuclear reactors will be needed, because renewable cannot replace the fossil fuels in volume. Also, when present reactors use only U235 (0.7% of the uranium), present reserves (15 Mt) will be short around 2035 to fill an energy growth of more than 1.5%/a, new generation IV (in particular Fast Neutrons Reactors to increase uranium and thorium reserves by a factor of 60) will be needed around 2030.

-**Primary energy**
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 badly defined.

Figure 35: **World annual primary energy mix 1800-2005**

World primary energy mix 1800-2005

Jean Laherrere 2006   sources: IFP, Enerdata & BP
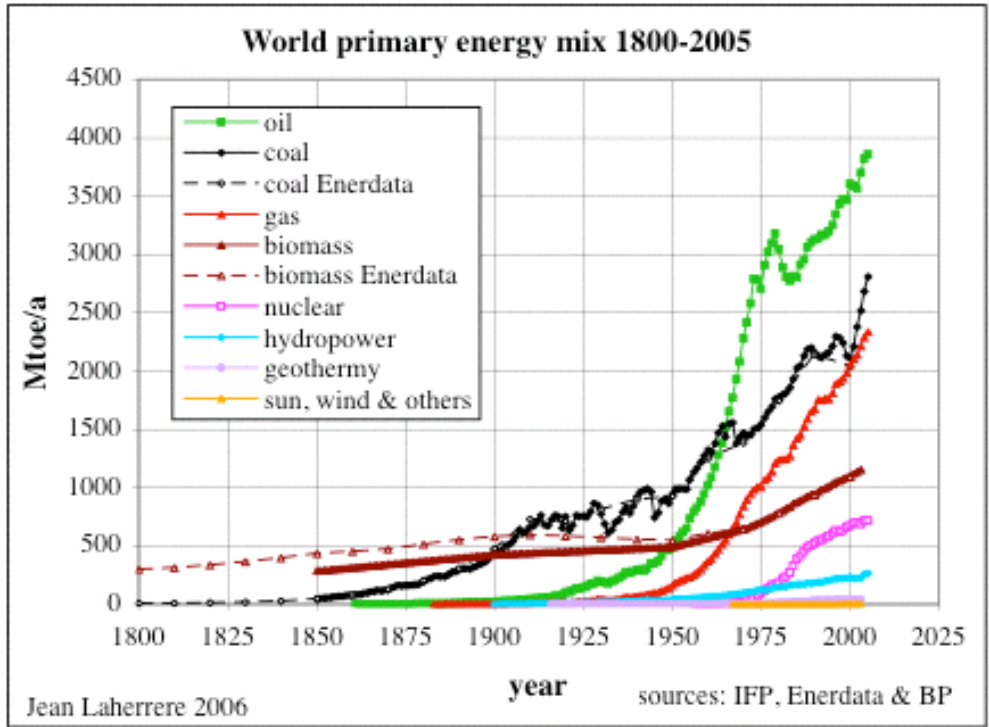
World primary energy displays an obvious concave curve from 1800 to 1973 first oil shock and beyond up to now (11,6 Gtoe in 2005) a fair (not for all, in particular in the last few years) convex curve. Official (USDOE and IEA) forecasts being the wishes of *business as usual* (continuing to have a over 3%/a growth for the next 30 years) lead to over 16 Gtoe in 2030. Extrapolation of the past 30 years leads towards an asymptote at 15 Gtoe. Fossil fuels forecast (figure 33) is plotted and the gap between primary energy and fossil fuels (being nuclear and renewables) was 2 Gtoe in 2005 and is likely to be 6 Gtoe in 2050. It is doubtful that renewables can fill this gap without the help of nuclear plants.

Figure 36: **World annual primary energy 1800-2100**

World primary energy & fossil fuel
Jean Laherrere 2006
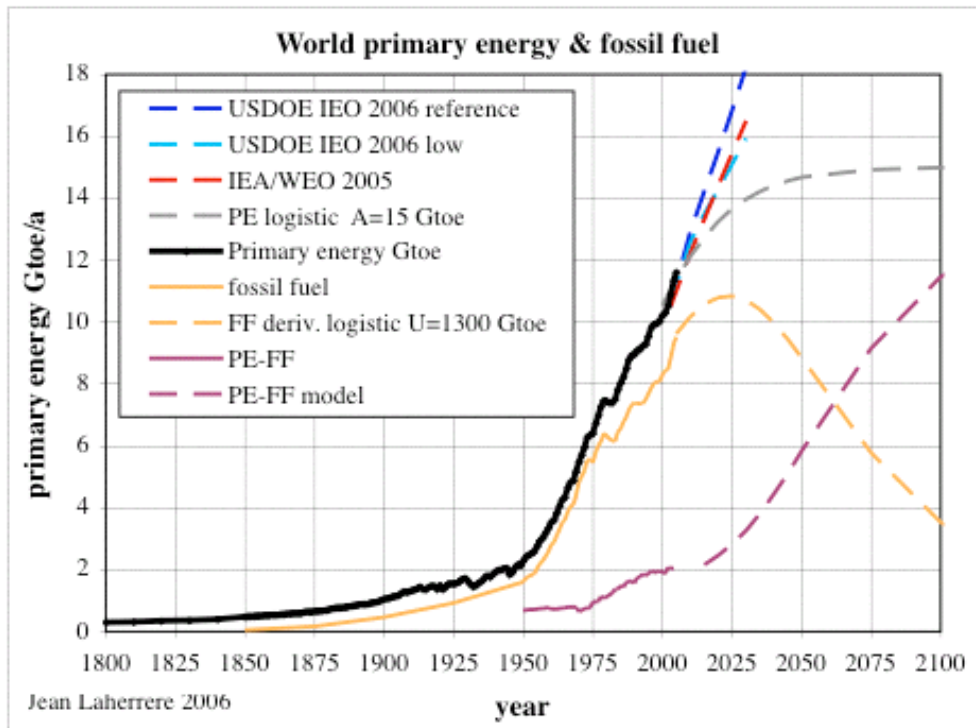
IPCC reports 2001 and 2007 are based on 40 energy scenarios (SRES) designed by IIASA on mostly unrealistic grounds (that I described already in an IIASA workshop in 2001 in particular for gas dreaming of methane hydrates). These 40 scenarios for 2100 range from 12 to 66 Gtoe, with an average of 37 Gtoe, meaning that the gap to fill beyond fossil fuels (at 4 Gtoe/a) could be 33 Gtoe !

Figure 37: **World IPCC scenarios for primary energy 1990-2100**

IPCC 40 scenarios SRES for primary energy
Jean Laherrere 2006
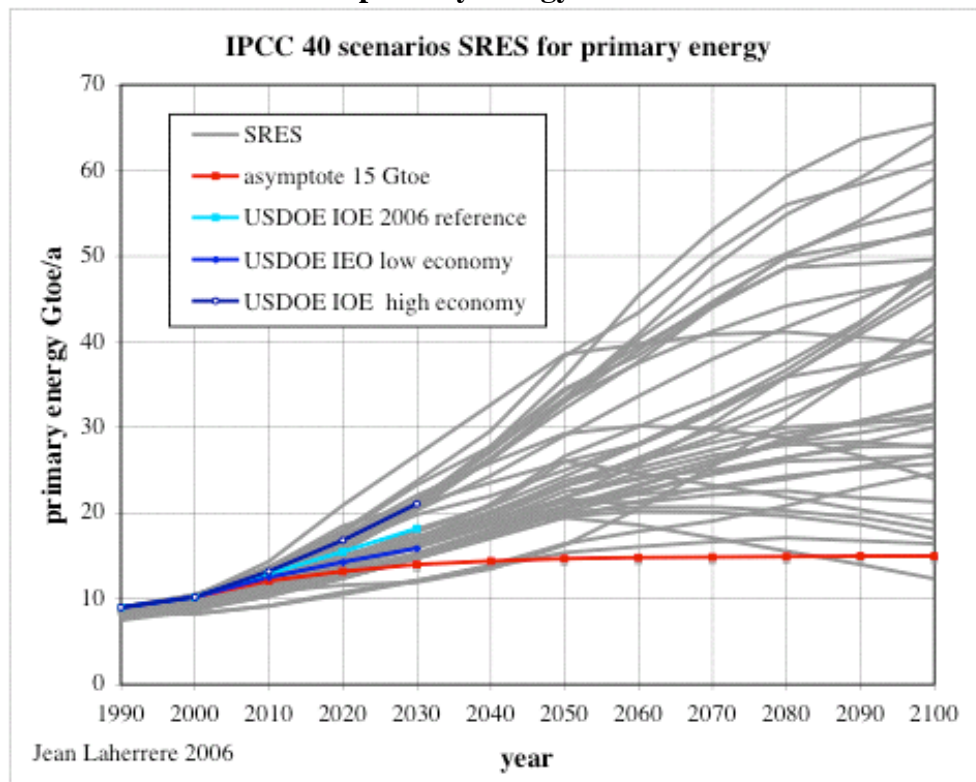
Conclusions

Fossil fuels public data are unreliable, in particular on reserves, confused with resources. Even production data are flawed, because publishing data is a political act and depends upon the motive of the author. There are several reserves definitions : US= proved = minimum, FSU = maximum and rest of the world = mean or expected value. Oil data are disturbed because OPEC members fight between themselves on quotas. IEA reports are also flawed (missing 1999 barrels led to the 10$/b). political remaining reserves are growing since the last 50 years when technical remaining (confidential) reserves are decreasing since 1980 because discovery is now much less than production.

Economists do not think wrong, they think on wrong data.

Official production forecasts are based on continuous growth wishes, denying any peak. Realistic forecasts need to estimate the ultimate recovery, based on the extrapolation of creaming curves, data mostly confidential except in UK and Norway.

There are many myths based on general statements without any proof, but dismissed by individual field data. R/P is a very poor parameter for forecasting the future, but used by many.

Oil (liquids including synthetic oils) will peak in less than 10 years, if there is no constraint from the demand or investments, or will follow a bumpy plateau with chaotic prices.

Gas is not global because the high cost of transport and shortage could occur before oil shortage in North America or Europe. World gas will peak around 2025.

Coal will peak around 2050, because reserves are often confused with resources (case of France). But in situ gasification, if viable, may convert resource into reserves.

Fossil fuel per capita is flat at 1,4 toe/cap since 1975 and will stay until 2025.

Primary energy will flatten and may trend towards 15 Gtoe. Even with this low level the gap with fossil fuels will be hard to fill without new generation nuclear plants.