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# Peak (or plateau) of fossil fuels

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## -1-**Oil**

### -Reporting data

Most of published oil & gas data is politically or financially motivated and is therefore not reliable. Technical data is mostly confidential and can only be bought from *scout* companies

### -production

-OPEC production for each member country is ruled by quotas, but because OPEC members have been cheating on quotas, OPEC past oil production figures are flawed and unreliable. Real data on oil transported by tankers must be bought from spy companies (Petrologistics in Geneva). Real data on field production and field reserves must be bought from IHS (former Petroconsultants), which is the only company to provide worldwide data, and others.

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

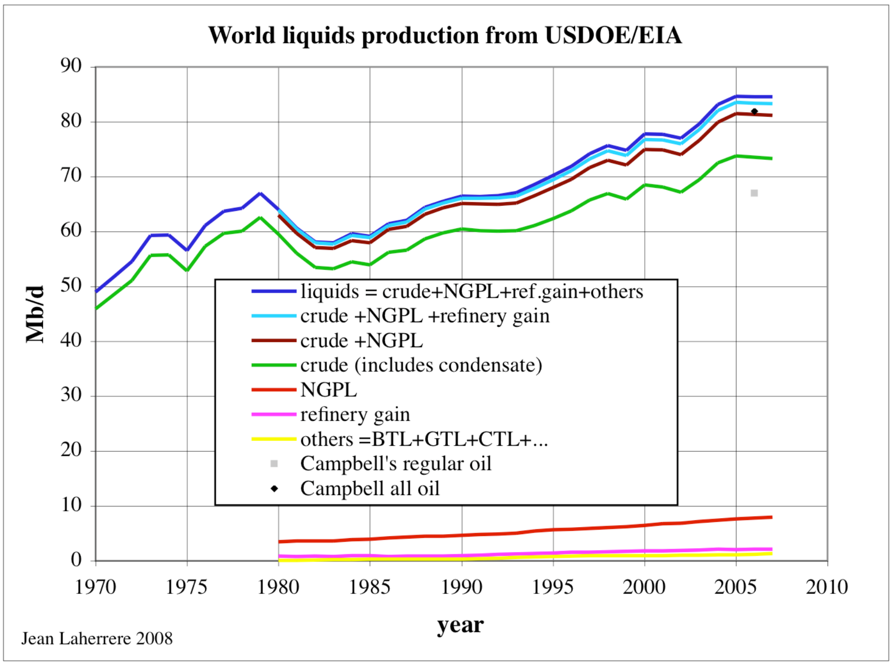
Data is either flawed by finance (stock market) or politics (quotas), or it is simply missing.
Ambiguity is often favoured on purpose

Oil and liquids: **oil 2007 production** can vary from regular (former conventional) oil as defined by Campbell (65,9 Mb/d) to crude oil (73 Mb/d) and finally to all liquids (85 Mb/d) including NGLs, synthetic oils from coal (CTL), biomass (BTL), and refinery gains.

| World oil production for **2007** | definition | Mb/d |
|---|---|---|
| OGJ Oil & Gas Journal | oil | 72.361 |
| WO World Oil magazine | crude/condensate | 74.515 796 |
| BP Statistical Review | liquids (excl BTL. CTL) | 81,532 910 152 325 8 |
| USDoE (Depart of Energy)/EIA | crude oil | 73.573 844 712 166 8 |
| | all liquids | 84.597 461 4 |
| IEA International Energy Agency | oil | 85.4 |

The number of significant digits is ridiculous in front of the real accuracy of the data, when the difference between IEA and EIA is about 1 Mb/d for 2006

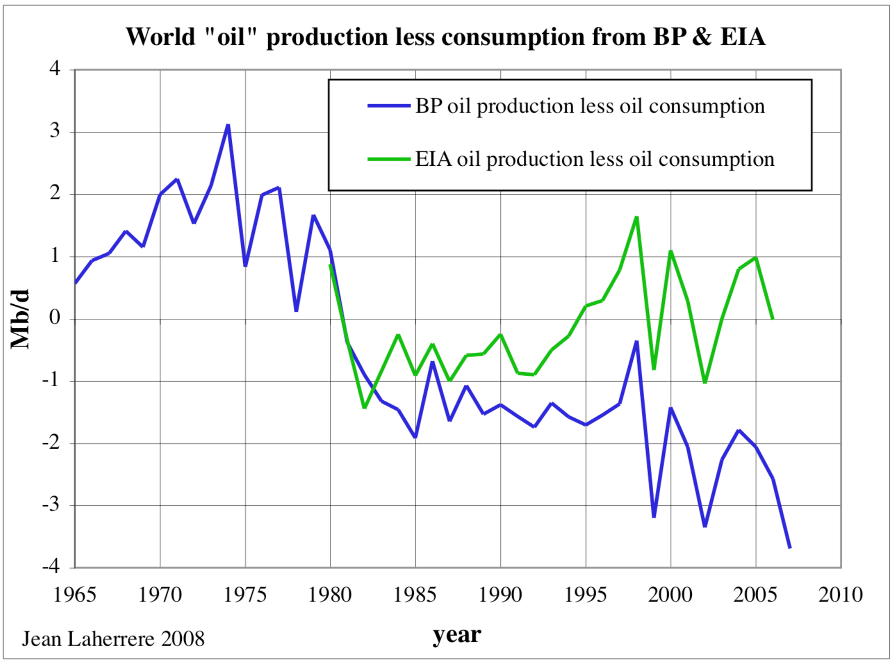
Figure 1: world liquids production from USDOE/EIA



Colin Campbell, founder of ASPO, has replaced *conventional oil* by *regular oil*, excluding arctic, deepwater (>500 m) and heavy oil (<17.5 °API), omitting refinery gains and synthetic oils (XTL = anything to Liquids) in the "*all oil*".

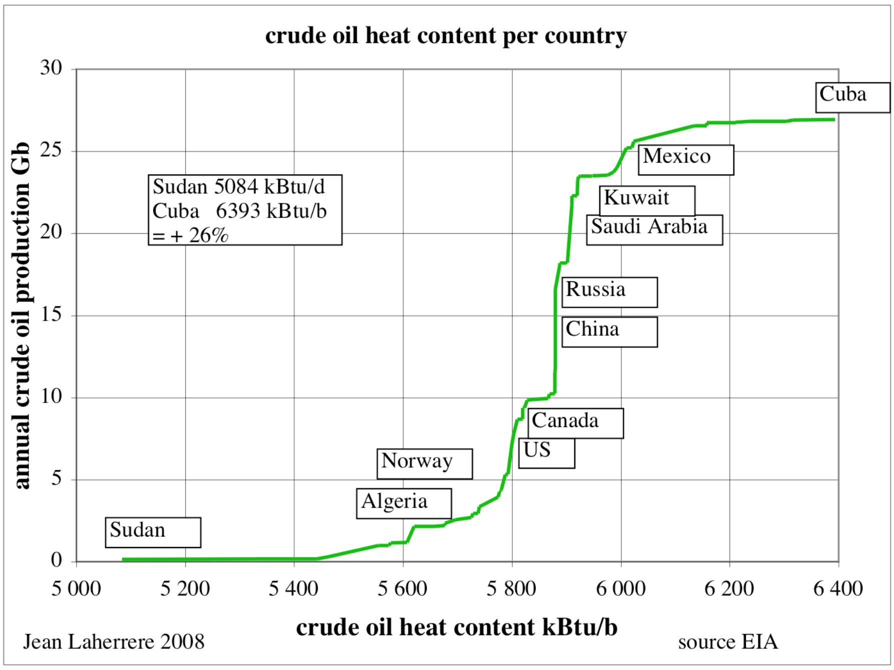
BP Statistical review "oil production" is not the same as "oil consumption" and the difference is widening

Figure 2: "oil" production less "oil consumption" for BP & EIA



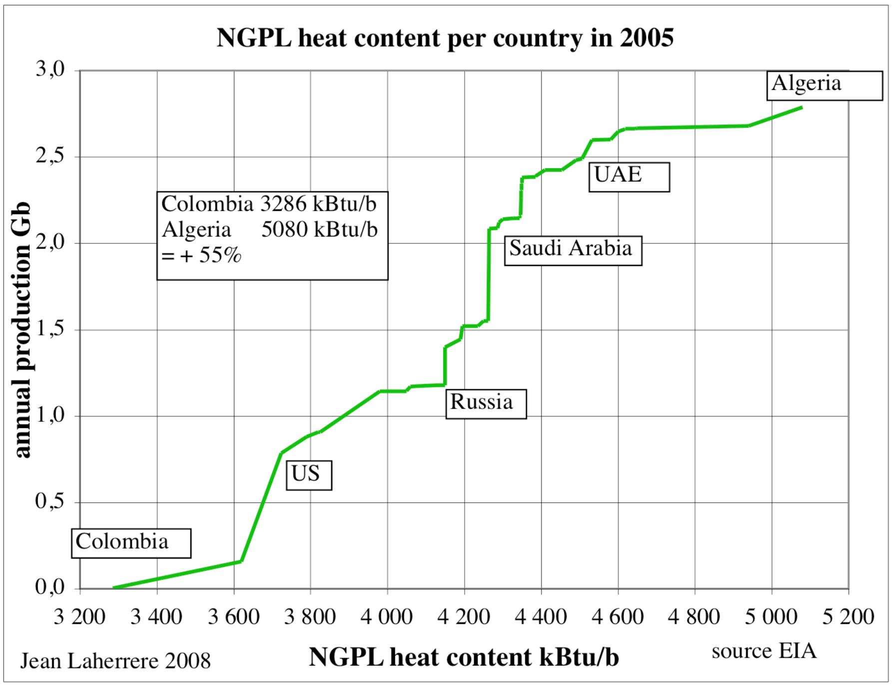

One barrel of crude oil in Cuba is 26% more energetic than one barrel in Sudan because the heat content varies from 5084 kBtu/b to 6393 kBtu/b. The median is about 5900 kBtu/b

Figure 3: crude oil heat content




The *natural gas plant liquids* heat content varies from 3286 kBtu/b in Colombia to 5080 kBtu/b in Algeria (+55%). The median is about 4250 kBtu/b, which is **28% less than crude oil heat content**

Figure 4: natural gas plant liquids heat content




**-reserves**

There is no consensus on oil reserves definition and estimates:
Published proved oil reserves at **end 2007**

| Oil **Gb** | OGJ | BP | WO |
|---|---|---|---|
| World | 1 331.698 077 | 1 237,875 464 625 99 | 1 183.891 |
| Russia | 60.000 000 | 79,432 084 5 | 76,000 |
| Norway | 6.865 325 | 8,171 588 188 604 87 | 6,693 |
| Canada | 176.592 000 | 27,664 029 323 866 1 | 25.157 |
| China | 16.000 000 | 15,493 4 | 18,052 |

Again ridiculous number of significant digits in front of the divergence

There are 4 different classifications on oil reserves in use:

**-US:** all energy companies listed in the US stock market are obliged by the SEC (1978 rules) to report only proved reserves (**1P**), assumed to be the **minimum;** these reserves are audited. SEC is presently changing the rules allowing the report of probable in 2009

**-OPEC:** because quotas depend upon reserves, OPEC members report proved reserves (**1P**), which corresponds to their wish since it is not audited.

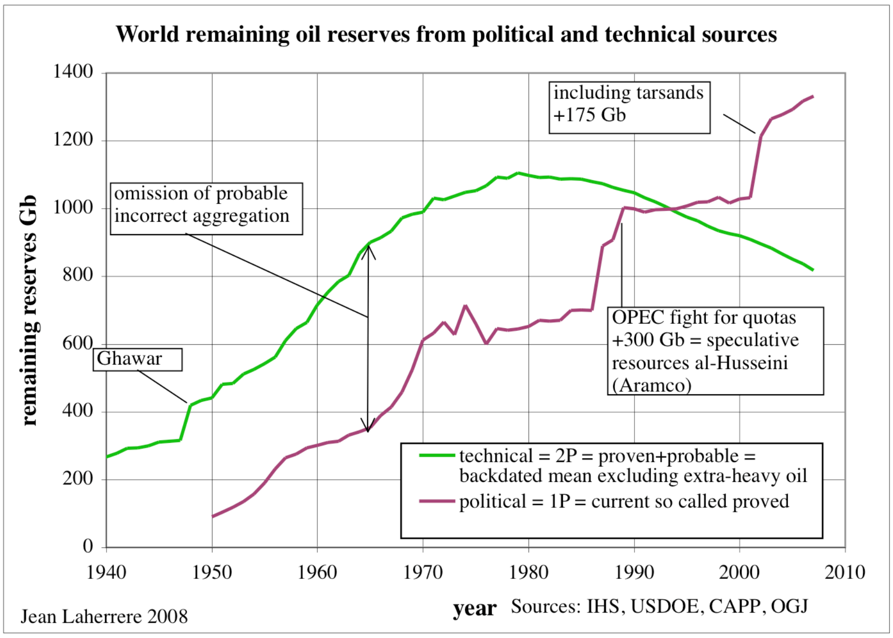
**-FSU classification**: ABC1 (Khalimov 1979) reports **maximum** theoretical recovery, being about equal to proven plus probable plus possible (**3P**). Khalimov in 1993 stated that Russian reserves were *grossly exaggerated.*

**-Rest of the world:** reports reserves as proven plus probable (**2P** close to the **expected value** used to compute the net present value of the development, when decided) following the 1997 SPE/WPC classification, definition and guidelines (I was a member of the task force). Field developments are decided on the value of 2P reserves which is the base of the net present value of the project (mean value).

When oil reserves are reported by official national agencies, they cannot be denied by any other official agency, otherwise it is viewed as diplomatic offence.
USDOE/EIA, IEA, BP Statistical Review are obliged to report the enquiry done by OGJ before the end of the year for the values at year end before any study was done (proved reserves were ruled to be at year end prices, not yet known)

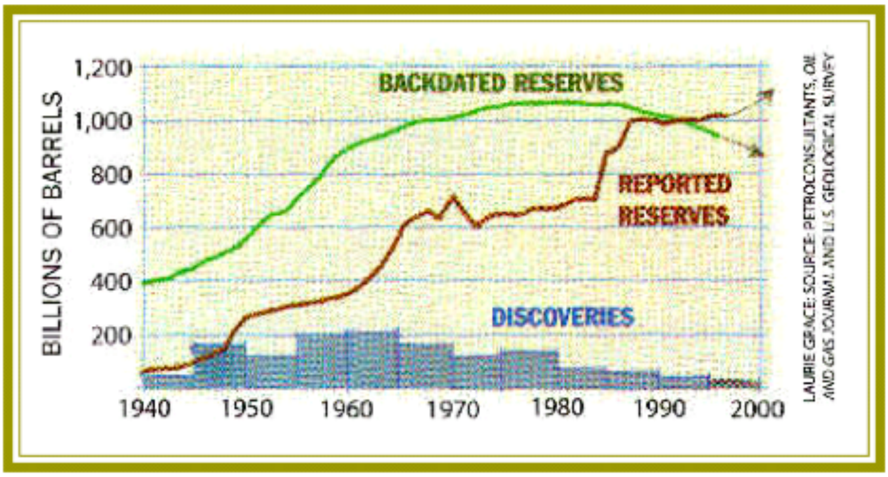
The technical data is the compilation of several databases corrected to be homogeneous to a 2P value and is compared for remaining reserves to the political data (USDOE, OGJ) which is assumed to be the proved reserves. Political data is almost always rising or flat when the technical data has decreased since 1980, when discovery was less than production.

Figure 5: World remaining oil reserves from political and technical sources 1940-2007




The same plot was given in Scientific American March 1998 "**The end of cheap oil**" C.J.Campbell & J.H.Laherrere and the forecast of increase for the political data and decrease for the technical was very good, except the increase of political was larger than anticipated when they added unconventional to a conventional pattern.

Figure 6: Same plot in Scientific American March 1998 Campbell C.J, Laherrère J.H. "**The end of cheap oil**" 1940-1996




Published data is mainly political and should be always treated as unreliable.

Economists, relying mainly on BP Statistical Review, are not thinking wrong, they think on wrong data.

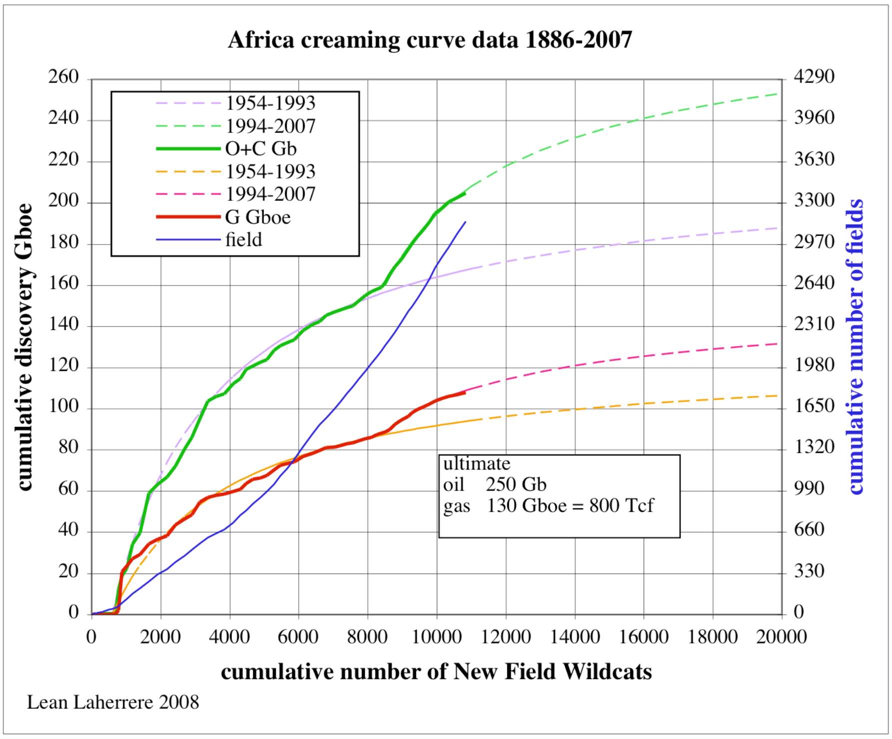
It is wrong to confuse
-political or financial reserves with technical reserves
-reserves (what will be produced) with resources (what is in the ground)
-ultimate reserves (past production + future until complete depletion) with remaining reserves at a certain date

## - Creaming curve

The creaming curve is the best way to present discoveries by plotting the cumulative backdated mean reserve value (technical data) versus the cumulative number of pure exploratory wells (= New Field Wildcats). It always possible to model the creaming curve with several hyperbolas, and the extrapolation of the last cycle up to a limited amount of wells (double the present) gives the ultimate value.

For Africa there are two cycles, the last one being mainly the deepwater (with little change in the discovery ratio = blue curve) and the ultimate is estimated at 250 Gb for oil and 800 Tcf for gas

Figure 7: Africa oil creaming curve

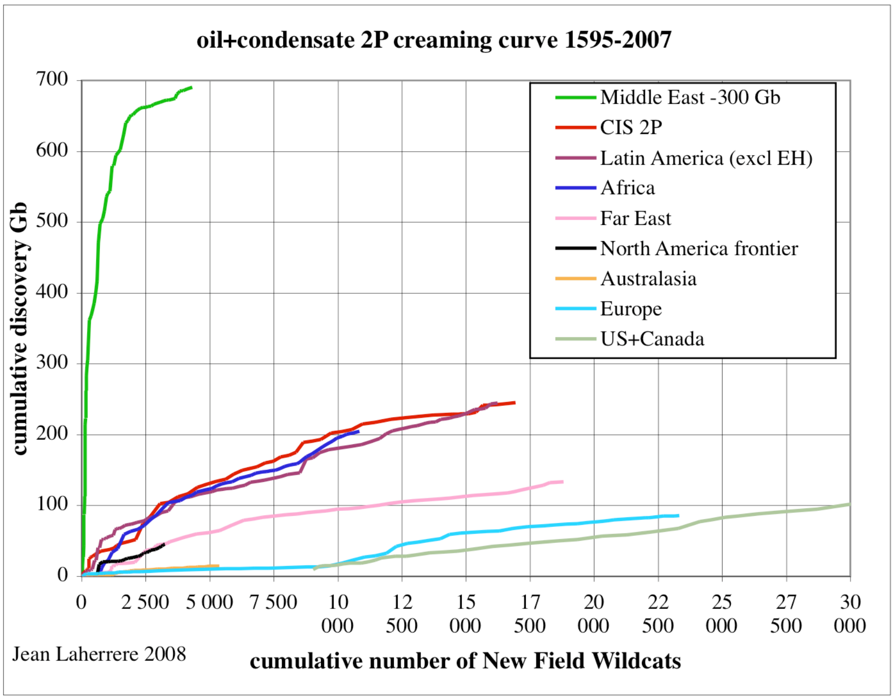



The data from technical database has to be corrected to obtain a 2P values in the ME (reducing by 300 Gb of speculative resources as described by Sadad Al-Husseini) and in FSU (ABCI reduced to 2P by removing 30%) and extra-heavy oil has to be removed from Venezuela.

For the crude oil less extra-heavy (EH) the creaming curves by continent show a large range, with ME being largely gifted. But FSU, Latin America and Africa have similar ultimates.

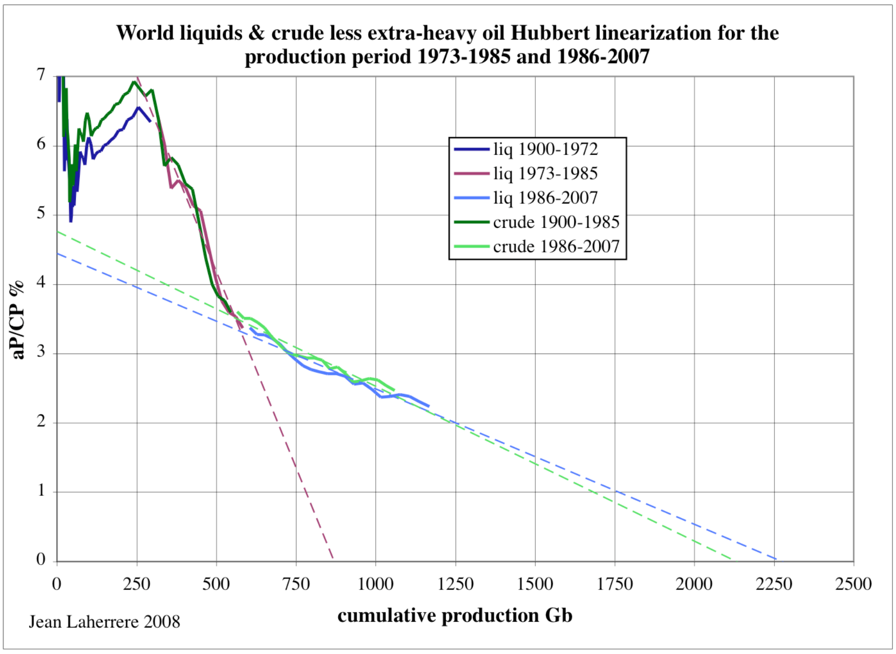
US has a different pattern where too many NFW were drilled because onshore oil belongs to the individual owner of the ground, in contrary to the rest of the world where oil belongs to nations.

Figure 8: oil less EH creaming curves by continent

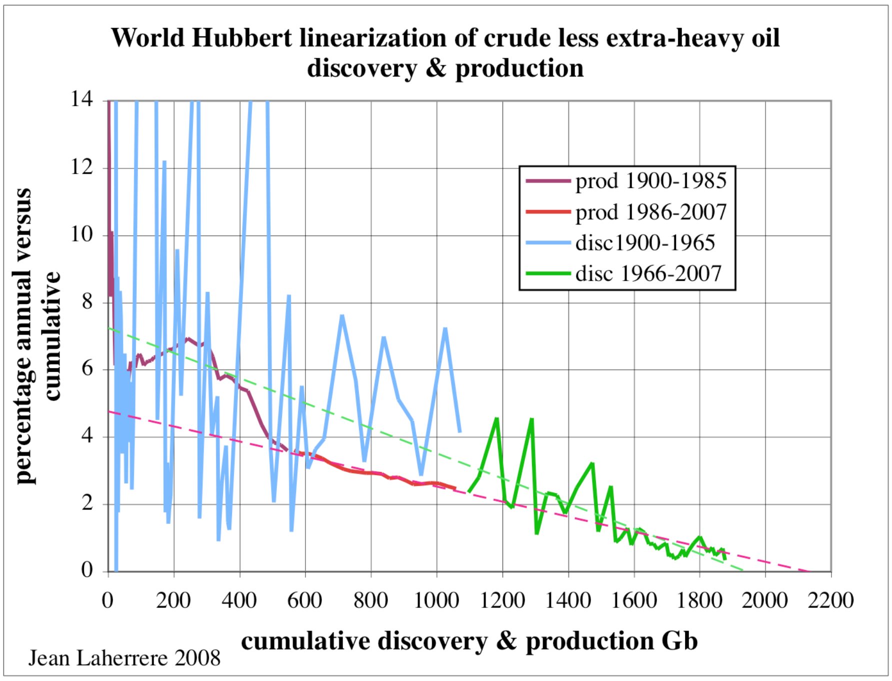



### -Ultimate and Hubbert linearization

Hubbert linearization of oil production is used by many (lacking discovery data) to estimate ultimate, but linear extrapolation works only if production follows a logistic curve (in fact derivative). Some portions are linear, but not all the curve, so it is hard to believe that the last linear portion will be the last one. Constraints on production (OPEP quotas) disturb the pattern.
Crude oil data takes USDOE/EIA as reference, because they updated their data (up to several years later). Crude oil includes condensate because in the US it is not distinguished at the well head.
World liquids production or crude oil less EH displays a Hubbert linearization far from being one simple linear trend. There is a roughly linear portion from 1973-1985 (first oil shock to the oil counter shock) and another rough linear portion from 1986 to 2007. The coming depression could change this trend as 1985 did.
Figure 9: World liquids and crude oil less extra-heavy Hubbert linearization for 1973-1985 and 1986-2007

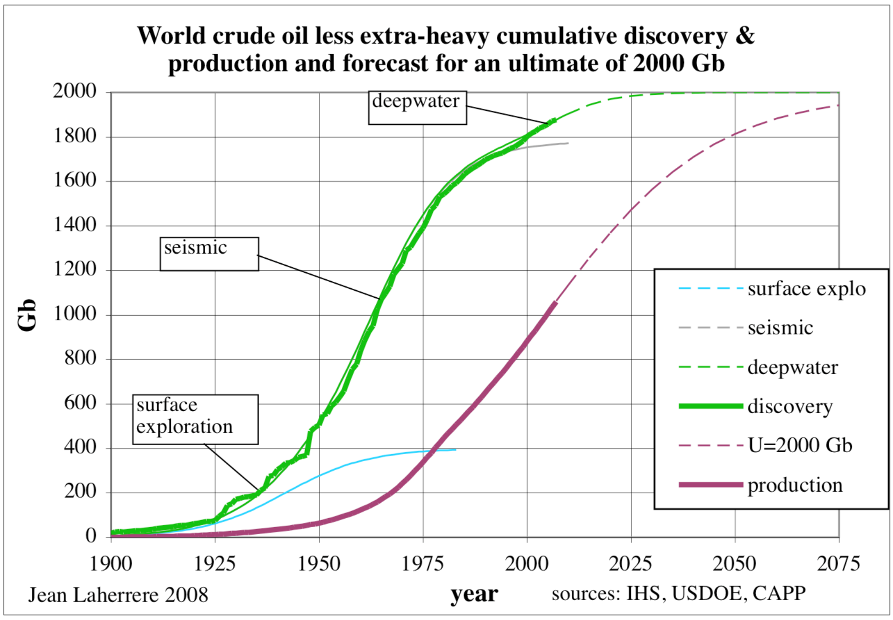


For crude less extra-heavy (EH) oil, the Hubbert linearization (green trend) for the period 1986-2007 is about 2100 Gb, but the extrapolation of the cumulative discovery fits better with a 2000 Tb, yet the accuracy is not good enough to exclude 2100 Gb. But it is obvious that the linearization for liquids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



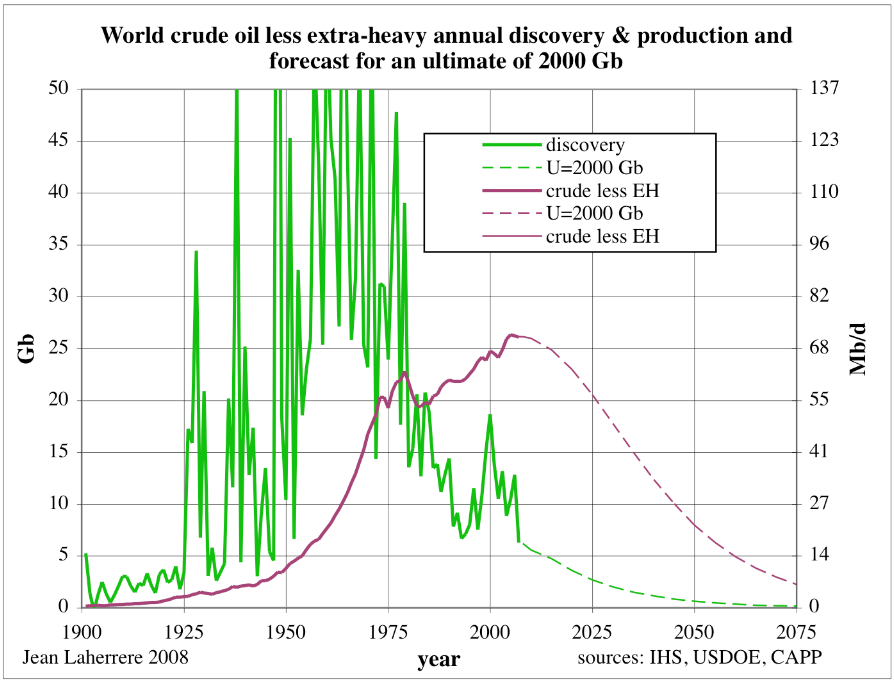

### -Forecast

Extrapolation of discovery data (in particular the creaming curve) is a much more reliable tool, when reserves estimates are close to the mean (expected value) and are backdated. Current proved values are useless as shown in the first graph.
Cumulative mean backdated discovery can be easily modelled with a S curve (logistic curve) or in more detail with three S curves, the first one corresponding to the surface exploration up to 1945, the second with seismic exploration up to 1995 and the last one being deepwater. If there is no new cycle (most of the petroleum systems have been drilled (even Antarctica with JOIDES) and their potential evaluated looking at the possible source-rocks: a few wells are enough for that). The yet to find YTF can be deducted from the known cumulative discovery (about 1,9 Tb) and the rounded 2 Tb ultimate. YTF is less than 200 Gb for easy oil.
Figure 11: World *crude less extra-heavy oil* **cumulative** discovery and production with forecast for an ultimate of 2 Tb




The same data is displayed annually

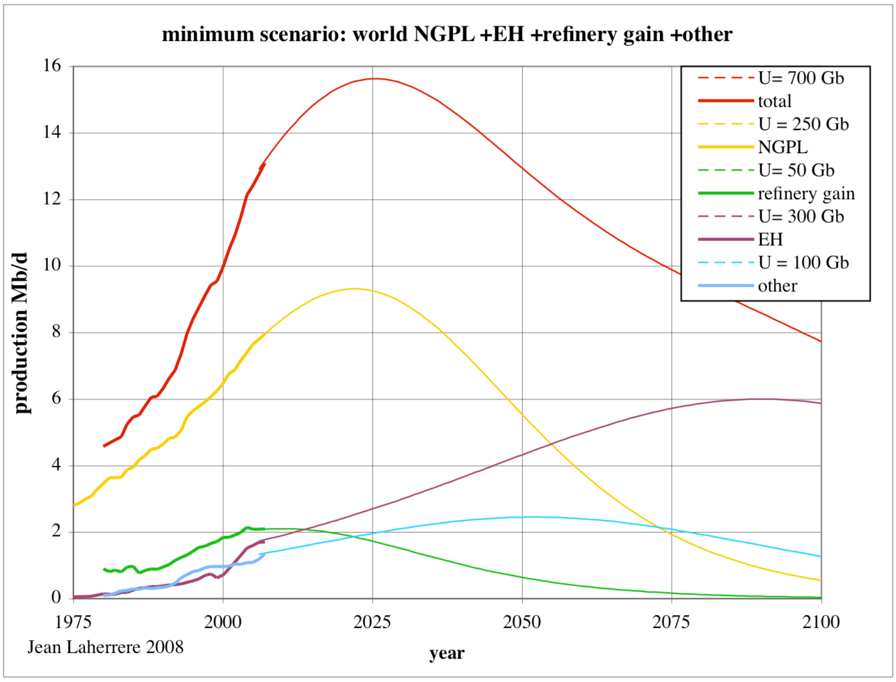
Figure 12: World *crude less extra-heavy oil* **annual** discovery and production with forecast for an ultimate of 2 Tb




To satisfy the oil demand which includes all the liquids with XTL (as GTL, CTL, BTL) the oil supply must answer by breaking down the oil supply in several items

To obtain the minimum scenario, past data of liquids outside the crude oil less EH were extrapolated with an ultimate of 700 Gb broken down into NGPL = 250 Gb in connection with NG ultimate of 10 Pcf, extra-heavy = 300 Gb, refinery gain = 50 Gb in connection with crude oil ultimate of 2 Gb, other (XTL) = 100 Gb because biofuels are connected to oil through productivity.

Figure 13: minimum forecast of NGPL + EH + refinery + *other* production U=700 Gb

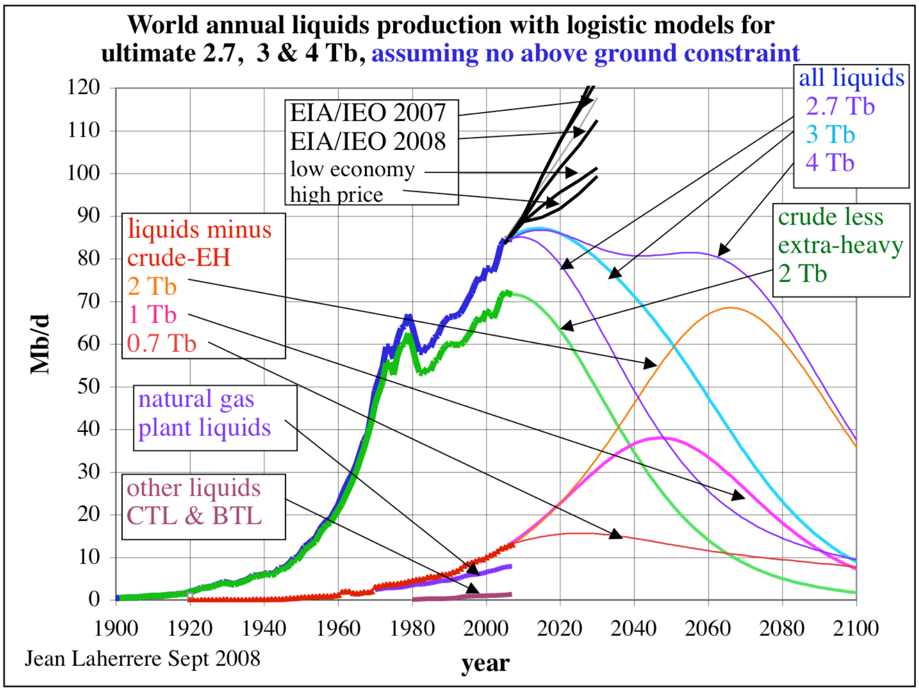



The minimum scenario for liquids is then for an ultimate of 2,7 Tb (2+0,7), when the likely ultimate is taken as 3 Tb (2 +1) and the maximum unlikely as 4 Tb (2+2)

| All liquids ultimate estimated is the sum of | likely 3 Tb | mini 2.7 Tb |
|---|---|---|
| -crude less extra-heavy | 2000 Gb | 2000 Gb |
| -extra-heavy | 500 Gb | 300 Gb |
| -natural gas liquids and GTL | 250 Gb | 250 Gb |
| -synthetic oil (BTL, CTL) & refinery gains | 250 Gb | 150 Gb |

In the graph the blue is all liquids, the green = cheap oil = crude less EH oil and the red = expensive = all liquids less cheap. In the unlikely maxi the red ultimate is 2 Tb, doubling the likely and it does not change the date of the peak only the slope after peak. Expensive oil needs time, not only large investment but also a large staff . Dealing with time, nature cannot be pushed too hard: *it is impossible to have a baby in one month with nine women!*

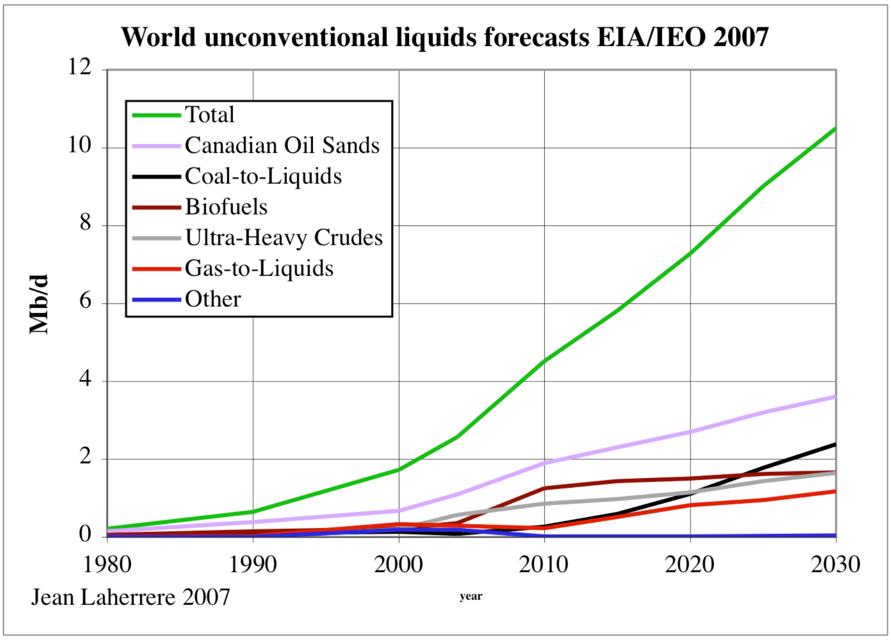
Figure 14: world liquids annual production for ultimates of 2.7, 3 & 4 Tb assuming **no constraints *above ground*,** and USDOE/EIA 5 scenarios



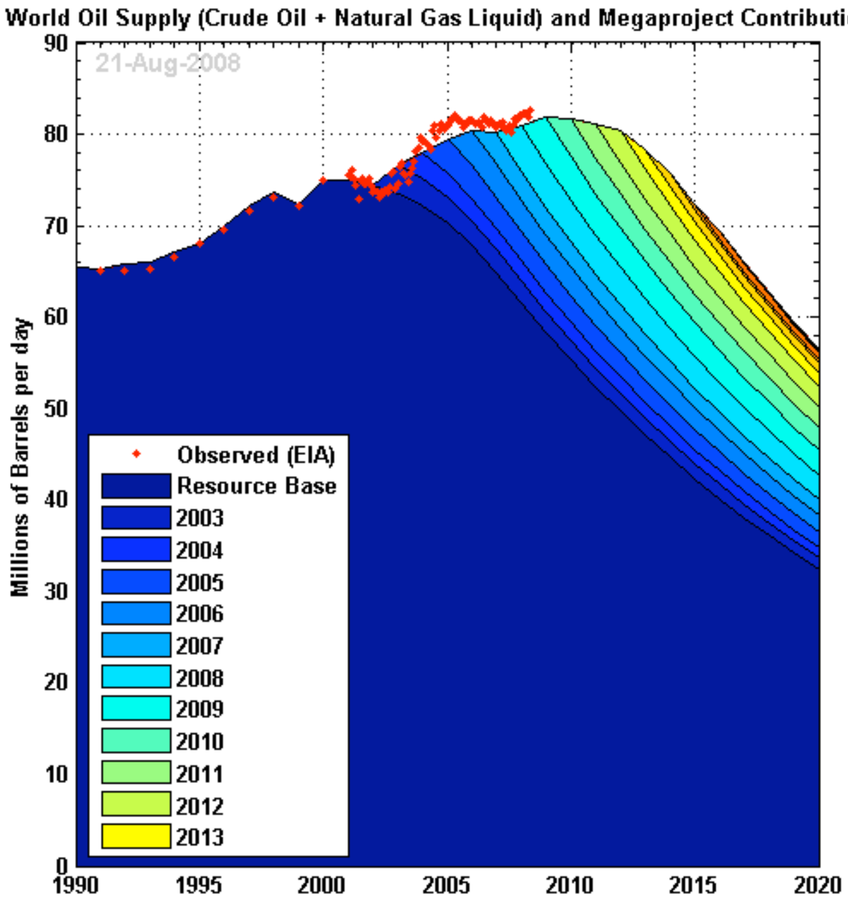
The 2008 EIA/EIO now forecasts 5 scenarios (only 3 in 2007) adding two economy scenarios. The reference case is mainly political called Business as Usual (BAU) to please our society of consumption addicted to growth. But constant growth is impossible in a limited environment and what goes up has to come down one day!
In my forecasts all liquids will not pass 95 Mb/d, but EIO low economy and high price are about 100 Mb/d for 2030 against 112 Mb/d for reference and beyond for high economy and low price

This modelling deals with constraints below the ground (geology of the reservoir) and assumes that there is no constraint *from above ground*. For many years I have plotted a smooth peak, but saying that it is unlikely because constraints from economy (following Paul Volcker 2004 forecast of a recession, or weak demand in front of high prices as in 1980), from politics (nationalisation or war or drilling ban), lack for IOCS of new areas to explore, lack of equipments or staff.
It is why I forecast in the text instead a **bumpy plateau with chaotic oil prices.**
It is difficult to model an unexpected bumpy plateau on a graph without a precise hypothesis.

The most difficult is to forecast unconventional oil production, because the size of the tank (large reserves already known for long time, centuries for Athabasca) does not matter, it is the size of the tap (flow). EIA/IEO 2007 shows the breakdown until 2030 where Athabasca will be the first with CTL the second with 2.5 Mb/d, which is unlikely because China has decided to stop all CTL projects except the two Shenhua projects close to completion (already late) for a capacity of less than 0,1 Mb/d.
Figure 15: USDOE/EIA 2007 forecast for unconventional oil

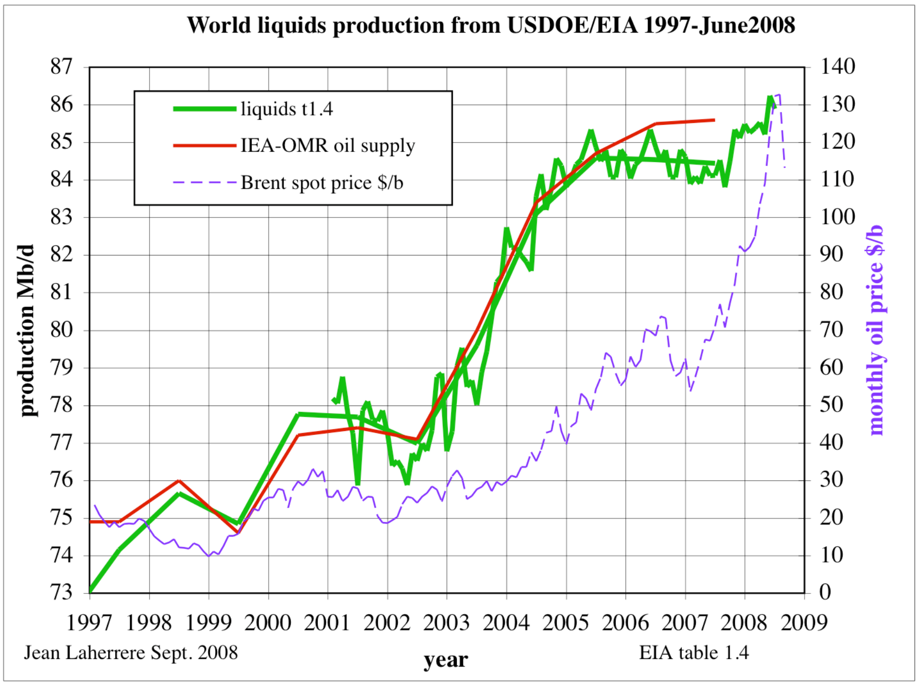



For the short term, forecasts from ultimates are not accurate enough, and known planned megaprojects must be studied. Chris Skrebowski started to do it in 2006 forecasting an oil peak in 2010 at 92 Mb/d. If the megaprojects are known and could be relied on after reduction of aggregation from capacity and time, the most difficult task is to forecast the decline of present fields. Several studies have been published but the data is incomplete and main OPEP field production is disturbed by quotas.
The average world decline of presently producing fields is estimated by CERA at 4.5%; but 8% by Schlumberger. It is hard to know because unreliable and incomplete data.
Now the Oil Drum updated the study for crude +NGL.
Figure 16: forecast of crude oil +NGL *The oil drum* from *megaprojects*



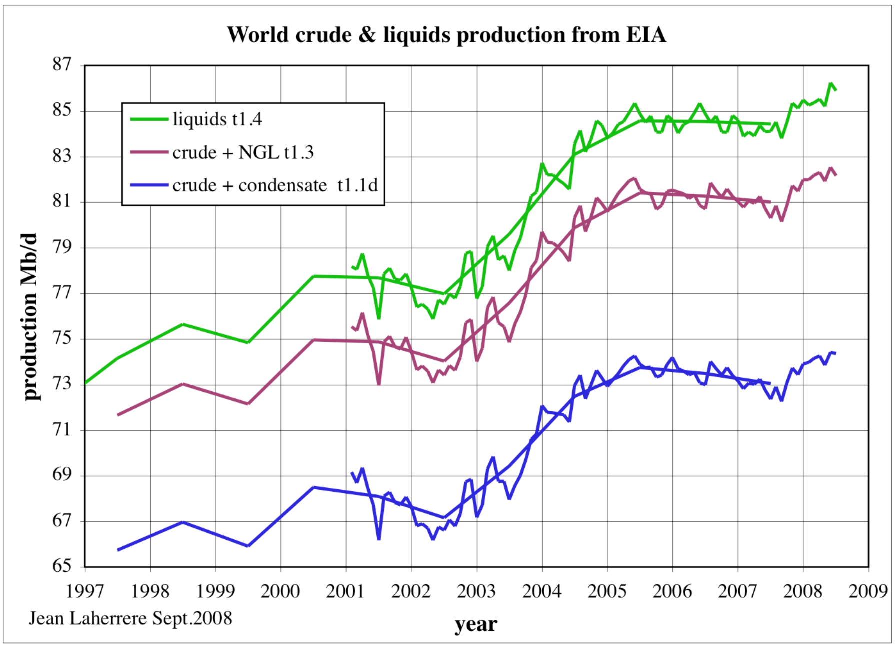

But after 2012 new megaprojects should be added and the slope is misleading.

Figure 14 showing a smooth peak assuming no constraints above the ground is unlikely because *above ground* constraints are many, of which the largest seems to be the coming depression.
**That is why since 2001 I forecast a bumpy liquids plateau with chaotic oil price**.
On the last monthly data from USDOE on liquids, what do we see: a plateau? or just one more step as in 2001? It is obvious that production is bumpy.
Figure 17: World liquids production 1997-June 2008



But the claim made by some for a 2005 peak for crude oil (which includes condensate in USDOE report) seems to be contradicted by the production of February 2008

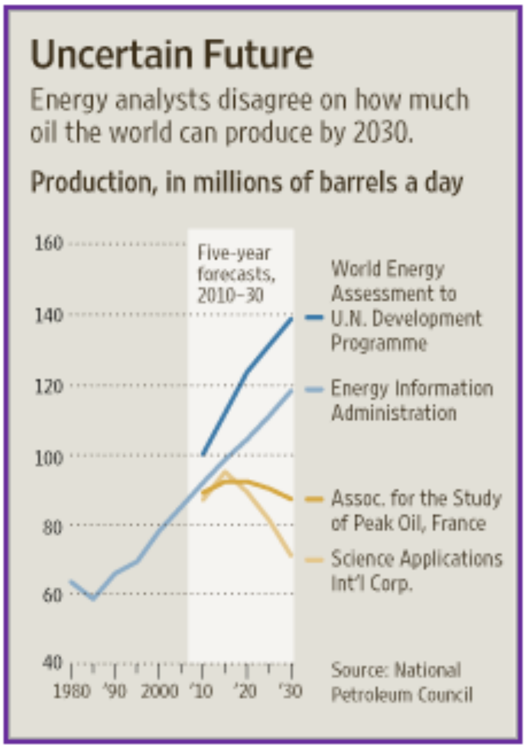
Figure 18: World crude oil & liquids production 1997-June 2008 from EIA




**-Other forecasts**

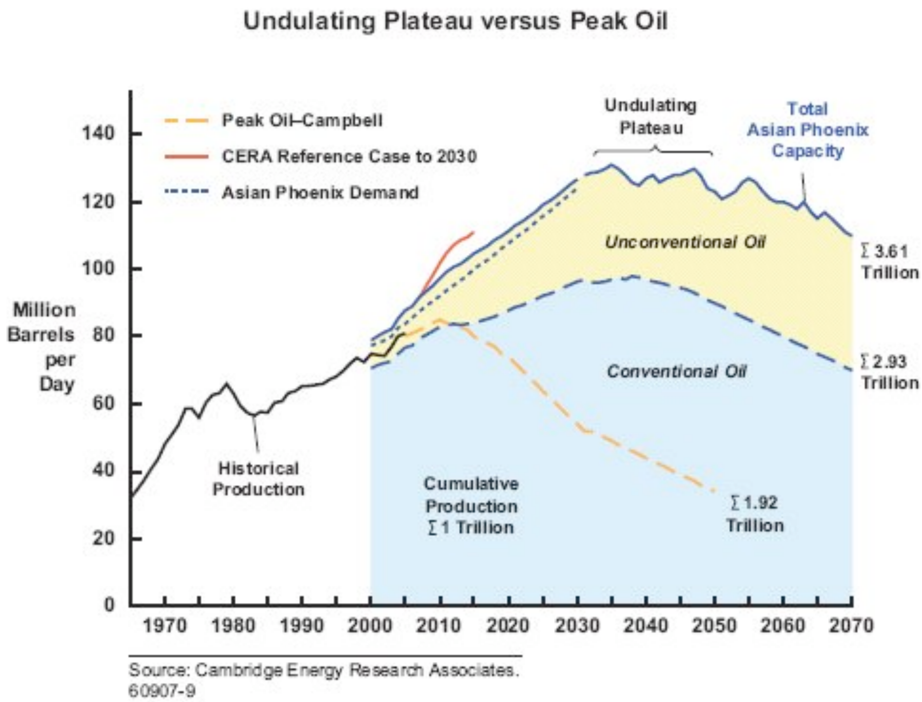
National Petroleum Council 2007 *Hard truths* ( 2 years & 350 persons) gives ASPO France as reference

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




CERA claims that peak oil is a myth but talks about a plateau (truncated peak?), yet its undulating plateau is for the period 2030-2050 and for a volume described by Total CEO, Ch. de Margerie, as almost impossible!

Figure 20**:** CERA 2007 forecast for world liquids production




ASPO USA and partners has challenged CERA in Feb 2008 with a $100 000 bet that their 112 Mb/d capacity in 2017 will not be reached. CERA did not answer: win by forfeiture.

Luis de Sousa in The Oil Drum 18 Sept.2008 has plotted the world oil exports from 1965 to 2020: the peak is passed!

Figure 21: world oil exports from L de Sousa TOD WOE(2)

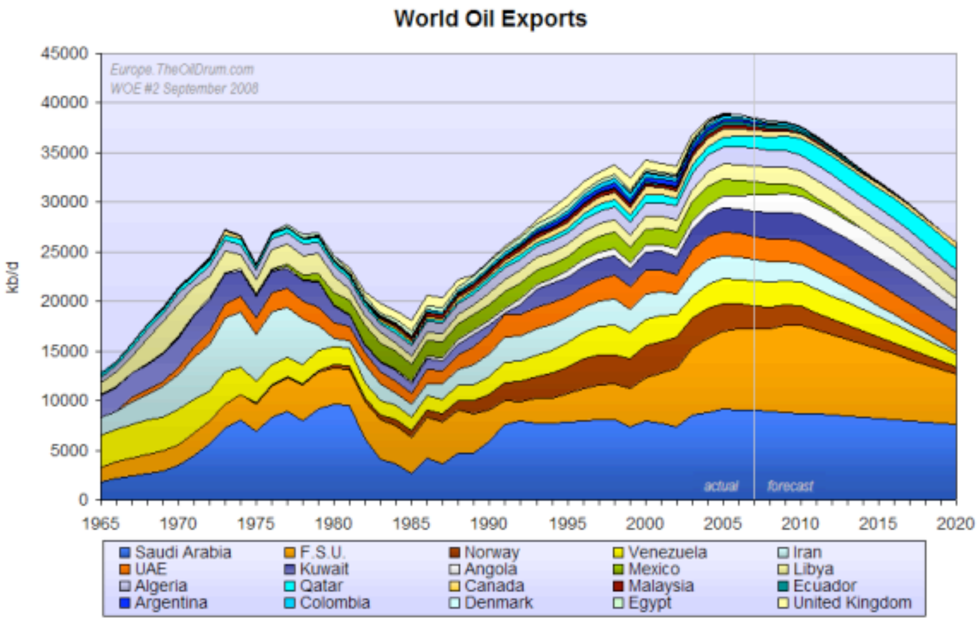


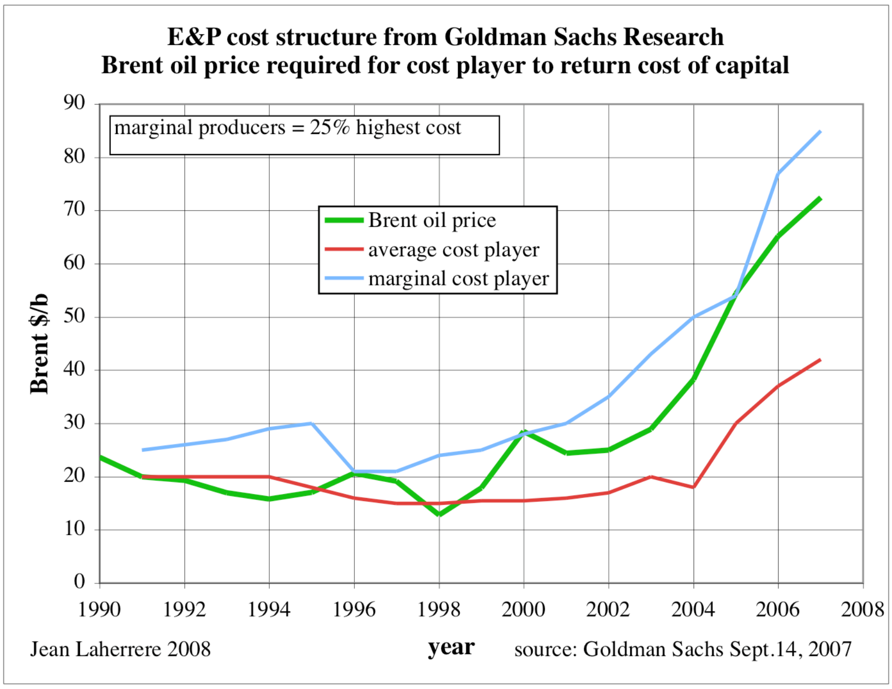

*Figure 16 – World Oil Exports as of September 2008. Click to enlarge.*

**-marginal cost or breakeven point**

Goldman Sachs has studied oil costs for 60 oil companies (IOCs). With the increases in oil, iron, services and equipment prices, the marginal players (25% highest cost) (blue curve) need 85 $/b in 2007 to get a fair return on capital (Brent 2007 = 72 $/b).

It means that, if oil price goes down below 80 $/b, many operators will be bankrupted.

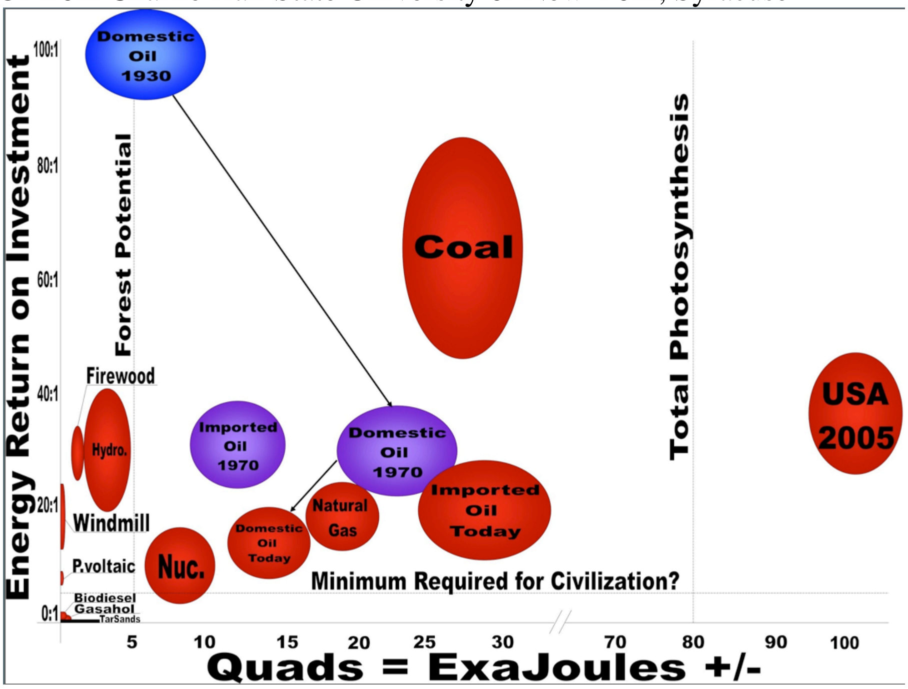
Figure 22: E&P cost required for a return on capital from Goldman Sachs 2007




Total has declared that their tarsands projects need 90$/b and deepwater 70 $/b to achieve a ROR of 12%, few years ago their breakeven point was 20 $/b!
US natural gas breakeven point has increased from 4 $/Mbtu in 2002 to 8 $/Mbtu in 2007 (Credit Suisse) close to NG US price!

- **limitation by EROI** or **EROEI** = Energy return On Energy Invested

Energy production is limited not by cost but by energetic balance: it should not spend more energy in the recovery that what can be produced: EROEI should be higher than 1
Figure 23: EROI from Charlie Hall State University of New York, Syracuse



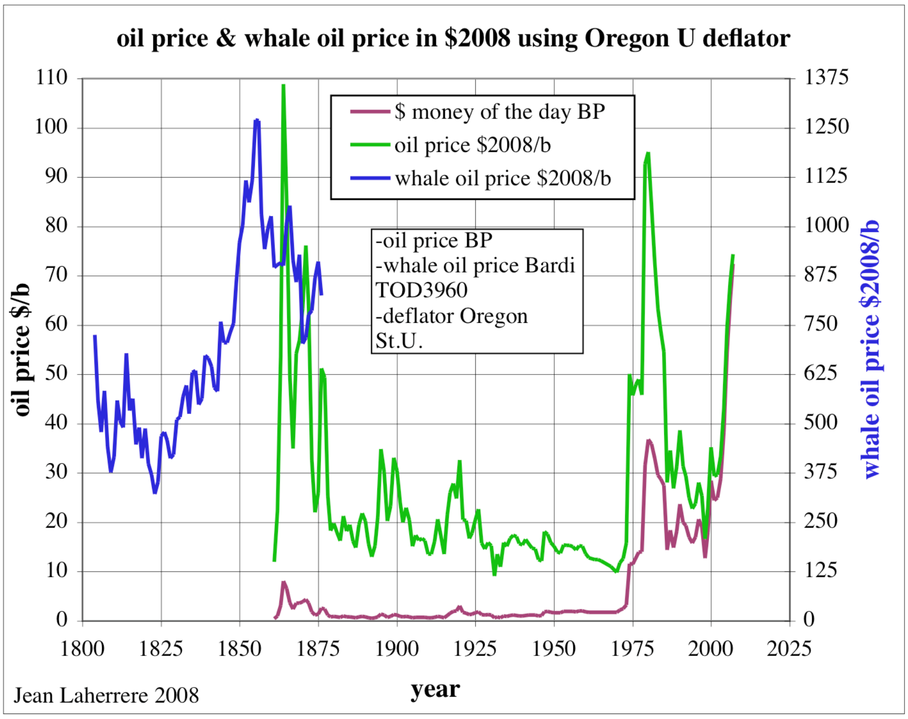

**-Time is one of the most important items, often forgotten**

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

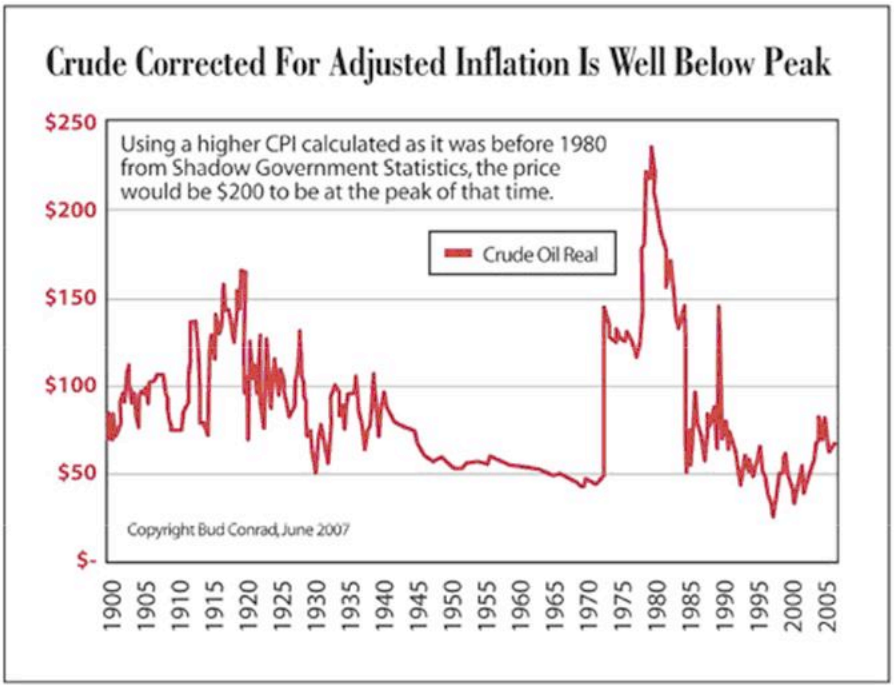
Time is an important factor which is usually underestimated.
The Mc Namara law (from NASA experience) said for frontier projects that the ratio between initial proposals and reality is about pi for cost and e (Euler number = 2,7) for time.
There are many present examples of time lag: Kashagan 2013 instead of 2005, Total Athabasca projects 3 years delay, EPR nuclear plants in Finland and France

**- oil price**

Scientific American article *The end of cheap oil* was published in March 1998 when oil price was 13 $/b. It was only on in October 2005 when oil price reached 50 $/b that medias started to be interested in our message.
Many complain that energy is expensive but *whale oil* used for lightning was in 1854 over 1200 $2008/b in 1860 and oil price about 100 $2008/b in 1864 and in 1979 with official inflation index.
Figure 24: US whale oil and crude oil price in $2008 (official inflation from Oregon State Univ.)

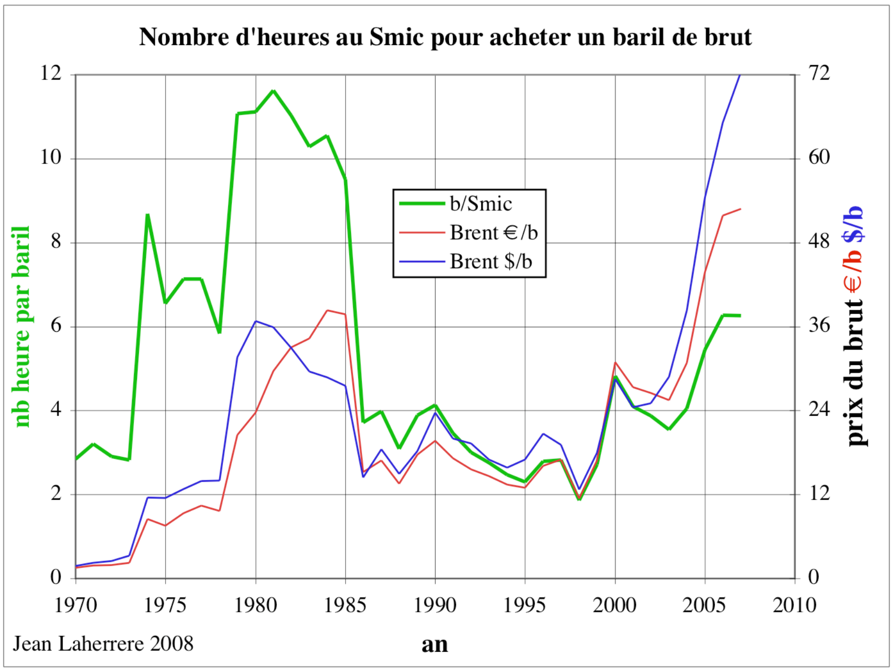



But inflation index are flawed by politics and manipulated. Conrad has corrected the inflation and estimates that oil price in 1980 was about 200 $today/b
Figure 25: 1900-2005 oil price $2005 with corrected inflation from Conrad




To avoid using manipulated inflation index, it is better to measure how many hours of work at minimum wage are needed to buy one barrel of oil. Using the French minimum wage (SMIC) more than 11 hours were needed in 1980 when only about 6 hours were enough in 2007, confirming Conrad graph.

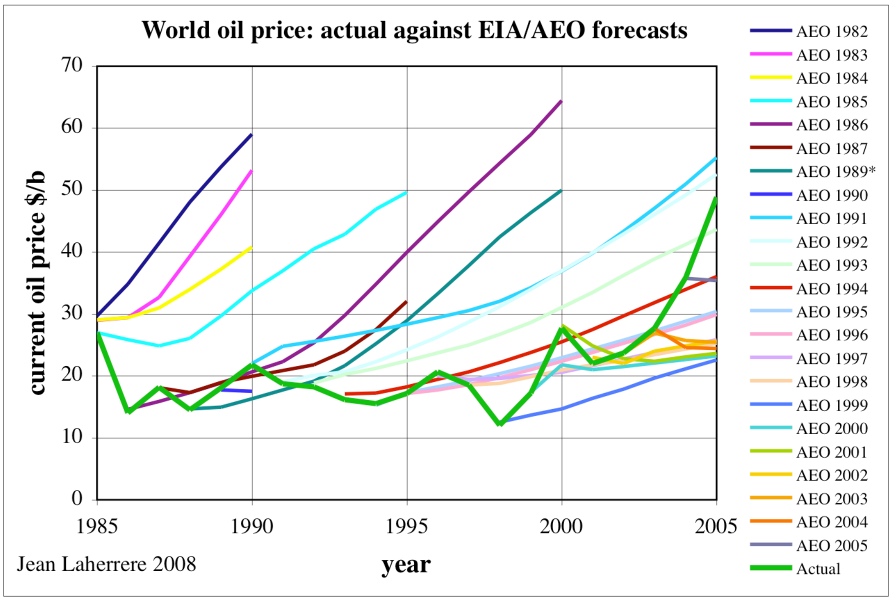
Figure 26: number of SMIC minimum wage needed to buy one barrel of oil




Oil price in $ are rising because the value of dollar is falling (145 $/b when euro = 1,6 $), and the recent fall in $/b is due to the rise of $ against euro (about 1,4 $ now).

Forecasts in oil price were always wrong in particular for USDOE/EIA/AEO

Figure 27: always wrong oil price forecast by EIA from 1982 to 2005

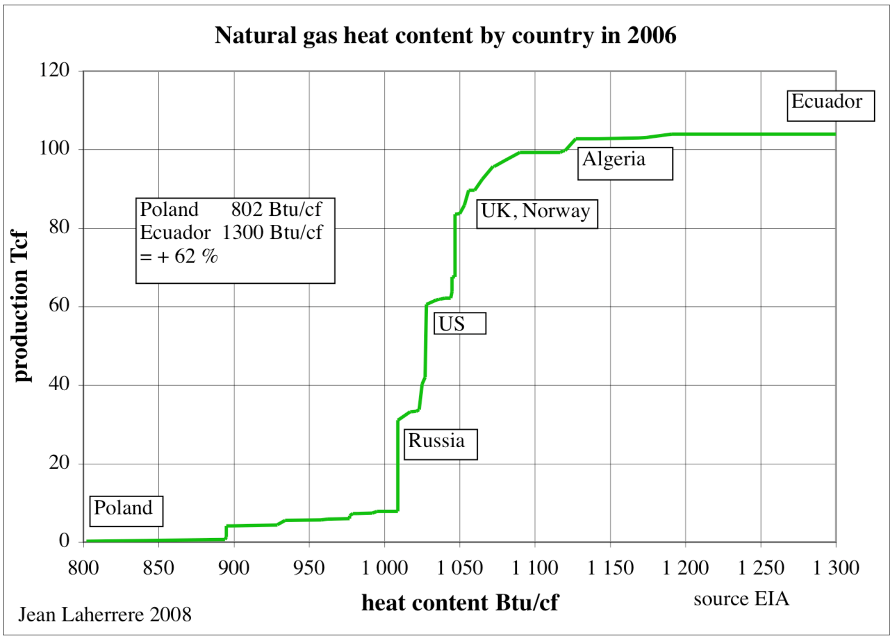



I always refuse to forecast oil price, only to say that it will be chaotic.

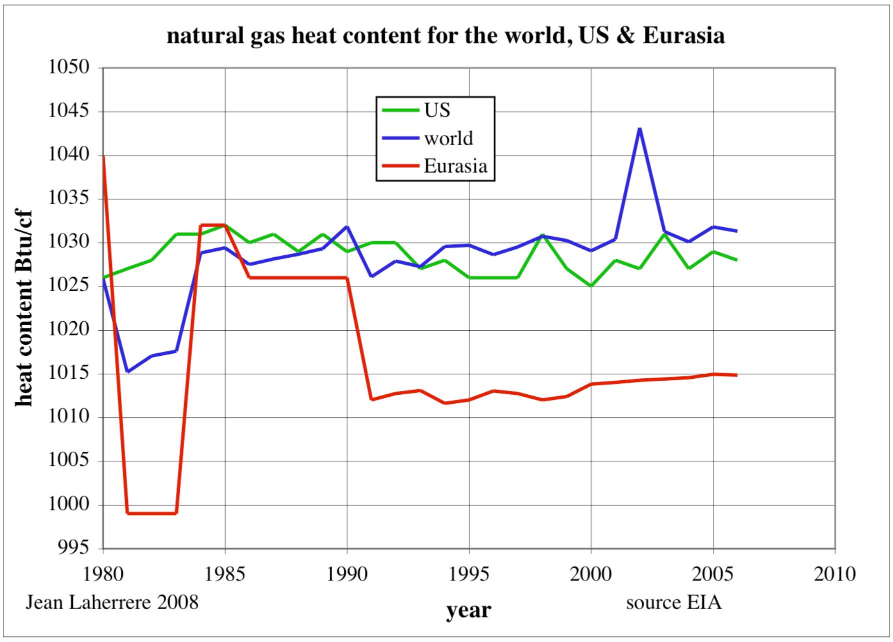
## -2-Natural Gas = NG

### -data

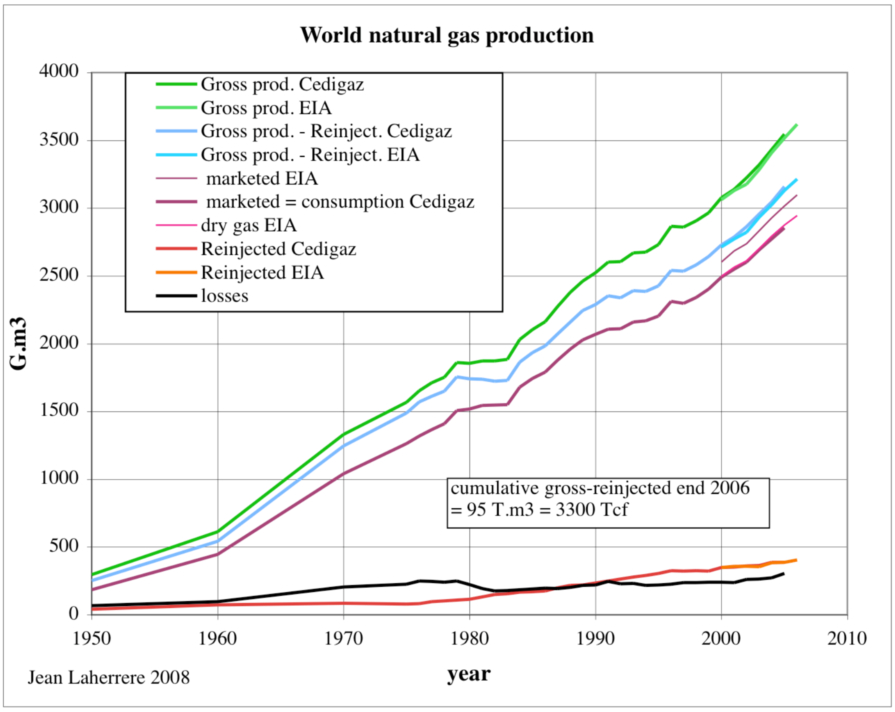
Natural gas is different from oil because
-energy content range is higher
-transport cost is 10 times higher, so there are 4 NG markets against one global for oil market and many gasfields are stranded in remote places
NG gas in Ecuador is 62% more energetic than in Colombia. The heat content varies from 800 to 1300 Btu/cf with a median at 1025 Btu/cf
Figure 28: natural gas heat content by country




Heat content does not vary much in the US (slight decline), but widely in Eurasia (FSU) because unreliable data before breakdown
Figure 29: natural gas heat content for the world, US & Eurasia



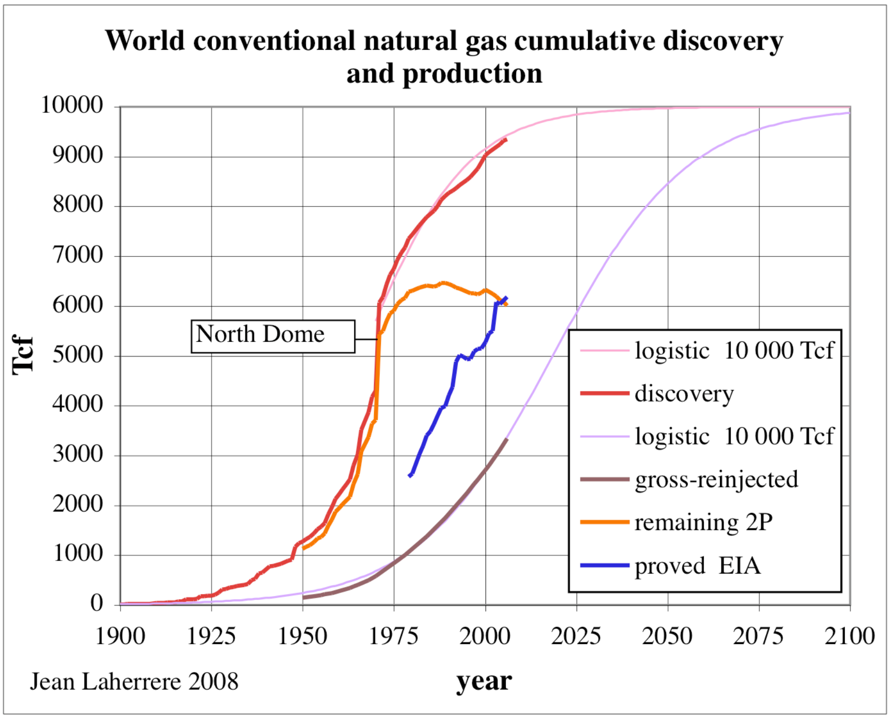

There is the same ambiguity on natural gas production data: unreliability for reinjected, flared, marketed and dry because numbers vary with sources.
Flared volumes vary between official number and measures from satellites (NOAA site)
Figure 30: world natural gas production



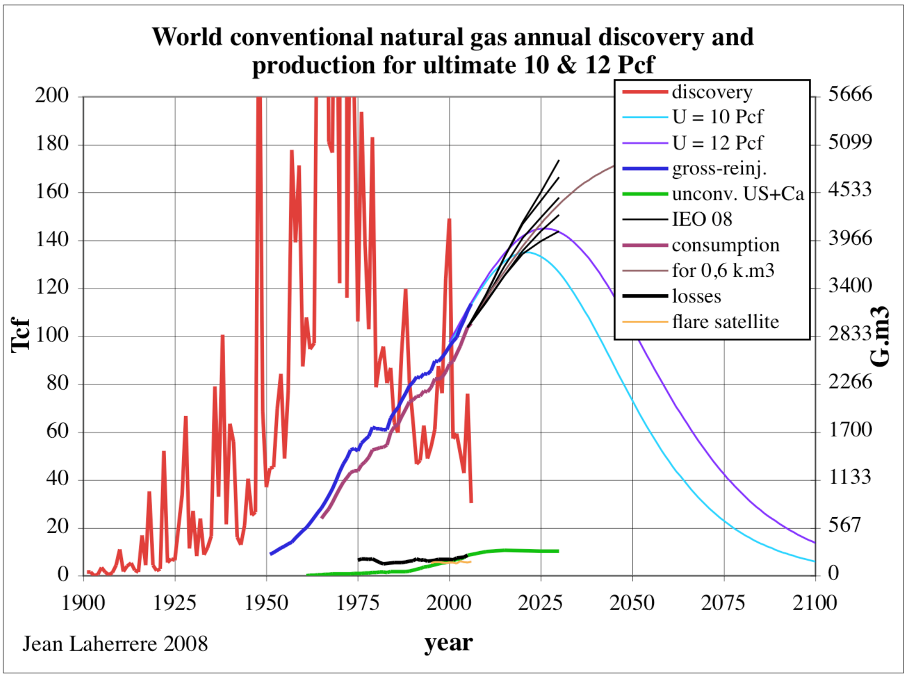

The question of how much of the reinjected gas could be fully recovered in the future is still unanswered. In our study we assume that 100% will be recovered after reinjection.

**-world forecast**

Using (like for oil) technical databases to plot the cumulative **conventional NG** discovery, the past can be easily modelled with a S curve for an ultimate of 10 000 Tcf = 10 Pcf. The YET (yet to find) is less than 10 % of the present discoveries (like for oil).
Cumulative production forecast fits also well with a 10 Pcf ultimate
Figure 31: world conventional natural gas cumulative discovery and production



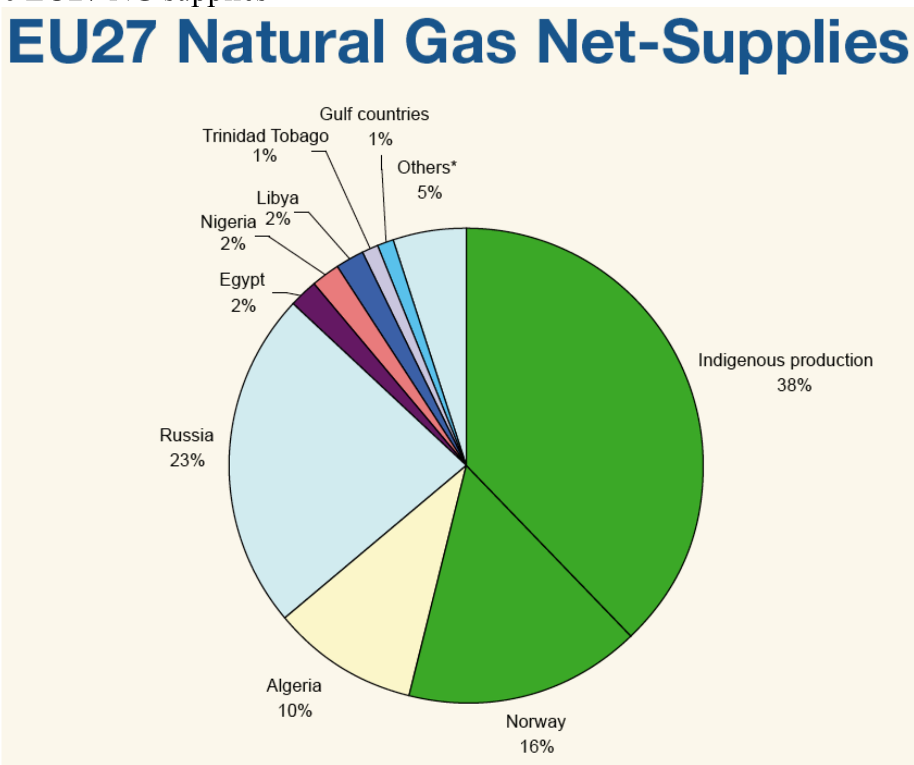

The remaining technical data (in orange) is, as for oil, completely the opposite of the political data (EIA) (in blue) as for trend, but in agreement for 2006 value (in contrary with oil)
If the ultimate for conventional NG is estimated at 10 Pcf, unconventional gas ultimate is harder to guess, but the official forecast for US unconventional NG is far from the published volume of resources and we estimate the unconventional ultimate at 2 Pcf, for a total global of 12 Pcf.
The annual conventional discovery & gross-reinjected production are plotted with forecast for U = 10 & 12 Pcf. The NG peak is around 2025 at around 140 Tcf/a. NG consumption is also forecasted from population UN forecast assuming a NG consumption per capita at 0.6 k.m3/a. NG peak in 2025 will oblige the world to decrease NG consumption. EIA/IEO 2008 reference production is in agreement with our consumption forecast, but low economy and high price forecast for 2030 are close to my NG peak.
Figure 32: world conventional natural gas annual discovery and production for an ultimate of 10 & 12 Pcf and EIA/IEO 2008



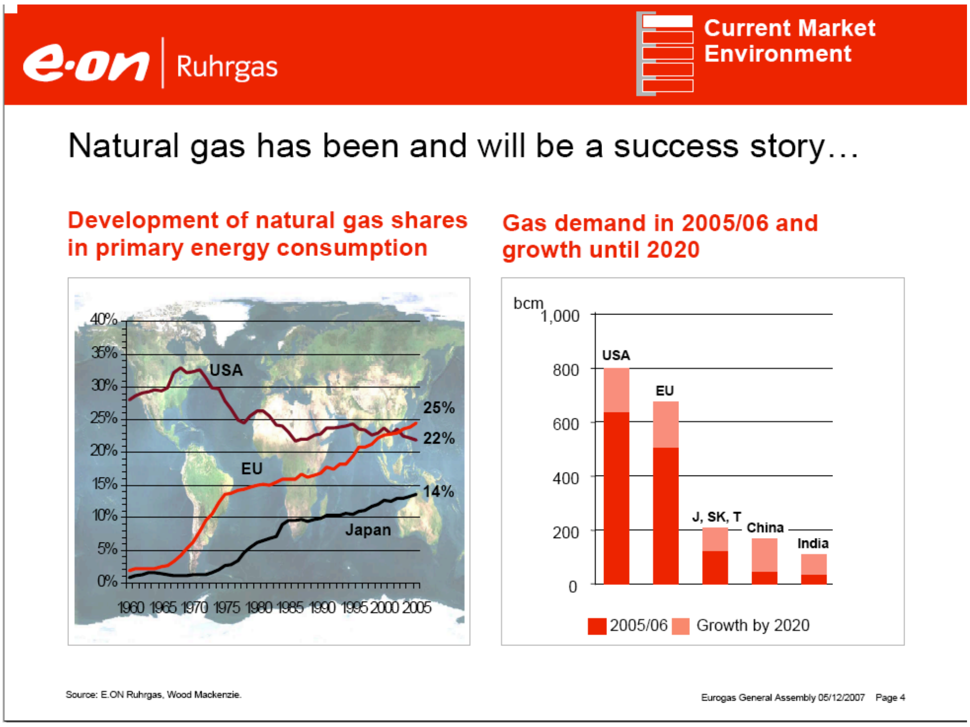
But there are three main NG markets in the world being North America, Europe and Asia Pacific, a fourth market is starting in South America.
The problems of NG supply will occur soon in Europe, because the uncertainty of the NG suppliers, in particular Russia on which Europe is counting too much.

**-Europe NG production and consumption**

The European Union supplies in 2006, showing the importance of Russia 23 % (buying supply from other FSU countries), Norway 16% and Algeria 10%
Figure 32: 2006 EU27 NG supplies

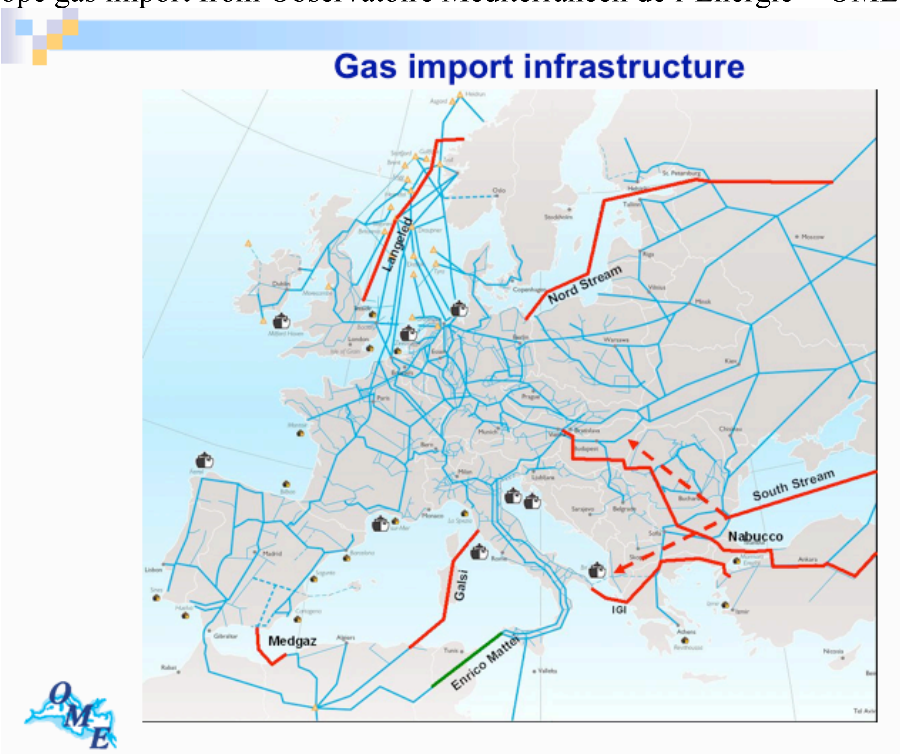



The increase of NG share in Europe primary energy has been large compared to Japan when it decreases in the US:
Figure 34: NG share in primary energy in Europe compared to Japan and US



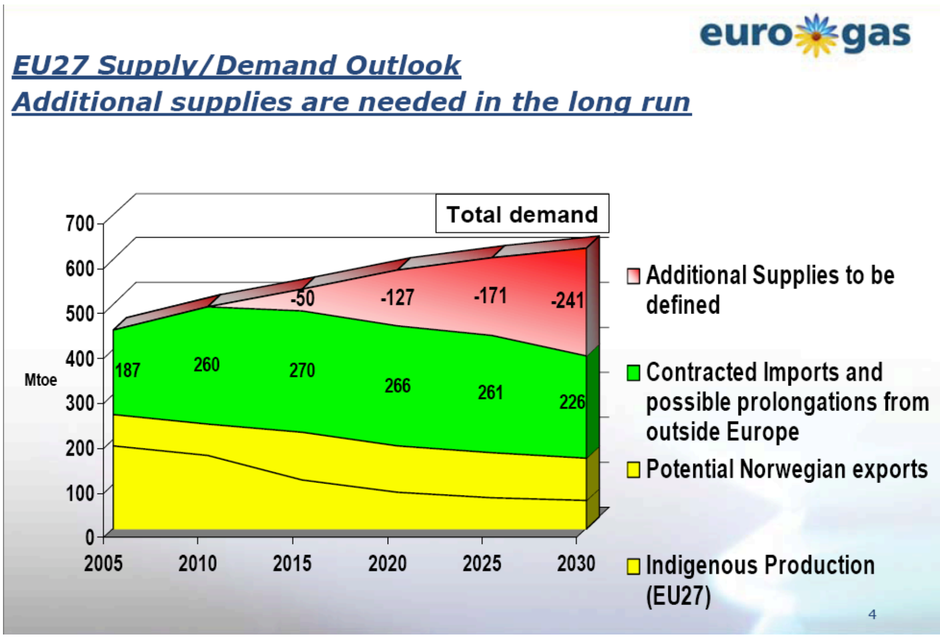

The network of gas import is large and there are many projects, some of which are in doubt (Nabucco).

Figure 35: Europe gas import from Observatoire Mediterraneen de l'Energie = OME (Nice 2007)

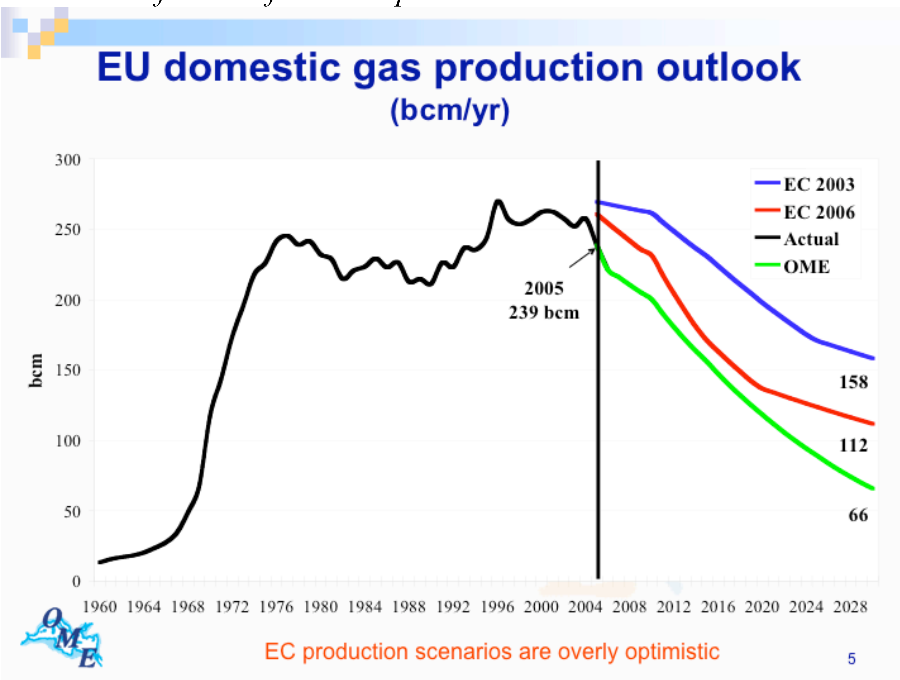



Eurogas forecasts in addition to the identified contracts additional supplies to be defined in 2030 of 241 Mtoe = 268 G.m3, meaning that what is *to be defined* is more than what is *contracted*.

Figure 36: Eurogas forecast (long-term outlook to 2030) for EU27

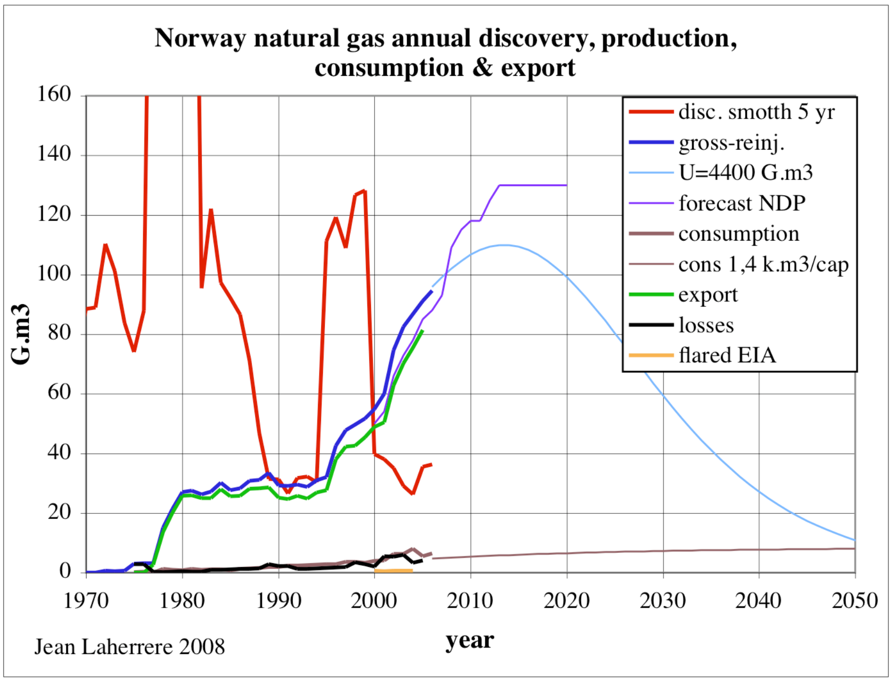



OME has published in June 2007 « Natural gas: Supply and market Security Issues- Europe and its suppliers »
Figure 37: *prevision OME forecast for EU27 production*



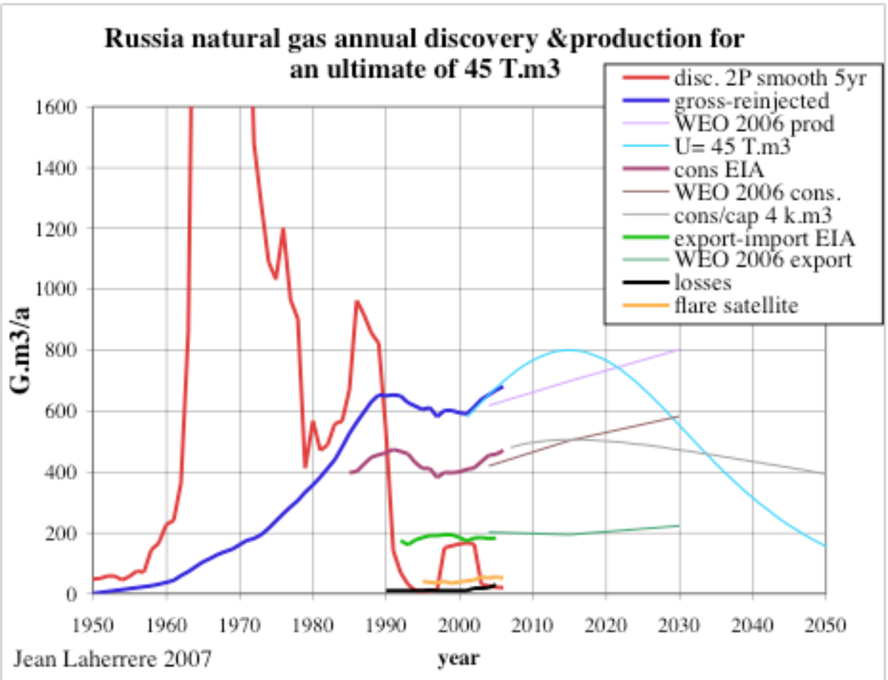

In a paper in Nice 2007 and Prague 2008, we have studied in detail NG production and consumption of all Europe suppliers to get the capacity of export with forecasts up to 2050 and the main graphs are shown below

Norway NG will peak around 2015 and their export too
Figure 38: Norway: natural gas annual discovery, production for ultimate 4.4 T.m3 (no other constraints), consumption, export & losses




Russia reported reserves are overestimated and Gazprom official reserves were reduced by an audit of DGMN by 30%. Russia NG production will peak around 2015 and will match consumption (despite declining population) around 2030 leaving no export.

Figure 39: Russia: natural gas annual discovery, production ultimate 45 T.m3 (no other constraints), consumption, export &losses

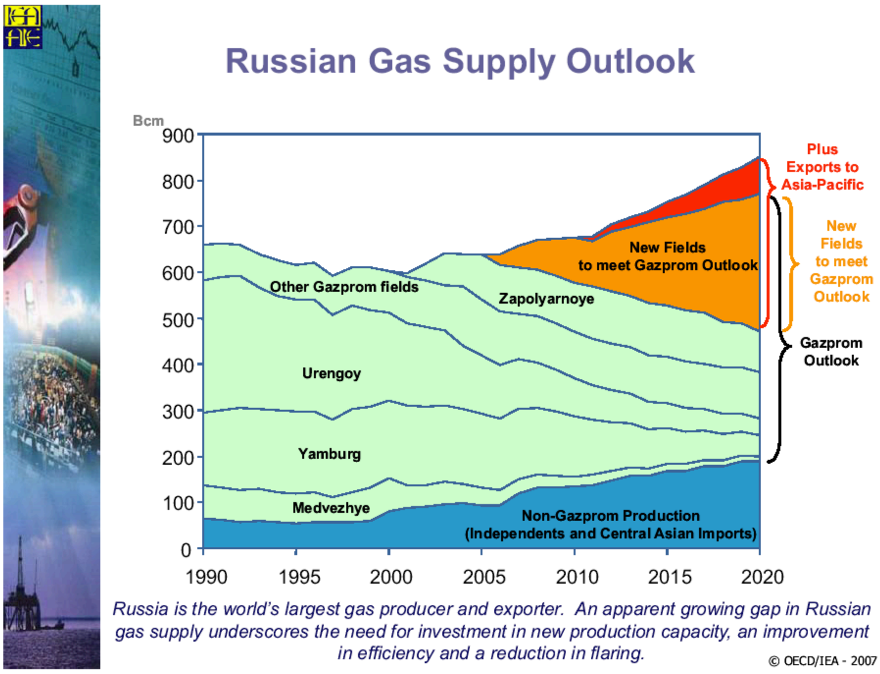



IEA states no flaring for Russia, when Cedigaz reports 6,8 G.m3 and satellite 50 G.m3 ! No comment!

NG consumption is foreseen to decline with population when IEA forecasts an increase.

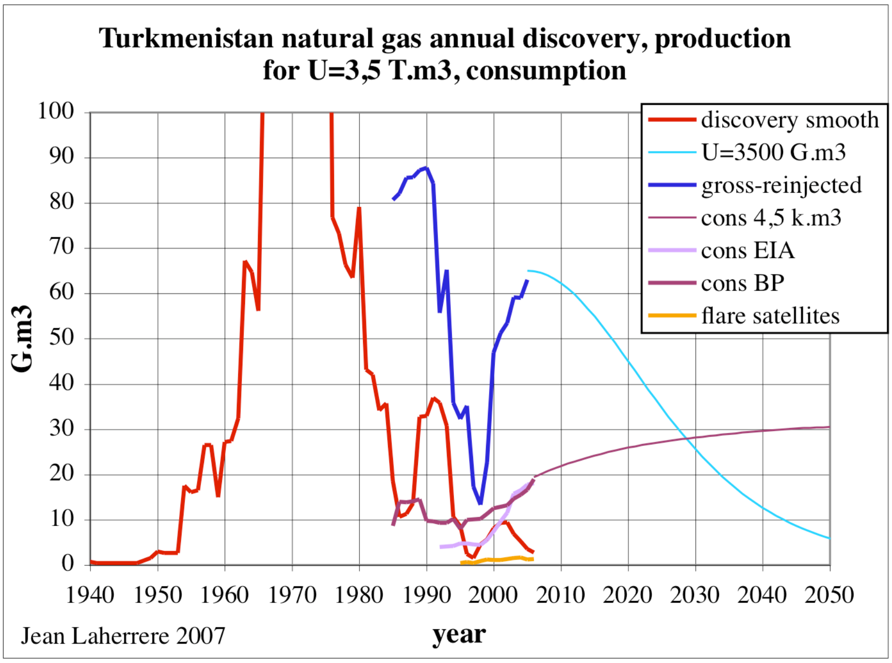
NG waste was huge in Russia because there was no meter in Moscow with heating included in the rent. Natural gas price has to be increased and consumption to be charged to the user to motivate him. IEA forecasts an important decline in Gazprom gasfields but the development of new gasfields is needed to satisfy the demand. Gazprom policy is criticized by Vladimir Milov who doubts about the possibility of Gazprom to finance development of difficult gasfields as those in Yamal peninsula (Bovanenko found in 1971with 150 Tcf is larger than Shtokman found in 1988 with 127 Tcf). Western money is asked to develop Shtokman, but not for Bovanenko!

Figure 40: Russia: natural gas production forecast by IEA 1990-2020



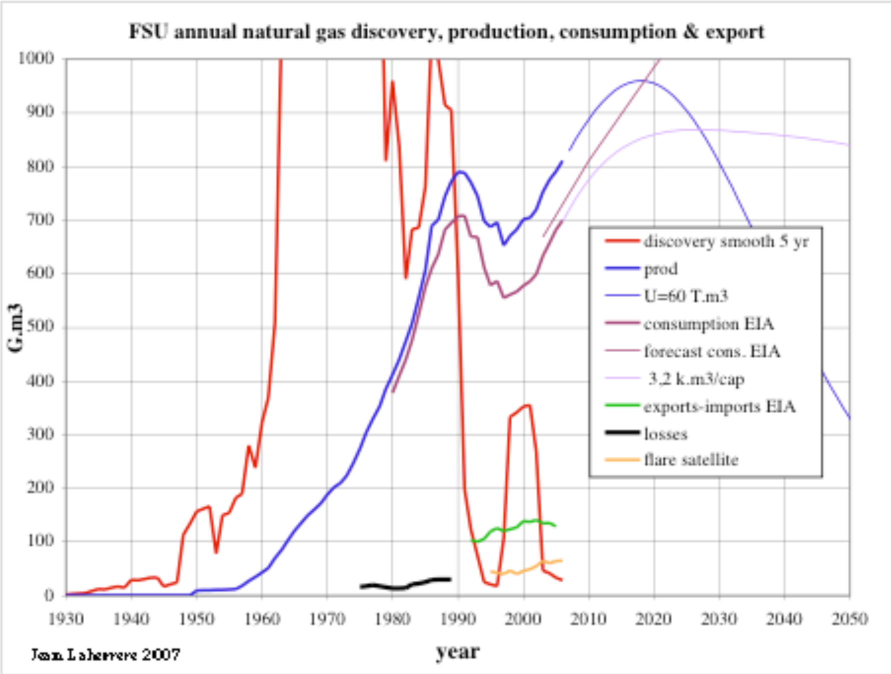

Russia controls all the NG exports of the FSU and relies on Turkmenistan to export NG.
Turkmenistan NG peak should be now and domestic consumption will stop NG export around 2030

Figure 41: Turkmenistan: annual gas discovery, production and consumption



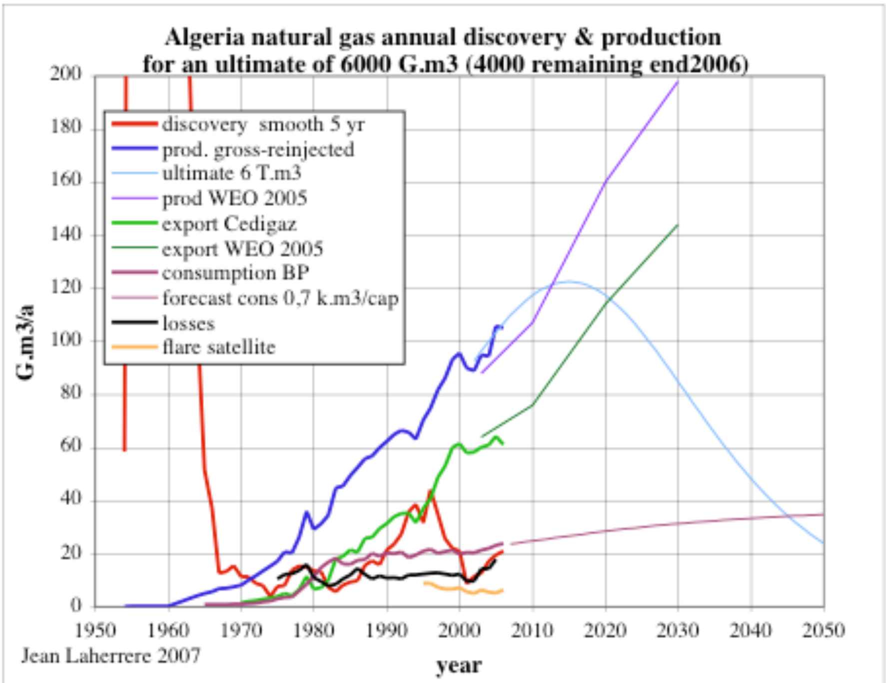

FSU NG peak should be around 2015 and capacity of export should stop around 2025 or before assuming EIA consumption, meaning that all projects of large gas pipeline are unrealistic for a life shorter than 15 years.
FSU will be unable to supply Europe and any project to supply in addition Asia seems unreal.

Figure 42: FSU: natural gas annual discovery, production for ultimate 60 T.m3 (no other constraints), export & losses



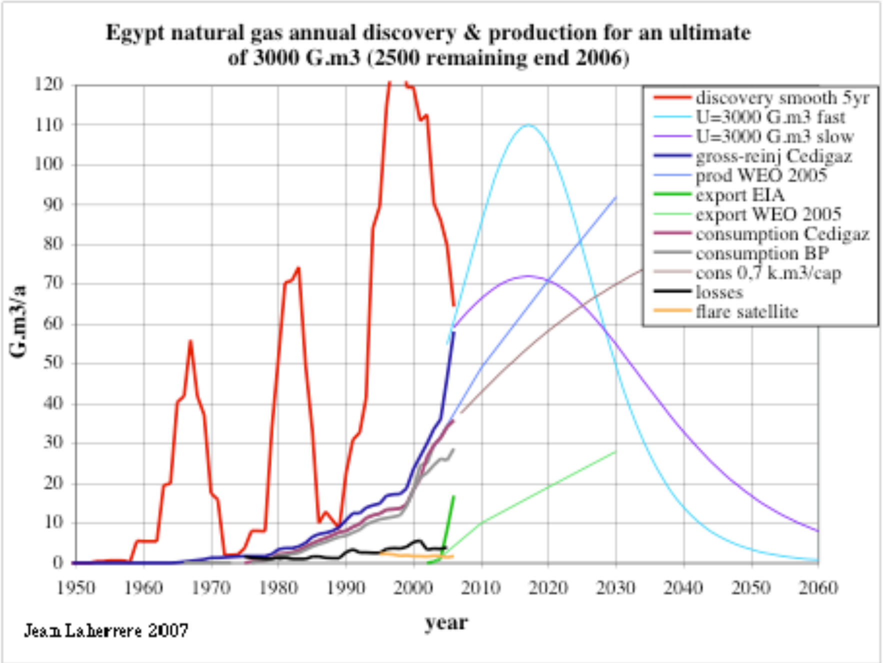

Algeria has large NG reserves thanks to Hassi R'mel (I participated in its discovery), but Algeria NG peak will be around 2015, yet exports will stop only around 2050 because of the low level of domestic consumption

Figure 43: Algeria: annual discovery, production for an ultimate of 6 T.m3 (no other constraint), consumption, export and losses

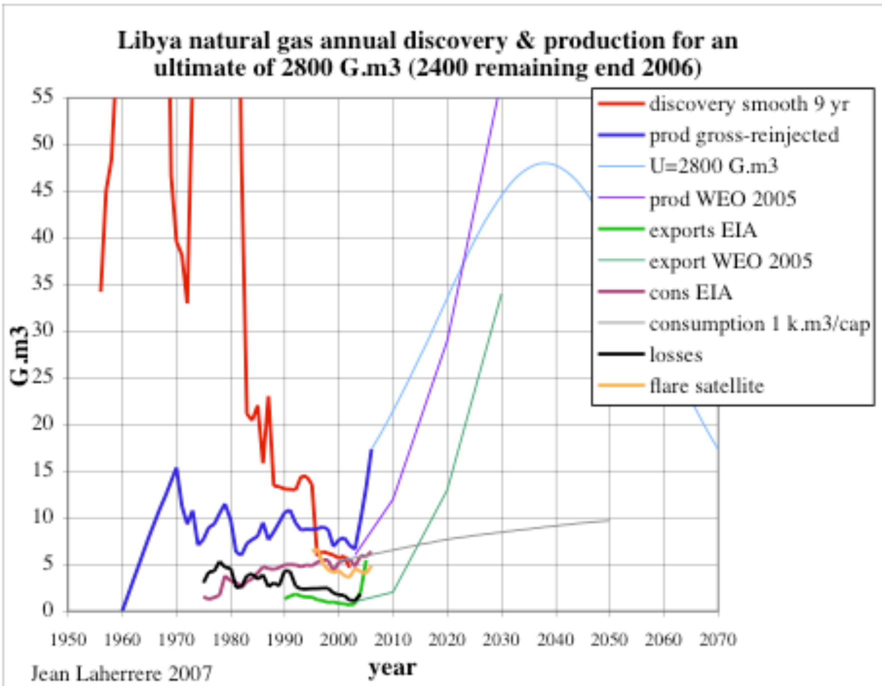



Egypt NG production will also peak around 2015 and export should stop around 2025.

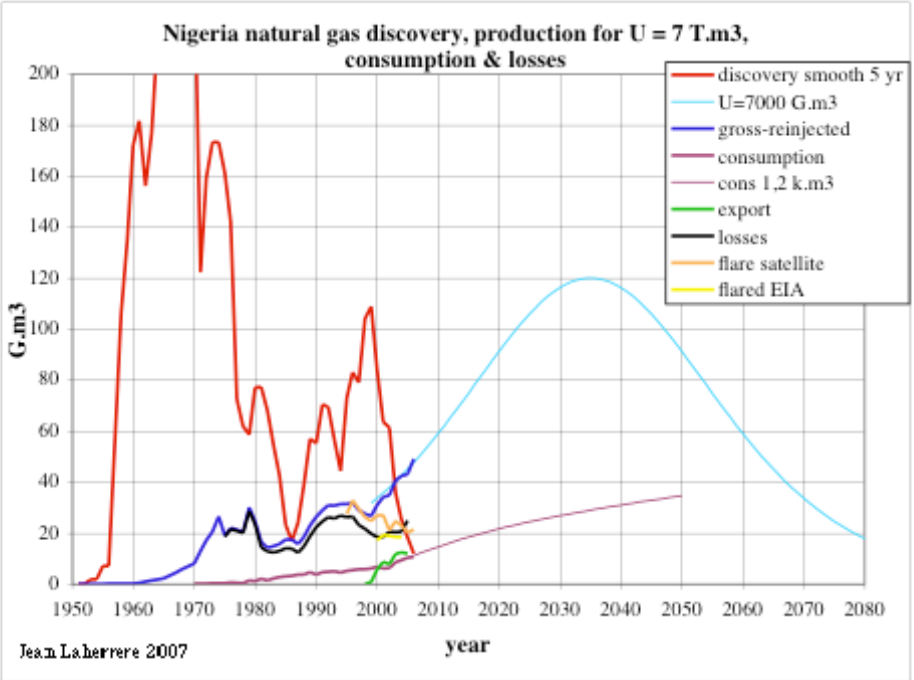
Figure 44: Egypt: annual discovery & production for 3 T.m3 ultimate (no other constraint), consumption, export & losses




Libya NG peak will be around 2040 and capacity of export should be beyond 2070.
Figure 45: Libya: annual natural gas discovery, production for a 2.8 T.m3 ultimate (no other constraint), consumption, export & losses

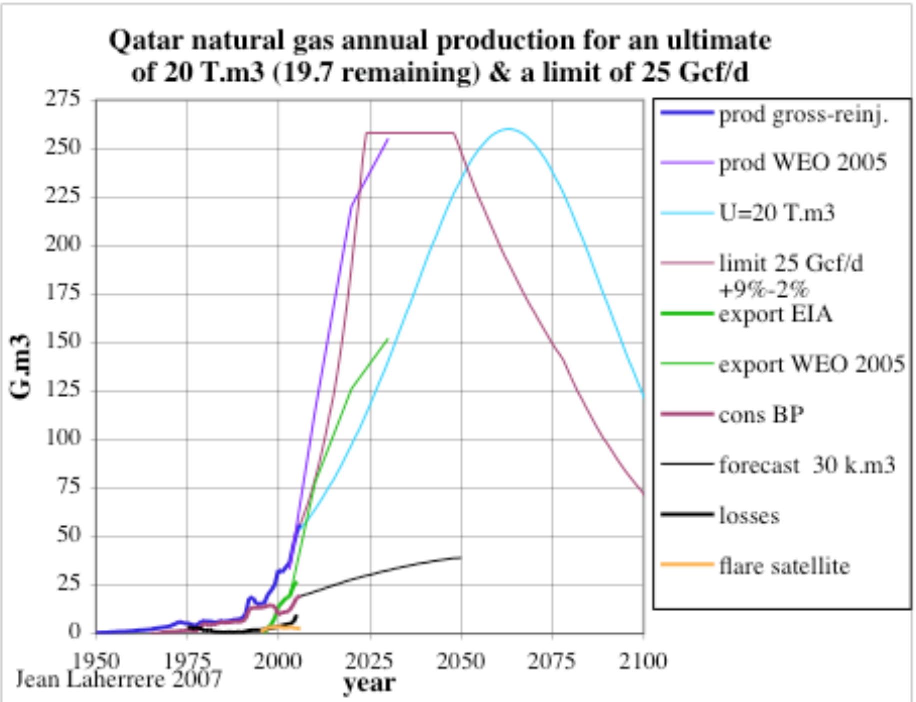



Nigeria NG peak will be around 2035 and export could extend until 2070, like Libya
Figure 46: Nigeria: natural gas annual discovery, production for a 7 T.m3 ultimate (no other constraints), export & losses



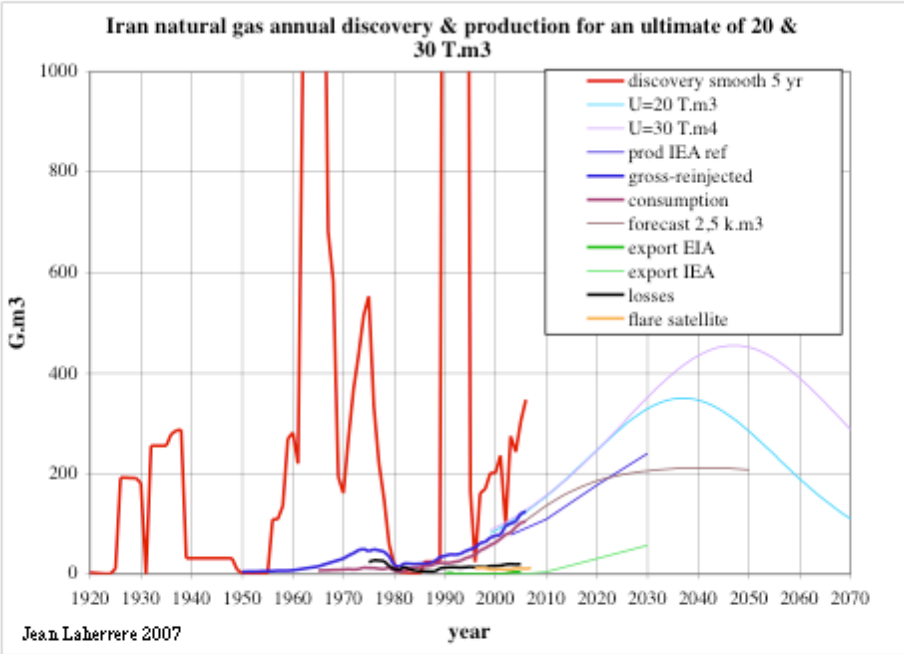

North gasfield (2/3 in Qatar, 1/3 in Iran) is a huge field being more than 10% of the world ultimate. Because of the small population Qatar has decided to limit its NG production at 25 Gcf/d and so could export well beyond 2100.

Figure 47: Qatar: natural gas annual discovery, production for a 20 T.m3 ultimate (no other constraint), consumption, export & losses

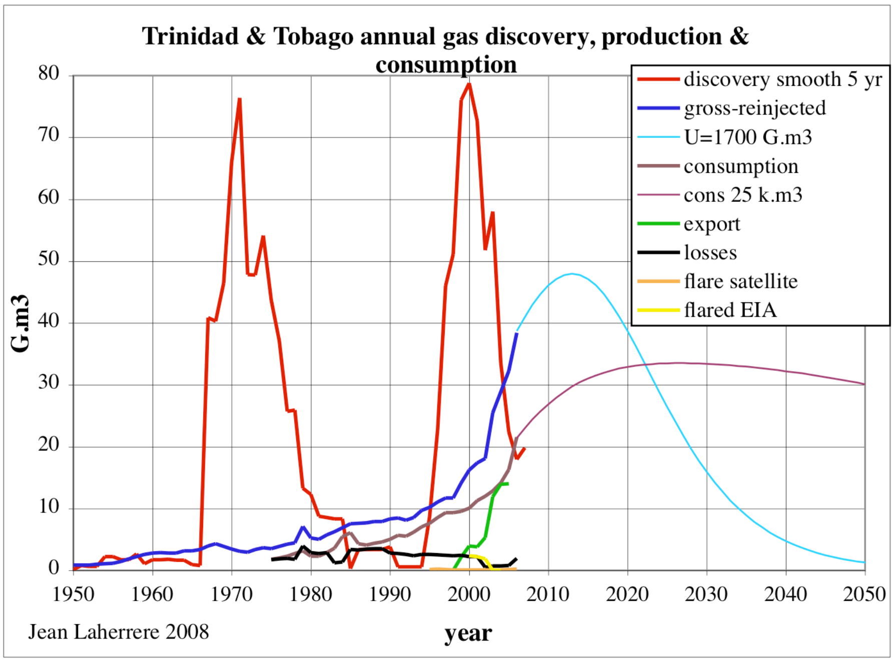



Iran NG peak will be around 2040 and export can extend beyond 2060 or later.

Figure 48: Iran: natural gas annual discovery, production for a 20-30 T.m3 ultimate (no other constraints), consumption, export & losses



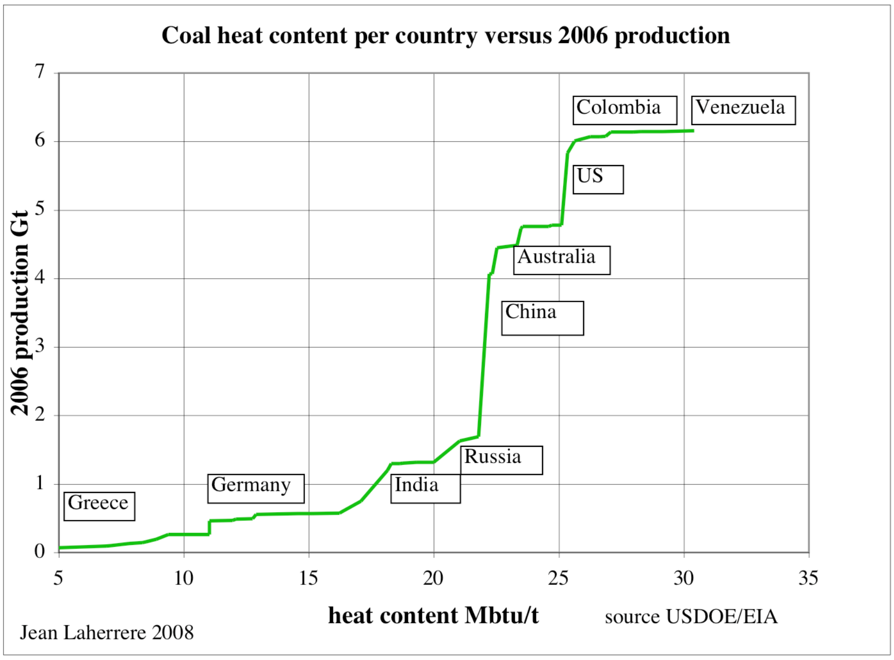

Trinidad NG peak will be around 2015 and export should stop around 2025.
Figure 49: Trinidad : natural gas annual discovery, production for a 1.7 T.m3 ultimate (no other constraints), consumption, export & losses




## -3-coal

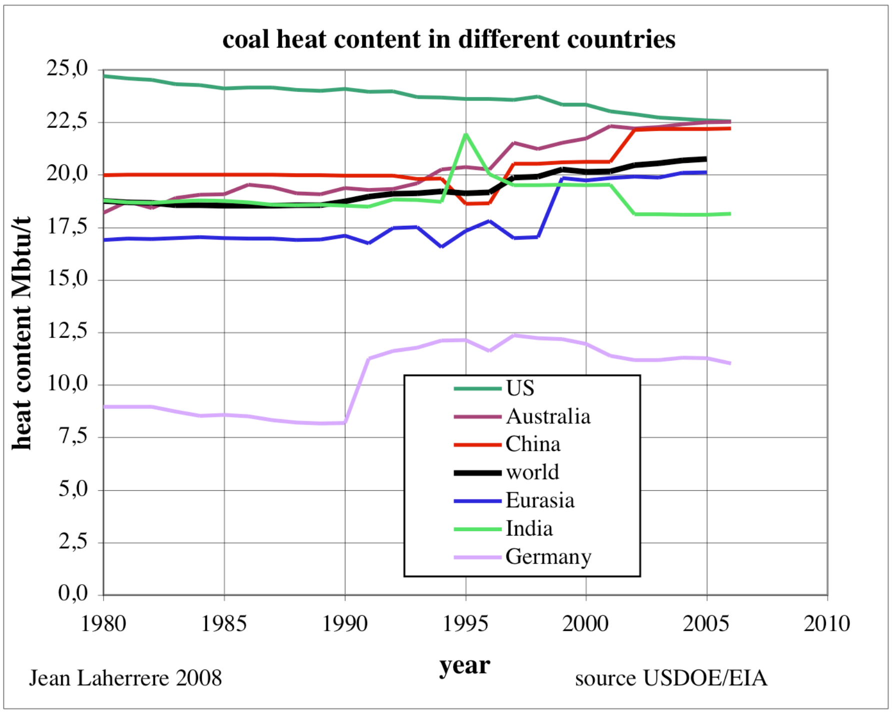
### -data

There is two different categories of coal: with different names anthracite & bituminous and subbituminous and lignite; or hard coal and soft coal, depending the amount of water and ashes. Coal quality varies greatly when reported globally as tonnes, from 5 Mbtu/t in Greece to 30 Mbtu/t in Venezuela (six times more). It is why coal production should be reported in Gtoe or Gtoc.
Figure 50: Coal heat content in 2006 per country versus production



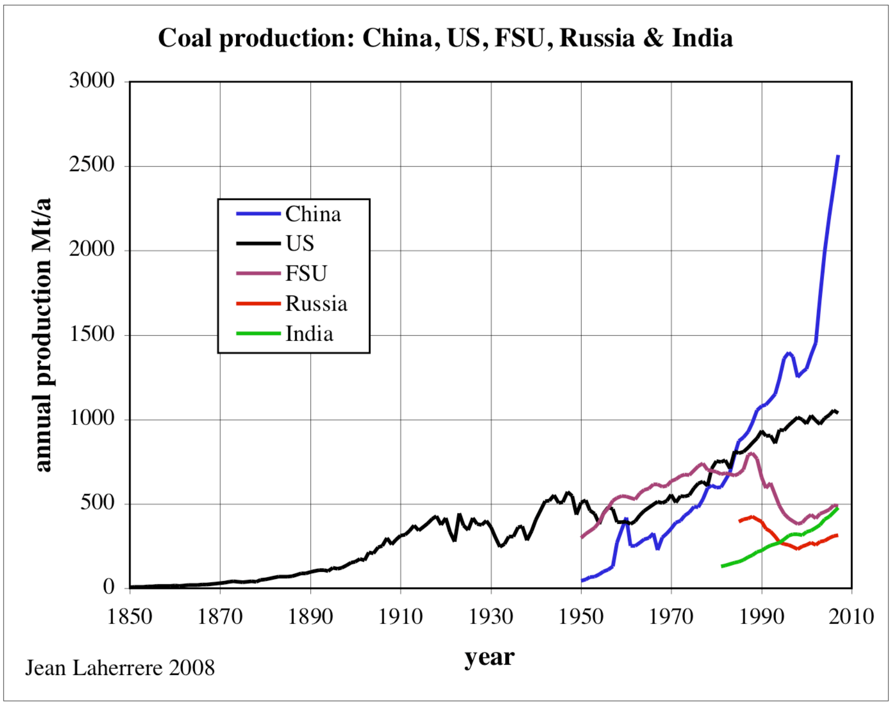

Heat content is decreasing in the US, increasing in Australia, erratic in China and Eurasia, showing the unreliability of this data.

Figure 51: Coal heat content in different countries 1980-2006

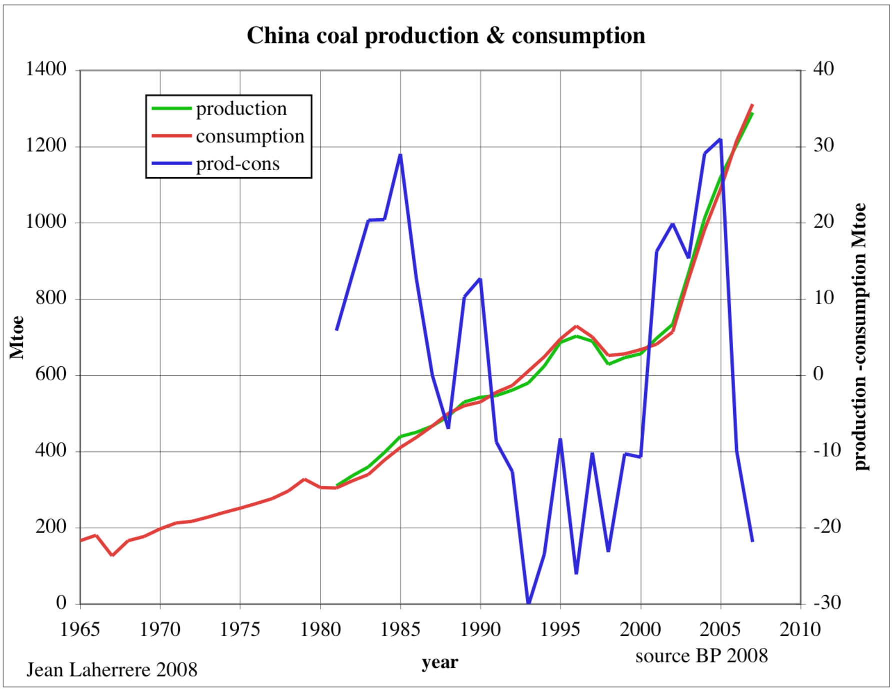



China coal production has increased sharply for the last few years compared to the US or India.

Figure 52: coal production: China, FSU, Russia & India




The China balance between production and consumption was chaotic with cycle. It seems that now China knows that it will have to import coal and they have decided to cancel all CTL projects except the two close to completion (already late) in Shenhua.
There are 4 millions Chinese coal miners and each week a hundred have died.
Figure 53: China coal production & consumption

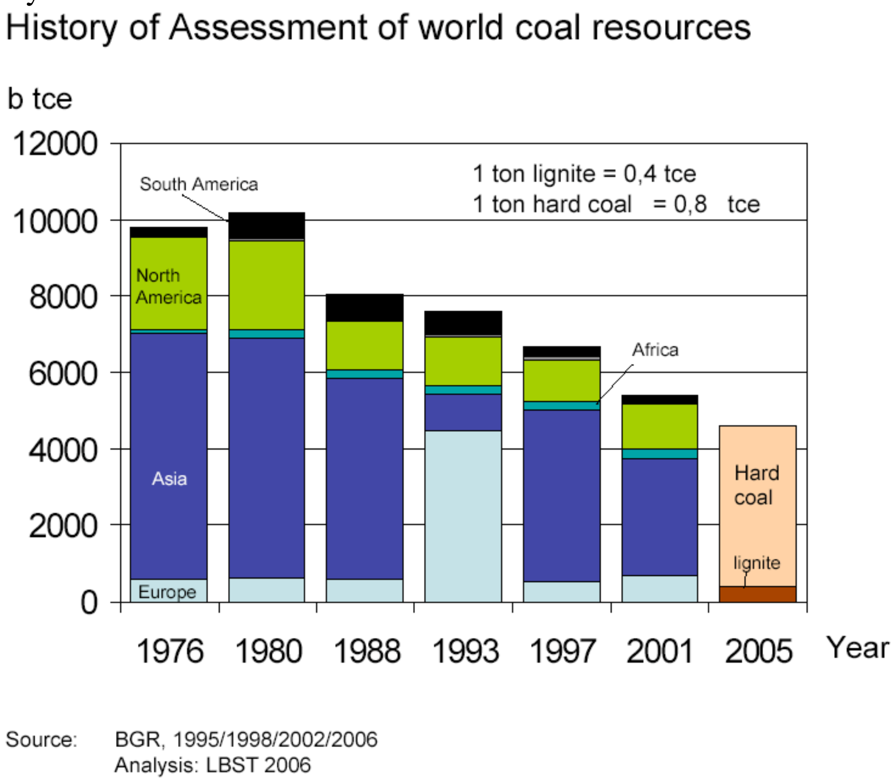



For coal it is more difficult to get reliable reserve data, because there is no coal scout company selling technical data and reserves published, such as those from national agencies, use different definitions and play on the **ambiguity between reserves (future production) and resources (in the ground)**. Coal is solid, and contrary to oil, past production data cannot provide information for future production. Reserves depend upon economy (thickness of the seams and depth). Offshore coal and beds deeper than 1500 m are considered as only resources because of EREOI. Only in situ

gasification (no commercial pilot despite experiments for the last 50 years) could change the picture.
Coal exploration was stopped because the large reported R/P and undiscovered is hard to be estimated in the absence of a good creaming curve.
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 been a little chaotic (change of staff?):

| BGR | **reserves** | | | | **resources** | | | |
|---|---|---|---|---|---|---|---|---|
| **Gtoe** | 1997 | 2001 | 2005 | 2006 | 1997 | 2001 | 2005 | 2006 |
| hard coal | 340 | 421 | 437 | 437 | 3503 | 2474 | 2489 | 5311 |
| lignite | 50 | 47 | 49 | 70 | 760 | 291 | 242 | 765 |
| coal | 389 | 467 | 487 | 507 | 4262 | 2765 | 2731 | 6076 |

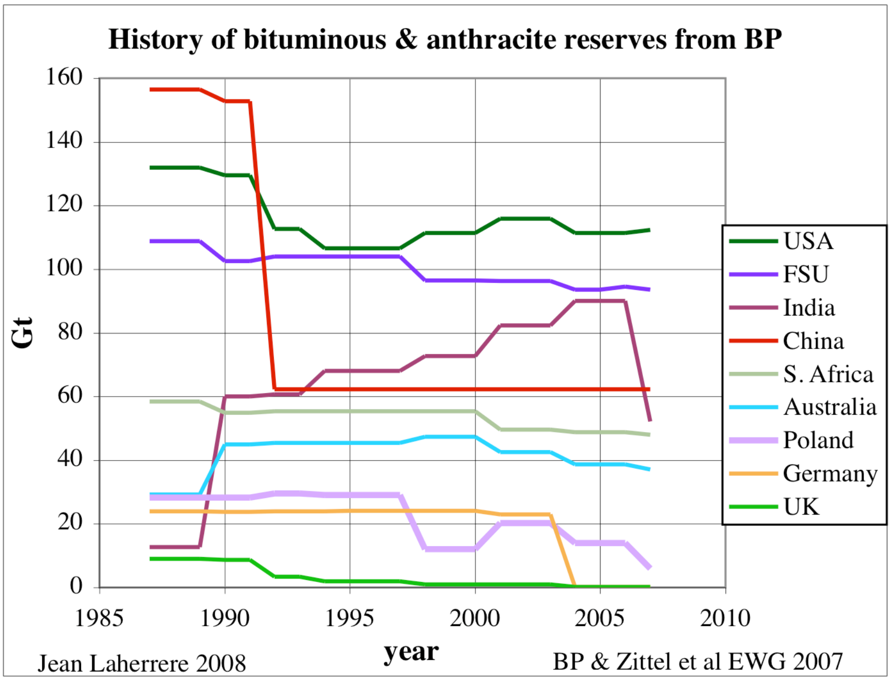
In fact BGR coal resources have been in decline since 1980 from Zittel et al 2007 Energy Watch Group 2007 (« Coal : resources and future production » EWG-series n°1/2007 March) Europe resources display an erratic spike in 1993 and the world resources have been divided by half ! But in 2006 up again (new leader?)! Soft brown was changed into lignite
Figure 54: History of assessment of world coal resources from Zittel et al 2007



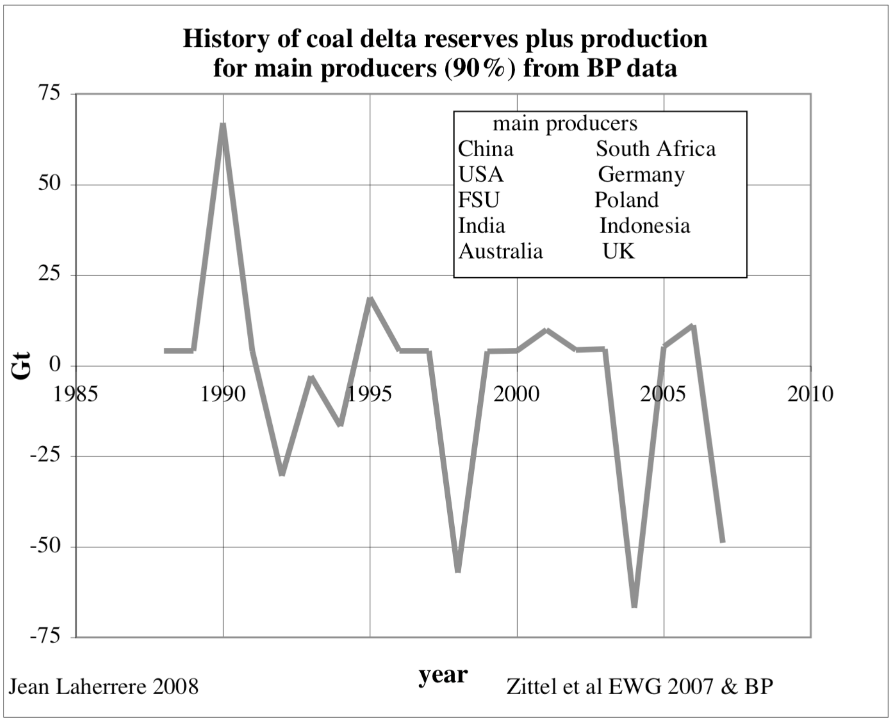

It seems that the BGR increase in 2006 comes mainly from China (production has doubled for lignite (previous soft brown). But BP does not show any increase at all in reserves (as for OPEP oil!)

| | | BGR | BGR | BP | BP | BP |
|---|---|---|---|---|---|---|
| | | 2005 | 2006 | 2005 | 2006 | 2007 |
| prod Mt | hard | 2113 | 2381 | | | |
| reserves Gt | hard | 95,9 | 167 | 62,2 | 62,2 | 62,2 |
| resources Gt | hard | 888,5 | 4200 | | | |
| prod Mt | soft brown | 48 | 100 | | | |
| reserves Gt | soft brown | 18,6 | 25 | 52,3 | 52,3 | 52,3 |
| resources Gt | soft brown | 86,8 | 327 | | | |
| prod all Mt | all | 2161 | 2481 | 2205 | 2373 | 2537 |

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 55: History of bituminous & anthracite reserves from BP



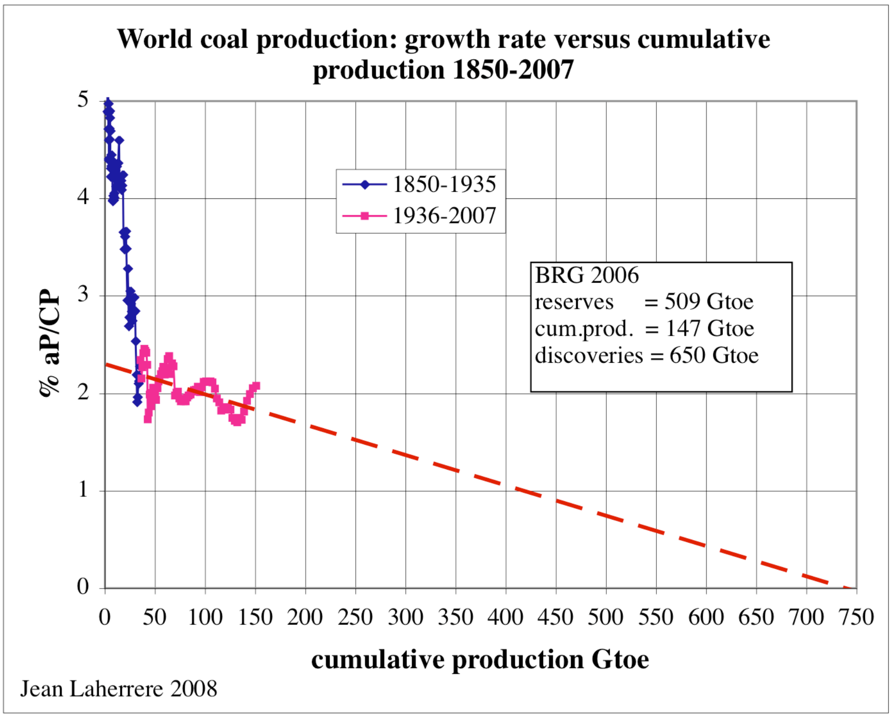

The sum of annual delta reserves and annual production for the main producers (90% of the world production) displays chaotic evolution from 1988 to 2007, meaning that coal data is highly unreliable.
Figure 56: History of coal delta reserves plus production for main producers from BP




**-forecast**

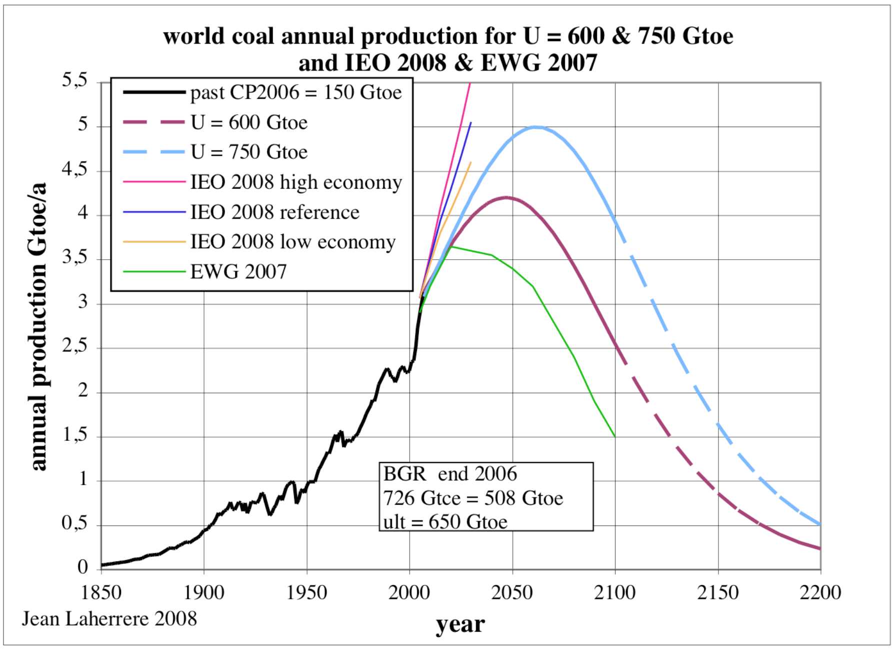
World coal Hubbert linearization displays a chaotic trend but the average on the last 70 years could be extrapolated towards 750 Gtoe, when BGR 2006 estimates is 509 Gtoe remaining and 147 Gtoe already produced or a cumulative discovery of 650 Gtoe.

Figure 57: world coal production Hubbert linearization




World coal production is forecasted using ultimates of 600 & 750 Gtoe, giving a coal peak around 2050, when EIA/IEO 2008 5 scenarios are far higher and EWG 2007 far below.

Figure 58: world coal annual production for U=600 & 750 Gtoe and IEO 2008 & EWG 2007

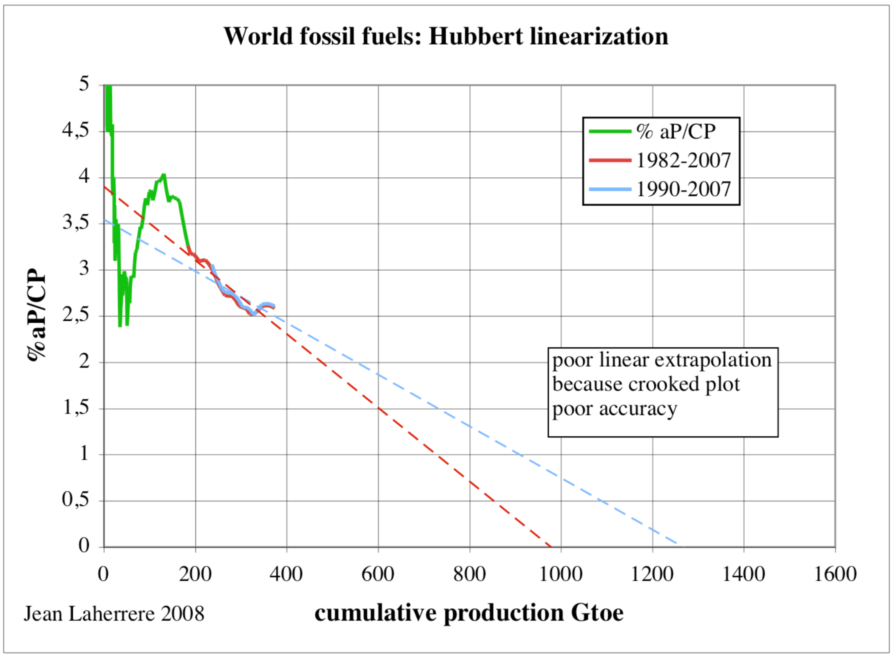



**-4-fossil fuels = FF**

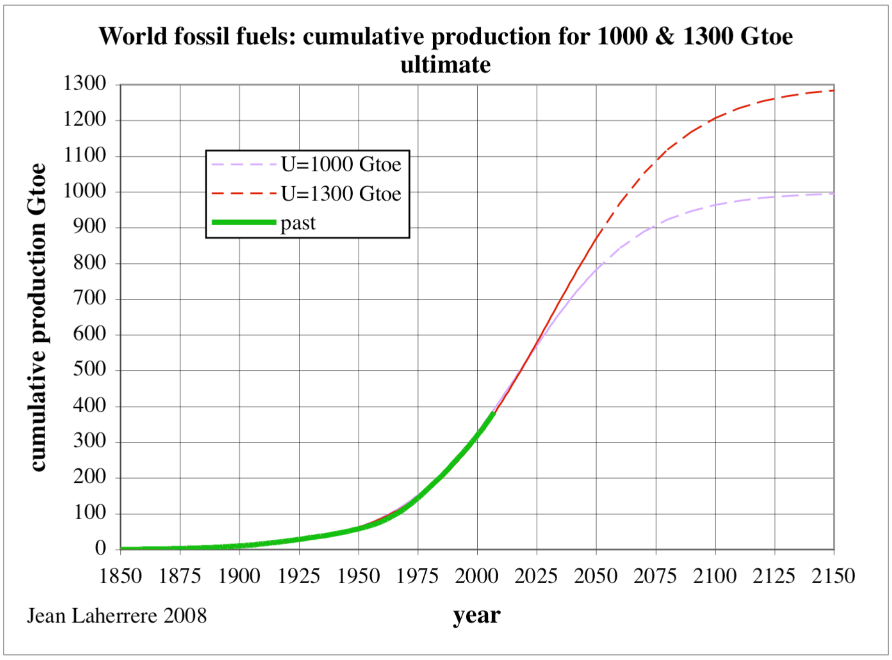
**-forecast**

FF Hubbert linearization is crooked and any linear extrapolation completely unreliable between 1000 and 1300 Gtoe.

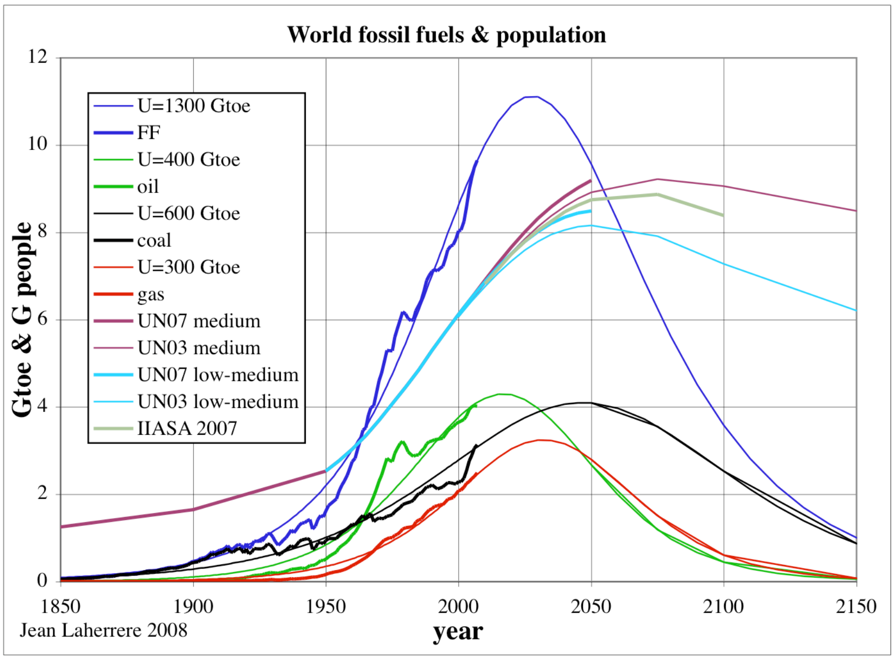
Figure 59: FF production Hubbert linearization




FF cumulative production can be easily modelled with U= 1000 or 1300 Gtoe.
Figure 60: FF cumulative production for U=1000 & 1300 Gtoe




From the already estimated ultimates: 600 Gtoe for coal, 400 Gtoe for liquids and 300 Gtoe for gas, the FF ultimate is taken as 1300 Gtoe assuming no other constraint than below ground.
World population with UN forecasts is also plotted (medium and low-medium scenarios) & IIASA showing a peak around 2050 at 9 G people.
Figure 61: world FF annual production with oil, gas, coal & population 1850-2150



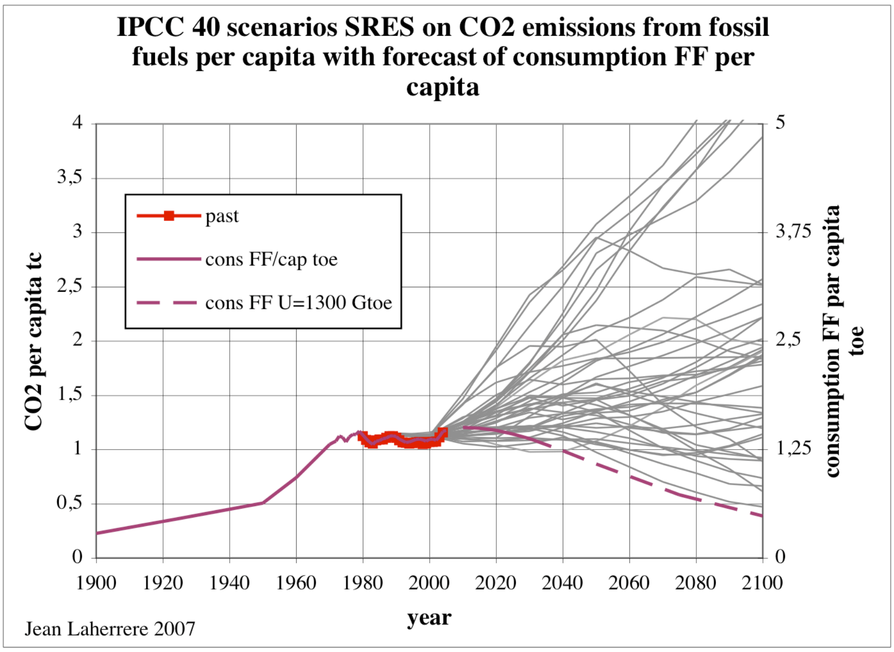

Assuming no other constraints than below ground: oil peak around 2015, gas peak around 2025, coal peak around 2050 like population.
But because above ground constraints likely plateau will prevail with chaotic energy prices.

**-CO2 emissions & FF consumption**

The 40 SRES scenarios (designed in 1998 and used by IPCC 2001 & 2007 reports) for CO2 emission per capita were never fitted to past data and to industry forecasts. The large range of these SRES is almost completely outside the FF previous forecast on consumption per capita.

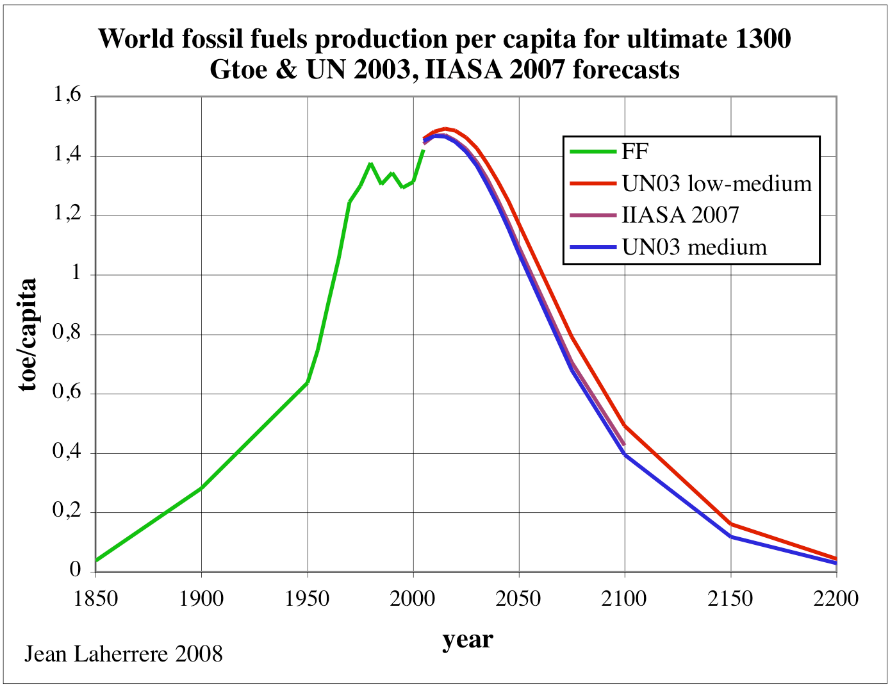
**GIGO = Garbage in, garbage out**

Figure 62: IPCC scenarios on CO2 emissions per capita combined by FF production forecast per capita for U=1300 Gtoe.




The world FF production (or consumption) per capita has raised sharply during the Glorious thirties (1945-1975) and was flat for the last 30 years around 1,3 t/cap. It will stay around 1,5 t/cap for the next 25 years before declining sharply.

It means that it is possible during the next 20 years to shift to other energies, to save energy and to provide a better distribution of energy between poor countries and rich countries.
Figure 63: world FF production per capita 1850-2200




**-5-Ageing of structures, staff and data**
Oil & gas structures, mainly made of iron, rust (like bridges = Minneapolis)
Average age of oil & gas staff is around 45 years
Data deteriorates in magnetic memories if not updated, even optic disks, in addition to obsolescence of readers and softwares
Time factor is (most of the time) badly accounted.

**-6-Irrational (stupid) human behaviour leading to major failures**
-Chernobyl = lack of surrounding container and operations against security rules
-Y2K bug = only 2 digits for year
-Airbus 380 = electric wiring with two different softwares in Toulouse and Hamburg
-Collapse of Minneapolis bridge = lack of maintenance (30% of the 570 000 US bridges unsafe!)
-Katrina flooding New Orleans = weak levees built only for category 3 storms.
-US subprimes = assumption of continuous growth in housing price
-Subprimes conversion into no risk shares (securization) = assumption that aggregation by large number reduces risks, in contrary of globalisation
-Dubai artificial islands and towers based on limitless energy

Einstein speaking about infinite: *there are two examples: Universe and human stupidity, but I am not sure of the first one*.

**-7-Breakthrough to hope for future energy**
-fast breeder
-fusion : either ITER or Megajoules
-in-situ coal gasification
-cellulosic ethanol with exotic enzymes
-oil or hydrogen from algae
-cheap, light, high power battery

-in-situ oil shale pyrolysis
Most of these needed breakthroughs will not succeed, but if one does, it may change greatly the energy scene.

**-Conclusions**

Since 2001 I have claimed that there will an oil bumpy plateau with chaotic prices.
Fossil fuels will likely plateau: now for oil; in a decade for gas, but local shortage soon; in few decades for coal.
World fossil fuels consumption per capita will stay flat for the next 20 years and then decline sharply.
It is unlikely that other energies could to fill the gap to satisfy a growing demand
The only solution is to save energy by changing our behaviour, in particular our way of life in a consumption society.
The coming depression and high oil price could offer the cure for change in our way of life!
Americans use twice more energy per capita than Europeans, with similar income.
Falling oil price will damage oil savings.
High oil price will damage globalisation.
GDP is a poor indicator of growth and is not connected with happiness or well-being.
*Business as usual* forecasts are doomed to fail because a constant growth is impossible in a limited world
Paul Valery wrote in 1931: *Le temps du monde fini commence*

But the more I now, the more I know that I do not know, and the others neither