Earley Environmental Group – April 2012

Peak Oil

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Summary of Presentation

1. Oil price & The conventional oil peak
2. Why does oil production in a region peak?
3. Peak is *counter-intuitive*
4. Past forecasts – were they really wrong?
5. Data by country (see note, below)
6. There is a lot of oil & 'nearly-oil' - *but*
7. Current forecasts - the conventional oil peak is likely to dominate.
8. The views of DTI / BERR / DECC
9. Conclusions on Peak Oil
10. What to do?

Note: In the public presentation proprietary data were shown for Russia, Iran, Iraq & Saudi Arabia. These data are excluded from this file so that it may be freely distributed.

The University of Reading, UK
'Oil Resources Group': Past & present

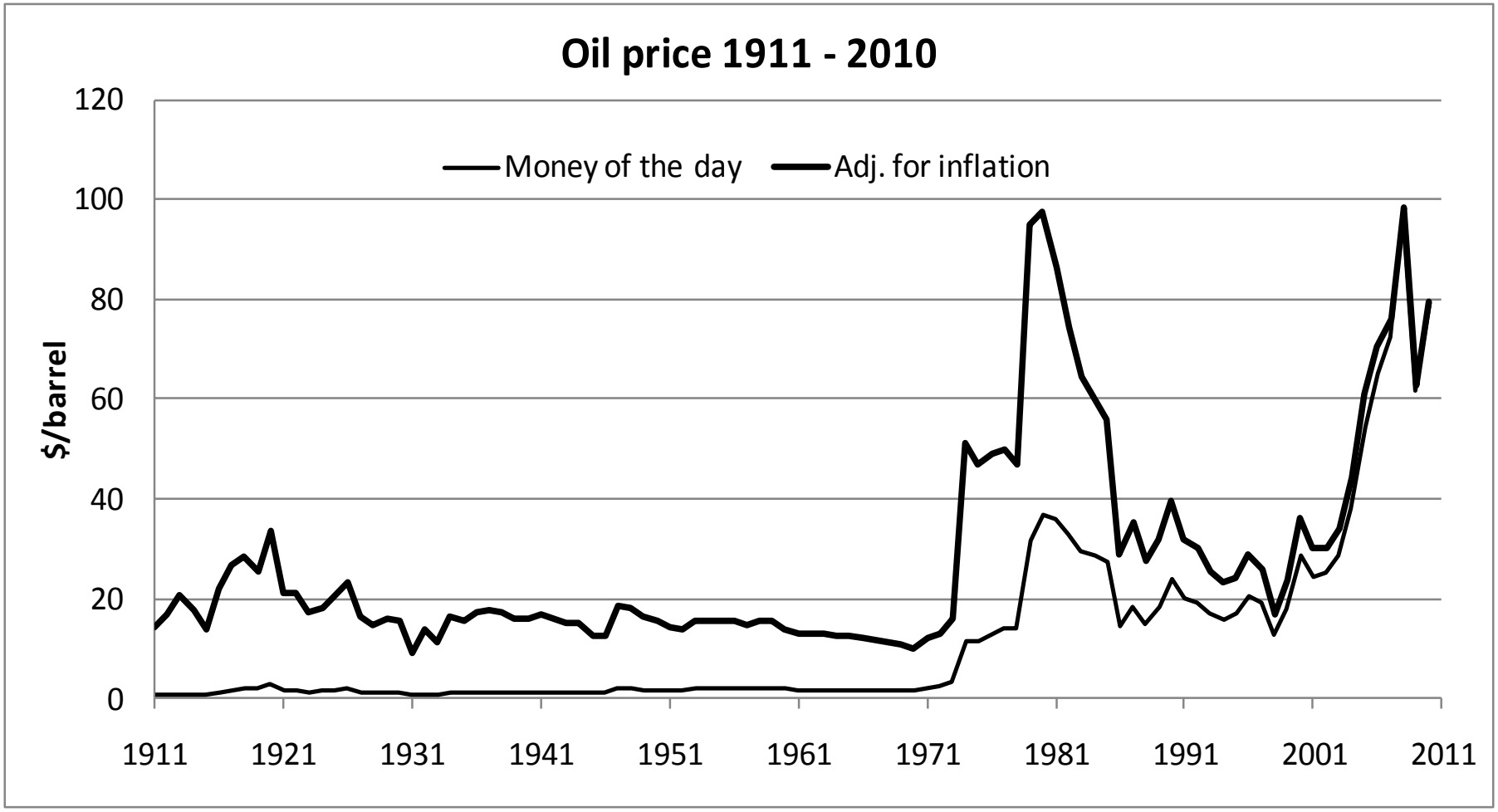
Postgraduate Research Institute for Sedimentology
Prof. M.L. Coleman (ex-BP), Prof. B.W. Sellwood.

Department of Engineering
Dr. J.D. Burton, Mr. R.H. Booth (ex-Shell),
Dr. R.M. Mayer (ex-BP), Prof. P.D. Dunn,
MSc. students (also City University).

Department of Cybernetics
Dr. G.R. Whitfield, Dr. R.W. Bentley (ex-Exxon).

Affiliated: Dr. D. Fleming, independent economist.

- For many years the only UK academic group doing quantitative research on future global hydrocarbon supply.

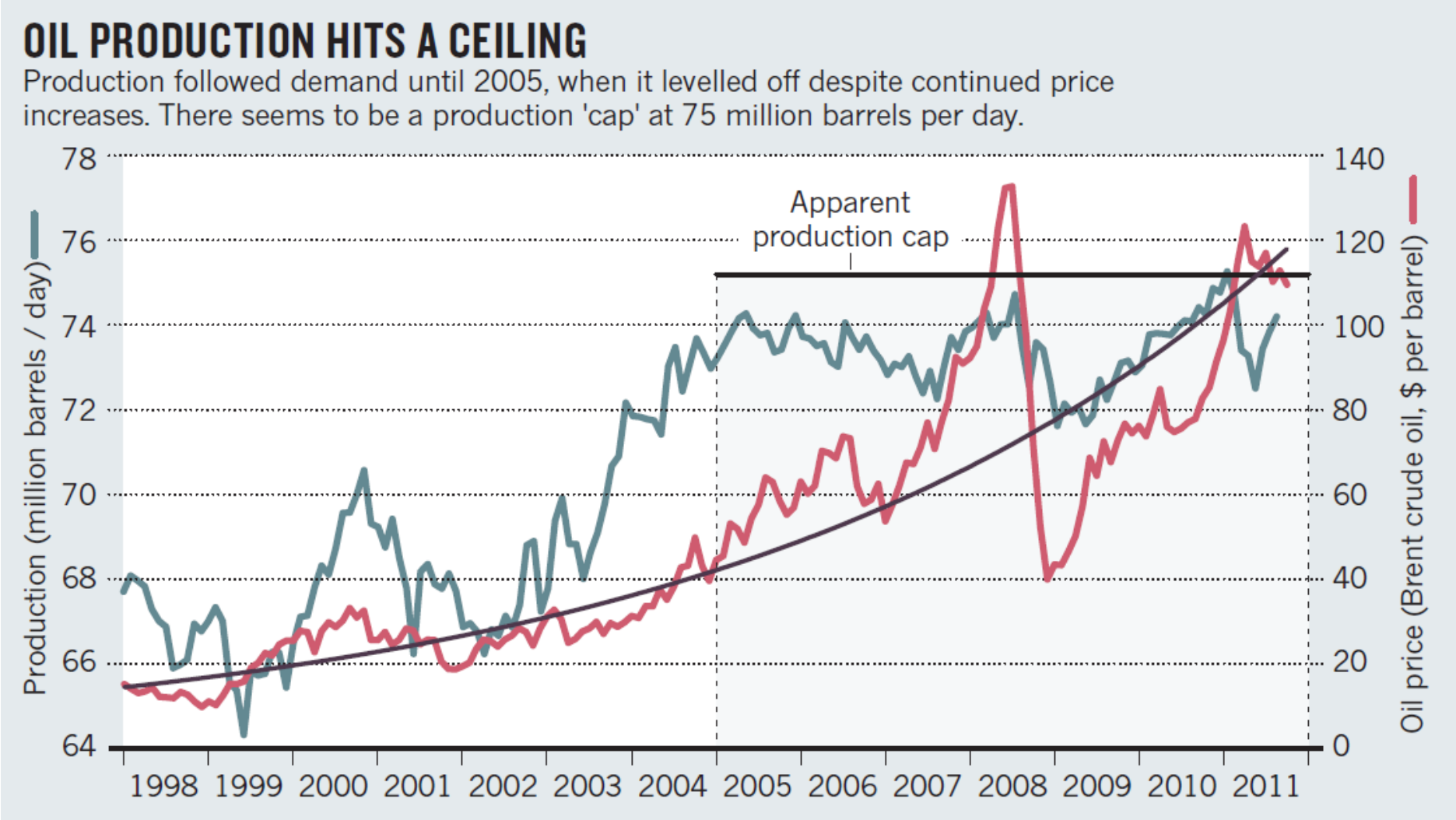


Data source: BP Statistical Review

1. **Oil price 1911 - 2010:** **Adjusted for inflation, over the last century the price was as high as today's only during the 'oil shocks' of the 1970s. Those resulted in stagnant economies, global inflation, high levels of unemployment, and large developing-country debt.**

Oil Production and Price

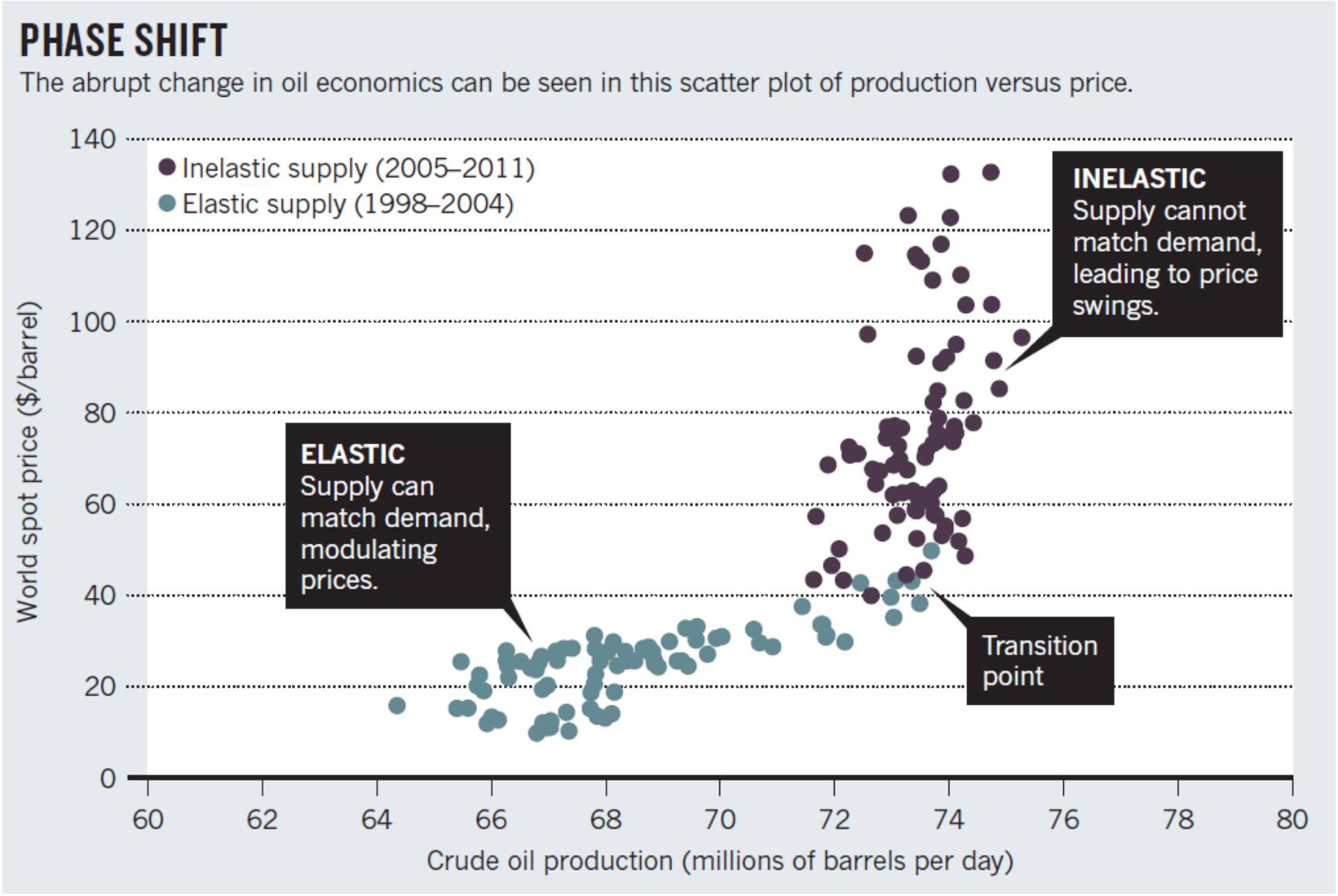
Source: *Murray / King comment* in Nature



Source: Murray, J. and King, D. (2012) Oil's Tipping Point has Passed, Nature, Volume 481, 433-435

Crude Oil Price versus Crude Oil Production from 1998 to present

Murray / King comment in Nature

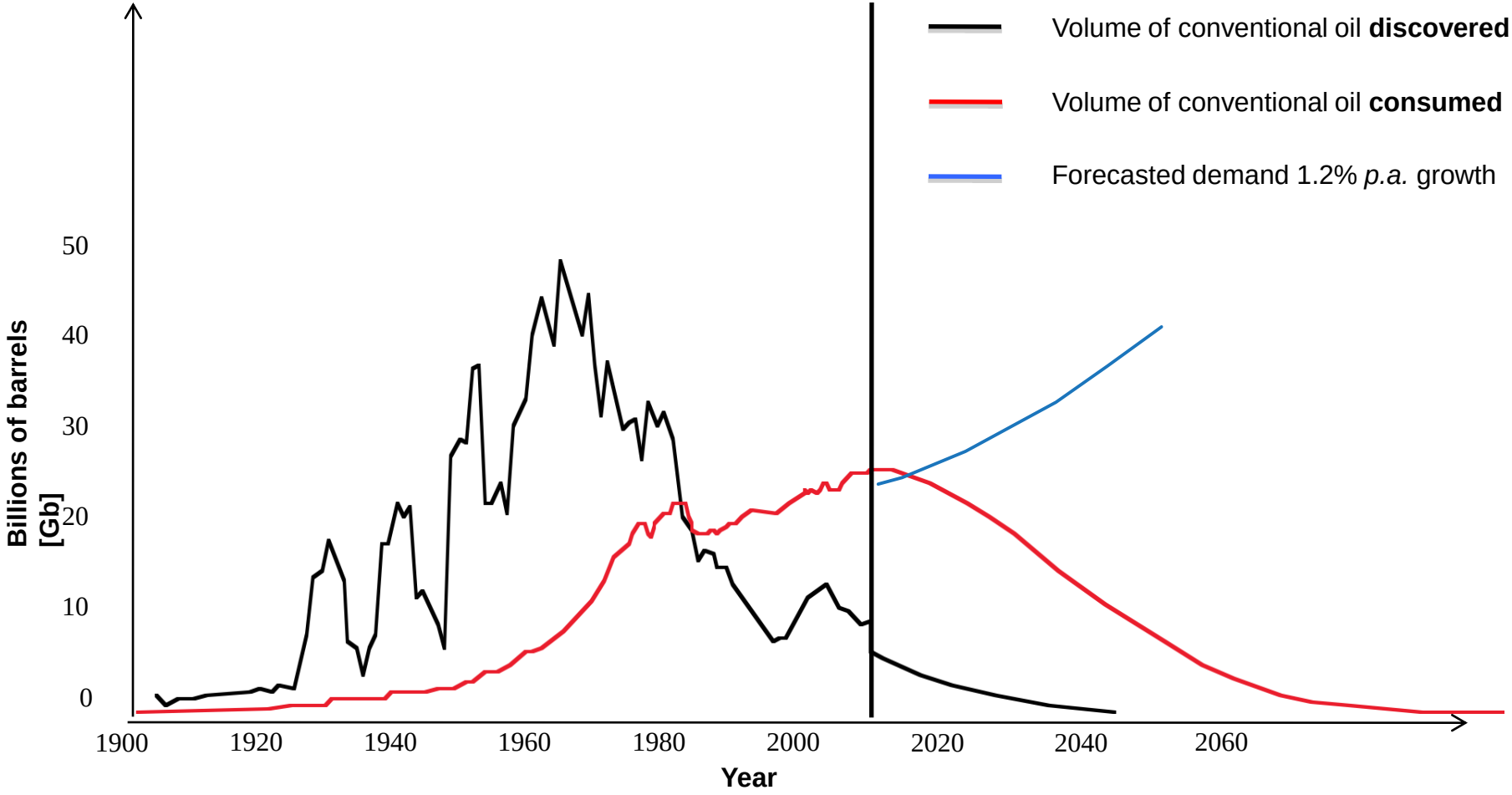


Source: Murray, J. and King, D. (2012) Oil's Tipping Point has Passed, Nature, Volume 481, 433-435

Conventional Oil Supply and Demand

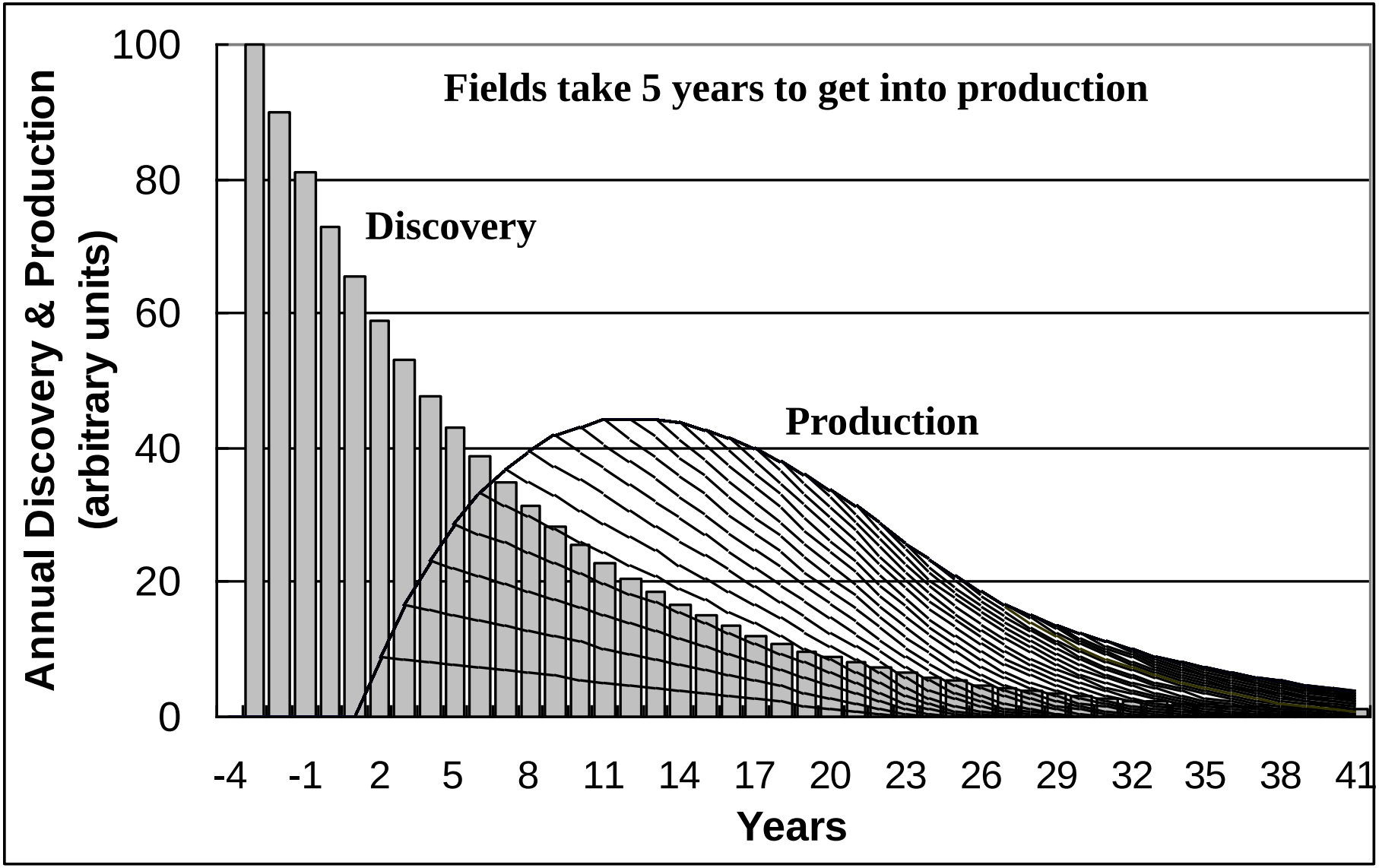
- The Conventional oil peak is about now.

Murray / King comment in Nature

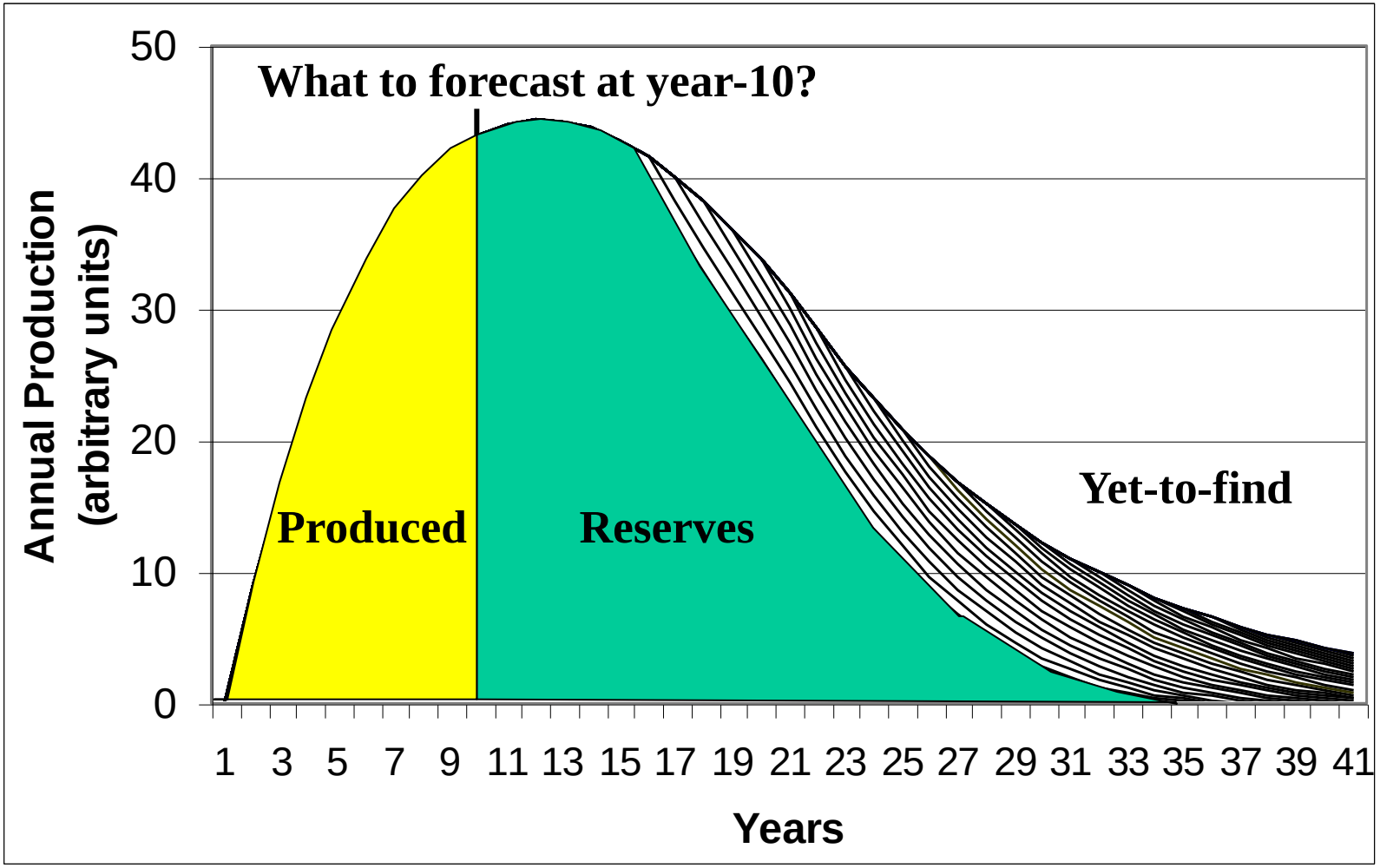


Source: N.A. Owen, O.R. Inderwildi and D.A King, 'The status of conventional world oil reserves - Hype or cause for concern?' (2010) Energy Policy, doi:10.1016/j.enpol.2010.02.026

2. Why does conventional oil prodn. in a region peak?
Simple model: Discovery, then production - big fields first.



3. Conv. oil peak is *counter-intuitive*. It occurs when production is rising, reserves are large, new fields are being discovered, & technology is increasing recovery factors.

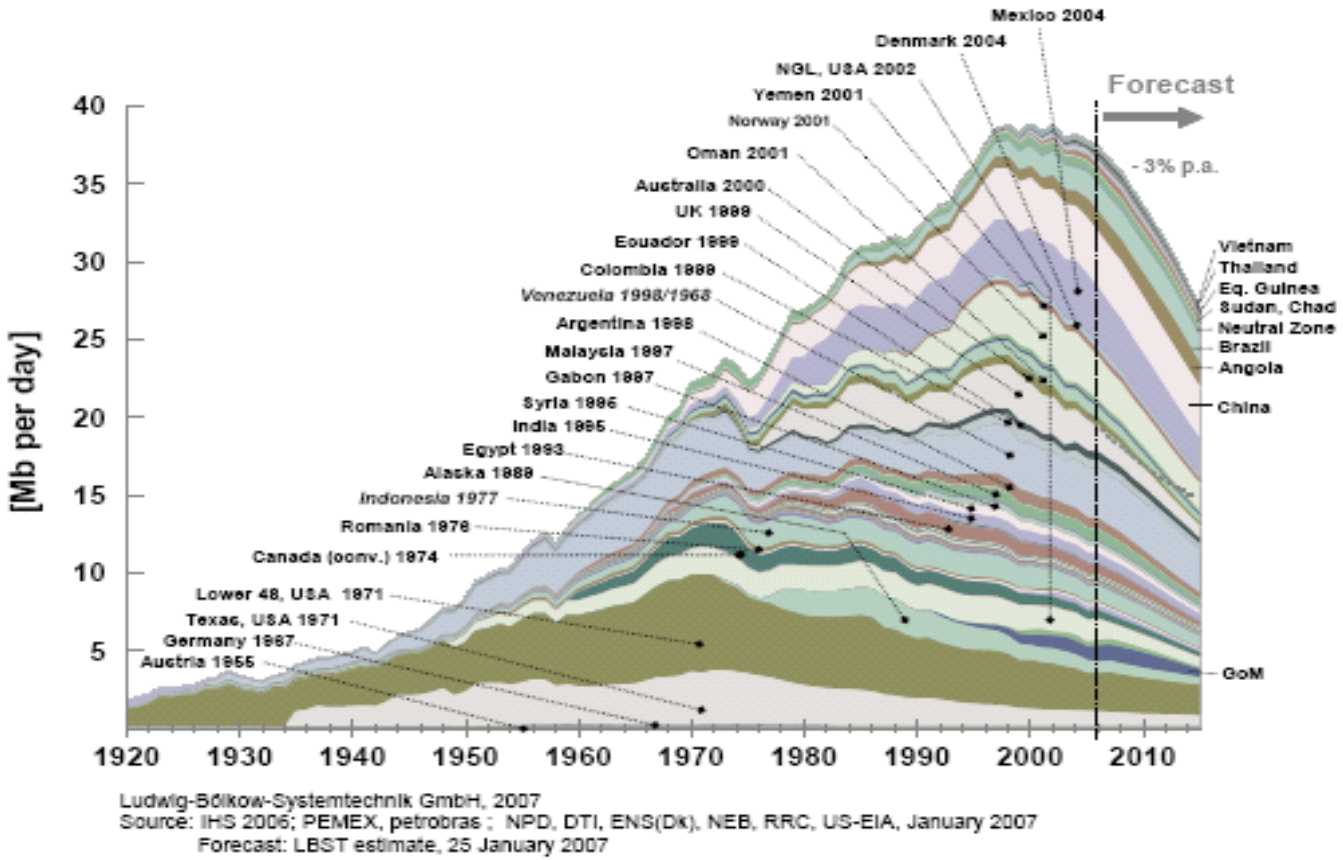


Validity of this model

This general model of peak is borne out by the ~60 countries now past their conventional oil peak.

(See R. Bentley: *An Explanation of Oil Peaking*.)

Figure 5: Oil producing countries ex OPEC and ex FSU



Ludwig-Bölkow-Systemtechnik GmbH, 2007
Source: IHS 2006; PEMEX, petrobras ; NPD, DTI, ENS(Dk), NEB, RRC, US-EIA, January 2007
Forecast: LBST estimate, 25 January 2007

A Note on Oil Reserves - *Bad data & Good data*

Public-domain *proved* reserves ('1P')

For oil forecasting these are atrocious data:

- under-reported, over-reported, not reported.

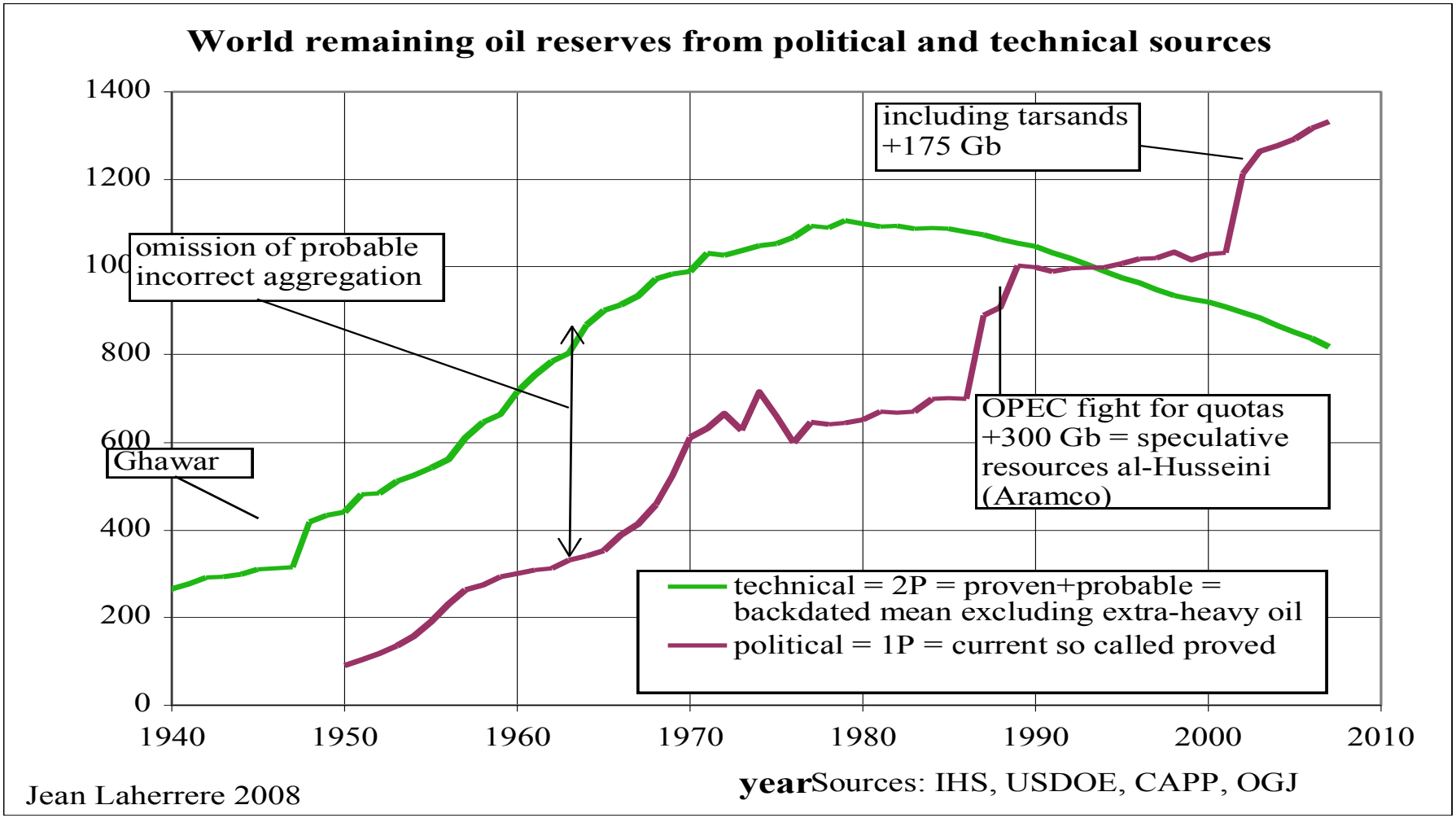
Industry *proved plus probable* reserves ('2P')

Must use 2P data to assess future production

Data: from oil field owners & operators;
also IHS Energy,Wood Mackenzie, PFC Energy,
Data Monitor (was Energyfiles), etc.; also IFP, BGR.

(See: R.W. Bentley, S.A. Mannan, and S.J. Wheeler. *Assessing the date of the global oil peak: The need to use 2P reserves*. Energy Policy, vol. 35, pp 6364–6382, Elsevier, 2007).

Difference between ever-growing global proved reserves ('1P', magenta) and diminishing proved+probable ('2P', green).



The use of proved reserves by most analysts, and the assumption by many that this is all the oil a region can still produce, have been major failings.

4. Past oil forecasts – Were they really wrong?

- So often said: “Can’t trust oil forecasts - thirty years ago we were told we had only 30 years’ of oil left; now we have 40 years’ left!”

But the ‘30 years’ of oil was only that in *proved* reserves. This omitted the large amount of oil in *probable* reserves, and in ‘reserves growth’ due to technical improvement, and in the yet-to-be-discovered.

In the 1970s, calculating peak from this *total* expected amount of oil put the global *production peak* (not *global exhaustion*) around the year 2000.

Demand reduction due to ‘73 & ‘78 oil shocks moved this peak to ~2010.

Estimates for date of World peak, 1956 - 1981

Date/Author	Methodology	Ult. (Gb)	Peak Yr.	Mb/d
'56 Hubbert	Ult. from Weeks (mod.); hand-drawn curve	1250	~2000	35
'69 Hubbert	Logistic curve	1350	1990	65
	ditto	2100	2000	100
'72 ESSO	? * "increasingly scarce from ~ yr. 2000"	2100	*	
'72 Ward & Dubois	? [Report to the UN.]	2500	~2000	
'76 UK DoE	?		~2000	
'77 Ehrlich	?	1900	2000	
'77 Hubbert	Ult. from Nehring: Logistic (unconstrn'd.)	2000	1996	100
	Demand flat from 1974	ditto	2035	
	[Actual demand between these two cases.]			
'79 Shell	? ** "plateau within next 25 years"		**	
'79 BP	? Non-communist world, ex NGLs.	?	1985	
	[Actual demand fell, Ult. about right.]			
'81 World Bank	? *** "plateau from around turn of century"	1900	***	

? = Not known; probably mid-point peaking.

Others gave estimates for oil 'ultimate', but did not carry through to a peak date:
SPRU, UK: 1800-2480Gb; WEC/IFP: 1803 Gb; D. Meadows *et al.*: 1800-2500 Gb.

So: Past oil forecasts – Were they really wrong?

- No, we have had plenty of warning from well-recognised bodies since the 1950's that the peak in global conventional oil production was expected around 2000 - 2010.

(R.W. Bentley and G.A. Boyle. *Global oil production: forecasts and methodologies*. Environment and Planning B: Planning and Design, vol. 35, pp 609-626, 2008.)

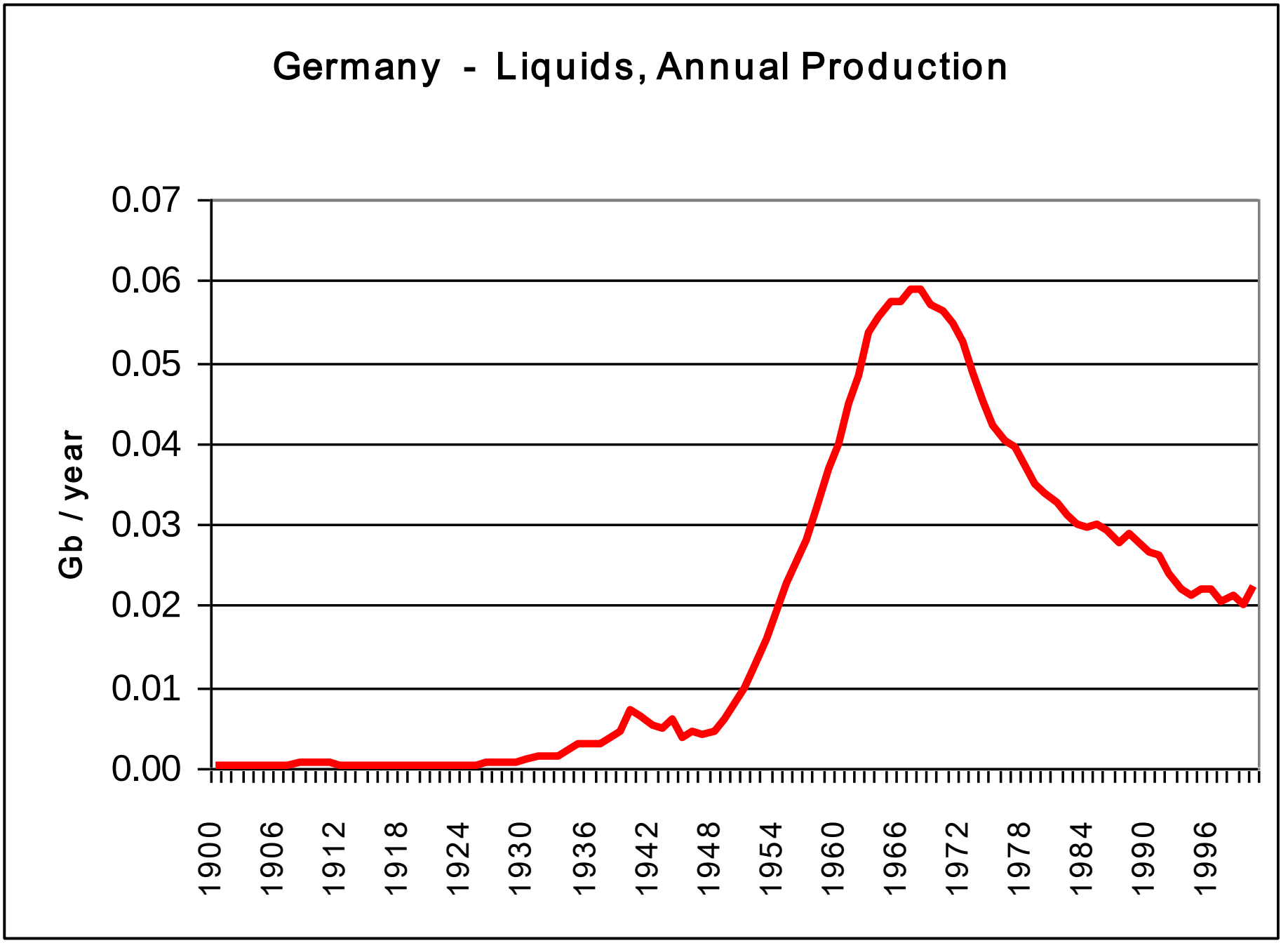
5. Industry Data – by country:

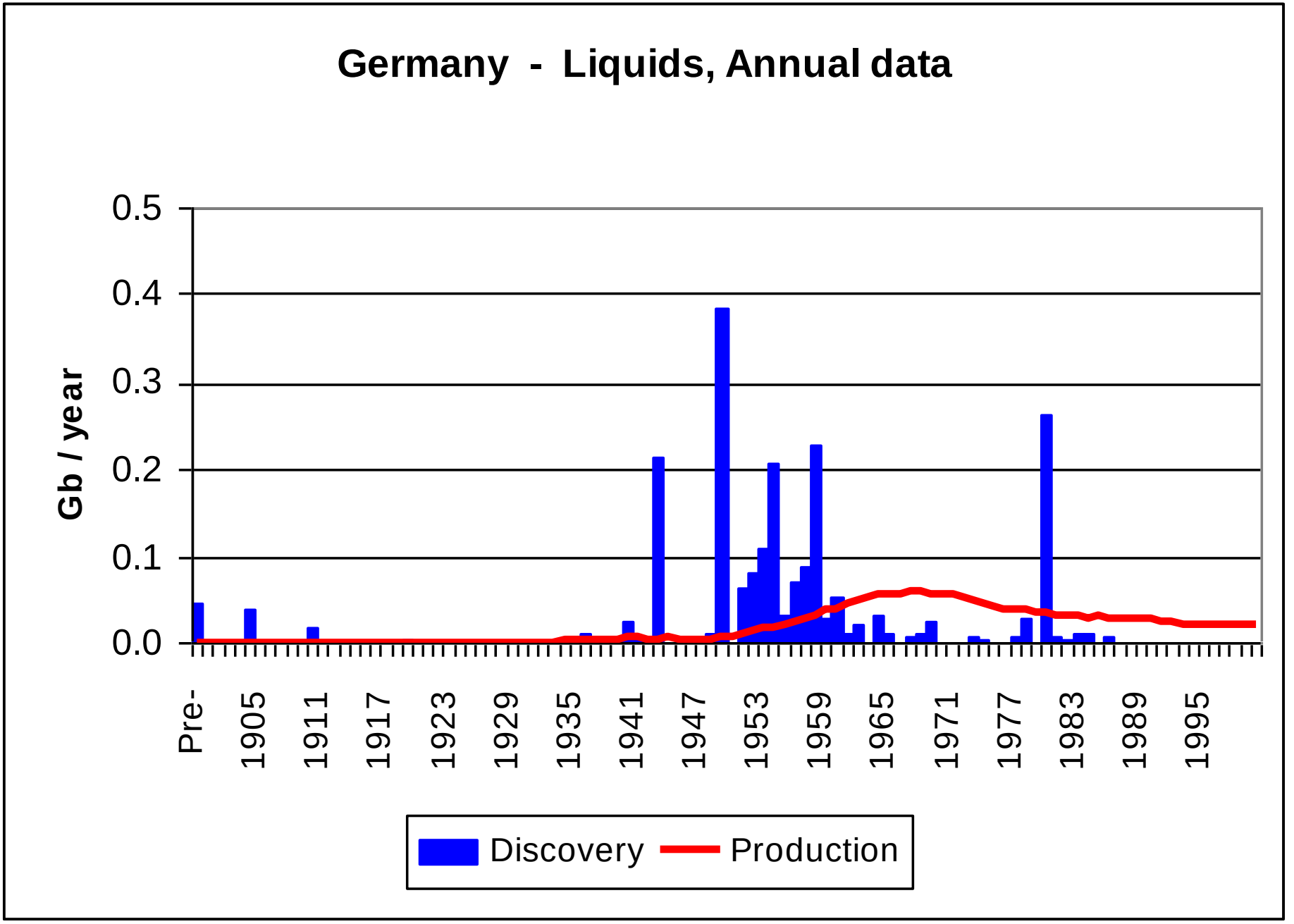
Graphs of:

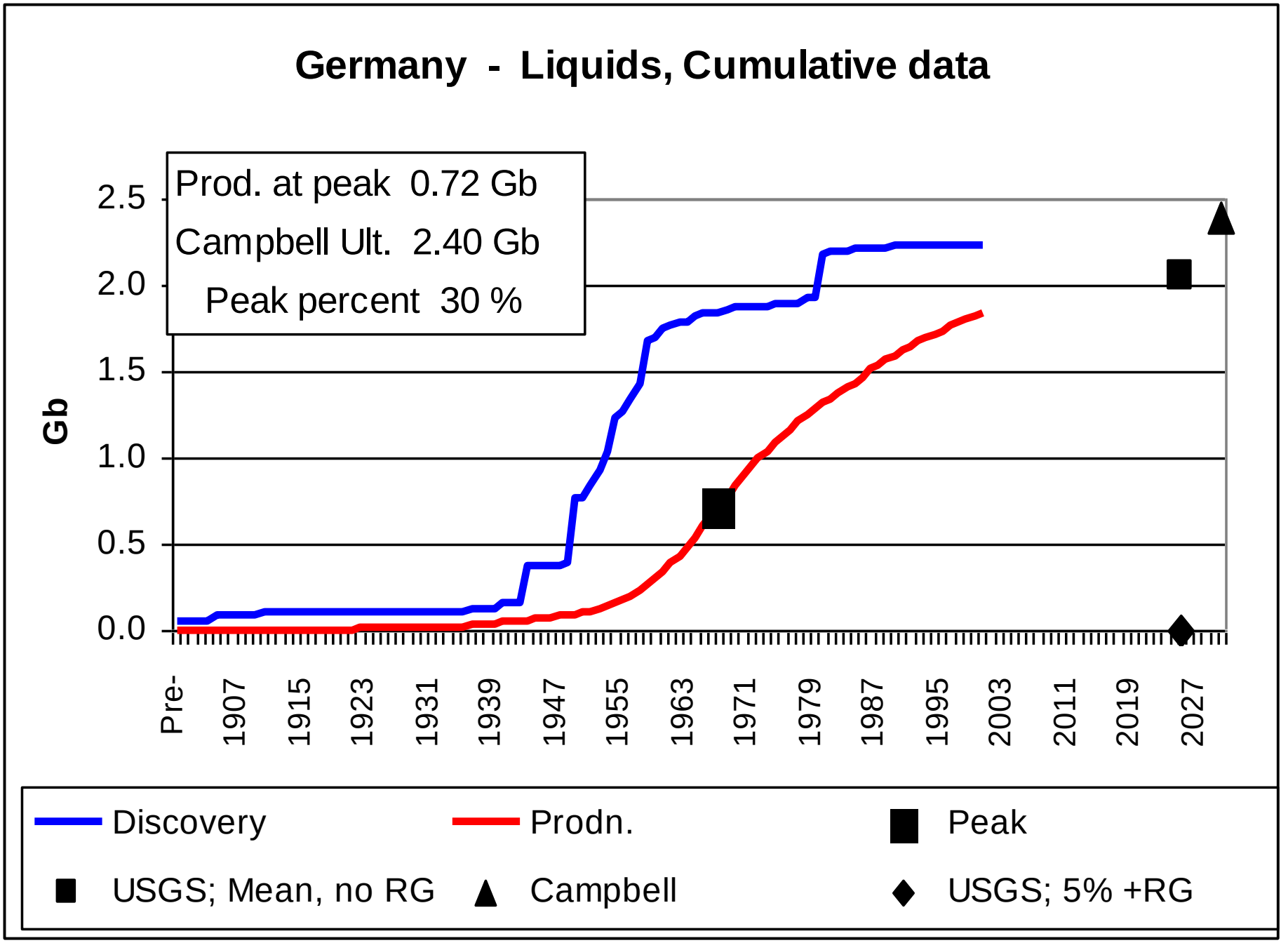
- Proved & probable ('2P') oil discovery
- Oil production

for Germany, UK, US, & the World; where 'oil' includes NGLs, but not oil from tar sands, shale oil, oil shale, GTLs, CTLs or biofuels.

Note: These data are proprietary to IHS Energy & Energyfiles Ltd., but permission has been given for publication.

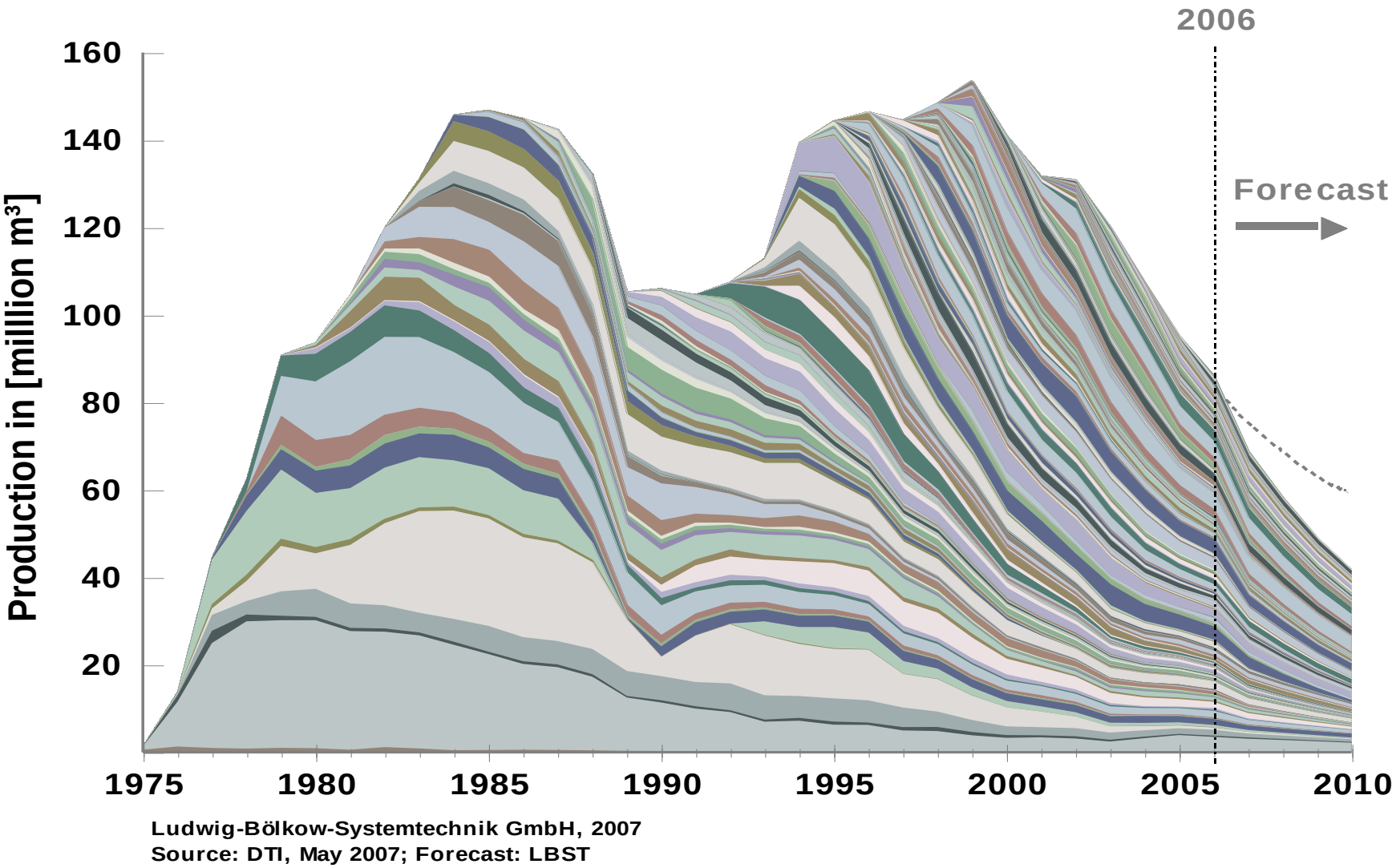

Germany - Liquids, Annual Production
Gb / year
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1900
1906
1912
1918
1924
1930
1936
1942
1948
1954
1960
1966
1972
1978
1984
1990
1996


Germany - Liquids, Annual data
Gb / year
0.5
0.4
0.3
0.2
0.1
0.0
Pre-
1905
1911
1917
1923
1929
1935
1941
1947
1953
1959
1965
1971
1977
1983
1989
1995
Discovery
Production


Germany - Liquids, Cumulative data
Prod. at peak 0.72 Gb
Campbell Ult. 2.40 Gb
Peak percent 30 %
Gb
2.5
2.0
1.5
1.0
0.5
0.0
Pre-
1907
1915
1923
1931
1939
1947
1955
1963
1971
1979
1987
1995
2003
2011
2019
2027
Discovery
Prodn.
Peak
USGS; Mean, no RG
Campbell
USGS; 5% +RG

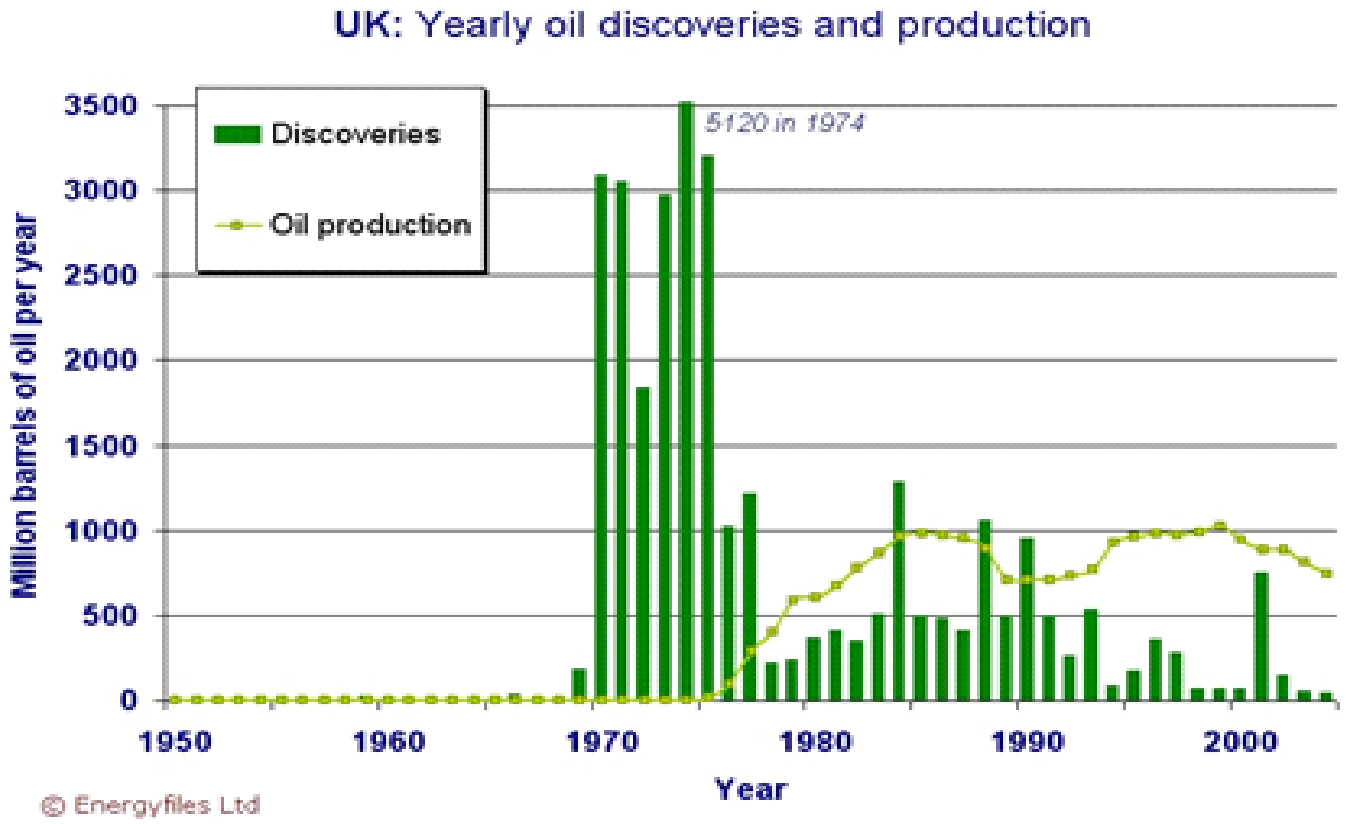
UK Oil Production by Field

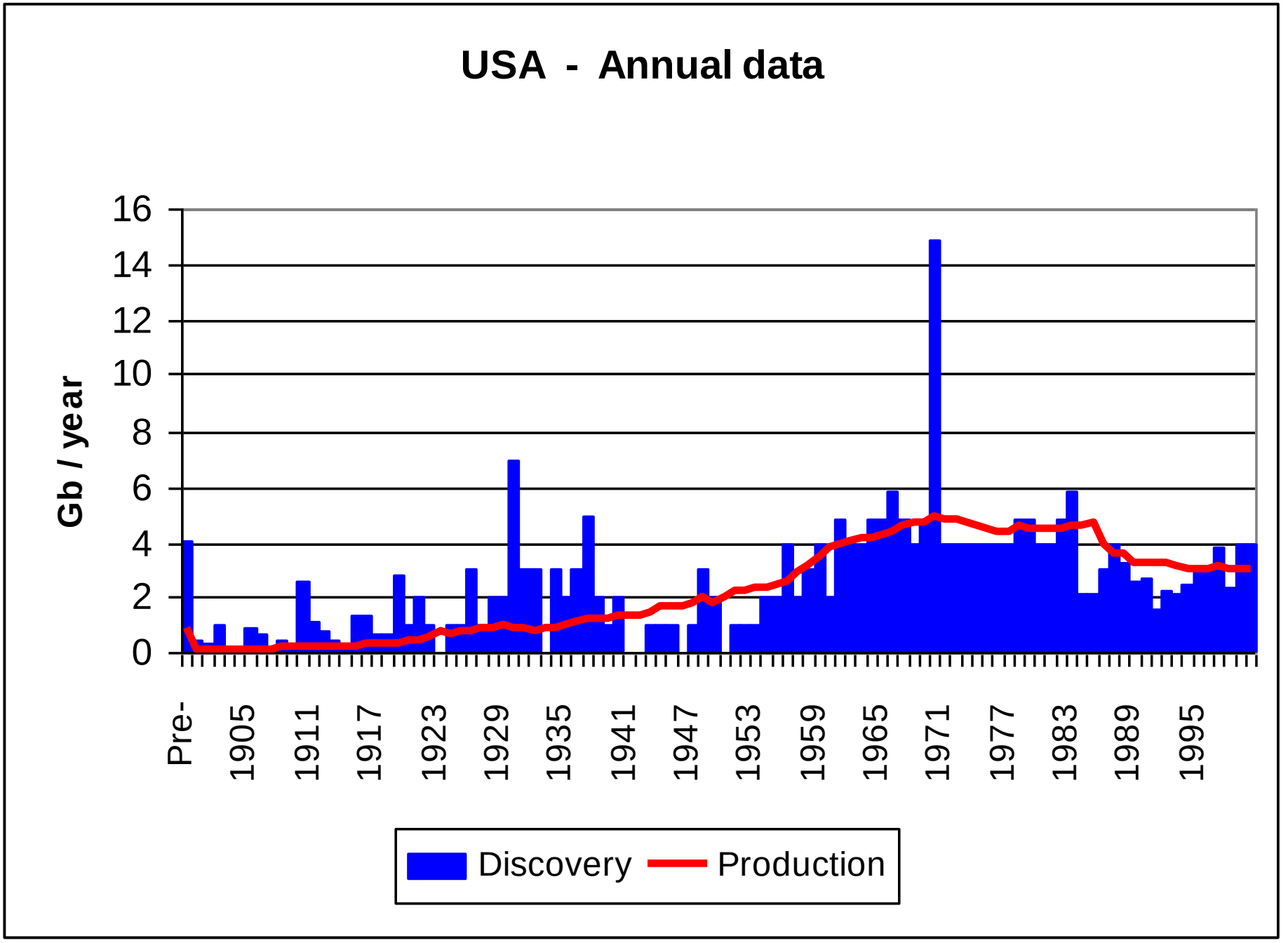
Source: LBST, Germany

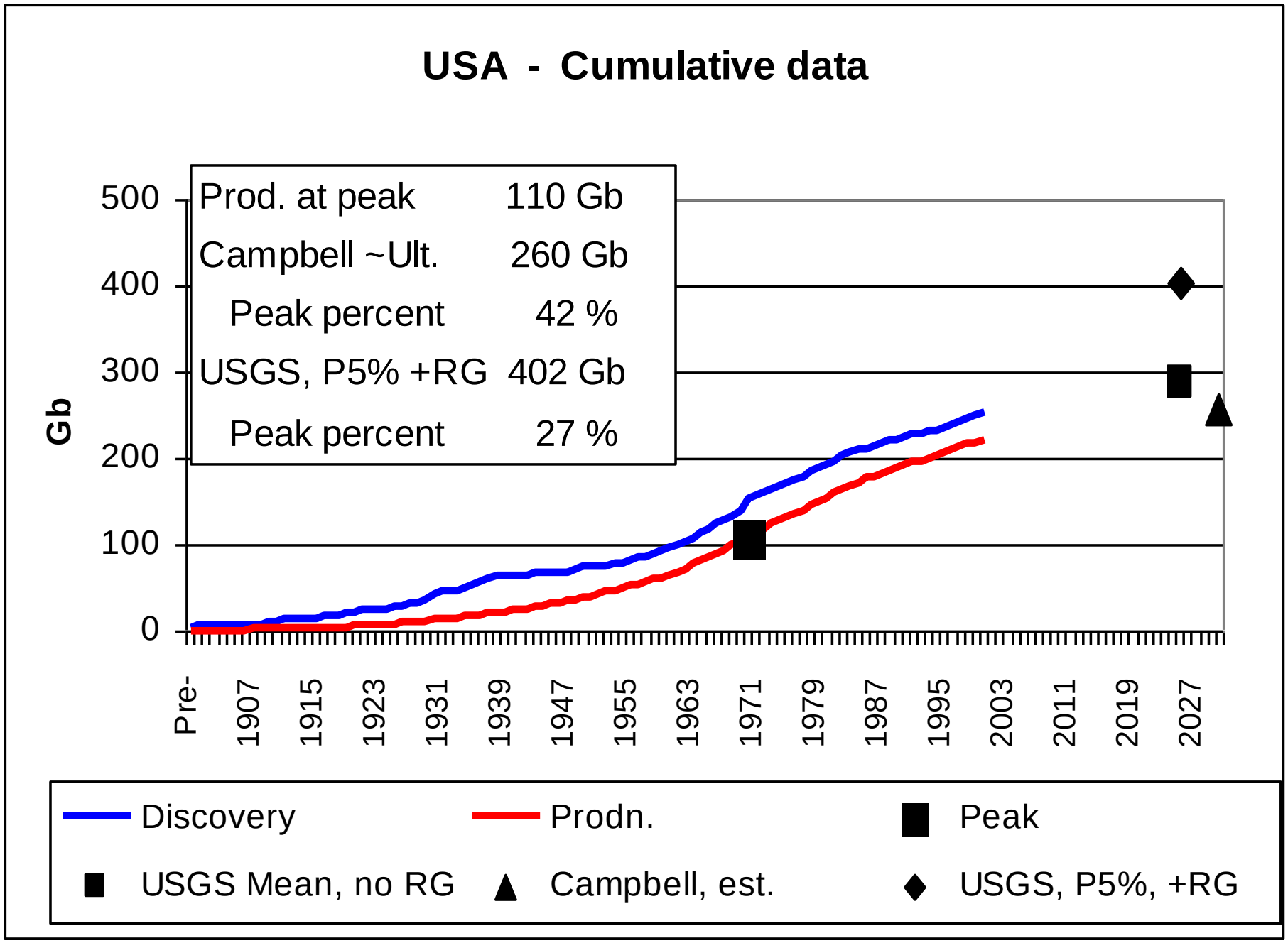


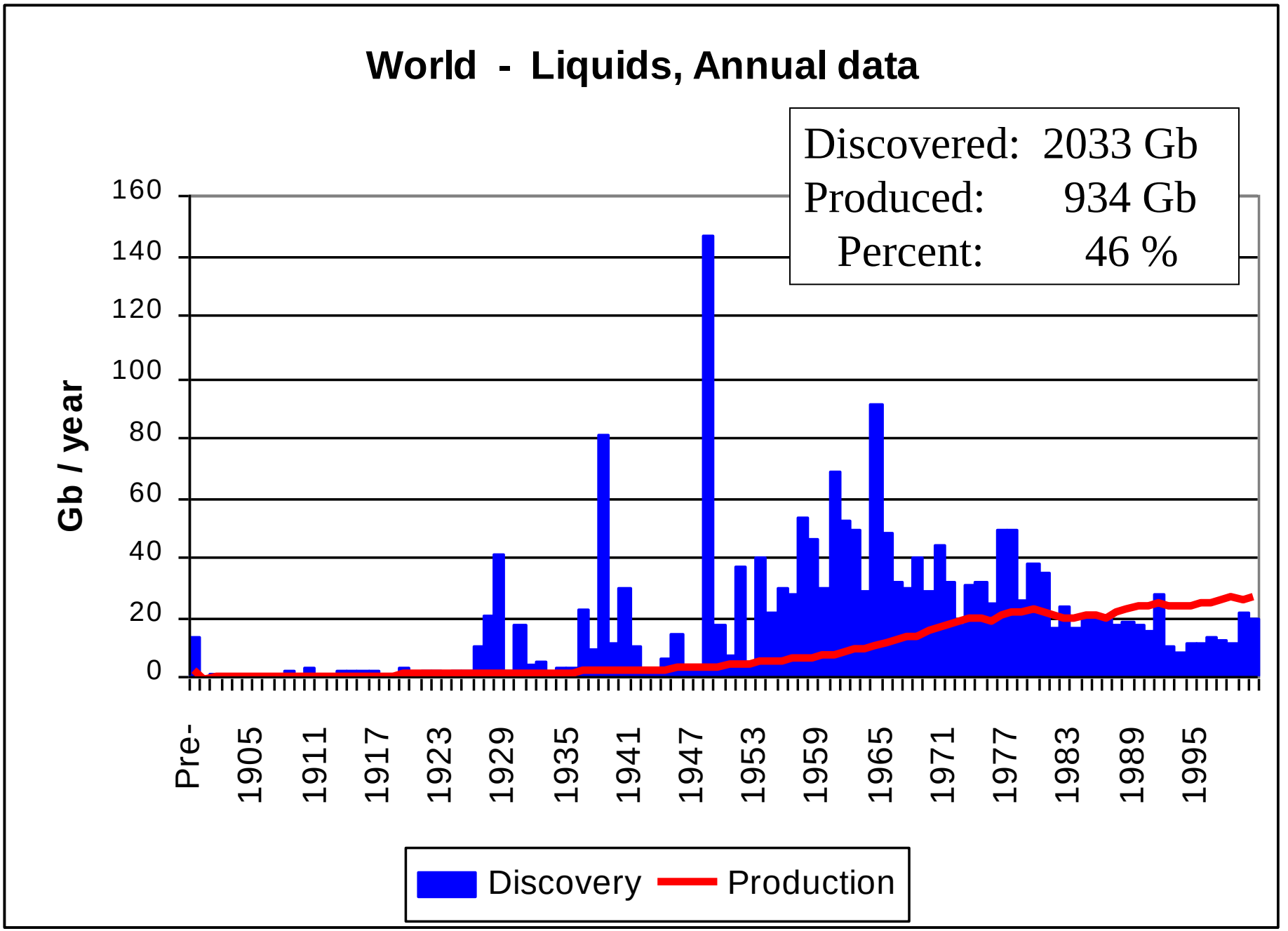
Predicting peak is not hard – the case of the UK.

Once 2P discovery has declined (~1978 in UK), the date of peak is pretty well known.




USA - Annual data
Gb / year
16
14
12
10
8
6
4
2
0
Pre-
1905
1911
1917
1923
1929
1935
1941
1947
1953
1959
1965
1971
1977
1983
1989
1995
Discovery
Production

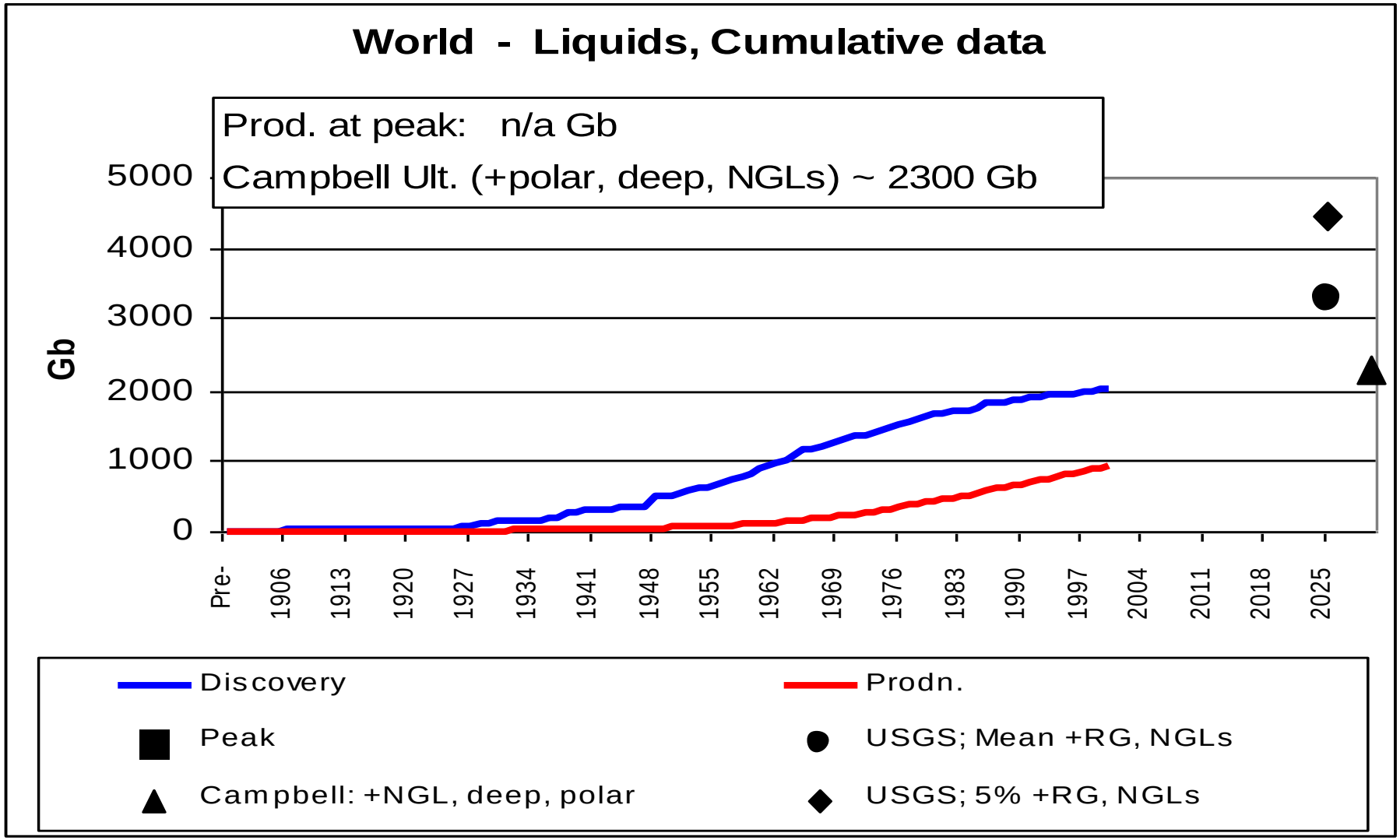

USA - Cumulative data
Prod. at peak 110 Gb
Campbell ~Ult. 260 Gb
Peak percent 42 %
USGS, P5% +RG 402 Gb
Peak percent 27 %
Gb
500
400
300
200
100
0
Pre-
1907
1915
1923
1931
1939
1947
1955
1963
1971
1979
1987
1995
2003
2011
2019
2027
Discovery
Prodn.
Peak
USGS Mean, no RG
Campbell, est.
USGS, P5%, +RG


World - Liquids, Annual data
Discovered: 2033 Gb
Produced: 934 Gb
Percent: 46 %
Gb / year
160
140
120
100
80
60
40
20
0
Pre-
1905
1911
1917
1923
1929
1935
1941
1947
1953
1959
1965
1971
1977
1983
1989
1995
Discovery
Production

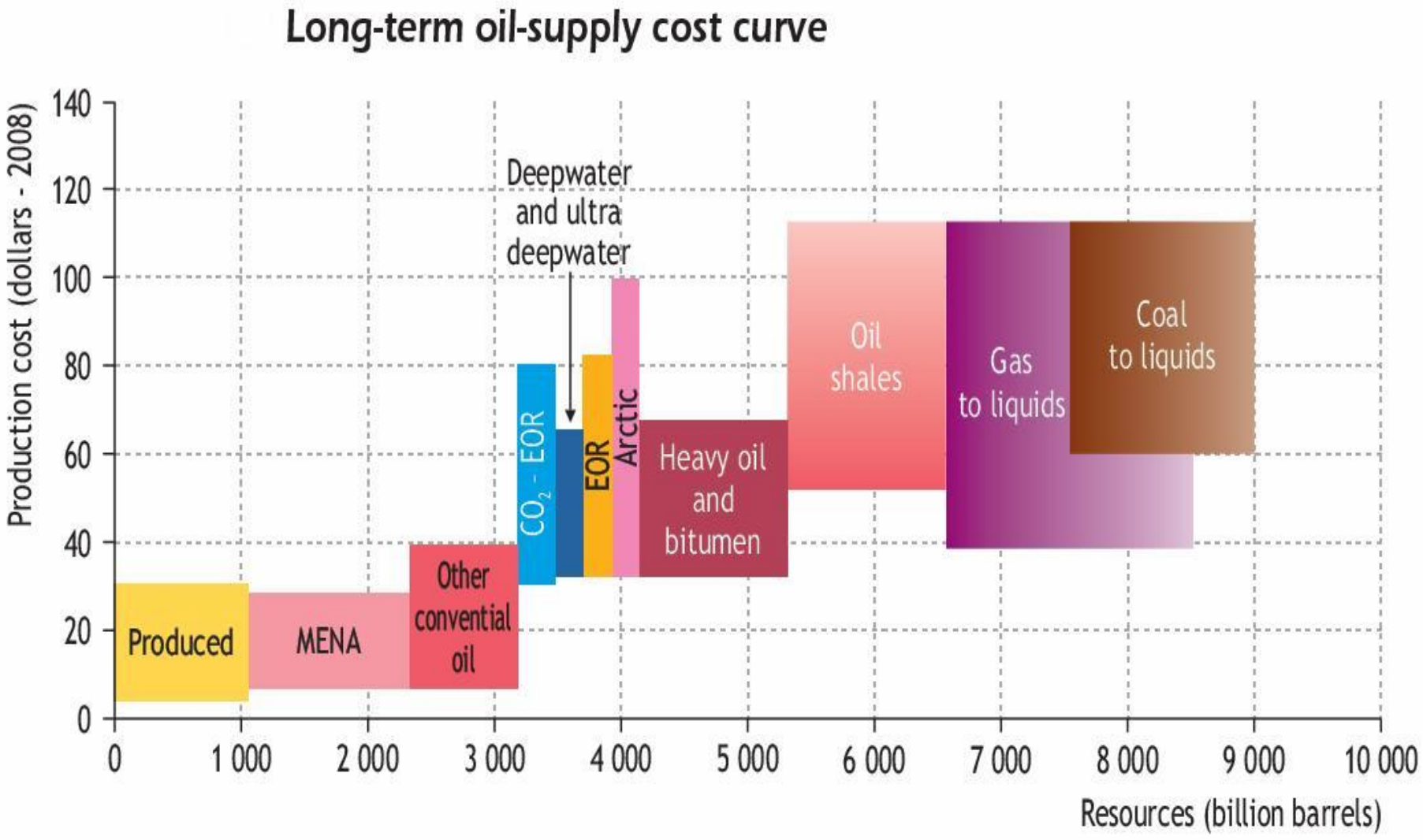
World cumulative plot - 2P discovery trend vs. est'd. 'ultimates'

- High estimates of global URR do not match 2P discovery trend.

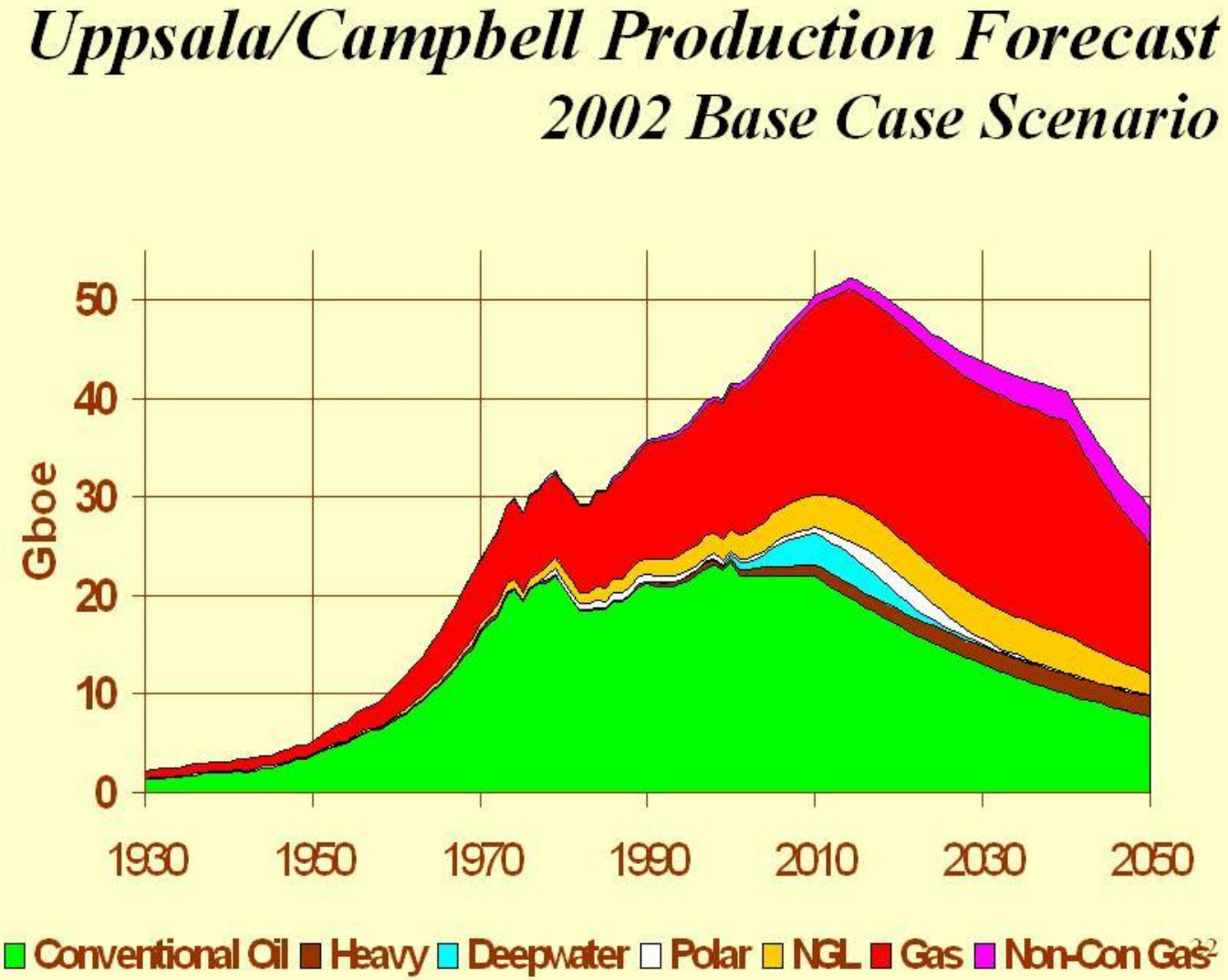
Oil + NGLs 2P discovery & prod'n., 1900-2000. Source: IHS Energy, 2001.

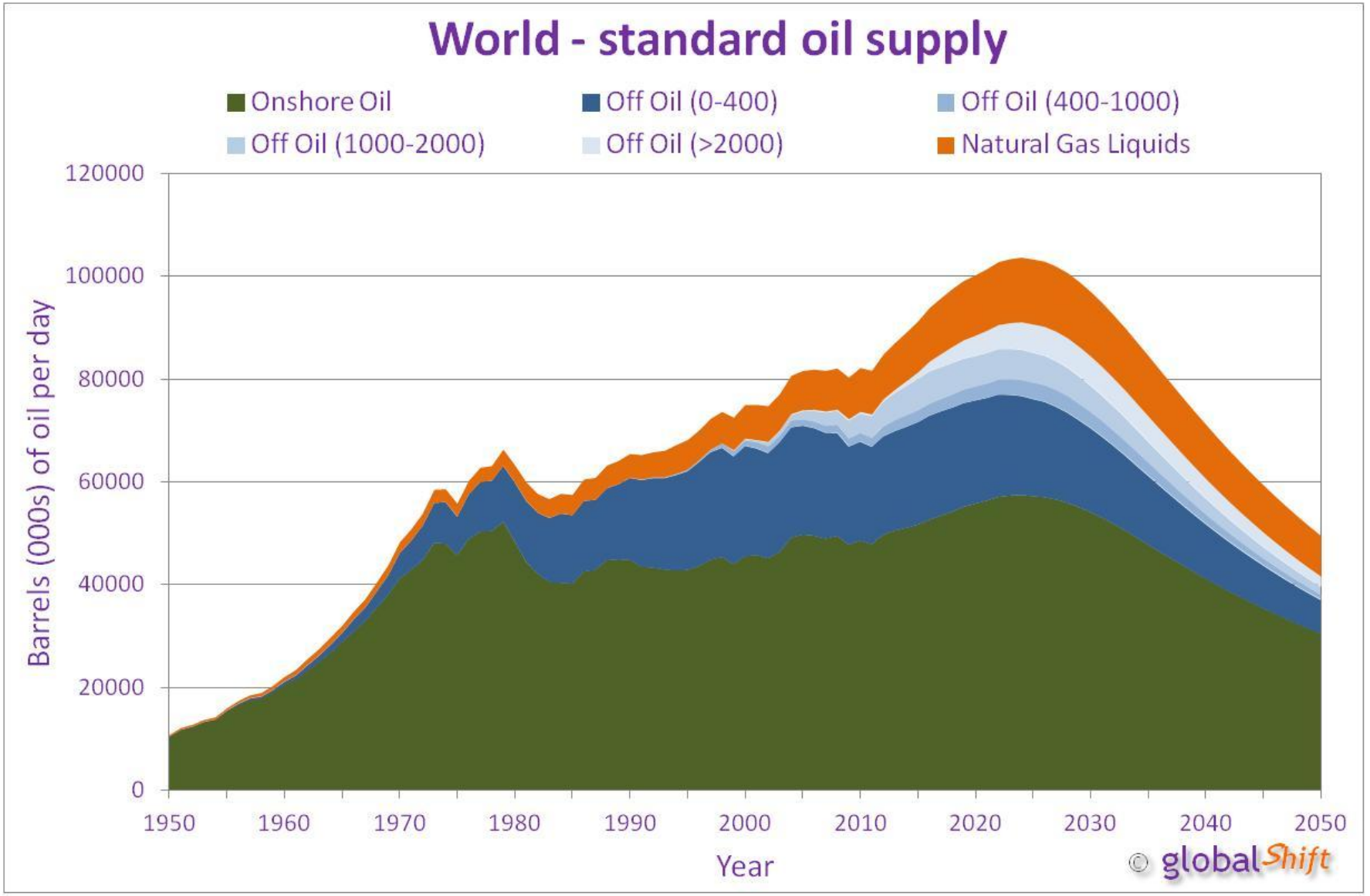


6. There is a lot of oil & 'nearly-oil' - Source: IEA

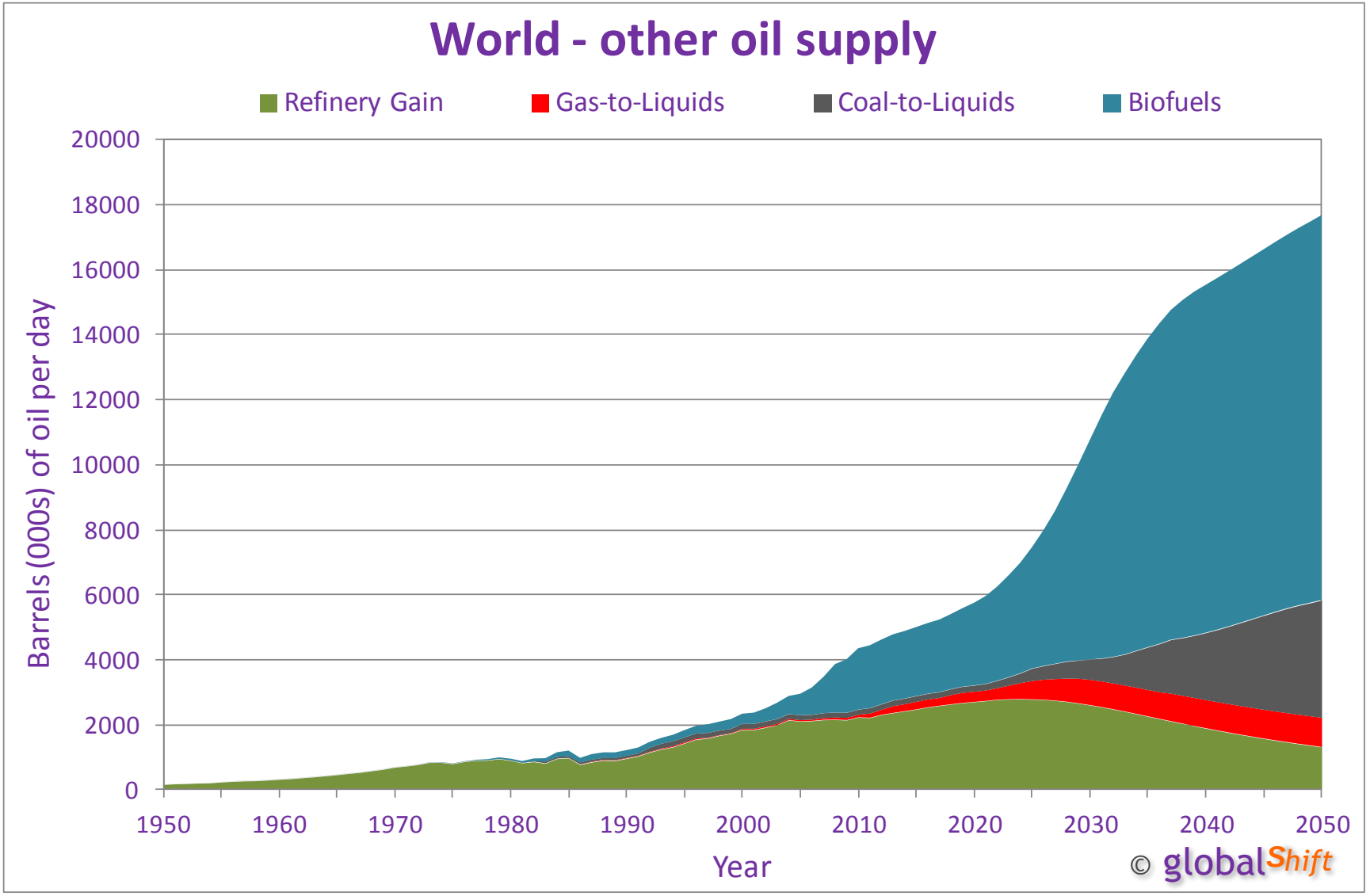


7. Current Forecasts –
The conventional oil peak is likely to dominate

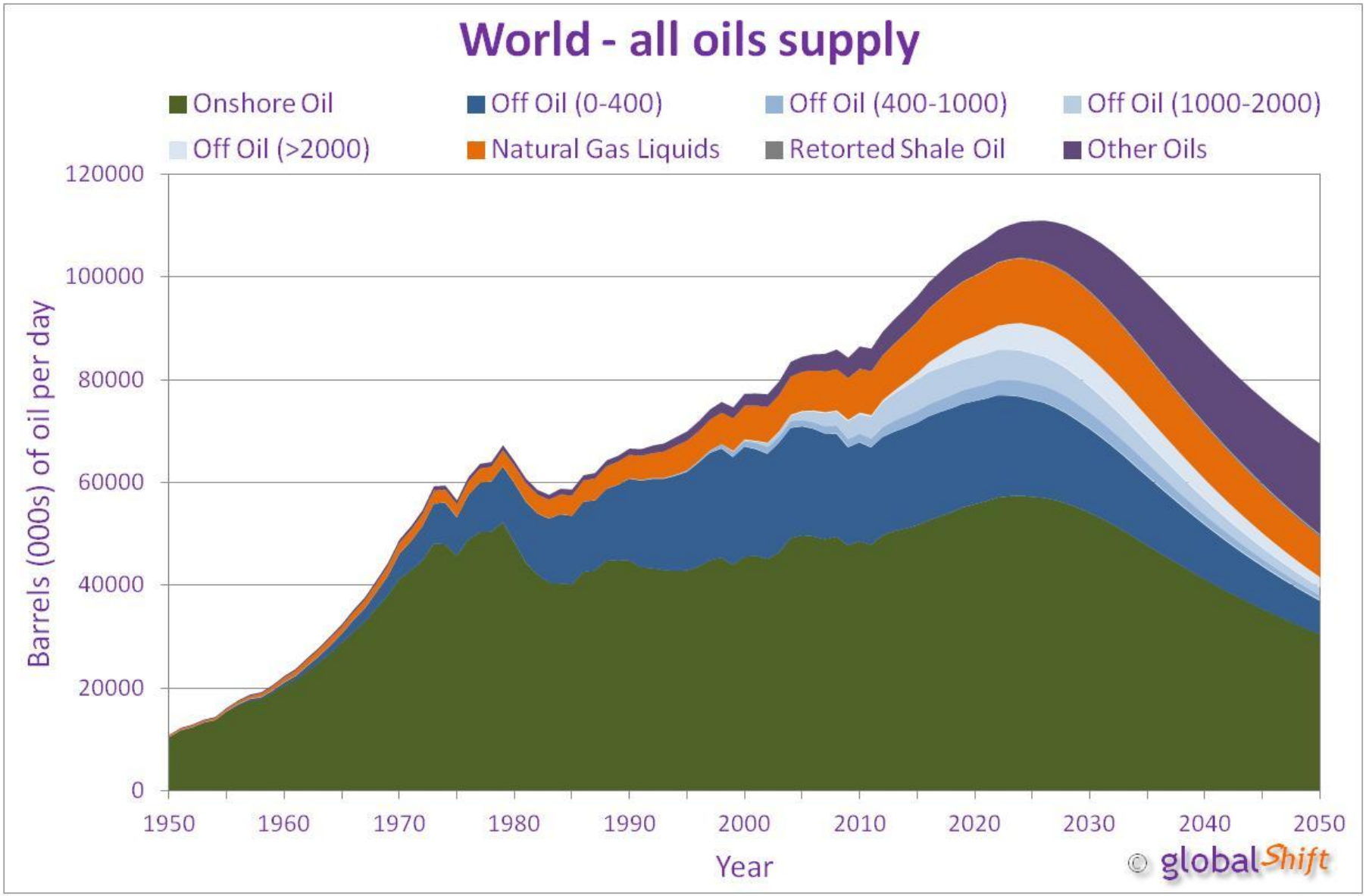




Forecasts from 2010



Forecasts from 2010

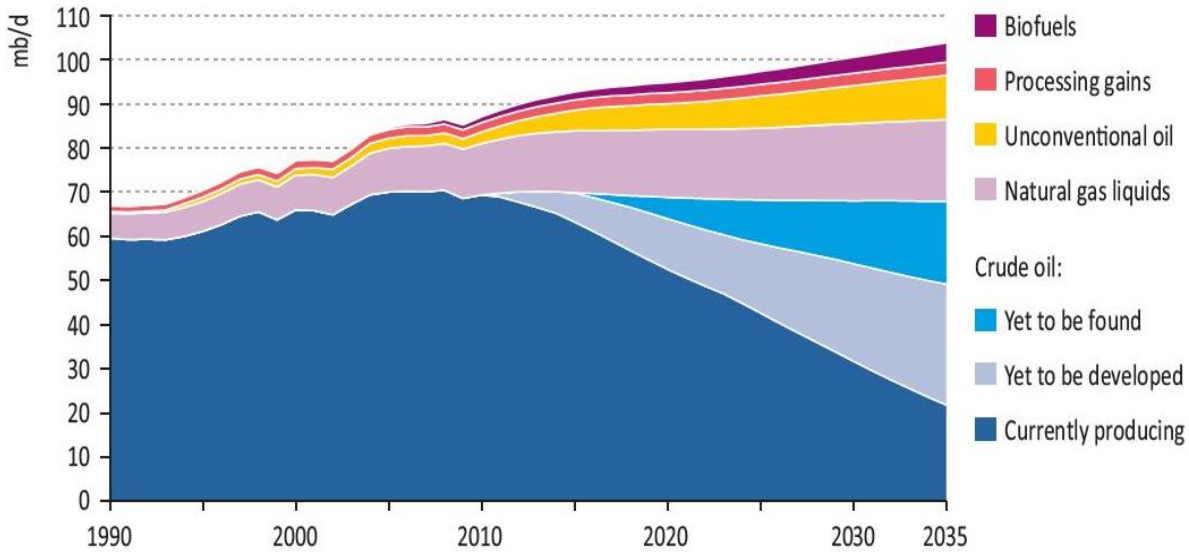


Forecasts from 2010

Top-down or bottom-up? Source: R Miller

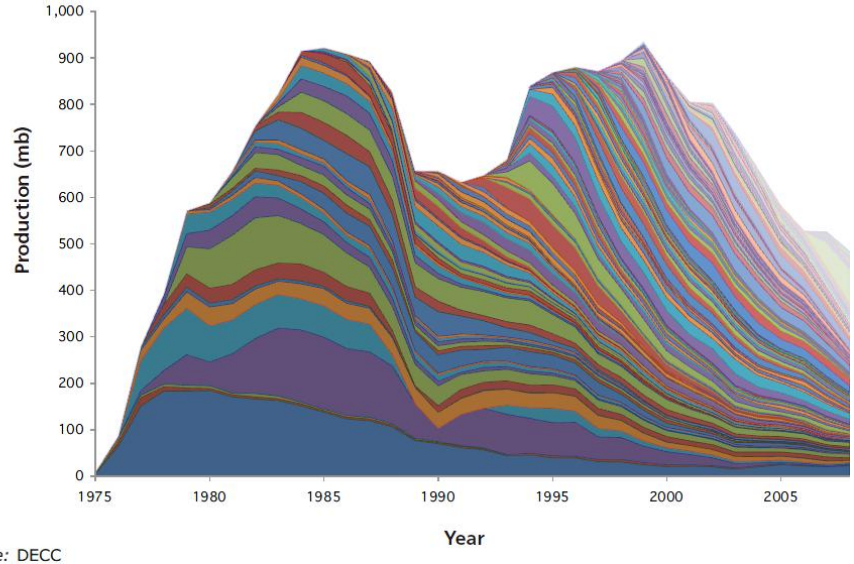
The top-down picture shows *what* has happened globally, but not *why*

The bottom-up picture shows why things happen. Large fields start earliest, enter decline, and new fields cannot compensate



IEA, WEO 2011

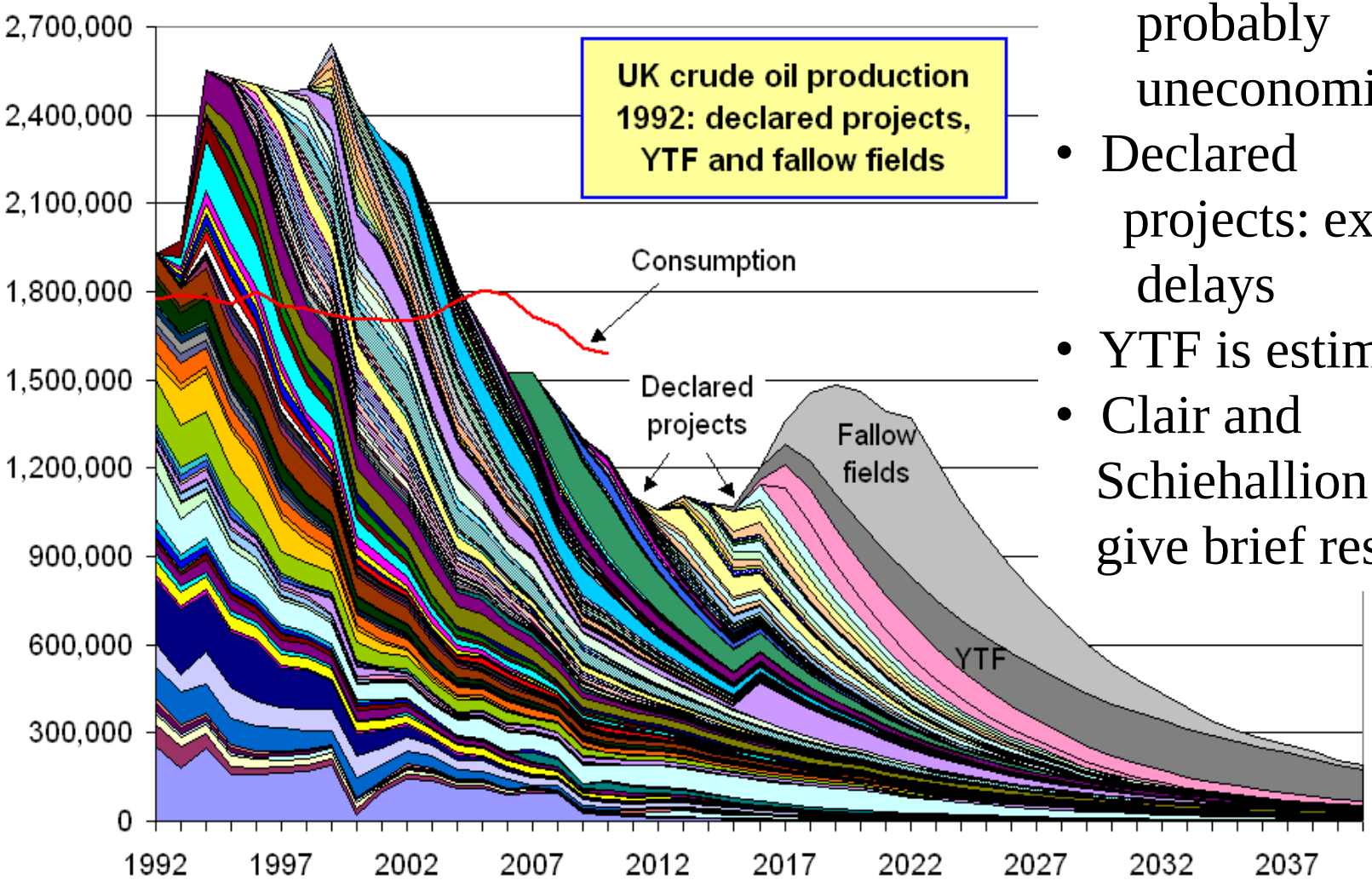
Figure 1.6 Oil production in the UKCS by field



Source: DECC

The UK bottom-up model

Source: R Miller

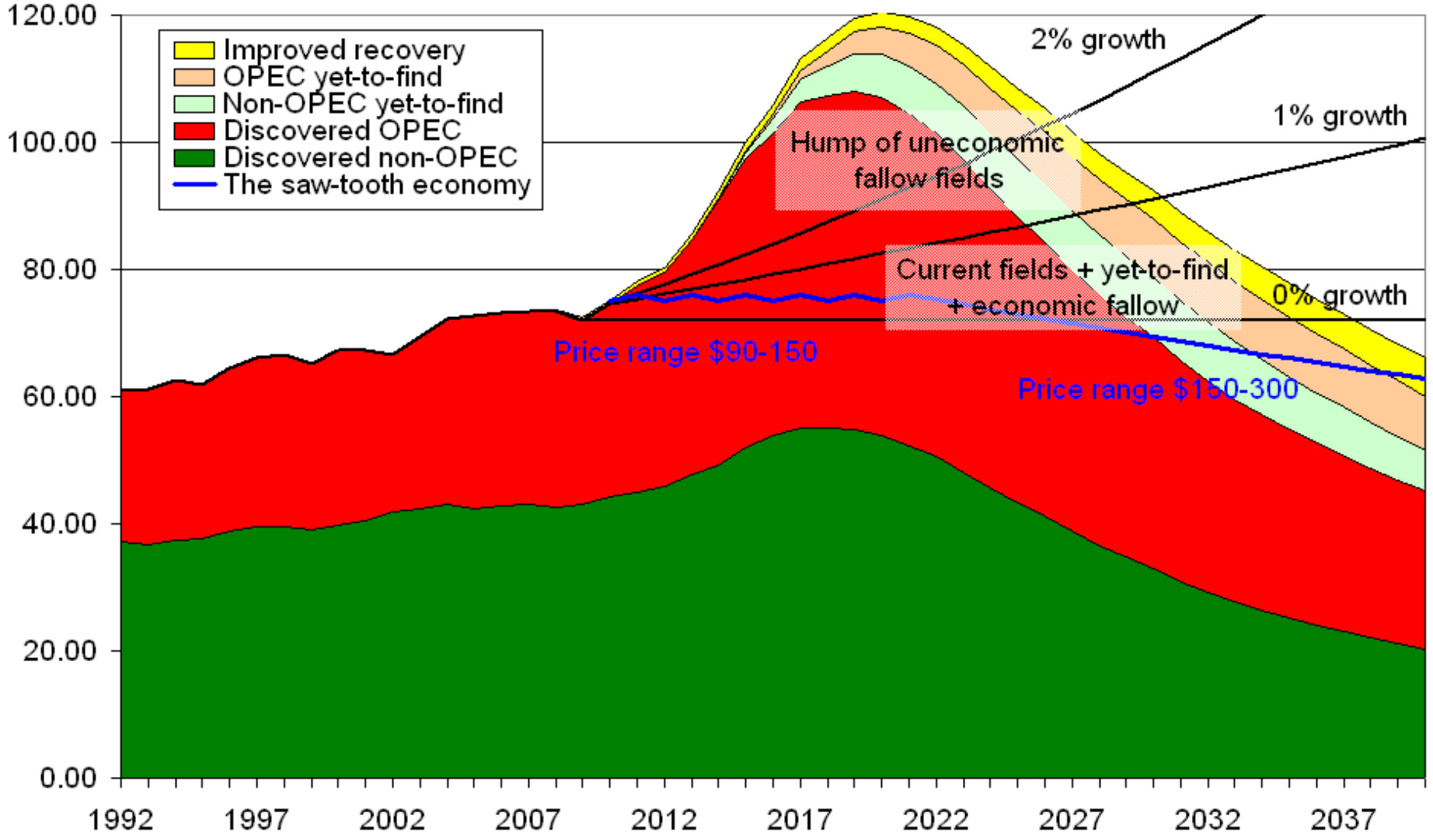


- Fallow fields are probably uneconomic
- Declared projects: expect delays
- YTF is estimate
- Clair and Schiehallion may give brief respite

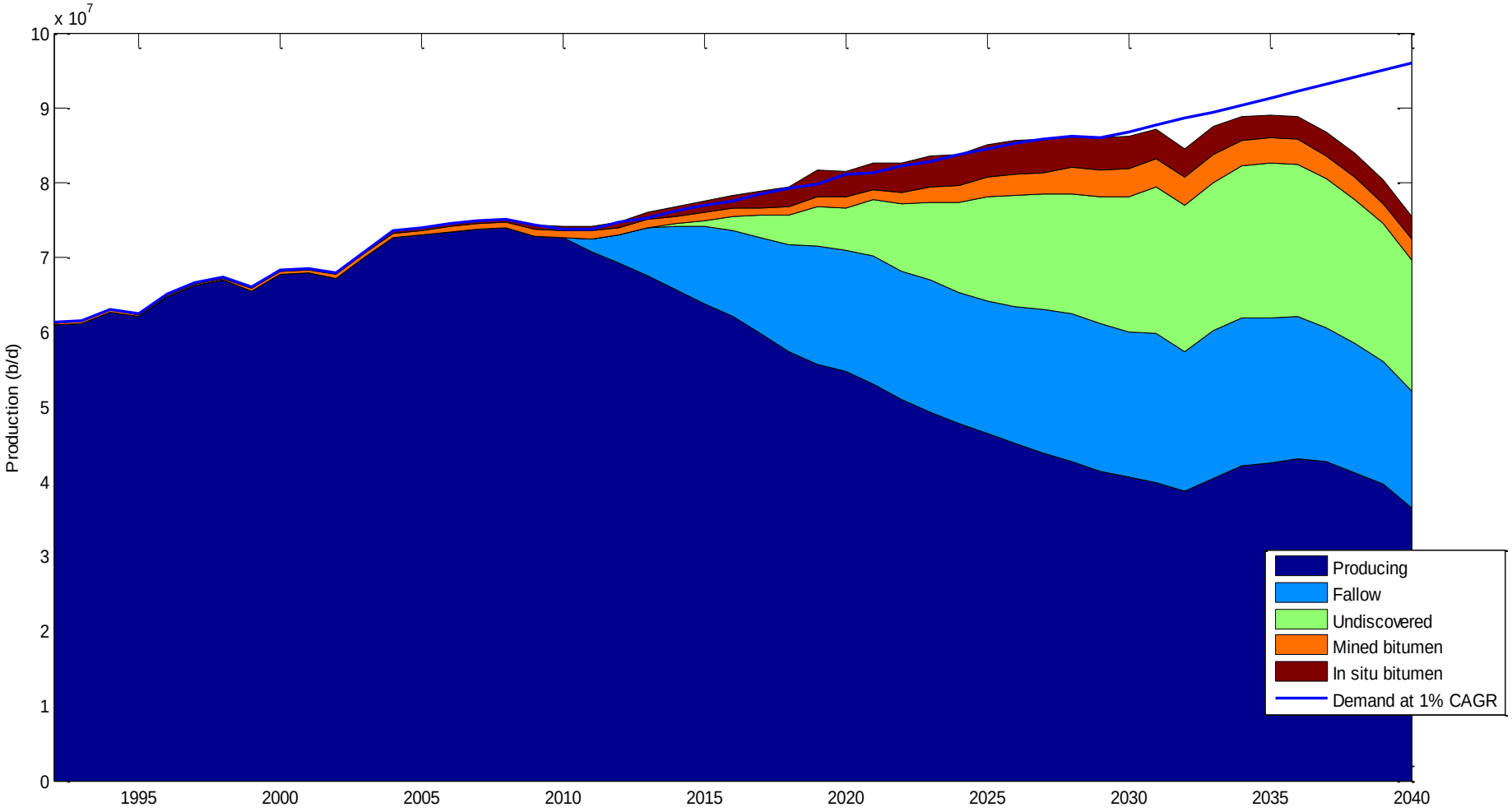
Key all-oil risks and projections to 2040.

Oil sands reach 9.5 Mb/d. "Saw-tooth" and prices are concepts, not projections.

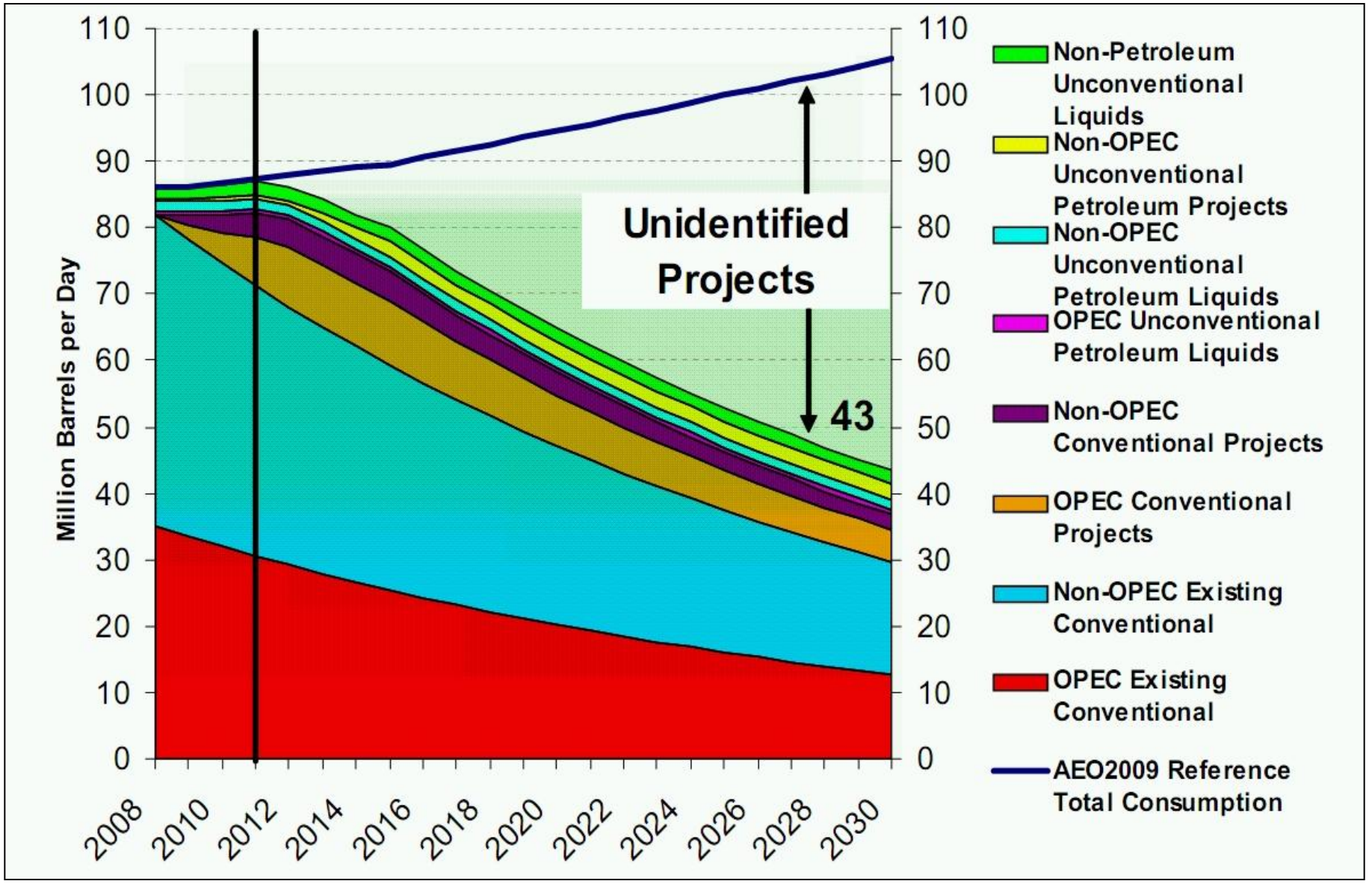
Source: R. Miller



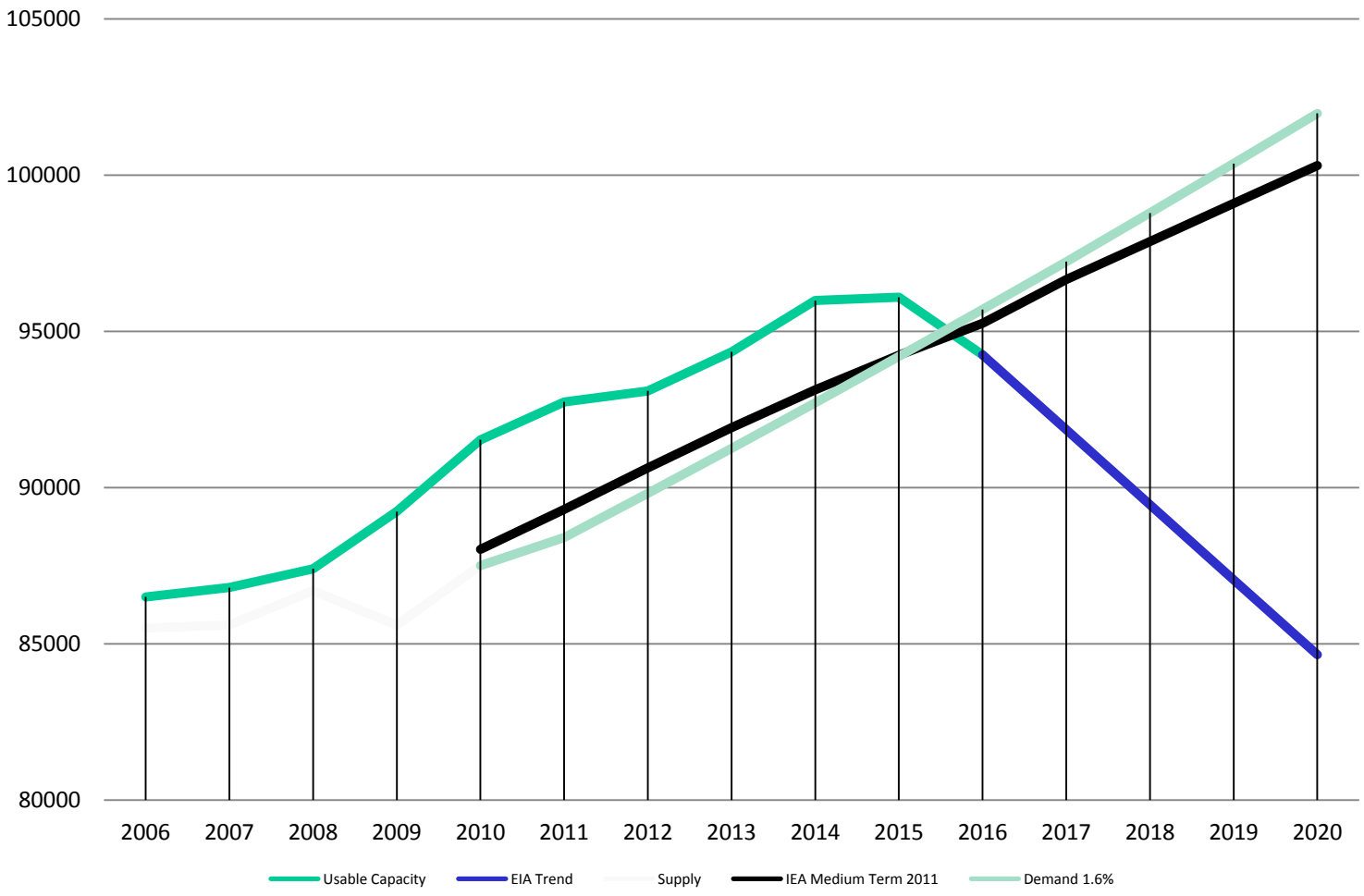
Growth at 1% CAGR Source: Miller & McGlade



The future supply challenge Source: Peak Oil Consulting



Supply and Demand to 2020 Source: Peak Oil Consulting



UKERC *Global Oil Depletion* report, Oct. 2009.

UK Energy Research Centre
- Technology and Policy Assessment report.

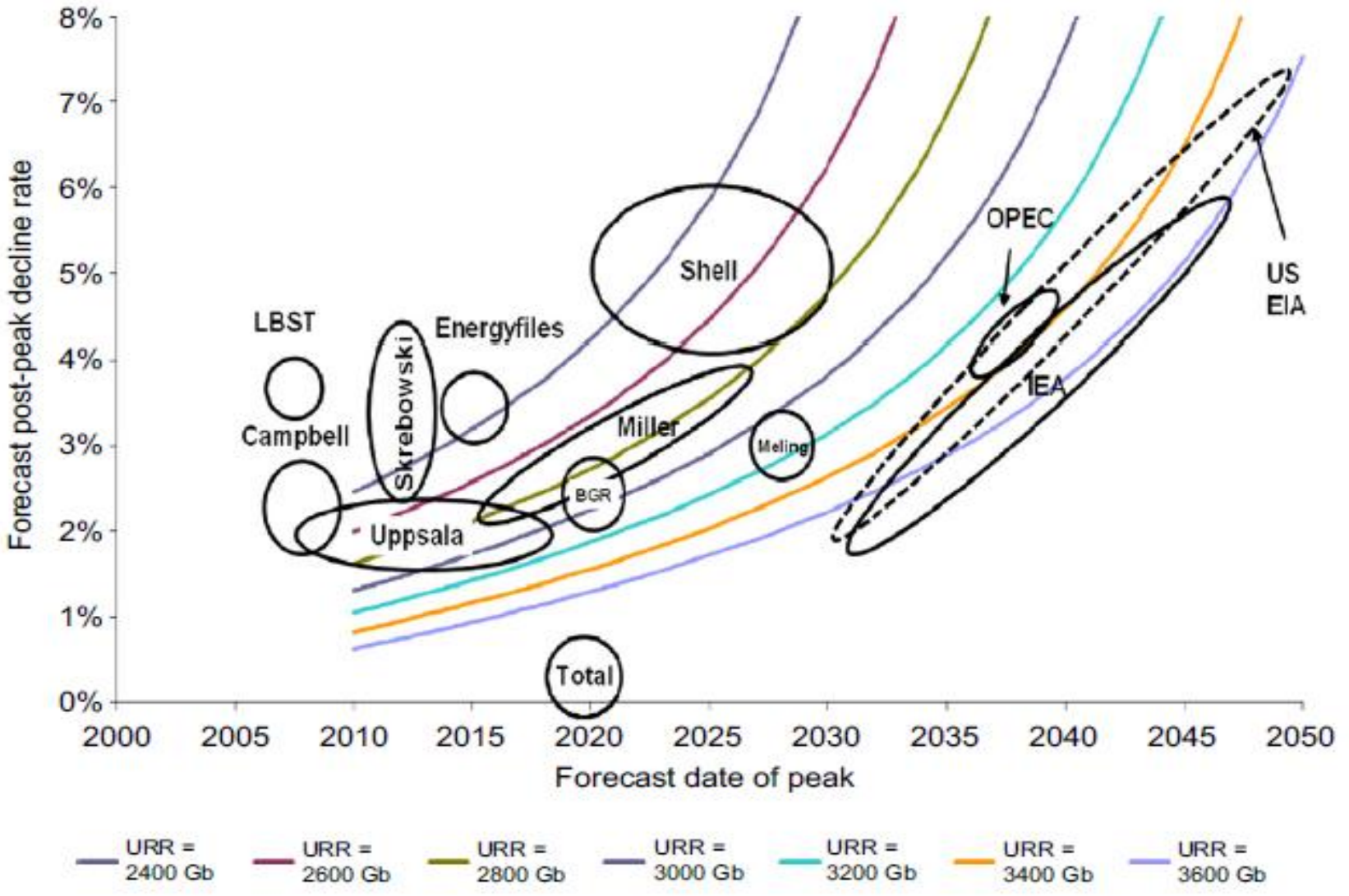
Authors: Steve Sorrell, Jamie Speirs, Adam Brandt, Richard Miller, Roger Bentley.

"What evidence is there to support the proposition that global demand for conventional oil will be constrained by physical depletion before 2030?" *

**Conventional oil:* crude oil, condensate and natural gas liquids (NGLs)

Comparison of Oil Forecasts – The 'Miller' plot

Date of peak vs. post-peak decline and ult. recoverable resource



UKERC Report: Main Finding

- A global peak is likely before 2030 and there is a significant risk of a peak before 2020.

8. Views of DTI, BERR, DECC

The University of Reading 'Oil Group' *variously told that:*

- "**Oil is not important to the UK economy -** it takes a declining share of the energy mix, and now represents only a small percentage of the UK's GDP. "
- "Not likely to be problem, but even if there were a risk, then **the market is the best solution**."
- "**The IEA's 'Resources into Reserves' report** discounts any medium-term supply problem: there are more than enough conventional oil resources for well over 40 years of world supply."

More recently BERR said:

- "**The world has just found a giant field – Tupi;** implying that oil peaking calculations are unduly pessimistic."

9. Conclusions on Peak Oil

- Cheap conventional oil has almost certainly peaked, (as forecast in Campbell/Laherrère 'The End of Cheap Oil', Sci. Am., Mar. '98).
- A world economy with indebted governments and highly-leveraged institutions is fragile vs. increases in energy cost.
- But 'all-oil', incl. shale oil, oil shale, GTLs, CTLs and biofuels (and provided price stays high, and above-ground constraints stay moderate) can yield a great deal of oil. (Forecasts from Smith, Miller, etc. put the 'unconstrained all-oil' peak close to 2030; tho' such production is unlikely due to cost, price impact on demand, politics, & other factors.)

Conclusions contd.

We are now therefore in an uncomfortable, risky, oil world:

- prices will be volatile, and high on average, further damaging economies;
- net energy returns are falling;
- the decline in pre-peak suppliers increases above-ground risk.

Had we heeded the forecasts of the conventional oil peak we could have been much better prepared.

10. What to do?

Some actions:

a). Modelling

b). Demand reduction / Alternatives

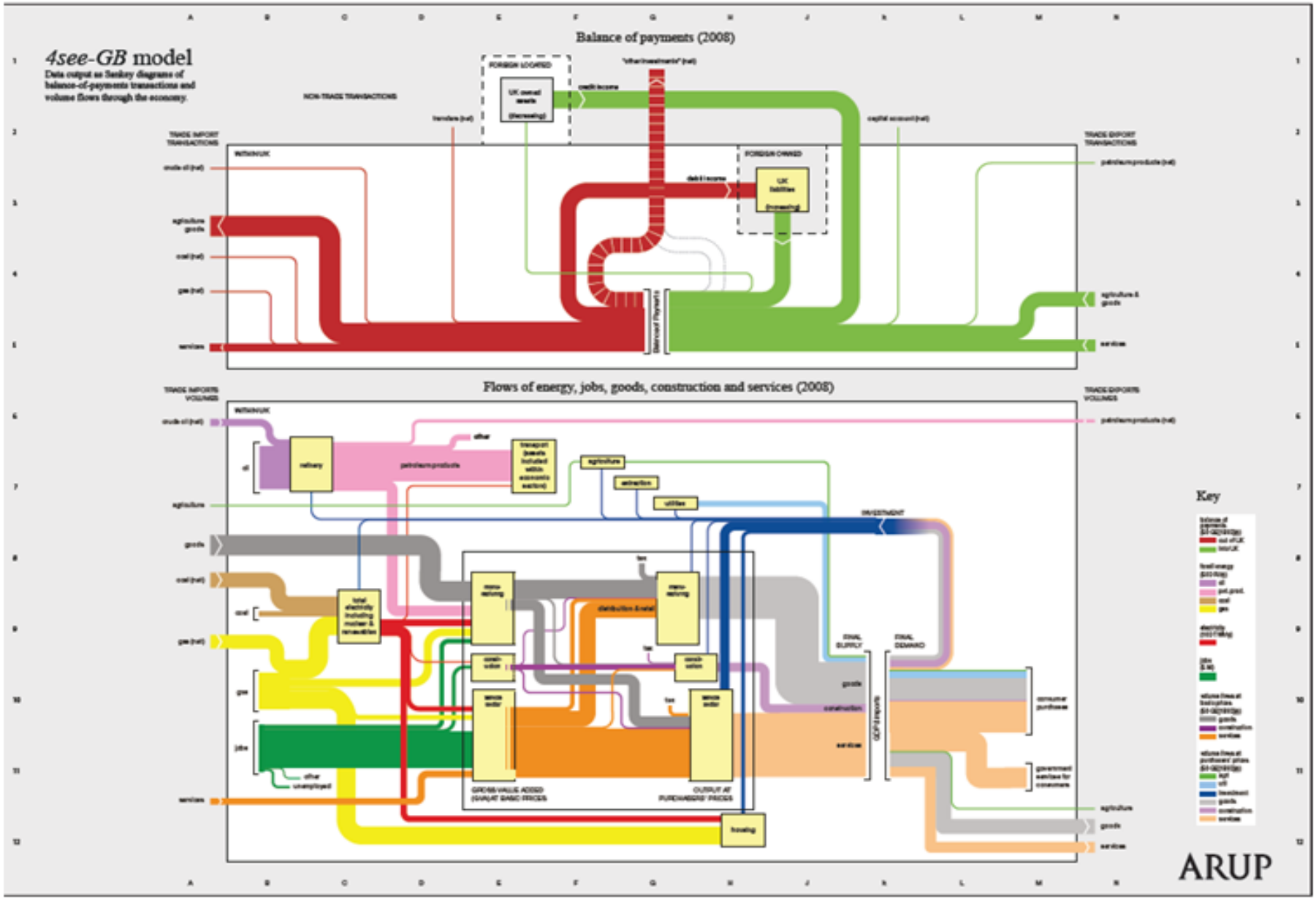
c). Beware carbon emissions

Actions: a). Modelling

The main question we need to ask:

- *Given the fossil fuel global production-rate limits (of oil and gas, and probably coal), and the danger of rapid climate change, are we faced with societal collapse, or can we transition smoothly to the sunny uplands of renewable energy?*
- No-one, as far as I know, is modelling this correctly.
- It would seem useful to have an answer.

Modelling: Arup's *'4see' energy / economy model*



Actions: b). Demand Reduction / Alternatives - R. Mayer:

Reducing mismatch between demand and supply

Recover energy from drive lines that is currently wasted, such as:

- Inertial energy of vehicles when braking
- Inertial energy of shipping containers when lowered by RTG cranes

Vehicle Efficiency EU standards, etc.

Identify applications where oil can be substituted by other fuels, such as:

- Oil heating by ground-source heat pumps
- Oil electricity generation by renewable energy sources
- Diesel/petrol drive lines by electric drive lines in vehicles (rail & road)

Use energy storage to smooth mismatch between demand and supply so enabling prime mover to be downsized

Demand Reduction contd. *Transforming the market for oil saving & non-oil products*

Market transformation process

- Establish the benefits and costs through publically funded demonstrations
- Provide incentives for change
- Inform and educate the public

(Example: Switch to lead-free petrol (1983 to 1993)

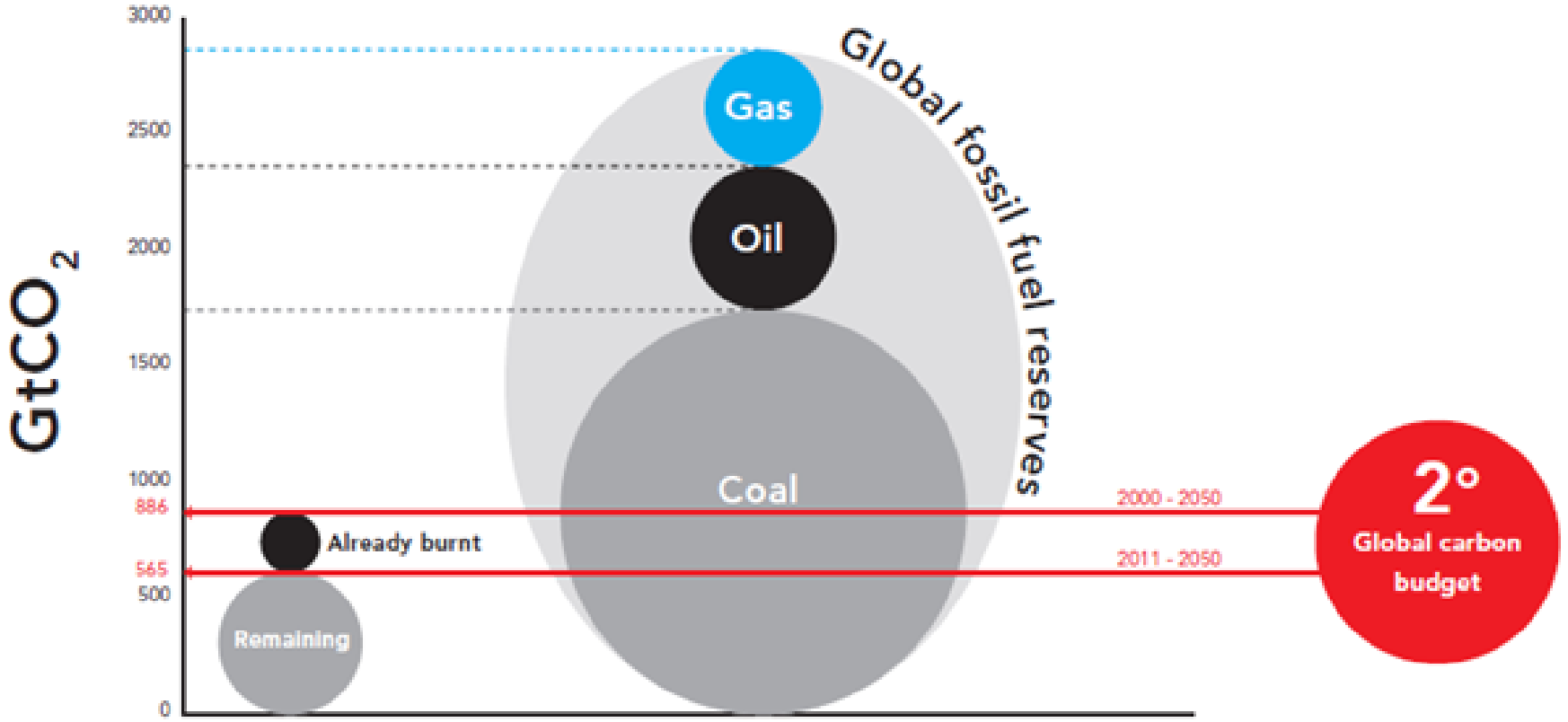
- Gained acceptance of motor industry
- Introduced an incentive of 5p reduction per gallon in lead-free
- Educated all school children in the dangers of leaded petrol and what parents needed to do to switch to lead-free petrol
- Sustained campaign to inform public via press and TV over a 10 year time period)

Actions: c). Beware carbon emissions of alternatives

J. Leggett: *Unburnable carbon*

Comparison of the global 2°C carbon budget with fossil fuel reserves CO_2 emissions potential

Fig.1



Thank you for your attention