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Peak oil and other peaks

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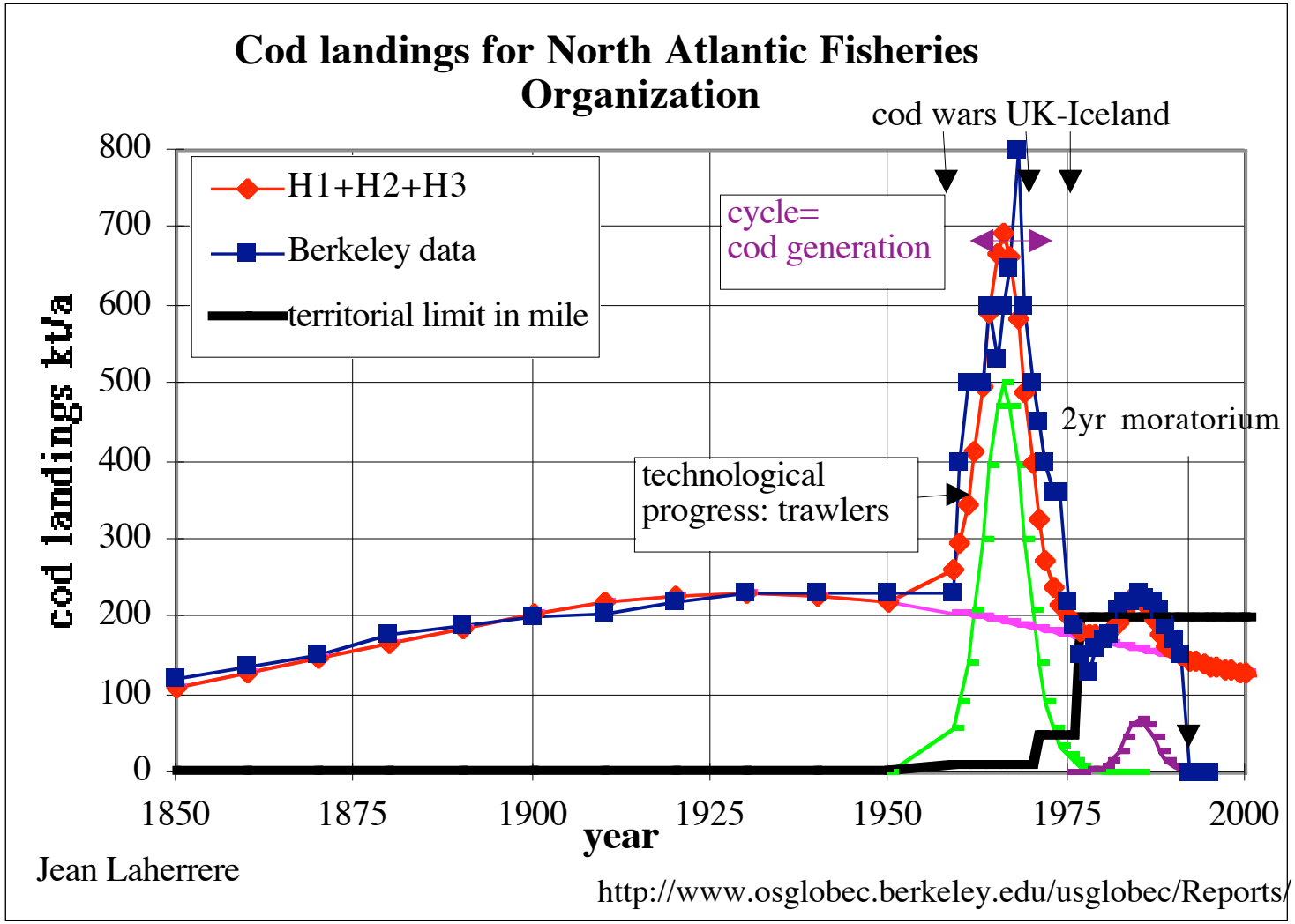
Peak oil (Google 1 690 000) **or oil peak** (104 000)**?**
The highest level or only a high point?
One peak (one cycle = Hubbert peak) **or several peaks** (several cycles)**?**
Peak by lack of demand or by lack of supply?
Peak or bumpy plateau?

Present basic facts

-What goes up must come down, life is cycle
-what was born will die: sun, earth, mankind and civilization
-constant growth has no future in a limited world
-several peaks and symmetrical cycles
-US oil production has peaked in 1970, world production will peak (maximum) one day
-North Atlantic cod landings has peaked in 1965 and cod is considered as extinct in the Grand Banks
-a graph is worth a thousand words

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



Technology (trawlers) has increased the production, but killed the species after bad estimation of the resources (quotas were designed to fish 20% of the cod resources when in fact they fished 60% plus fishing their food) ! North Sea cod fishing seems to go the same way!

-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 quotas) or poor in front of a tax collector).

-words such as **energy, oil, reserves, conventional, reasonable, sustainable, are badly defined on purpose**

-oil production can be either 72 Mb/d for crude or 83 Mb/d for liquids = oil demand

-as **OPEC members cheat on quotas, production data is badly reported**

-reserves are uncertain, but many definitions, as the SEC (US Securities and Exchange Commission) 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 and Russian classification too optimistic

-reserves represent what will be recovered in future

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

-reserve growth occurs when reserves are reported as the minimum (proved), but does not occur statistically when reported as mean (expected) value

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

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

There are three worlds:

-**economists** having only access to political data, believing that money and technology can do anything

-**managers or politicians** who have to show growth to be well considered

-**technicians** having access to real data and knowing the limits of techniques but hardly free to speak, only if retired

-Political or personal motives: OPEC oil quotas are based on reserves and there is little change in OGJ reporting

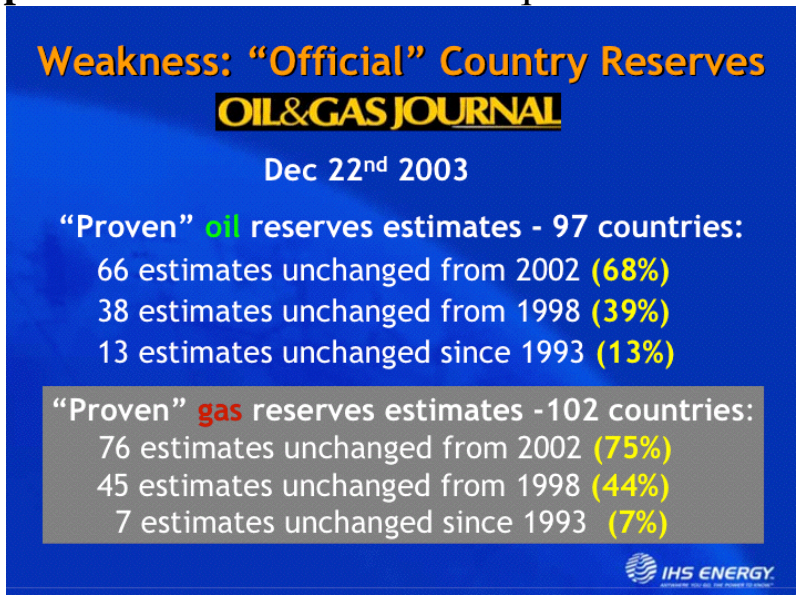


Figure 2: **IEA 1998 forecast by JM Bourdaire: there is a problem**

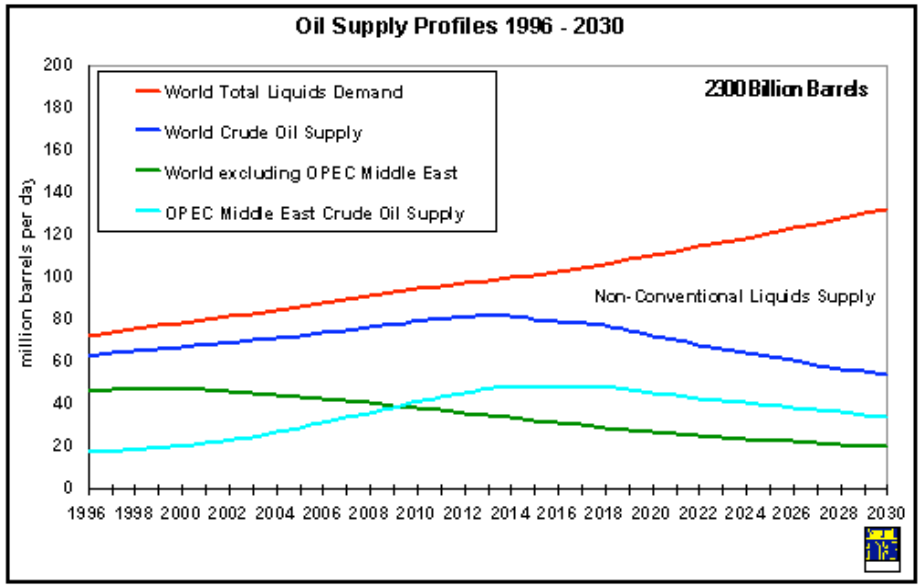


Figure 3: **IEA 2002 forecast by O. Appert: there is no problem**,

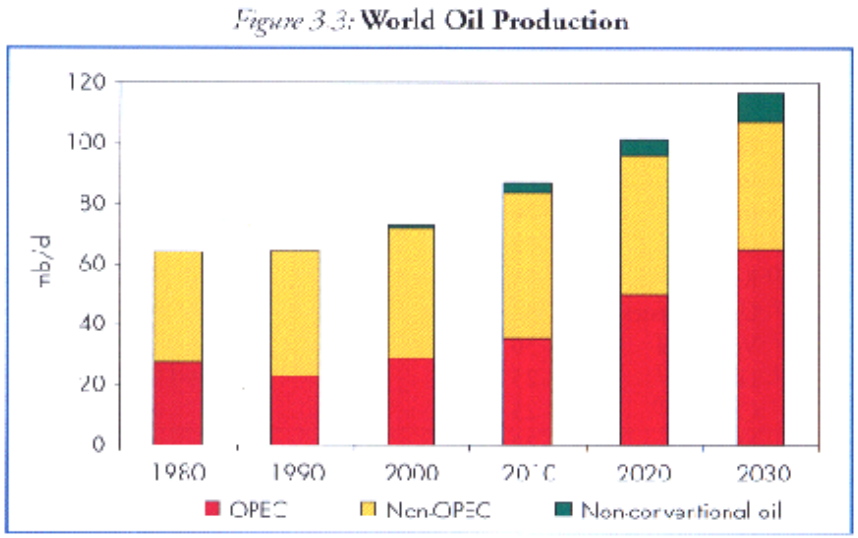


Figure 4: **IEA 2004 forecast by F.Birol: there could be problem**

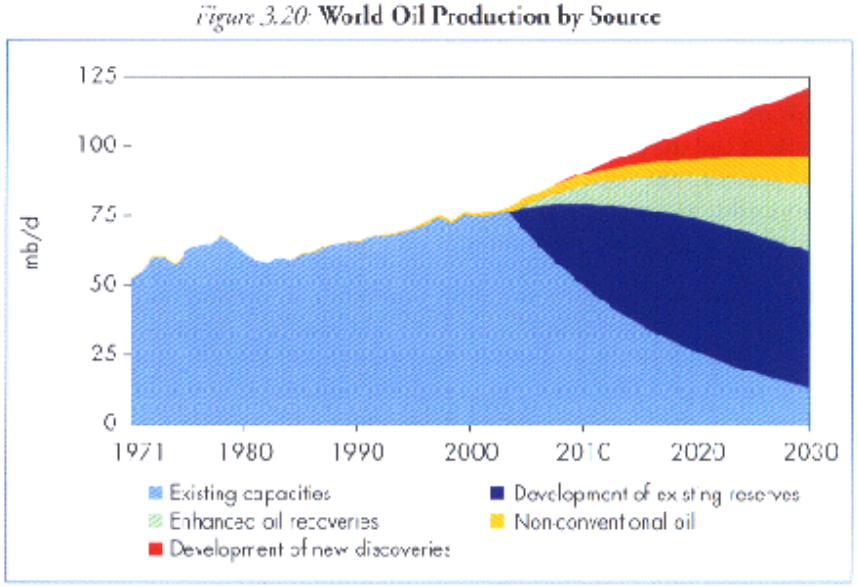
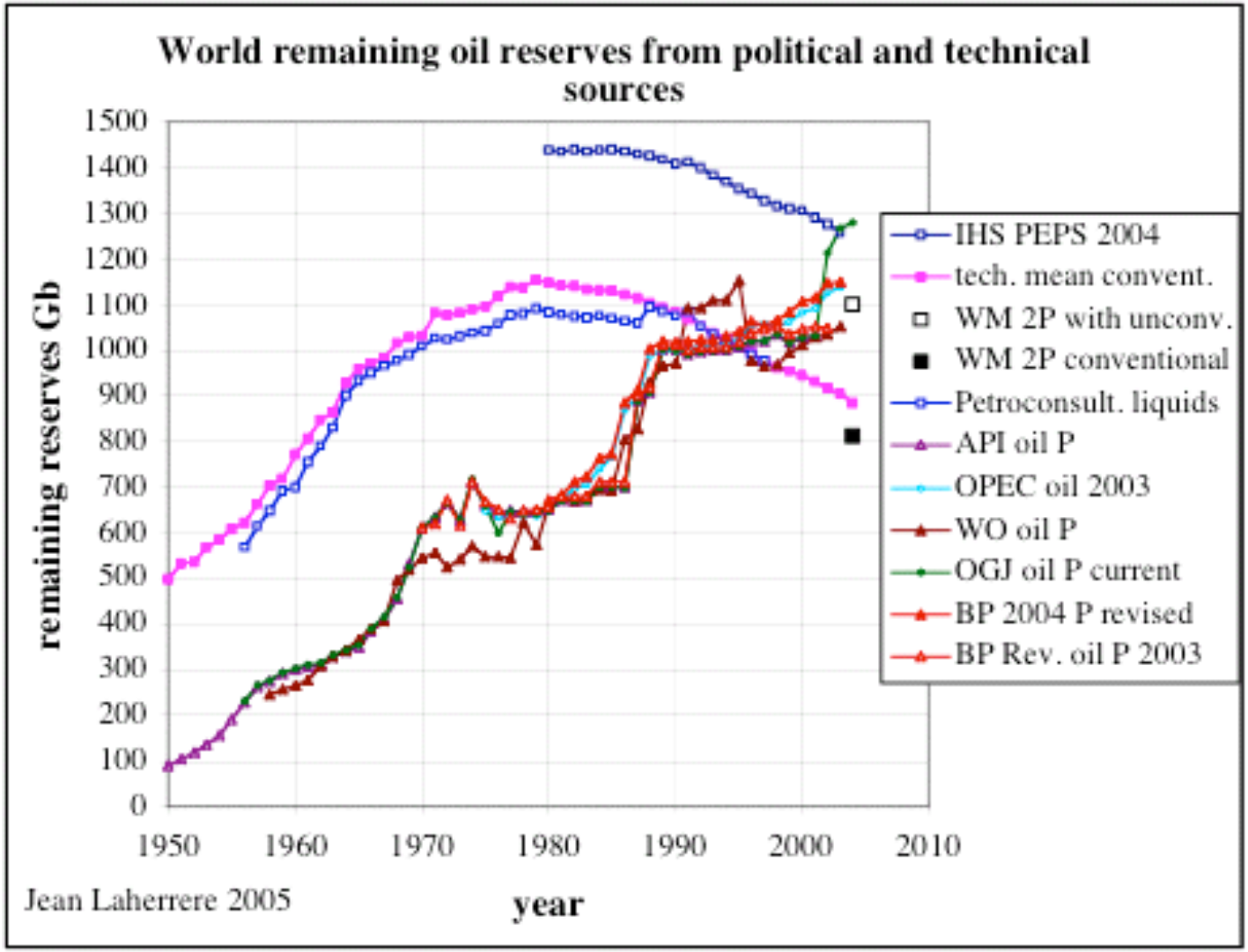


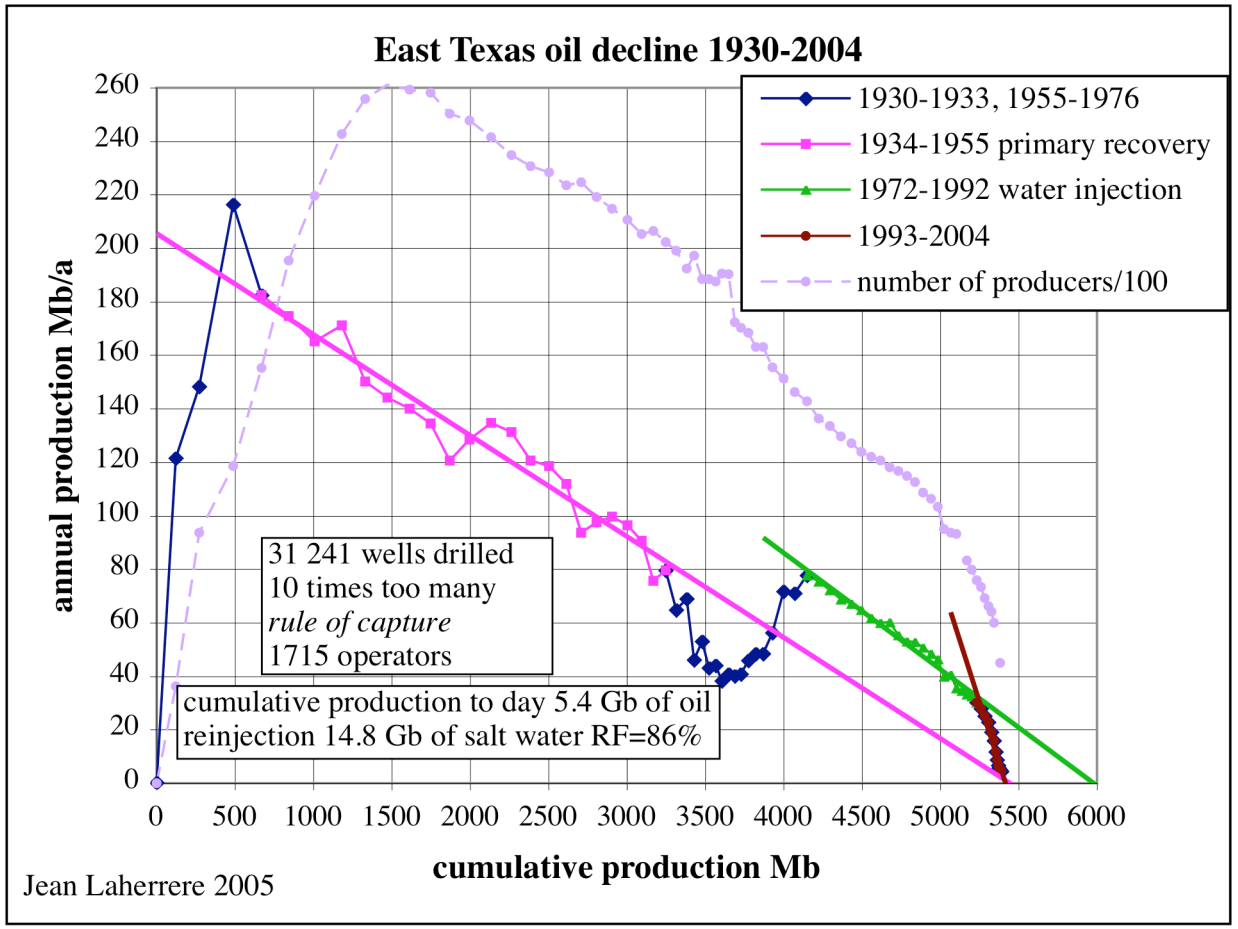
Figure 5: **World remaining conventional oil & gas reserves from political and technical sources**



Political data do not diverge as coming from national oil companies, when technical data from scouting vary
Oil remaining reserves has peaked in 1980!

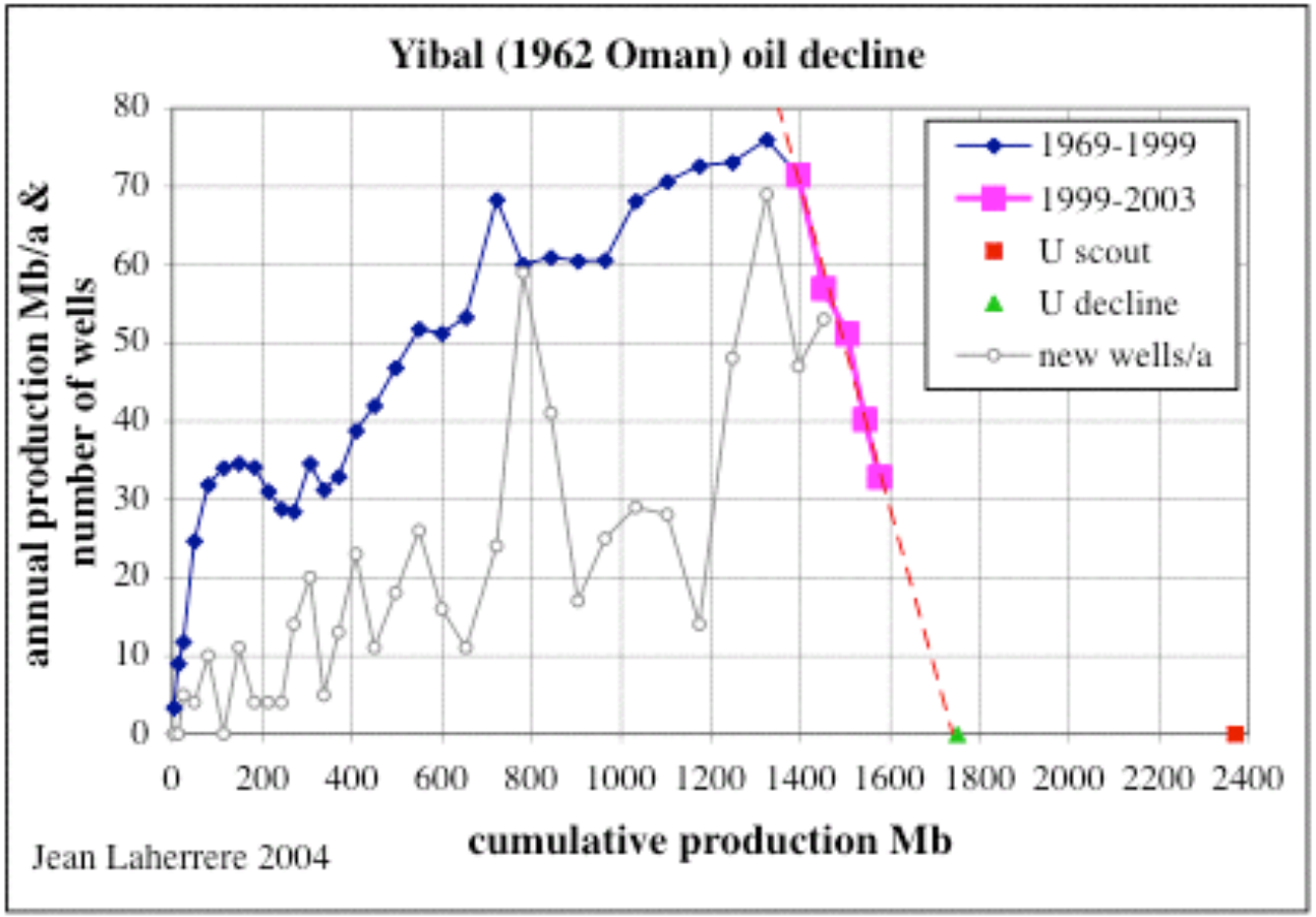
-**Reserve growth** USGS 2001 report = world reserve growth = 700 Gb, based on US proved reserve growth of old fields applied to the rest of the world proven+probable reserves = unscientific approach, furthermore reserve growth is often negative

Figure 6: **Oil decline of East Texas, largest US L48 oilfield 1930-2003**



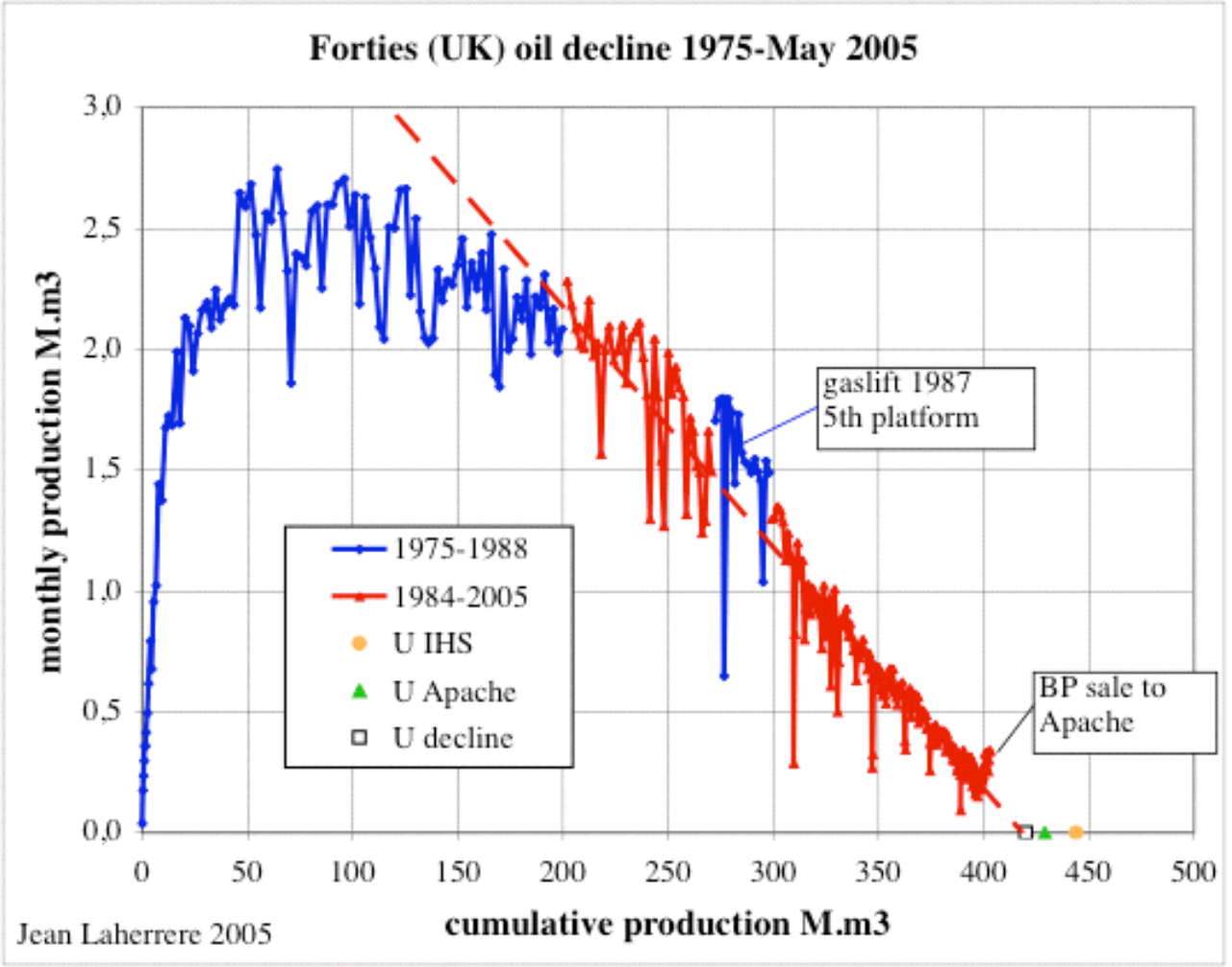
Over 30 000 wells have been drilled (by over 1700 different operators) 10 times too many, because *rule of capture*! There is a very active water drive and the recovery is estimated at 86 %. Present water cut is over 98% =14 000 b/d of oil with 1 000 000 b/d of water from 4500 wells!

Figure 7: **Oil decline of Yibal, largest field in Oman 1969-2003,** operated by Shell



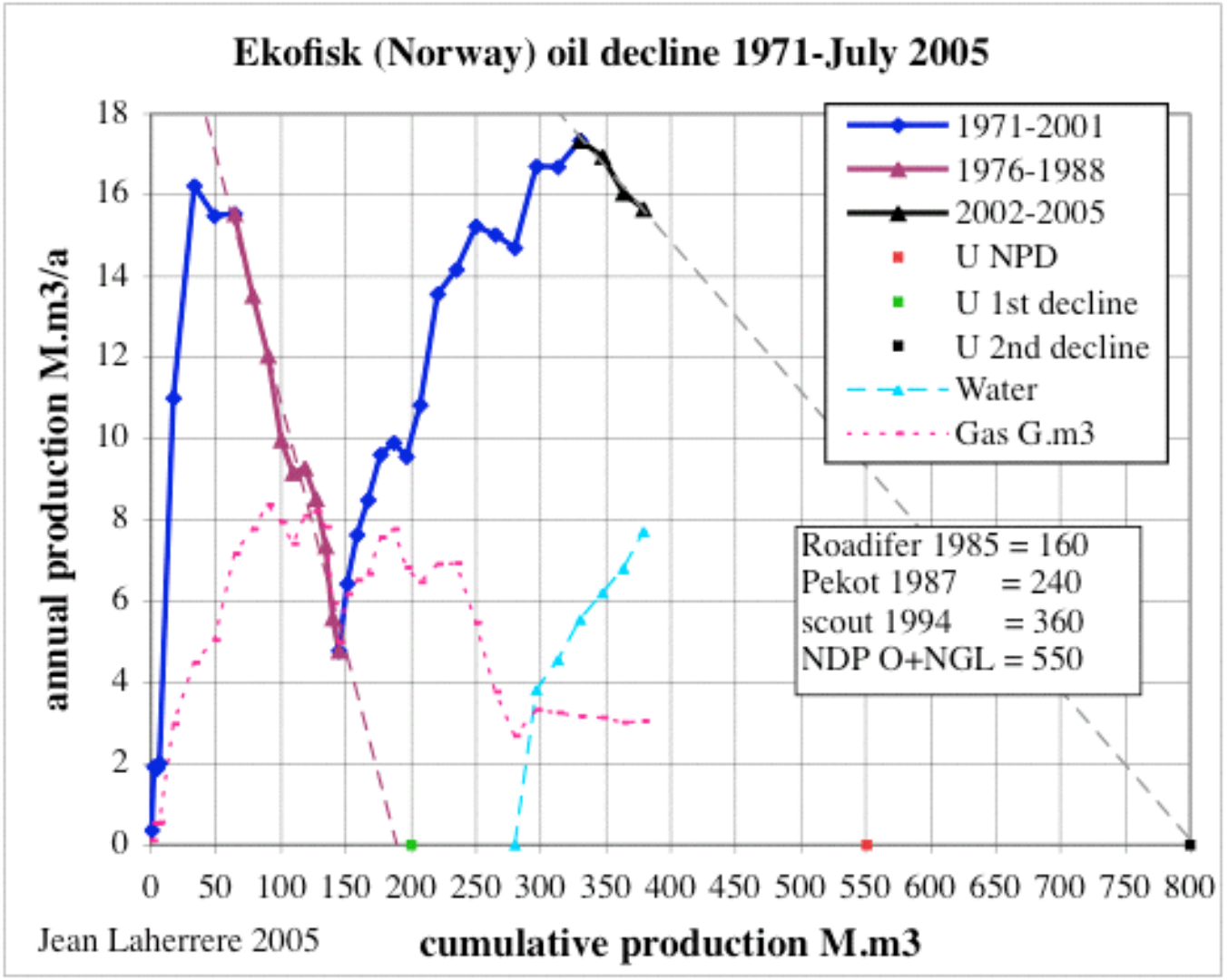
Horizontal wells allow producing faster, but no more in conventional fields. Field production pattern usually declines slowly (old good practice = maximum oil recovery), as shown by East Texas and Forties. Now good practice is to get current maximum profit (pressure from shareholders, mainly pension plans)! Oil produced ten years later has little present value today!

Figure 8: **Oil decline of Forties (UK North Sea) 1984-2005** operated by BP & sold to Apache



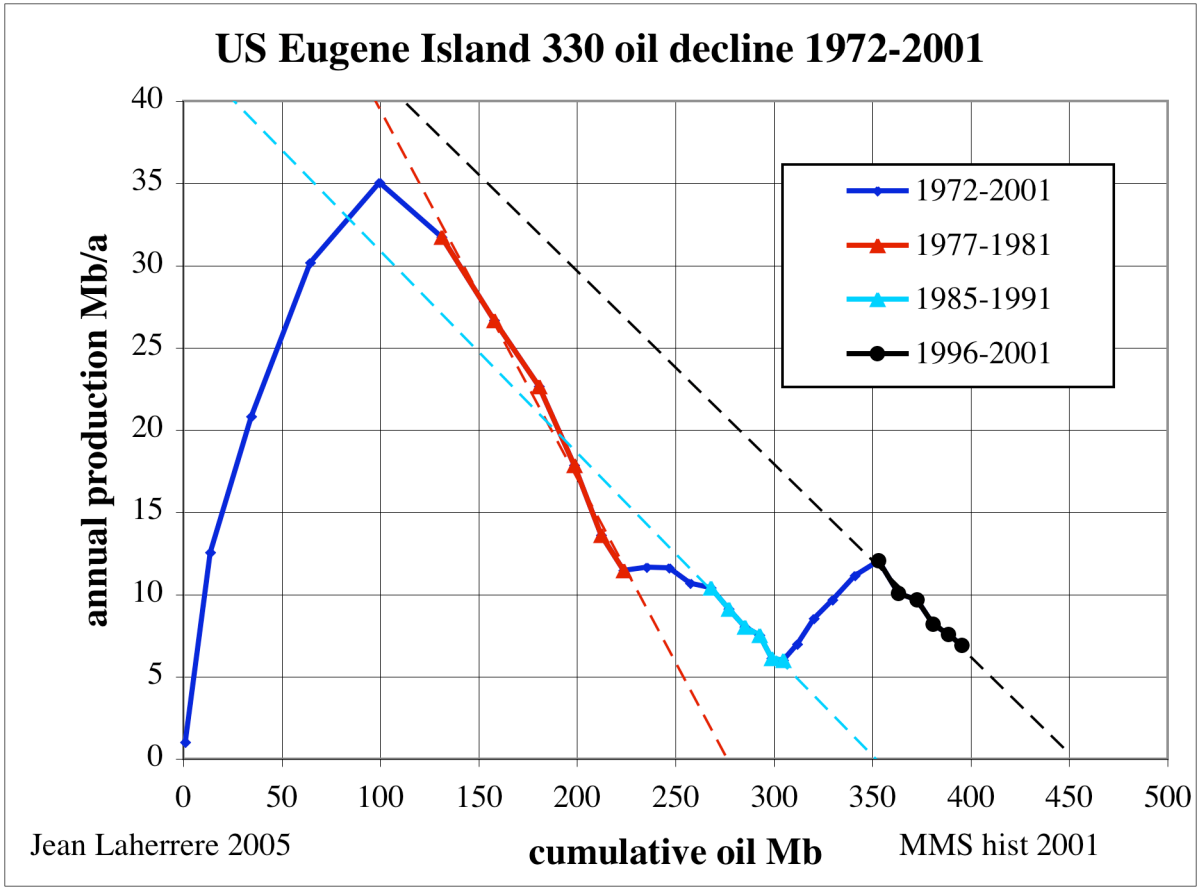
Technology (gaslift) allows producing quicker oil, but no more, as shown by the decline same after as before gaslift

Figure 9: **Oil decline of Ekofisk (Norway) 1971-2003 = exception**



Ekofisk is one of the few example of positive reserve growth due to exceptional reservoir = chalk giving a 7 m sea-floor subsidence after compaction and a strong recovery increase

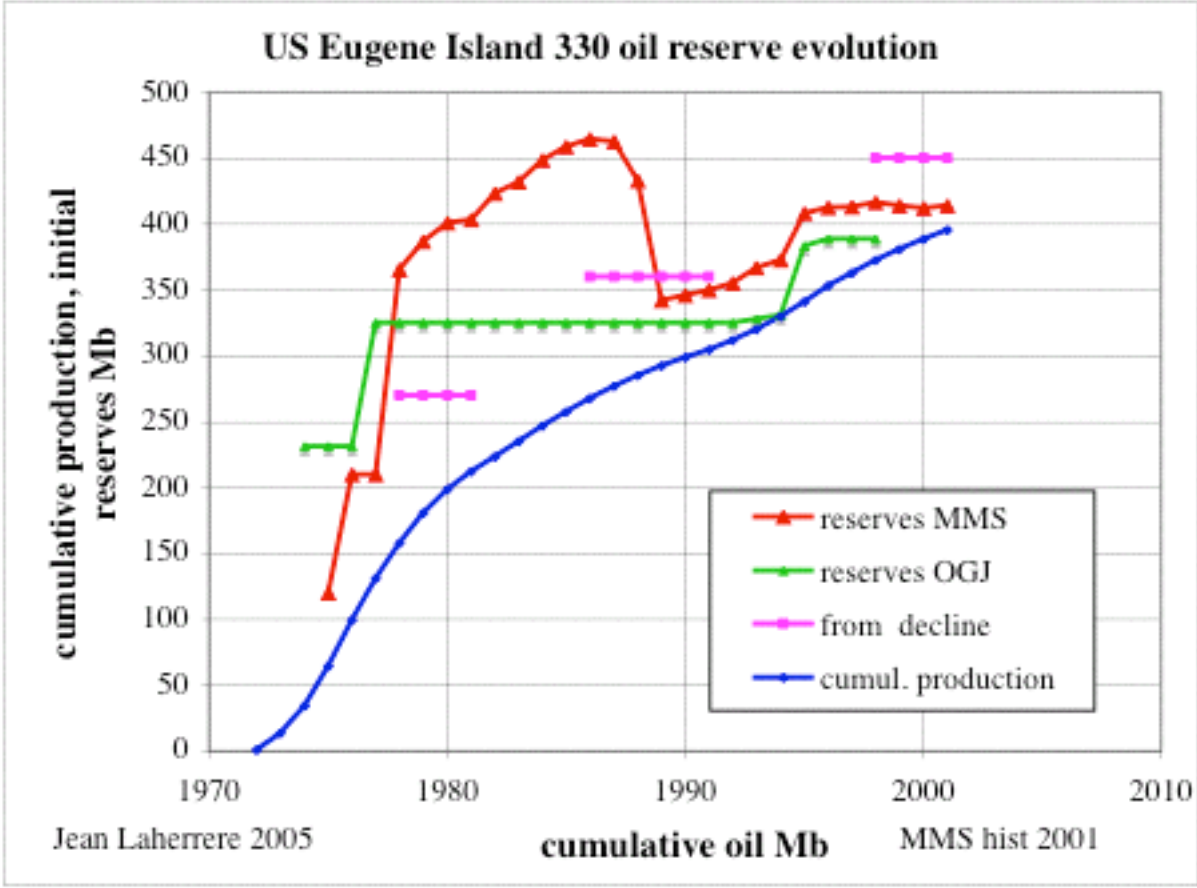
Figure 10: **Oil decline of Eugene island 330 (Gulf of Mexico)** 1972-2000 **= exception** = large fault connecting source-rock and reservoir



Eugene Island 330 reserve growth was described by the Wall Street Journal (Cooper 1999) as example of abiogenic source coming from the mantle, even suggesting that oil is renewable!

But there is no positive reserve growth on data coming form the MMS (USDOI-Mineral Management Services) which rule the Gulf of Mexico, as in fact their present estimate is far below 1986 value

Figure 11: **Oil reserve evolution of Eugene island 330 1972-2001**



Reserve growth is the main argument of the present USGS head of reserves estimate (T.Ahlbrandt) in contrary of his predecessor Ch. Masters who was denying any growth by using inferred estimates and not proved values. USGS 2000 estimates are as end of 1995, almost 10 years old, but still used by many to justify oil abundance!

-**Resources assessment**

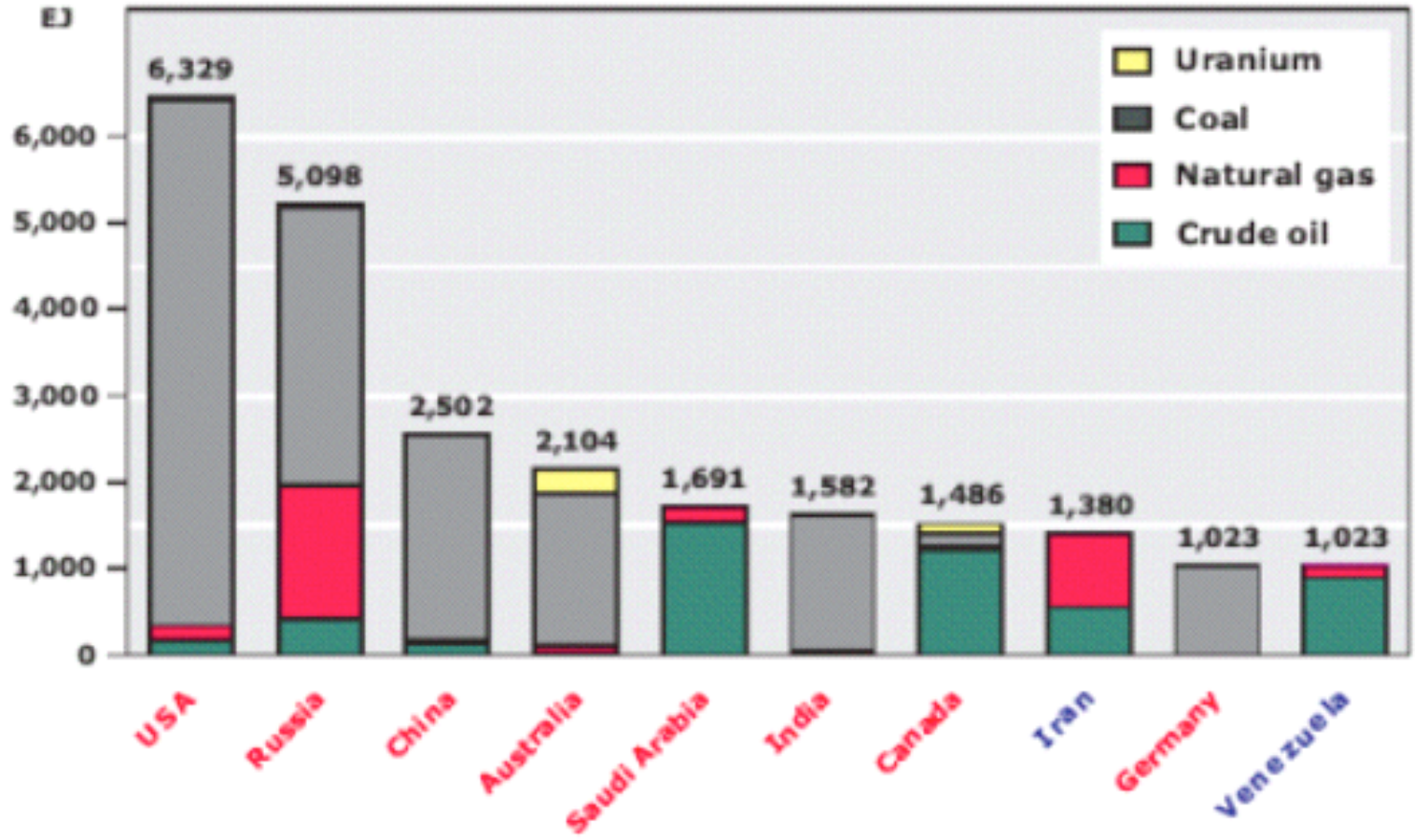
Remaining reserves at estimate year in Gtoe

BGR- Germany	**reserves**		**resources**	
estimate year	**1997**	**2001**	**1997**	**2001**
conventional oil	151	152	76	84
non-conventional oil	134	66	574	250
conventional natural gas	116	122	172	165
non-conventional gas	2	2	2458	1163
hard coal	341	423	3519	2486
soft brown coal	50	47	763	292
uranium	24	15	179	174
thorium	22	22	23	23

Strong decrease in non-conventional resources from 1997 to 2001

BGR is the only agency really assessing the world resources and it is not enough !

BGR displays this interesting graph of the largest fossil fuel reserve countries.
Figure 12: Remaining fossil fuel reserves in 2001 for the largest countries

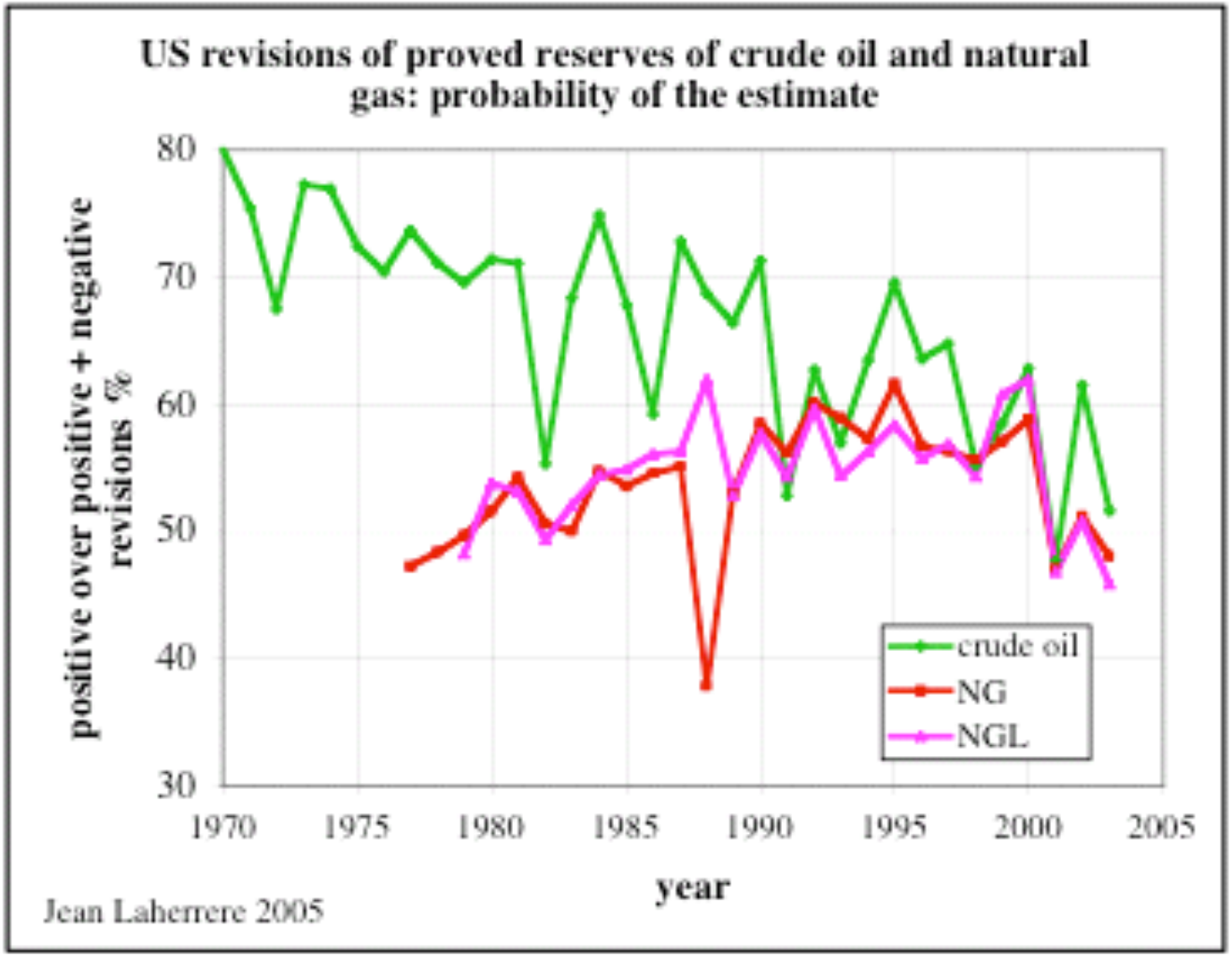


But by capita Australia is the most gifted with reserves of 2500 toe/cap, compared to 1600 for Saudi Arabia, 800 for Russia, 500 for US and 50 for China!

-**Oil**

-**oil reserves and probability**

Figure 13: **US revisions of proved oil & gas reserves giving the probability of the estimate**

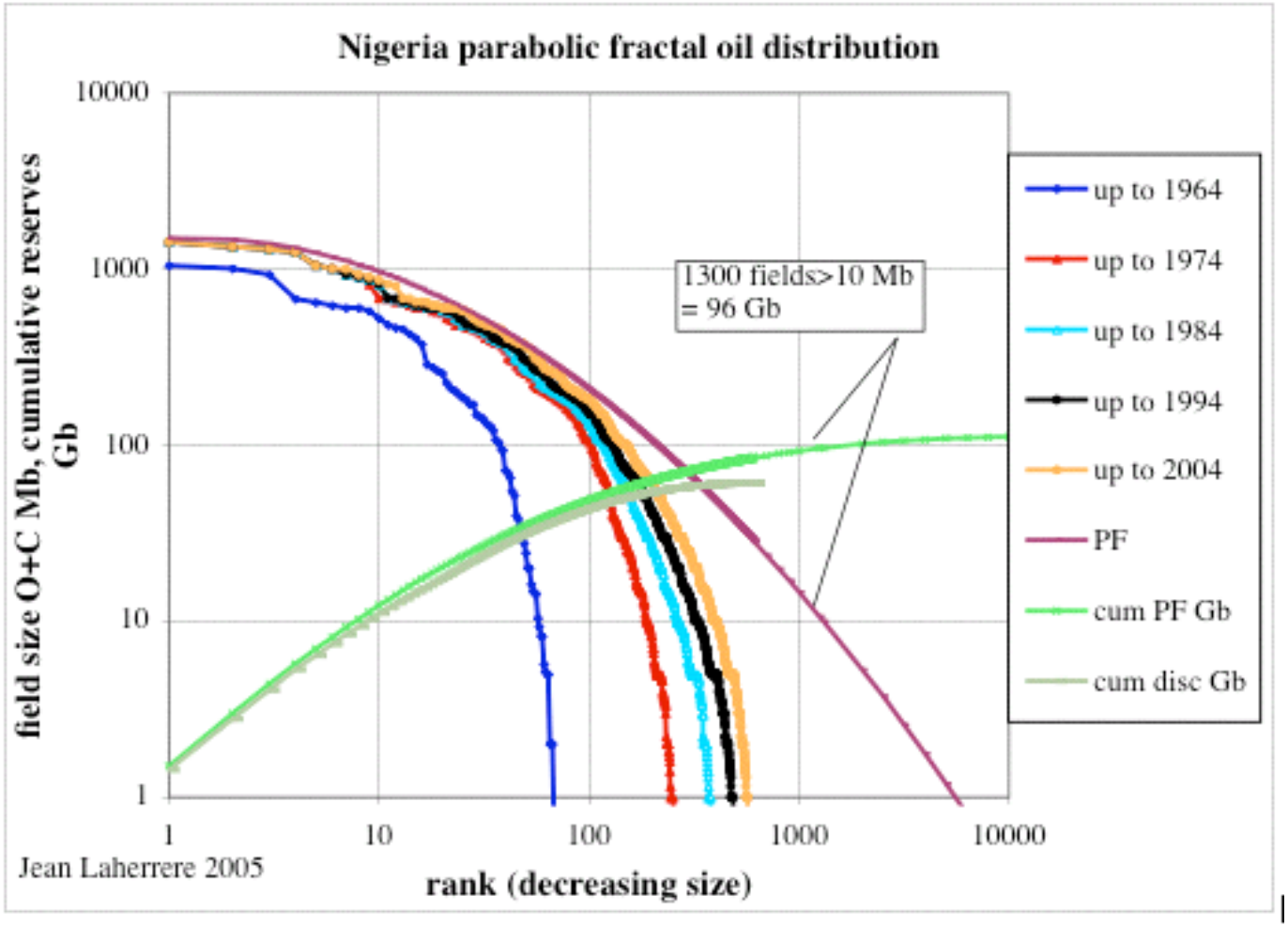


Present probability of US proved reserves is about 50%, far from the SPE/WPC definition of 90%

Reserves distribution

Oil reserves gather in fields as human beings in urban agglomerations or stars in galaxies or earth quakes. It is not, in a size-rang log-log graph, a power law (straight line) as reported by many, but a parabolic fractal as shown by the distribution in the Niger delta :

Figure 14: **Nigeria parabolic fractal distribution (Niger Delta petroleum system)**



Probability
Probabilistic approach in oil reserve estimate is subjective as every field is different, contrary to a random distribution.

The subjective probability involves guessing what is the minimum, most likely and maximum of the parameters: area, pay, porosity, and saturation. Only post-mortem evaluation is the key of improvement. But many do not want to display their past errors! Recognizing error is the best way of future success!

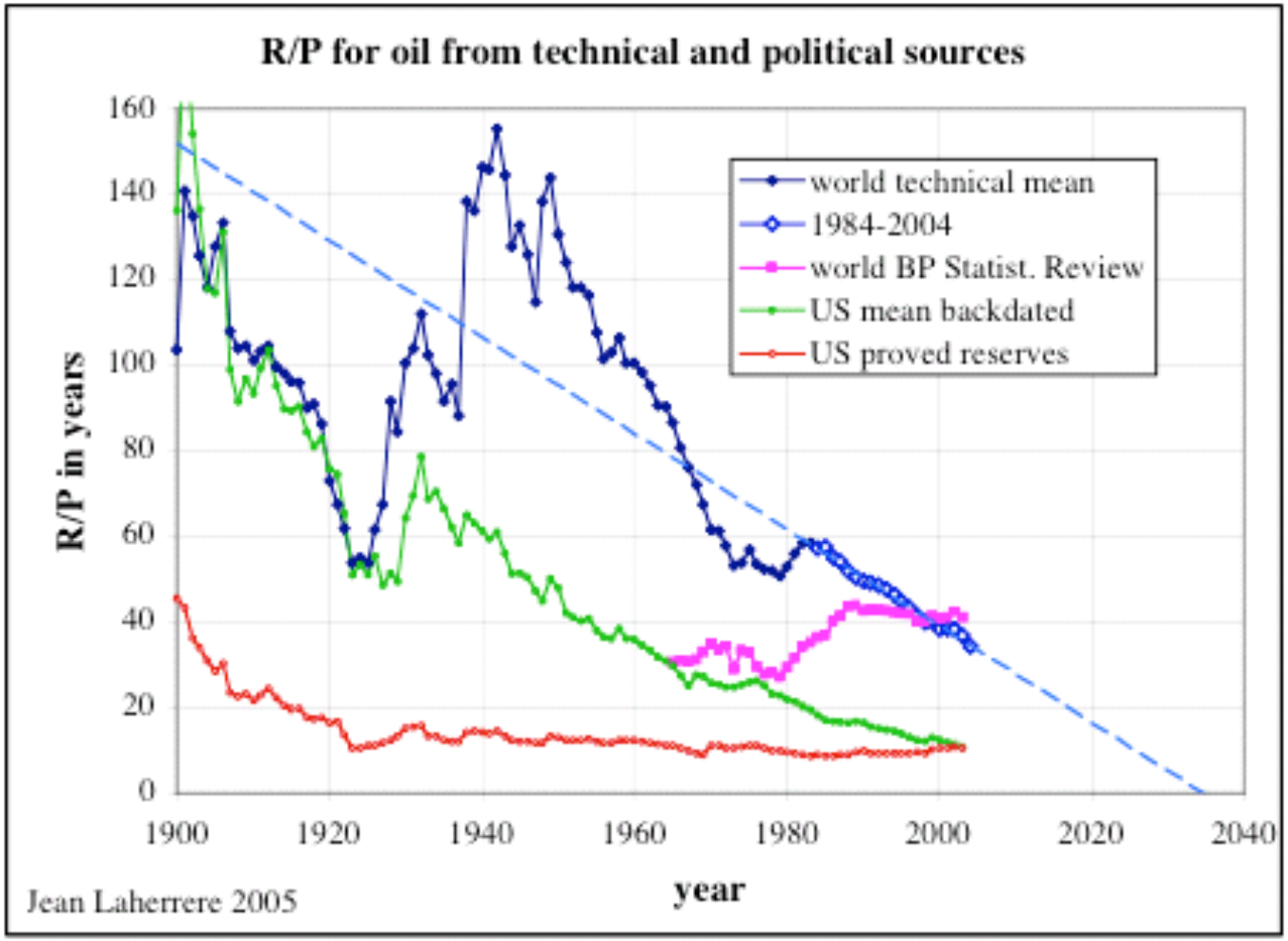
Probability reporting to the medias is often based on wishful thinking, as the NASA reporting a crash in 1 out of 100 000 before 1986 Challenger crash (25^{th} flight), then at the enquiry Nobel price Feynman estimated at 1 out of 100. But the 2003 Columbia crash at the 107^{th} flight shows that he was maybe too optimistic.

Higgs boson was claimed in 2000 to have been discovered with a probability of only 2, 3, 4, 6 and 90 (varying with authors on the web) out of 1000 to be wrong and it is hard for me to see how the "about 3 σ" was estimated with such a narrow confidence level, compared of the uncertainty of this disputed discovery!
I will be pleased to learn more!

-**Oil production forecast**

Medias and politicians claimed that there is oil for the next 40 years and gas for 60 years

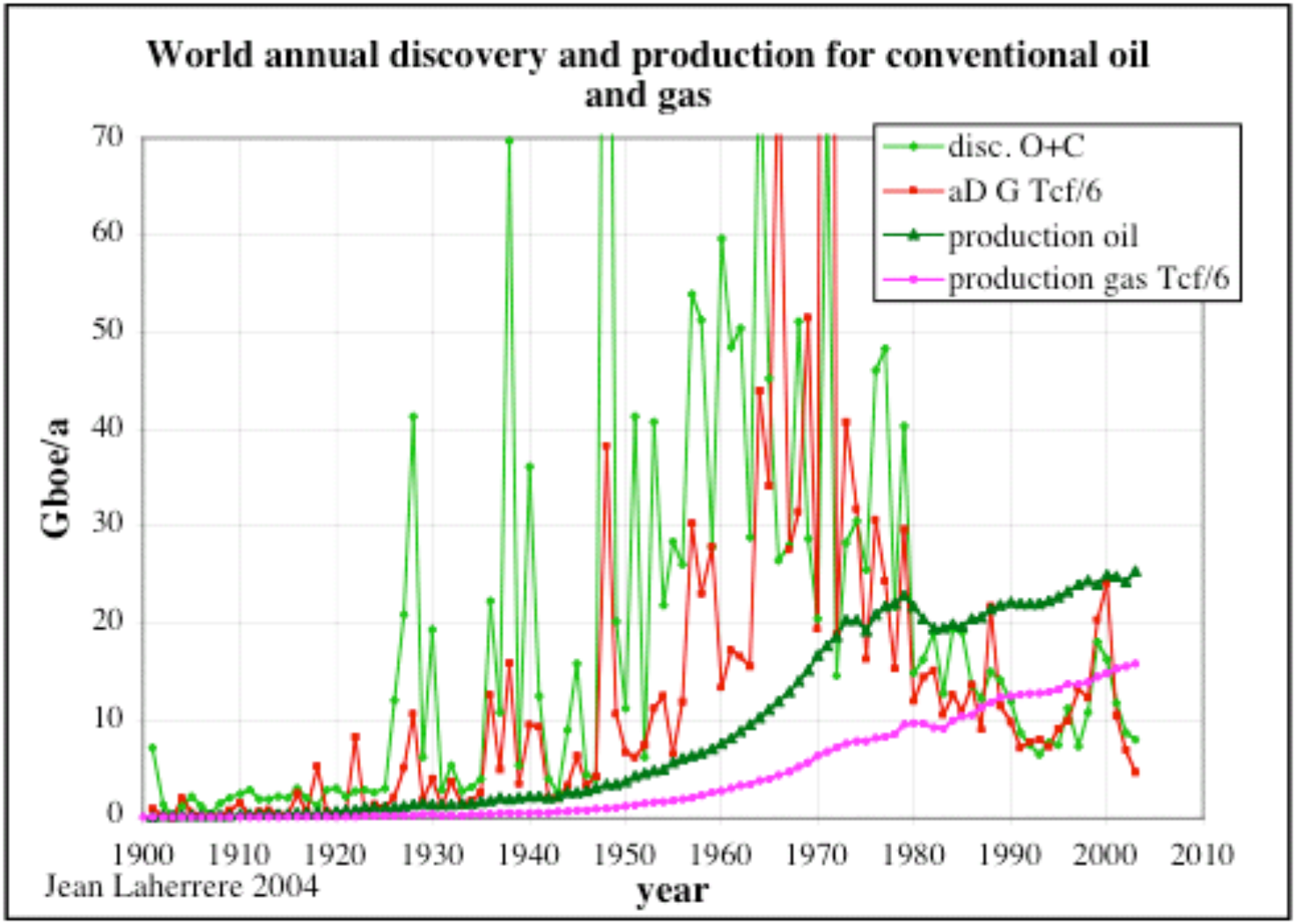
Figure 15: **R/P from technical and political sources for world oil & gas**



R/P from US proved reserves is about 10 years since the last 80 years!

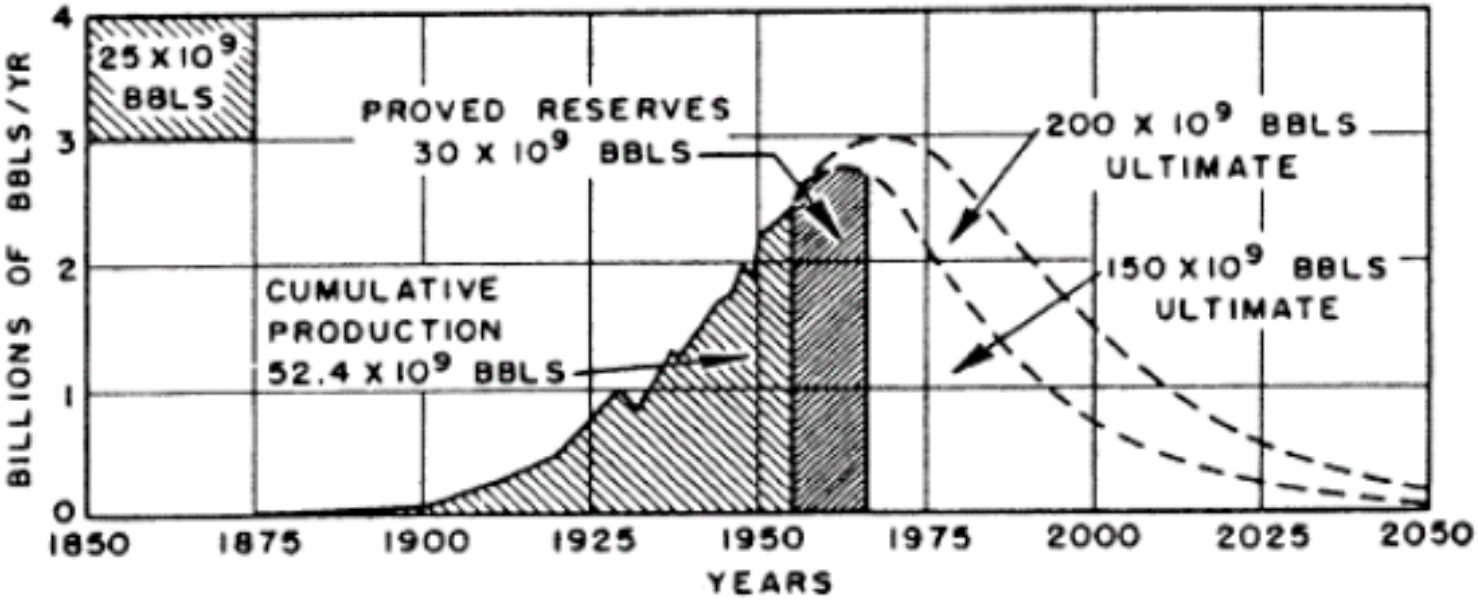
R/P is a very poor parameter but used by all!

Figure 16: **World annual discovery & production for conventional oil & gas**



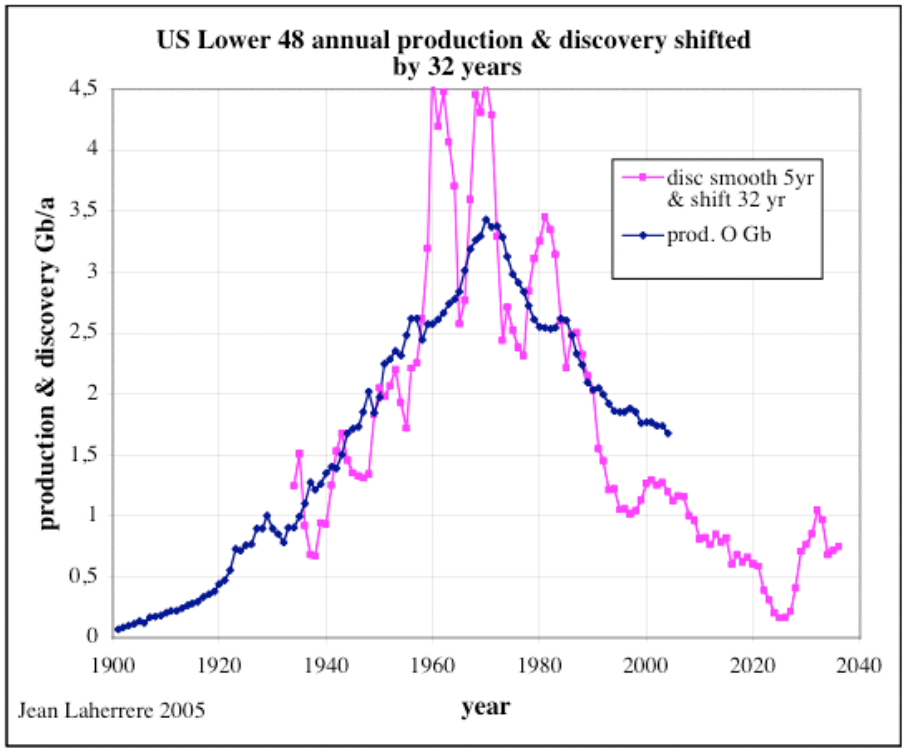
Since 1980, oil production is more than twice discovery (Chevron willyoujoinus.com), gas production about discovery

Figure 17: **King Hubbert forecast the US oil production in 1956**



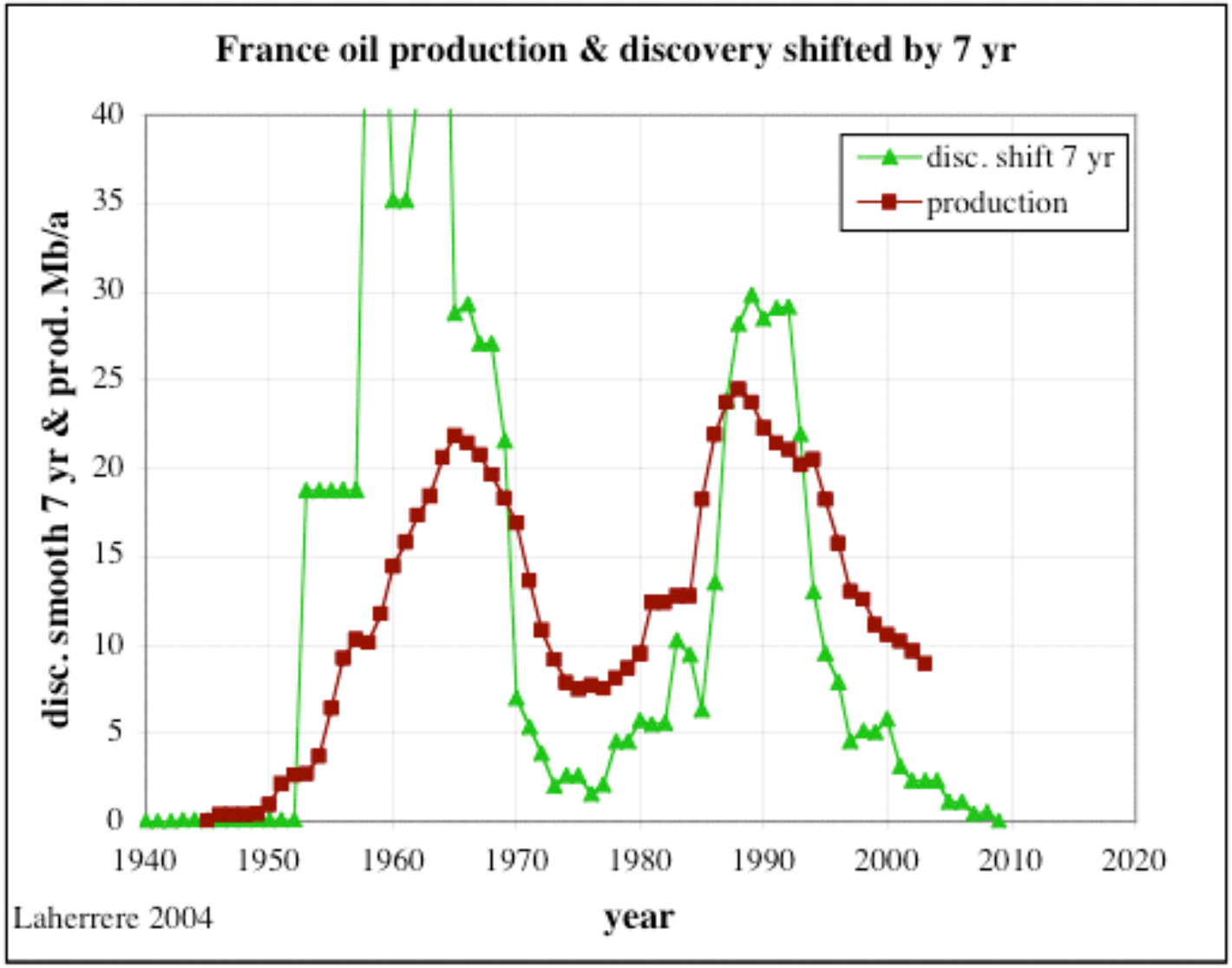
Hubbert forecasted in 1956 from his hand plot (area below the curve = ultimate U) that US oil production will peak in 1965 for U=150 Gb = his estimate or 1970 for U=200 Gb (highest value of Delphi survey)
US (excluding Alaska which joins only in 1959) production peaked in 1970 as the ultimate is close to 200 Gb and random behavior (normal curve) can be expected as there are over 20 000 independent producers (central limit theorem)

Figure 18: **US Lower 48 annual production and mean discovery shifted by 32 years**



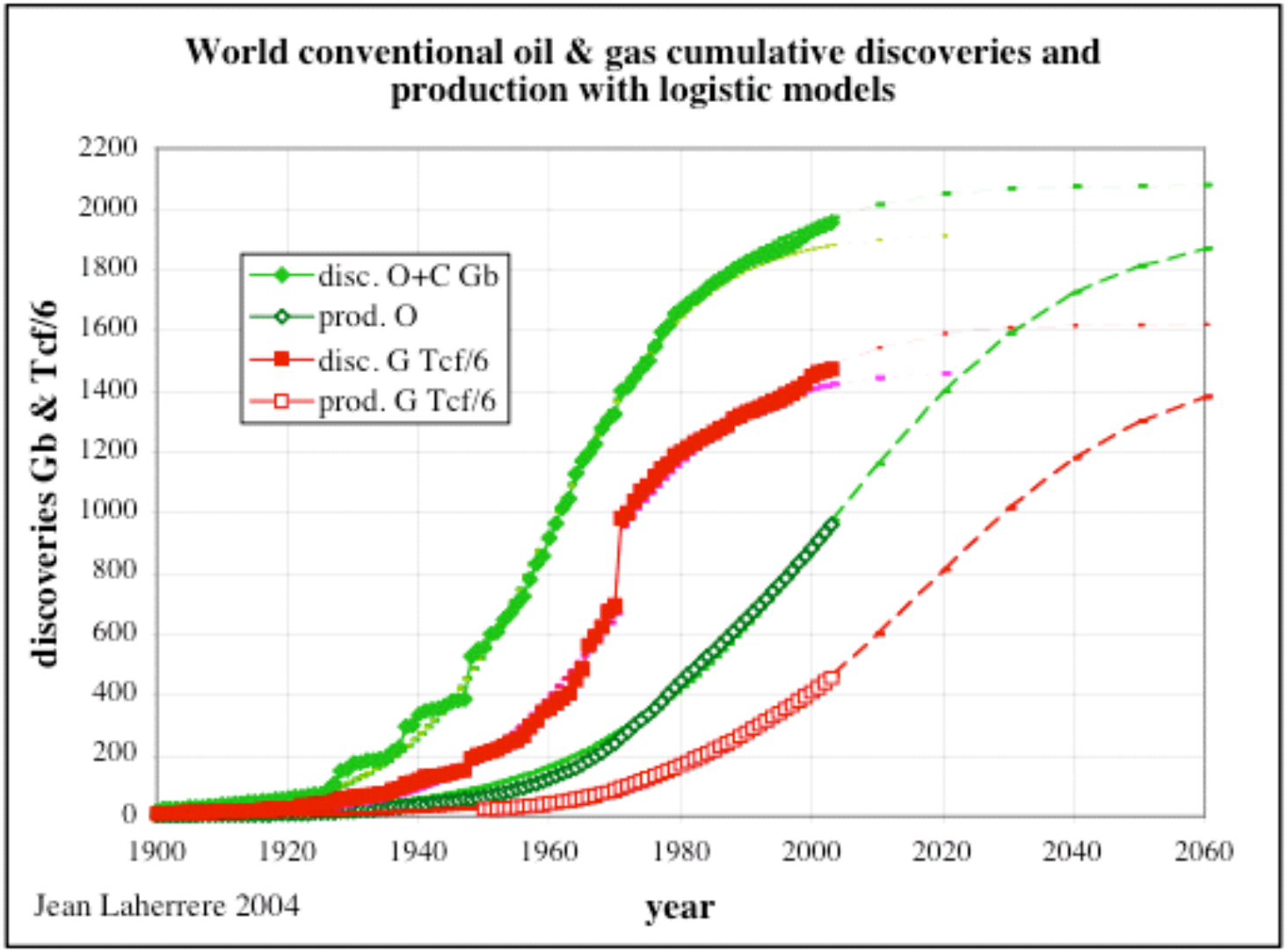
Production mimics discovery.

Figure 19: **France oil production and shifted discovery: 2 discovery cycles & 2 production cycles**



Most countries display several peaks for discovery, as production.

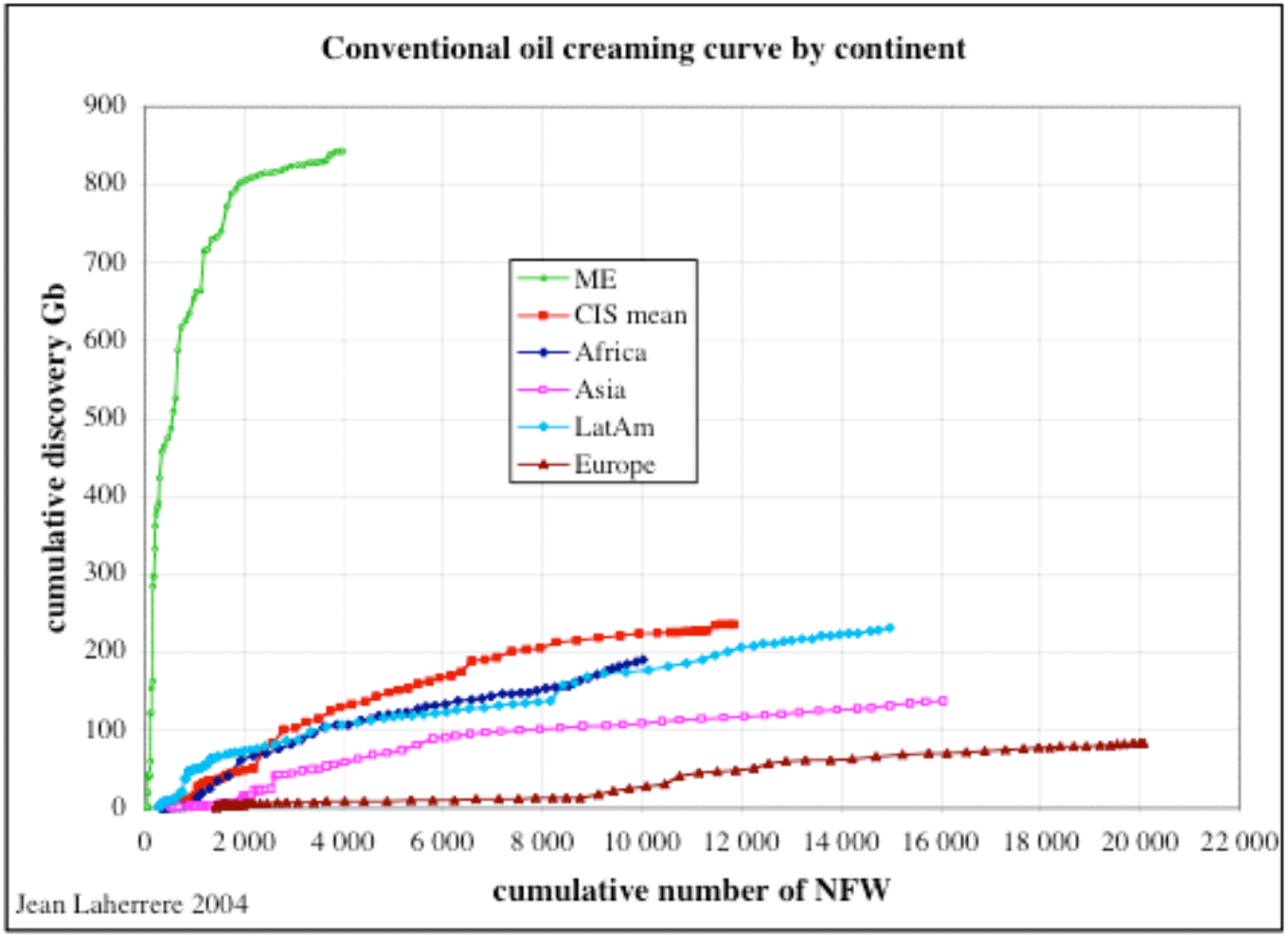
Figure 20: **World conventional oil & gas discoveries and production with logistic models**



Most of cumulative discoveries and productions can be easily modelled with several logistic curves. It is not a rule, but a fact.

-**Creaming curves** = cumulative discovery versus cumulative number of exploratory wells

Figure 21: **Conventional oil creaming curve by continent**

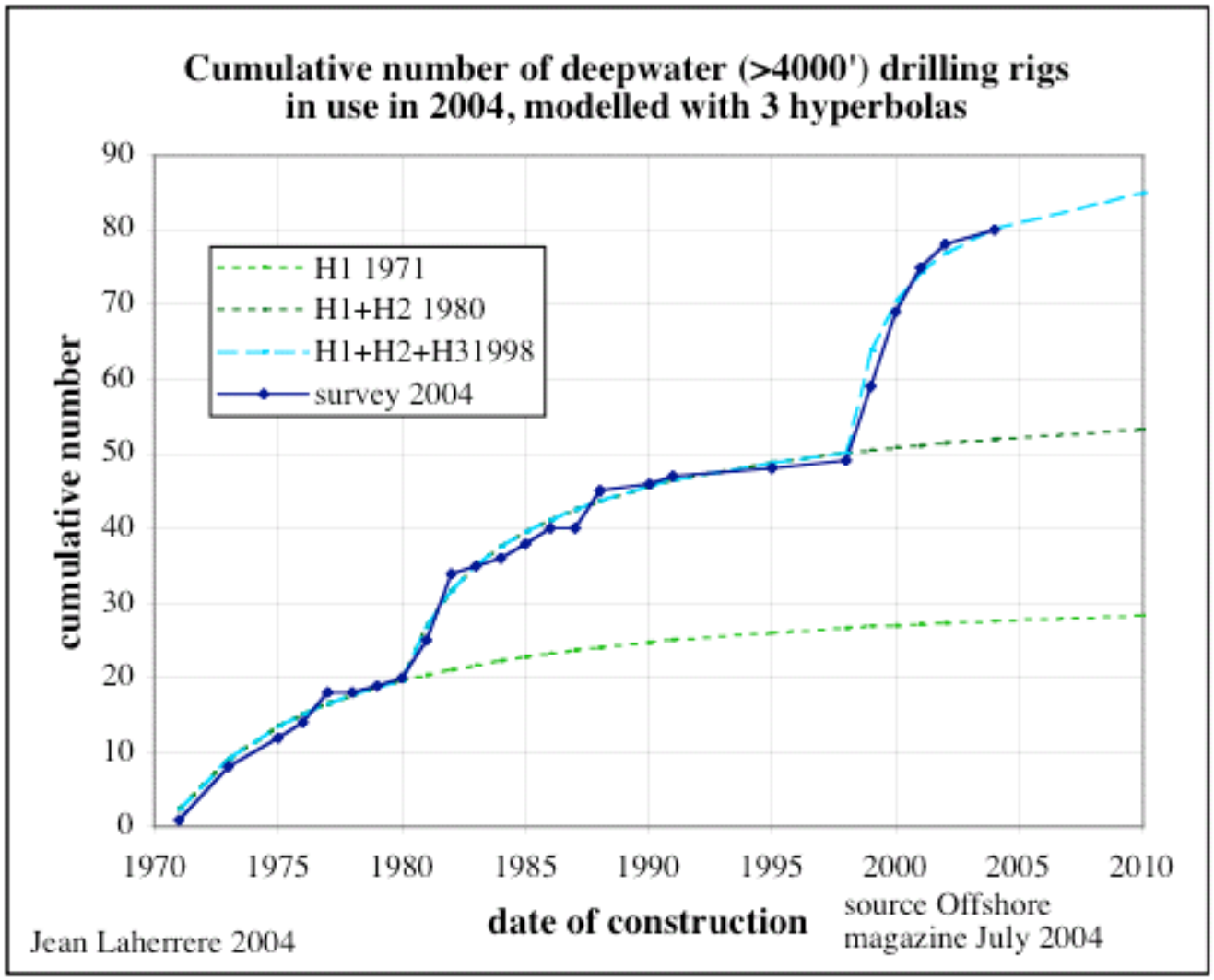


Huge difference in distribution between Middle East and the other continents

Most creaming curves can be easily modelled with several hyperbolas, showing the known “law of diminishing returns” in mineral exploration.

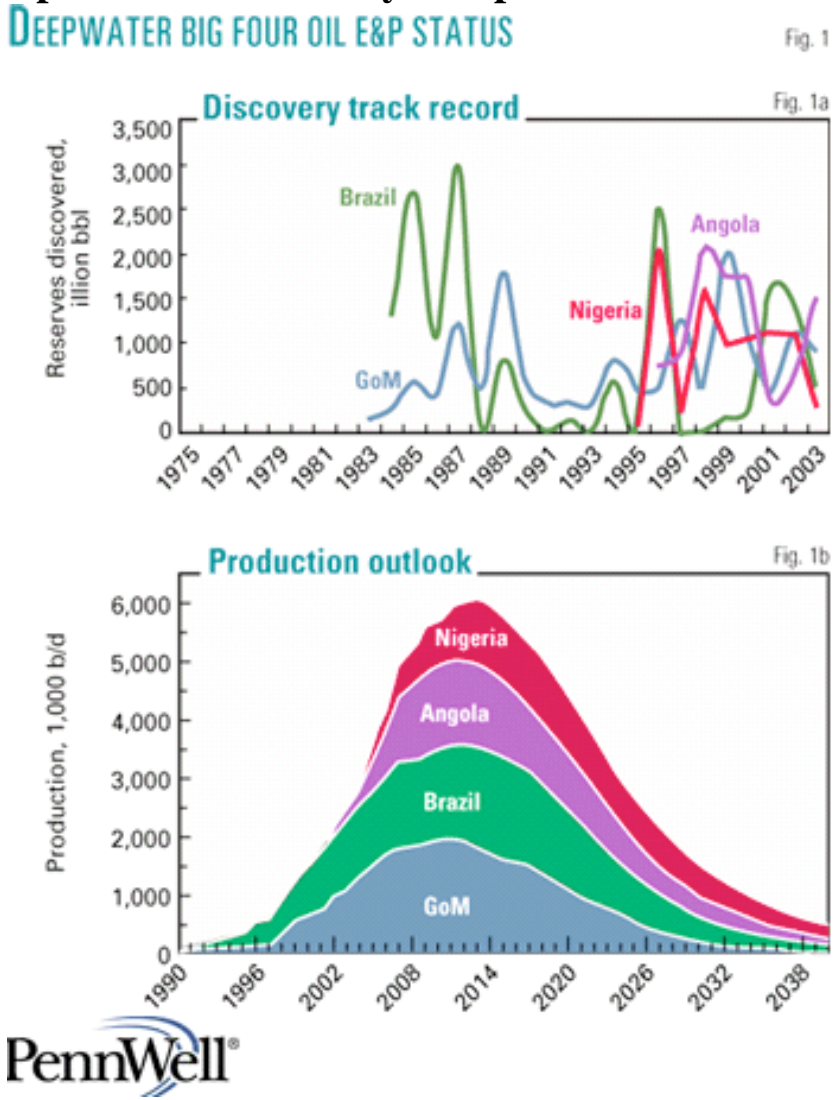
-**Deepwater**

Figure 22: **Cumulative number of deepwater drilling rigs in use in 2004, modeled with 3 hyperbolas**



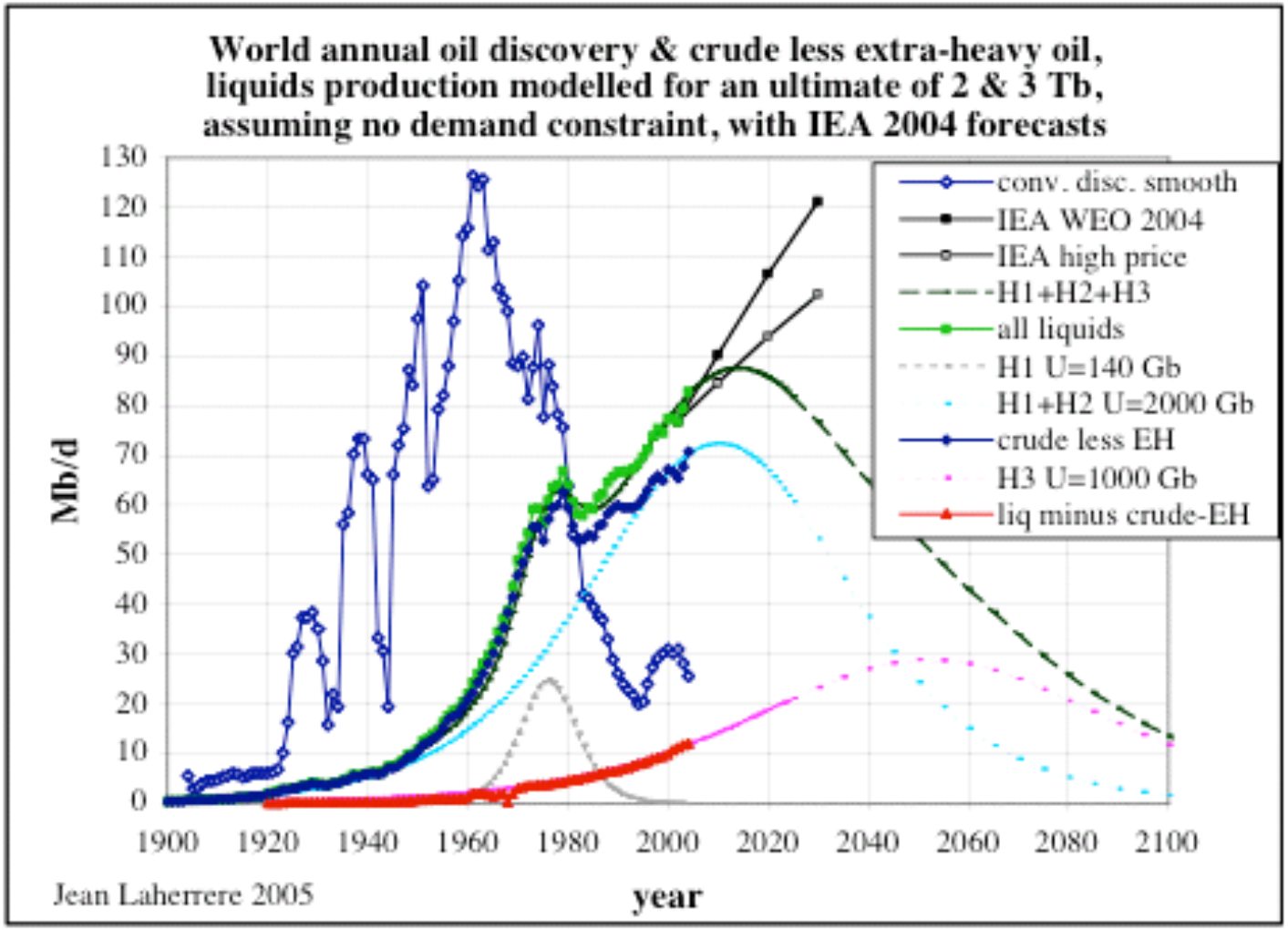
Already 3 cycles of deepwater exploration= 1971, 1980, 1998! Deepwater exploration is not new!

Figure 23: **Deepwater oil discovery and production**



Two peaks for discovery but likely one peak for production as there are no large finds outside Gulf of Mexico, Brazil, Angola and nigeria

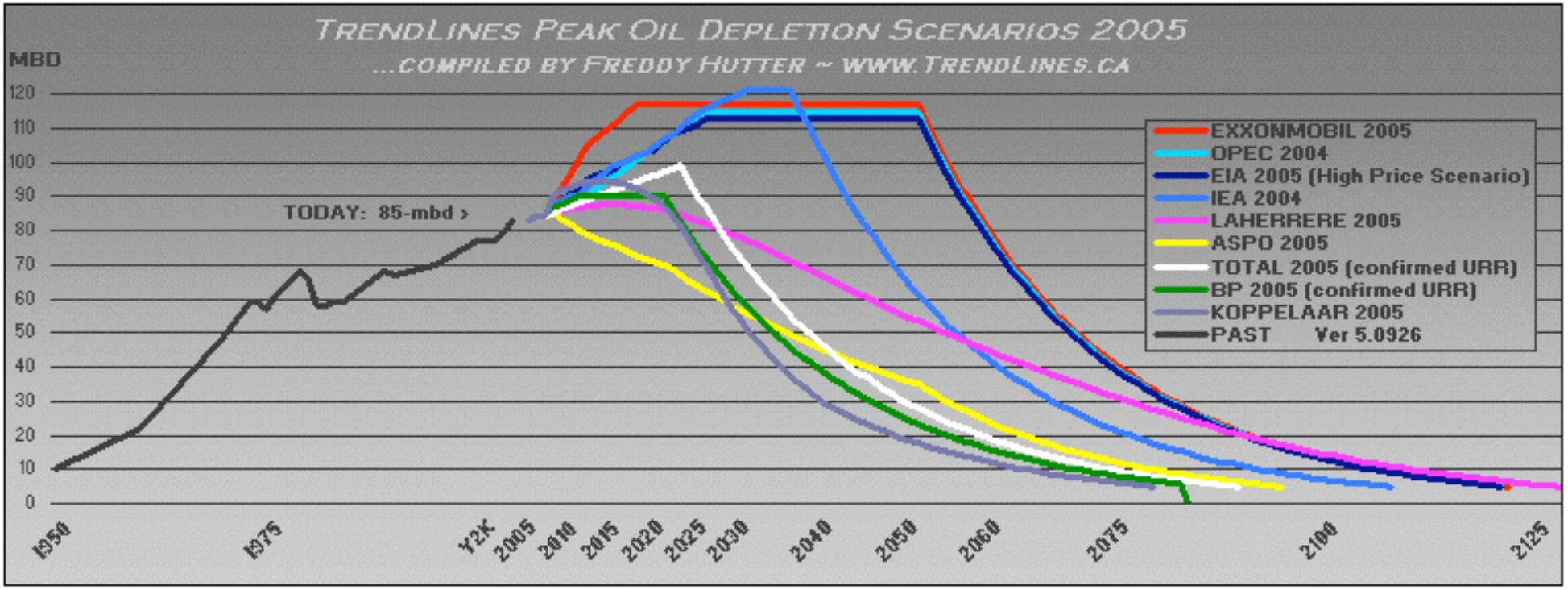
Figure 24: **World liquids production** (no demand constraint) = peak in the 2010s, but likely **bumpy plateau**



Ultimate oil = 3 Tb, which is the sum of
2000 Gb crude less extra-heavy +500 Gb extra-heavy +250 Gb natural gas liquids + 250 Gb synthetic & refinery gains

-**Comparison of different oil forecasts**

Figure 25: **World liquids production different forecasts** plotted by Trendlines



Forecasts can be grouped into 3 groups

-peak at less than 100 Mb/d

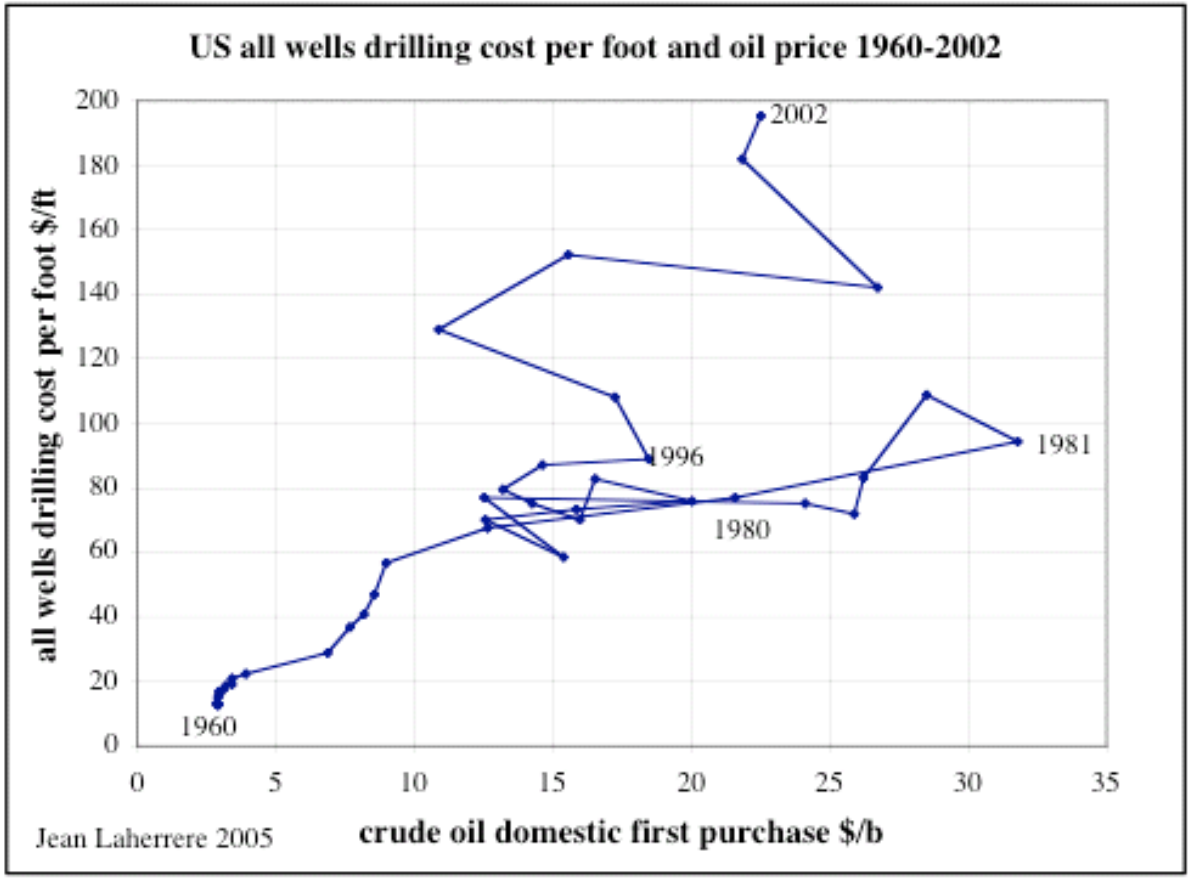
-peak around 120 Mb/d

-no foreseeable peak (not shown on this graph)

-Finding or operating cost and reality

Some claim that with technology costs are down, but facts are different. Drilling cost depends upon oil price.

Figure 26: **US drilling cost versus oil price**



Finding or operating cost has little meaning as it should be done by field and on the entire life.

Break even point from companies in 2004: 25 $/b for Shell, 21 $/b for Total

Only data on development in $/b/d are reliable because short period and known price and maximum capacity. The range in $/b/d was about 1 000 easy, 5 000 offshore, 10 000 deepwater, 25 000 extra-heavy oil (but much longer plateau), 50 000 GTL, CTL. But prices are going up with oil price, rigs and labor shortage.

Natural gas

Figure 27: **Conventional gas creaming curve by continent**

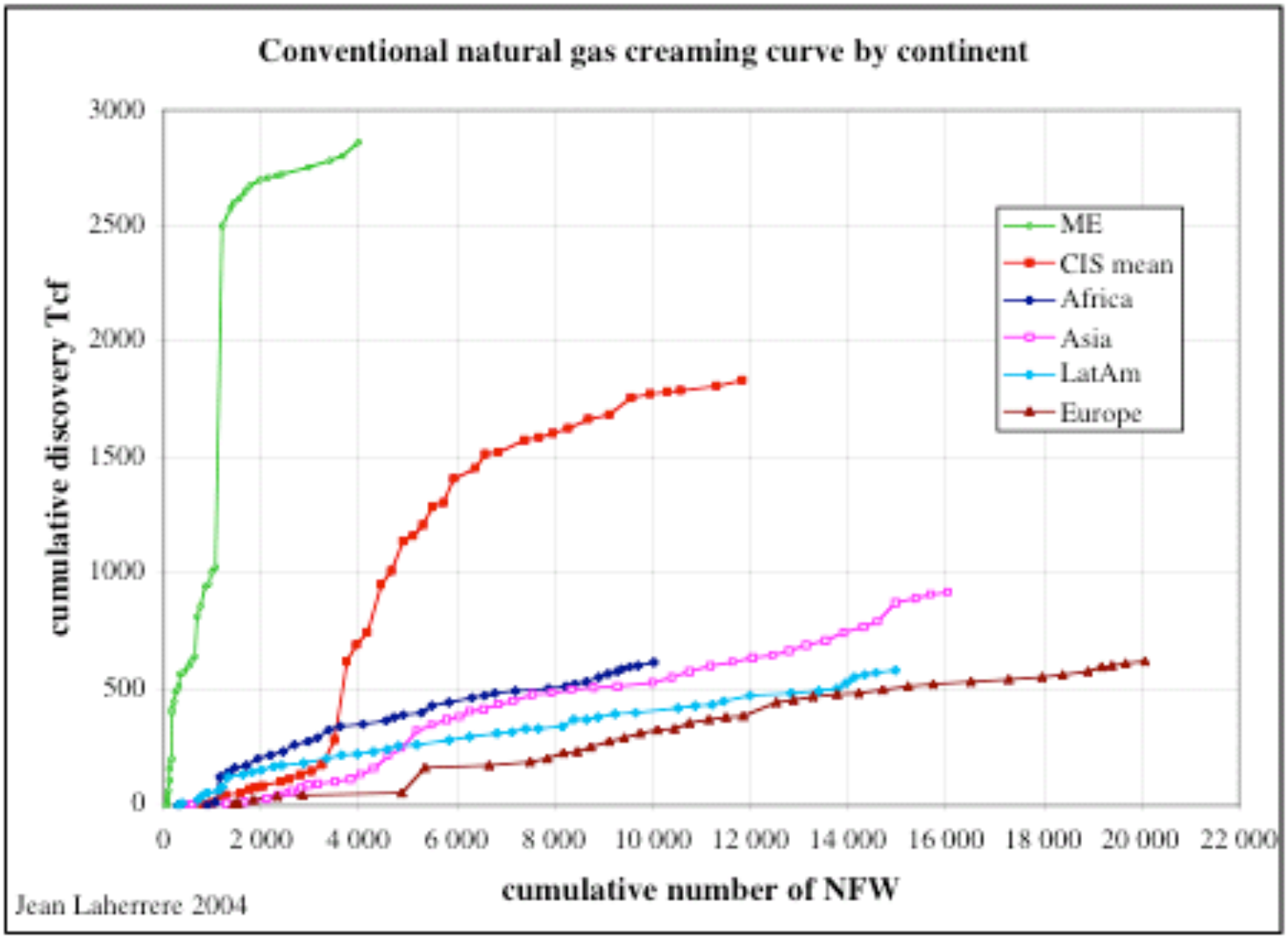
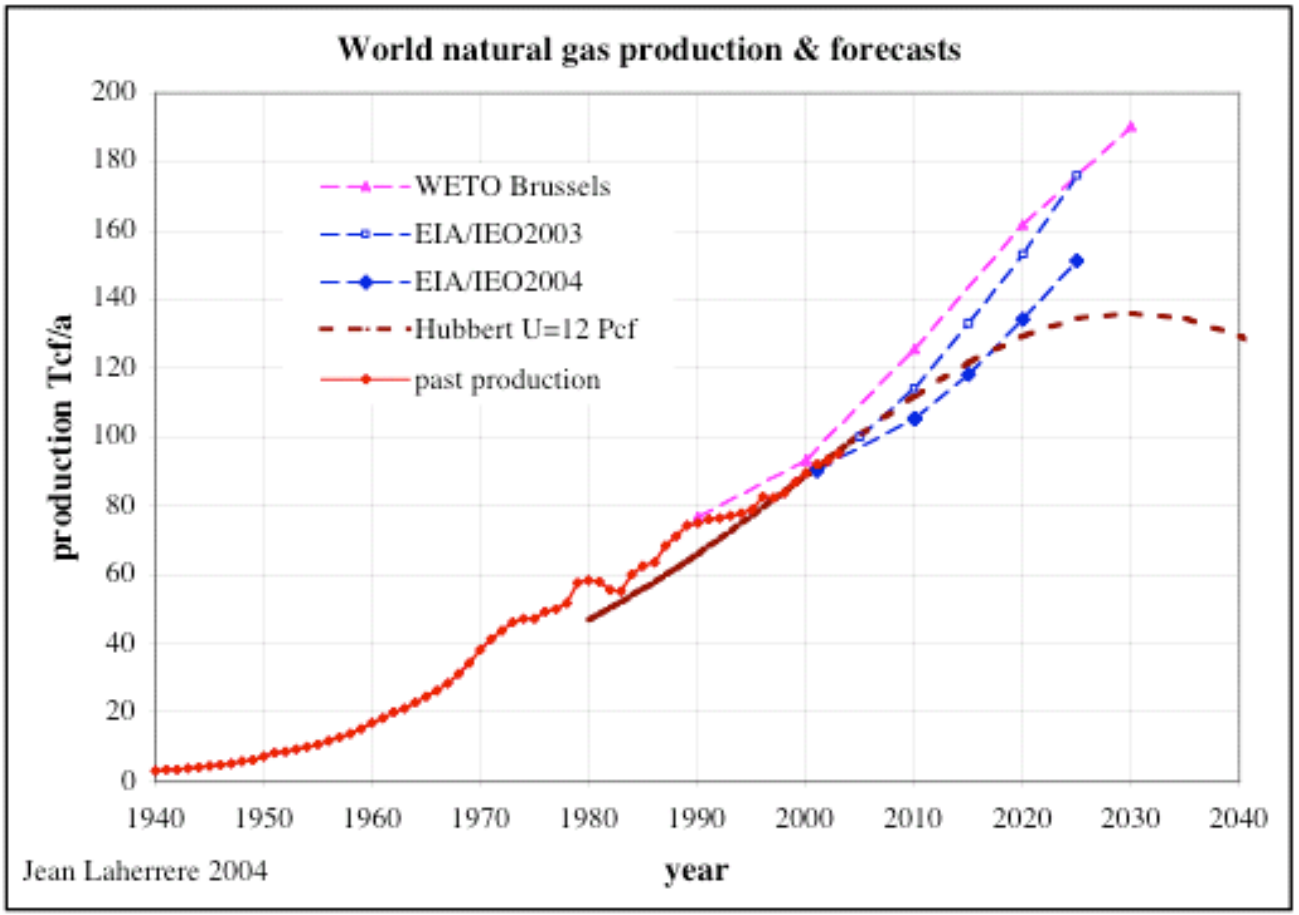
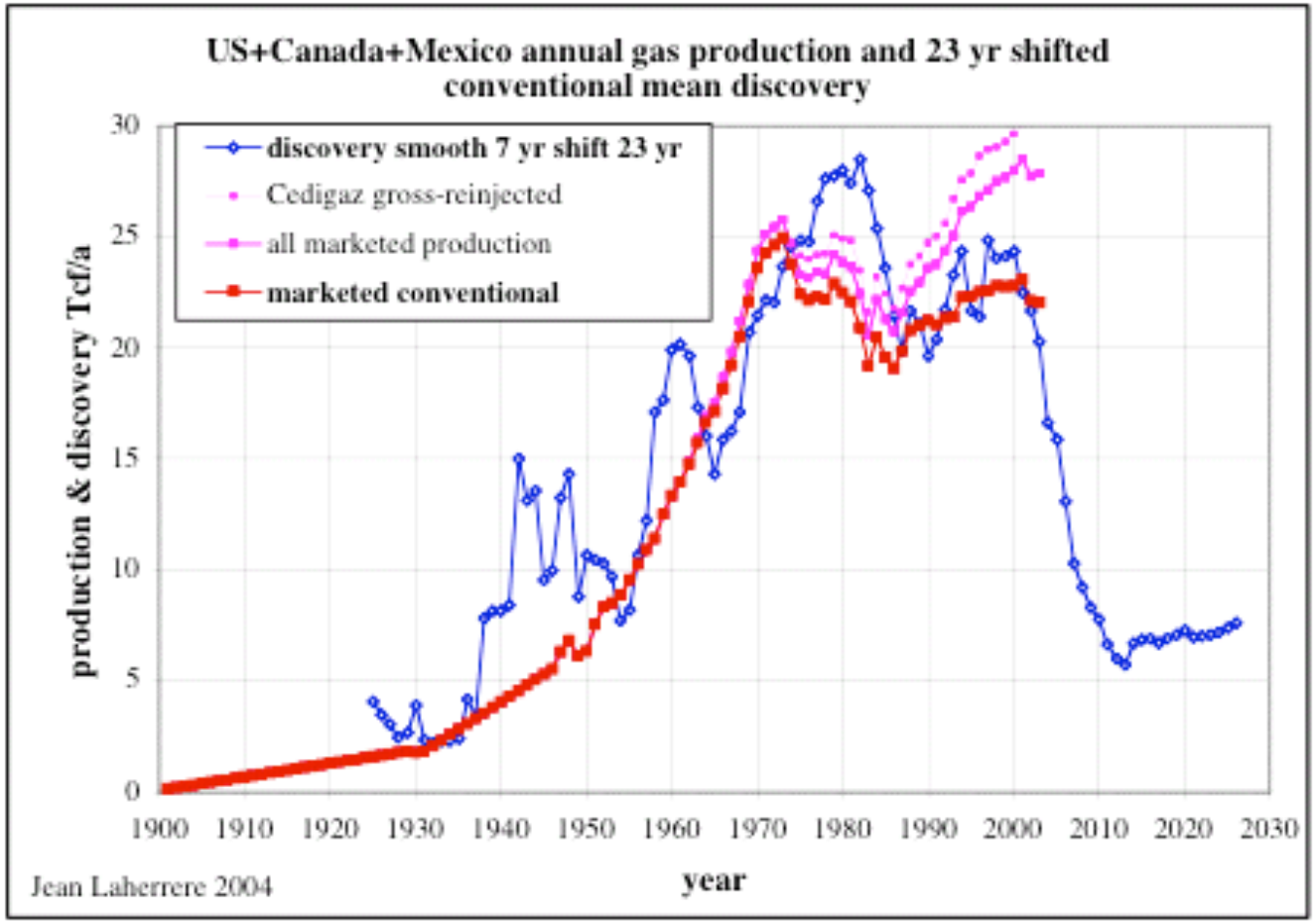


Figure 28: **World gas production & forecasts**



But **3 gas markets**, because gas is 5 to 10 times more expensive to transport than oil:
Europe, North America and Asia Pacific
Shortage very soon in North America (rush on LNG terminals) and soon in Europe (Russia reserves overestimated by 30%)

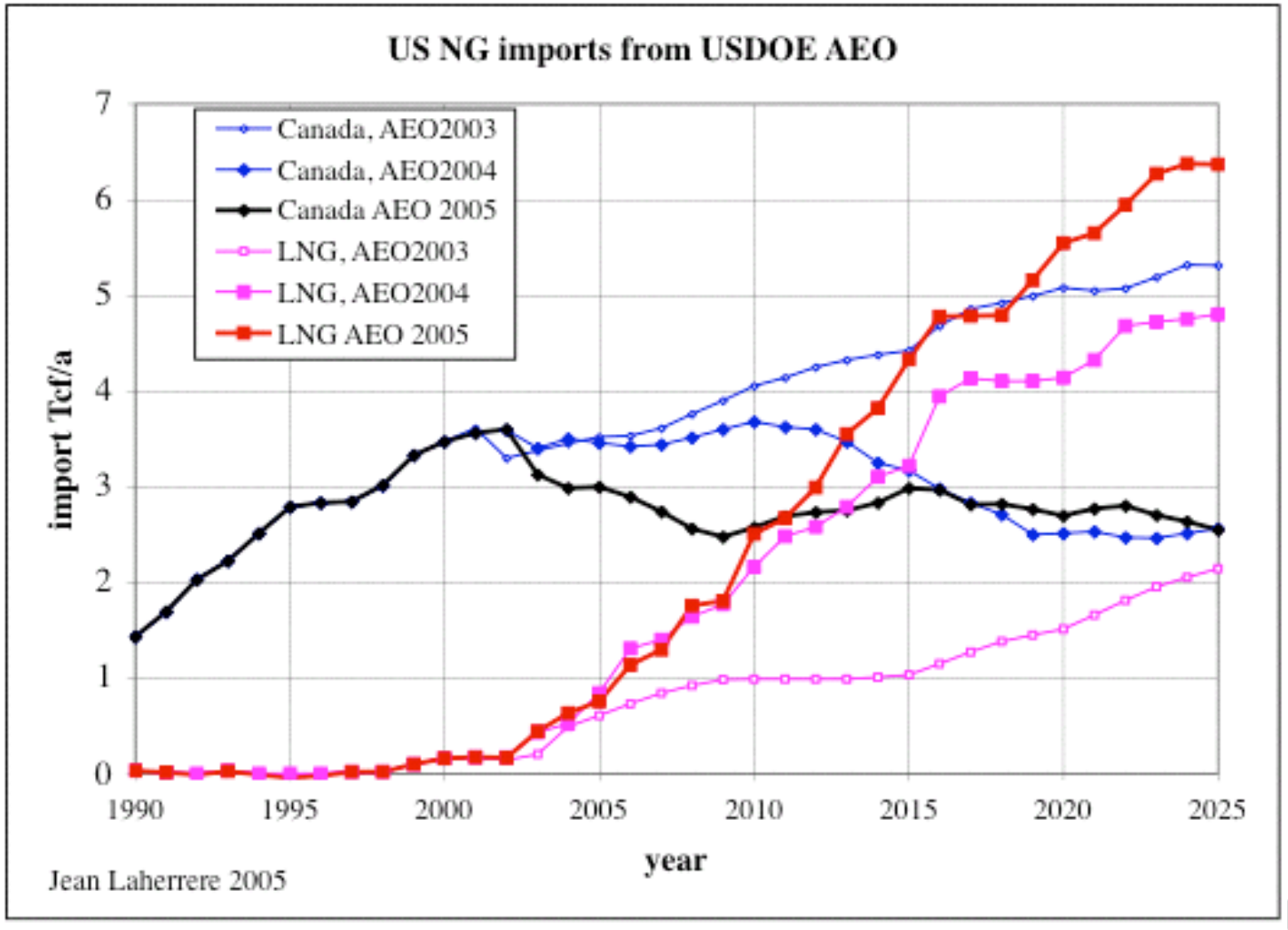
Figure 29: **US + Canada + Mexico annual conventional gas production and shifted discovery**



North America gas production is peaking and will decline sharply

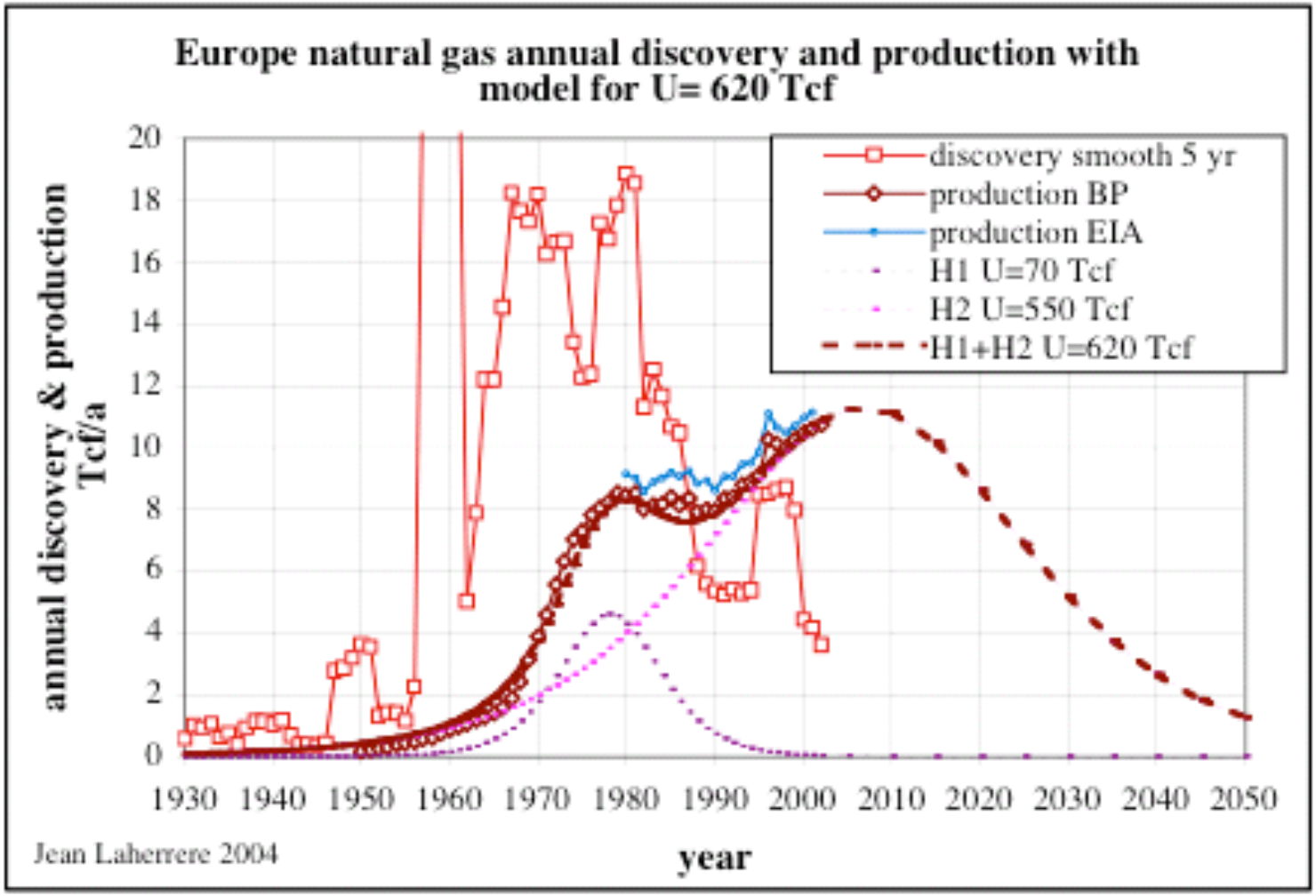
USDOE changed drastically their forecasts on imports from Canada and LNG from 2003 to 2005

Figure 30: **US gas imports from Canada and from NGL with USDOE forecasts in 2003, 2004 & 2005**



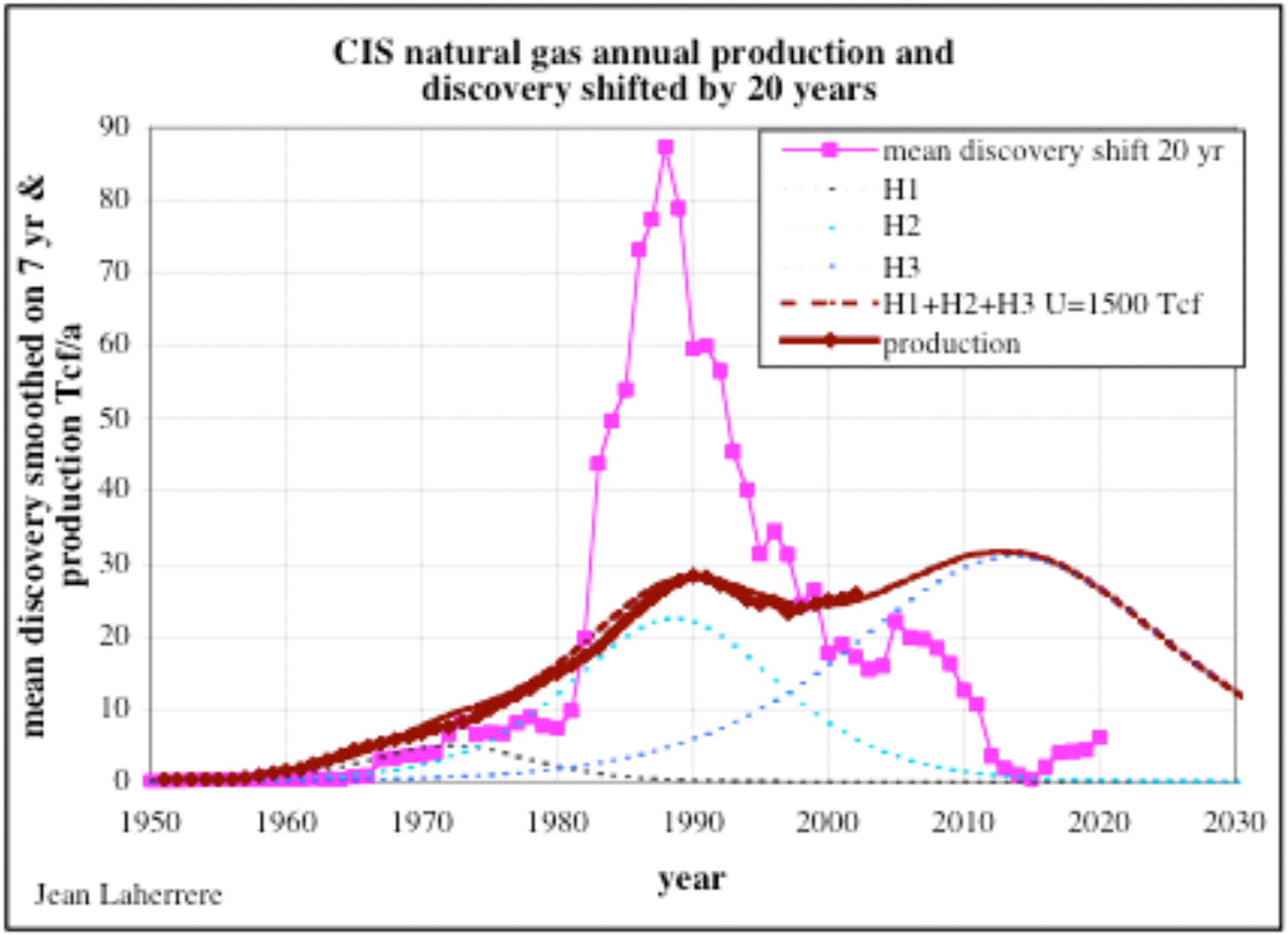
What will be next year forecast?

Figure 31: **Europe annual gas production and discovery**



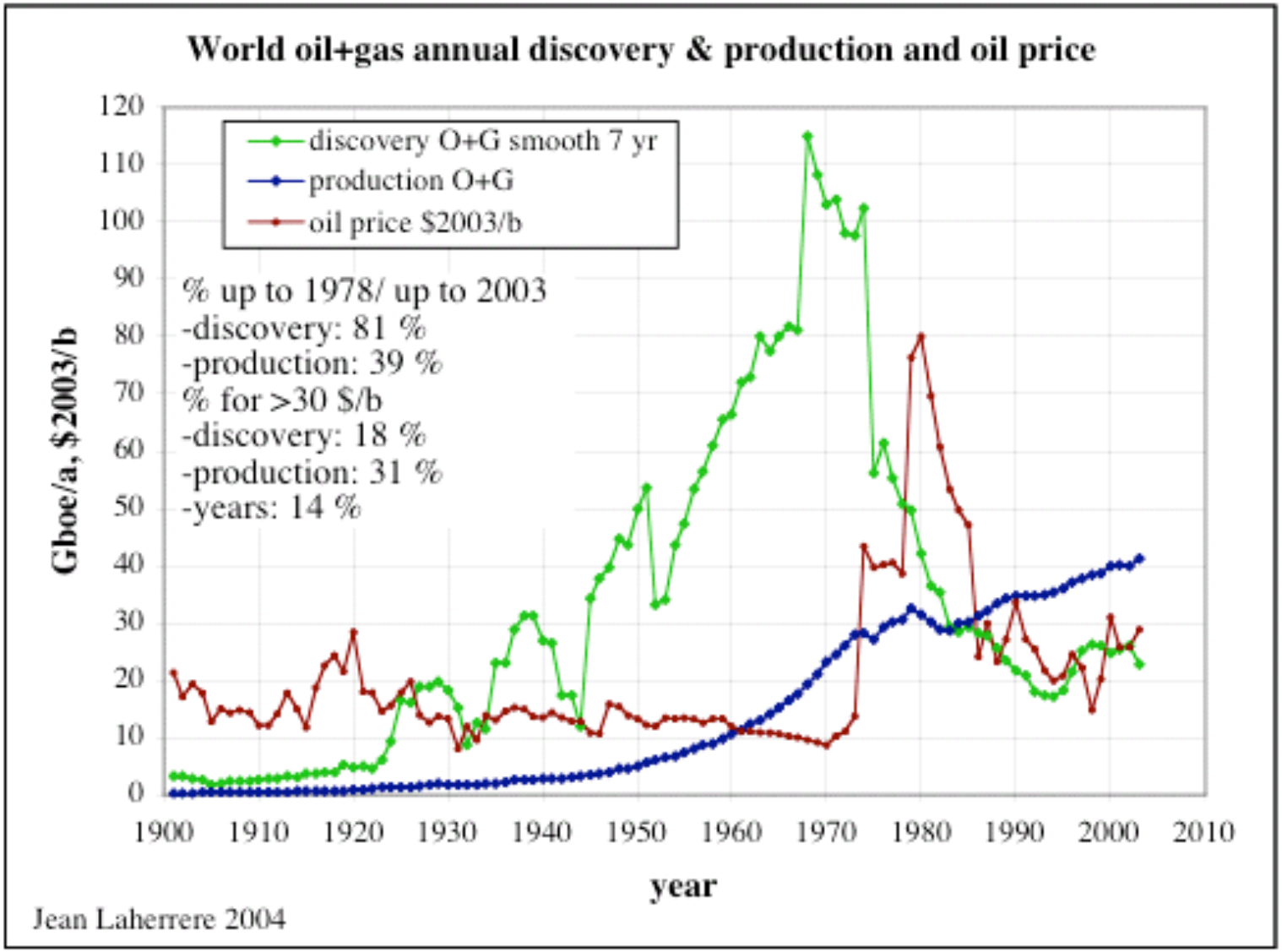
Europe gas production will peak soon

Figure 32: **FSU gas production and shifted discovery**



Russia gas production will peak soon and will not provide Europe needs!

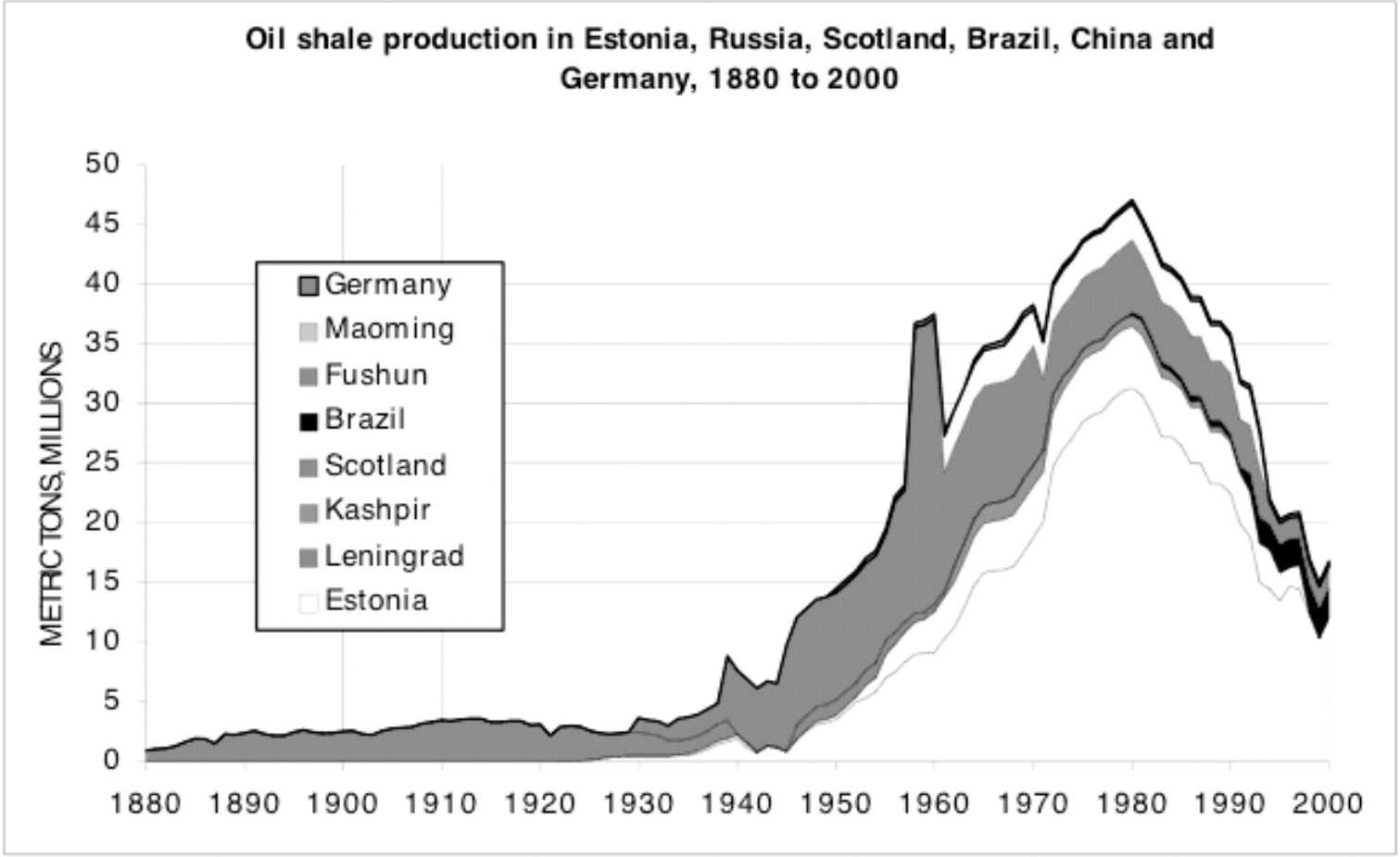
Figure 33: **World oil+gas production & discovery and oil price**



Oil price increase did not increase discovery, in contrary, it only decreased production for a while!

Oil shales which are in fact immature kerogen to be classified with lignite!

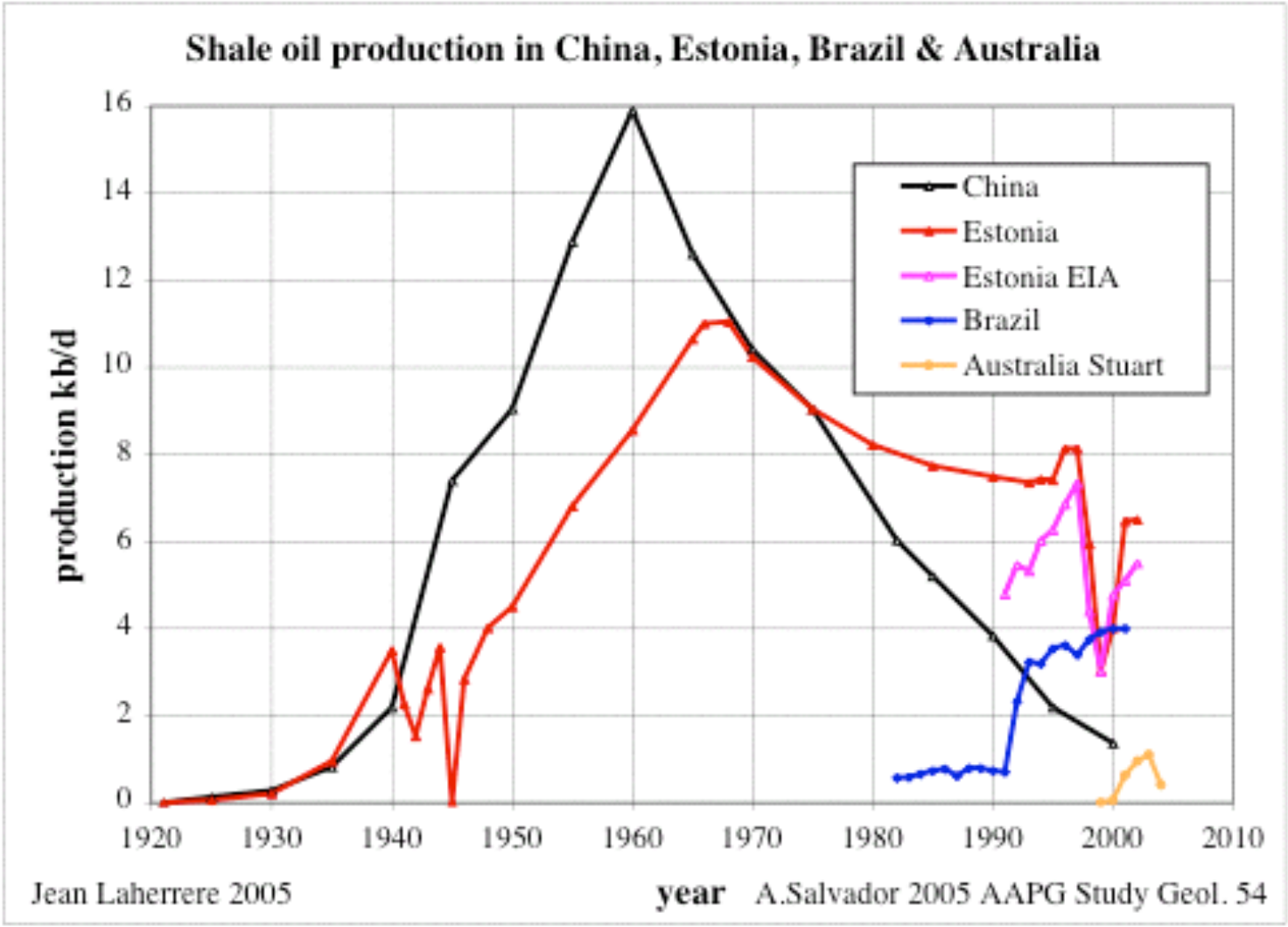
Figure 34: **Oil shale production** = long past (1837 in France «schistes d'Autun») and peak in 1980



source: Illustration #21 from paper: Origin and resources of some world oil shale deposits, by John R. Dyni, U.S. Geological Survey, Denver, CO, USA, presented at the Estonian Oil Shale Symposium, Tallinn, Nov. 18-20, 2002.

To enter into European Union, Estonia was obliged to reduce its future oil shale production to decrease pollution!

Shale oil is produced from mined shale oil by pyrolisis at 700°C (retorting)
Figure 35: **Shale oil production** = peak in 1960



In 2002, world shale oil production <12 kb/d = 0,015 % of world oil production. Mining is considered as impossible with environment, only one US in-situ pilot (Shell 10 b/d with 2000 $/d electric bill!)

-**Fossil Fuels**

Figure 36: **World coal annual/cumulative versus cumulative production** giving an ultimate of 450 Gtoe compared to BGR 600 Gtoe

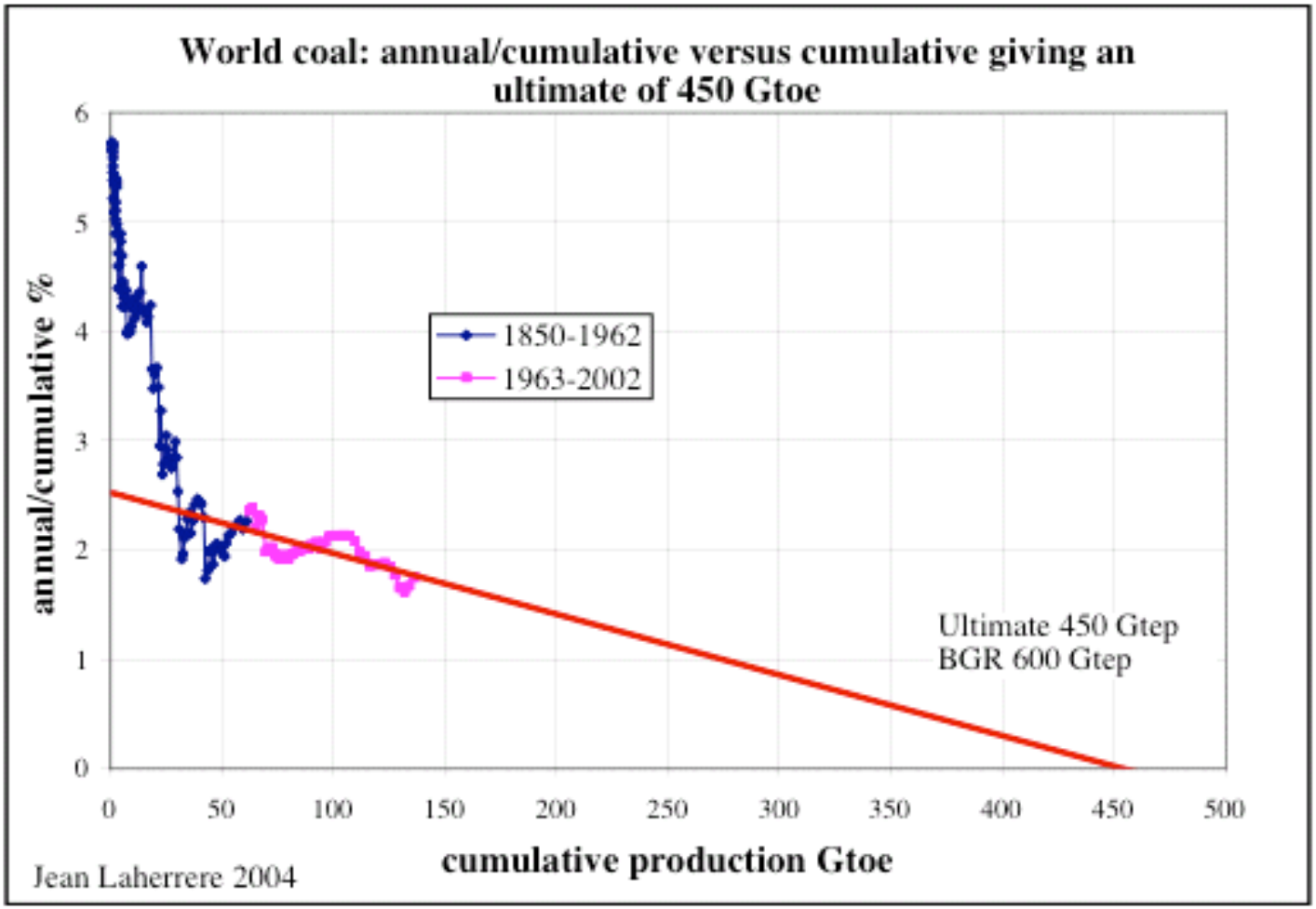
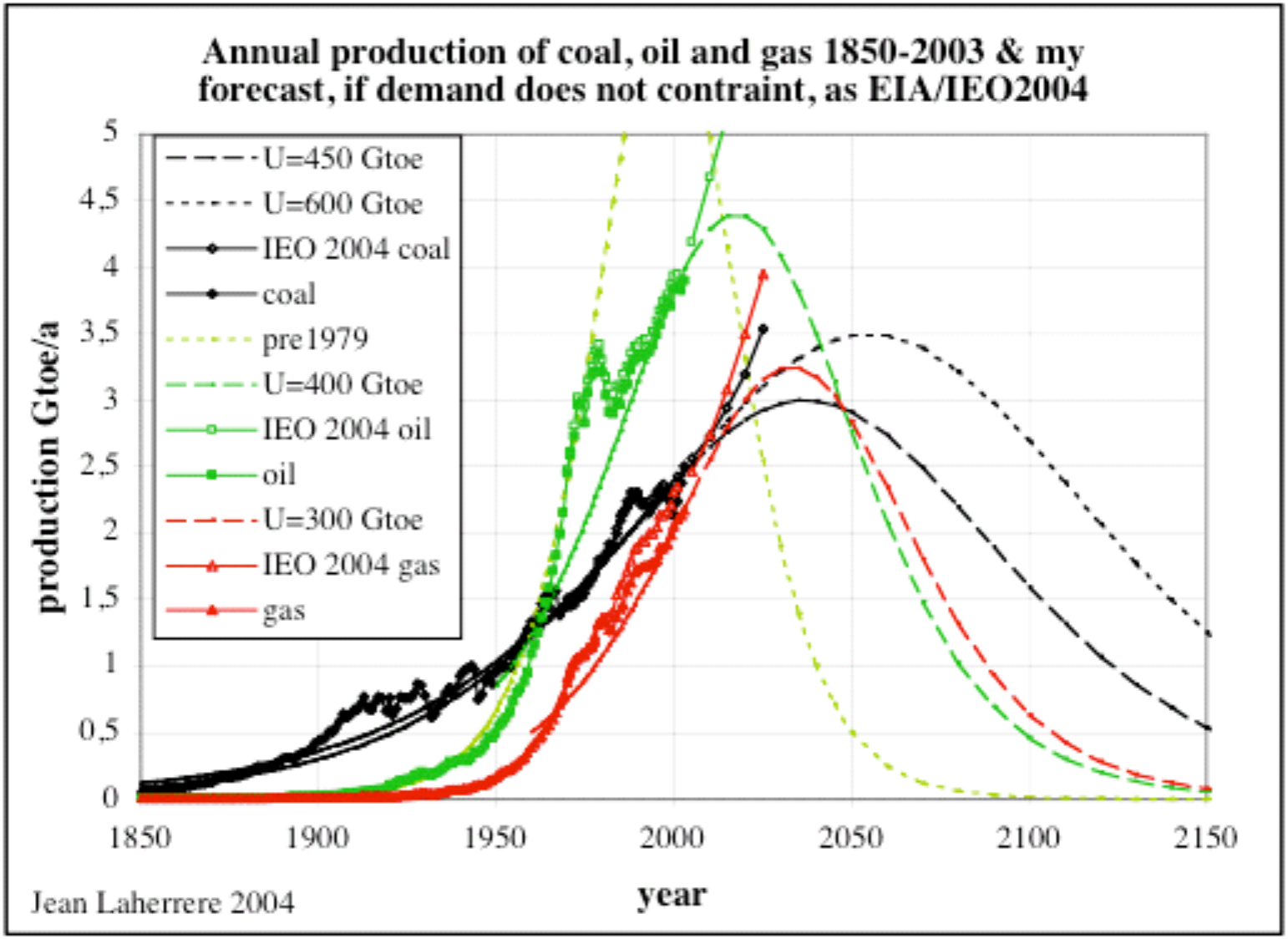


Figure 37: **World annual production of coal, oil and gas** with Hubbert models and USDOE forecasts



Peak if no constraint from demand: oil decade 2010, gas decade 2020, coal decade 2050

Figure 38: **World fossil fuels consumption per capita** with my forecast & USDOE

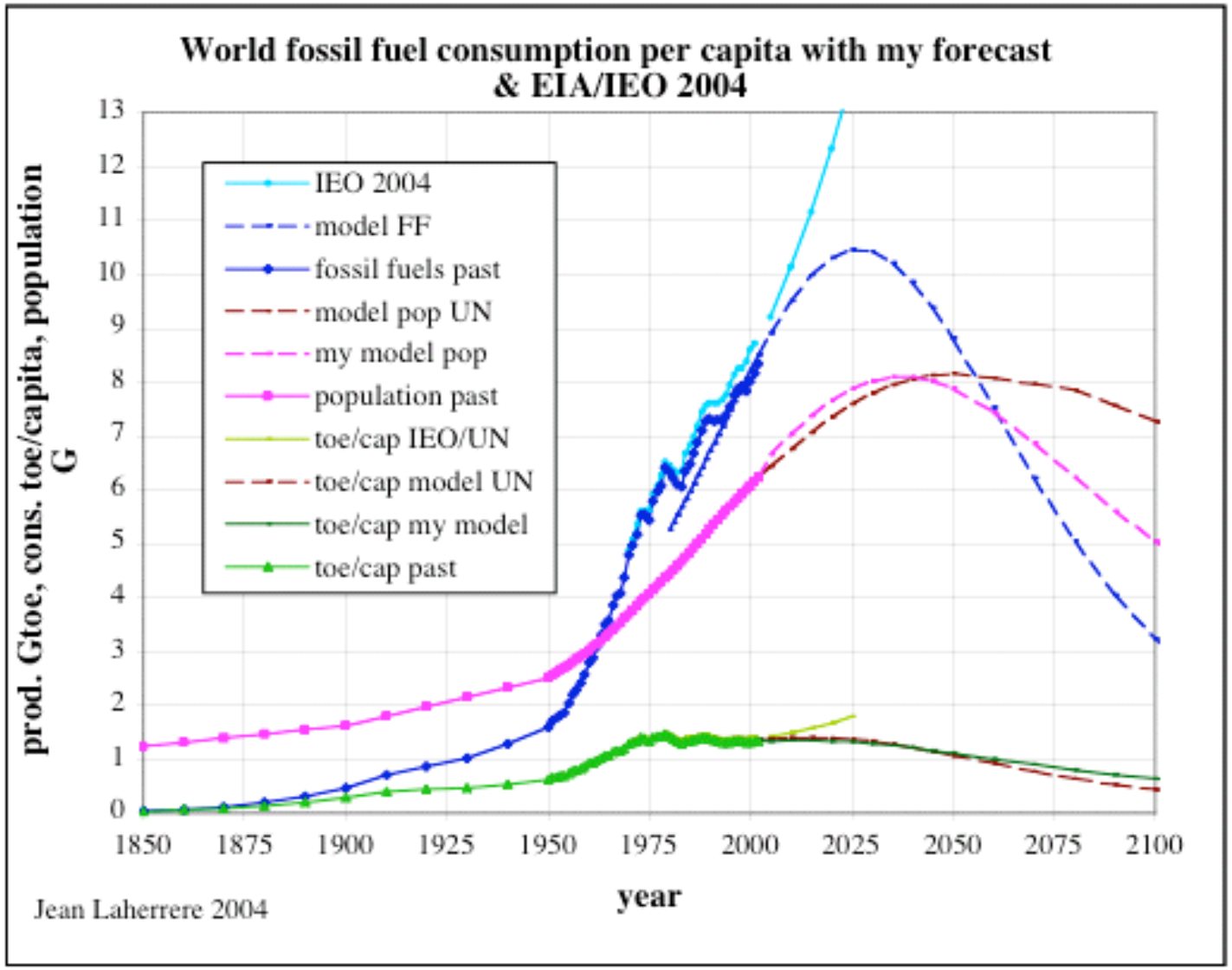
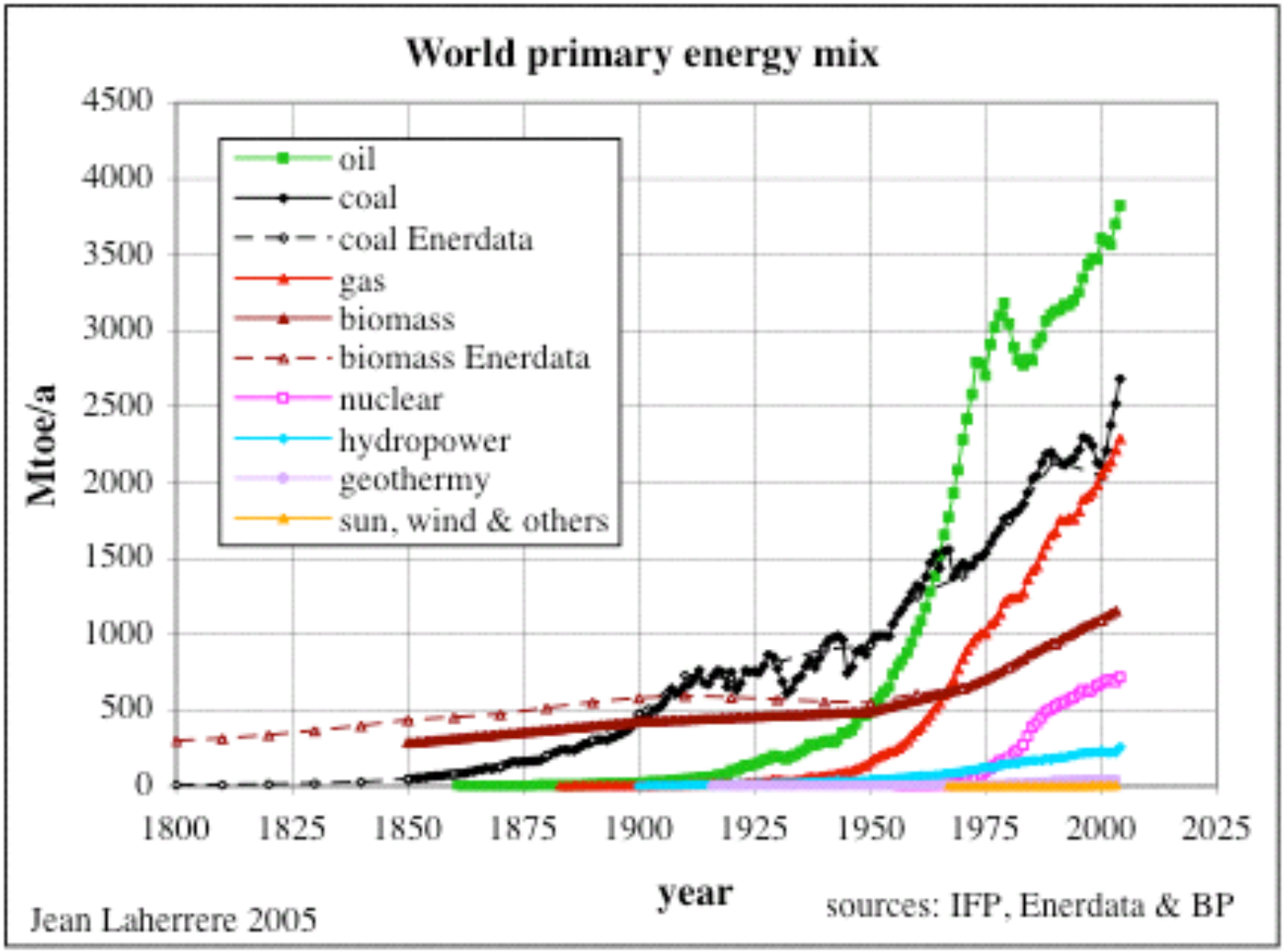
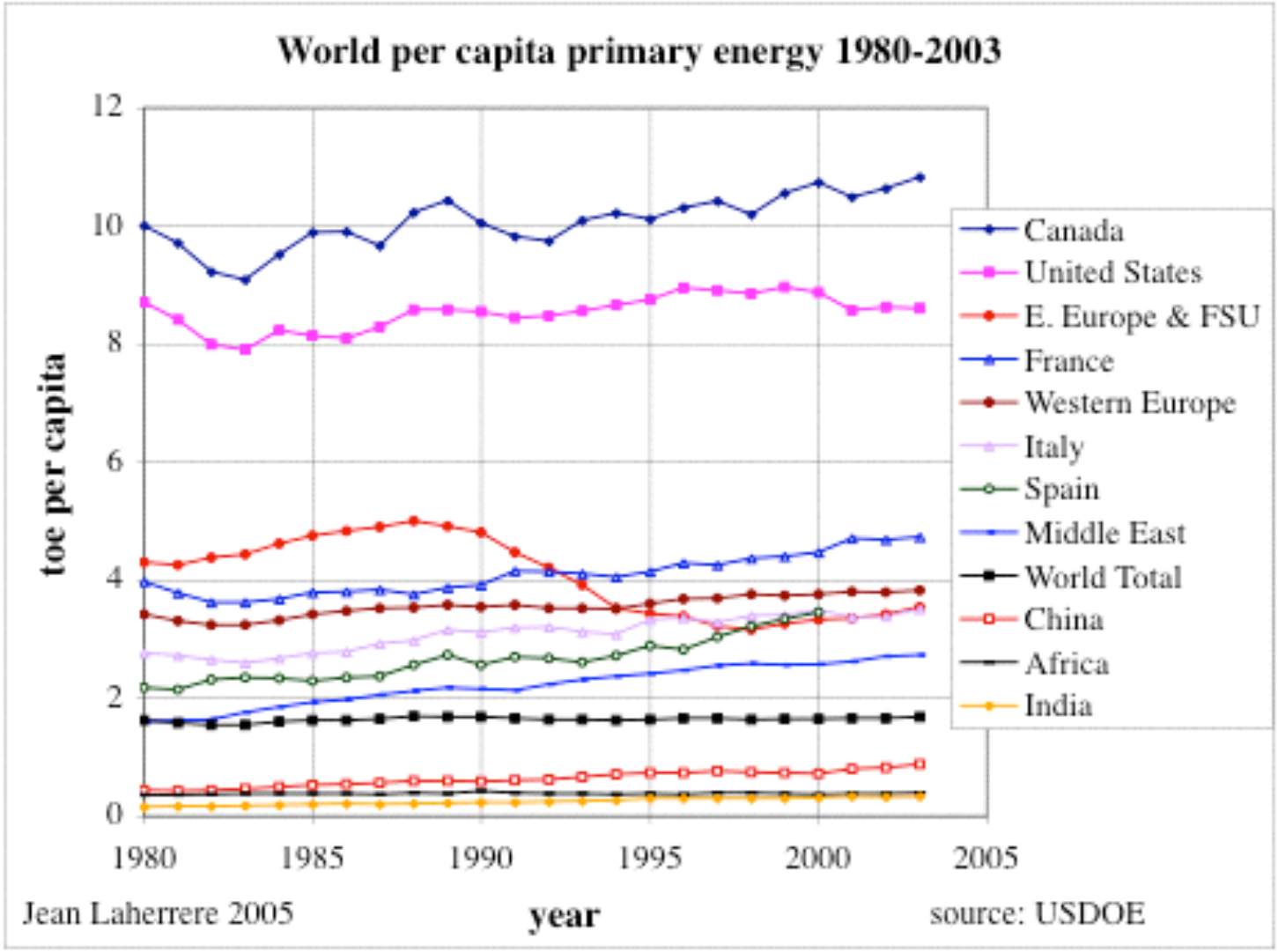


Figure 39: **World primary energy mix 1850-2004**



Muscle is omitted! Only horses in horsepower of cars!
Energy equivalence is based on questionable conventions, which are not discussed, because statu quo rules.
In 2001 France changed its equivalence to adopt IEA: final energy oil consumption went from 39.8 to 51.3 %!

Figure 40: **Primary energy per capita** 1980-2002



World primary energy per capita is flat for more than 20 years

Figure 41: **world primary energy annual/cumulative versus cumulative energy** giving an extrapolation of 1200 Gtoe

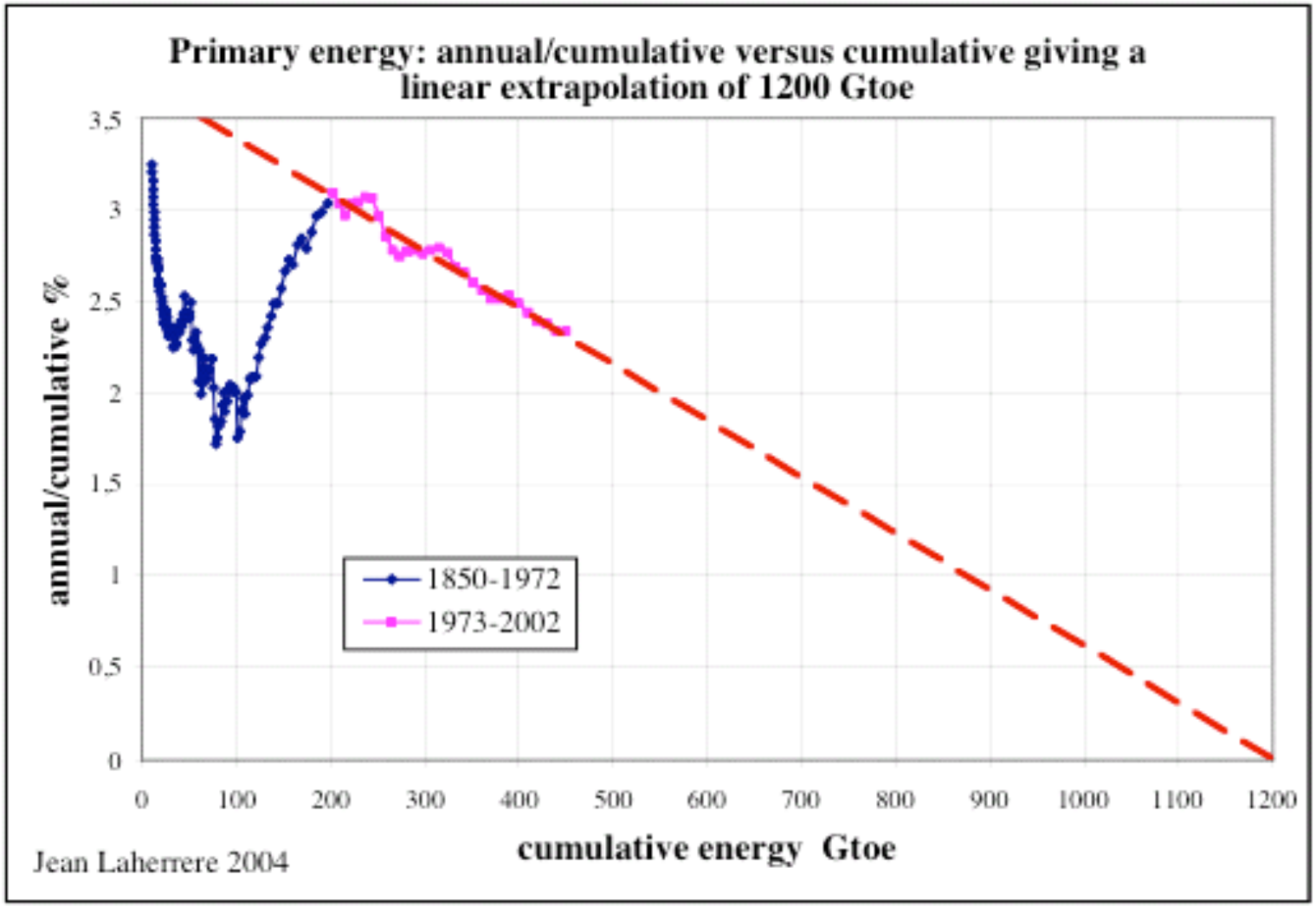
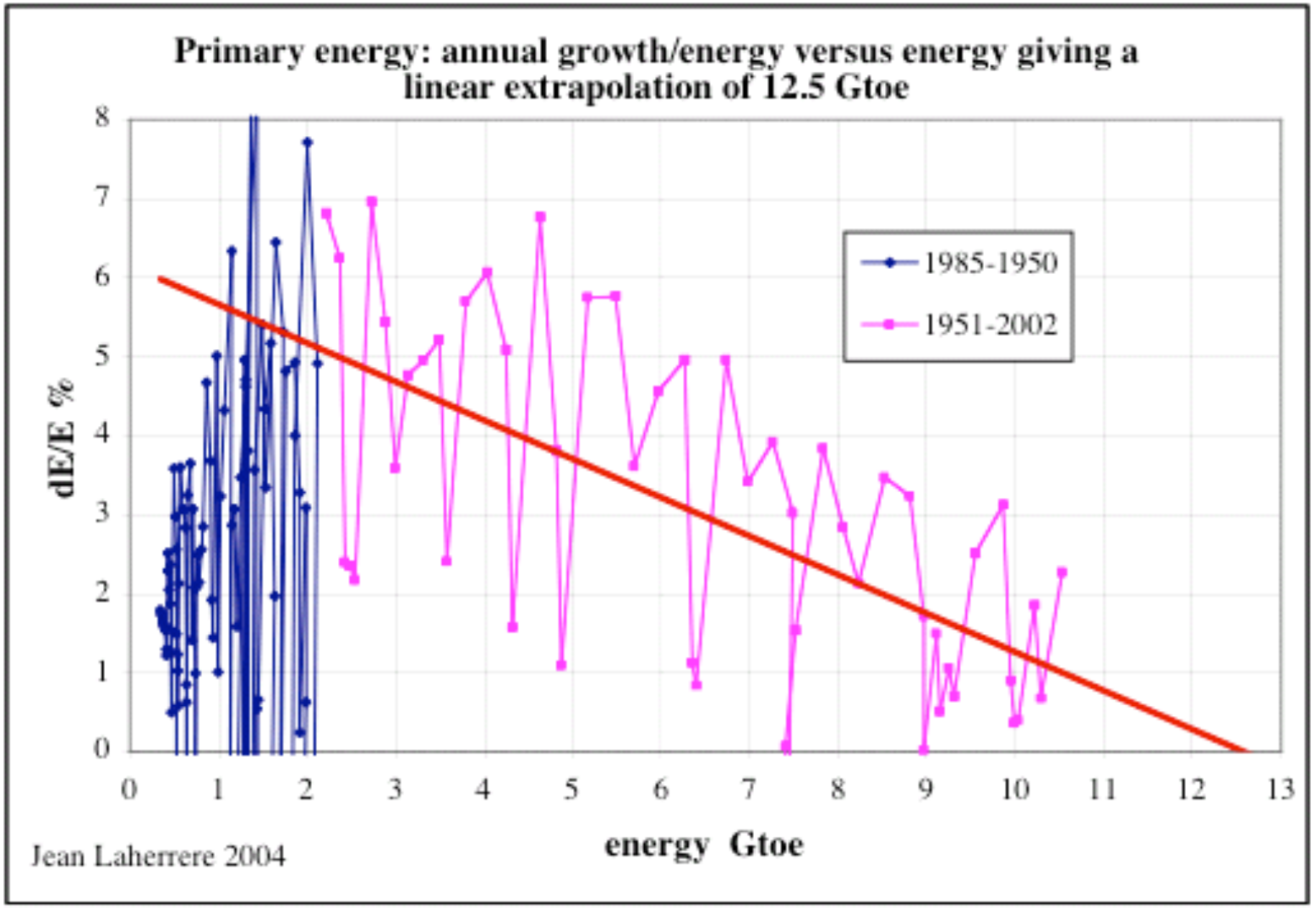
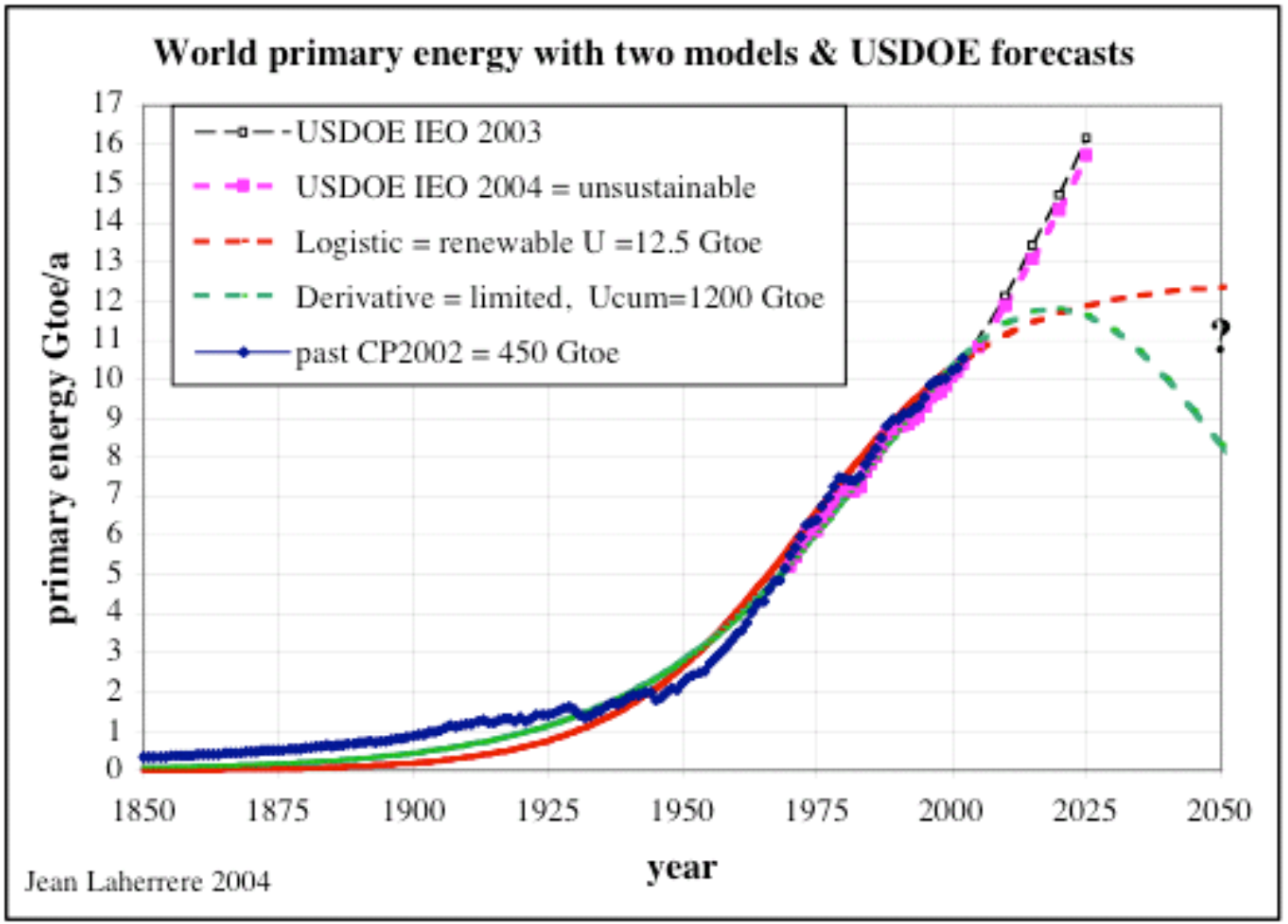


Figure 42: **world primary energy annual growth/energy versus energy** giving an extrapolation of 12.5 Gtoe



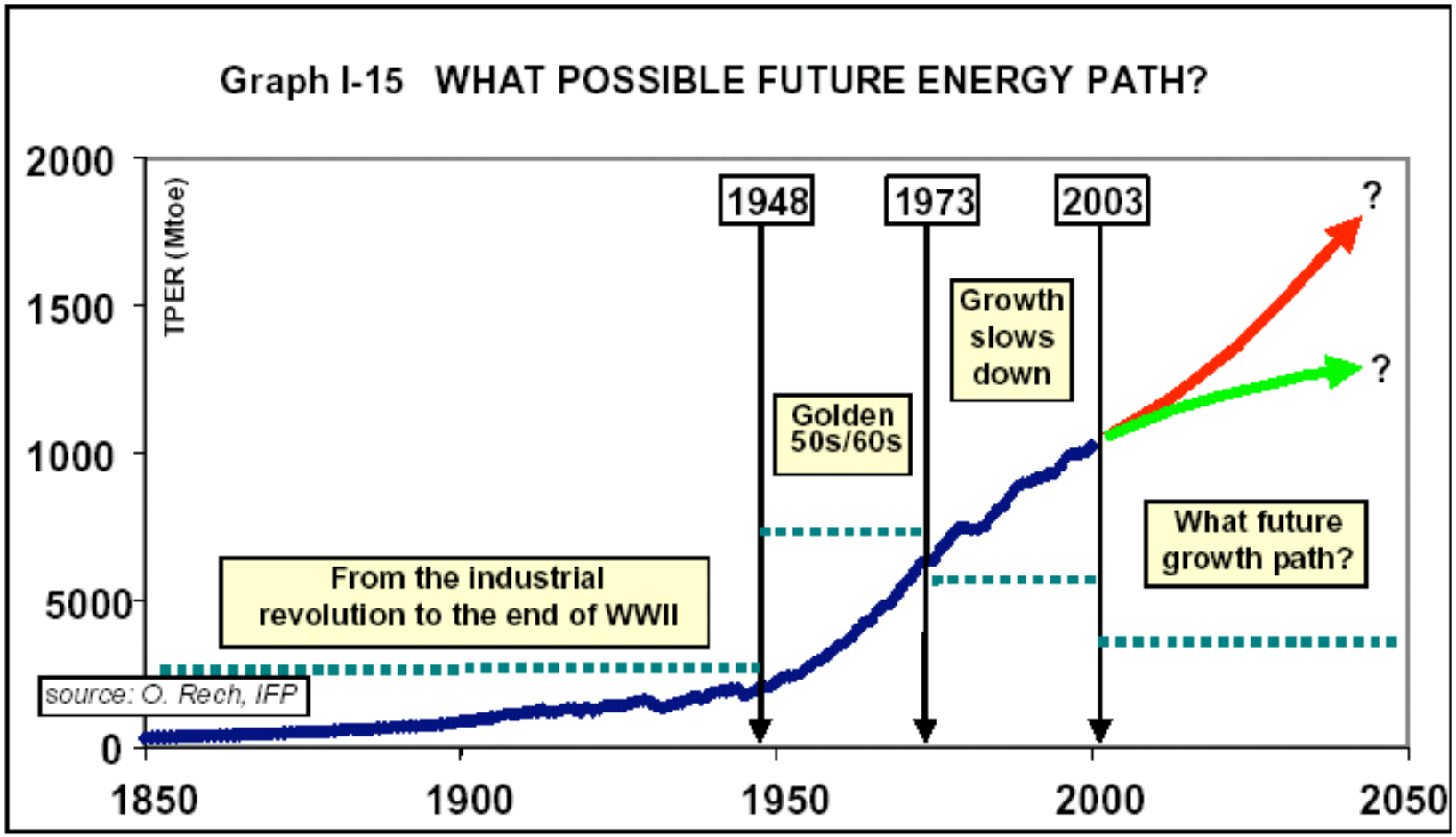
Past two graphs lead to a logistic model or a Hubbert model, primary energy will likely be between the two models, far from USDOE forecast

Figure 43: **World primary energy with two models and USDOE IEO (International Energy Outlook) forecasts**



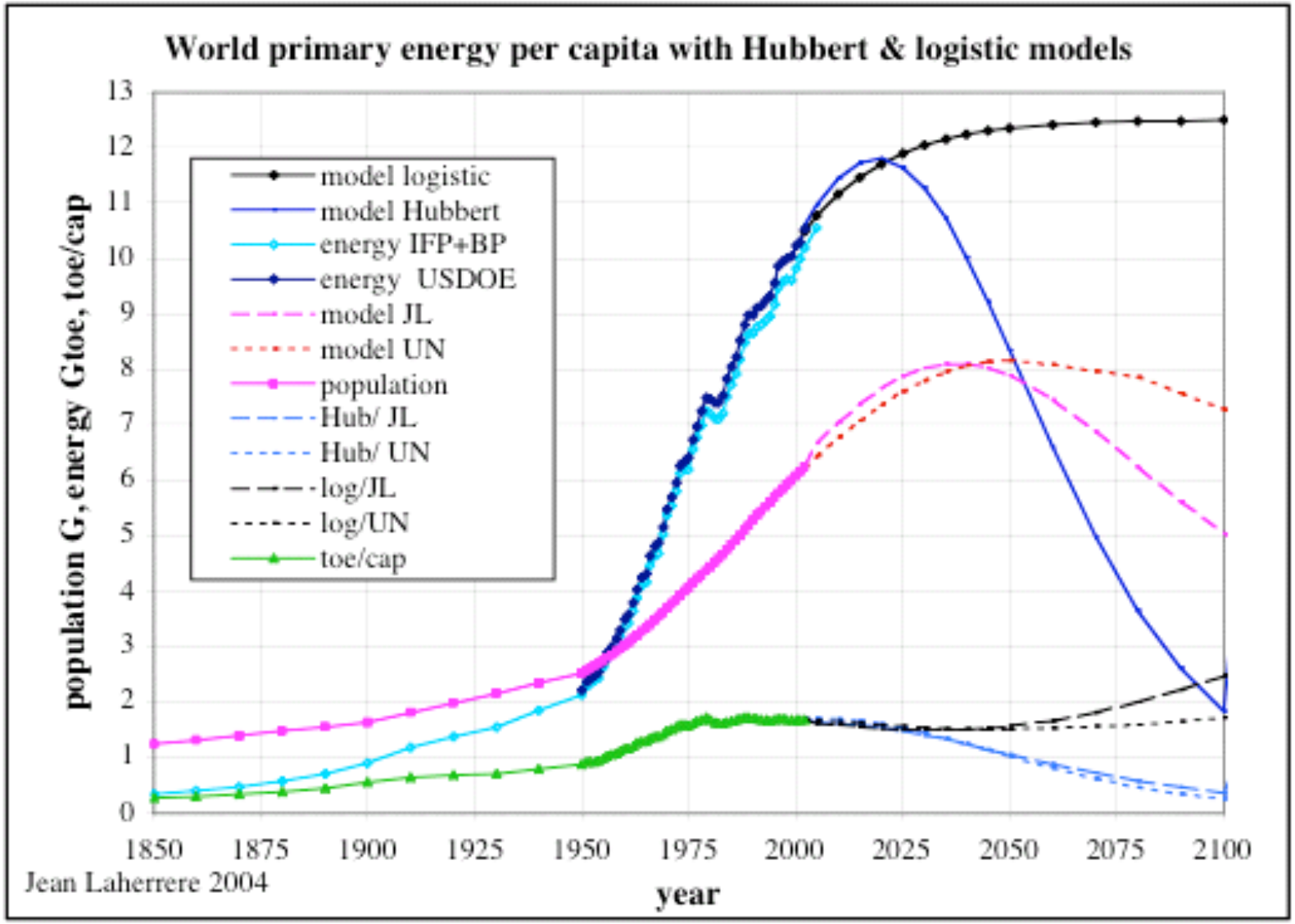
IEO 2005 for 2025 is back to 2003 level, even higher!

Figure 44: **WEC (World Energy Council) 2003 forecast for world primary energy 1850- 2050**



The future depends mainly on the consumer behavior (US with SUV and China new cars!)

Figure 45: **world primary energy per capita**

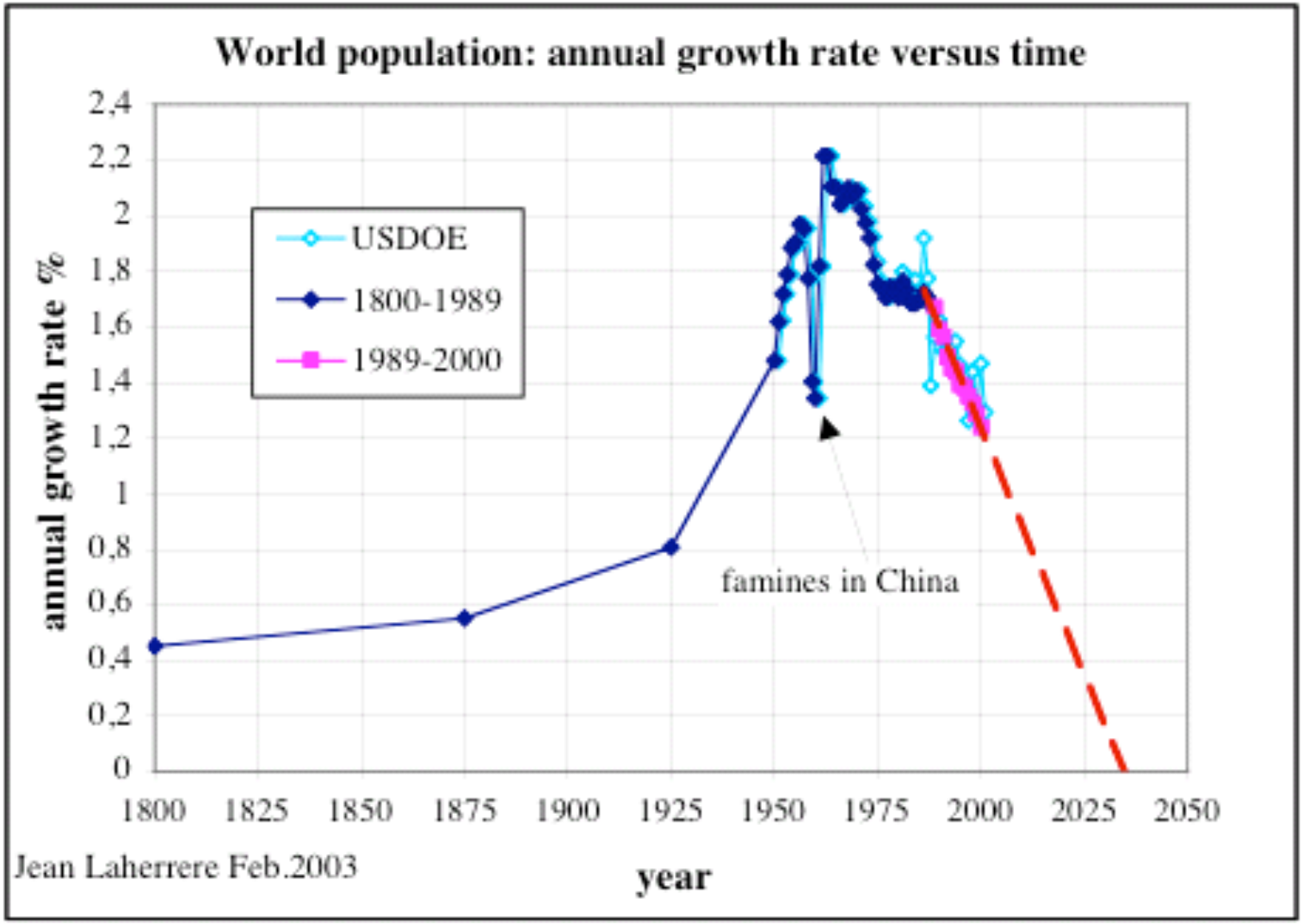


Primary energy per capita was constant for the past 25 years and will be for the next 25 years.

-**Population**

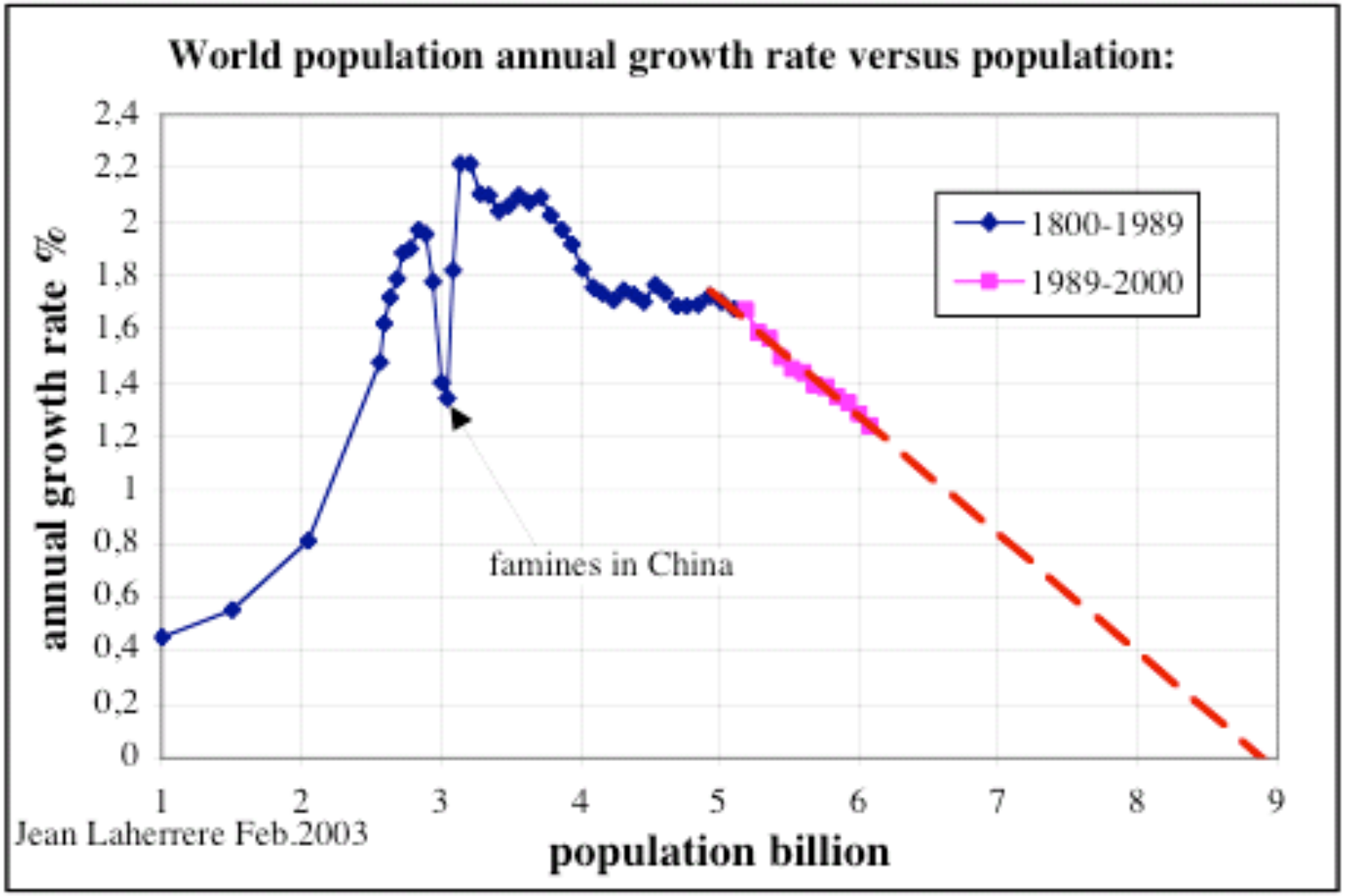
Energy per capita needs population forecast.

Figure 46: **World population 1800-2000 annual growth versus time**



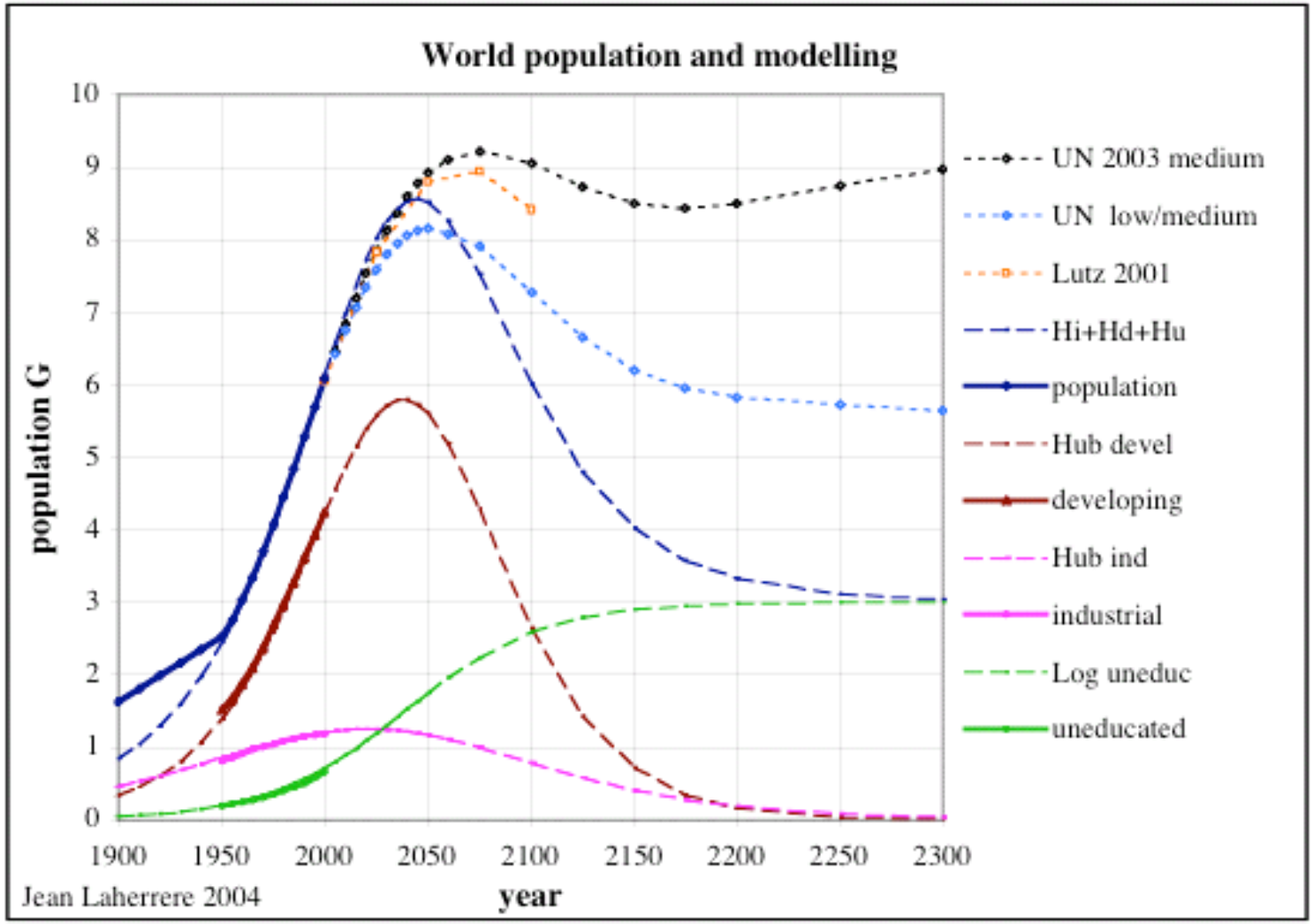
Linear extrapolation gives a no growth around 2030

Figure 47: **World population 1800-2000: annual growth versus population**

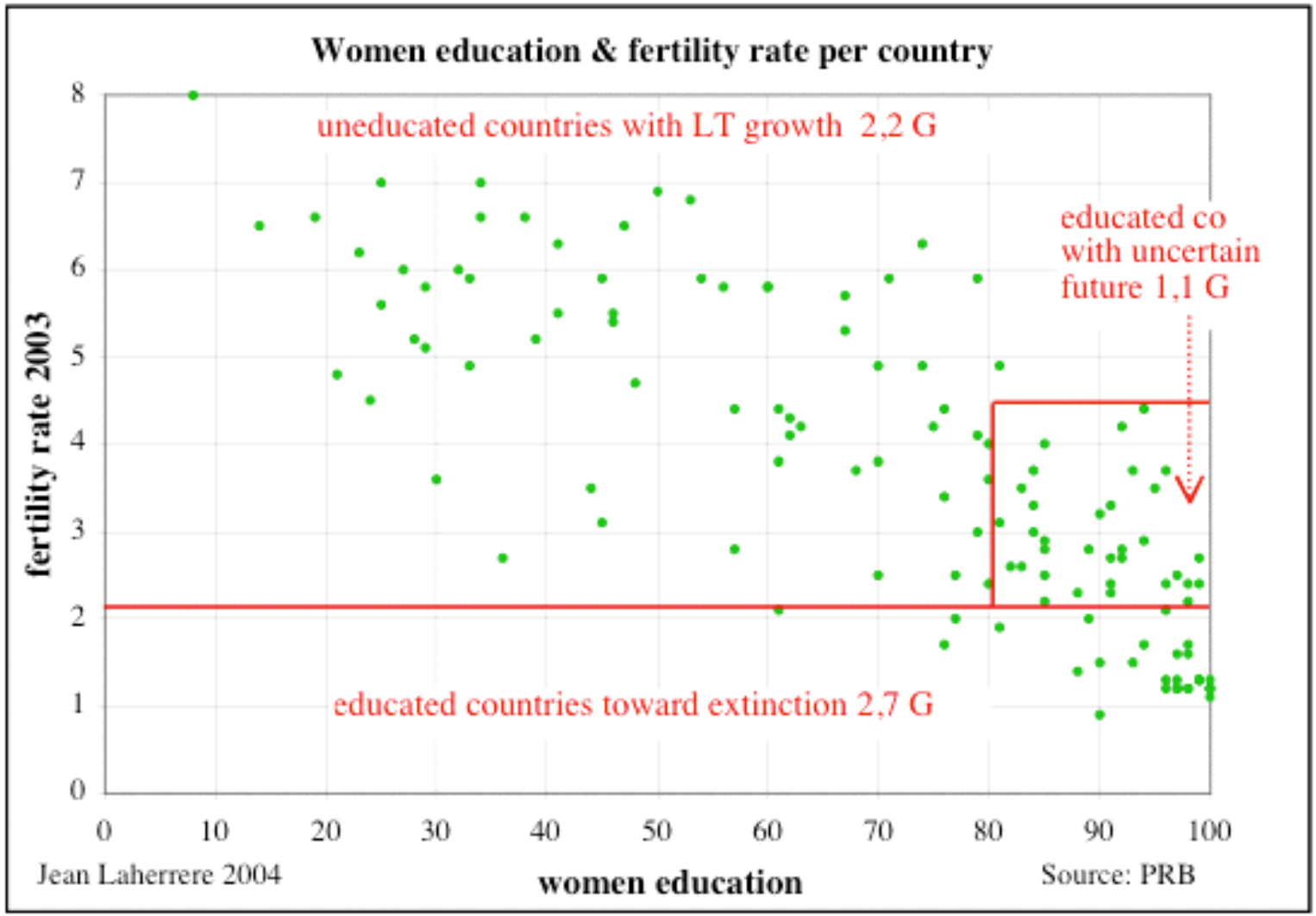


Linear extrapolation gives a peak less than 9 billion

Figure 48: **World population and forecasts**

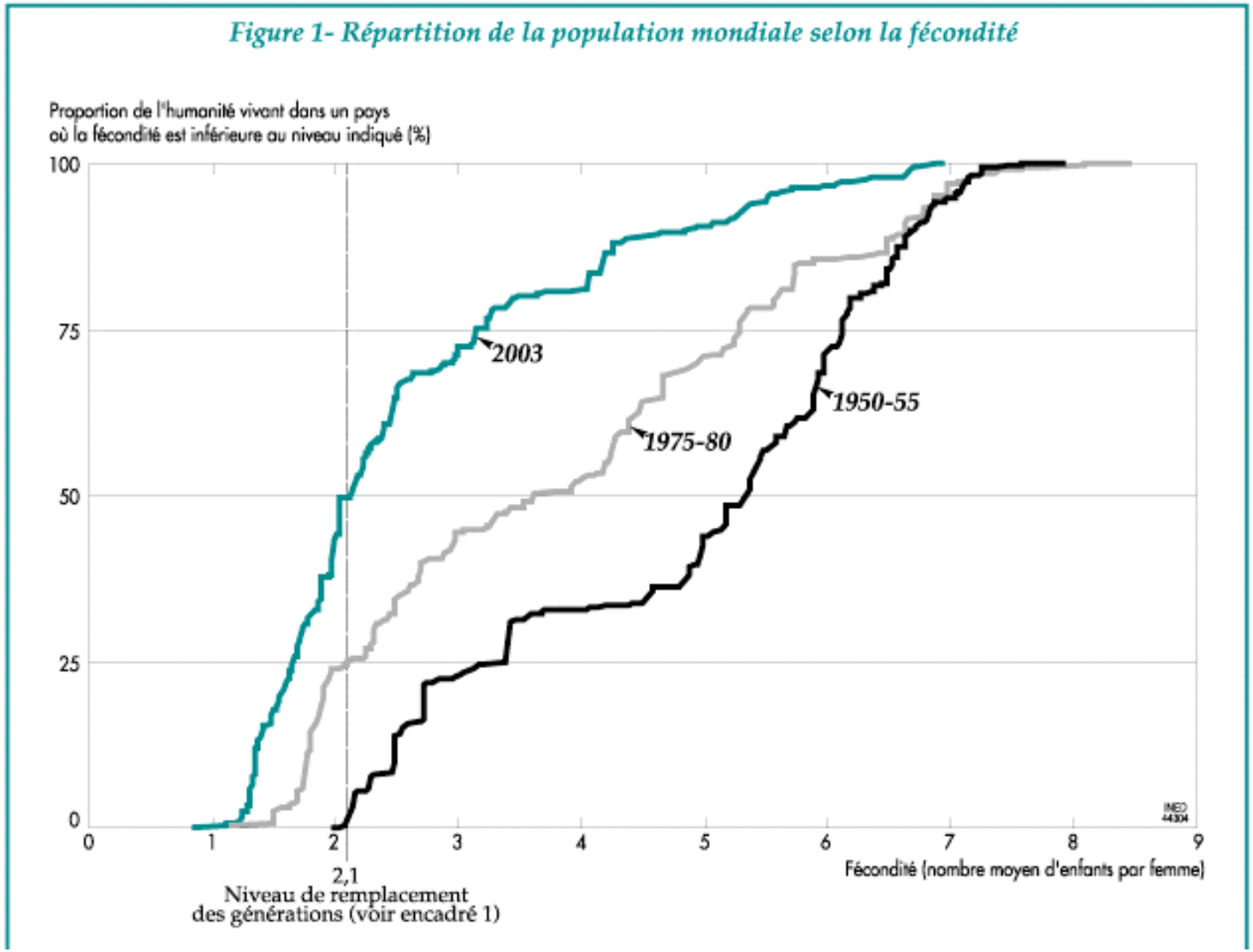


Every population forecast is based on fertility rate,
Figure 49: **relationship fertility rate and women education**



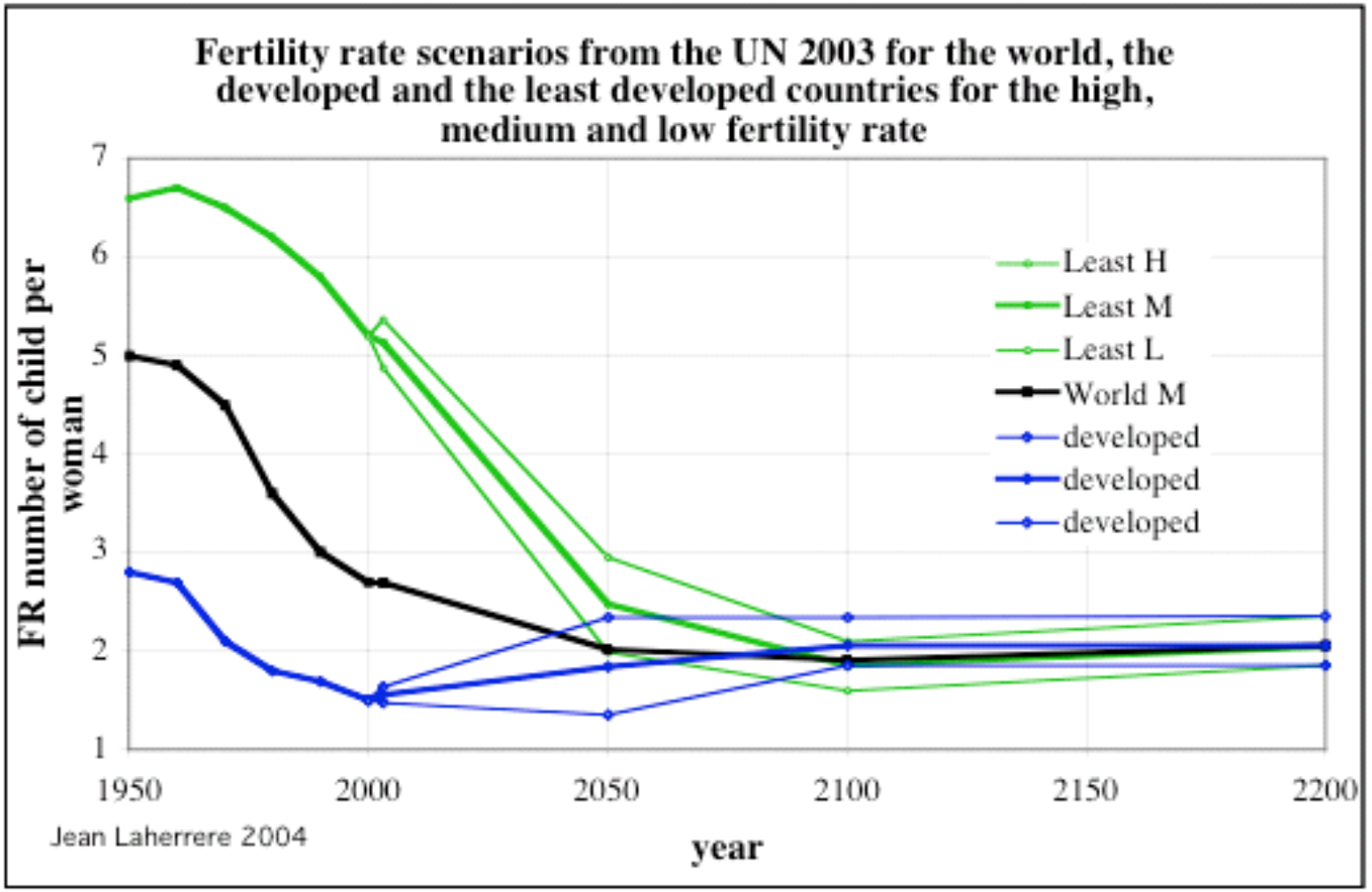
There are two worlds: -countries < 2 child/woman going towards extinction
-countries >5 child/woman with long-term growth

Figure 50: **Evolution of fertility rate as a percentage of total population** from INED 2004 (P&S 405)



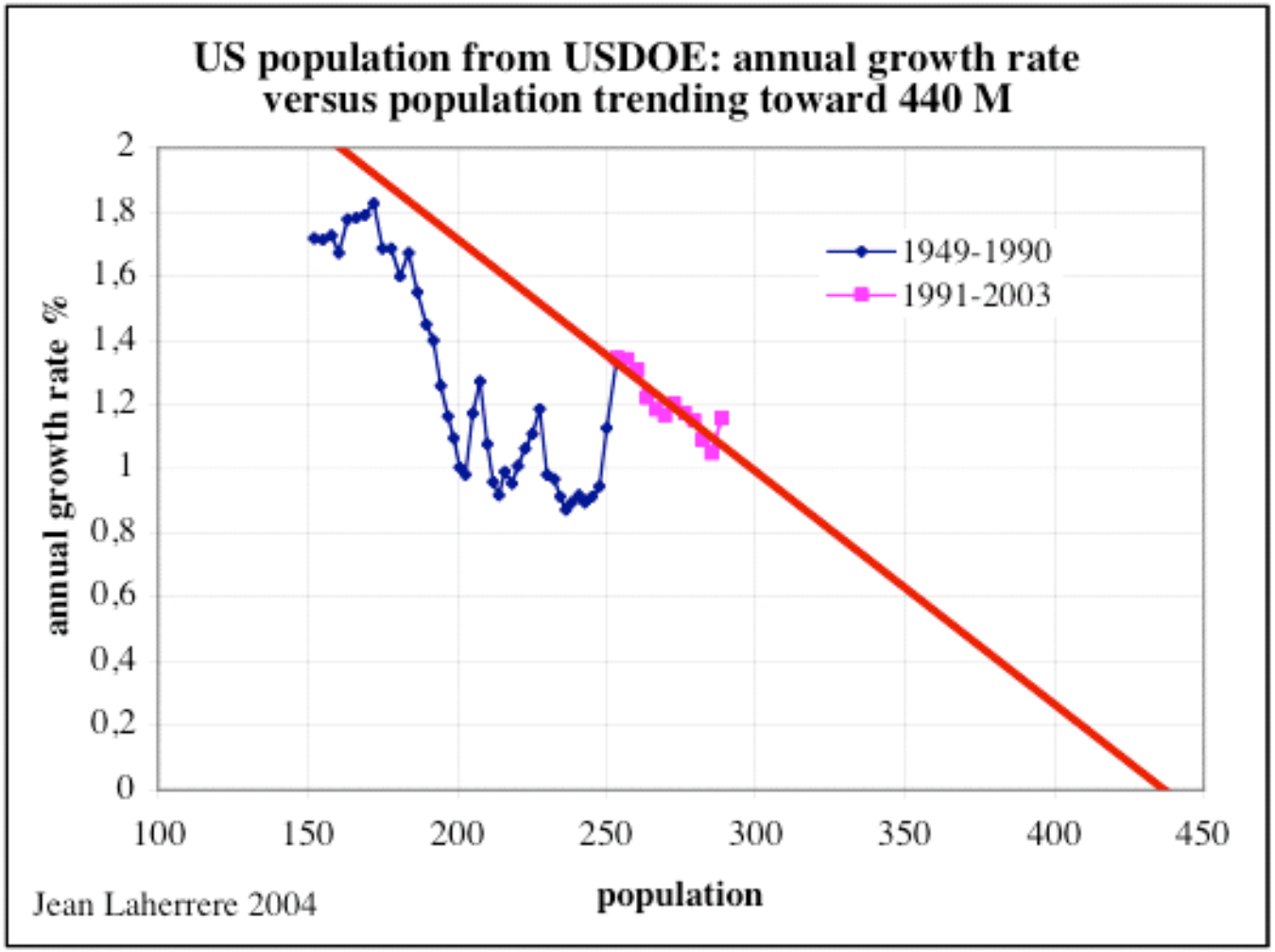
In 1950 no country was below the replacement rate (2.1 child per woman) , in 1975 a quarter of the world was below and in 2000 one half of the world was heading toward extinction !

Figure 51: **UN 2003 scenarios on fertility rate** = political goals (INED Population & Societes n°408)



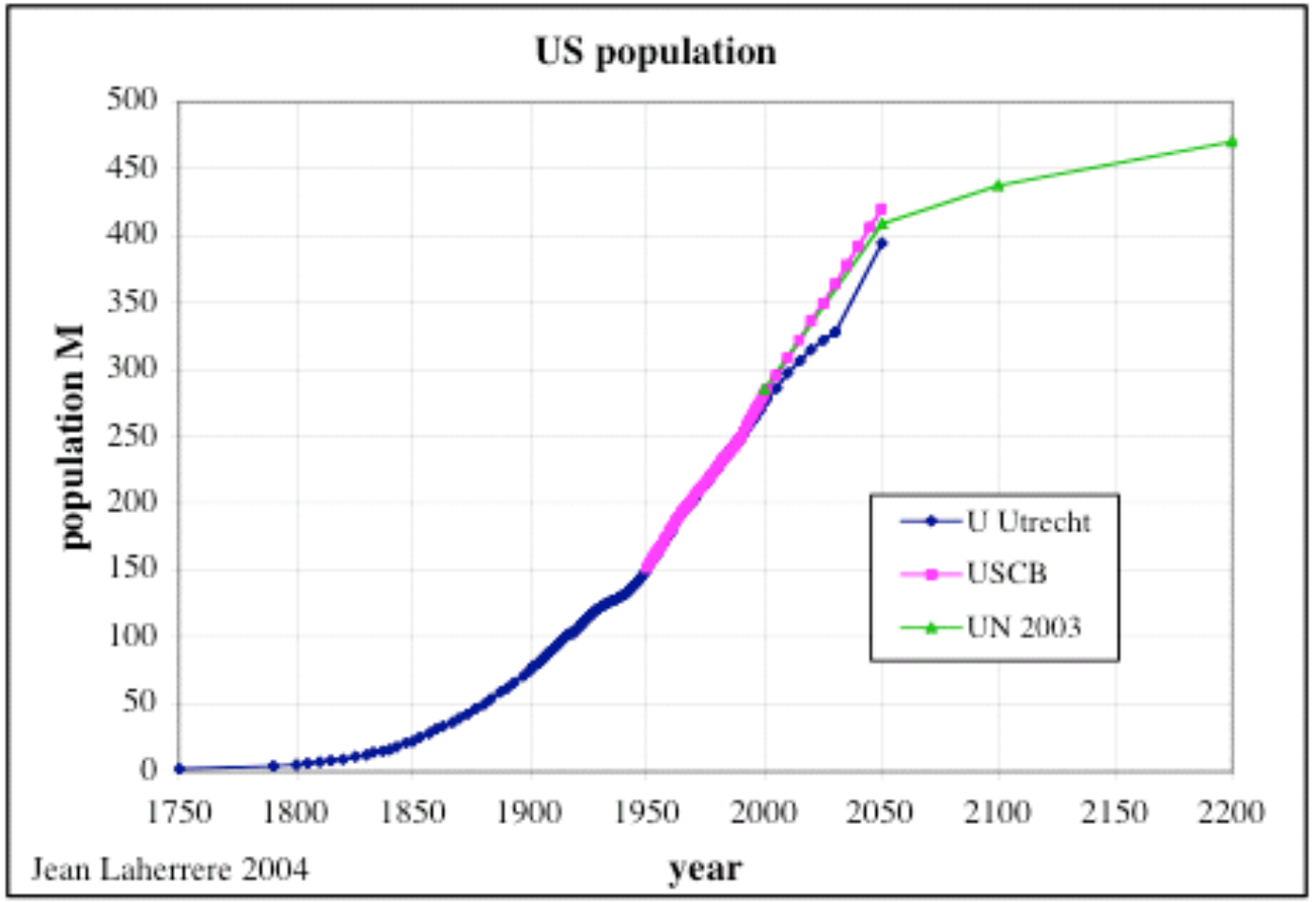
UN fertility rate forecasts are unrealistic wishful thinkings on future equality, showing in 2100 a fertility rate for developed countries higher than for the least developed countries

Figure 52: **US population: annual growth versus population**



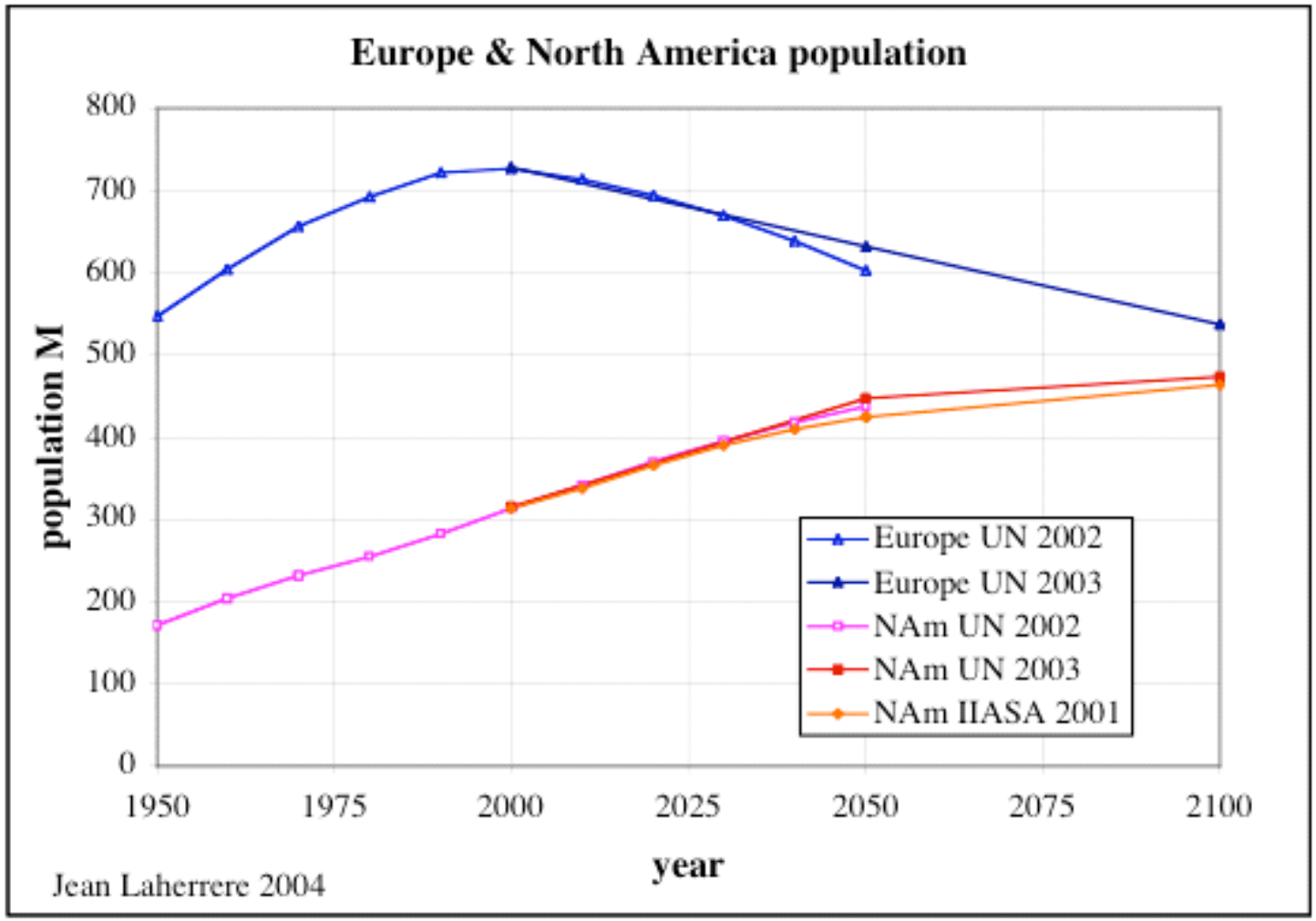
Linear extrapolation gives a peak of 440 million

Figure 53: **US population and several forecasts**



No peak forecasted for the US!

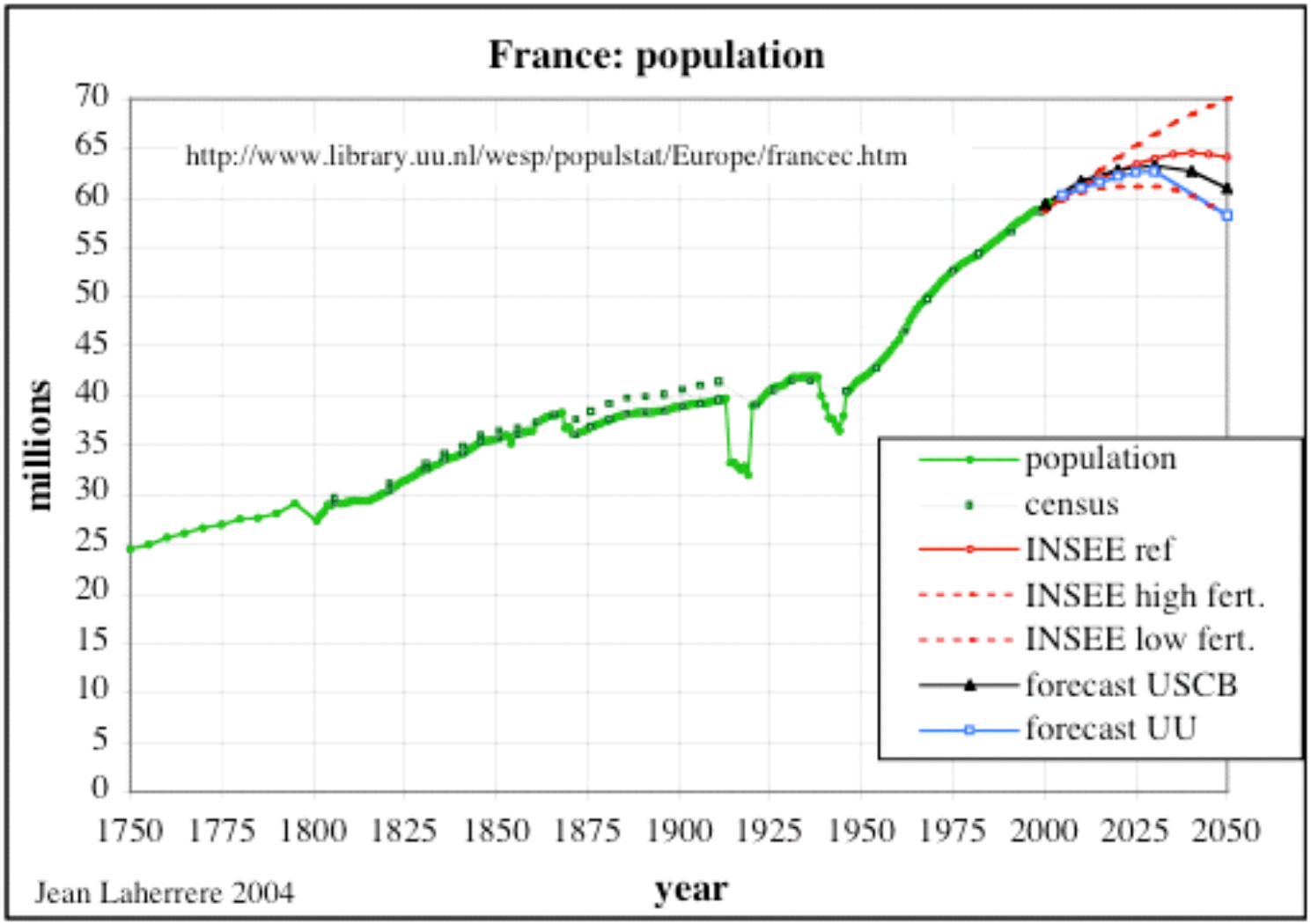
Figure 54: **Europe and North America population forecasts**



Europe has peaked around 2000 and cannot expect continuous economic growth

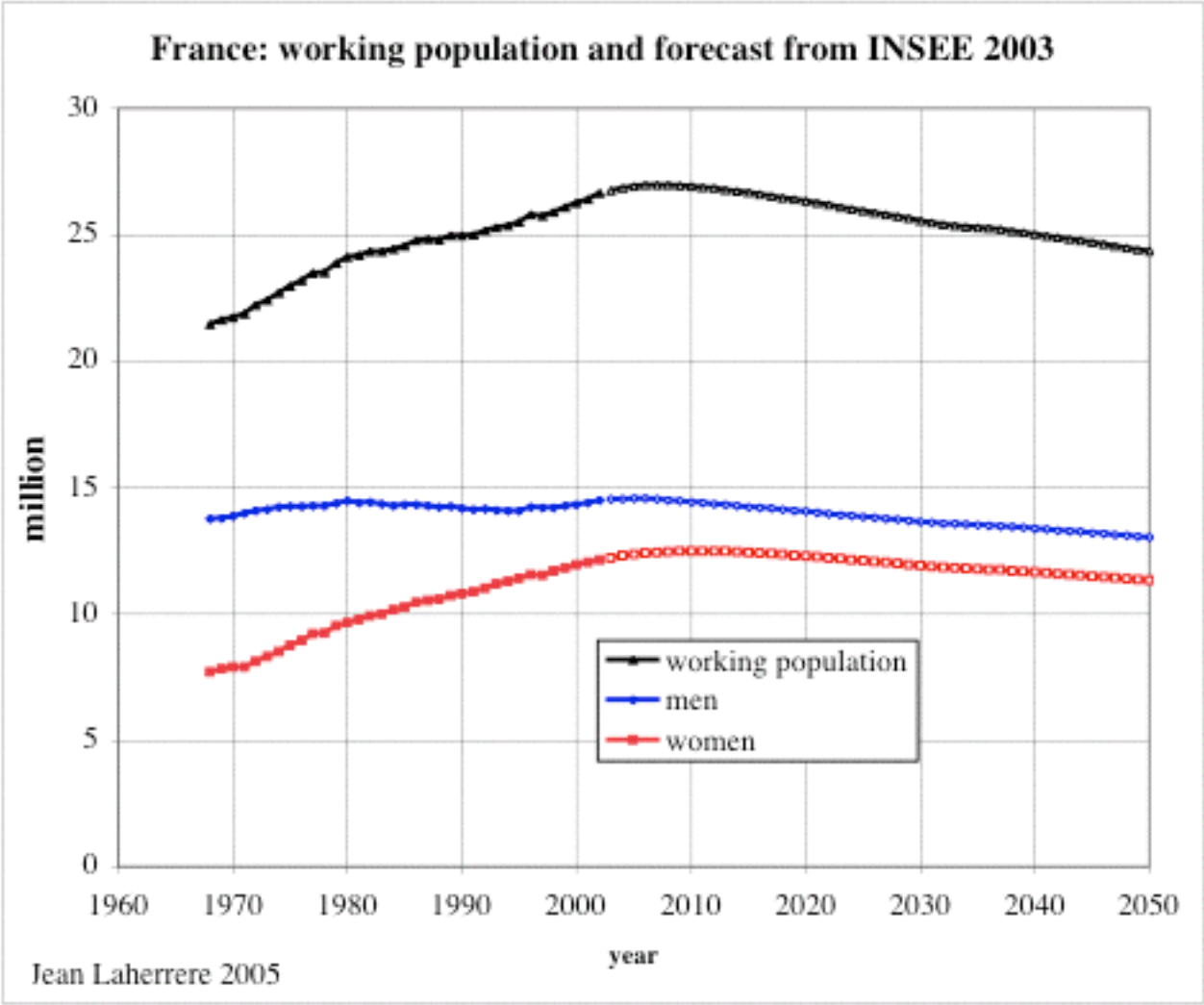
There are two different worlds: North America with growth and Europe with coming decline

Figure 55: **France population**



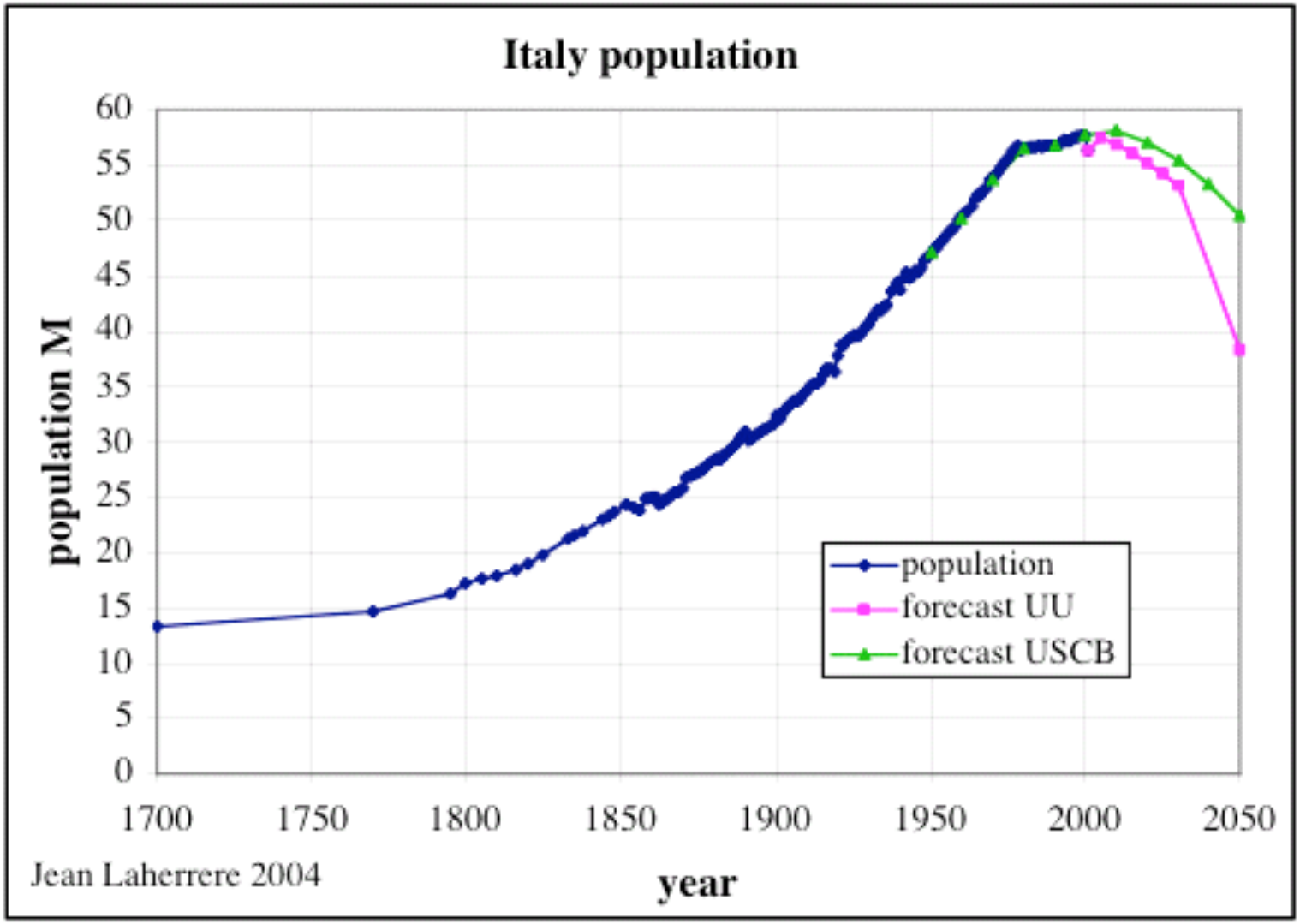
France (main) will peak around 2025

Figure 56: **France: working population & forecast from INSEE 2003**



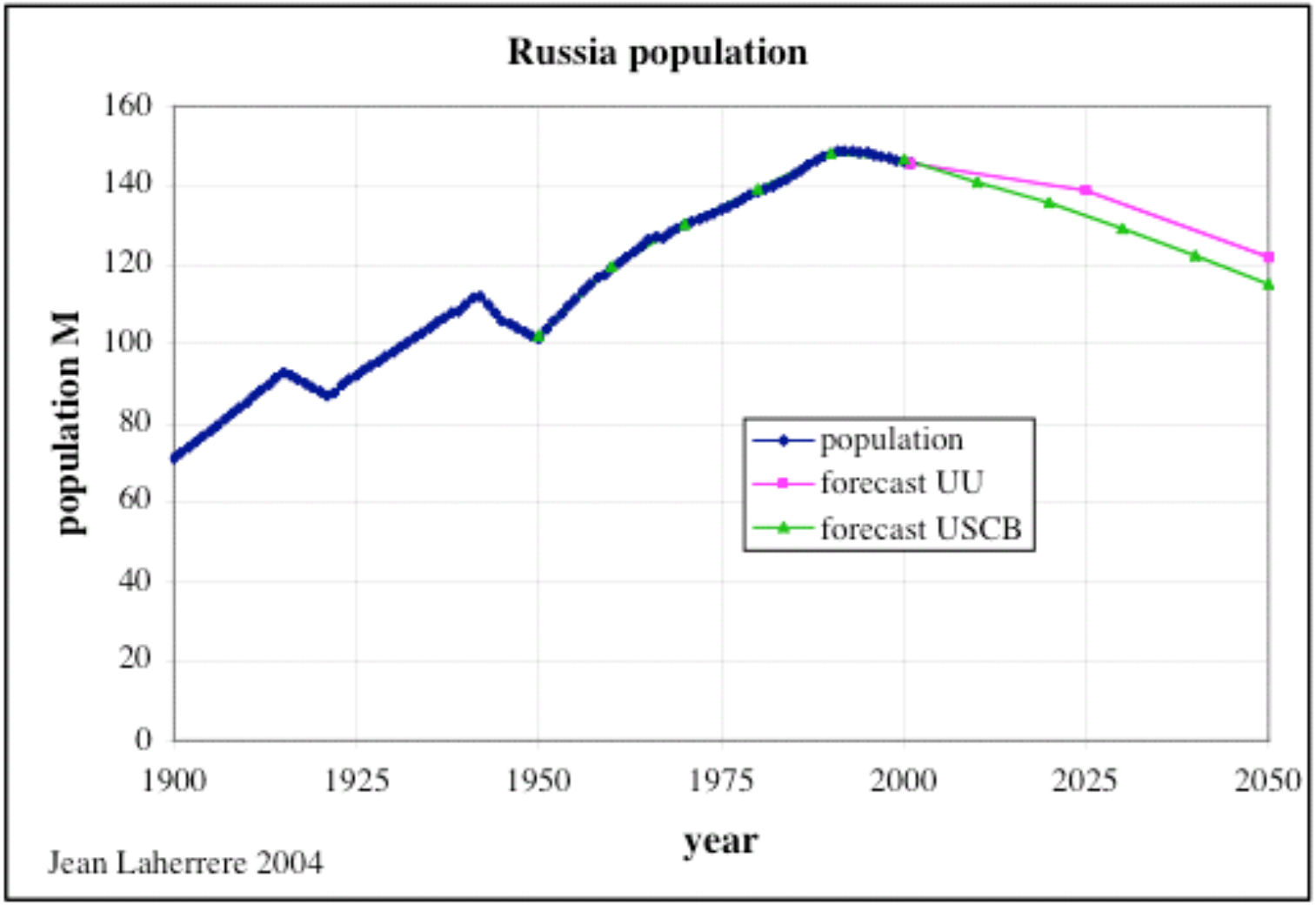
Working population will peak in France next year and economic growth is forecasted at 2,25%!

Figure 57: **Italy population**



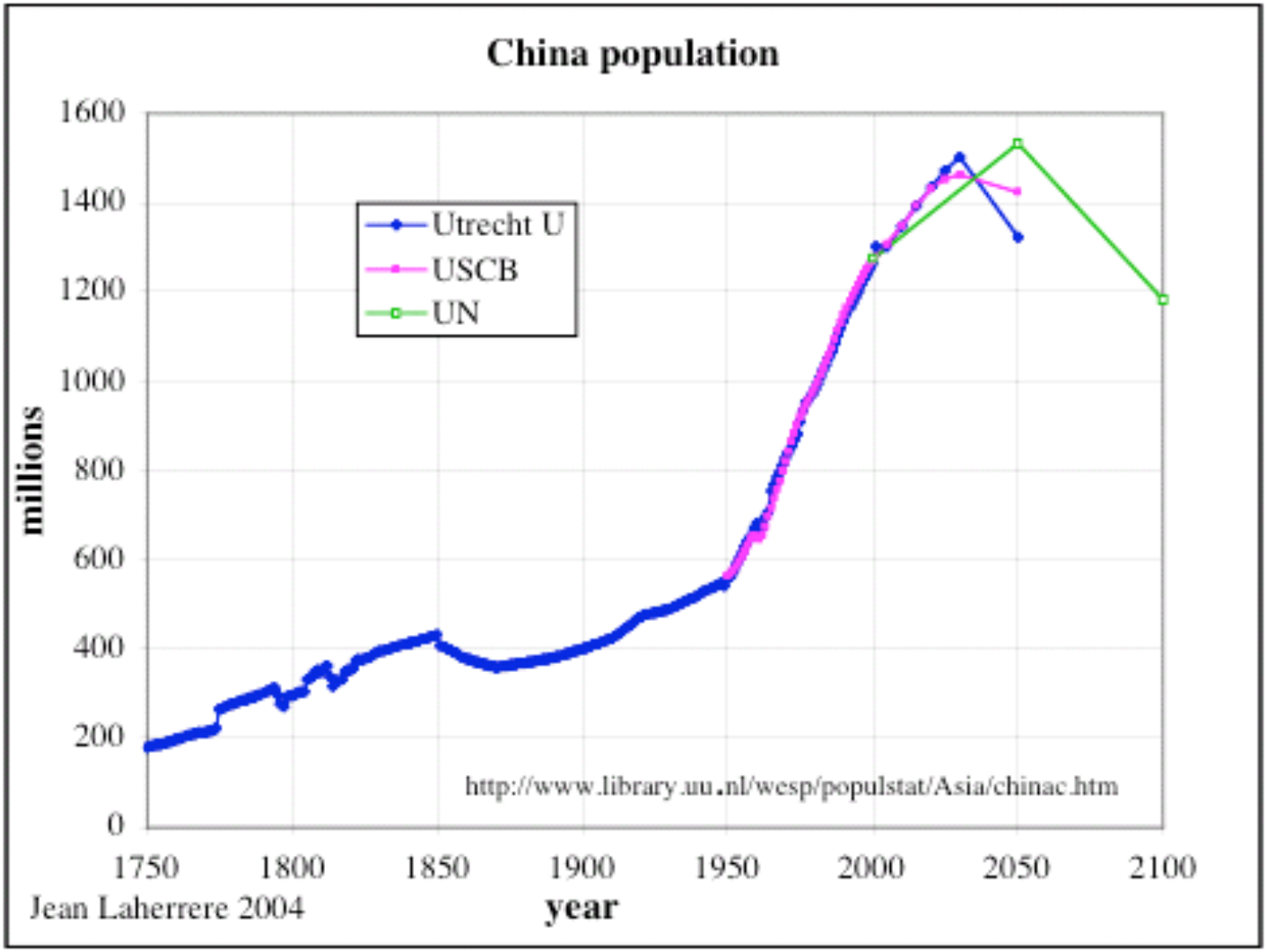
Italy is peaking and will decrease by 10 million in 2050

Figure 58: **Russia population**



Russia has peaked in 1990 and will lose 30 million by 2050

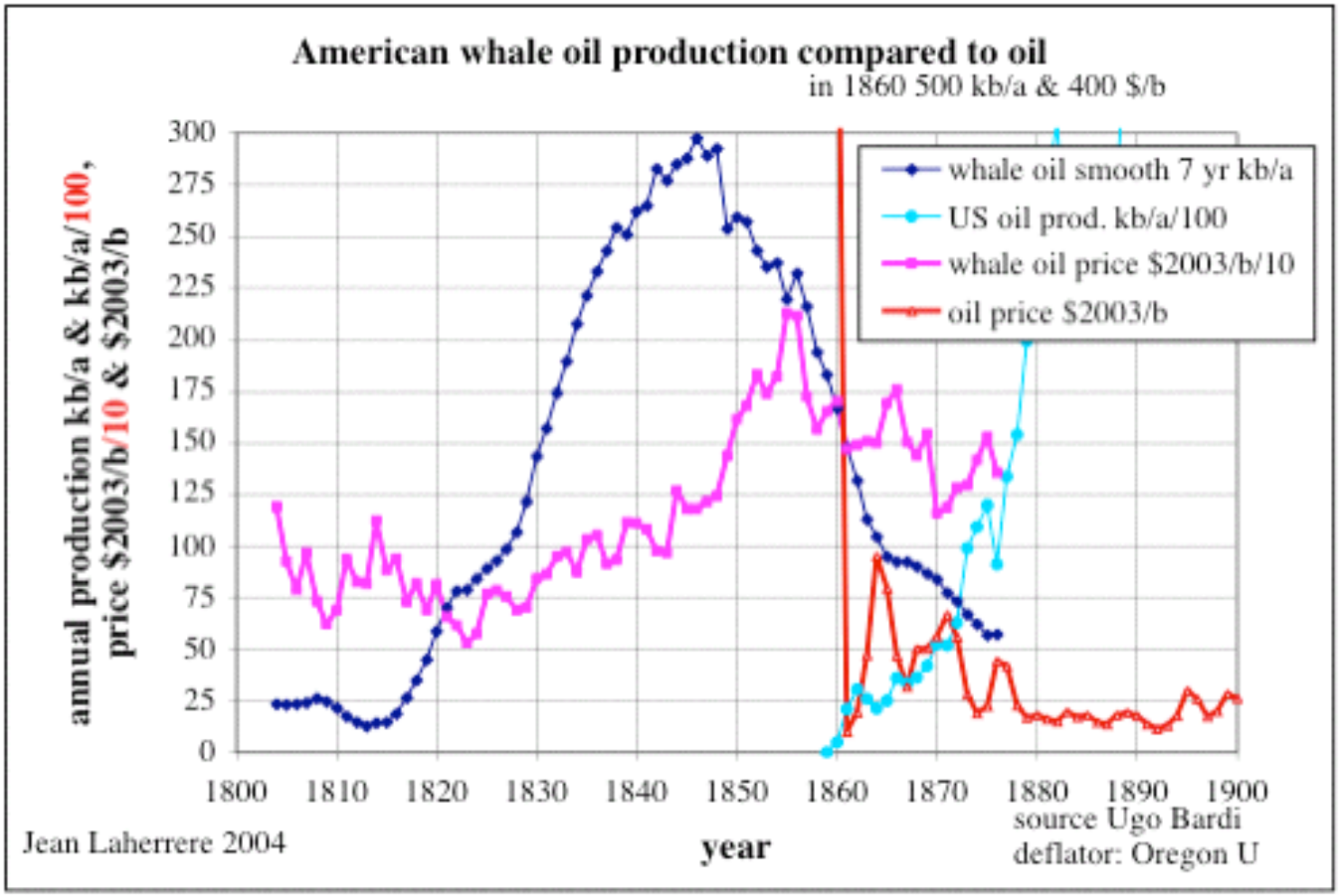
Figure 59: **China population**



China will peak between 2025-2050 and decline by more than 300 M by 2100

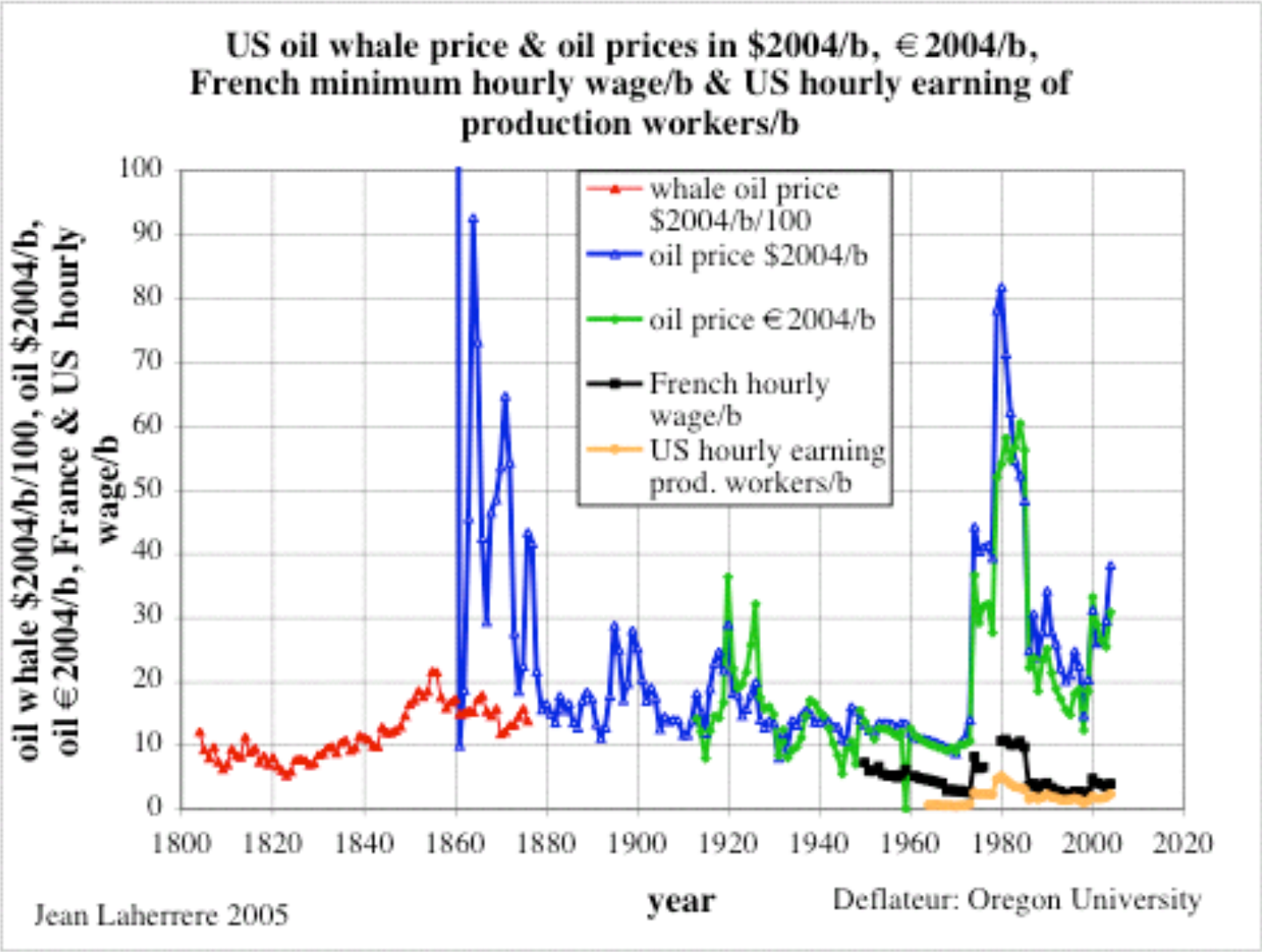
-**Price**

Figure 60: **US whale oil production** (peak in 1847) and price (peak in 1855) compared to oil 1800-1900



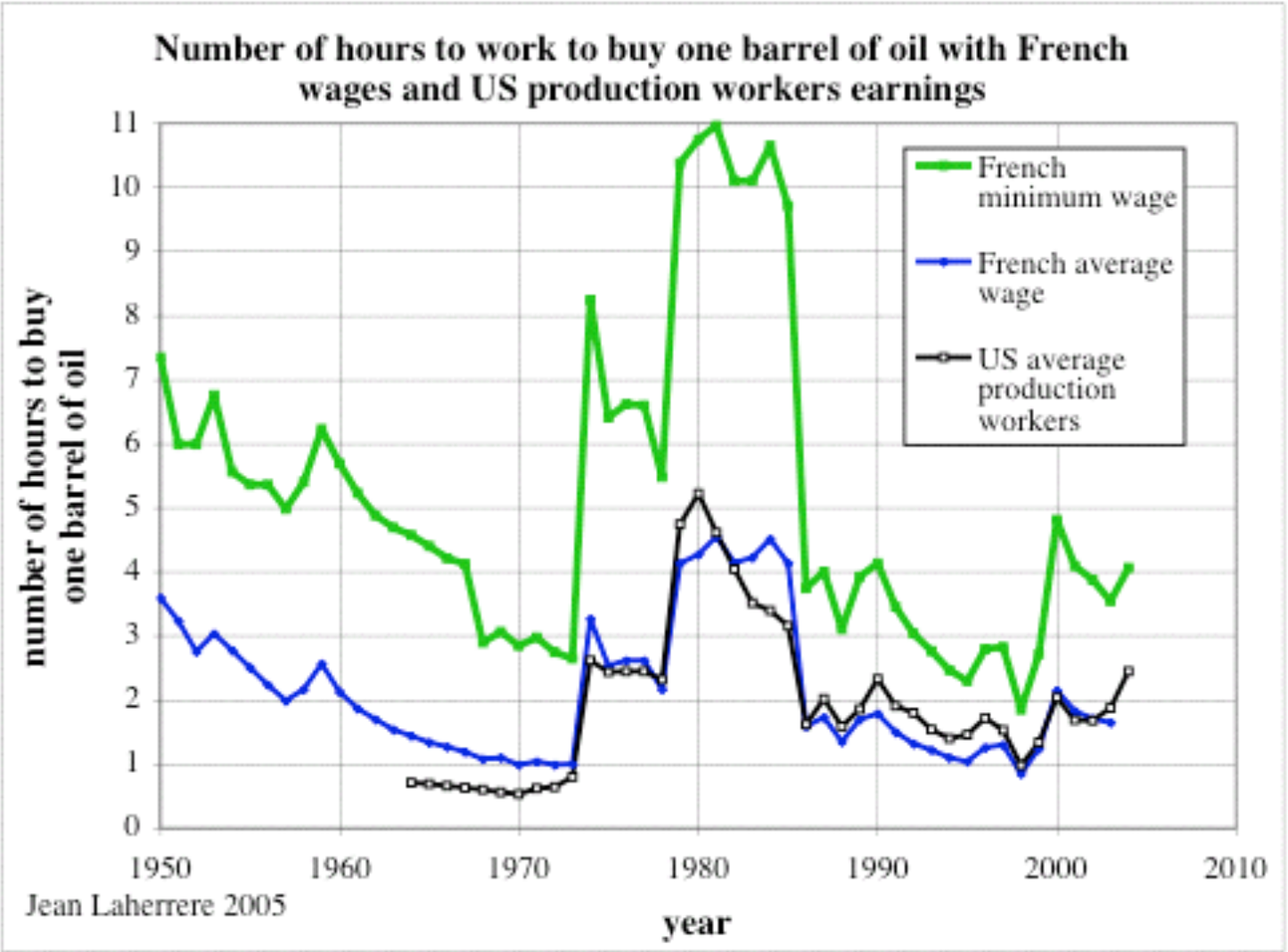
Whale oil production displays a Hubbert curve and whale oil price peaked in 1855 at 2000 $2003/b and in 1875 was 30 times more expensive than oil

Figure 61: **World whale oil, oil price in today dollar and euro as French minimum wage 1860-2004**



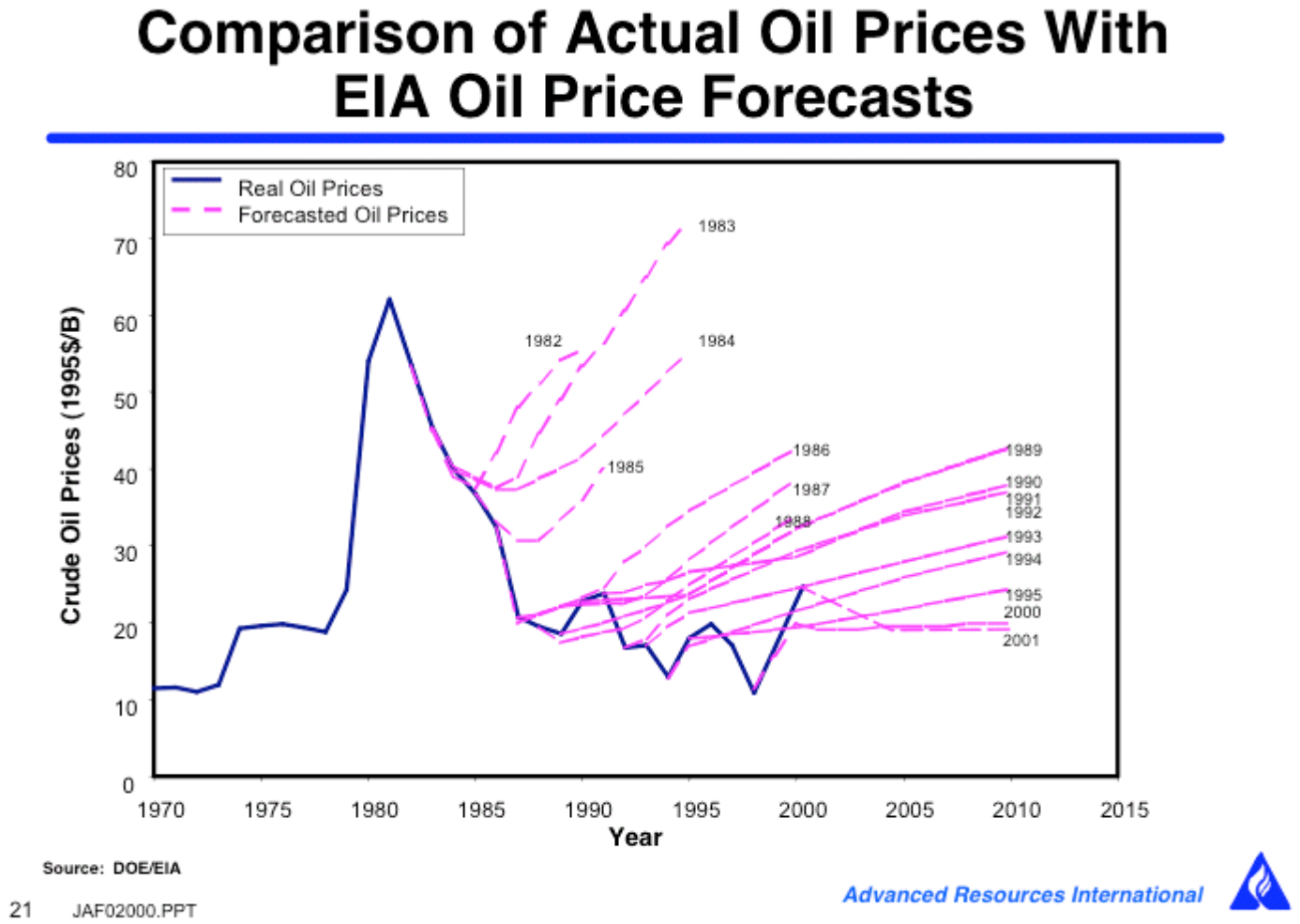
Present oil price is cheap compared to 1860 or 1980

Figure 62: **Number of hours to buy one barrel of oil with French and US wages**



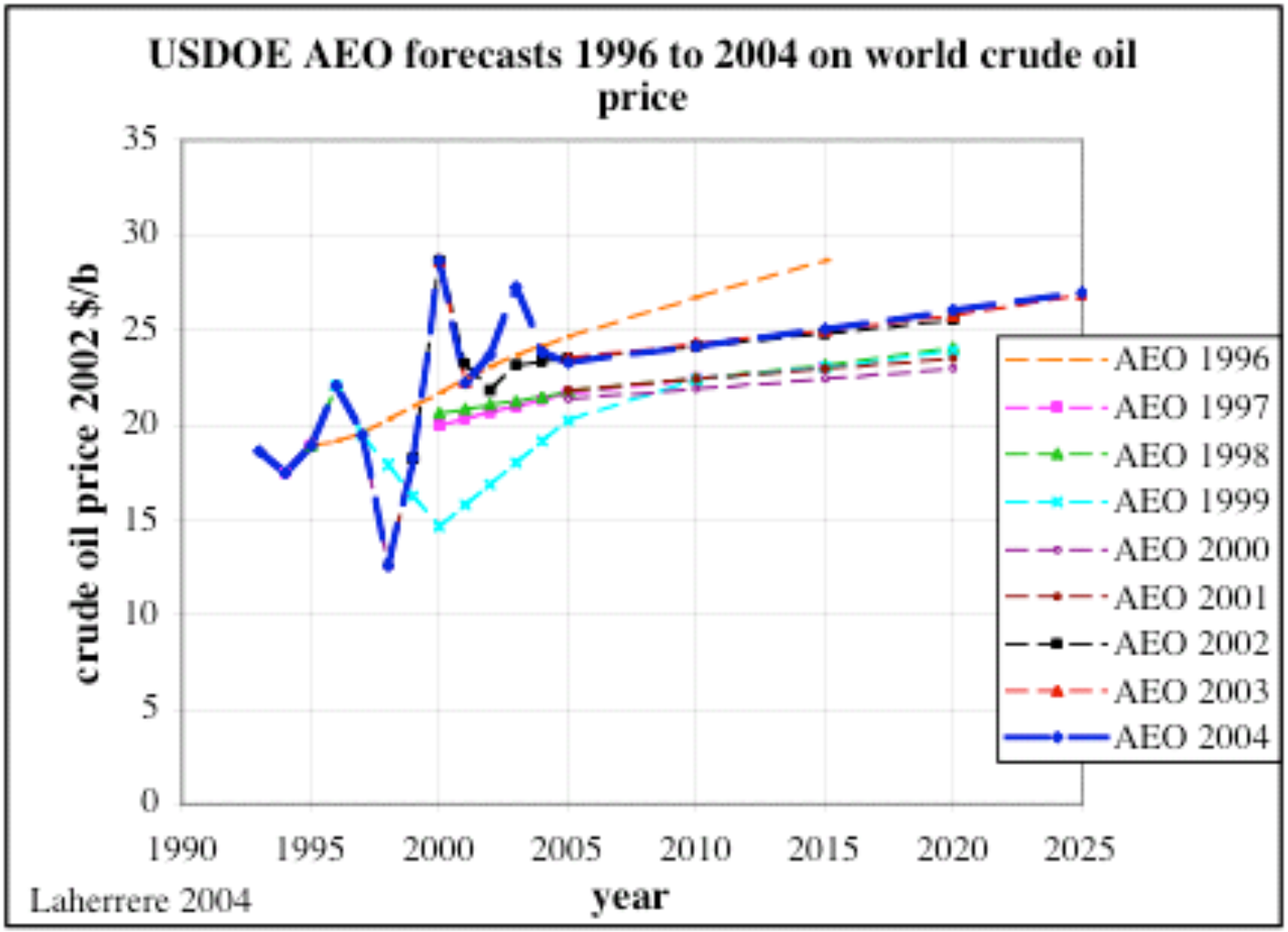
It was necessary to work (at French minimum wage) to buy one barrel of oil 7 hours in 1950, 3 in 1972, 11 in 1981, but 2 in 1998 and 4 in 2004. Today oil has to be at 100 $/b to work as much as in 1981!

Figure 63: **USDOE/EIA oil price forecasts 1982-2001 and actual price**



Forecasts on oil price have been always wrong

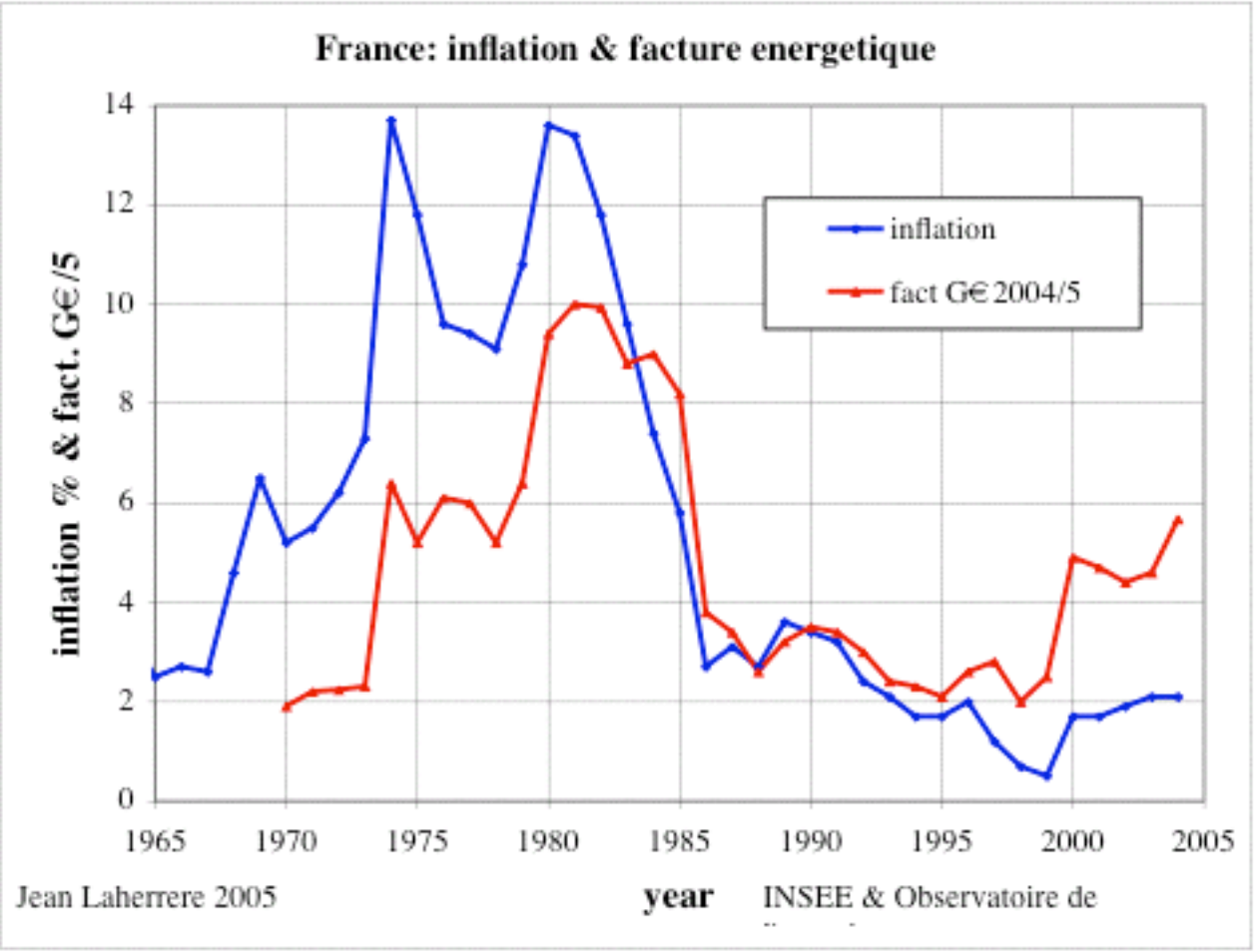
Figure 64: **USDOE long-term oil price forecasts 1996-2004**



USDOE 2004 forecast was 24.2 $2002/b in 2010! USDOE 2005 forecast is 25 $2003/b in 2010
It is why no one wants to invest in energy savings

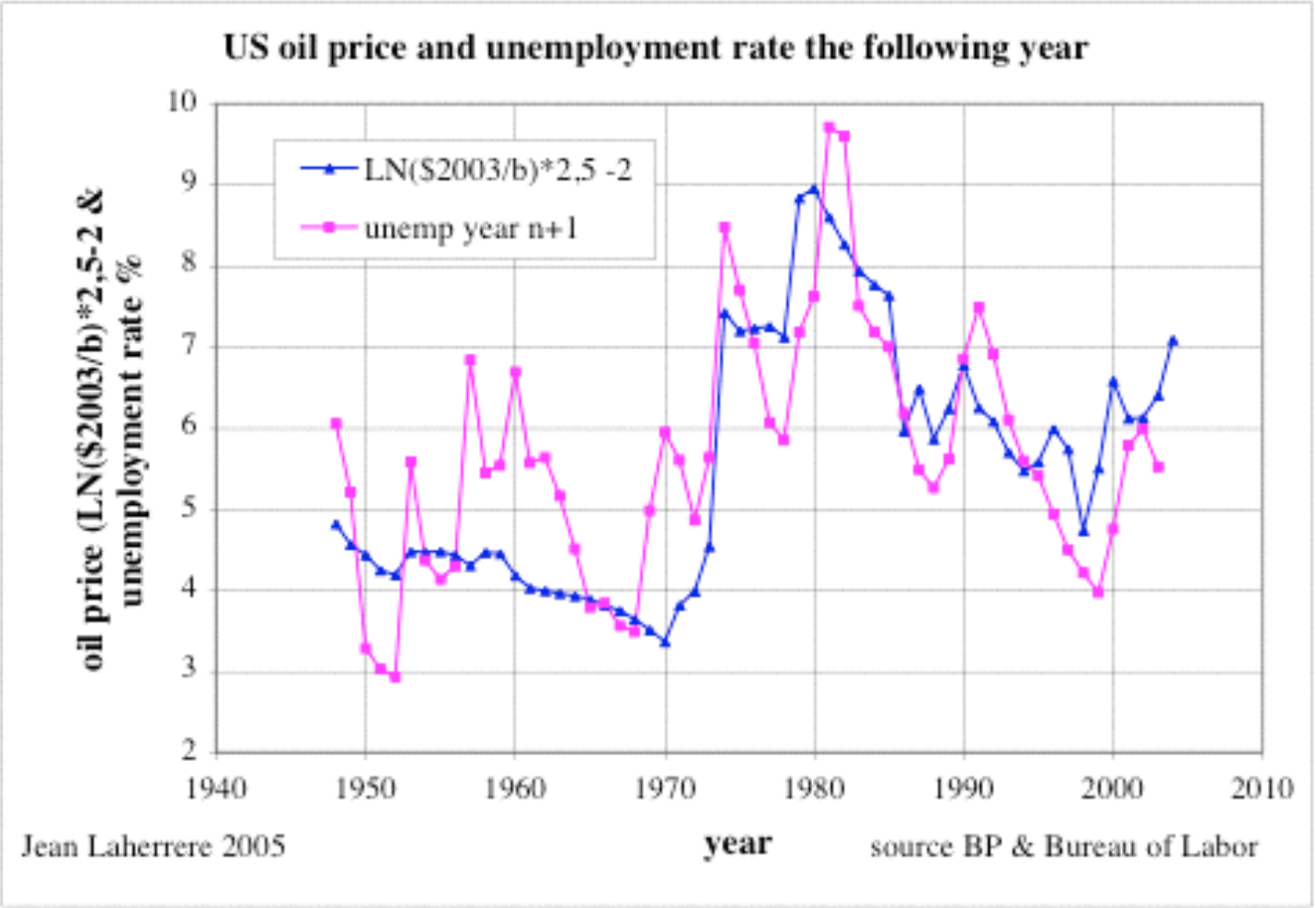
-Economy

Figure 65: **France energy bill and inflation**



Inflation should increase if the energy bill continues to grow!

Figure 66: **US oil price (log scale) and unemployment**



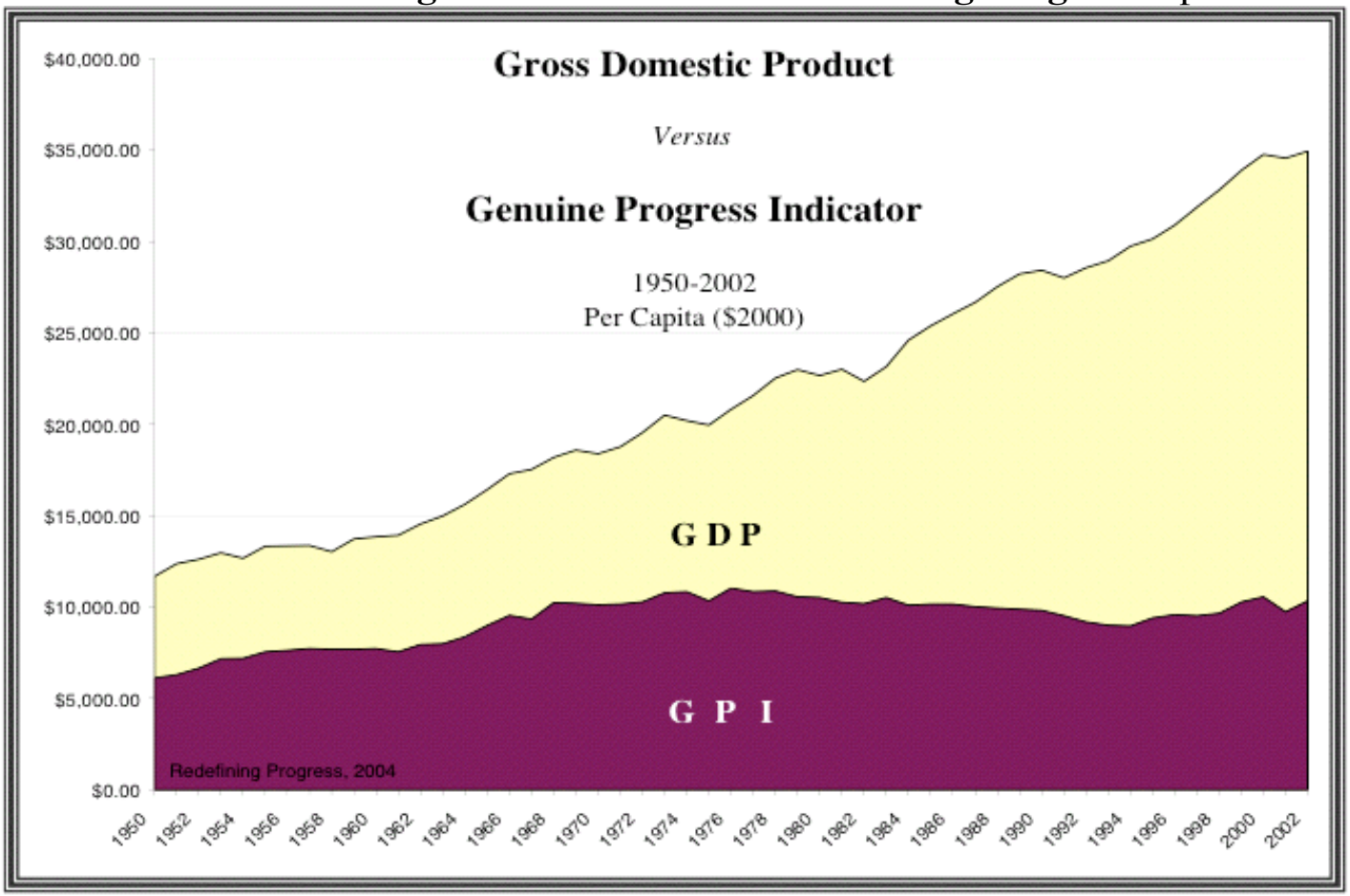
US unemployment should increase if oil price continue to grow!

-GDP

GDP is manipulated with several deflators, in particular the hedonic factor adding extra hundred of G$ for computer and software

GDP represent manipulated expenditures and not the wealth of a country.

Figure 67: **US GDP and Genuine Progress Indicator from Redefining Progress** = peak in 1977



Energetic intensity in toe/$GDP is flawed

-**GDP and happiness**

Figure 68: **Income and happiness in the US**

Richard Layard London School of Economics: peak in US happiness in 1956

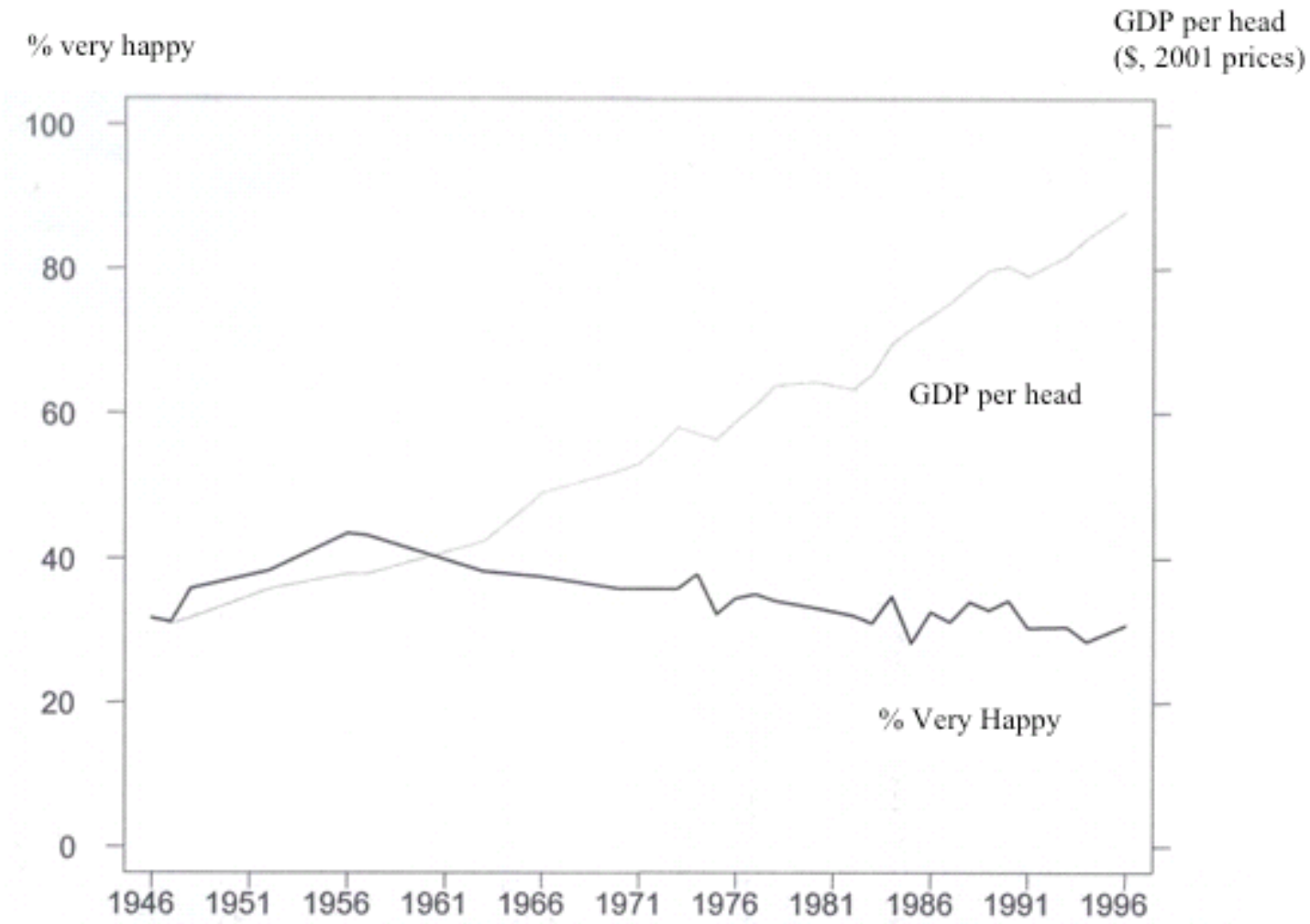
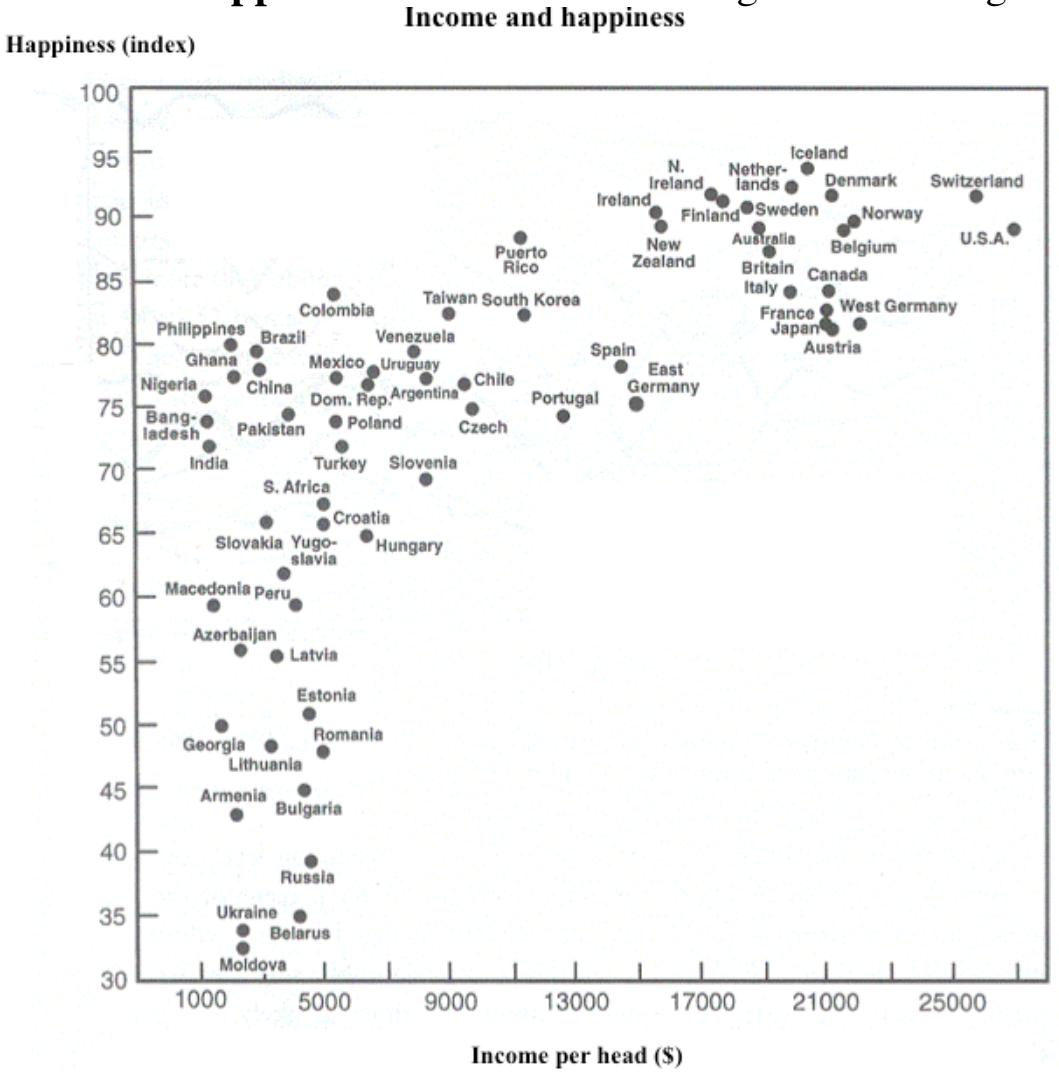


Figure 69: **Income and happiness in the world** from Inglehart & Klingermann 2000



Source: Inglehart and Klingemann (2000), Figure 7.2 and Table 7.1. Latest year (all in 1990s).

First Ireland, last Moldova

-New Scientist (2003):
the most happy countries = Nigeria, Mexico and Venezuela and the least = Russia, Armenia and Romania.
-University Erasmus Rotterdam = Eurobarometer
Ranking of the happiness index = How much people enjoy their life-as-a-whole on scale 0 to 10

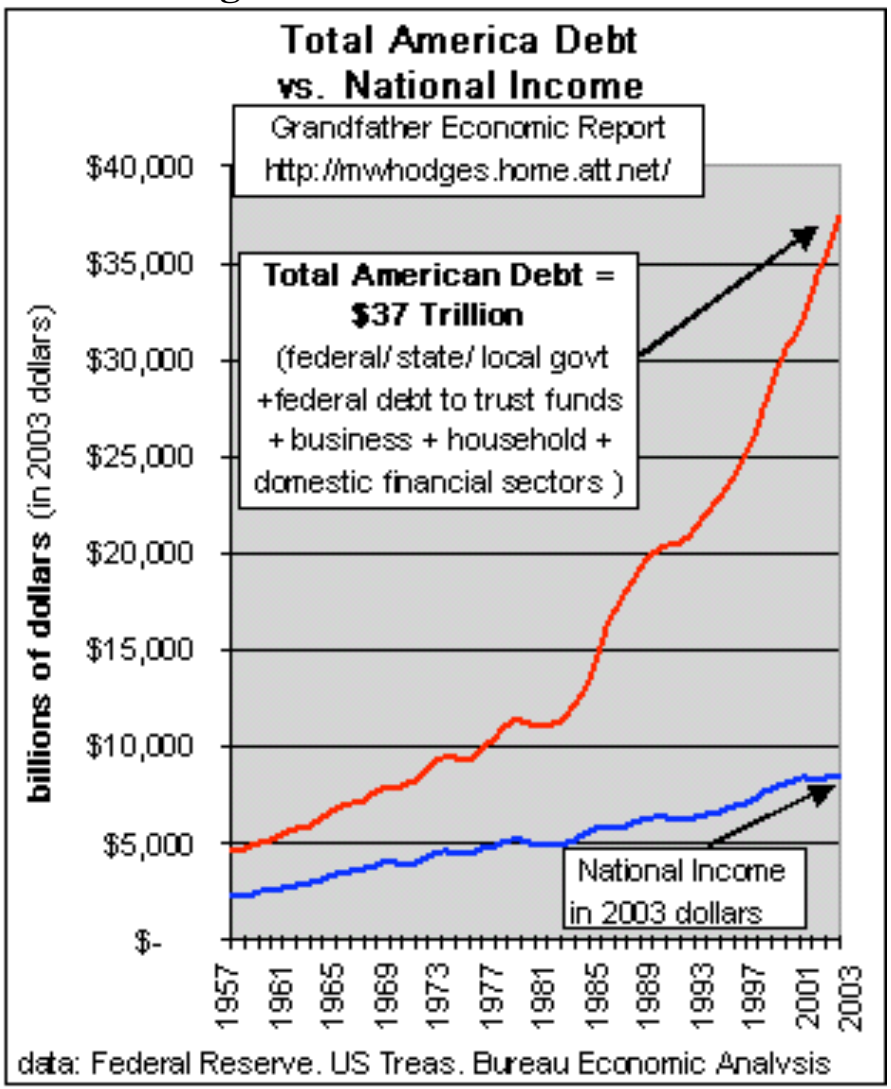
top		**bottom**	
Colombia	8,1	Bulgaria	4,5
Denmark	8	Russia	4,4
Malta	8	Belarus	4,3
Switzerland	8	Pakistan	4,3
Iceland	7,8	Georgia	4,1
Ireland	7,8	Armenia	3,7
Ghana	7,7	Ukraine	3,6
Canada	7,6	Moldova	3,5
Guatemala	7,6	Zimbabwe	3,3
Luxembourg	7,6	**Tanzania**	3,2
USA	7,4		
France	6,6		
Nigeria	6,5		

Happiness is hard to measure!

-**US economy**

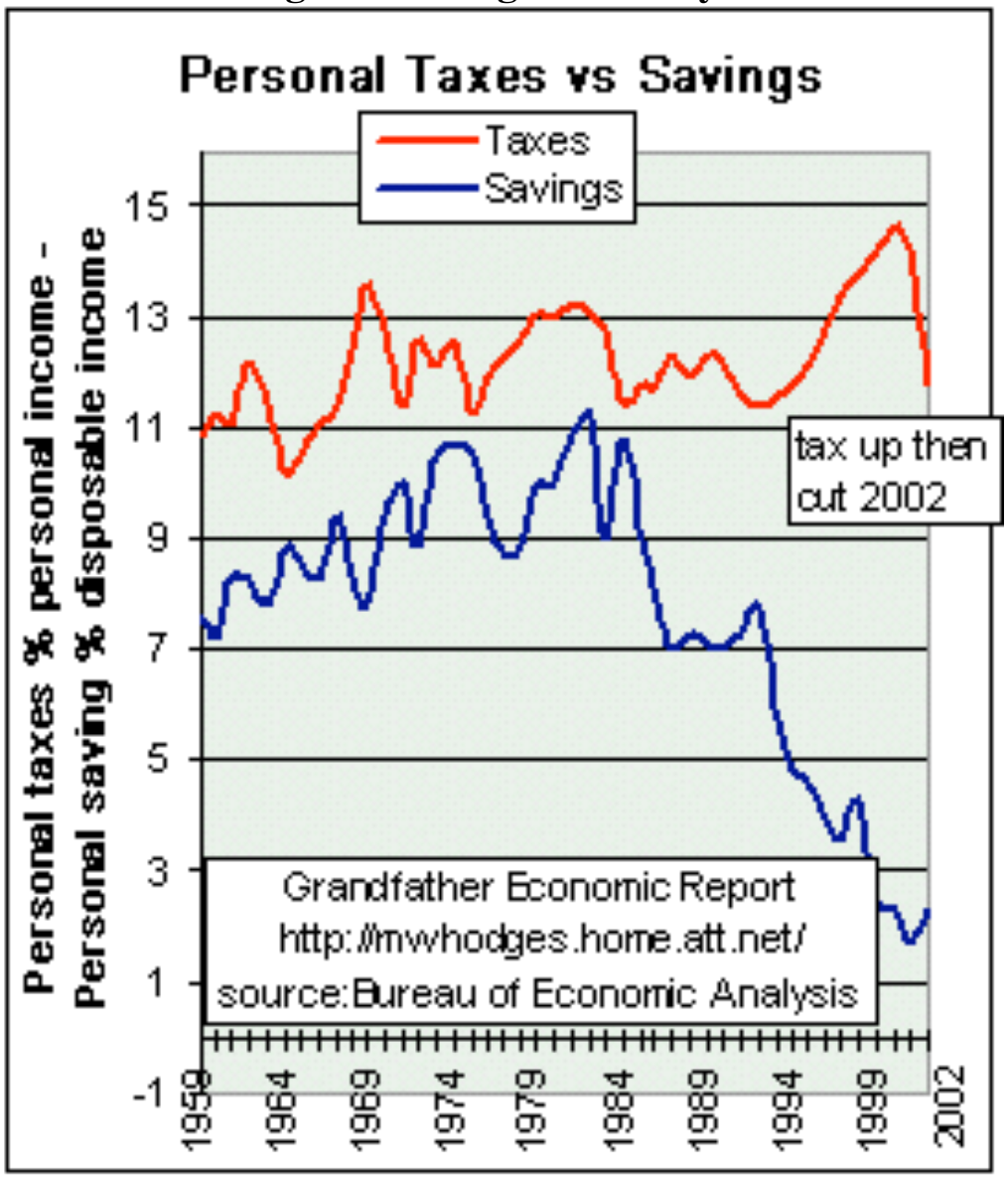
from Grandfather Economic Report:

Figure 70: **Total US debt grows much more than income**



Is it sustainable? When is the peak?

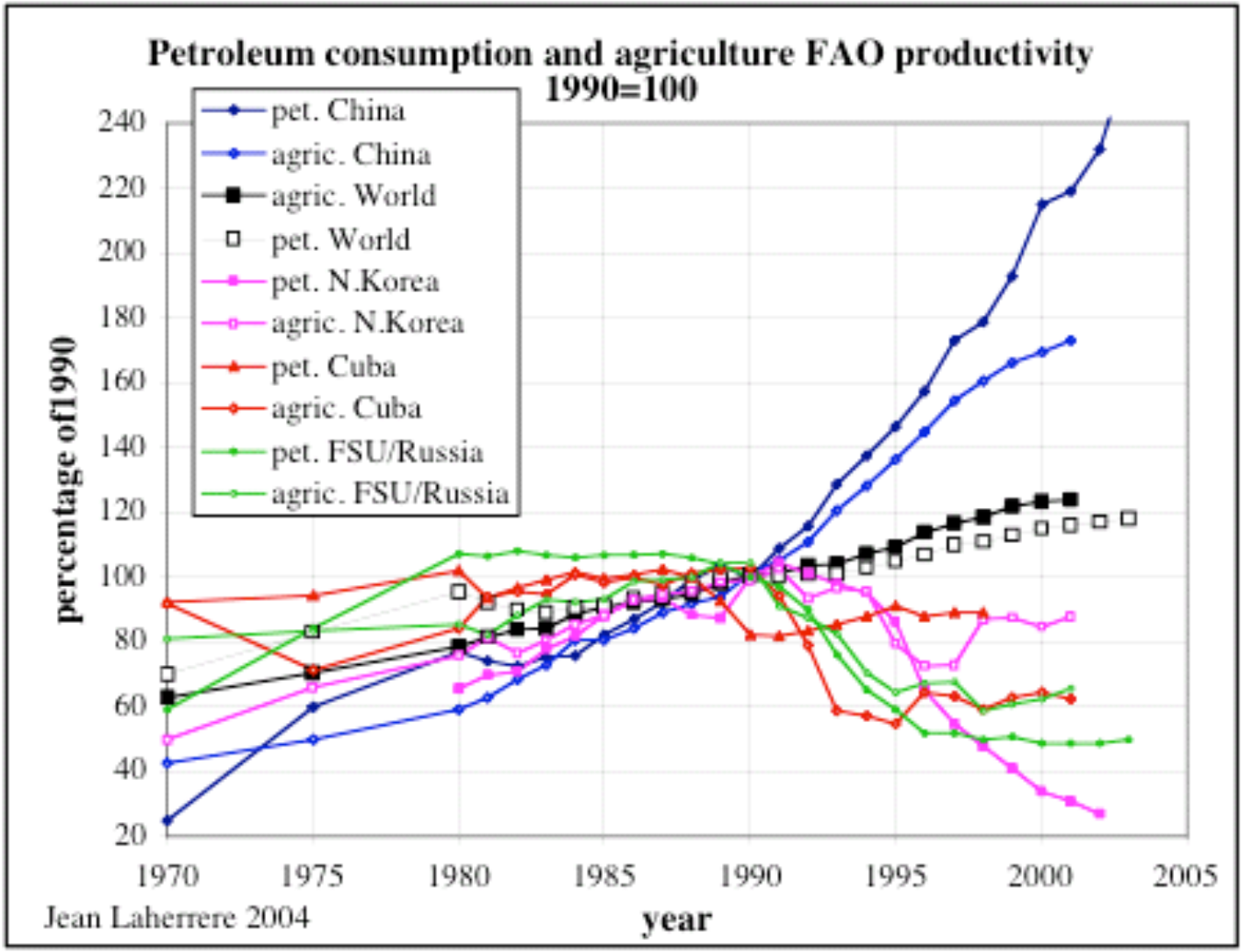
Figure 71: **US Personal savings are falling drastically**



US borrow 80% of the world savings to keep consuming, what about when they reach 100%?

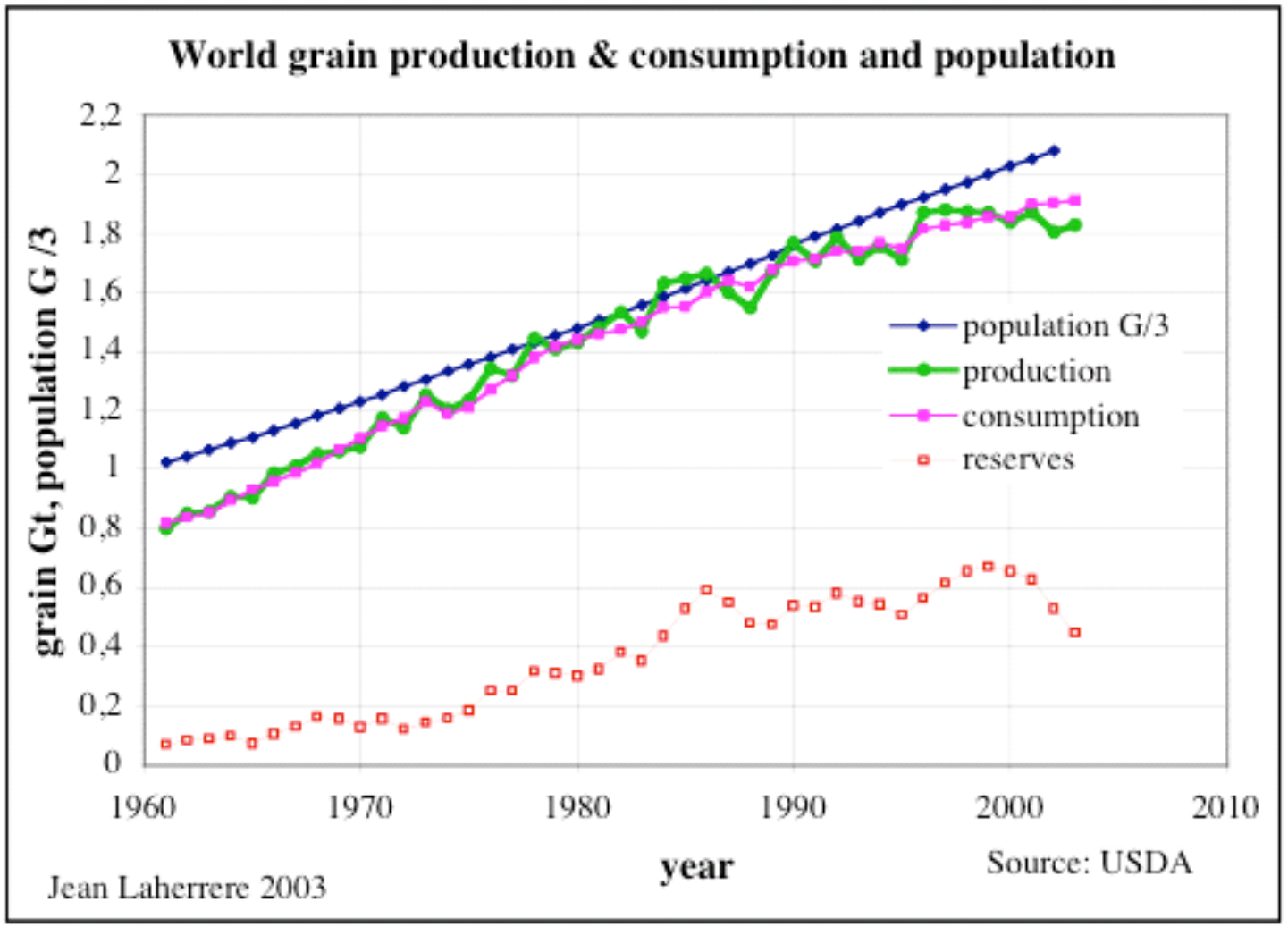
-Agriculture

Figure 72: **Petroleum consumption and agriculture productivity** 1990=100



Agriculture productivity varies with petroleum consumption. Agriculture converts oil into food!

Figure 73: **World grain production, consumption, reserves and population**



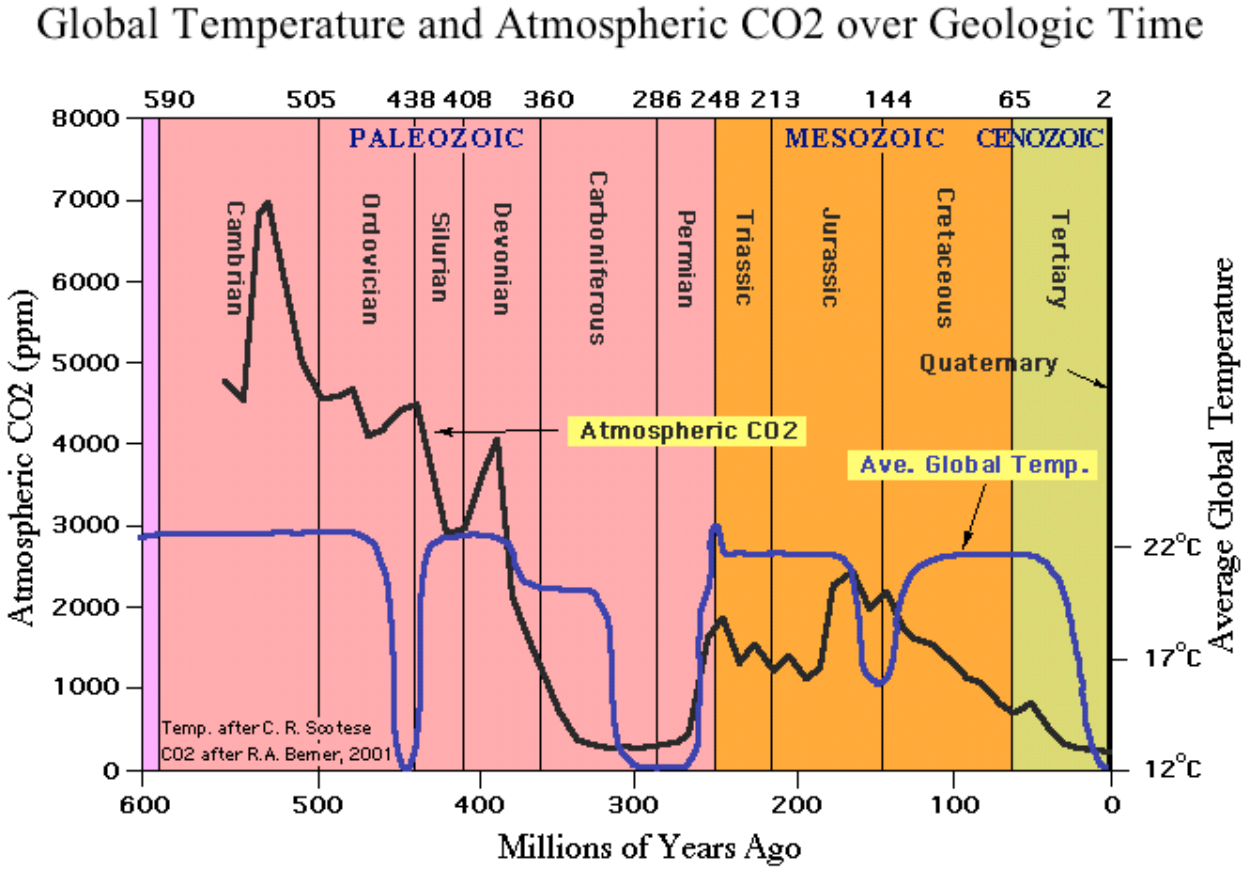
Since 1985 grain production increases less than population and less than consumption, leading to reserves decline

-**Global warming and climate change**

We are presently in an interglacial period within glaciations, which started two million years ago (lands at or around poles due to continent drift). Previous glaciations were 300 Ma ago. Climate changes all the times and geological layers are the best proof!

From the birth of Earth, temperature and CO2 has been most of time warmer than now.

Figure 74: Earth temperature for the last 600 Ma from Gehrard 2004



Late Carboniferous to **Early Permian** time (315 mya -- 270 mya) is the only time period in the last 600 million years when **both** atmospheric **CO2** and **temperatures** were as low as they are today **(Quaternary Period).**

Global warming (all earth is warmer) can be different from climate change (locally but no global increase)

Human emissions are at the fourth order compared to solar system geometry being at first order.
Figure 75: relative significance of climate-affecting processes Gehrard 2001 AAPG

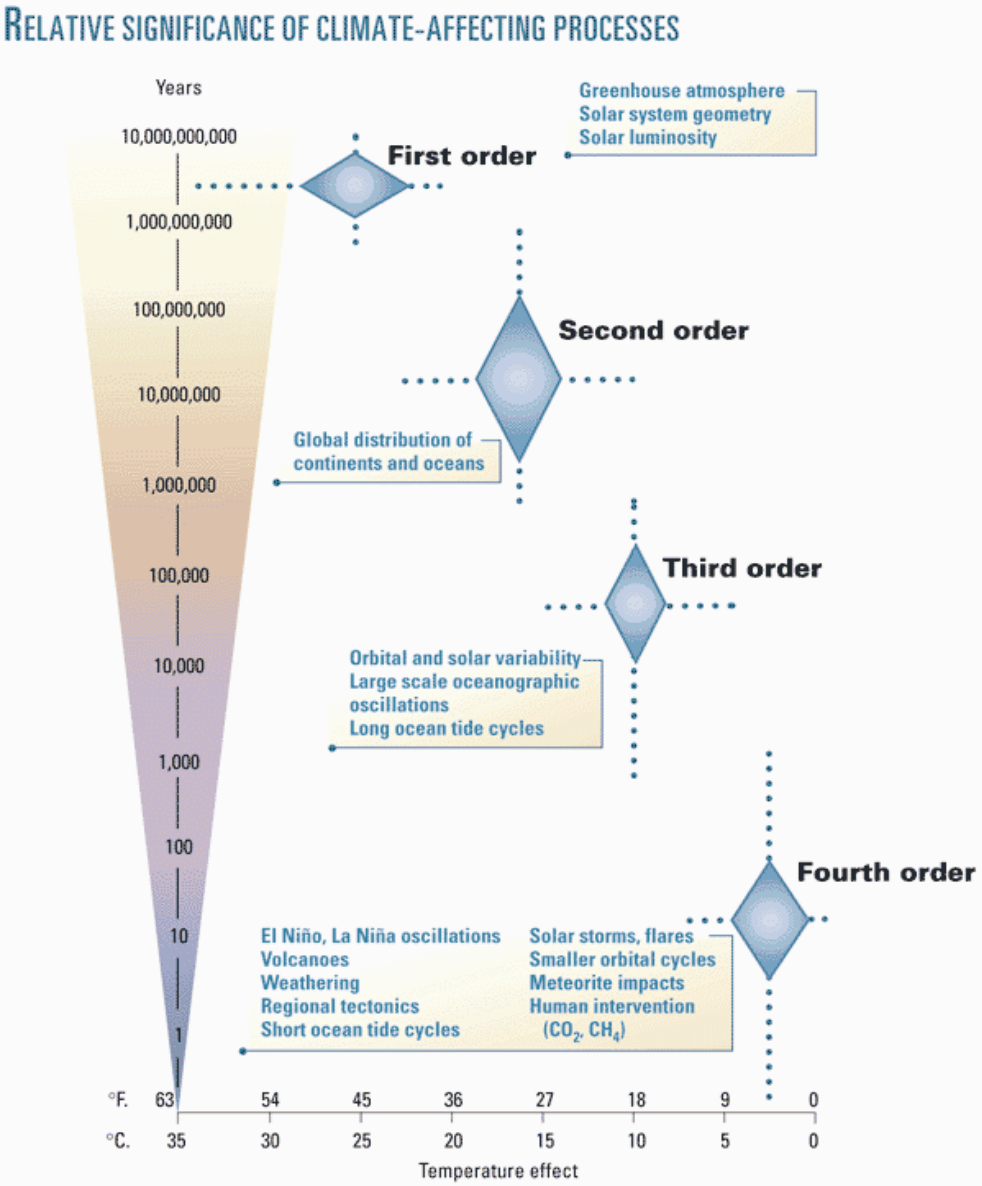
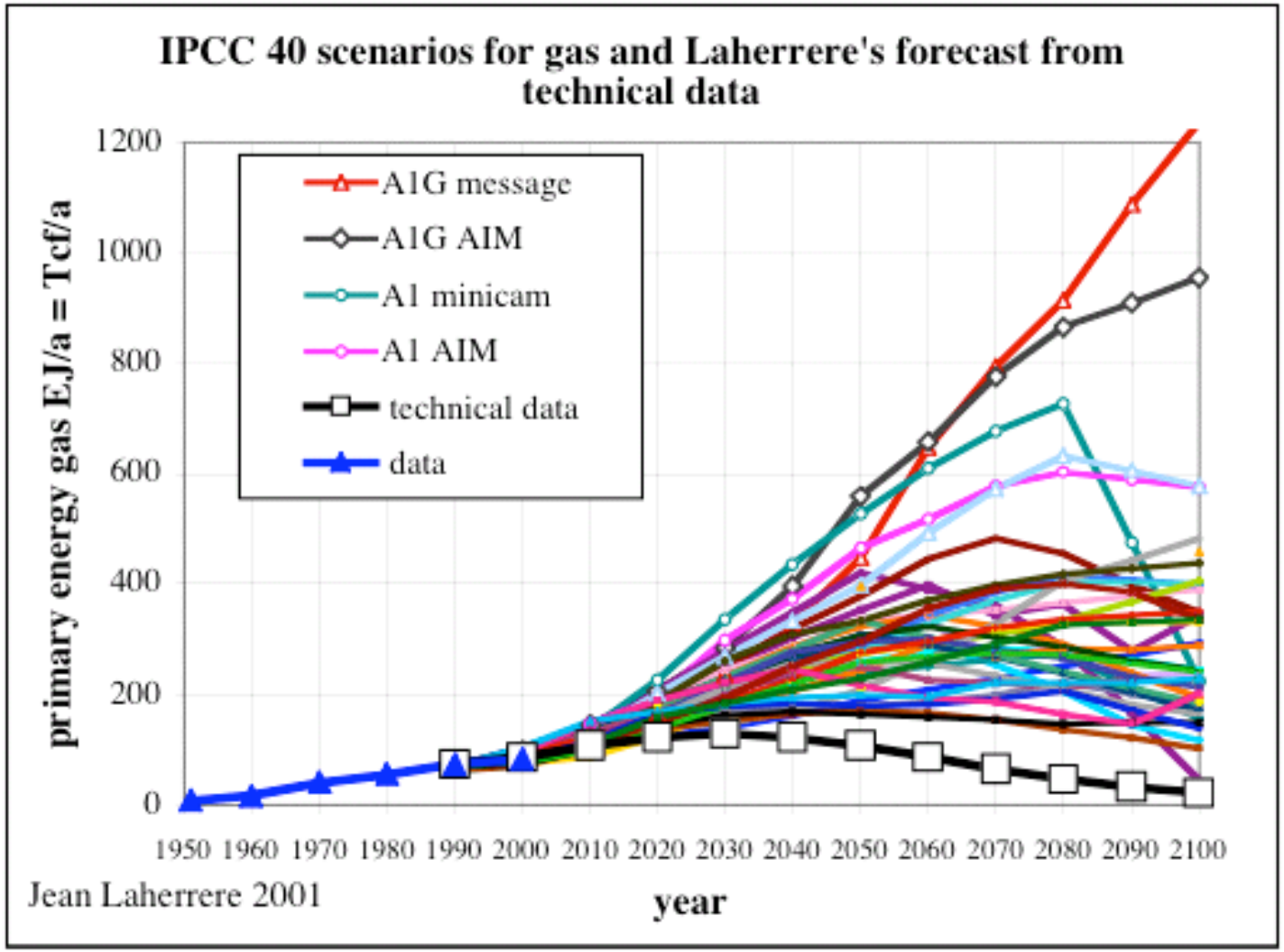


Figure 76: IIASA scenarios (IPCC report) for gas consumption compared to mine



IIASA dreams of a methane hydrate age!

Figure 77: IIASA scenarios (IPCC report) for oil consumption compared to mine

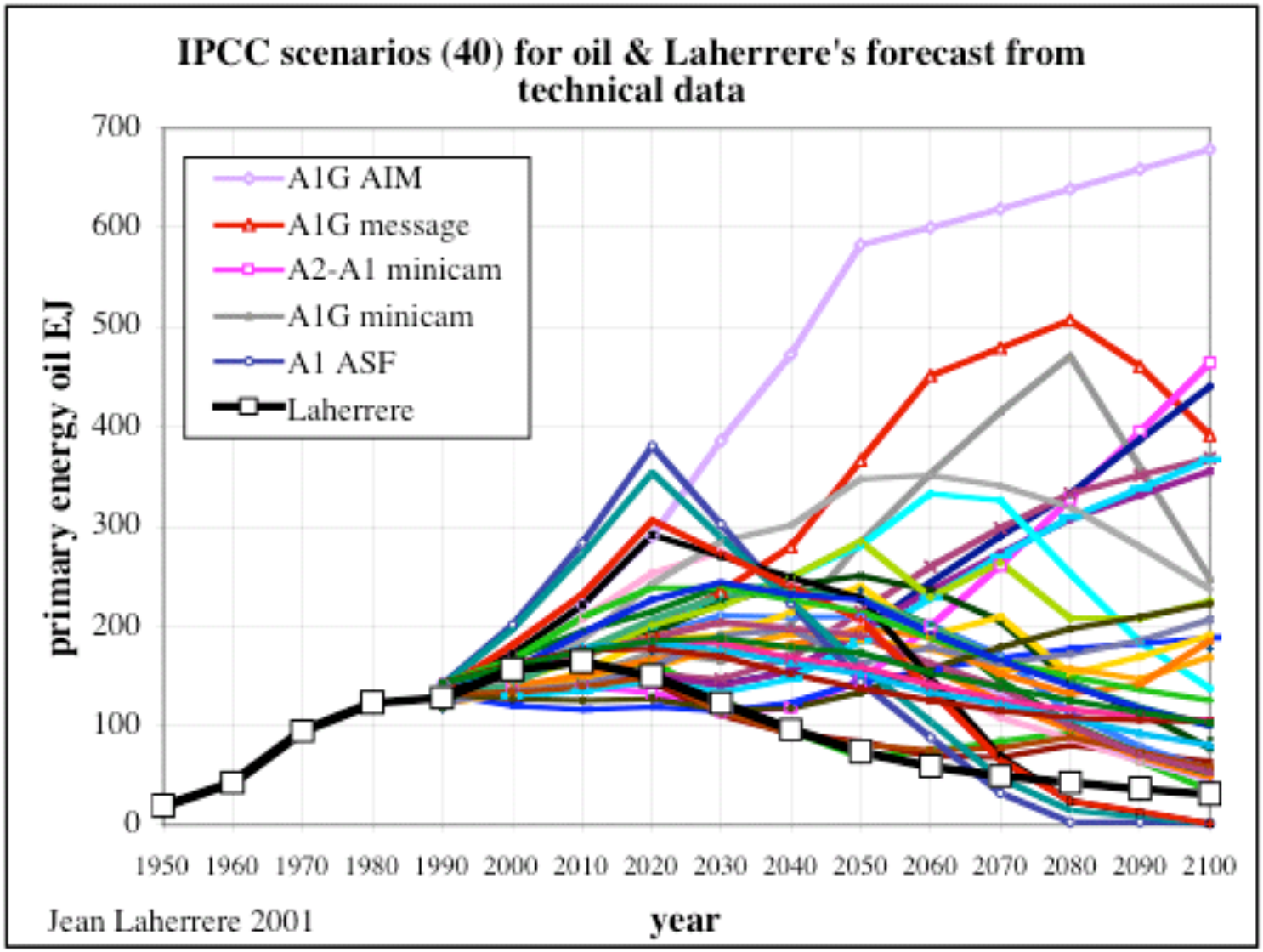


Figure 78: IIASA scenarios (IPCC report) for coal consumption compared to forecast from BGR ultimate

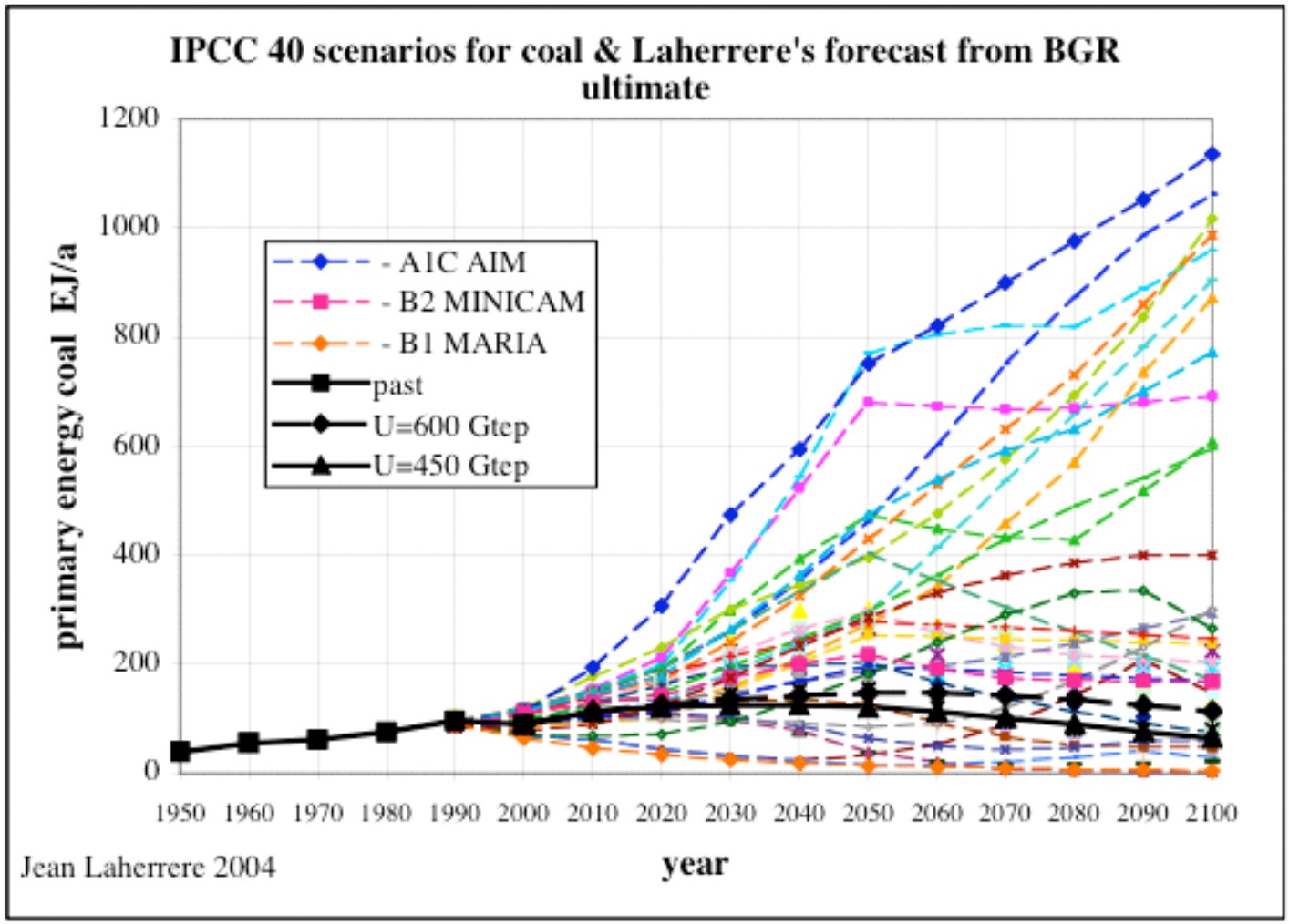
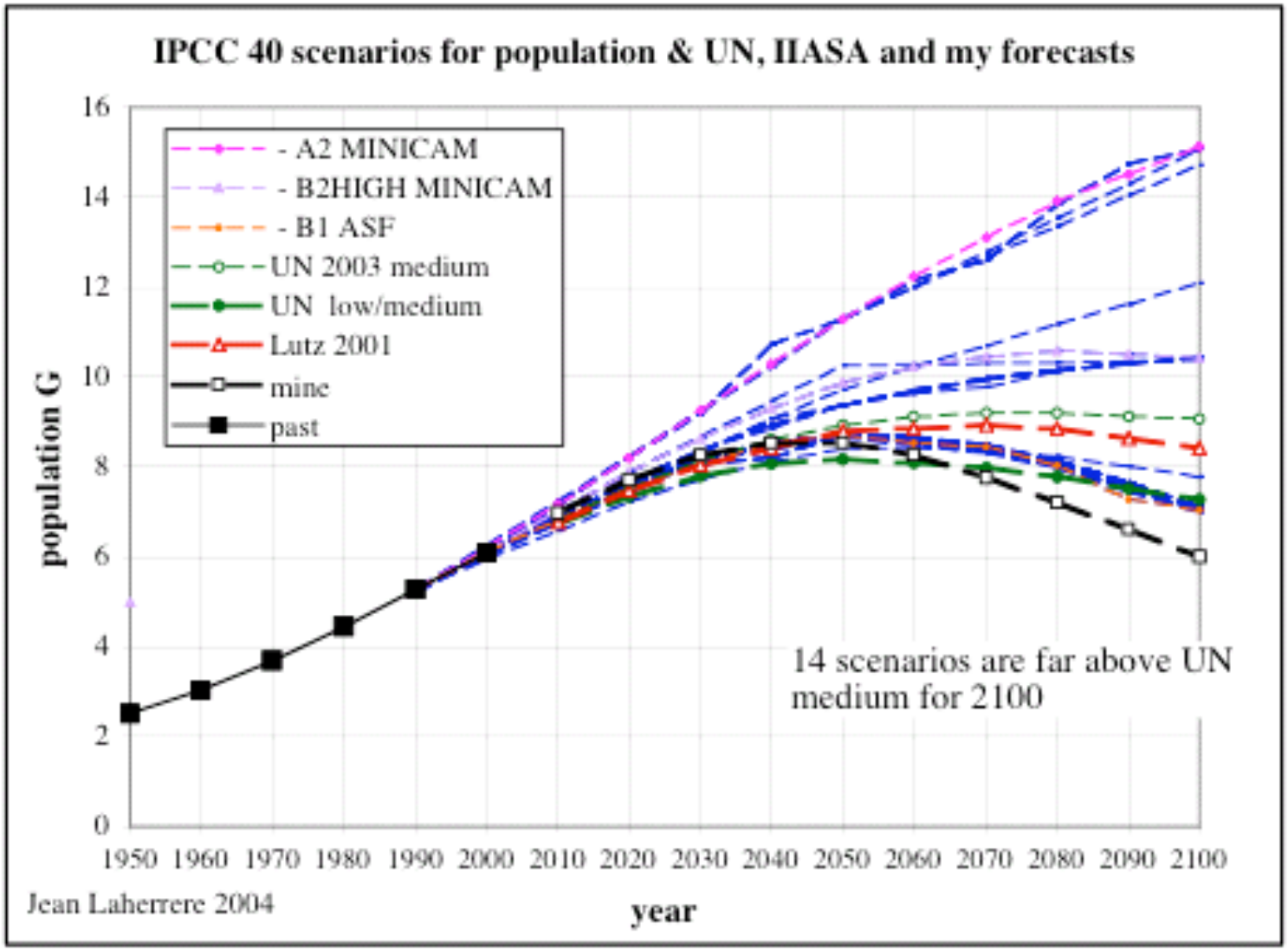


Figure 79: IIASA scenarios (IPCC report) for population compared to UN, IIASA (Lutz) and my forecast



-Conclusions

-what is born will peak and later die

-constant growth has no future in a limited world

-forecasting production requires good data, which is no the case as most actors cheats on data

-reserve uncertainty is large because of the geological complexity and the very limited amount of measures

-publishing production, reserves and population data is a political act, because it depends upon the image the author wants to give

-quality of data is poor, because of its political implication, and very few wish to improve it

-oil production mimics oil discovery with a certain lag (7 to 50 years), but is constrained also by demand and the first oil peak of 1979 was due to lower demand in front of high oil price expectancy (which was wrong!).

-US discovery peaked in the 30s and US oil production peaked in 1970. World oil discovery peaked in the 60s and production could peak in the next decade or so

-the coming oil peak could be in fact a bumpy plateau if economic depression constraints the demand and delays the peak

-world gas production peak will come later than oil peak, but a gas shortage could occur soon in North America and later in Europe

-coal resources seem to be less than reported by lack of good inventory and good definition; coal could peak much sooner than expected

-fossil fuels production will peak around 2030, but the production per capita, which was flat for the last 25 years, will stay flat for the next 25 years

-primary energy extrapolation of the past (10 Gtoe in 2003) leads to models of either peaking or flattening at 13 Gtoe
-high-energy price is the best solution to save energy and save future demand problems
-shortages in water, agriculture and fishery will likely occur sooner than for fossil fuels
-countries where women are educated are trending towards extinction, with fertility rate less than replacement
-Europe will lose 100 millions people in 2050 when North America will gain 100 millions!
-fossil fuels scenarios used by IPCC reports on climate change are unrealistic and obsolete, making IPCC conclusions unreliable for the report in 2001 and the coming one in 2007 = GIGO

More graphs and papers are on the site www.oilcrisis.com/laherrere

Any question and comment welcome now
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