Prague Praha 22 April 2008 Workshop "Natural Gas Security in Central Europe"

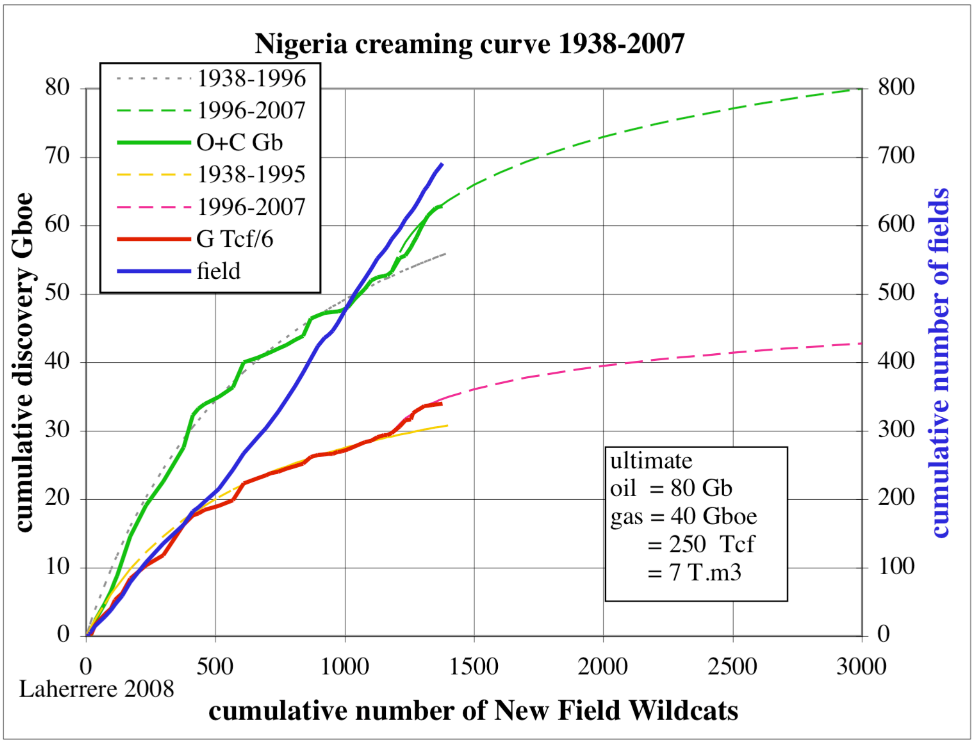
Forecasts of natural gas exports to Europe
Jean Laherrere ASPO France

PART 2

-Nigeria

Nigeria creaming curve displays two cycles, the last one being deepwater (small for gas). But the cumulative number of fields is a perfect straight line.

Figure 77: *Nigeria: oil & gas creaming curve 1938-2007*



Ultimate is 80 Gb for oil and 40 Gboe or 250 Tcf or 7000 G.m3 for gas.

Figure 78: *Nigeria: oil & gas cumulative discovery*

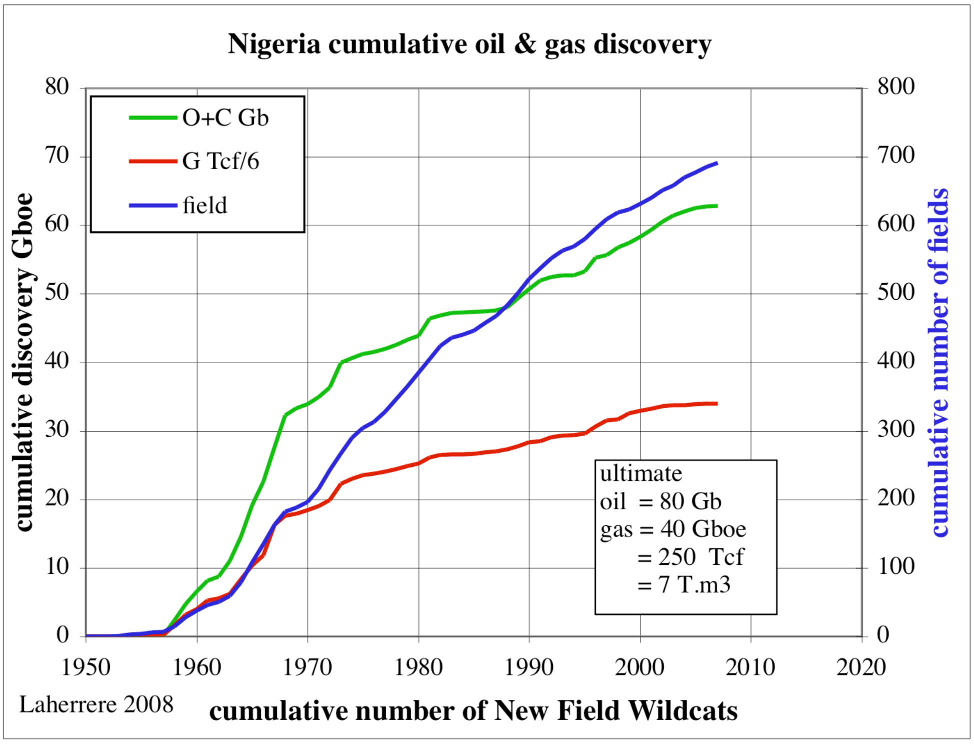
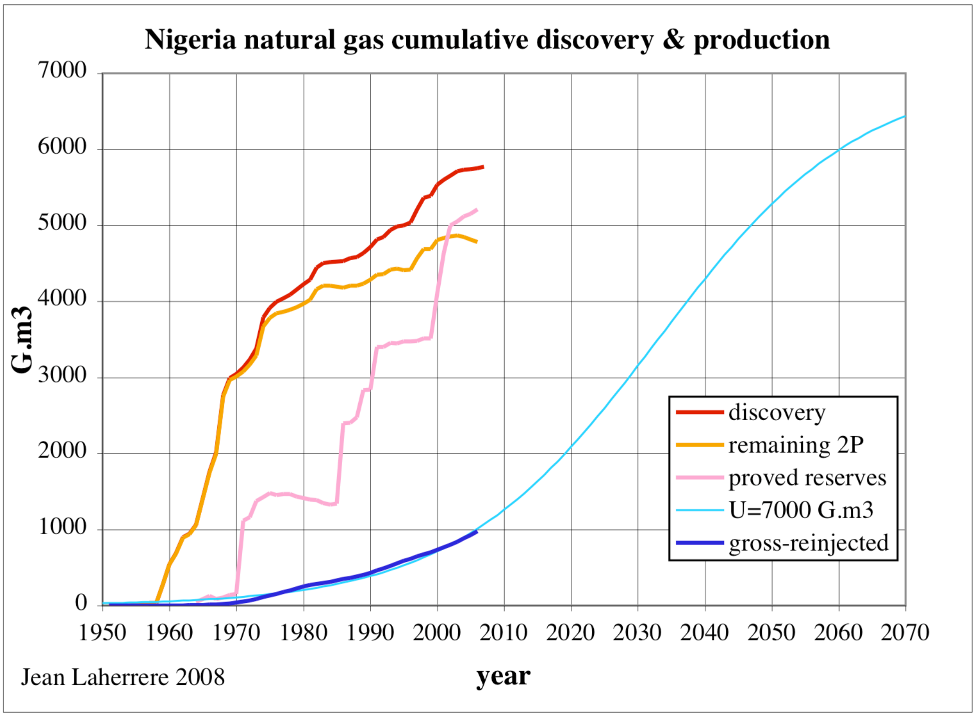
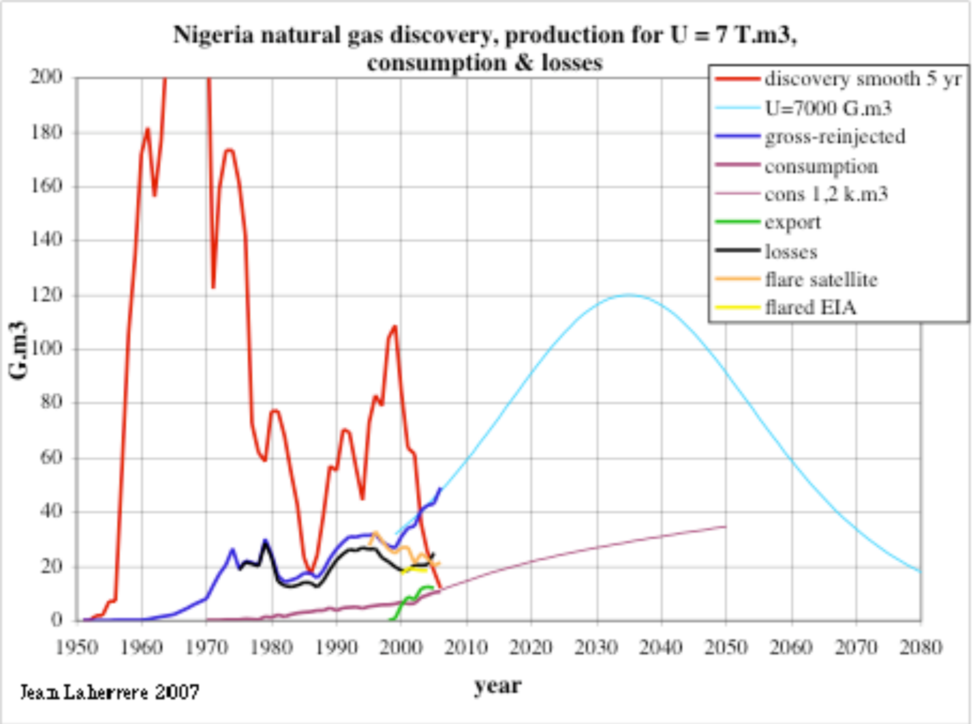


Figure 79*: Nigeria: natural gas cumulative discovery, production & remaining reserves*



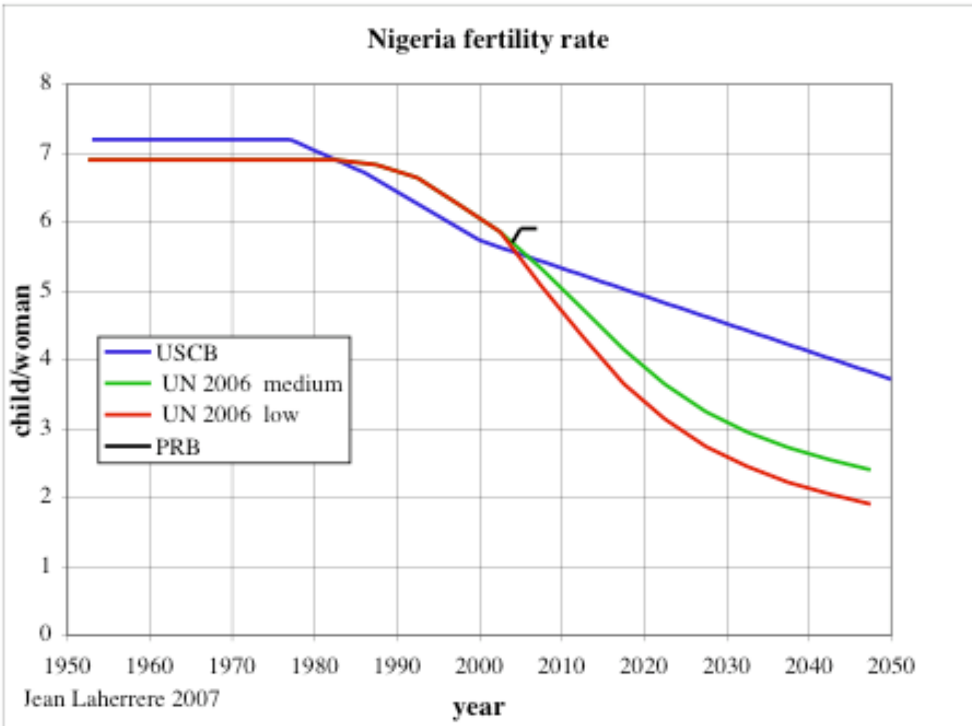
Natural gas annual discovery versus time displays 2 cycles but civil war has disturbed exploration and production. Despites interdiction and fines, natural gas is still flared (lack of gaspipes and investments from the national company partner of production). NOAA estimates from satellites were in 1995 about production, leaving little for consumption. Export started in 2000 and the potential is good up to 2050.
Gas consumption per capita is small, but population explodes. Forecast for domestic consumption in 2050 is 35 G.m3 for a probable production of 90 G.m3.

Figure 80: *Nigeria: natural gas annual discovery, production for ultimate 7 T.m3 (no other constraints), exportations & losses*



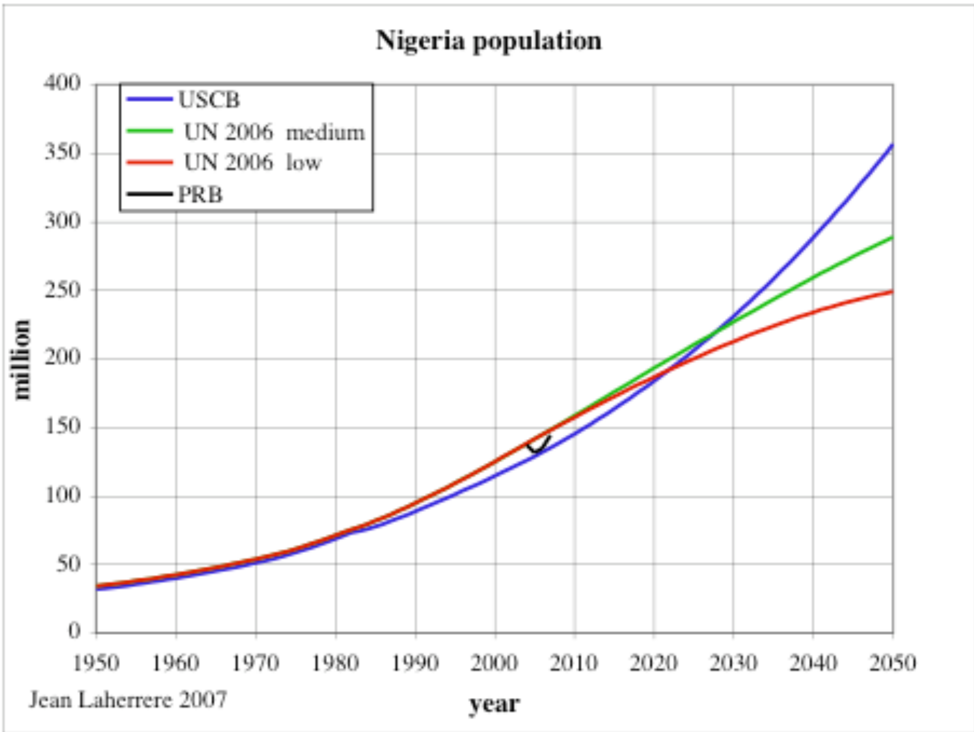
Estimate of Nigeria population has always been a problem because ethnic or religious disputes, every group wants to appear bigger. Before 1992 census, the UN estimate was 30% too high Fertility rate was 7 child per woman 30 years ago is now between 5.6 and 5.9. The UN forecast a decline to trend towards an identical rate in the long term but they are wishful thinking. USCB forecasts a rate for 2050 about 3,7 against 1.9 low Un and 2.4 medium UN.

Figure 81: *Nigeria : fertility rate*



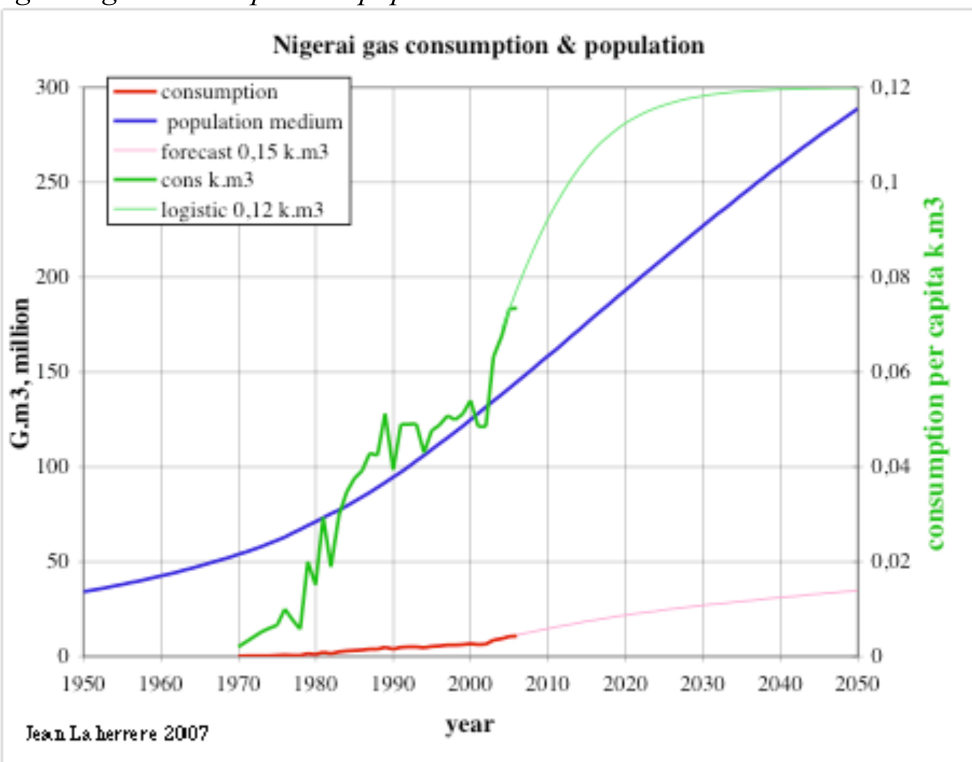
In 2050 Nigeria population could be 350 millions for USCB, but 290 for UN medium and 250 for UN low : very large uncertainty !

Figure 82: *Nigeria: population*



Natural gas consumption per capita is very low at 0.07 k.m3 (to compare with 23 for Qatar but 0.09 for Brazil and 0.17 for Indonesia). An asymptote at 1.2 k.m3 in 2050 will give a consumption of 35 G.m3 for the country.

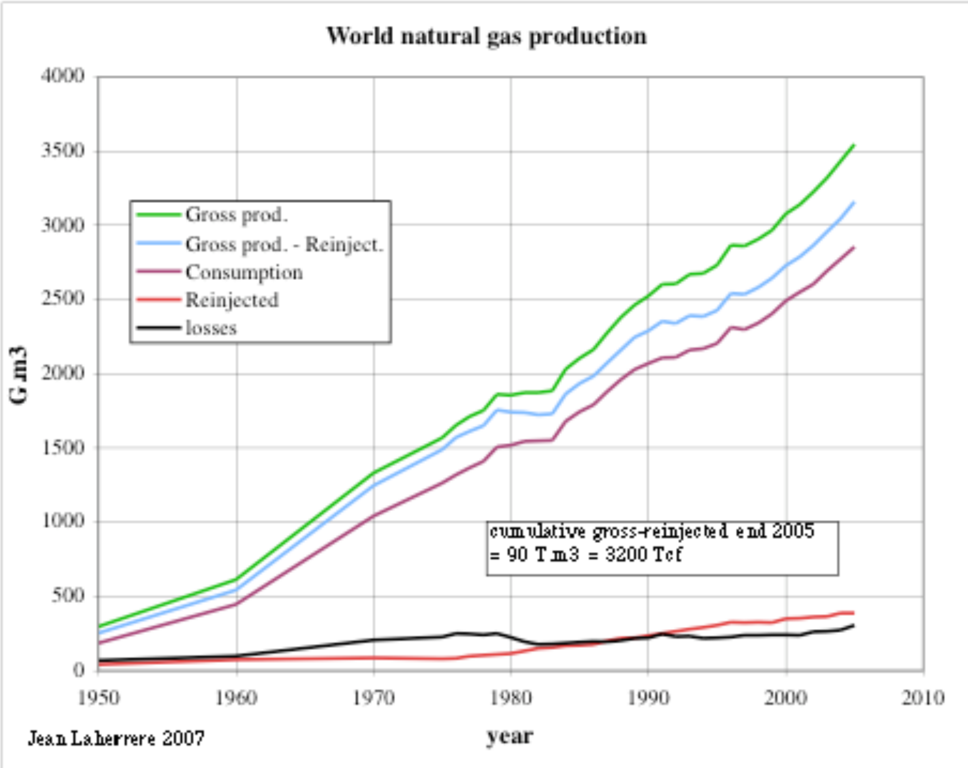
Figure 83: *Nigeria: gas consumption & population*



-World

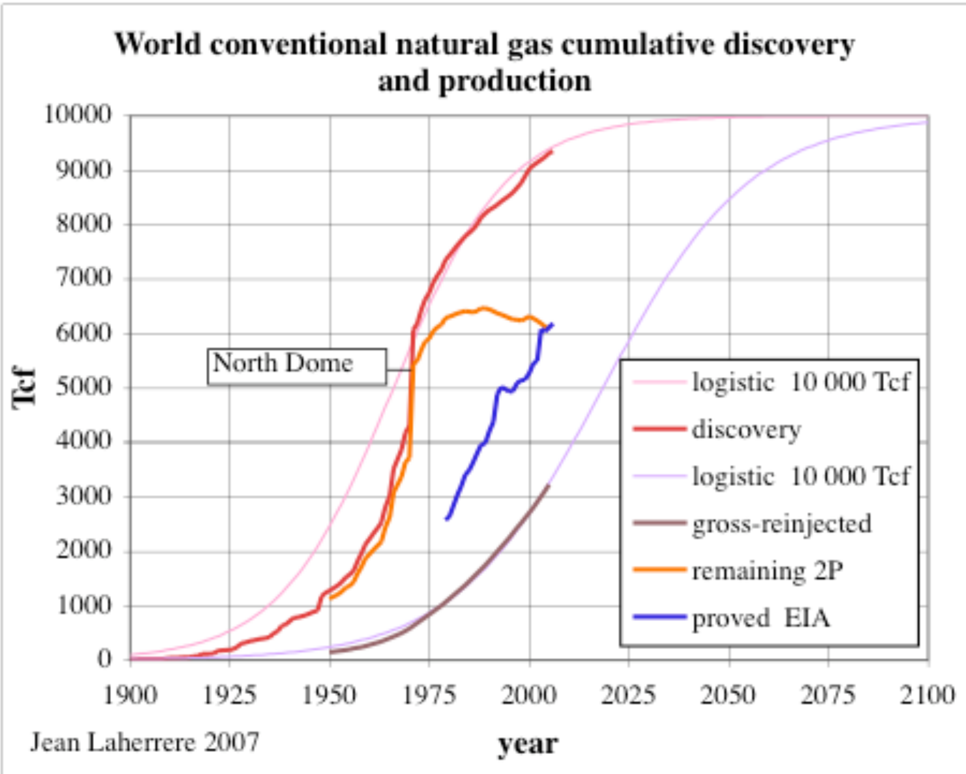
Natural gas production should take into account losses and reinjection, not just reporting only dry production. As seen in many statistics.

Figure 84: *world: natural gas production, consumption, reinjection and losses*



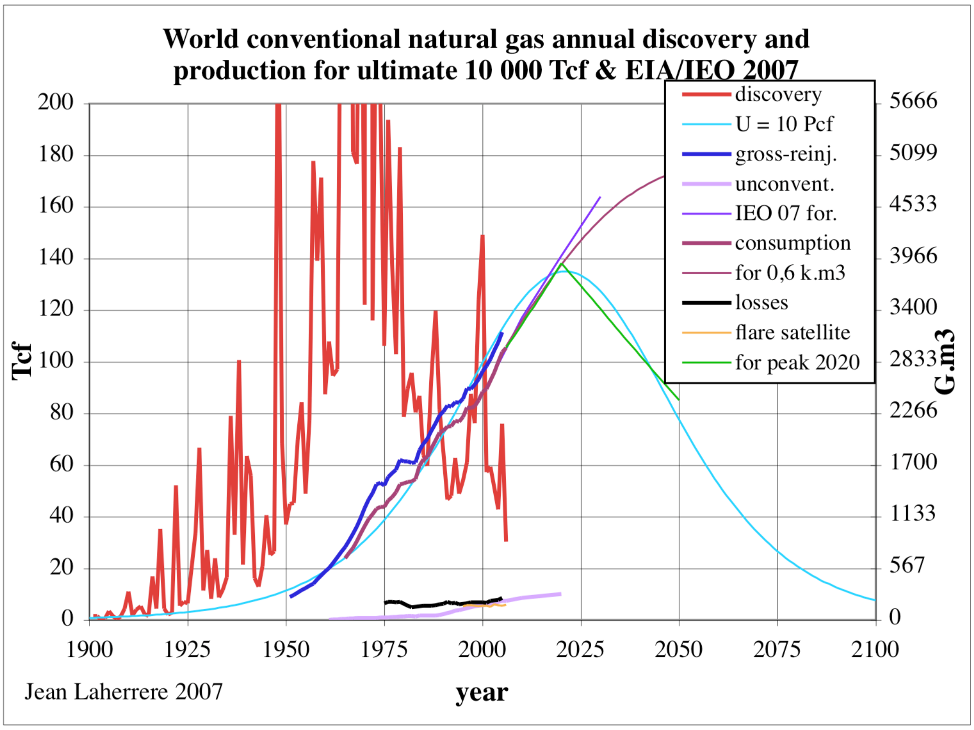
Natural gas cumulative production (gross minus reinjected) is about 3200 Tcf = 90 T.m3 to be compared to an ultimate of 12 000 Tcf (10 000 Tcf conventional + 2 000 Tcf unconventional)
Technical remaining 2P conventional reserves are equal to the so-called proved reserves.

Figure 85*: world: natural gas cumulative discovery, production & remaining technical and political reserves*



Natural gas conventional production will peak (assuming no constraint from demand, investment, politics) around 2020 at 135 Tcf/a (3.8 T.m3) when EIA forecasts continue to grow with no limit

because they want to satisfy the growth of business as usual. Unconventional (purple) will be around 10 Tcf/a in 2020, unable to compensate the decline of conventional beyond peak.
Figure 86: *world: natural gas conventional discovery, production for ultimate 10 Pcf (no other constraints), unconventional production, consumption & losses*



But, as population will peak around 2050 , consumption will not be satisfied beyond 2020 and should be constrained by price. Two consumption forecasts have been plotted. The first forecast is for an capita gas consumption growing towards 0,6 k.m3, which is outside production beyond 2020 and a second forecast with a growth of 1%/a until 2020 and after 2020 with a decline of 2%/a.

NPC (National Petroleum Council) 2007 report: «Hard truths: facing the hard truths about energy» displays the world natural gas production forecasts from different sources including ASPO France
Figure 87: *world: natural gas production different forecasts from NPC*

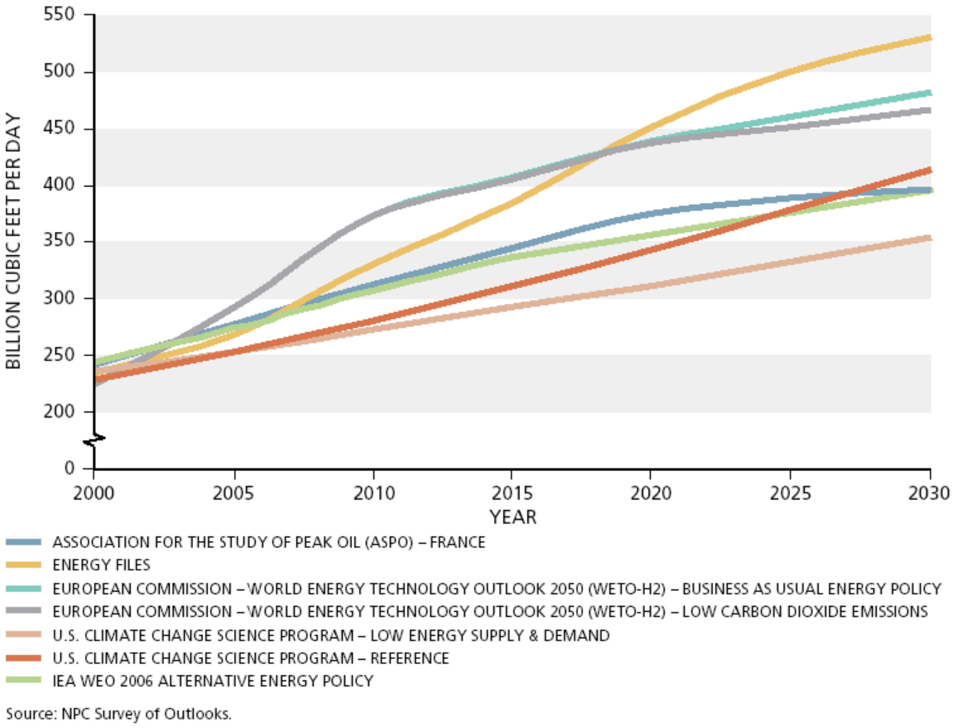
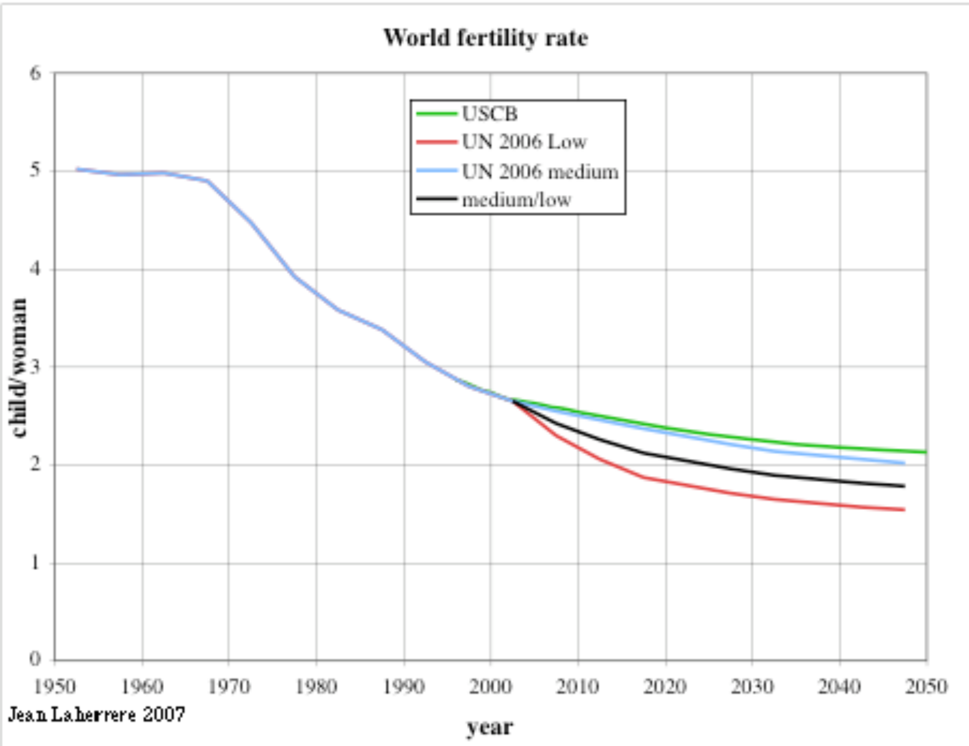


FIGURE 2-48. *Projected Global Natural Gas Production — Public Data*

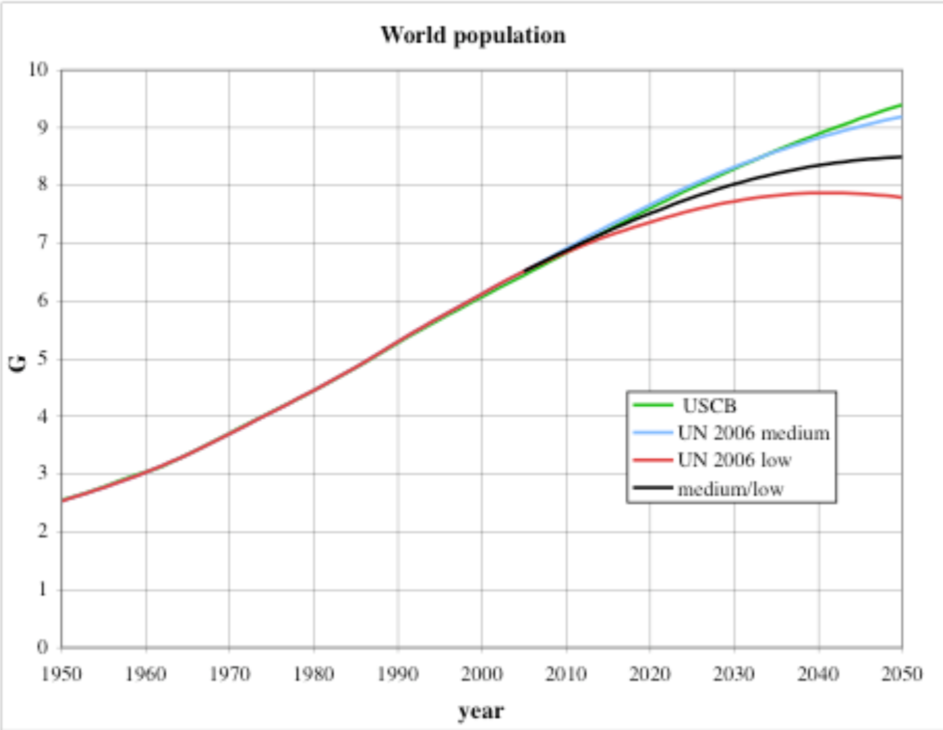
Fertility rate declines in countries where women are educated, but little in other countries. UN official forecasts are wishful thinking where long-term fertility rate will be the same for all countries. In the past UN forecasts for low/medium were closer to reality.

Figure 88*: world: fertility rate 1950-2050*



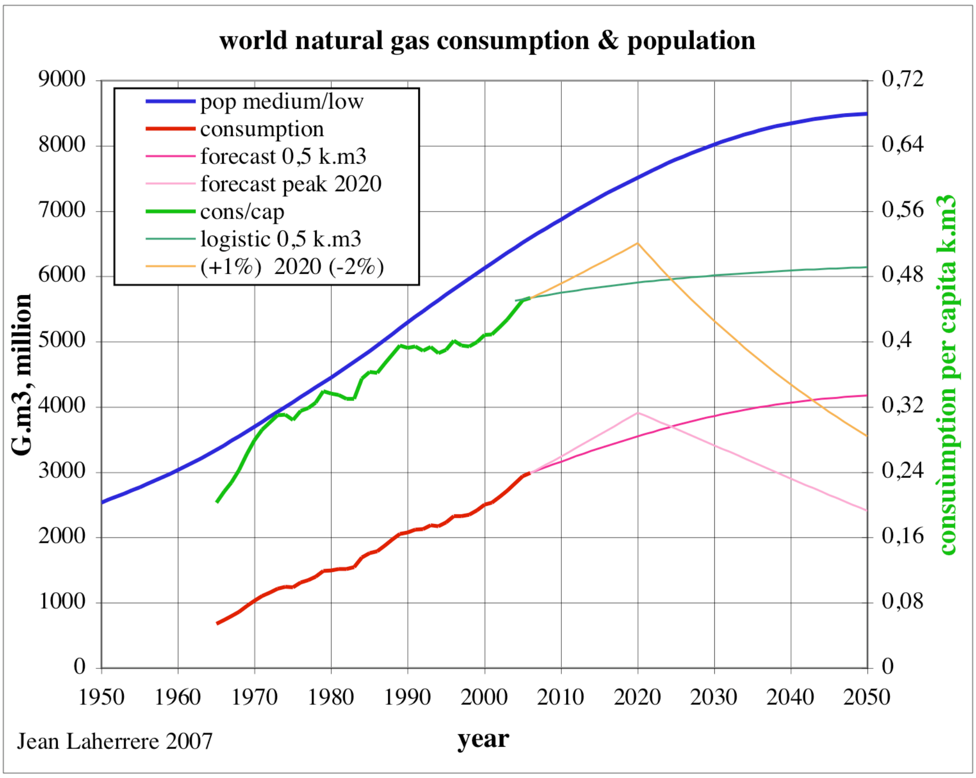
In 2050 medium forecast (9 G) is one billion higher than low forecast (8 G). Medium/low should be around 8.5 G.

Figure 89: *world: population 1950-2050*



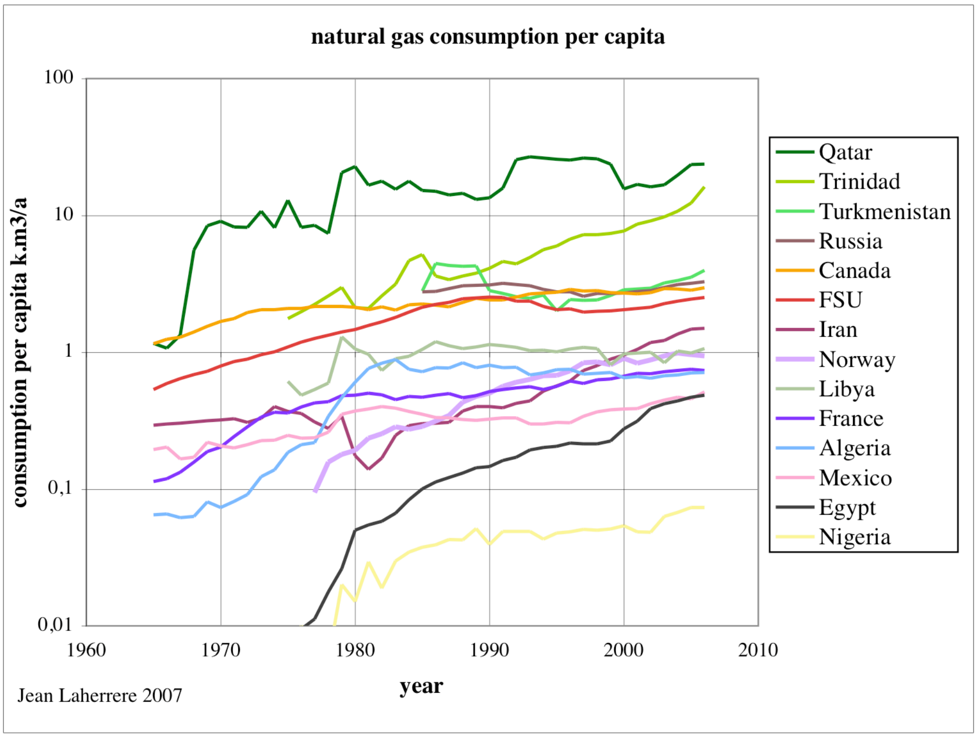
Natural gas consumption per capita has increased since 1970 at 1.5 %/a, reaching 0.45 k.m3 in 2006. Extrapolating the past it should flatten at 0.6 k.m3 in 2050, giving a total consumption at 5 T.m3 in 2050, being double production for the first forecast. So consumption per capita should decrease after 2020 and a second forecast was with a growth of 1%/a for capita consumption until a peak in 2020 and beyond a decline of 2%/a.

Figure 90*: world: natural gas consumption & population*



The natural gas annual consumption per capita varies widely between producing countries, the highest being Qatar around 20 k.m3 and the lowest being Nigeria with less than 0,1 k.m3

Figure 91*: natural gas consumption per capita (log scale) in some countries*



-Recapitulation

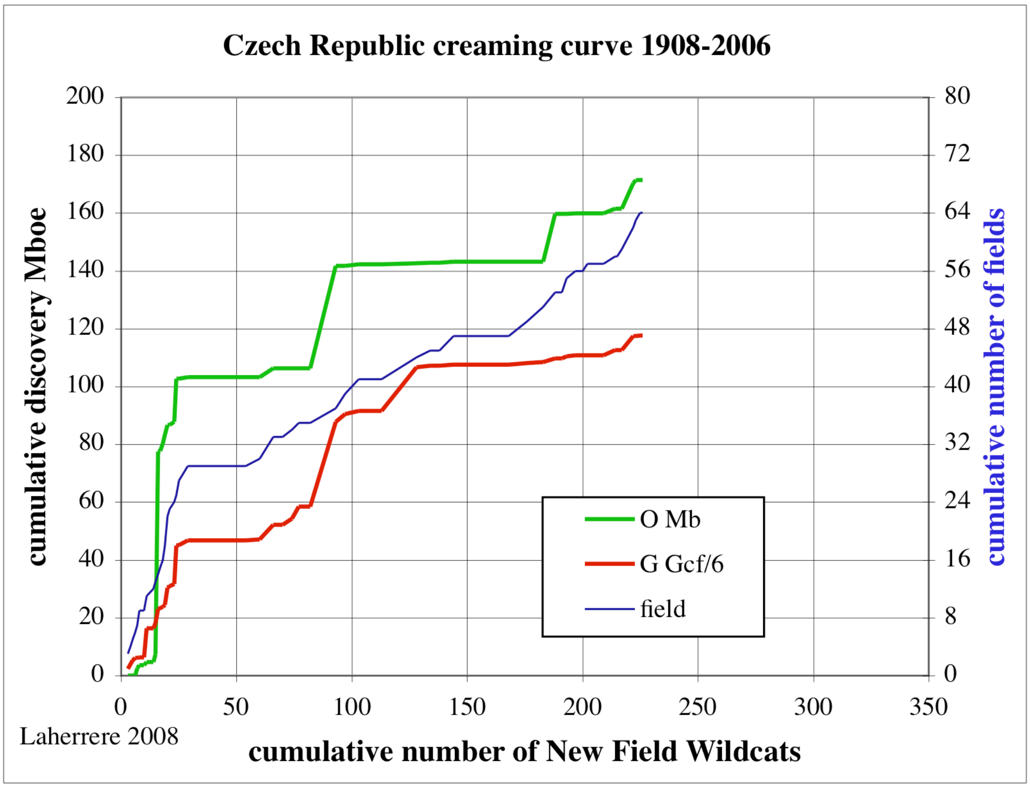
G.m3	gross-reinj 2006	peak year	peak prod	prod 2030	cons 2030	losses 2006	export 2030	export 2006
Algeria	107	2015	120	85	30	20	35	60
Egypt	58	2015	90	55	70	4	-20	17
Libya	17	2035	45	45	8	4	30	6
Nigeria	50	2035	120	115	30	25	65	12
Norway	96	2015	110	60	7	4	50	81
Russia	680	2015	800	550	470	50	50	200
FSU	810	2015	950	800	870	65	-120	130
Trinidad	38	2015	45	15	35	2	-20	14
Iran	125	2035	350	350	200	11	140	4
Qatar	56	2040	250	250	40	10	200	30
conv. world	3250	2020	3900	3600				
unconvent.	210			400				
world	3460	2025		4000	4400			

Some countries as Egypt, FSU and Trinidad could not export in 2030, contrary to IEA forecast. The recent move by Gazprom to invest in Africa is a sign that Gazprom has not enough reserves at home!

-Czech Republic

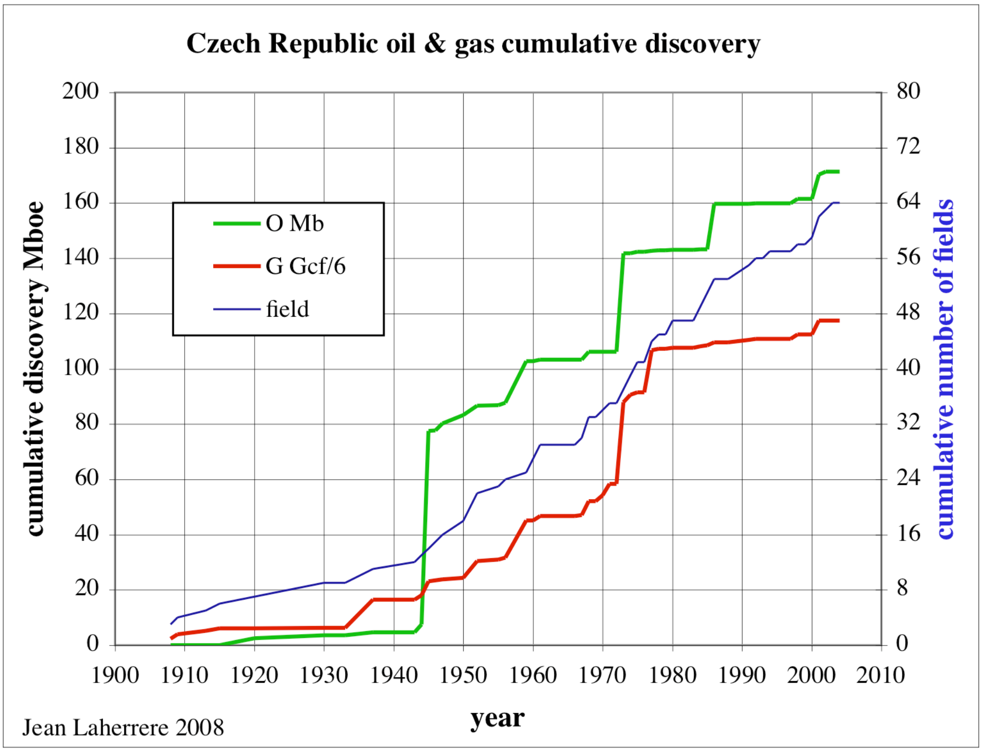
Oil & gas discoveries are still growing more for oil than for gas.

Figure 92: *Czech Republic: oil & gas creaming curve 1908-2006*



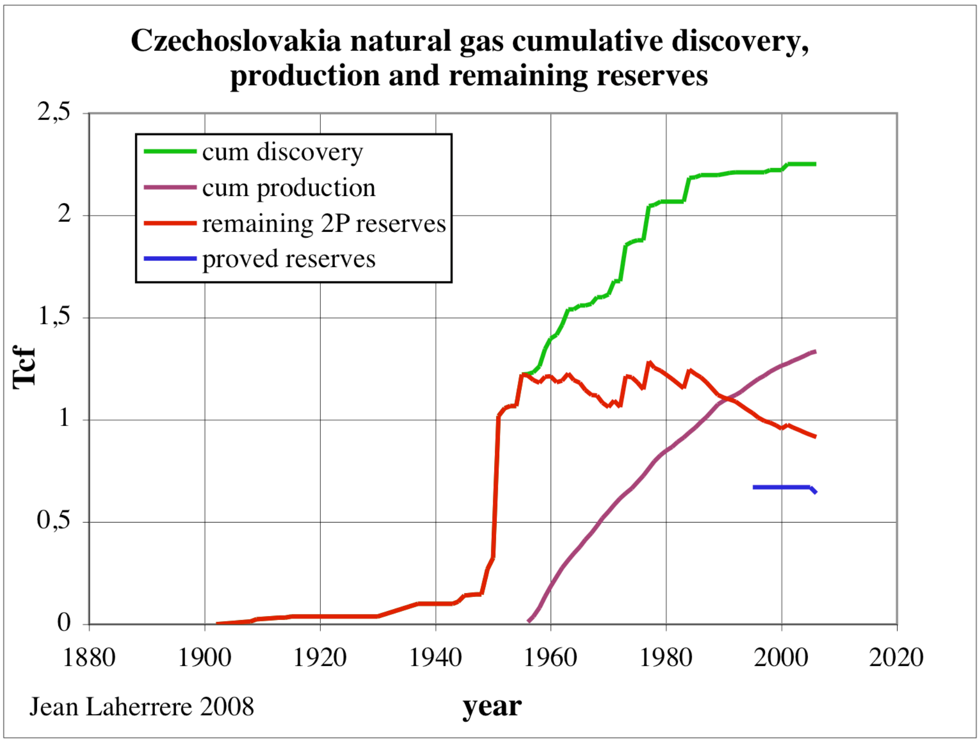
same data versus time

Figure 93: *Czech Republic: cumulative oil & gas discovery*



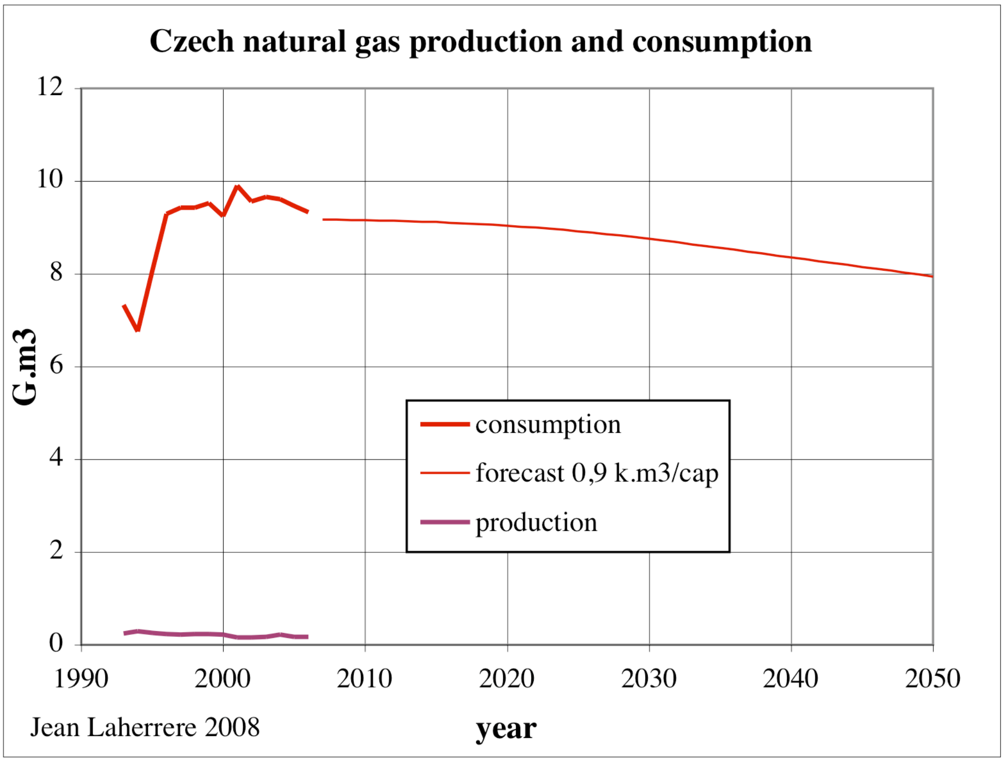
It is impossible to get the historical natural gas production and consumption for the Czech Republic before 1993, only for Czechoslovakia. In 2006 out of the 2,3 Tcf discovered, less of 1 Tcf remains to be produced (remaining 2P) when proved reserves are reported to be 0,14 Tcf for Czech and 0,5 Tcf for Slovak.

Figure 94: *Czechoslovakia: natural gas cumulative discovery, production and remaining reserves*



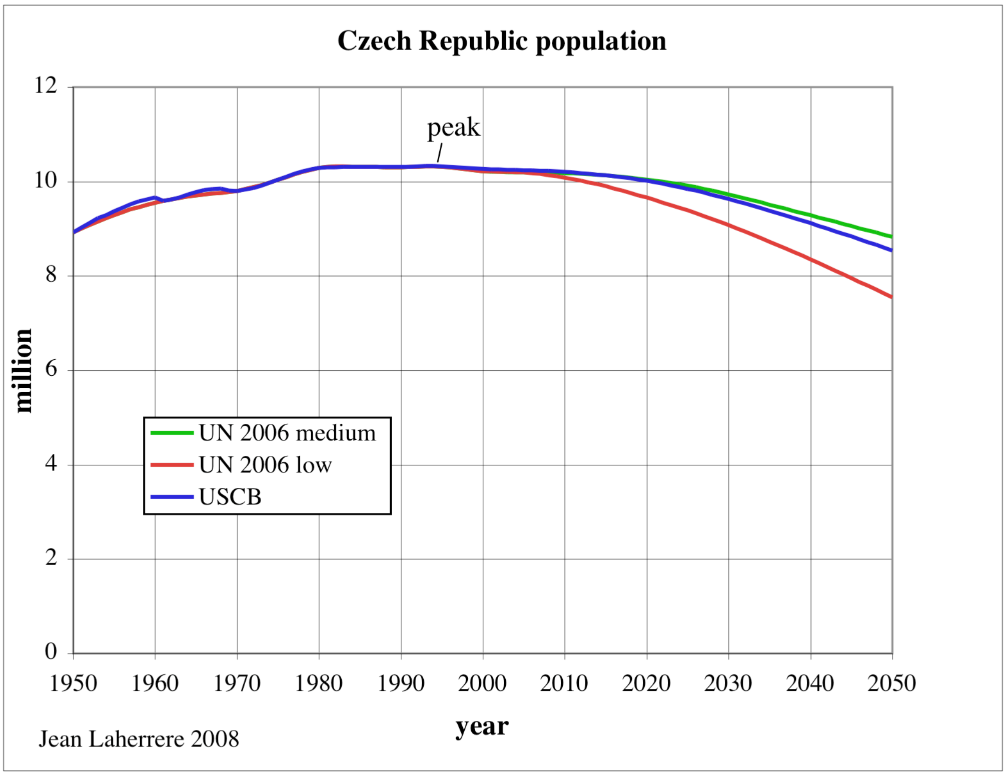
Czech natural gas annual production is insignificant in front of the consumption which has flattened since 1997

Figure 95: *Czech Republic: natural gas annual production & consumption*



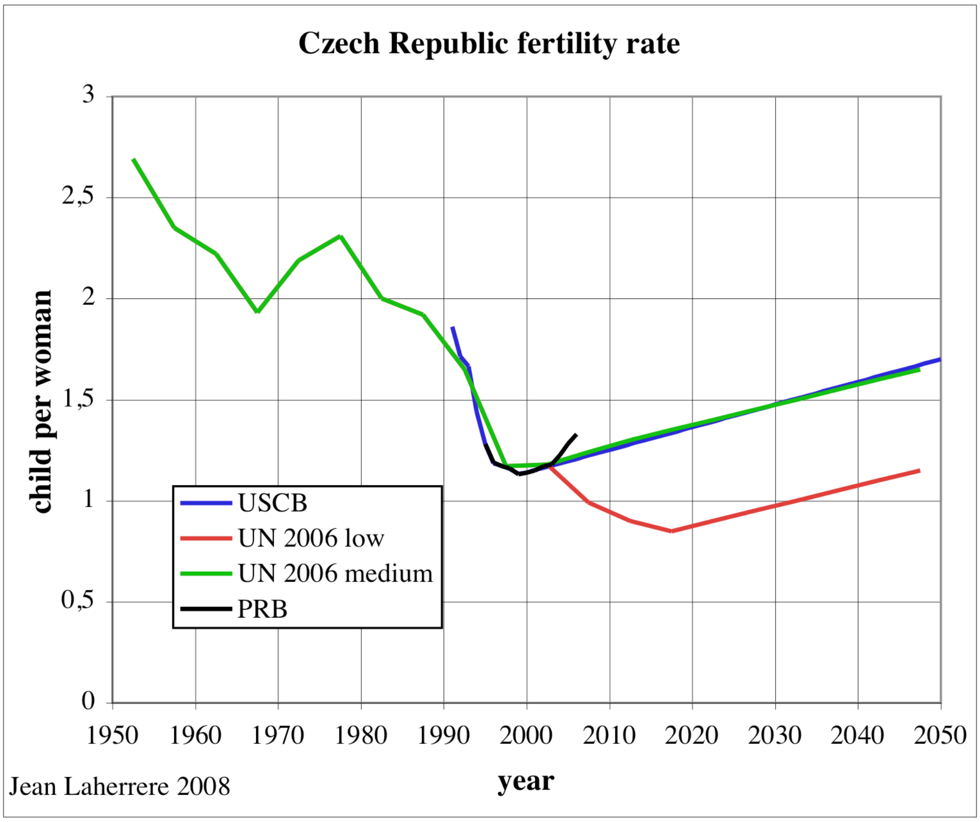
Czech population has peaked in 1992 and is forecasted to lose between one and two million in 2050.

Figure 96: *Czech Republic: population*



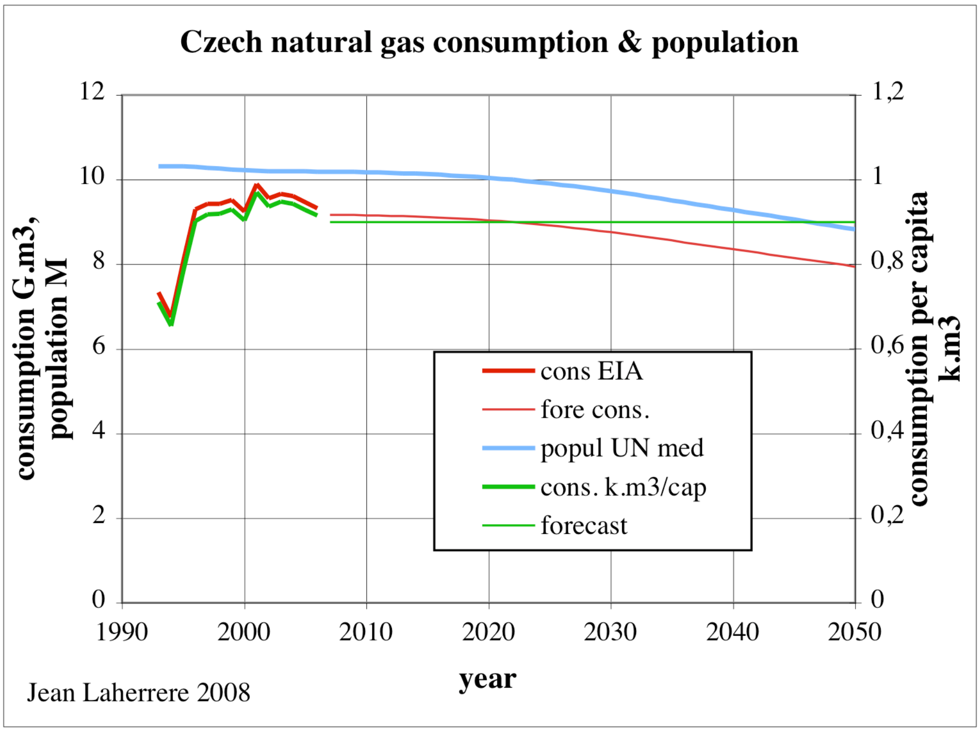
Fertility rate was very low in 2000 and seems to be in the increase but still far below the replacement level.

Figure 97: *Czech Republic: fertility rate*



Natural gas consumption per capita has flattened around 0.9 k.m3 and assumed to stay at this level

Figure 98: *Czech Republic: natural gas consumption and population*



-Other sources ?

The unconventional natural gas is claimed by many to compensate the coming decline of conventional gasfields. But despite that there is no consensus on the definition, unconventional gas is considered where the reservoir is tight, or adsorbed in shale or coal measures, where there is no defined water-contact (USGS continuous-type accumulations), polar, deepwater, hydrates, geopressured aquifers.

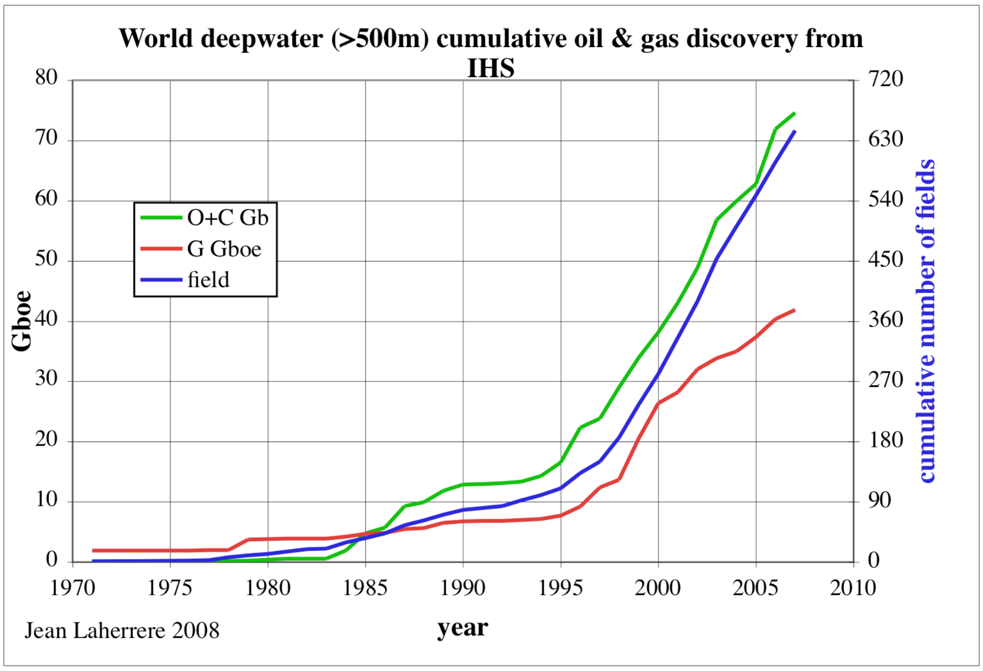
Perrodon, Laherrere & Campbell « the world's non-conventional oil and gas » 1998 did the inventory of unconventional gas, it is valid for the past before 1998.

-Deepwater

Deepwater is here defined as water depth being deeper than 500 m. The first discovery started in 1971 and now there are 650 discoveries for about 110 Gboe (average 170 Mboe). The cumulative number of discovery is a straight line since 1997, but gas cumulative discovery is flattening.

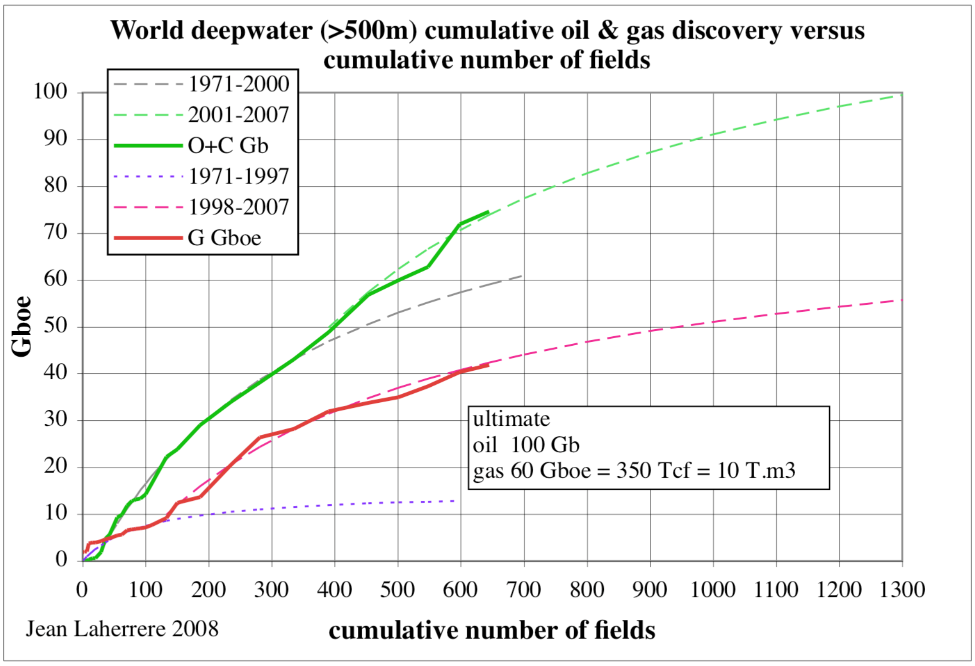
Only 165 fields have been developed, 60 fields developing and 130 appraisal. About 8 Gb have been produced for oil and 12 Tcf for gas.

Figure 99: *world deepwater oil & gas cumulative discovery*



Lacking the NFW to plot a creaming curve, the cumulative discovery versus the cumulative number of fields (similar to creaming curve if constant success ratio) displays two cycles for oil (1971-2000 & 2000-2007) and two for gas (1971-1997, 1998-2007) and ultimates could be estimated at 100 Gb for oil and for gas 60 Gboe or 350 Tcf or 10 T.m3

Figure 100: *world deepwater oil & gas cumulative discovery versus cumulative number of fields*



Deepwater gas represents less than 3% of the gas ultimate, being far less than the accuracy of this ultimate. It means that gas deepwater will not bring any help in the coming gas peak.

-Arctic

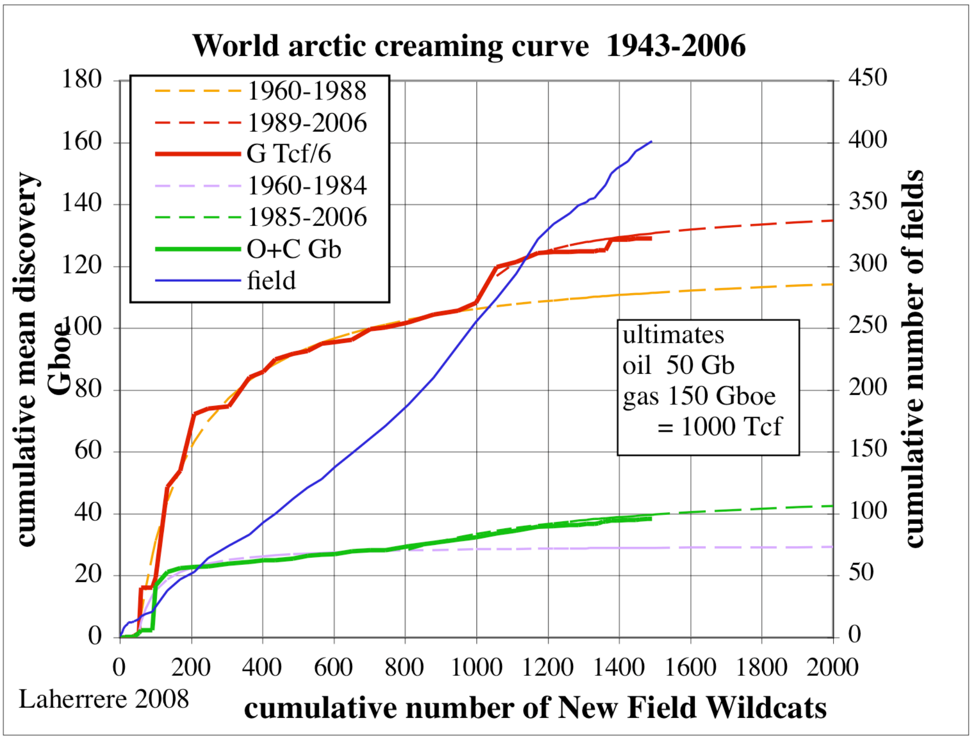
Using IHS database (Feb. 2007) arctic fields and NFW were extracted for latitudes north of 66°33’ 39’’ = present polar circle with an obliquity of 23° 26’ (obliquity can vary from 22° to 24°30 in a 40 000 years cycle) for Russia, Europe (Norway and Svalbard) and North America (US & Canada).

Arctic can be also defined as the isotherm of <10°C any month of the year.

Both definitions mean that Arctic area is changing slowly with time and climate and their difference involves very large areas (Bering Seas)
Figure 101: *arctic map defined as obliquity or 10°C isotherm*

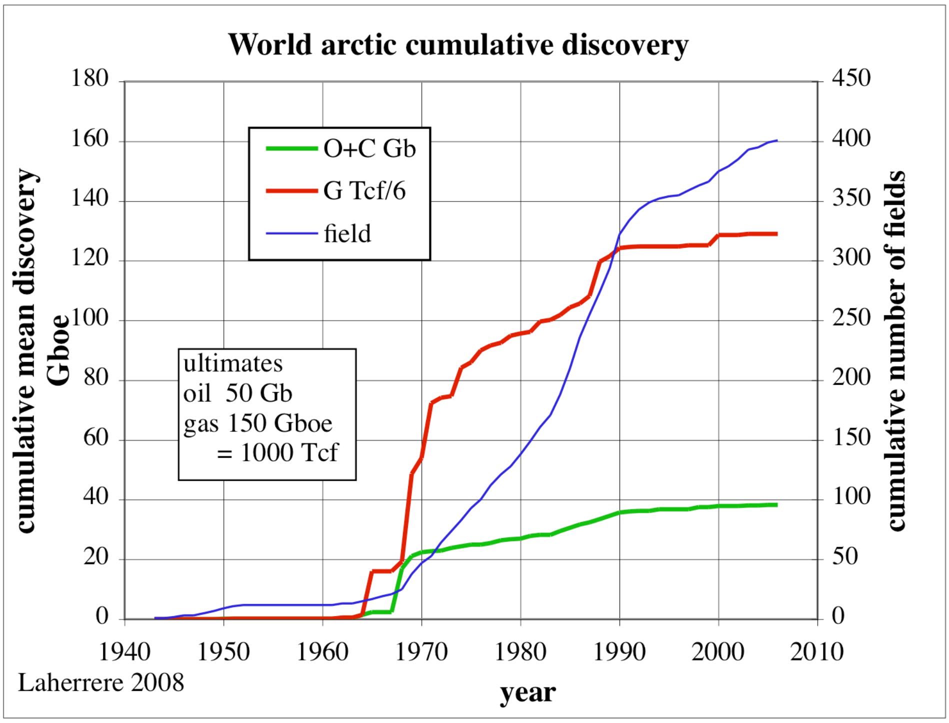
The Arctic. Source: University of Texas Libraries. Click for large version.

Arctic oil & gas creaming curve shows that gas is three time more abundant than oil and that exploration is mature because present discovery is close to ultimates which is 50 Gb for oil and 1000 Tcf (30 T.m3) for gas. There were two cycles for gas (1960-1988, 1989-2006), a third cycle should be small and will not change much the ultimate
Figure 102: *world arctic oil & gas creaming curve 1943-2006*



same data versus time

Figure 103: *world arctic oil & gas cumulative discovery*



Most of discoveries has been made between 1968 and 1990 and a large part of arctic gas reserves are still undeveloped (Prudhoe Bay which use the gas for oil repressuring) because the investments for gaspipes or NGL plants are huge.

Lately was excitement in the US Chukchi sale where 2 G$ was spent where Shell 105 M$ to buy back the Burger gasfield that they found in 1990 and surrendered few years later with 4 dry wells around

The projects to develop the North Slope ant the Mackenzie delta gas discoveries have been discussed for decades and still in planning. Mackenzie gas reserves will likely be used for steam for Athabasca tarsands.

Permafrost hydrates have been searched lately and production test carried out in Canada by Japan et al for a very small volume and the example of hydrate production in Messoyakha conventional gas field in Siberia is questionable
Arctic gas will not change much the coming gas peak.

-CBM, tight gas, shale gas
In US a large part of gas production is now from unconventional gas with first tight gas, then CBM and then shale gas (large present growth). But EIA forecasts for US unconventional gas is peaking as shown and the hope for Canada to compensate for conventional decline is fading.
These unconventional gas have been included in figure
Gas in tight reservoirs below aquiferous good reservoirs contains huge amount of gas. But the excitement of Elmworth discovery in Canada in 1976 about the deep basin of western Canada with estimate of 500 Tcf (John Masters The Hunters 1980) is now reduced to 5 Tcf, one hundred time less!

-**Dissolved gas in geopressured aquifers**
Perrodon et al 1998 mentions that the solubility of methane in fresh water at 130°C is increased by a factor of 30 when pressure increases from 200 to 10 000 psi. There were huge estimates of gas dissolved in brines as 35 000 Tcf in Western Siberia and the Caspian, 5 000 Tcf in the Gulf Coast alone. But the excitement is now down after few pilots in the Gulf Coast and Japan because environmental problems. No one is dreaming anymore on these dissolved gas.

-Hydrates
The excitement is now on oceanic methane hydrates which can store 150 times more than normal gas (500 times when liquefied). The oceanic hydrates are too dispersed to be produced (Laherrère J.H. 2002 "Hydrates: some questions from an independent O&G explorer" Introduction as chairman of RFP 9 "Economic use of hydrates: dream or reality ?" WPC Rio, Sept 5 http://www.oilcrisis.com/laherrere/hydratesRio).
Oceanic hydrates were the worry of all oceanographic international drilling: JOIDES, ODP, IODP and the Safety Panel (I was a member in the late 70s) has the duty to be sure to avoid hydrates and blow-up (no BOP (Blow-Out Preventor) was then on the drillship, but BOP was added later in order to drill through hydrates). Thousand of wells have been drilled and cored, very few cores (less than 5) have found more than 15 cm thick compact hydrate and in leg 164 one massive 15 cm hydrate was not found again in another well drilled 20 m apart.
Japan drilled and cored many wells in Nankai trough in 1999 and 2004 and no production pilot is planned. Japan went to permafrost hydrate in Canada (Mallik 2 in a conventional gasfield) for a production test with steam but the amount of methane produced was very small for this kind of environment.
In 2007 oceanic hydrates were cored in India, China and South Korea with claims of success, but little was shown to be excited.
OGJ 18 February 2008 : US-India study discovers **large gas hydrate presence** confirms this statement on unprecedented number of hydrate cores but publishes this only picture of a core where hydrate is millimetric !
Figure 104: *hydrate core from India 2007 drilling (OGJ 2008)*

Gas hydrates are an ice-like combination of natural gas and water formed by high pressure and low temperatures. The expedition collected an "unprecedented" number of gas hydrate cores. Photo from USGS.

Happily the NETL Methane Hydrate Newsletter (excellent Fire in the ice) Fall 2006
International team completes landmark Gas Hydrate expedition in the offshore of India
Publishes a better picture but instead of being millimetric it is centimetric to decimetric but far from representing huge reserves

Figure 105: *hydrate core from India 2007 drilling (NETL)*

Core sample of massive gas hydrate (courtesy NGHP Expedition 01)

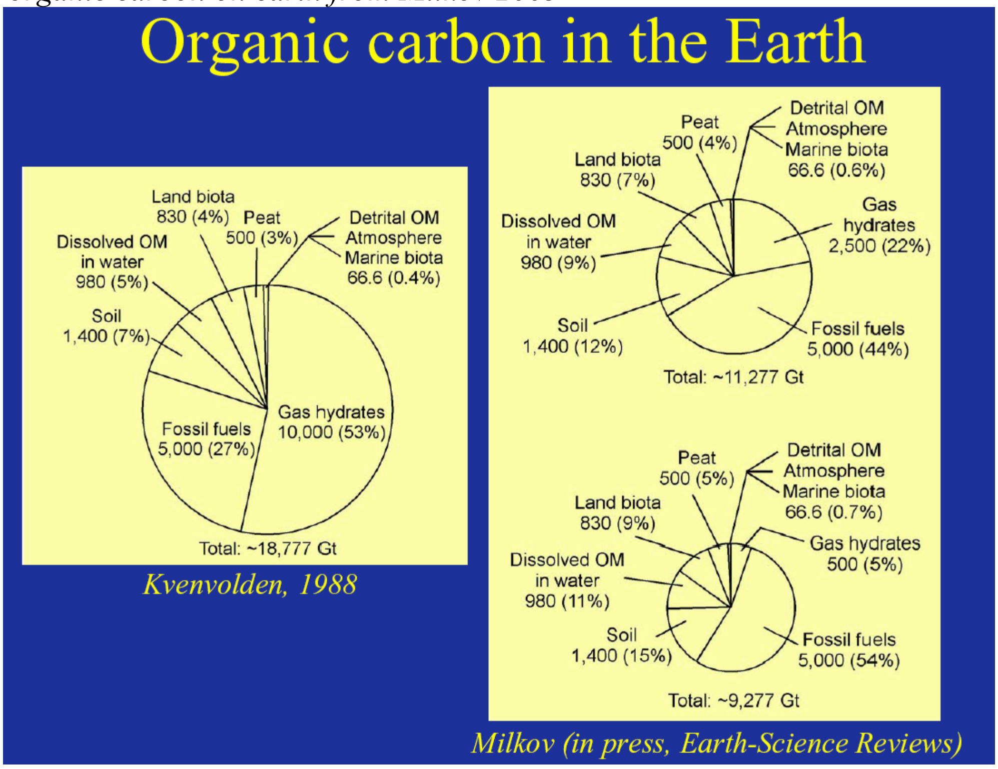
The horizontal extension of these few centimetre thick hydrates is likely metric, as for Leg 164 or outcrops the seafloor. In the same newsletter under *The gas hydrates resource pyramid* this picture of seafloor shows the a massive hydrate is decimetric in vertical and metric in horizontal, always within an shale sediment, being impermeable

Figure 106: *offshore Vancouver Island: hydrate on seafloor (NETL)*

Example of massive sea-floor mound from Offshore Vancouver Island (courtesy Ross Chapman, U.Victoria)

Alexei Milkow "*Gas Hydrate Resource Potential in the Gulf of Mexico*" Rice University (November 12, 2003) estimates hydrates between 500 and 2500 Gt, to compare with 10 000 Gt by Kvenvolden in 1988 (which is unrealistic looking at the geological time involved for hydrates compared to the fossil fuels).

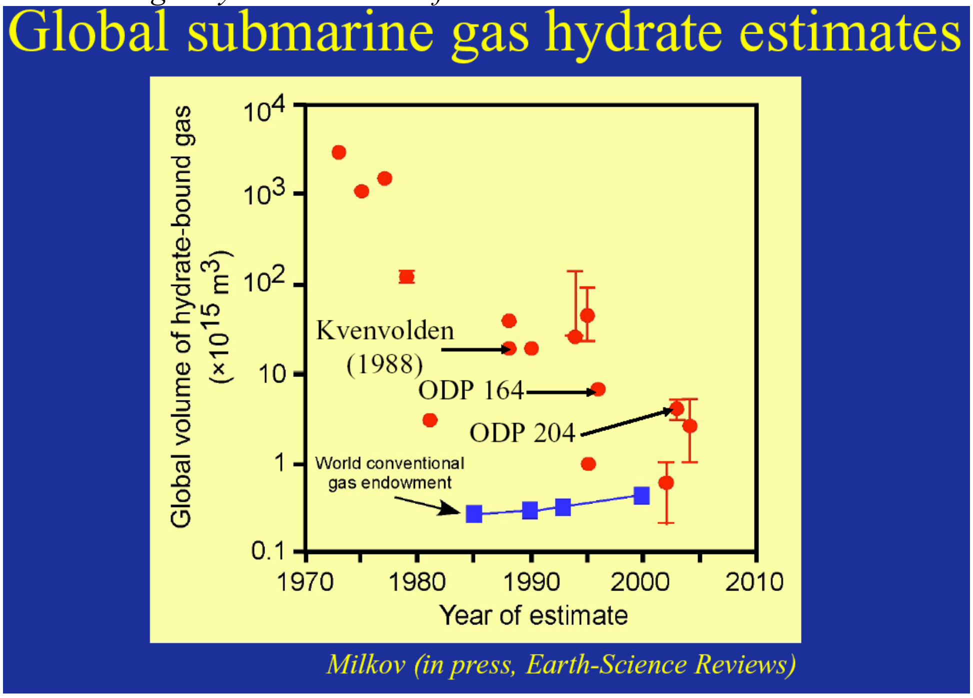
Figure 107: *organic carbon on earth from Milkov 2003*



With 500 Gt hydrates are lower than dissolved methane in geopressured which 30 years ago were described as the energy of future as hydrates is now.

Milkov shows that hydrates estimates have been in decline since 1973 divided by a ratio of more than 1000, being now about the volume of conventional gas, but without any technique to produce them.

Figure 108: *submarine gas hydrate estimates from Milkov 2003*



Resources (what is in the ground) should not be confused with reserves (what will be produced)!

-Gas from the mantle: abiotic gas

The astrophysicist Thomas Gold concluded that methane which exists in the universe (very simple element from inorganic origins) could be found in the earth mantle convinced the Swedish government and private people to dry 2 wells (7000 m) at a meteor crater in basement , but they found no gas, but oil: likely from the drilling mud or from an Ordovician shales into which the granite has been intruded or formed by the heat of the meteor impact. There are many articles on abiotic oil but I do not know any oil company looking for it even the Russian companies. Methane simple gas should not be confused very complicated hydrocarbons. Methane could exist in the mantle but the problem is porosity and permeability. There are also methane in wetlands and it is easy to get it !

-Biogas

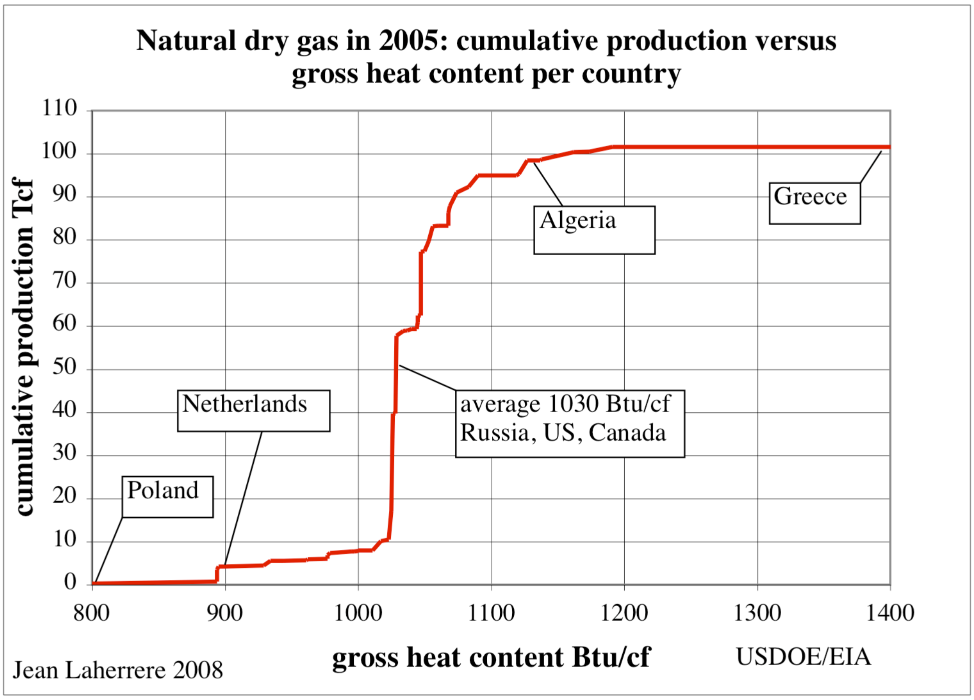
Methane found in the ground can be biogenic (few fields) or thermogenic (pyrolyse of kerogene). Methane is produced by many organisms on the earth's surface.

Neue 1993 estimates annual methane production

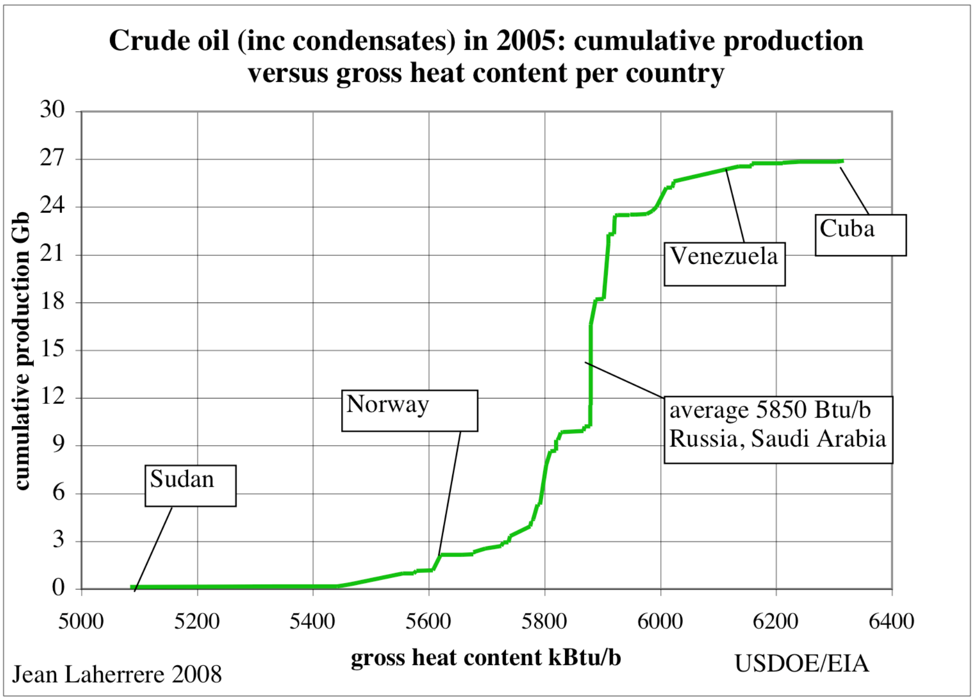
Methane sources	Location	Mt/year
Natural:	wetlands	120
	lakes, rivers	20
	oceans	10
	termites	10
	total	160
Anthropogenic	mining and petroleum	100
	enteric fermentation(cattle)	80
	flooded rice fields	50
	biomass burning	30
	landfills	30
	animal waste	30
	domestic sewage	20

total man-made 340
Grand Total 500
It is very hard to estimate future production of biogas, presently produced mainly when subventions are given.

-Natural gas & oil heat content
Natural dry gas gross heat content for 2005 varies from 800 Btu/cf in Poland to 1400 Btu/cf in Greece. The average is 1037 Btu/cf (close to Russia, US and Canada) when Algeria is 1127 Btu/cf and Netherlands 894 Btu/cf.
Figure 109: *natural dry gas in 2005: gross heat content & cumulative production*

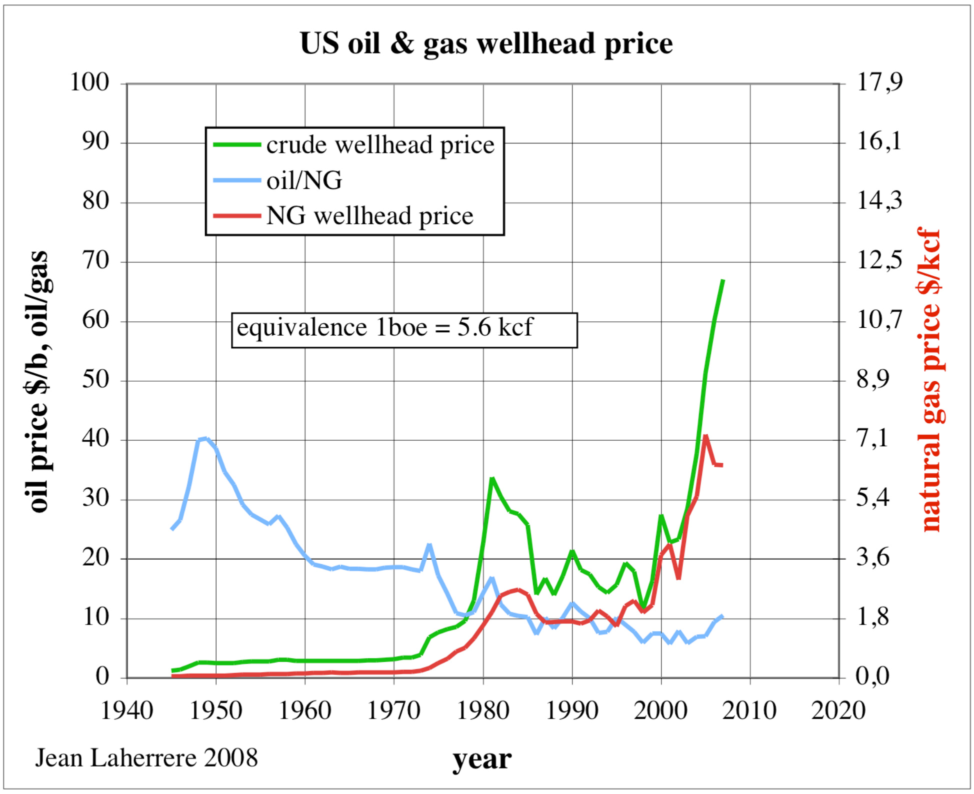


Crude oil (including condensates) gross heat content varies from 5100 and 6300 kBtu/b. The world average is 5850 kBtu/b
Figure 110: *crude oil in 2005: gross heat content & cumulative production*

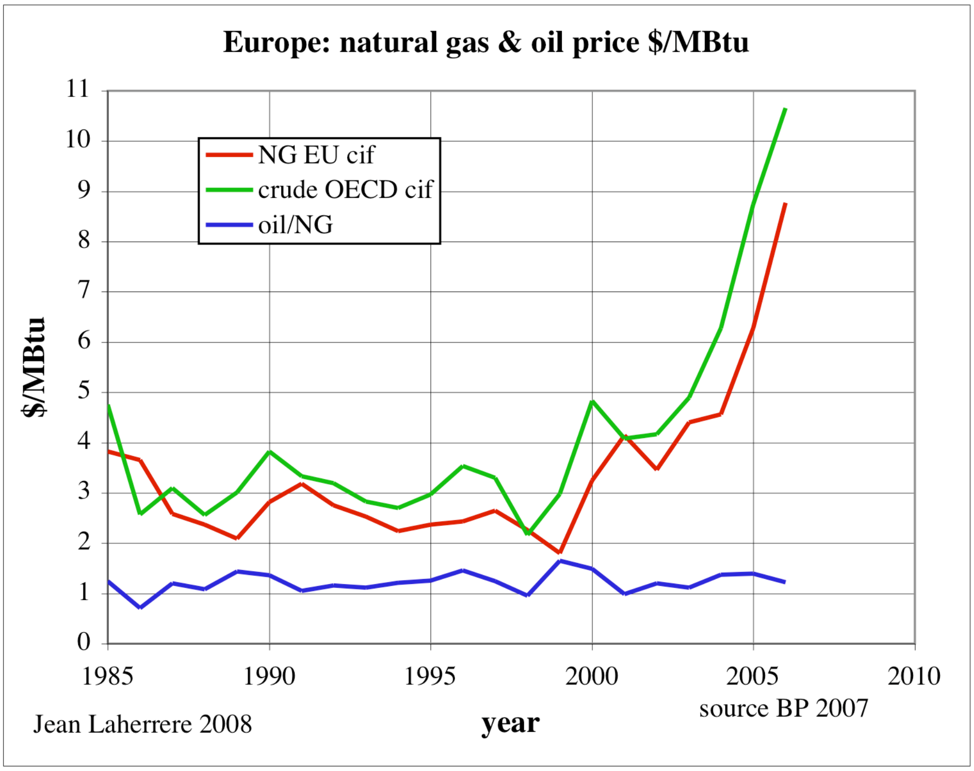


The US equivalence is 1 boe = 5800/1.029 = 5.5 kcf
The world equivalence for dry gas is 1 boe = 5858/1.037 = 5.65 kcf, when it is often taken a 6 kcf (IHS) and in all my graphs where it deals not with dry gas, but with gross gas. In the equivalence gas to oil, losses (flare and venting) should be taken into account.

-Natural gas price trend
The price of natural gas price should trend to the trend of the oil trend in heat equivalence (5,6 kcf/b), but locally it depends upon the NG supply. In the US the ratio of wellhead prices oil/gas from 1945 to 2006 peaking at 40, declining to around 6 in 2000 and back to 10 in 2007. The main reason is that because US high prices, most fertilizers plants have been closed and unconventional gas production pushed with high drilling, explaining the decline in US NG price in 2007.
Would the US natural gas price going to match oil price equivalent ?
Figure 111: *US oil & gas wellhead prices 1945-2007 with 5.6 kcf/b*

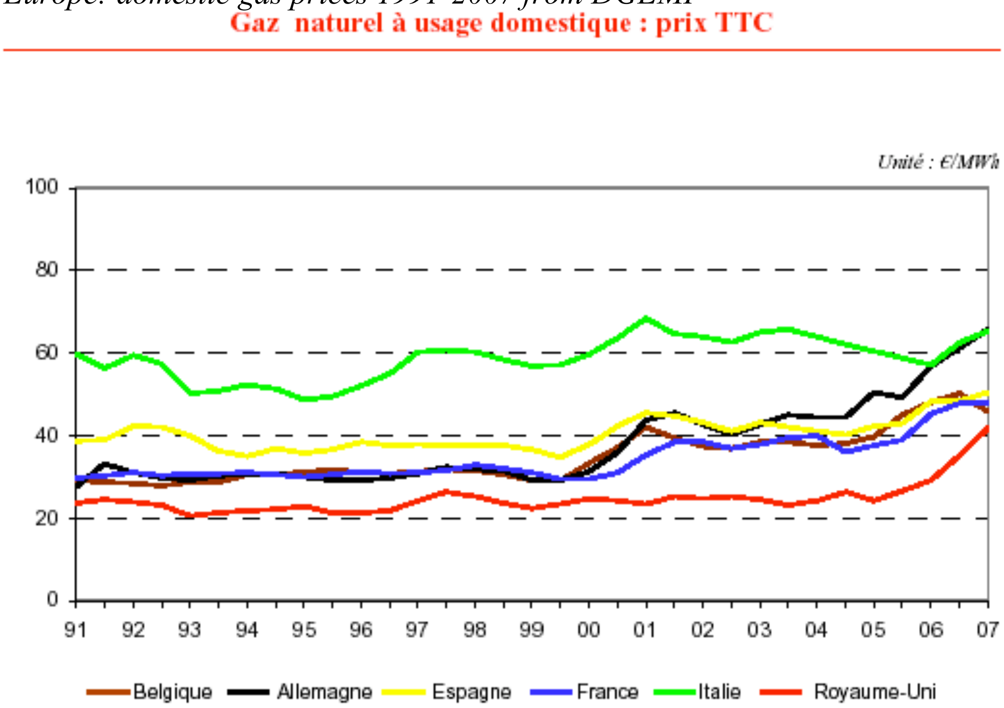


For Europe (BP data) the oil & gas price in $/Mbtu vary in parallel but oil being most of the time about 20 % higher. Will the ratio go to 1 ?
Figure 112: *Europe: oil & gas prices 1985-2006 from BP data*



The domestic gas price in Europe in €/MWh vary widely (more than double) with country being more expensive in Italy and cheaper in UK. The problem is that this gas price is mainly controlled by governments because official inflation goals, but for how long?

Figure 11”: *Europe: domestic gas prices 1991-2007 from DGEMP*



Europe will see chaotic natural gas supply and price in the coming future because the unknown from Gazprom potential.

-Conclusions
Past discoveries when properly estimated (confidential technical database) allows to estimate the world natural and to forecast the gas peak that can provide the ultimate (<4 T.m3) assuming no other constraints.
Because gas transport is expensive (10 times oil transport) there are several gas markets and investments (gaspipes or gas plants) lead to production pattern with steps, contrary to smooth forecasts plotted with bell-shape curves with no investment constraints.
Forecasted production from ultimates with short peaks are in contradiction with official forecasts with long plateaus in line with life of expensive equipments.
An detailed inventory of all natural gas planned megaprojects for the next 10 years is necessary, as it was done by Chris Skrebowski for oil, checking also if the country reserves allow such megaprojects
However forecasts from the confidential technical reserves allow to say that the official forecasts (to provide Business as Usual constant growth) for production and exports to Europe are unrealistic for the long term, counting too much on overestimated Russian reserves and developments which are delayed for several reasons as for the Yamal Peninsula (Bovanenko gas field).
There are little alternative (hydrogen, as electricity, is not an energy source and renewable cannot replace in volume fossil fuels) outside energy savings and Europe should try to obtain the best energy mix compatible with our wishes and what Nature can offer.

The best solution for Europe is to change consumer behaviour in order to make savings in our energy consumption and in particular natural gas as the shortage for Europe will occur soon.
EU natural gas consumption has declined by 1.5% in 2007 due to mild weather. Europe needs more than global warming, our consumption society of “always more” must be amended and it is up to each consumer, it means us. If not, limited Nature will force us to change.