The Future of Oil

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Conventional and Heavy Oil…

- Conventional – viscosity less than 50 cP
- Heavy oil 50 – 10,000 cP *in situ*
- Bitumen >10,000 cP
- Non-conventional resources were ignored in oil reserves estimates
- This is now changing… However!
  - "Reserves" is a tricky concept
  - Technology is moving quickly
  - Bankers and Stock Markets are conservative

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Argentina…

- A "mature" oil province
- 780,000 bbl/day (2004)
- Because of depletion, increases in conventional oil production unlikely
- How much heavy oil (>50 cP) is in Argentina?
- How much natural gas?
- These are critical issues

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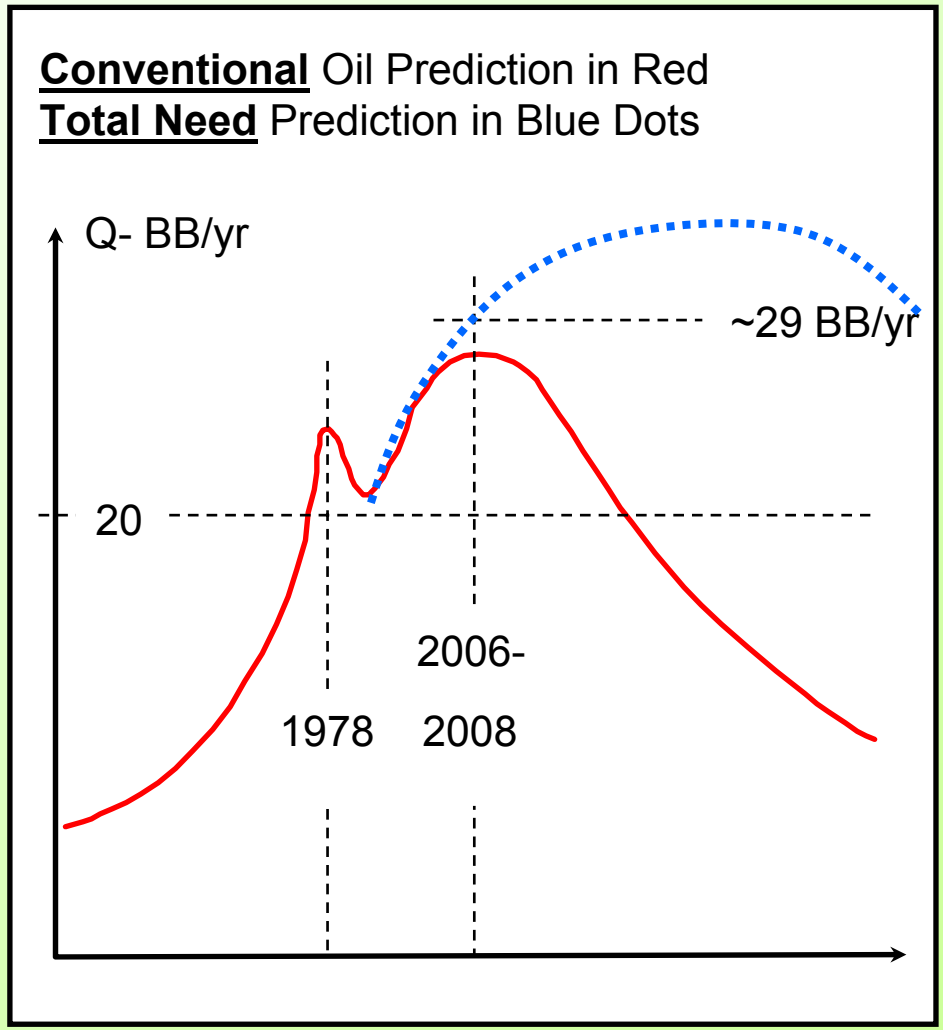
Future of **Conventional** Oil

- Predictions:
  - Demand +1.5-2%/yr
  - World production peaks in ~2006
  - Middle East >45%, >50% by 2015(?)
- Field depletion is about 3% per year
- A ~5% replenish-ment rate needed



Modified; red line from Campbell and Laherrère March Sci Am, 1998, p78

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What is the Issue?

- People are consuming more **energy**
- Countries want to develop (China, India…), increasing world demand significantly
- Developed countries are slowly consuming more and more energy, but…
- Energy intensity is decreasing (good!)
- Population growth is stabilizing (good!)
- Traditional pollution is abating (good!)
- This leaves CO_2 as the "new evil"

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Will the Oil Industry Change?

- The future of conventional oil…?
- Other potential fossil fuel resources: oil sands, shale oil, coal, hydrates…?
- Can we "see" the future at present?
- What does this mean for all of us?
- Is a strategic assessment needed?
- Should nations make technological investments in heavy oil?
- Kyoto implications?

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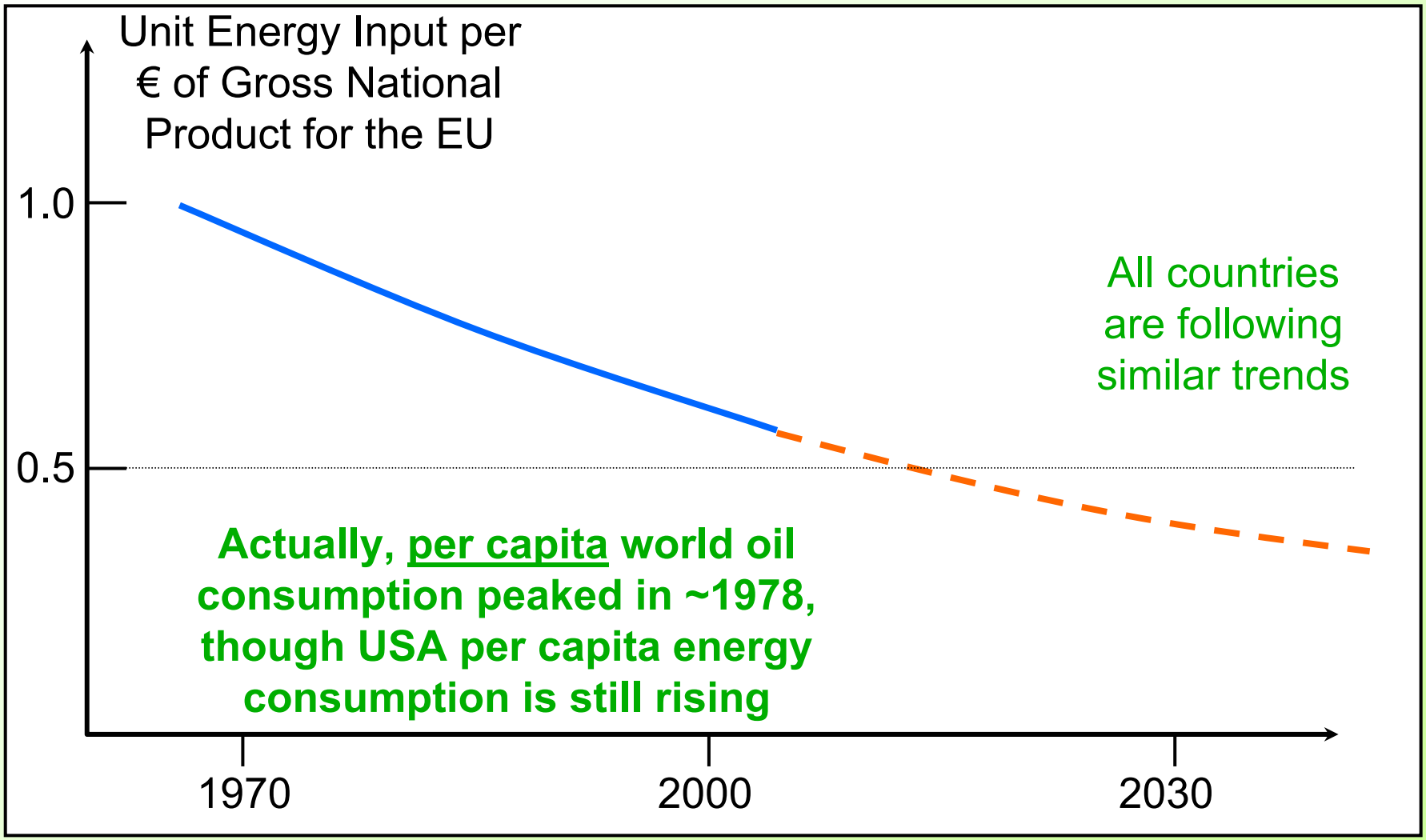
Energy Utilization Efficiency



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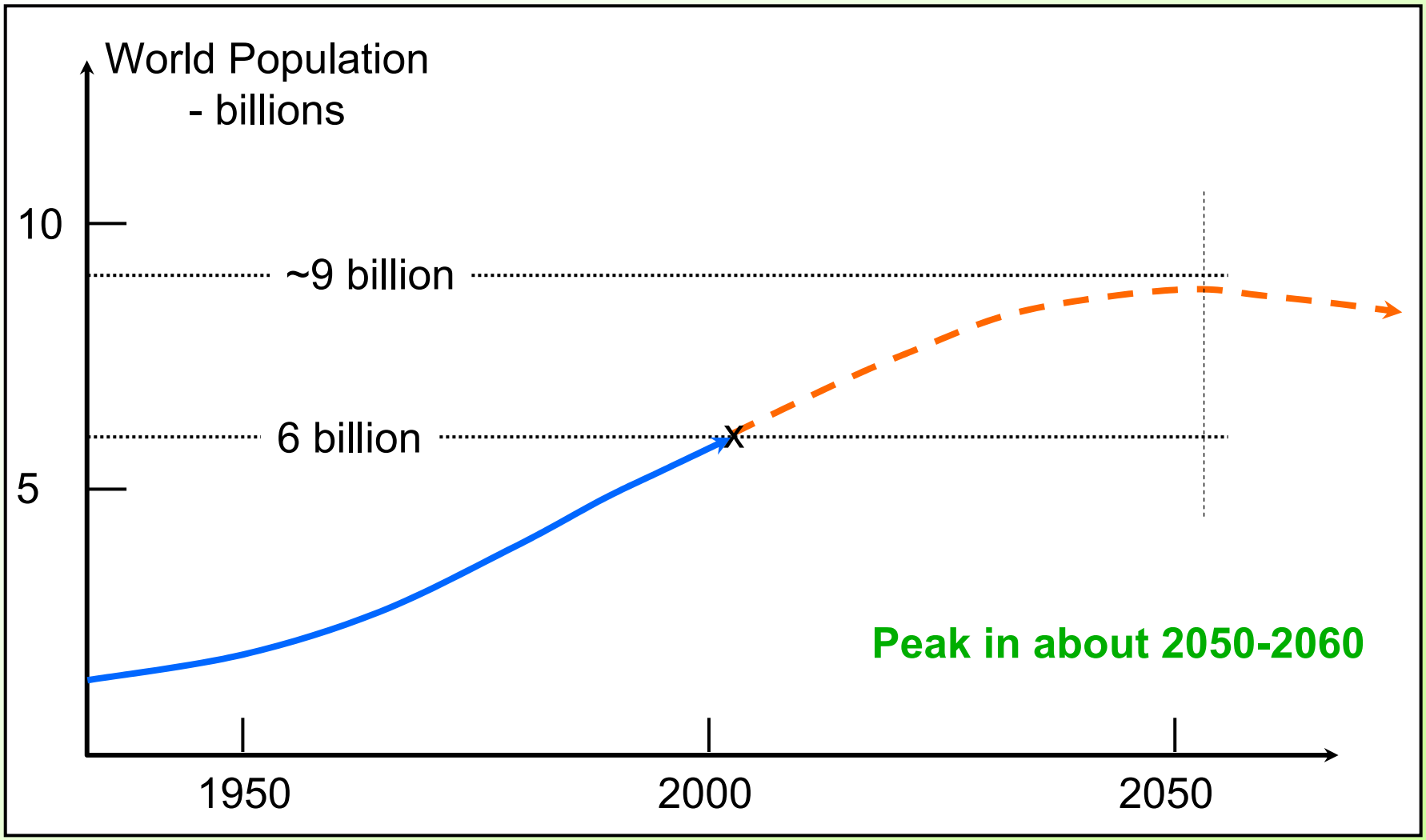
World Population Growth



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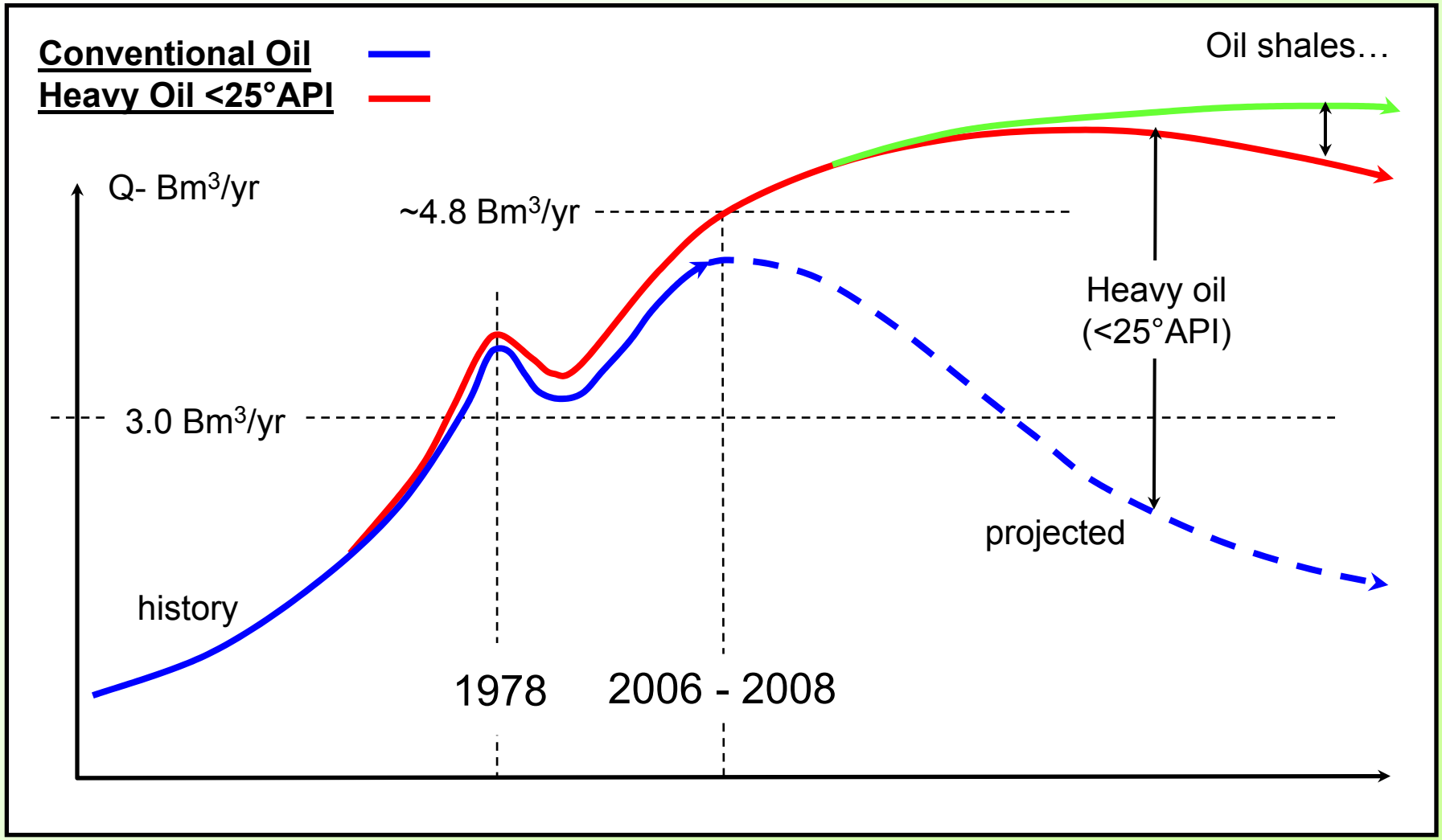
World Oil Consumption



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Some Facts…

- World consumption ~30 B bbl/yr
- Transportation > 80% of oil consumption
- World peak discoveries era ~1970's
- Conventional is ~95% of all oil "used" to date (i.e. over the last 120 years)
- Viscous oil now > 12% of world's oil supply
- "Rest of World" peaked in conventional oil production in 1996-1997, World in 2006?
- Natural gas will peak later (peak in 2020?)
- Middle East dominates exports till 2040

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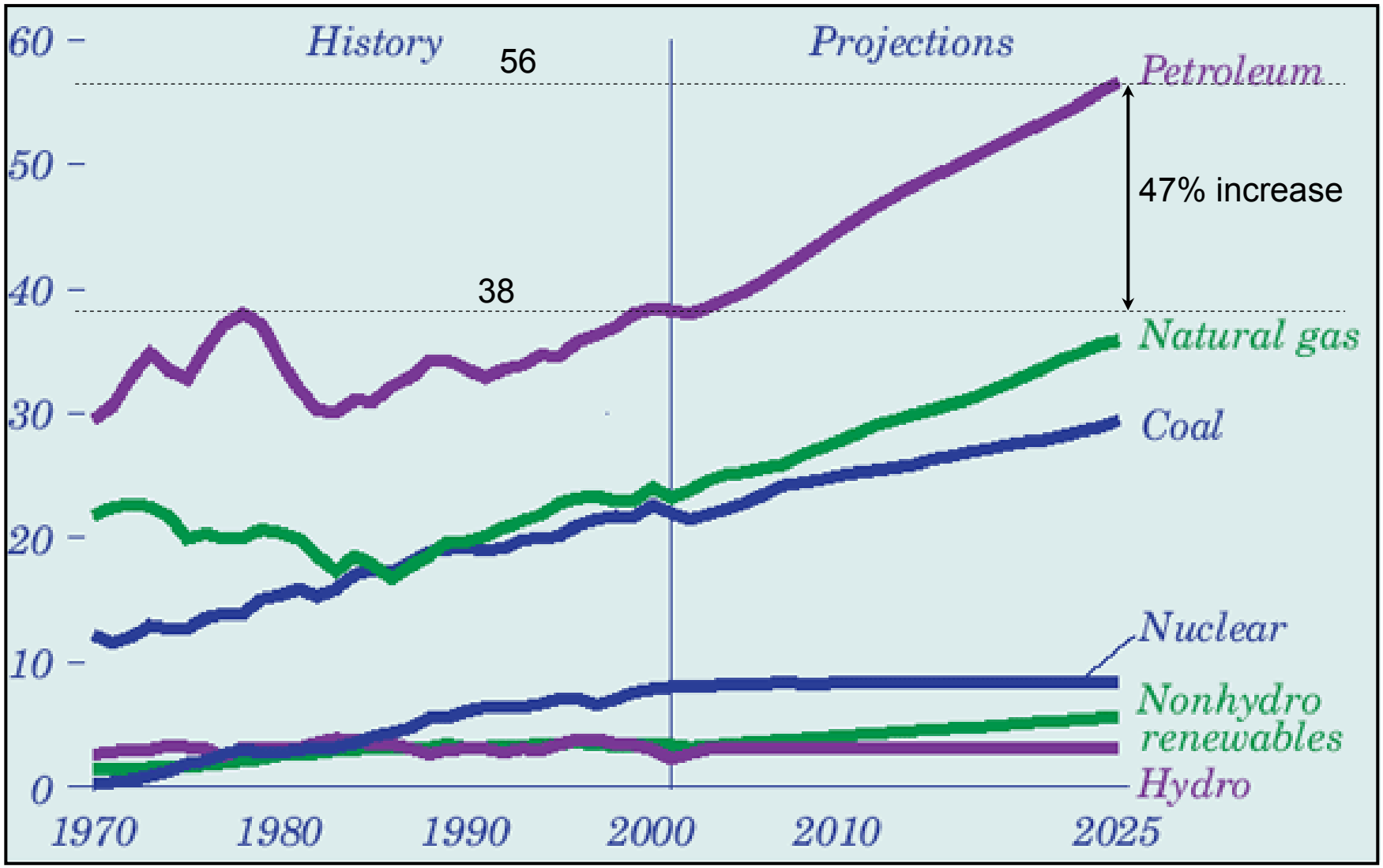
Lets Look at the US

- US: the world's largest energy consumer
  - → 2nd largest per capita (Canada is #1)
- US: the world's dominant economic force
- US consumes ~26% of world oil
- US population is increasing at a good pace, but Europe's is now declining slowly
- US GDP growth rate is ~2.8% vs ~ 7% for China, India…
- US has the most "mature" oil production

Figure 2. Energy consumption by fuel, 1970-2025 (quadrillion Btu)



Source: http://www.eia.doe.gov/oiaf/aeo/index.html

For the USA

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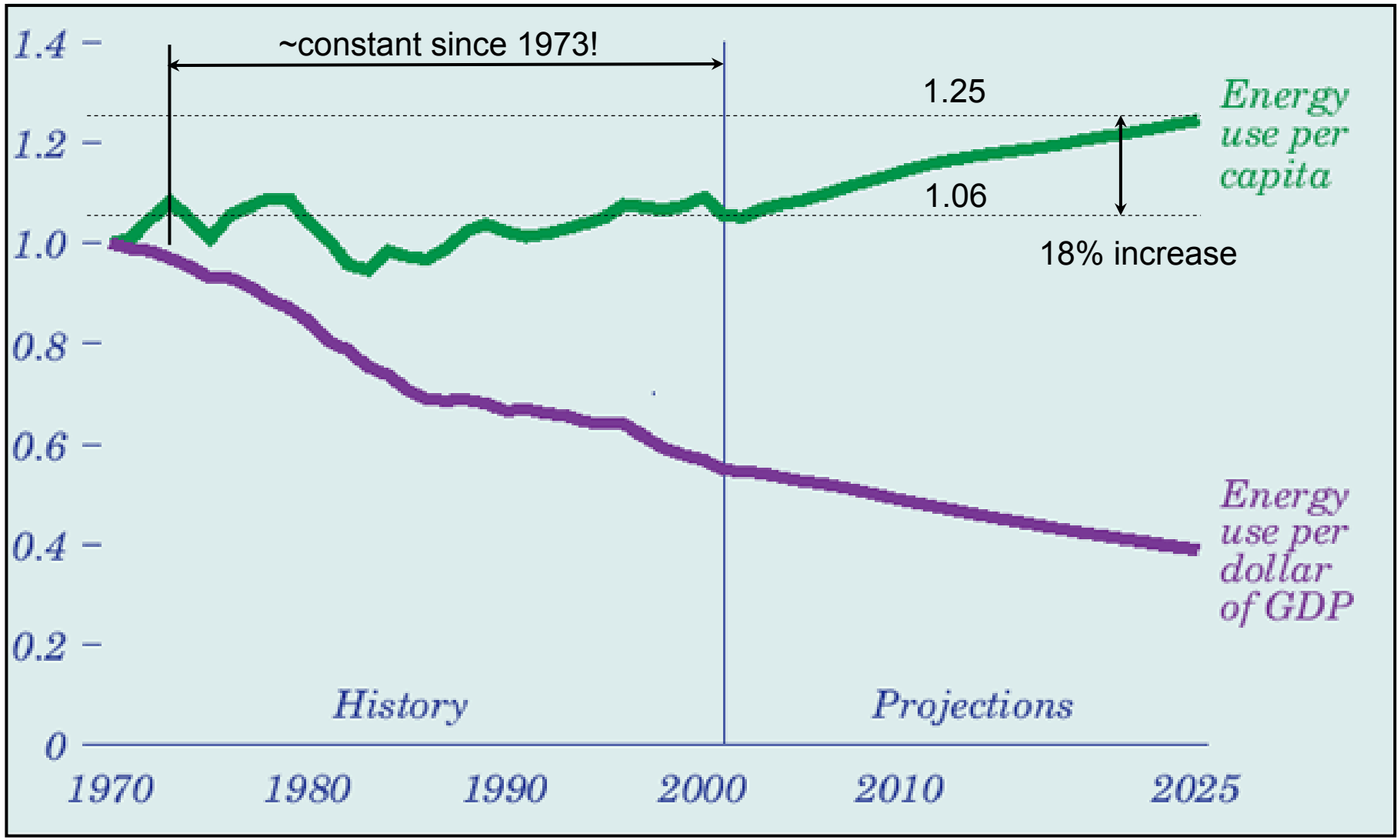
US Petroleum Use Growth

- Projected to rise by 47% between 2000 and 2025!
- Natural gas also will grow by >40%
- Much of this growth can be attributed to a continued population growth in USA, in contrast to almost all other western countries
- Many (including me) have said for years that this growth cannot be sustained

Figure 3. Energy use per capita and per dollar of gross domestic product, 1970-2025 (index, 1970 = 1)



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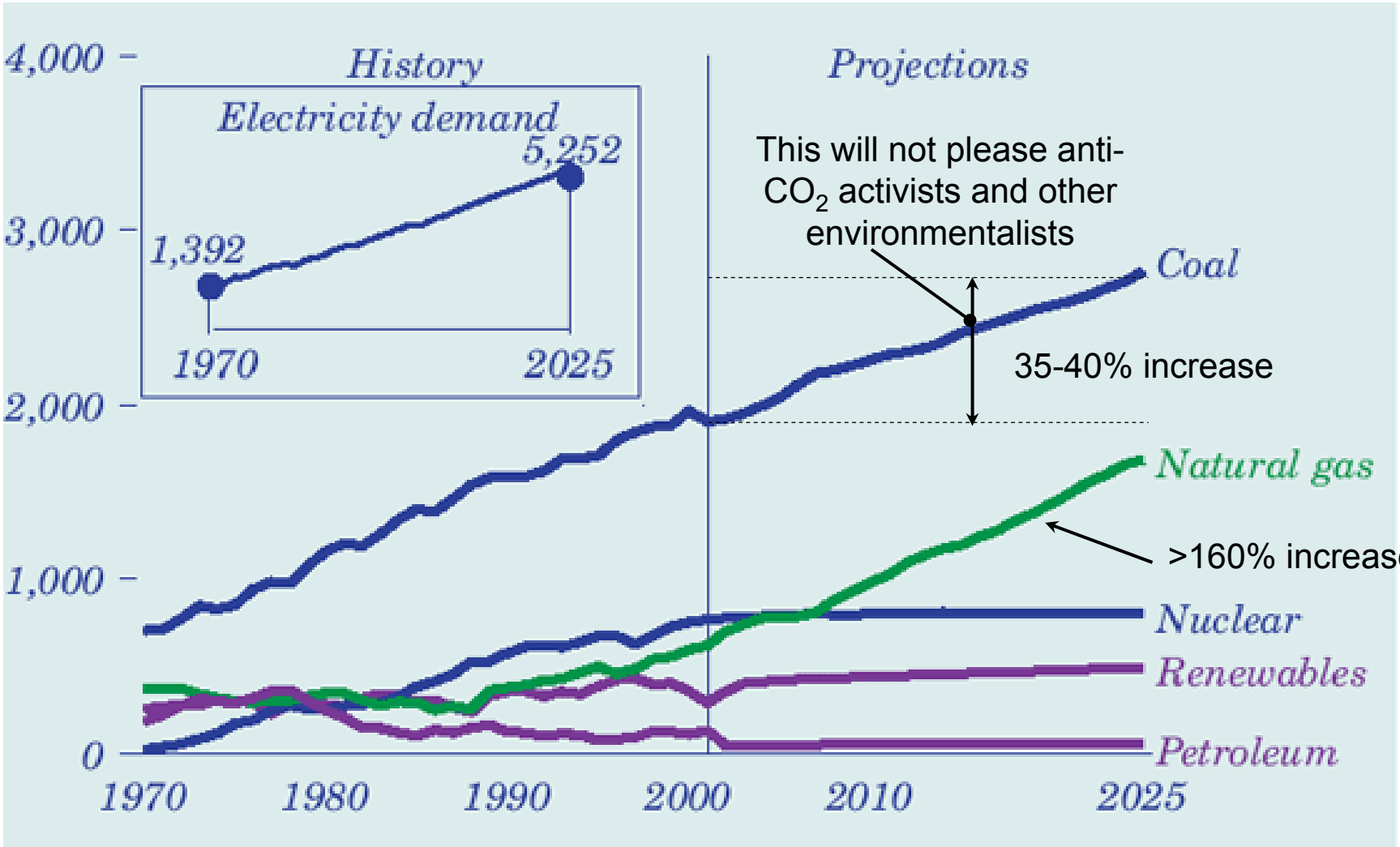
For the USA

Figure 4. Electricity generation by fuel, 1970-2025 (billion kilowatthours)



Source: http://www.eia.doe.gov/oiaf/aeo/index.html

For the USA

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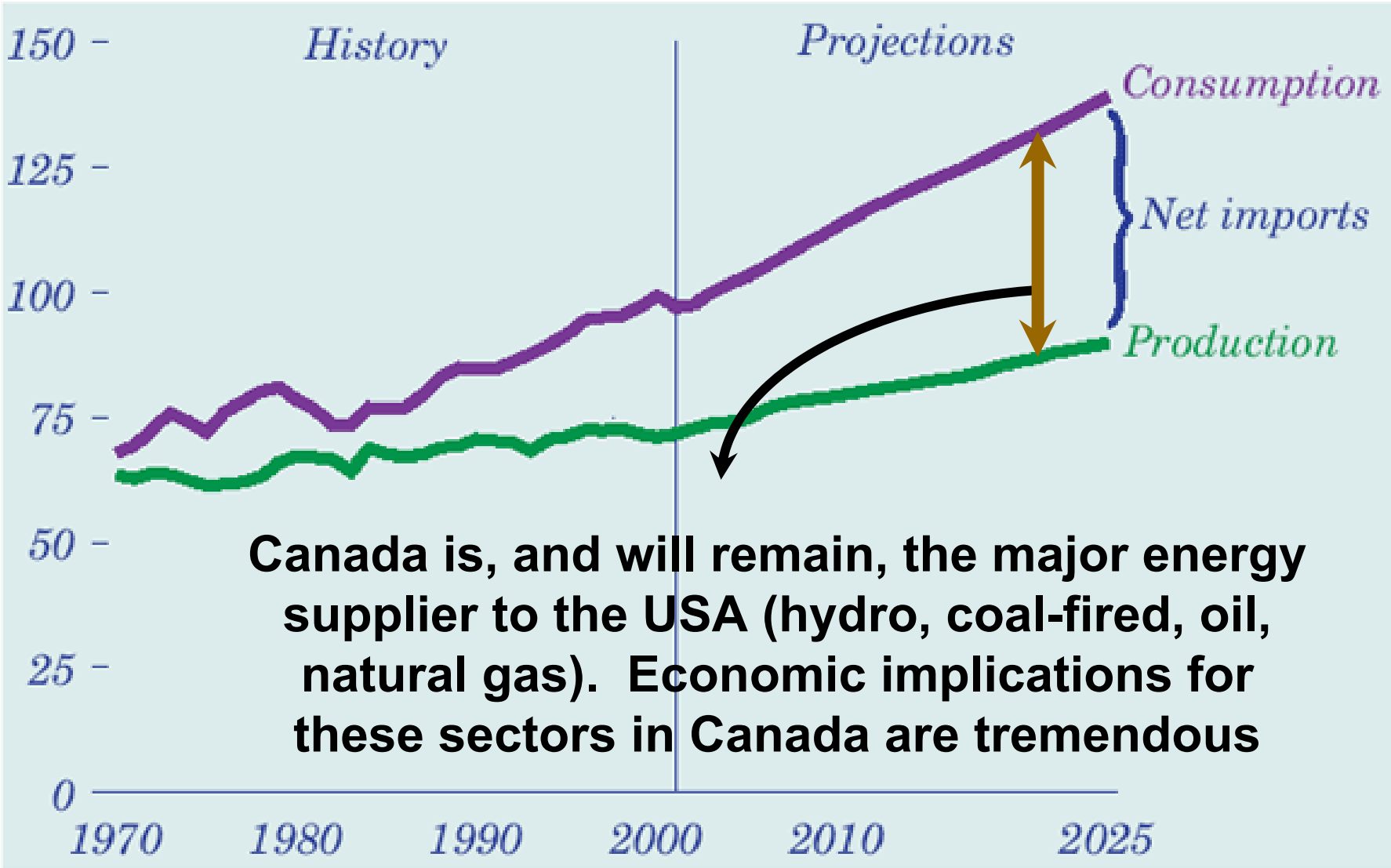
Electricity Generation Comments

- Natural gas generation is peaking!
  - NA gas production (Can and US) now flat
  - High prices are here to stay
  - New production (Arctic) on line only by 2009
  - Only option is massive LNG investments
- Coal consumption (CO_2 emissions!) set to rise by close to 40%!
- I don't believe gas use will rise so much
- I also don't think nuclear will remain flat

Figure 5. Total energy production and consumption, 1970-2025 (quadrillion Btu)

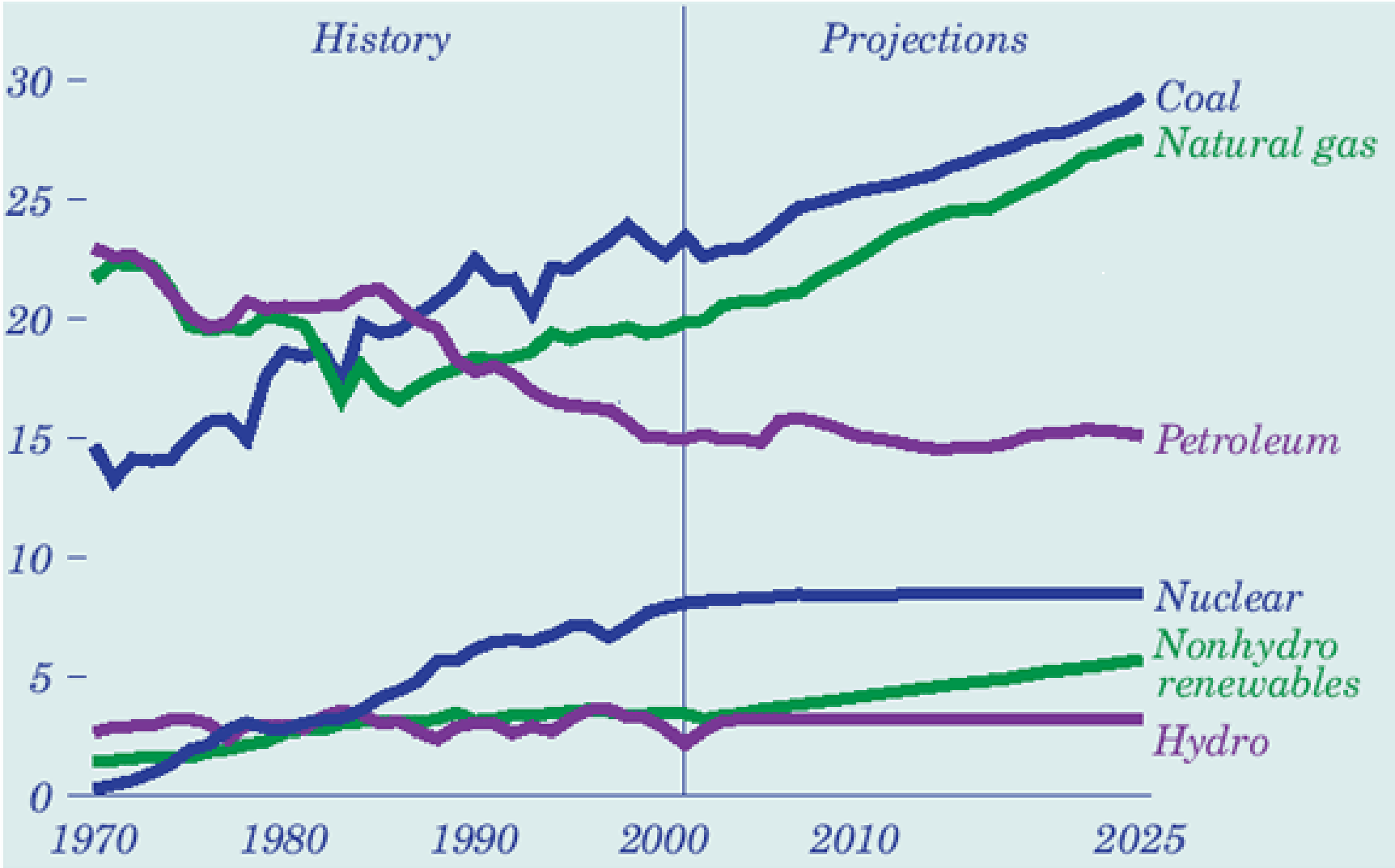


Canada is, and will remain, the major energy supplier to the USA (hydro, coal-fired, oil, natural gas). Economic implications for these sectors in Canada are tremendous

Source: http://www.eia.doe.gov/oiaf/aeo/index.html

For the USA

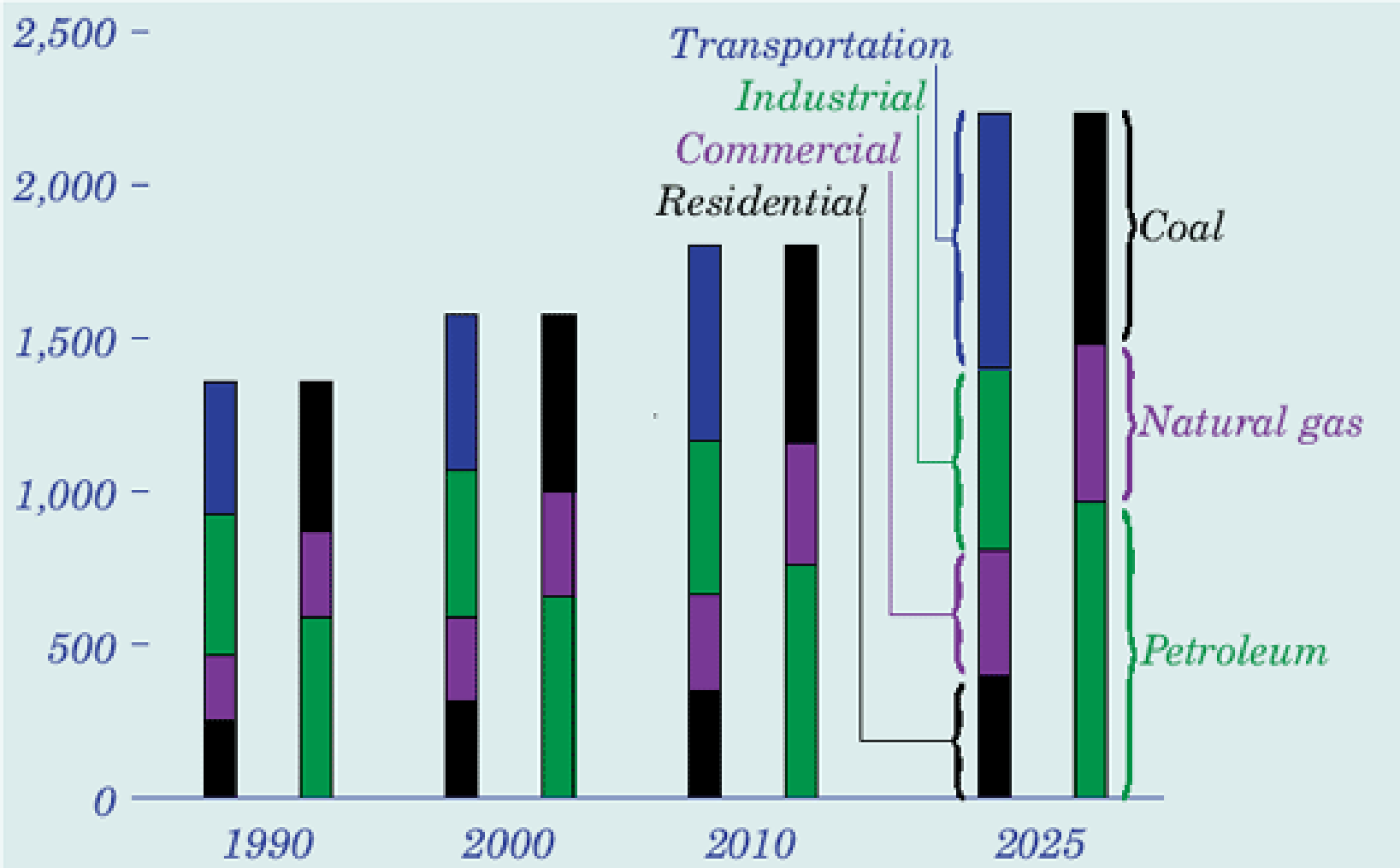
Figure 6. Energy production by fuel, 1970-2025 (quadrillion Btu)



Source: http://www.eia.doe.gov/oiaf/aeo/index.html

For the USA

Figure 7. Projected U.S. carbon dioxide emissions by sector and fuel, 1990-2025 (million metric tons carbon equivalent)



For the USA

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Comments on USA Projections

- Continued growth for oil in USA:
  - Based on population growth
  - Based on per capita GDP growth
- Role of nuclear power is underestimated
  - Nuclear is a carbon-free energy source
  - Technology is now far more advanced than '79
  - Geological waste disposal has proven feasible
- Gas growth predictions seem too high

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The Issues: Oil…

- What is the future for oil?
- What does this mean for us?
- What has been developed recently?
  - New production technologies (CHOPS, SAGD, PPT, VAPEX, hybrid schemes…)
  - New waste disposal practices
- What areas should companies watch?
  - Hybrid development schemes
  - Emerging production methods
  - Monitoring processes for optimization

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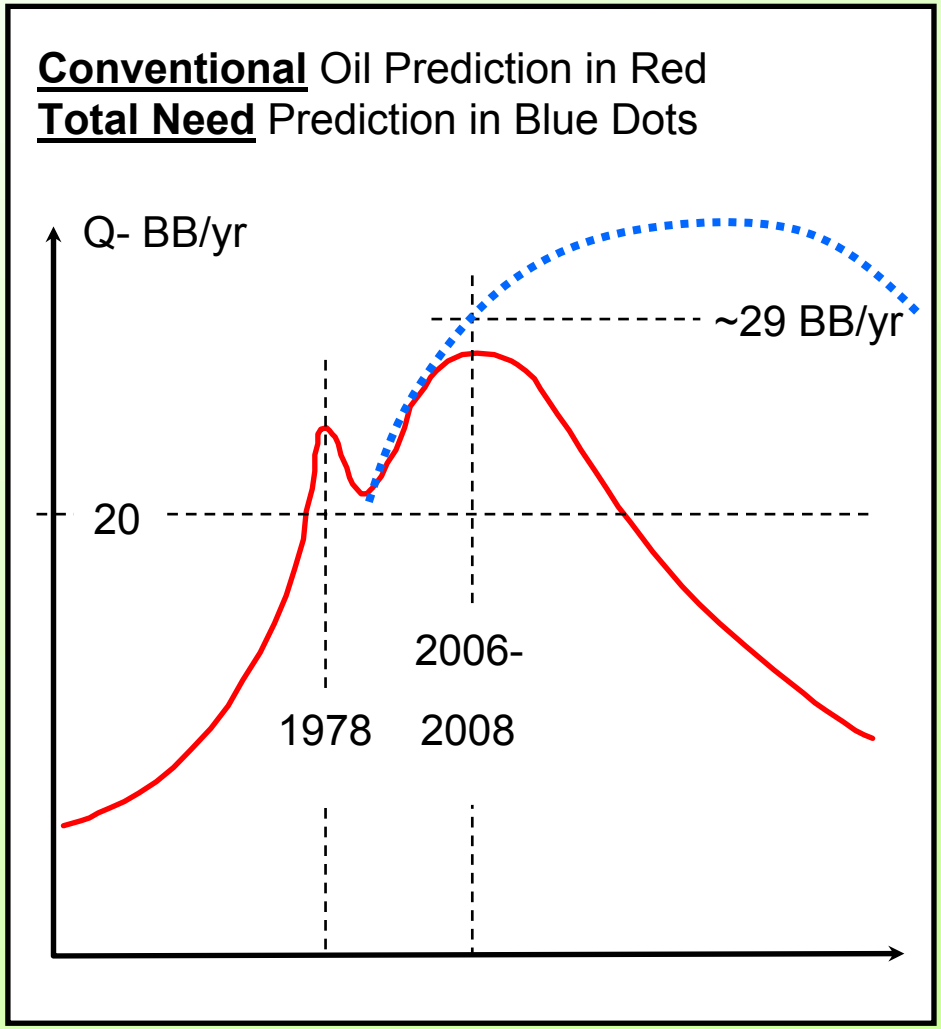
Future of Conventional Oil

- Predictions:
  - Demand +1.5-2%/yr
  - World production peaks in ~2006
  - Middle East @30%, 50% by 2010
- Cheap oil era may soon end (2006?)
- Heavy oil value ↑



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Future of the North Sea (S of 65°)

- A "mature" basin (not counting the Continental shelf up to Barents Sea)
  - No recent big discoveries > 200 MB
  - All fields on depletion curves
- North Sea was the last major basin discovered since 1970

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How is Petroleum Used?

- >80% is used as transportation fuel
- ~5-6% is used as petrochemical feedstock
- <10% is used as a fixed power source
- Other uses are minuscule…

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Oil = Transportation…

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Oil: Who Produces it?

Saudi	9.02
Russia	8.42
USA	7.80
Iran	3.96
Mexico	3.46
China	3.39
Norway	3.31
Canada	3.11
Venezuela	2.60
Nigeria	2.36
UAE	2.34
Kuwait	2.32…
…Argentina	0.78

- Canada is 8th
- However, growth in heavy oil and oil sands continues
- Where will other growth come from?
- Conventional is flat
- I believe that growth will mainly come from "technology" oil

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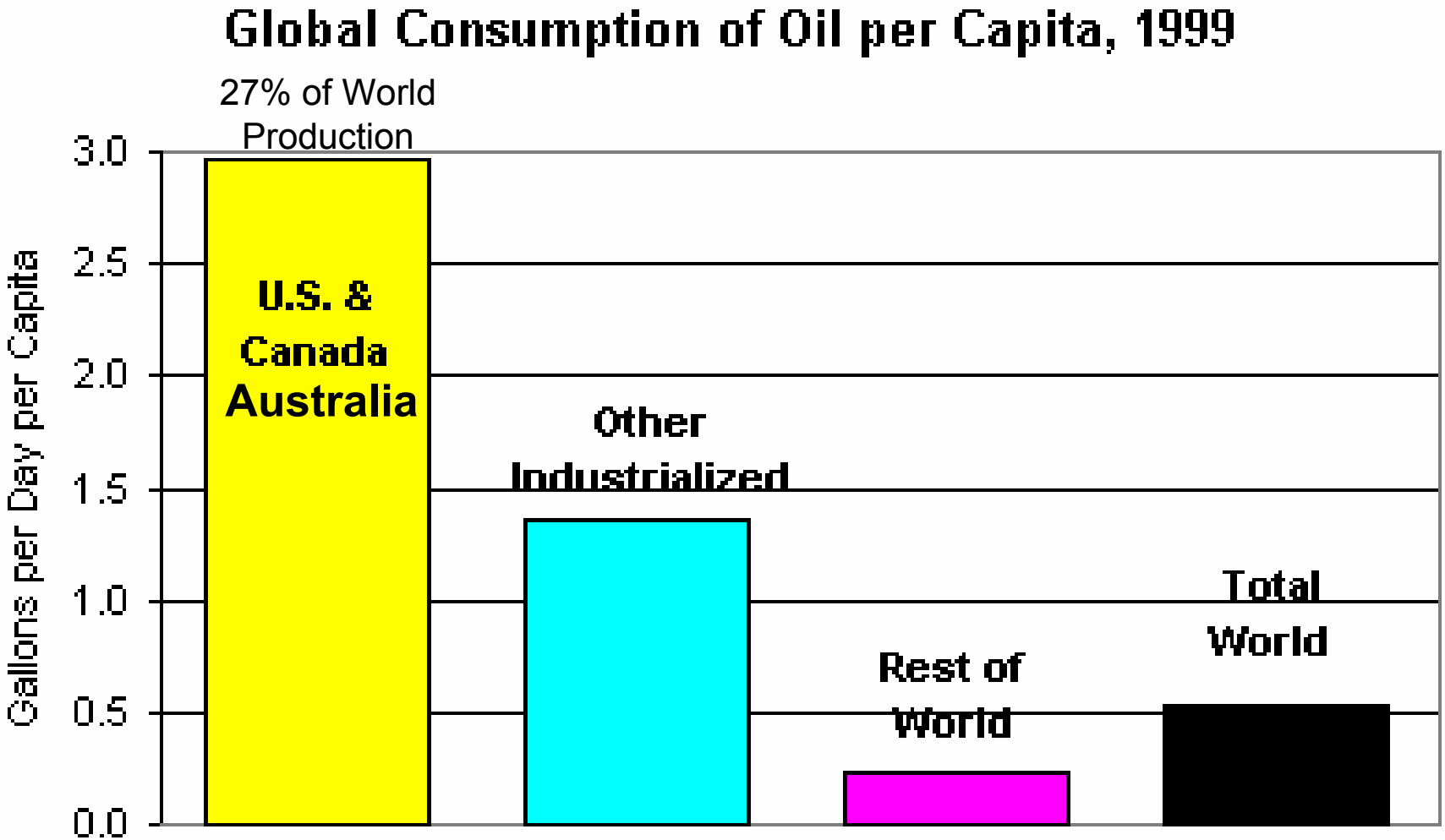
Who Consumes it??



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Who Exports it (2001 data)?

	Country	Exports (MMBOD)
1)	Saudi Arabia*	7.38
2)	Russia	4.76
3)	Norway	2.95
4)	Iran*	2.74
5)	Venezuela*	2.60
6)	United Arab Emirates*	2.09
7)	Nigeria*	2.00
8)	Iraq*	2.00
9)	Kuwait*	2.00
10)	Canada	2.00
11)	Mexico	1.70
12)	Libya and Algeria (each)	1.25

CANADA is actually number 10, all to the USA

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Taxes and Gasoline

- United States + ~40% of base price (×1.4)
- Canada + ~80% of base price
- Europe + ~200% of base price
- Norway, Britain… + ~250% of base price
- Iran, Venezuela, and many oil-rich countries sell gasoline for less than cost
- In other words, the price of a litre of gasoline is mainly a function of taxes
- True value of a litre is about US$0.50

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EU and USA (& Canada)

- Perhaps taxes, not supply, control prices!
- EU deplores low prices (i.e. taxes) in USA
  - Claiming they are more "green"
  - Actually, gasoline taxes are a great cash cow!
- USA has a long history of:
  - Low taxes, long distances, sprawling cities
  - A sudden change is not going to happen
- EU hoped "CO_2" would force USA to increase taxes, reduce price differences
- Don't count on it!

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What Controls Oil Future?

- There are two "schools of thought"…
  - Commodity economists (anti-depletionists)
  - Resource geologists (depletionists)
- These schools of thought are currently:
  - At complete odds with one another
  - Hold radically different world views
  - Now debating the "future of oil" publicly for the first time since the period 1973-1983
- However, it is possible to rationally reconcile and combine their views

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Both "Camps" Agree That…

- Fossil oil is a "fixed-volume resource", a peak and decline will eventually come
- Supplies of "easy-to-produce" and thus cheap fossil fuel oil are generally declining
- …
- However, even these two consensual views are deeply suspect, if not outright wrong.
- Let's try to understand why, where the "truth" lies, what lies are truth, and so on

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M. King Hubbert

- In 1956, MKH predicted 1970 peak oil production in the USA to within one year!
- In 1967, he predicted world peak ~2000
- Colin Campbell in 1996 predicted ~2005
- Ken Deffeyes in 2001 predicted ~2005
- Hubbert-based predictions have proven the most robust of all predictive methods
- USGS consistently overestimates OOIP
- I believe Hubbert-type predictions, but…!

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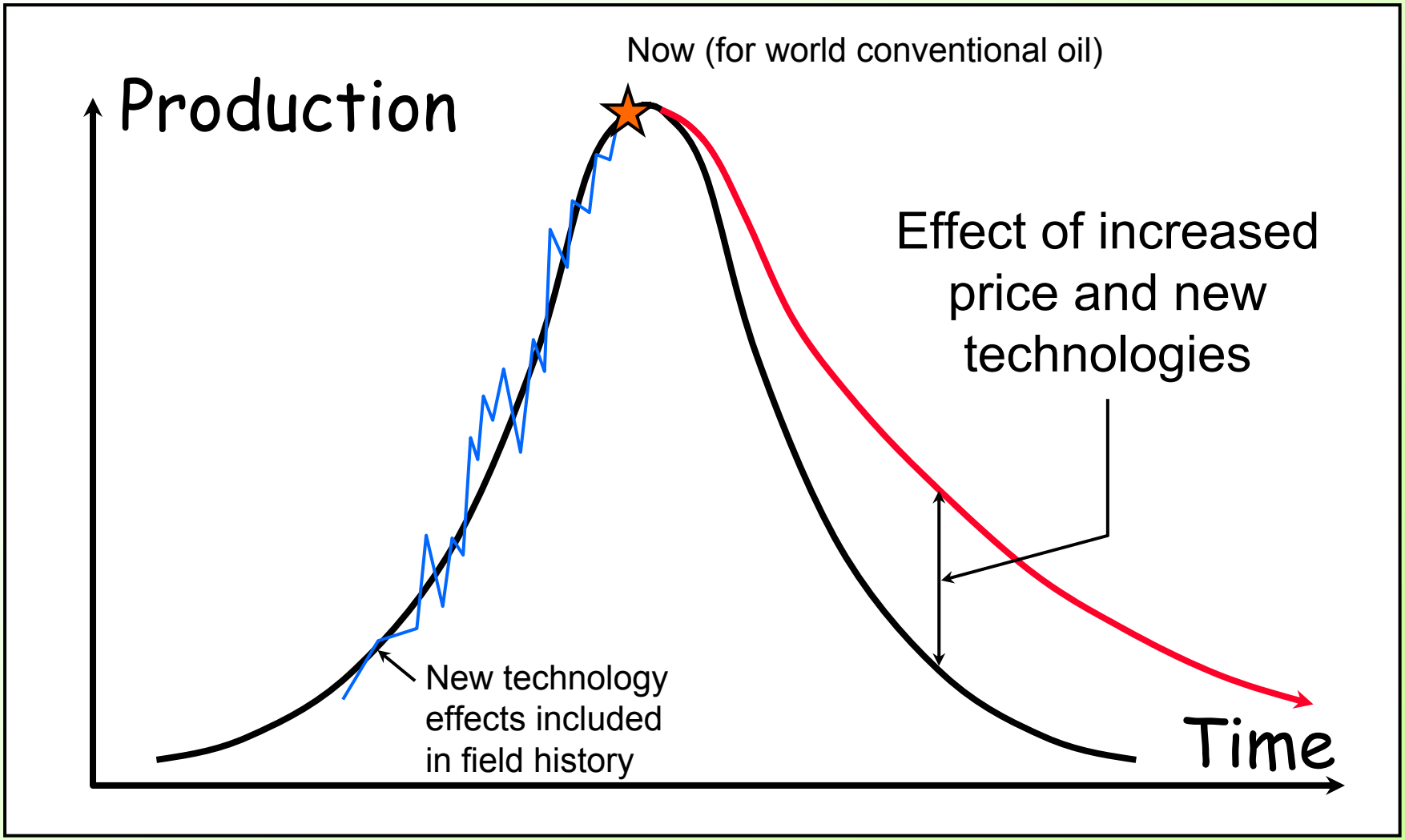
"Hubbert Curves"



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Hubbert Curve "Problems"

- Logistics curves apply to a single "fixed" resource (food, land, oil, gold…)
  - Critics say that oil is not a fixed resource
  - Is oil a true "commodity"? As is gold?
- Politics is assumed not to be an issue
  - Political interference changes curve shapes
- "All things being equal" is assumed
- It is seriously over-applied by proponents, without acknowledging its limitations

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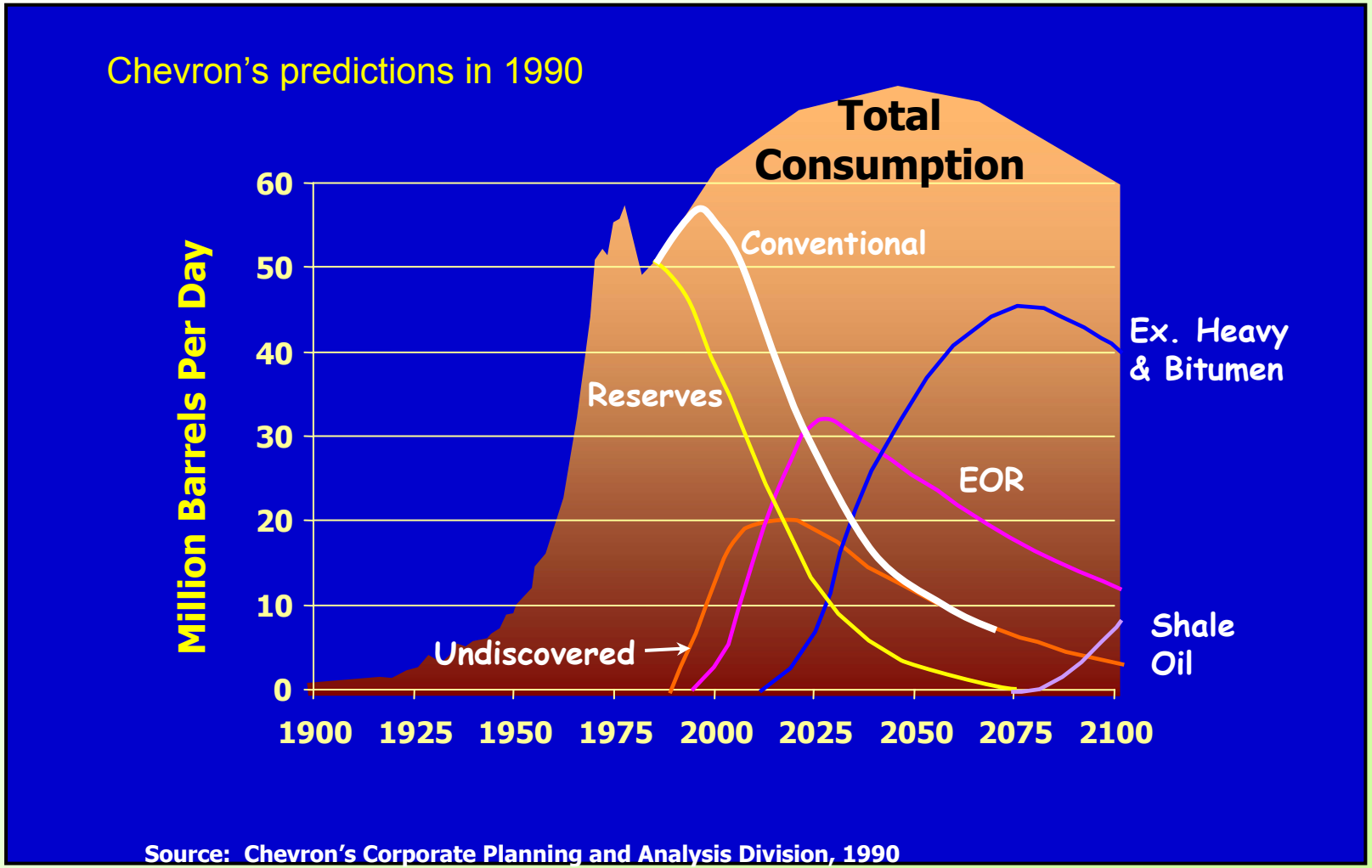
World Crude Oil Supply (1990)



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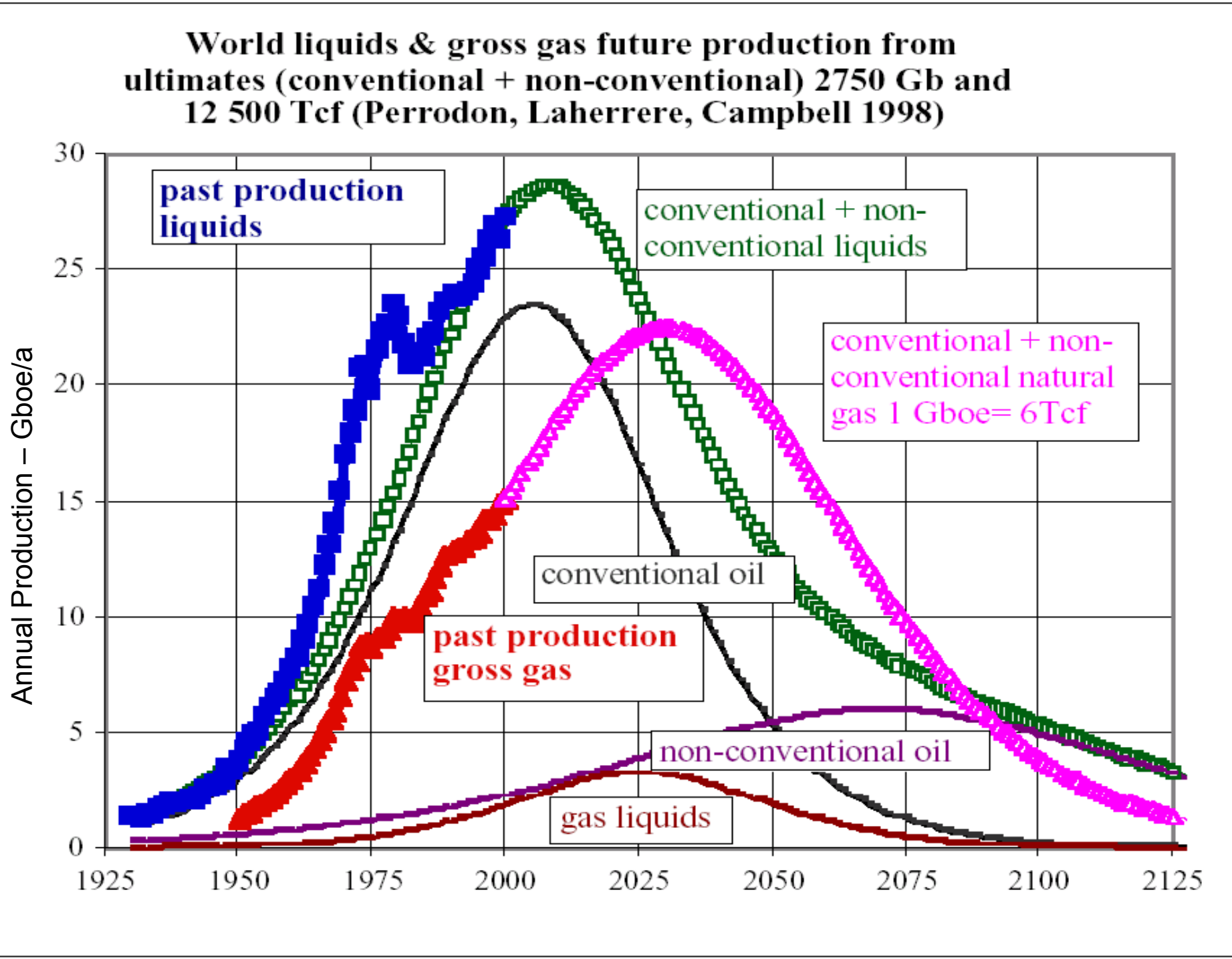
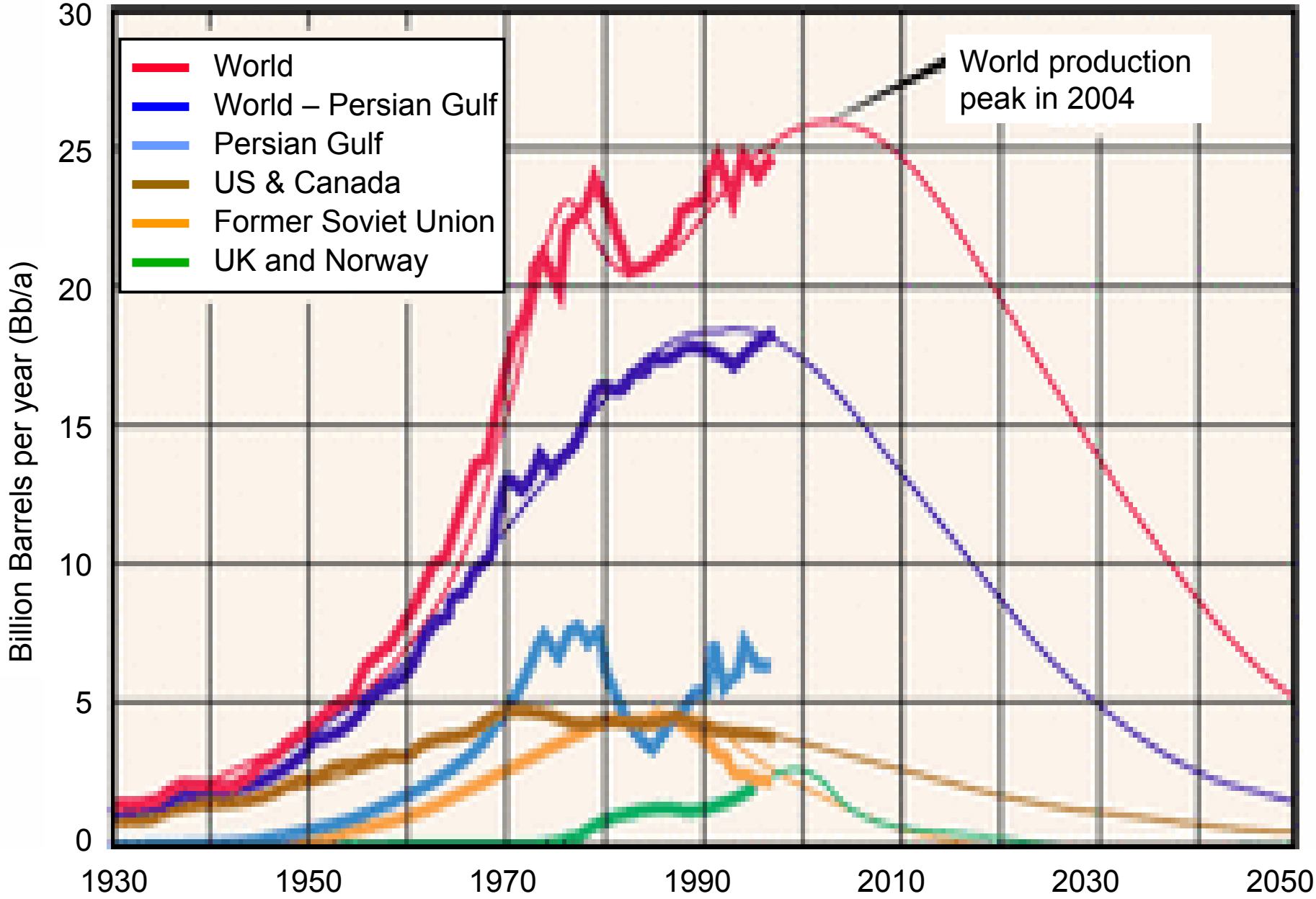
Chevron's 1990 Prediction

- Probably based on latest 1987 data
- Underestimated demand substantially
- Underestimated conventional discoveries
- Underestimated heavy oil development
- Did not account fully for reserves growth
- However:
  - Shapes are appropriate
  - The concept for new sources is correct, although the details are probably not…


World liquids & gross gas future production from ultimates (conventional + non-conventional) 2750 Gb and 12 500 Tcf (Perrodon, Laherrere, Campbell 1998)
Annual Production – Gboe/a
30
25
20
15
10
5
0
1925
1950
1975
2000
2025
2050
2075
2100
2125
past production liquids
conventional + non-conventional liquids
conventional + non-conventional natural gas 1 Gboe= 6Tcf
conventional oil
past production gross gas
non-conventional oil
gas liquids

CAMPBELL-LAHERRÈRE WORLD OIL PRODUCTION ESTIMATES



Source: US DOE EIA

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Comments on Campbell-LaHerrère

- Conventional oil predictions are reasonable
- URR for conventional oil used (heavy oil has recently altered the reserves picture)
- I believe he underestimates the impact of heavy oil, oil sands, oil shales on supply
- I believe he underestimates the impact of new and emerging technologies
- Nevertheless, the historical success of Hubbert predictions is impressive (also claimed to be purely coincidental)

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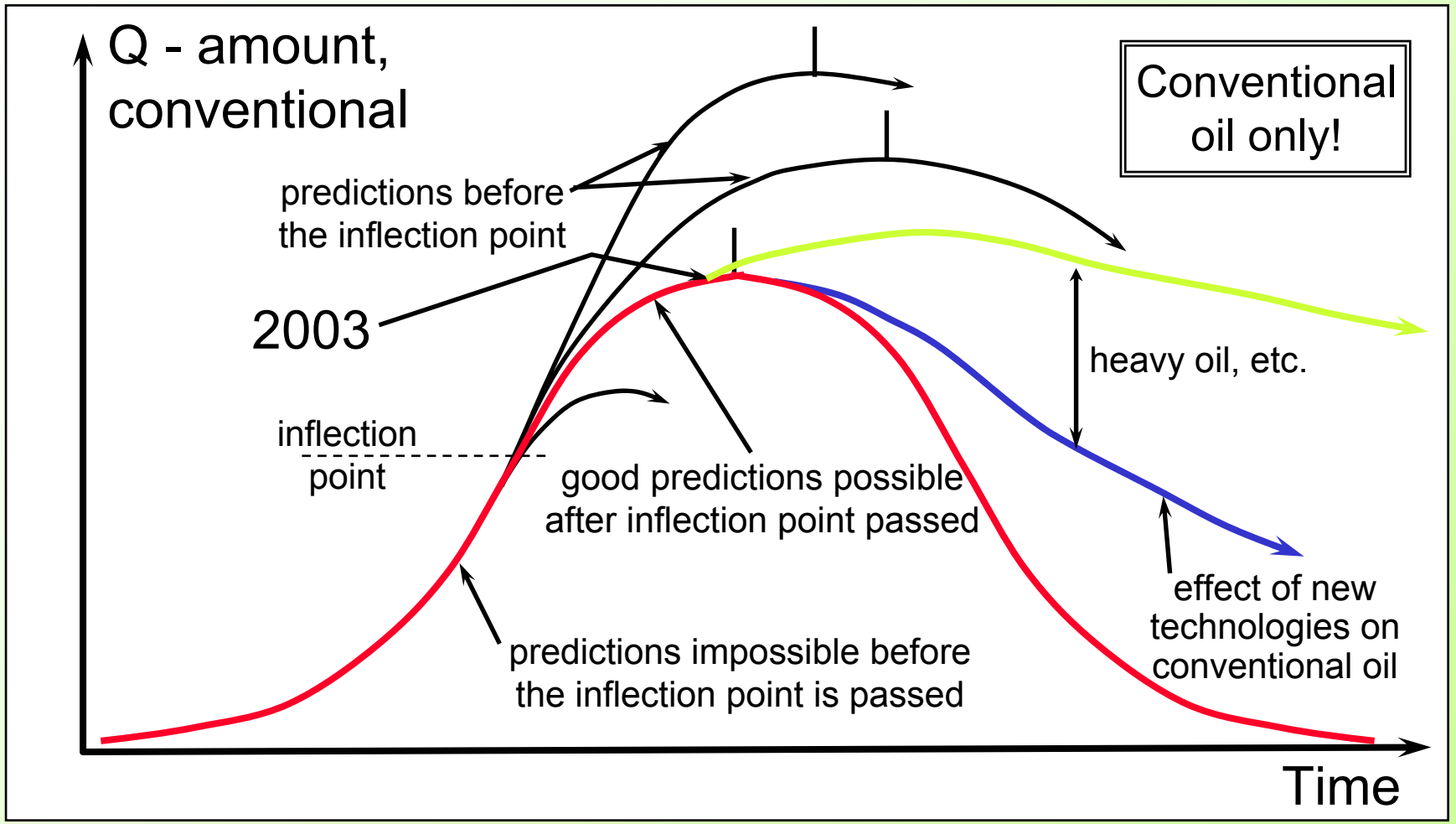
Predicting From History…



Can we realistically predict from History??

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Predictions …

- Conventional oil consumption not replaced by new reserves for 25 years
- Inflection point well-defined (~1978)
- Thus peak in conventional oil is near…
- But, things could change!
  - Depression, war, environmental disaster
  - Dramatic technological breakthroughs…
- Predictions cannot be based on these…
- Is the past the key to the future??

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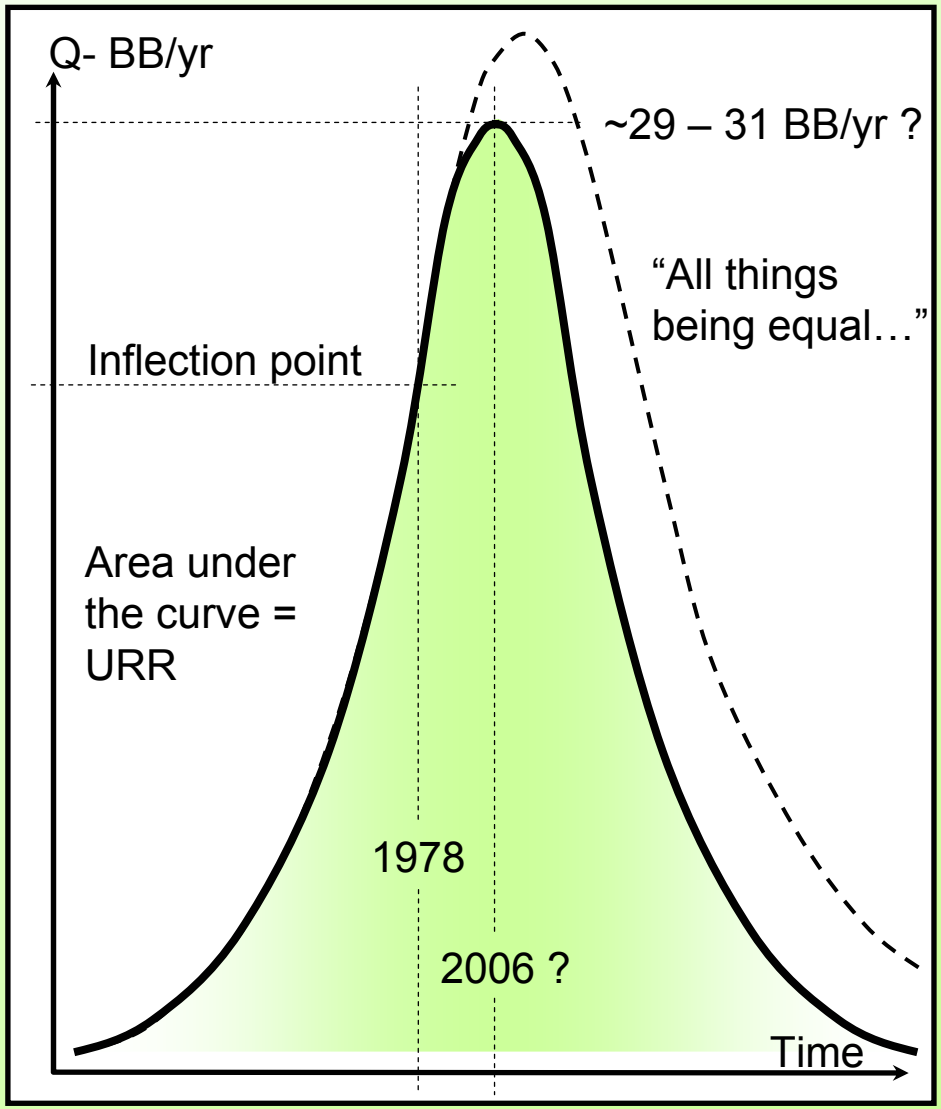
The Location of the "Peak"

- Assume a fixed fossil fuel base resource (ultimate recoverable)
- Assume a "logistics" curve of consumption
- Then, the peak in availability should occur near the 50% consumption point
- Peak is sensitive to URR assumption



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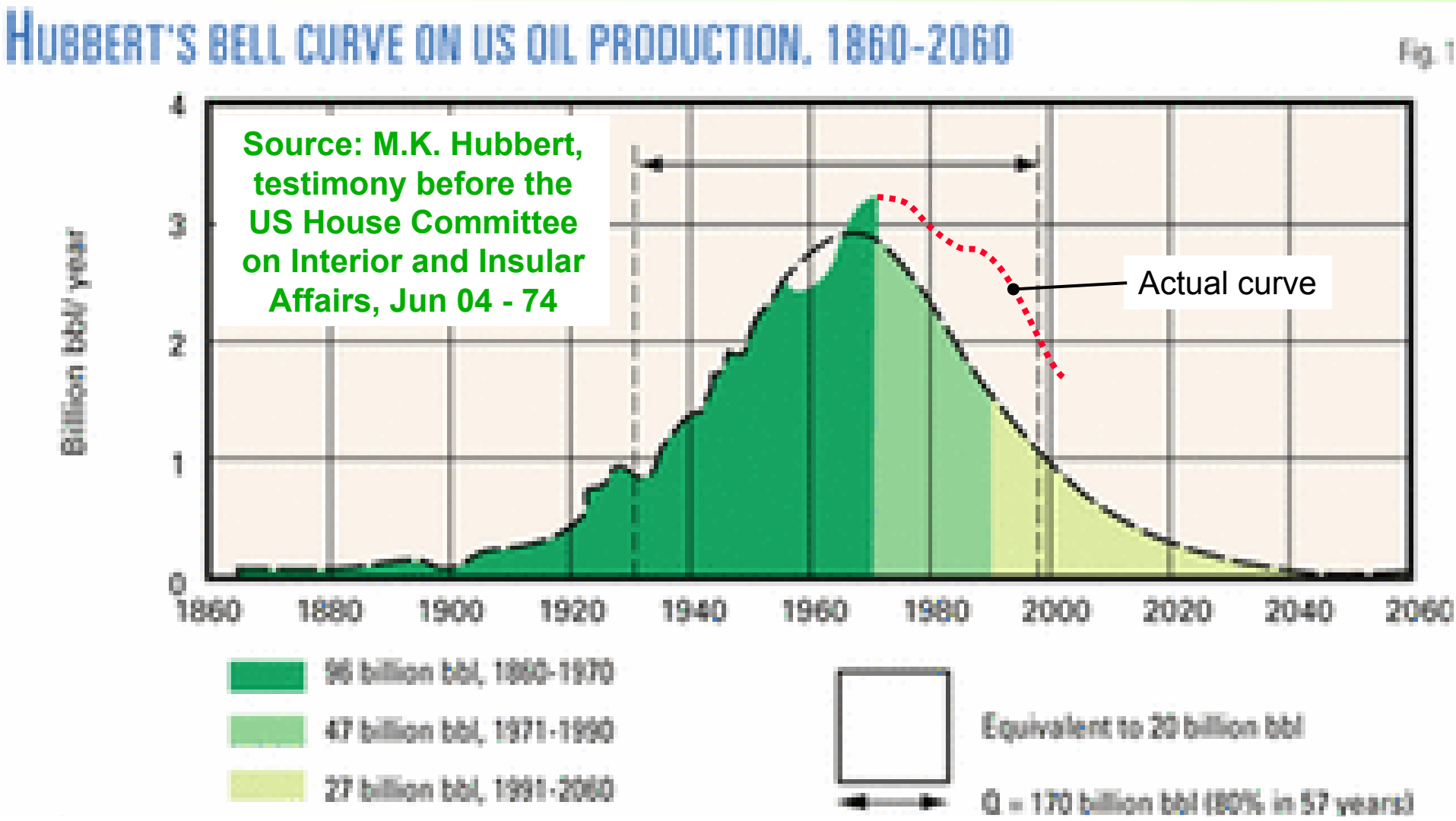
Hubbert's Curve for the USA…



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Some Critiques of Predictions…

- The role of heavy oil is underestimated: it is not "present" in the historical records
- Emergence of new technologies in the last decade is not accounted for (yet…)
  - Reserves are rising (+177 BB from Canada, June 10 2003, PricewaterhouseCooper)
  - Technology will affect conventional oil as well
- Thus, predictions based on history are useful, but to be used with some caution

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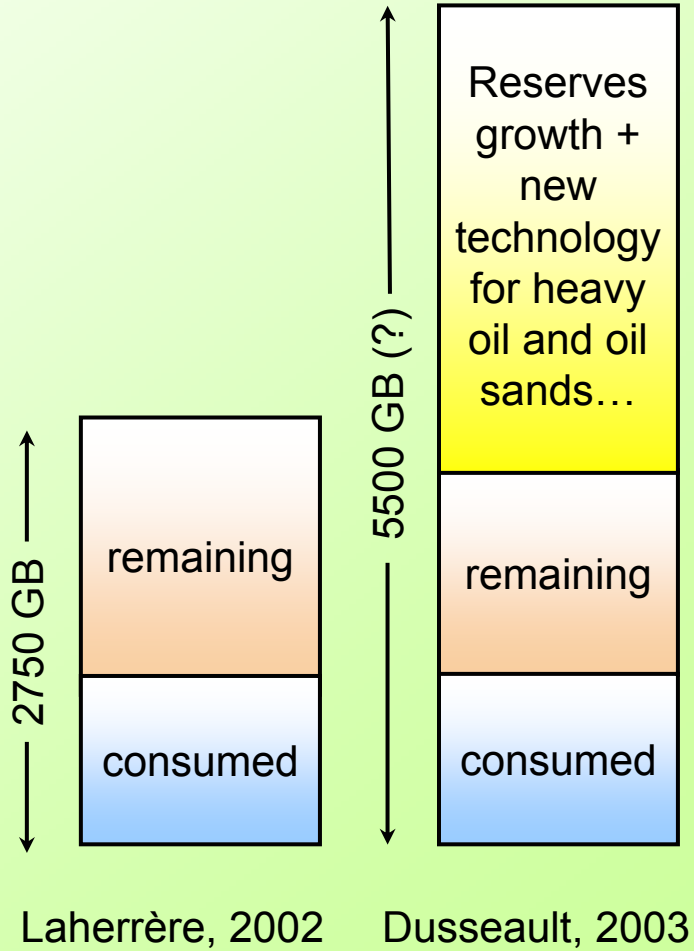
50% of "Recoverable" Oil…

- URR is assumed to be ~essentially fixed by depletionists (C&L)
- E.g. they assume only ~300 BB from "nonconventional oil"
- However, if you include 25% of the 11-13 TB of heavy crude and bitumen…
- You see the problem!



Ultimate Recoverable Reserves

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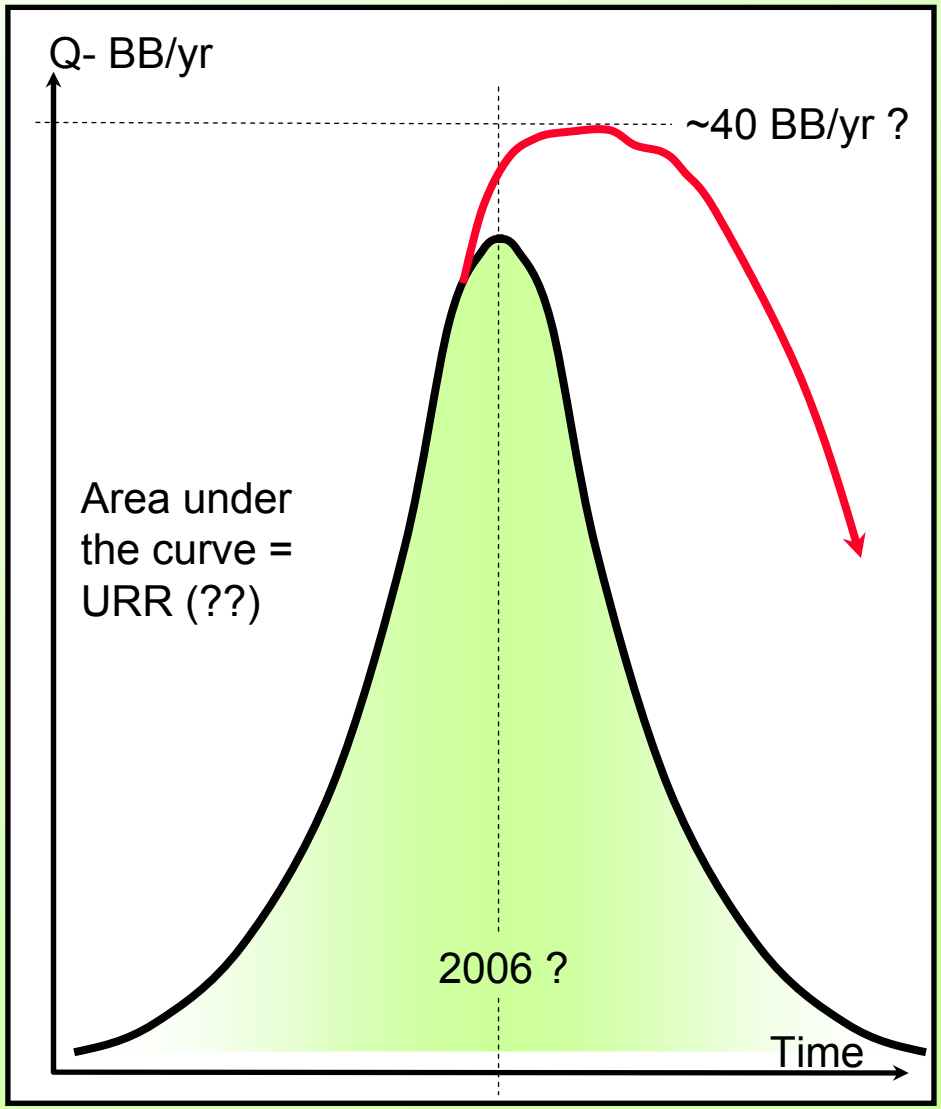
Will This Affect the Peak??

- It depends what you define as the peak…
  - Conventional liquids?
  - All fossil liquids?
  - All HC liquids from all sources?
  - Cheap and easy liquids?
- E.g.: non-conventional liquids rising, but conventional oil is flat



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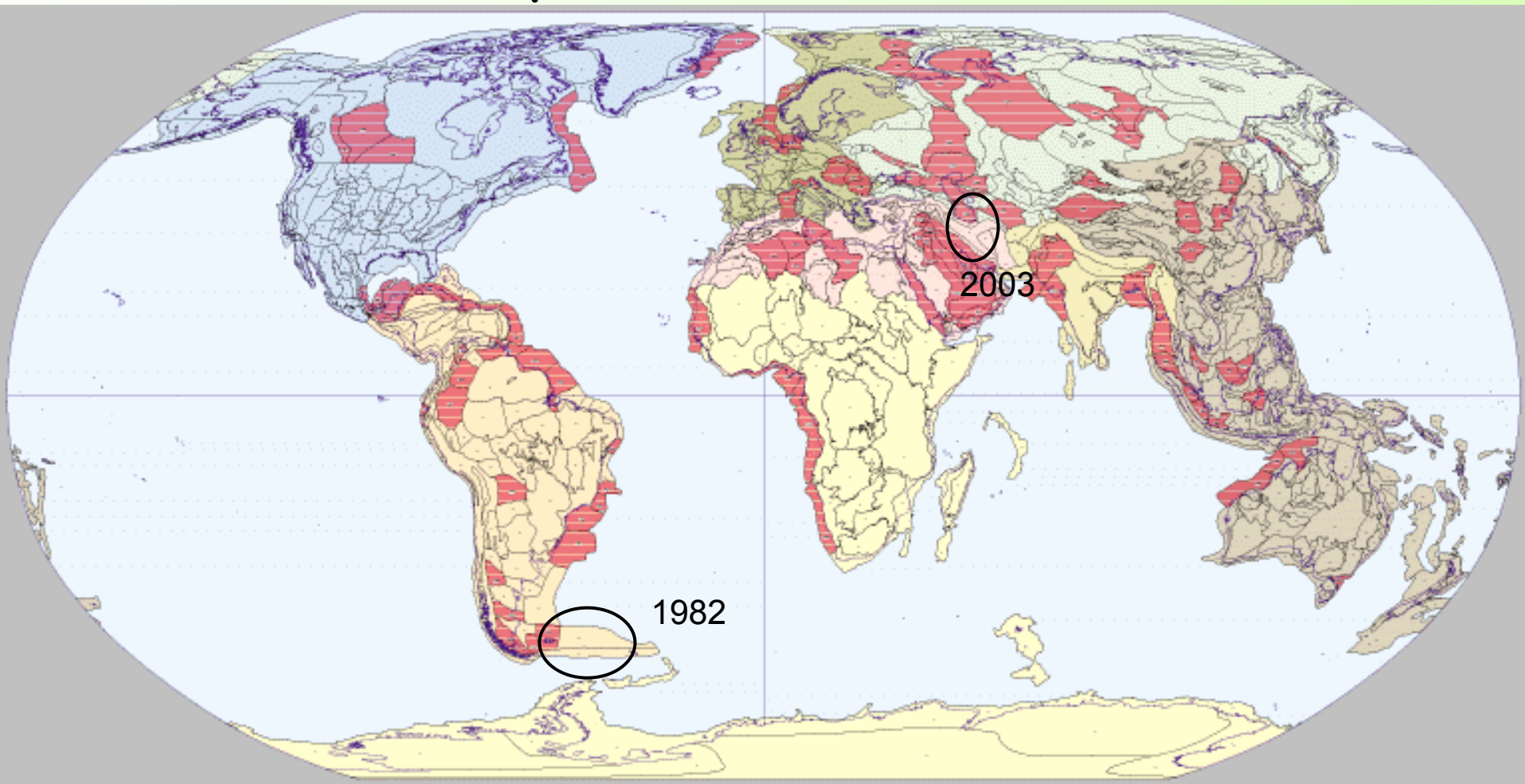
A World of Basins…

- The world is finite, and all major basins have been explored…



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Are There Many Basins Left?

- All major "easy" basins are now explored:
  - Seismic lines have been run
  - A few test holes drilled
  - Geochemistry, HC generation has been done
  - Comparisons to other basins have been done
- Offshore Arctic, Antarctic?
- Deep offshore (>200 m depth), limited
- Remote oil is difficult, so is deep oil
- Conclusion: we are running out of basins

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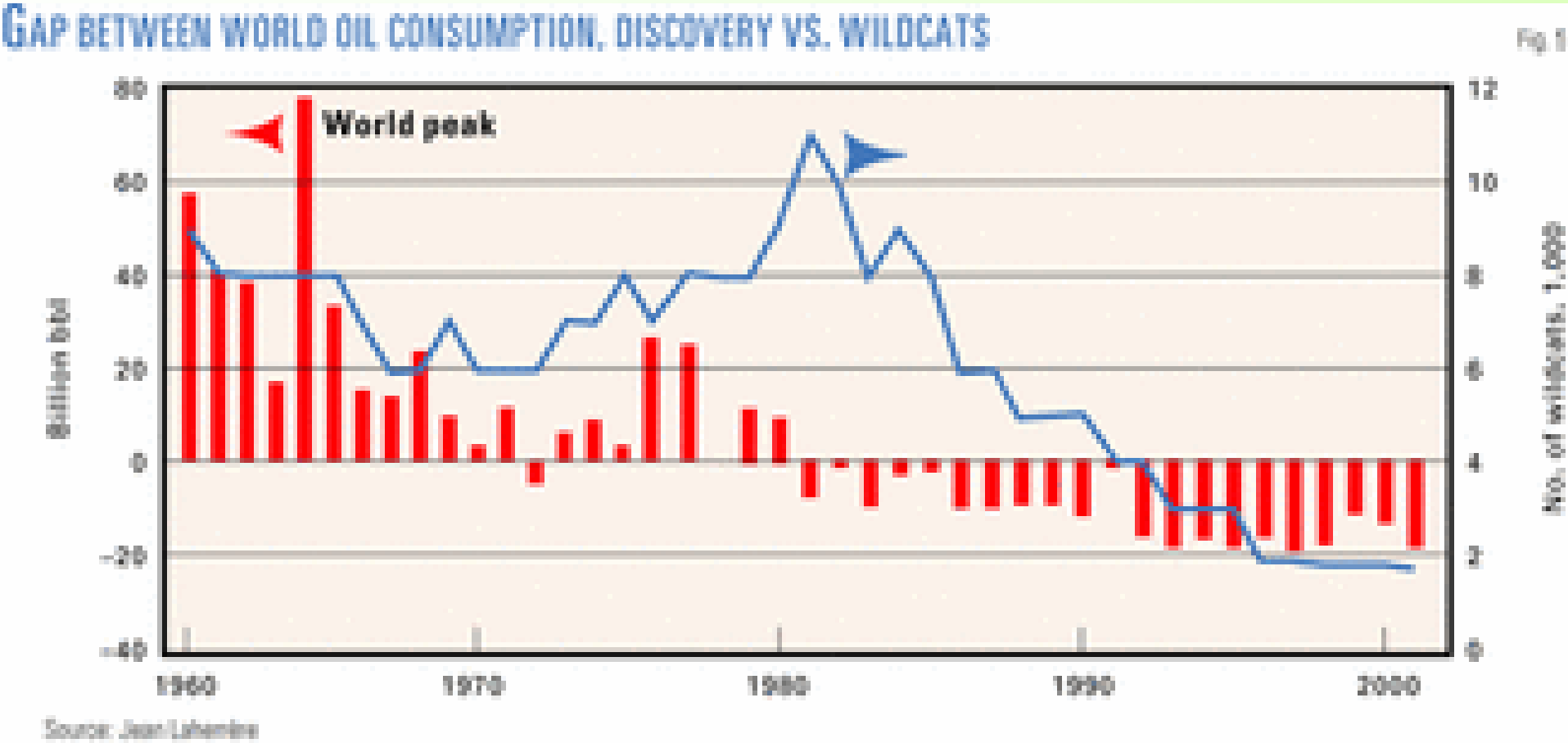
Replacing Consumption??



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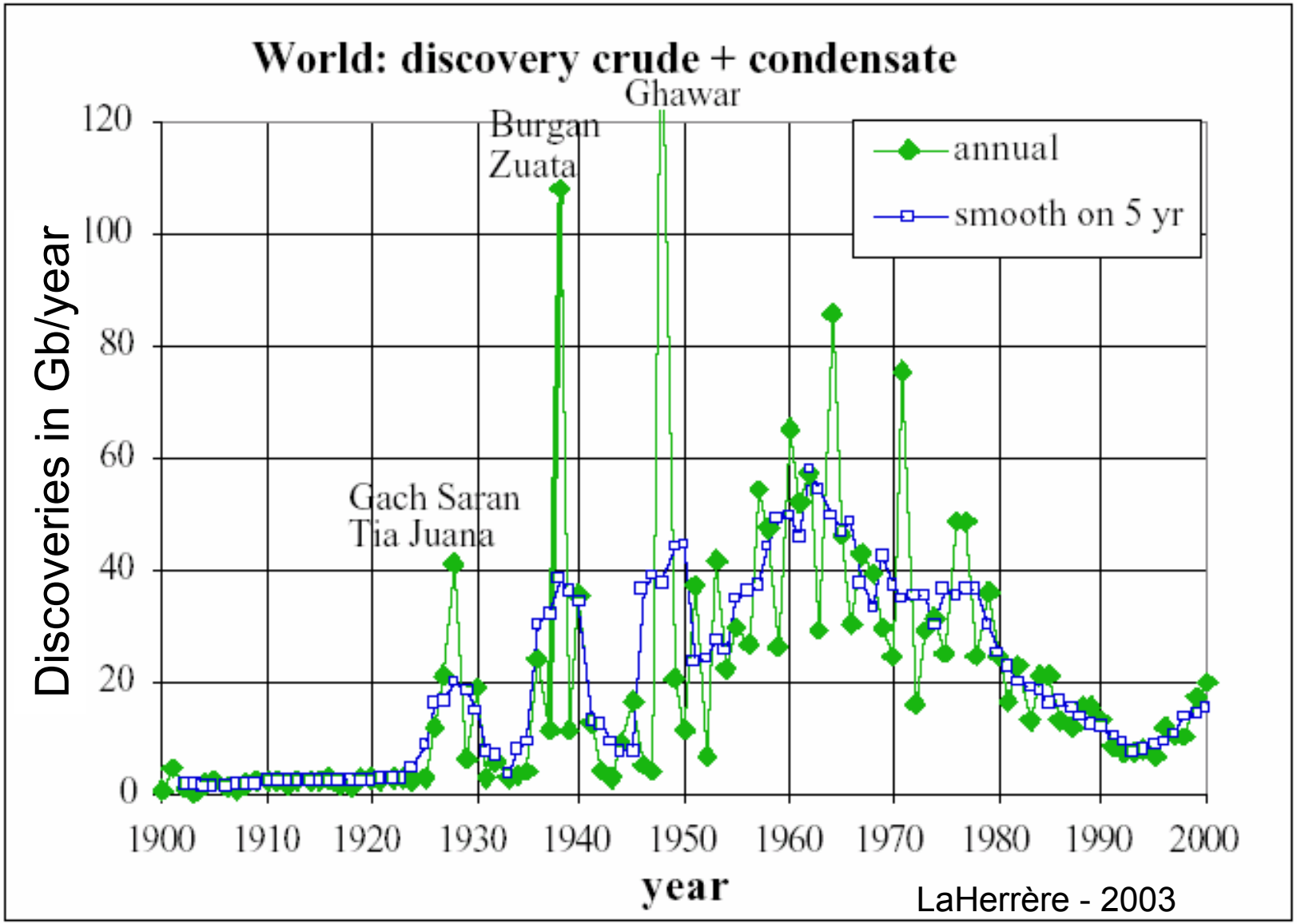
History of Oil Discoveries…



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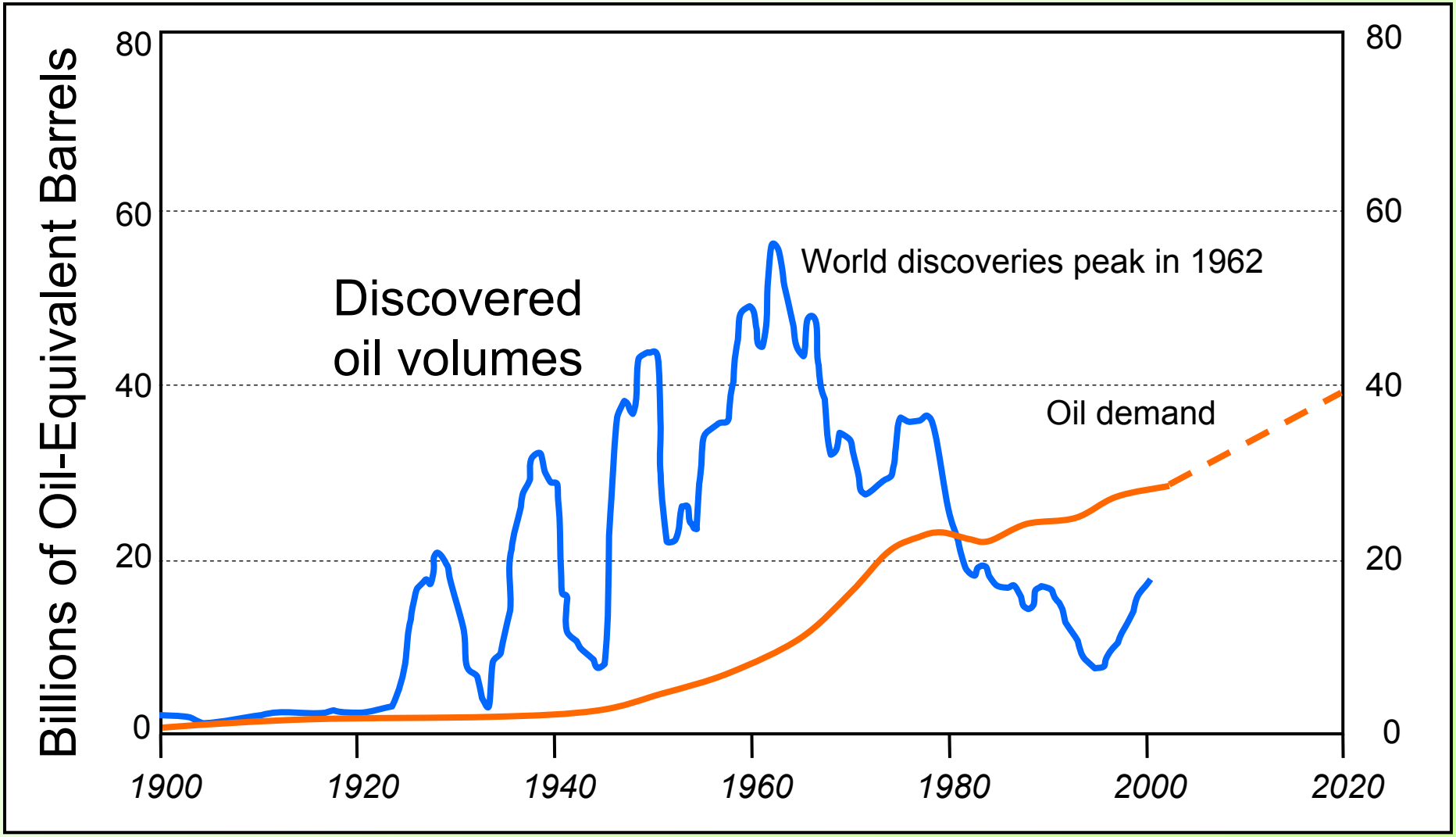
History of Oil Discoveries…



Longwell (Exxon-Mobil – 2002)

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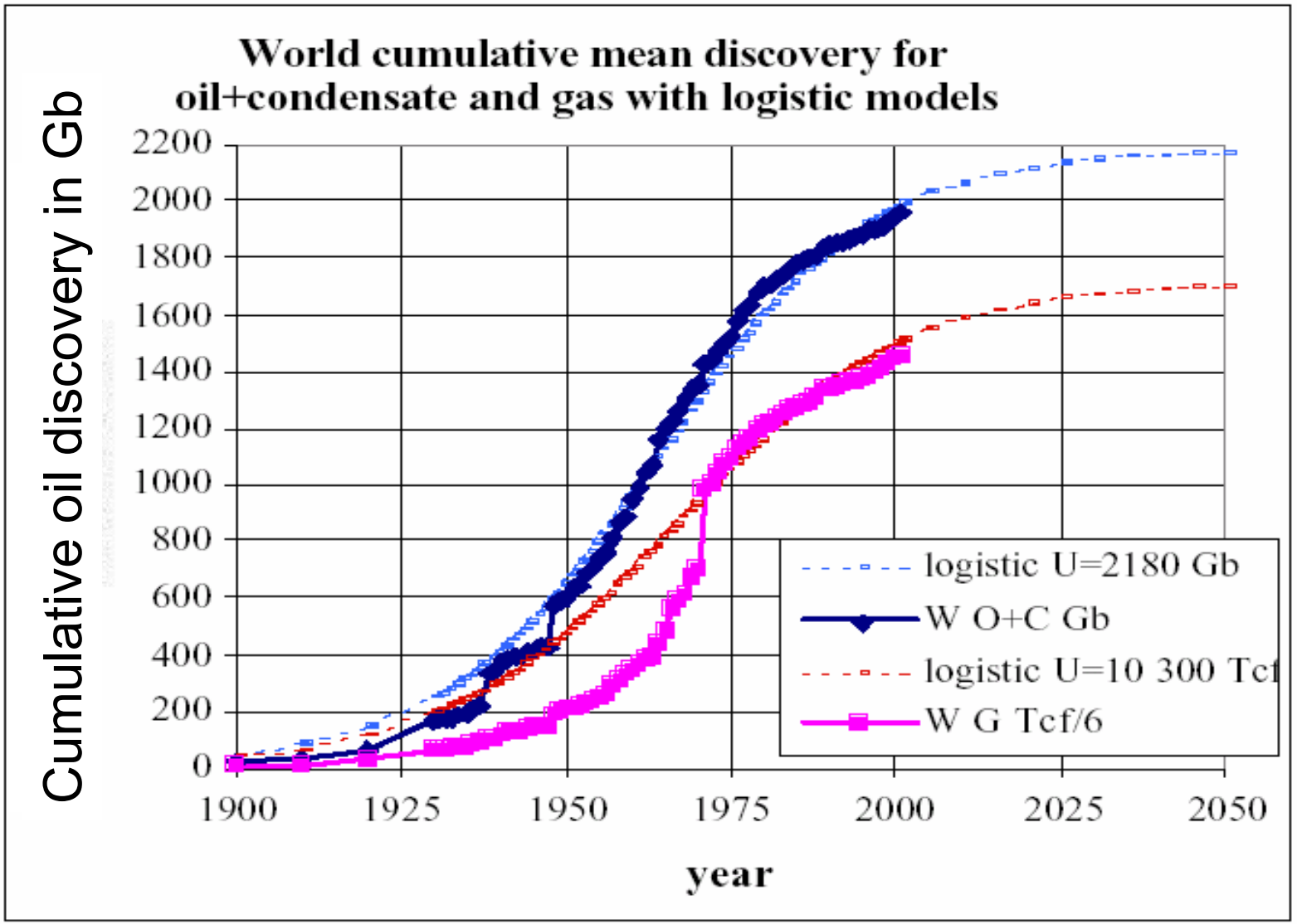
LaHerrère's Asymptotic Plot



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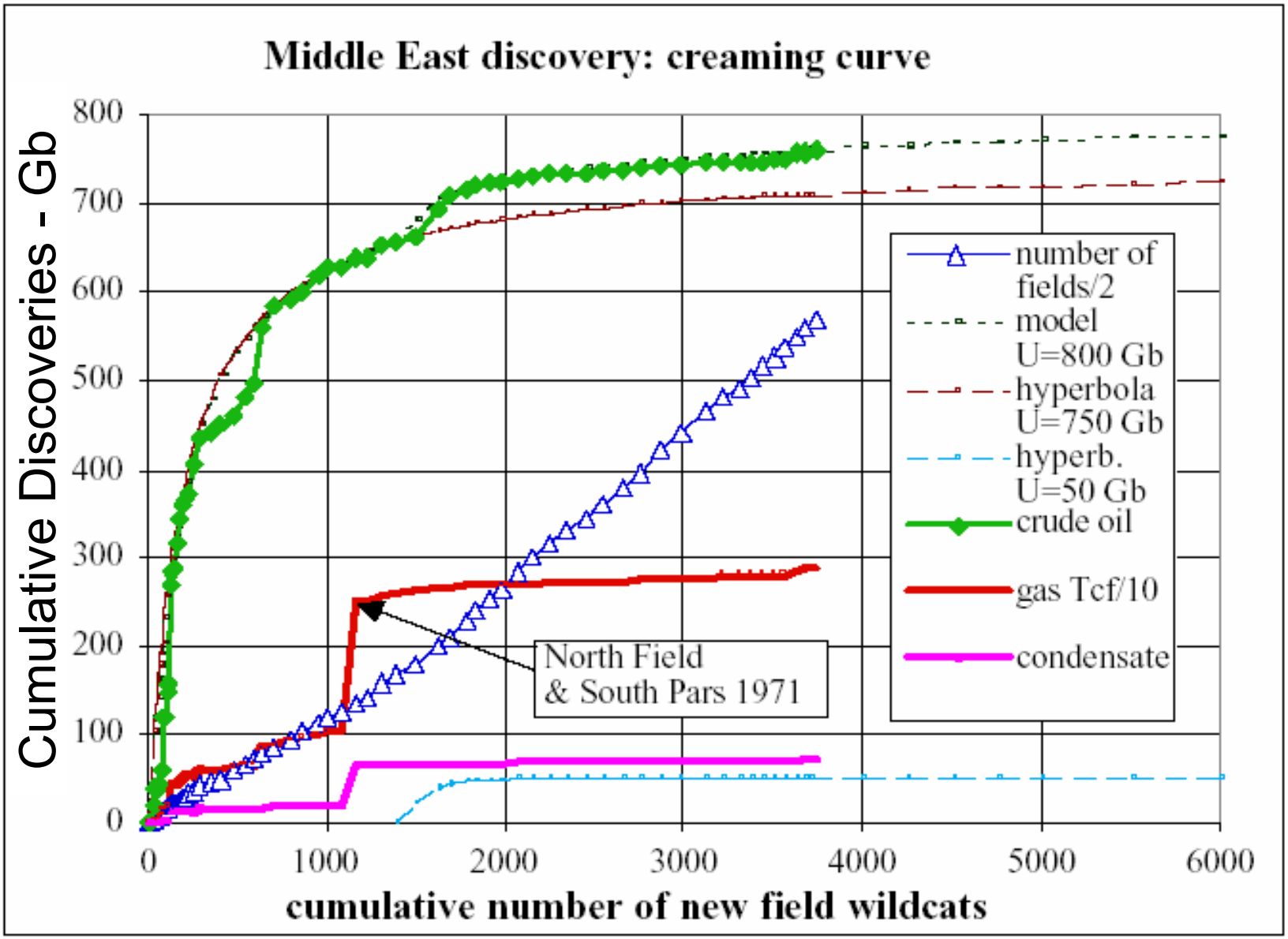
The "Creaming Curve"



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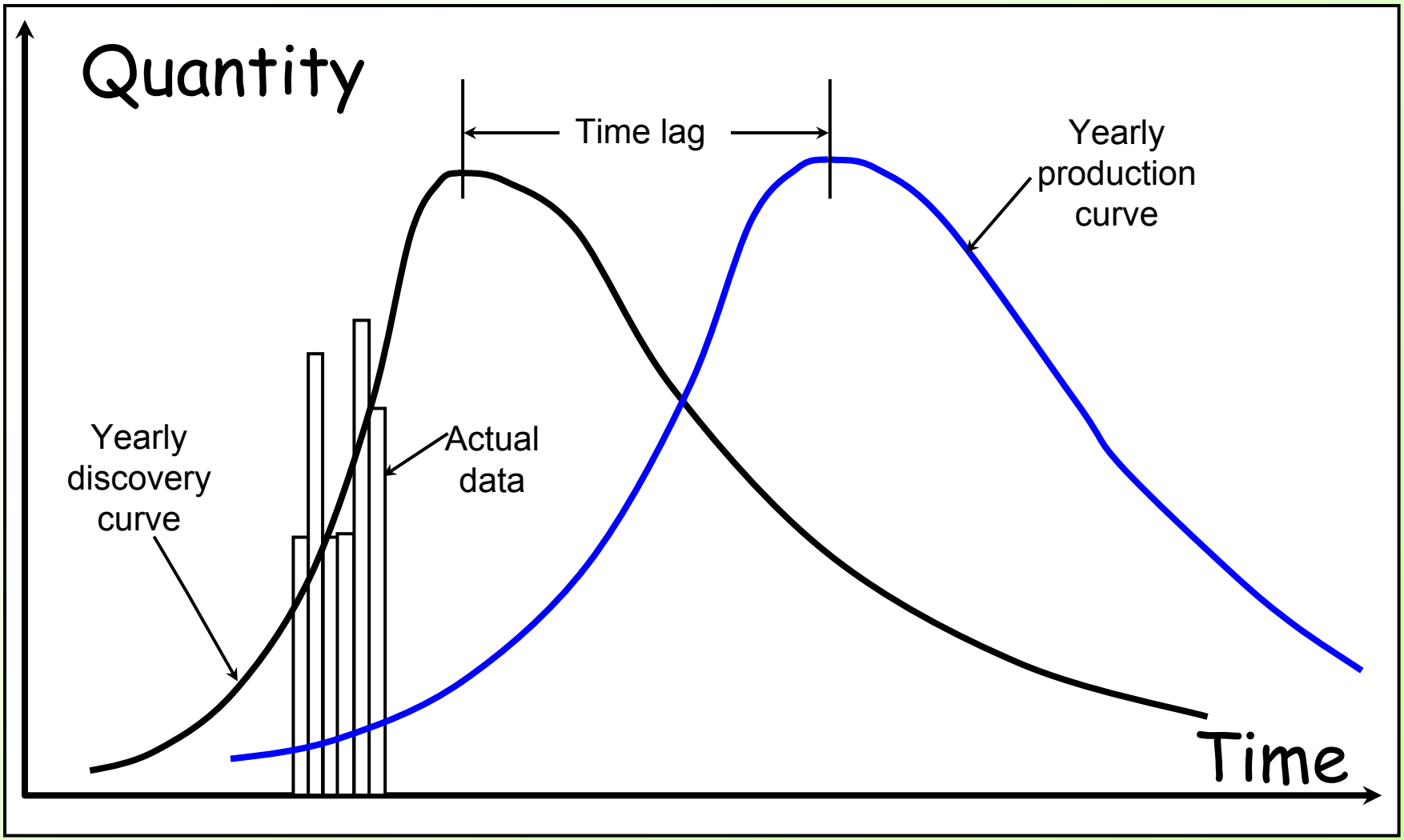
Hubbert Curves & Discoveries



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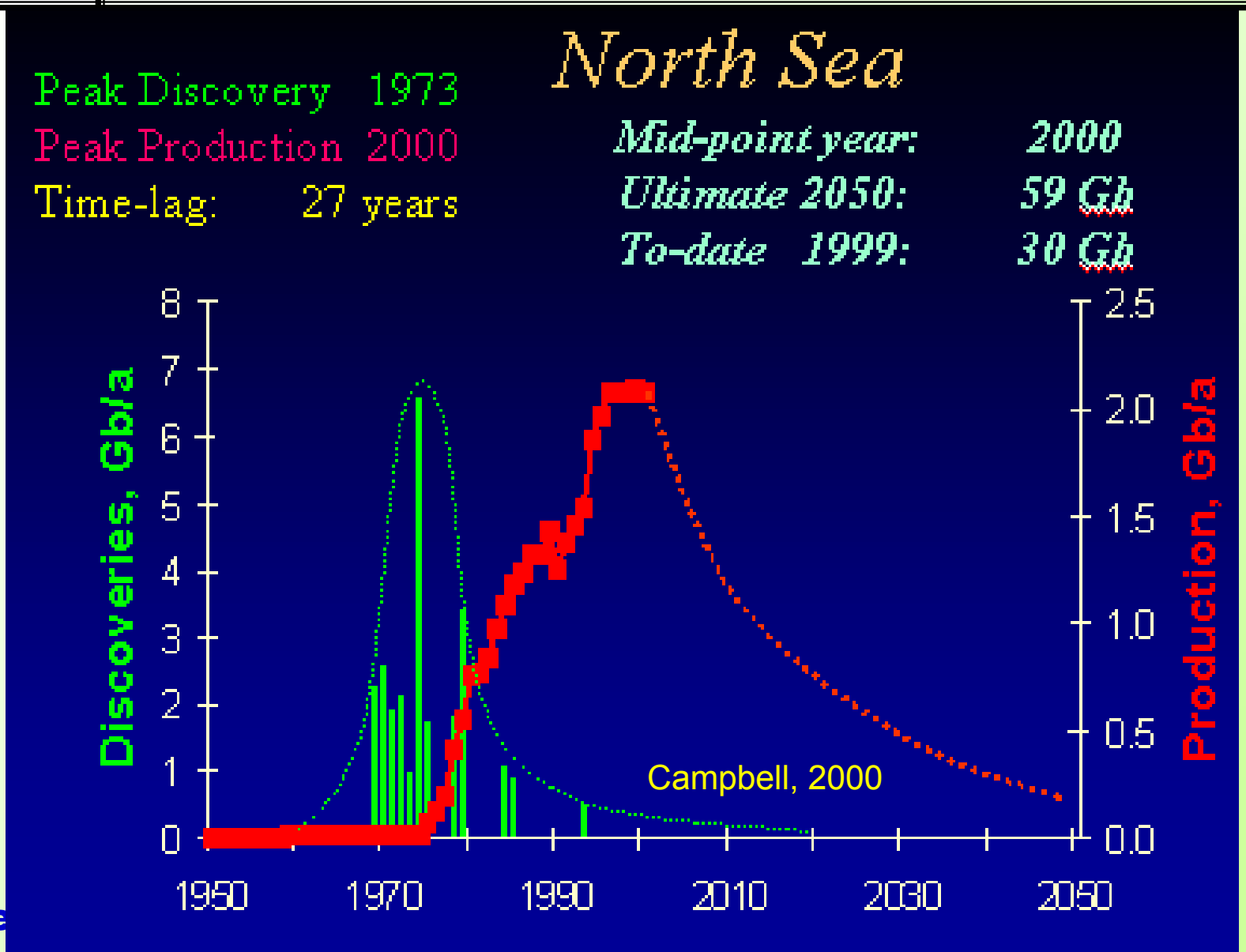
Production Lags Discoveries



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Discoveries and Production

- Discoveries must equal sum of:
  - Depletion of all existing fields (~2.5%/yr)
  - Aggregate increase in consumption (~1.8%/yr)
- There is a time lag between peaks (USA ~35 yrs, 27 yrs for North Sea, …)
- For the world, discoveries peak for conventional oil came in ~ late 1960's
- Conventional oil prod. will peak soon
- However, this is not the whole picture

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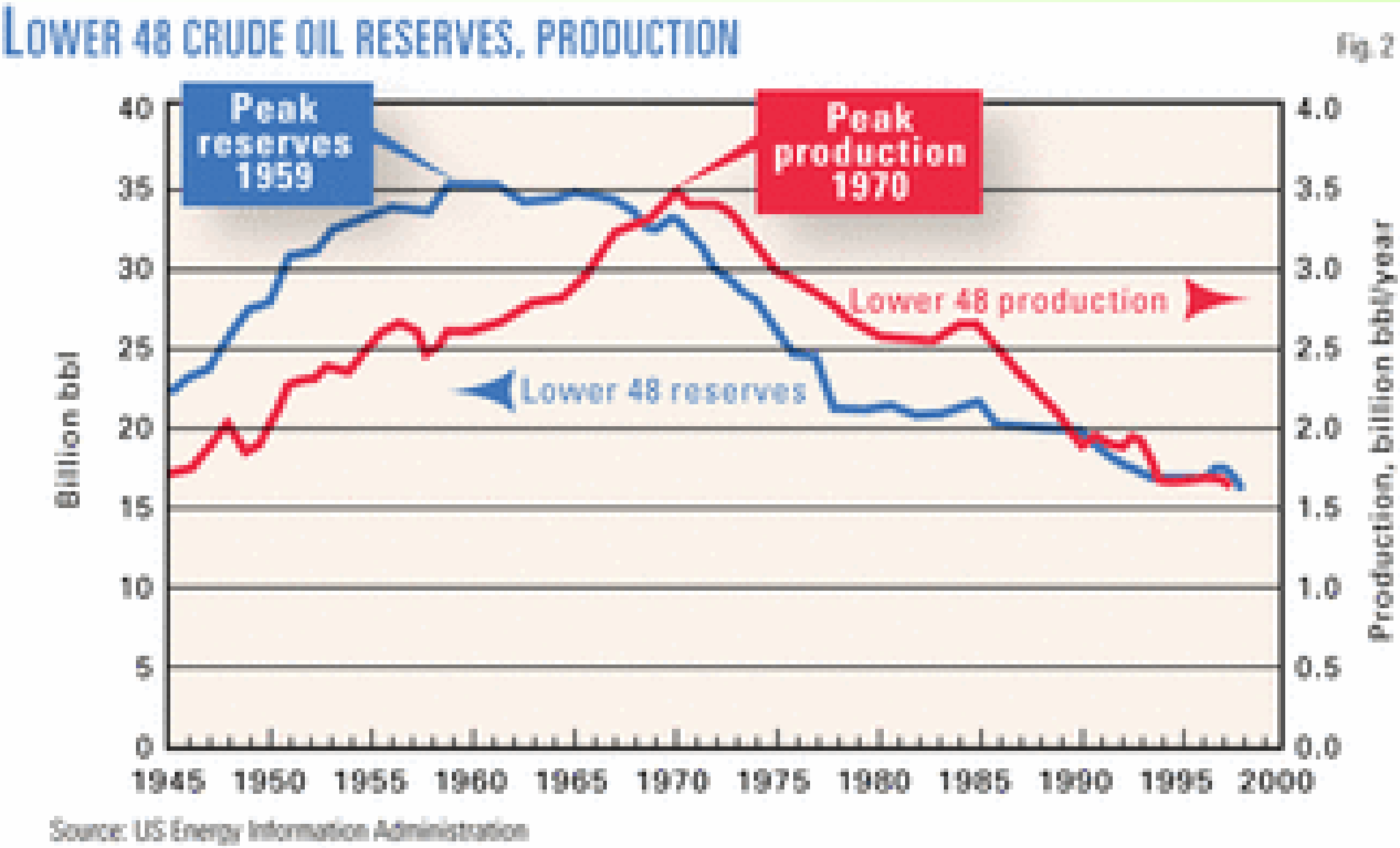
Discovery-Production Delay



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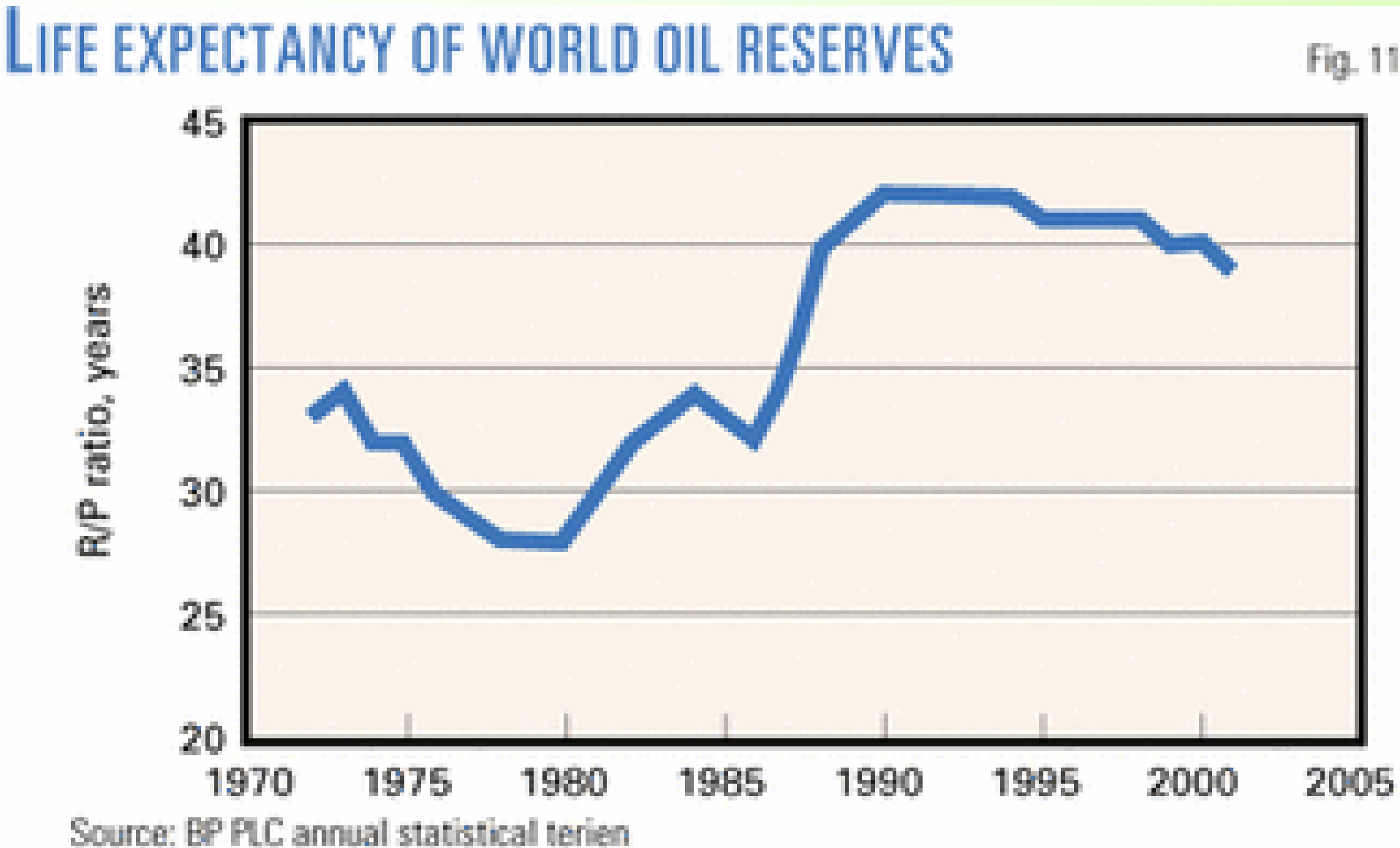
Life Expectancy of Reserves



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However…

- In the US, reserves growth has added more oil to URR than exploration! Why??
  - Field is discovered, recoverable is estimated
  - This first estimate is very conservative (93%)
  - Field has a "life", but during this life, better methods of extraction, IOR developed
  - Stripper wells, massive water injection, components of gravity drainage, etc. all help
- This process tends to extend the life of the oil field, and new "reserves" added…

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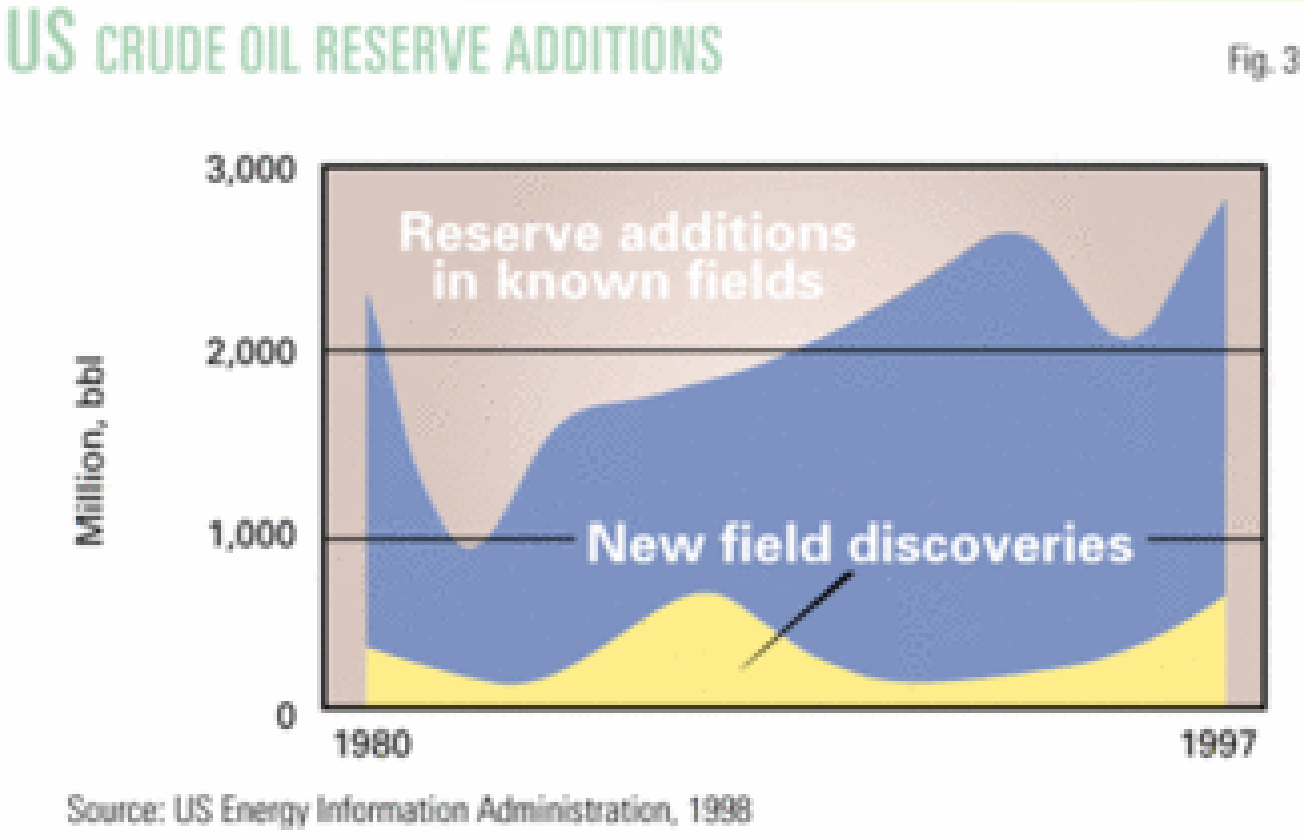
Reserves Additions - USA



From 1977 to 1995, 88% of "added reserves" in USA was "reserves growth", not discoveries!

WHY??

- Extensions to fields,
- New technologies
- Better-than-expected recovery
- Etc.

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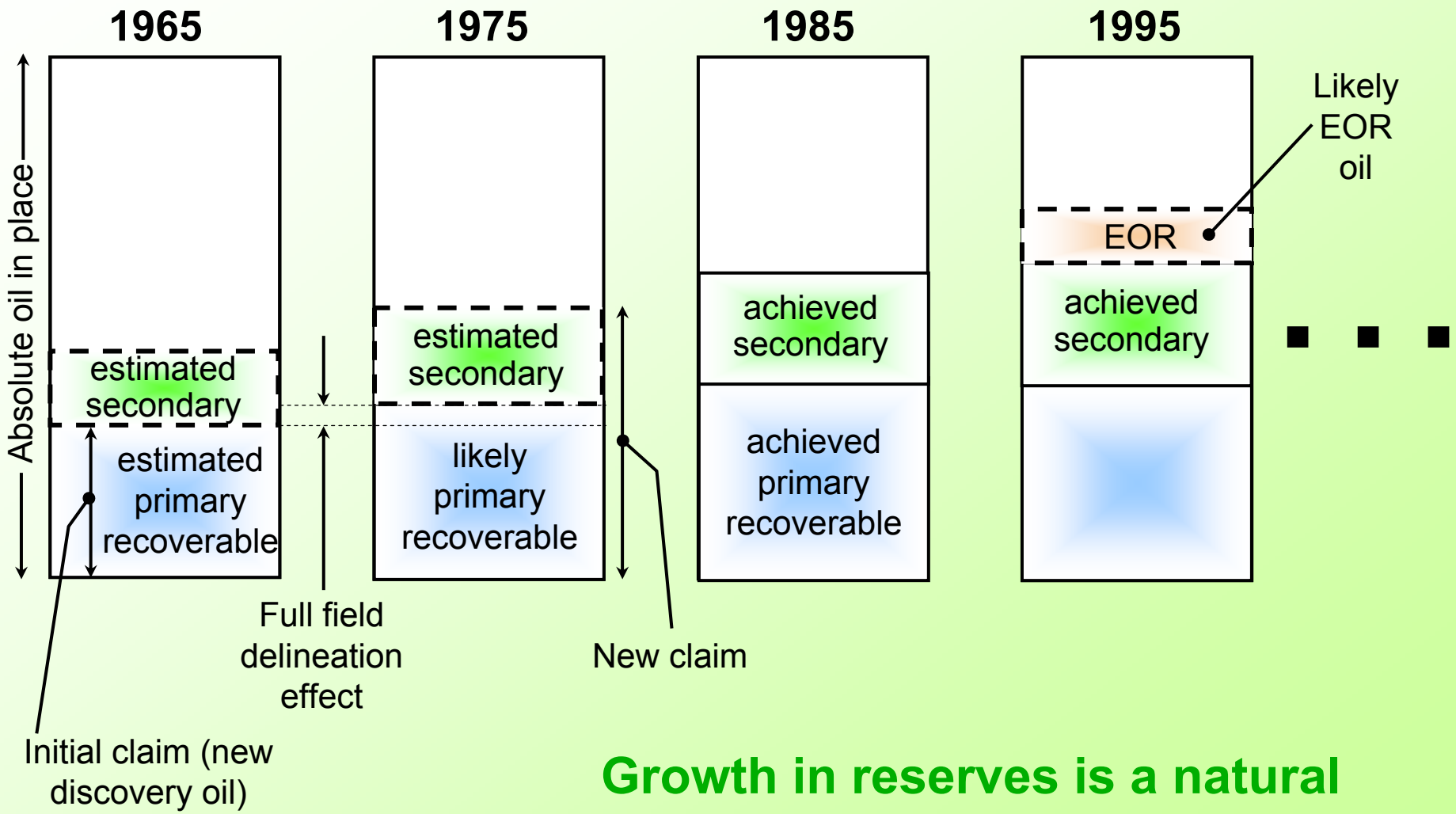
Reserves "Growth"…



Growth in reserves is a natural phenomenon, but it cannot "create" new oil, only exploit oil in place…

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Reserves Growth Psychology…

- Engineers prefer to underestimate rather than overestimate recoverable oil
- For stock promotion reasons, companies like to "book" new reserves occasionally
  - ➔ Stepouts, new methods, better mapping, etc.
- Field is then sold to small operators
  - ➔ More value is then squeezed out by low overhead companies = more "reserves growth"
- Also: politics! OPEC countries have quotas based on their recoverable reserves

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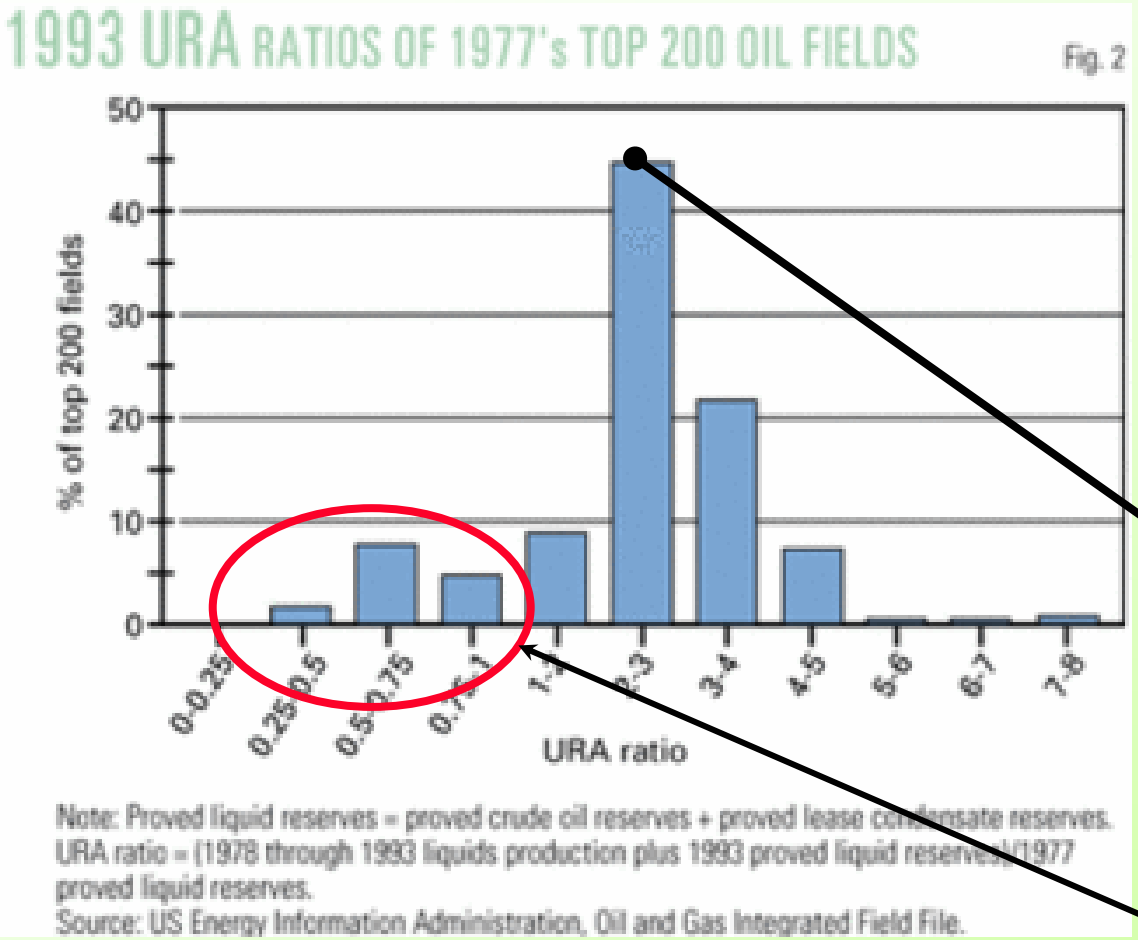
Back-Dating Reserves



Because of the reserves growth phenomenon, making predictions based on ultimately recoverable reserves means that the data have to be retro-actively updated.

E.g.: ~45% of fields discovered in 1977 in the USA ended up by 1993 having from 2 to 3 times more recoverable oil.

15% of fields actually produced less than the original estimates.

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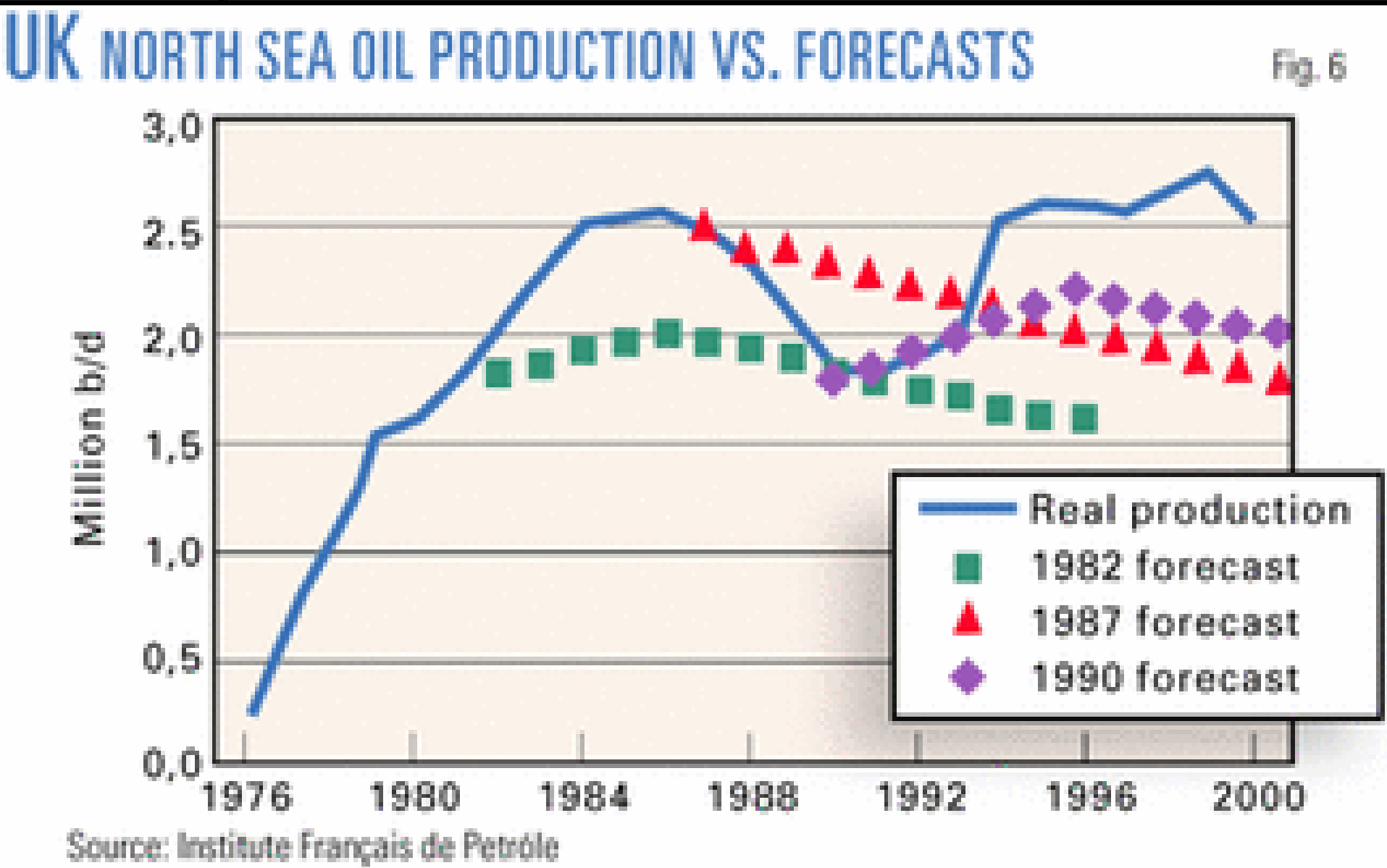
Are Forecasts Valid?



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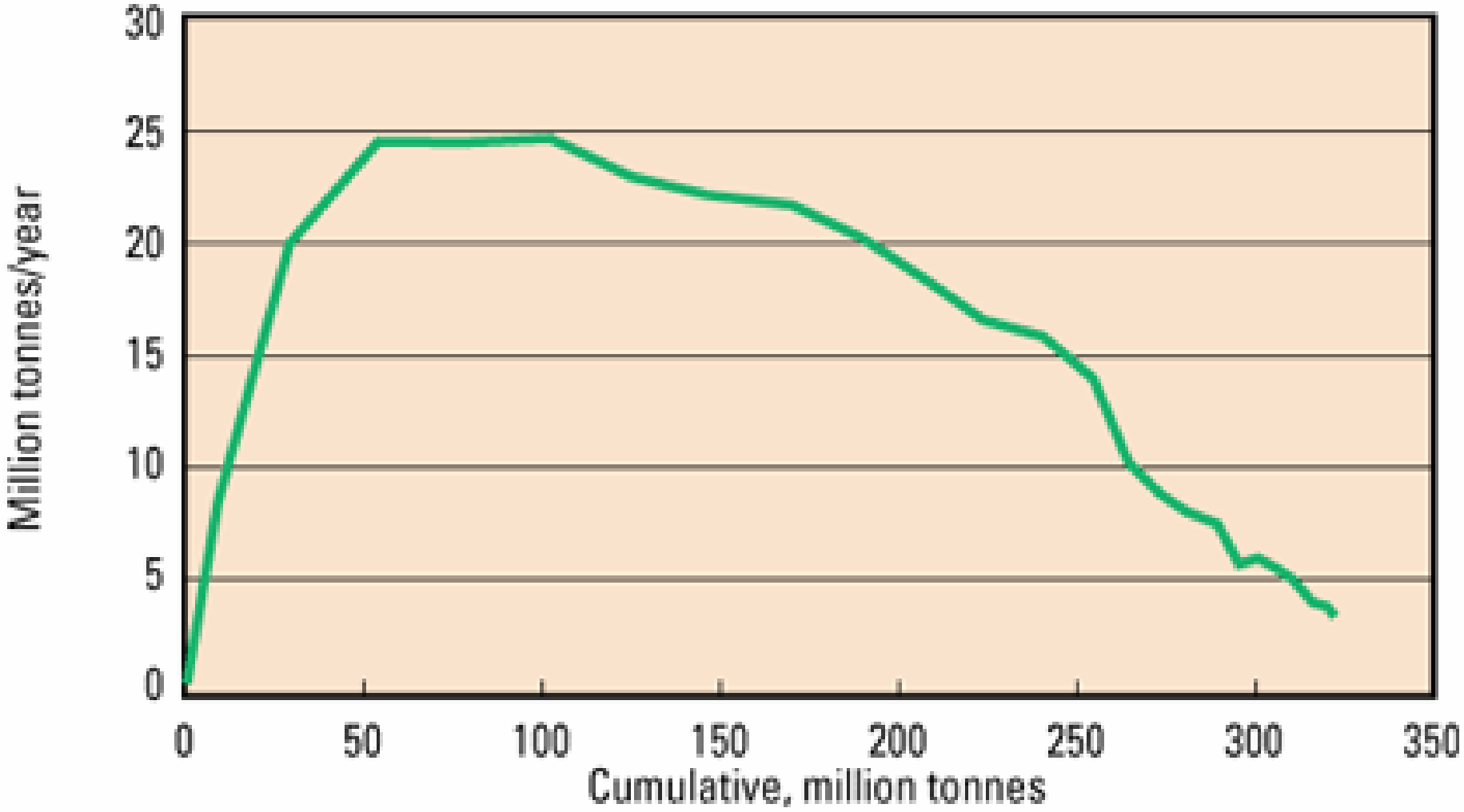
A Classic Depletion Curve

FORTIES FIELD OIL PRODUCTION

Fig. 2



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Depletion Curve

- Differences exist among depletion curves
- Technologies are developed
- Offshore -high OPEX; onshore -low OPEX
- Lynch (O&G J, July 4, 2003) claims that these differences invalidate predictions
  - This is a silly criticism, especially when you look at his example of Murchison
  - Murchison was a small field, and only an extra 5% was produced during the rejuvenation…

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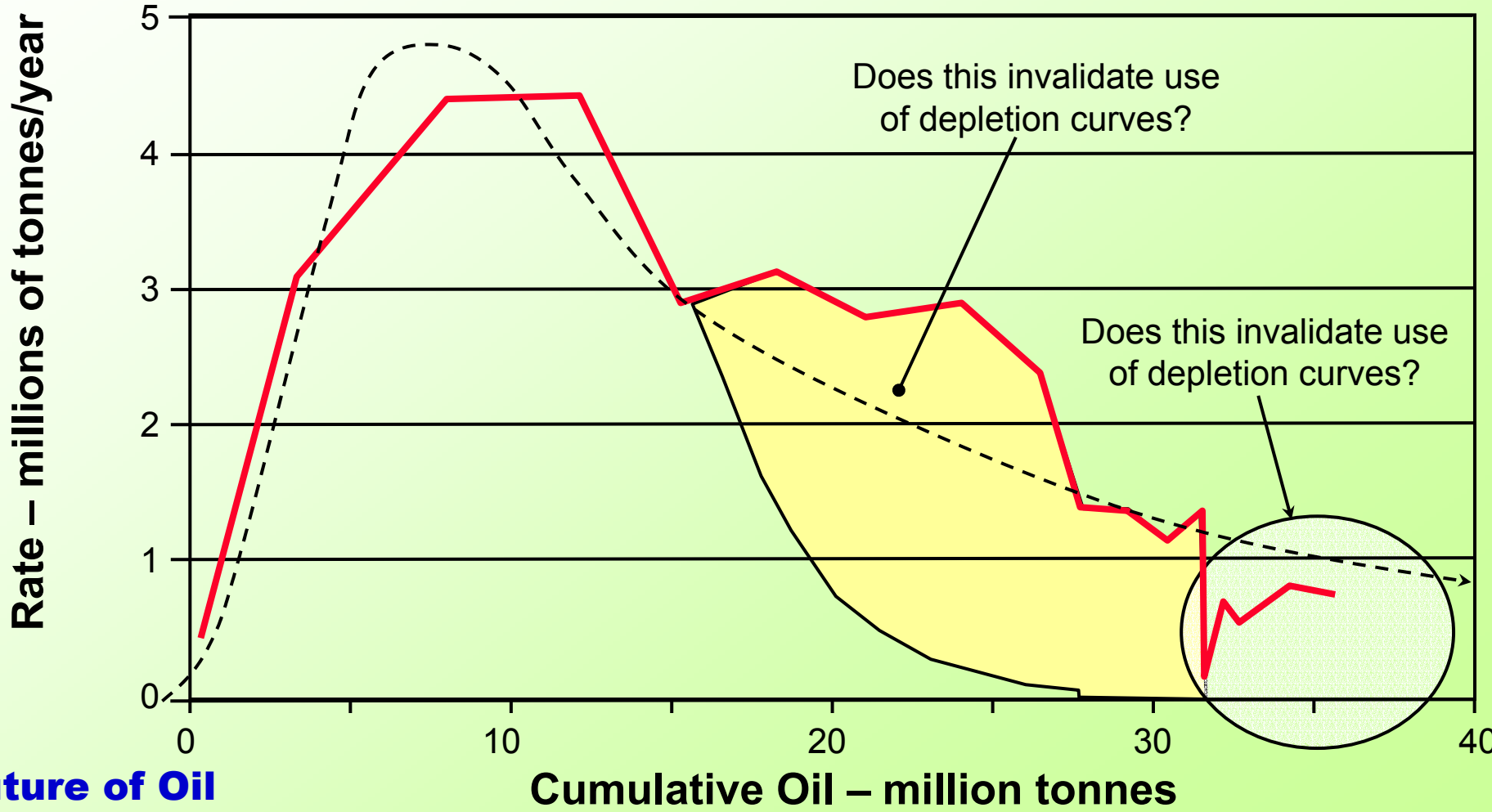
Some Late-Life Rejuvenation…

Murchison Field Oil Production



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Some Additional Comments

- The depletion curve for a single field is not a representation of an entire basin
- The smallest unit of application of the Hubbert analysis should be basin level
- The real depletion curve is closer to log-normal for a given field
- The sum of a centrally clustered group of log-normal curves is a Gaussian curve with a strong positive tail…

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Criticisms of Hubbert's Curves

- Looking at all countries, some do not follow classical Hubbert's curves:
  - Russia's peak-trough-rise in 1985 – 2003 has excellent explanations
  - Canada's peak-trough-rise in 1970 – 2003 is based on new heavy oil, oil sand technologies
  - If two separate areas are combined…
  - If a new discovery paradigm is developed…
  - And so on…
- These do not invalidate the concept

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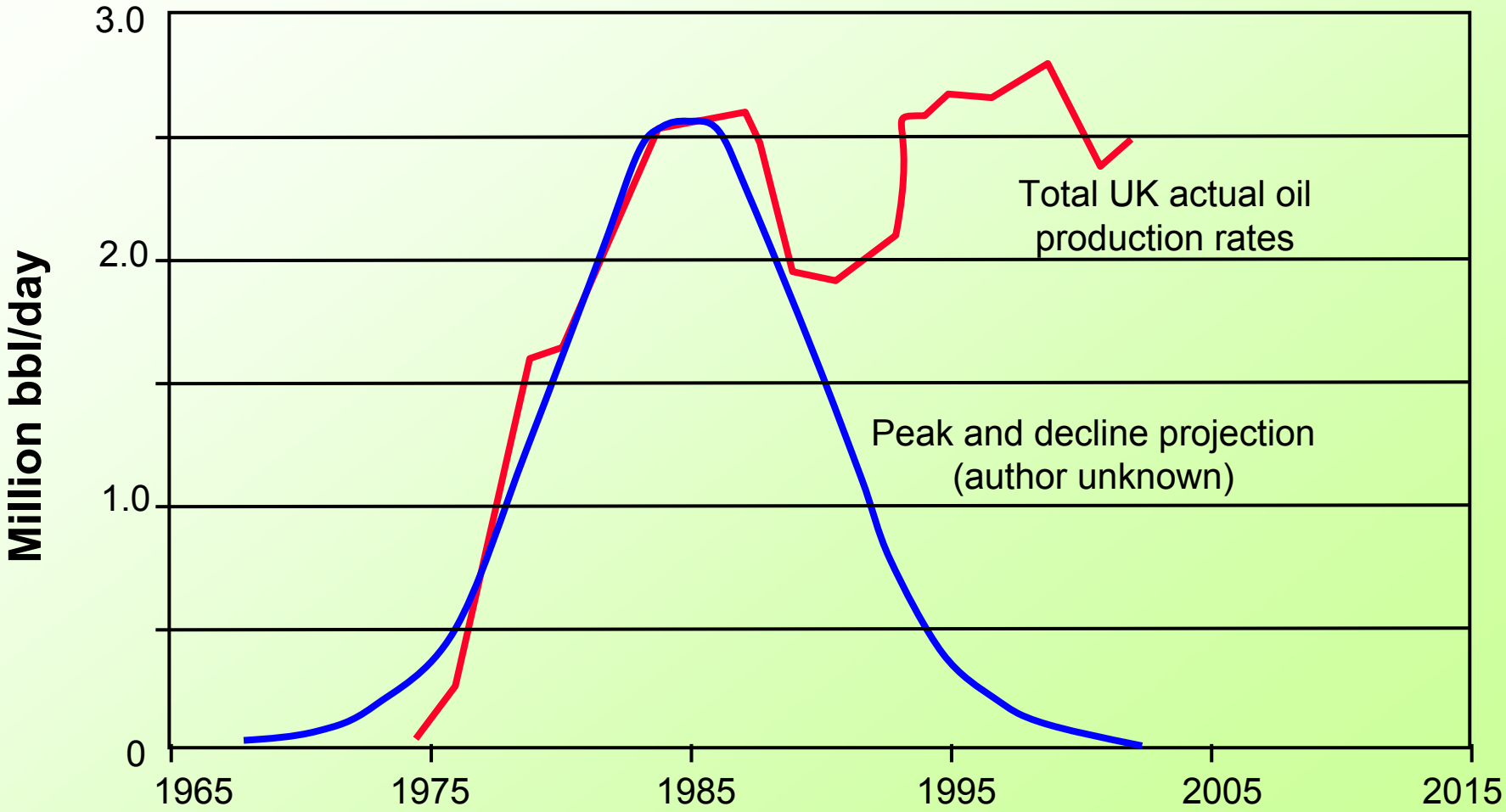
E.g.: Do Hubbert Curves Work??

Hubbert Curve vs. UK Oil Production



Source: WoodMackenzie historical data,

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Michael Lynch's Arguments…

- This UK North Sea curve is clearly not a classic Hubbert-type curve
- Therefore Lynch claims it invalidates the entire concept of a logistics approach
- Again, this is a silly criticism…
  - The 1988 Piper event…
  - The data appear to contain two "periods"
  - Perhaps different discovery areas, etc…
- Exceptions always exist, but the concept appears robust, with many "successes"

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Also, There Was a Disaster

- The Piper fire in 1988 resulted in:
  - Loss of Piper production
  - Loss of a substantial amount of surrounding production because of pipelines and tie-ins
  - Full production re-established only in 1993
- So, the progress of the UK to a peak production was delayed by 4-5 years
- Also, Hubbert curves should be basin-specific, in my opinion
- Let's replot the previous diagram…

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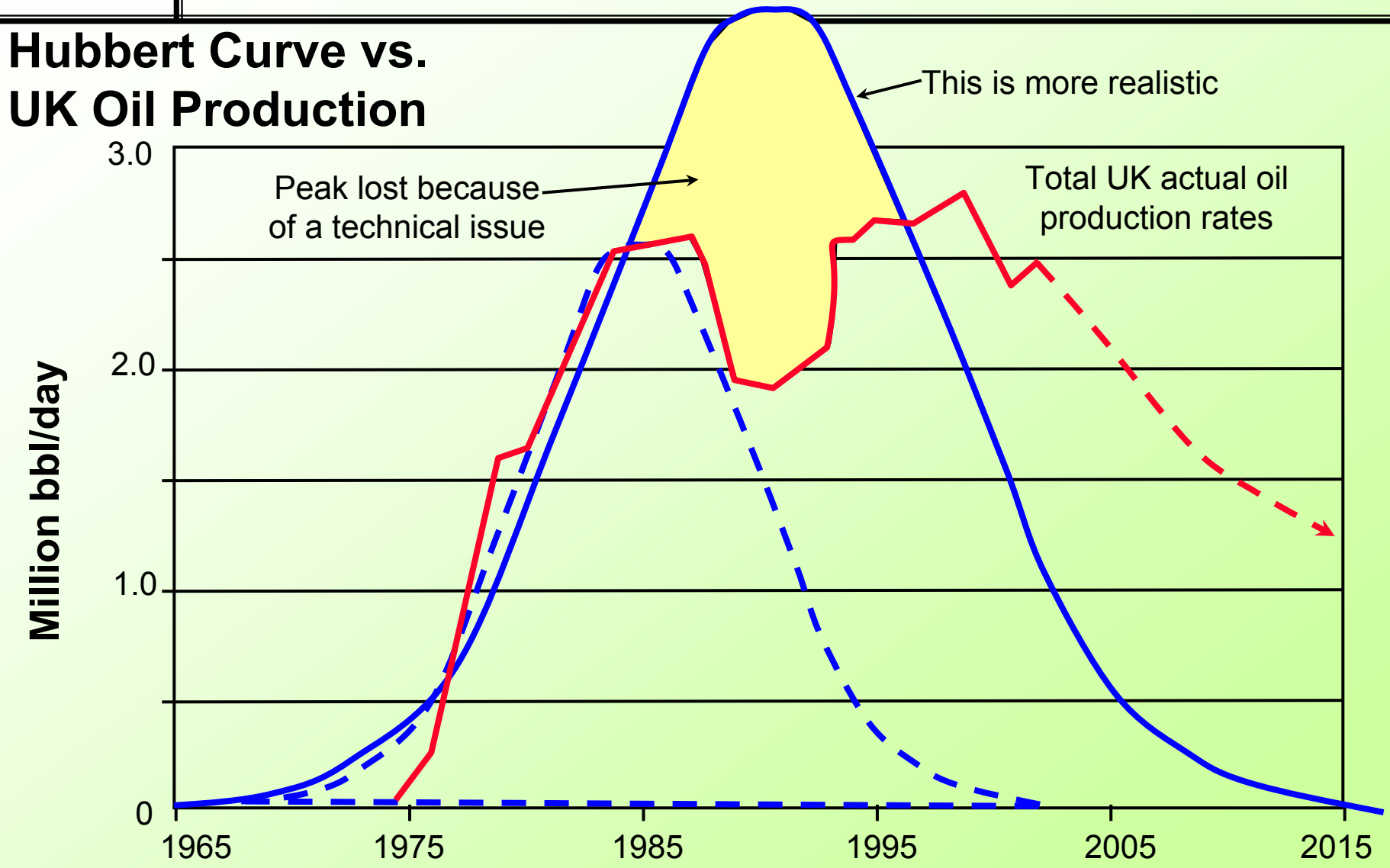
Curves are Never Perfect…



Source: WoodMackenzie historical data, Deutche Bank, 2003

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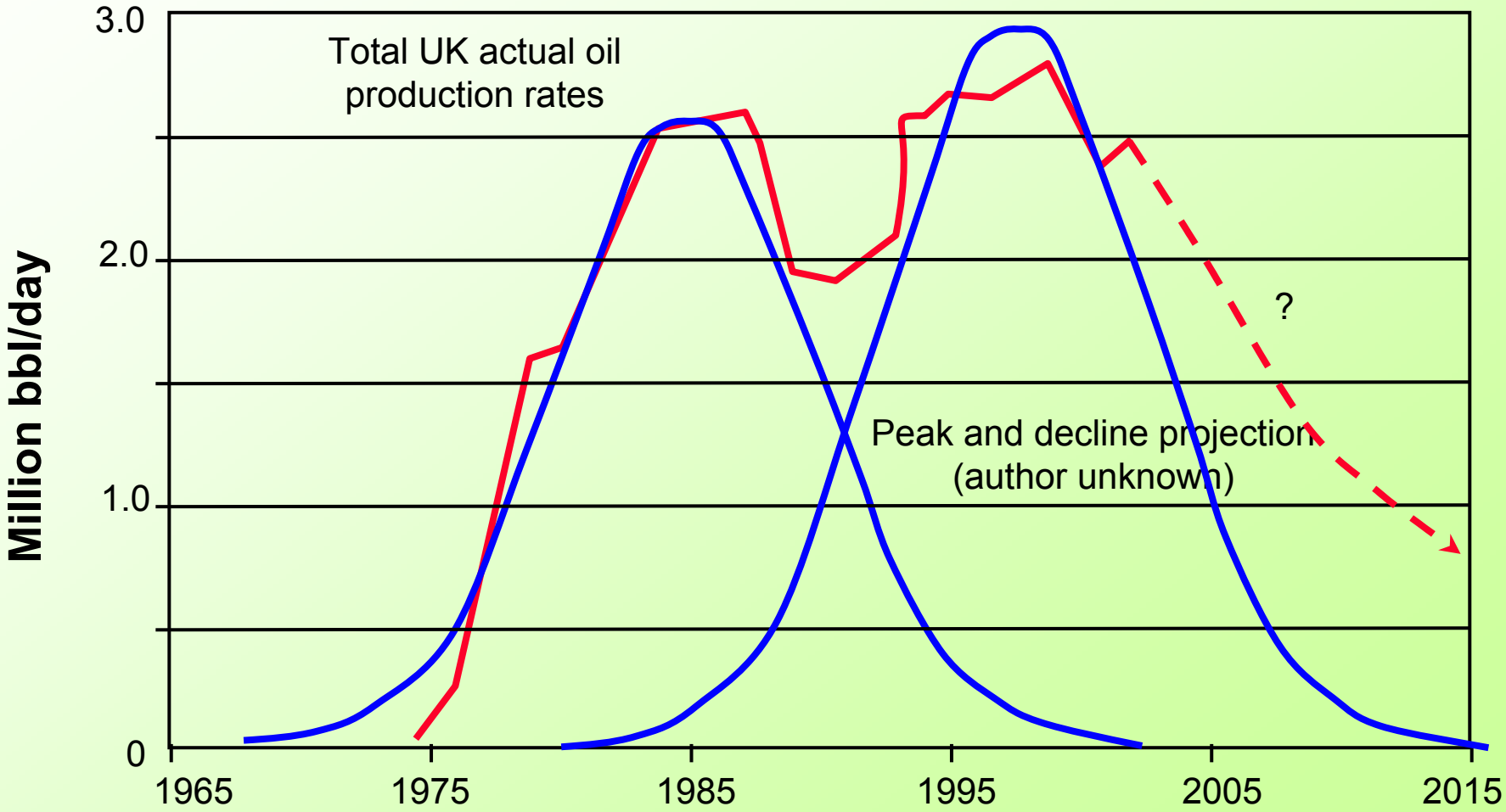
Is the Curve the Sum of Two?

Hubbert Curve vs. UK Oil Production



Source: WoodMackenzie historical data,

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However, Lynch has a Point…

- Even though the UK curve can be "explained"…
- Clearly, URR is not a fixed quantity…
  - Technology will increase it
  - New heavy oil, tar sands reserves to be added
  - Eventually, shale oil will be added
  - Furthermore, oil is not limited by the amount of fossil oil in sedimentary basins…
- We must look at some further concepts and ideas to understand oil supply…

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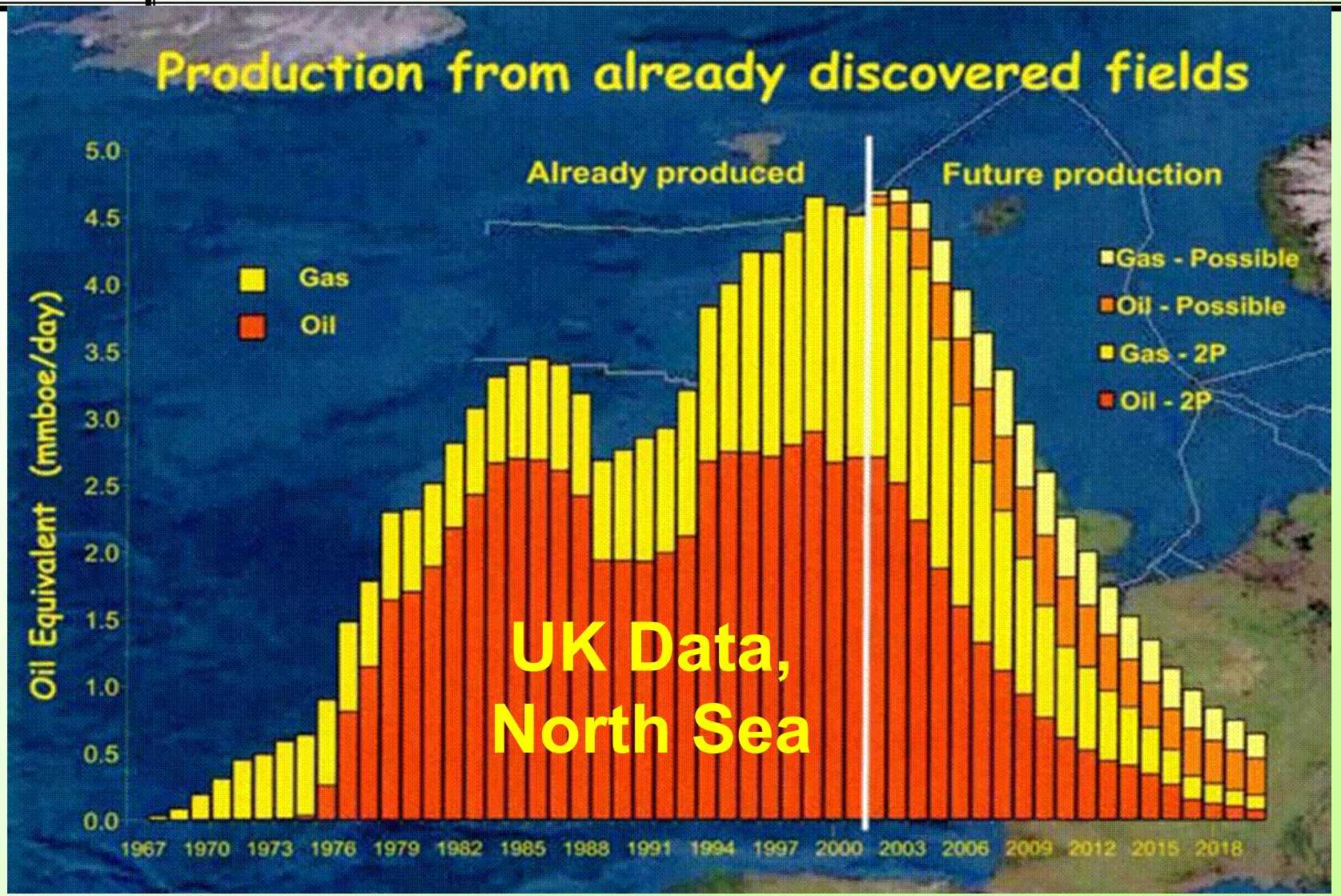
North Sea Oil Production - UK



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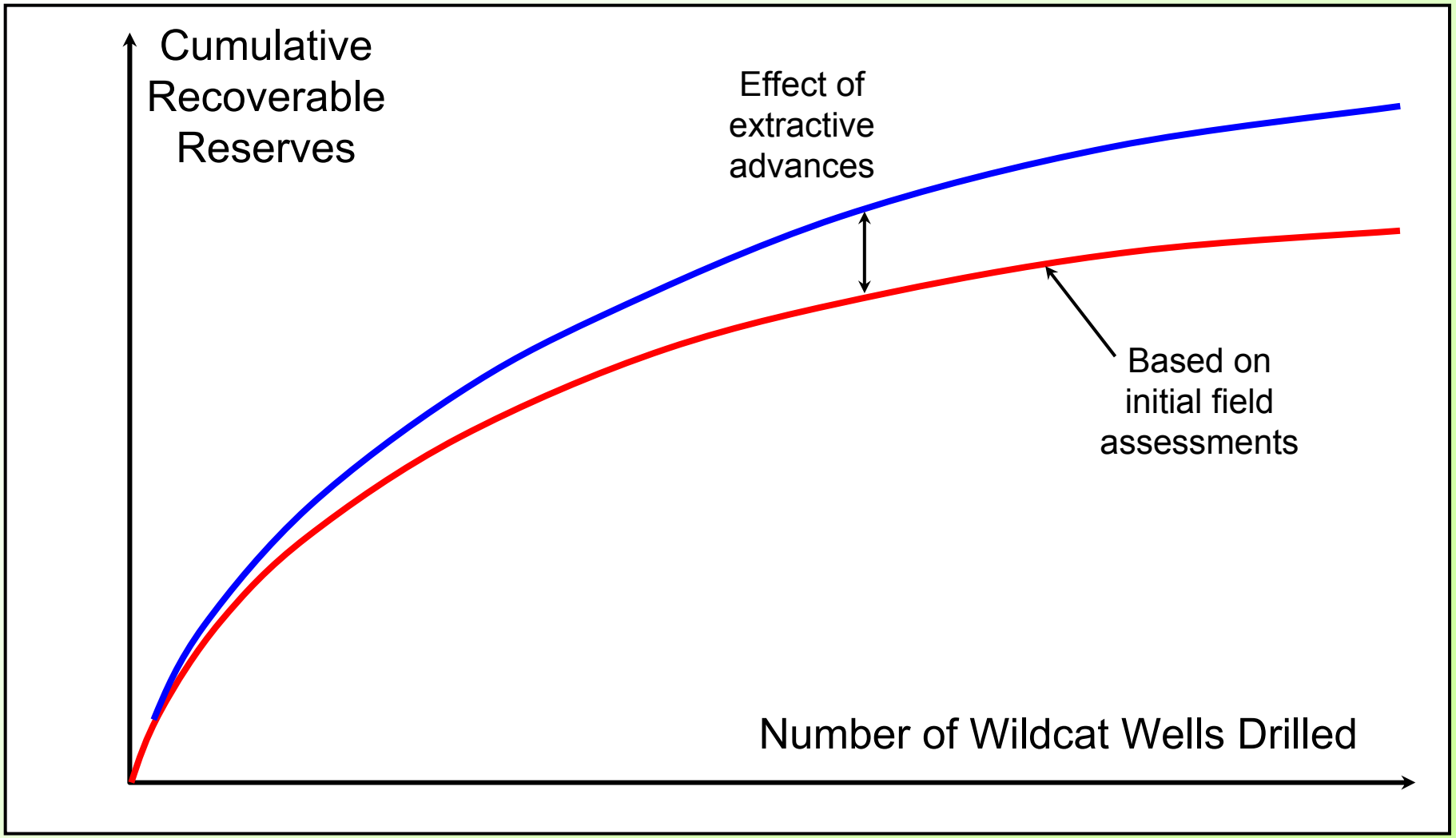
Can We Just Drill More Wells?



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Drilling More Wildcat Wells

- The more wells drilled, the more oil found
- However, the relationship is ~hyperbolic
- As the size of discoveries drops, the Law of Diminishing Returns starts to act
- Exploration costs rise
- New "plays" may temporarily rejuvenate a region, but the overall trend is smaller fields for more drilling
- There is a limit to oil you can "drill for"

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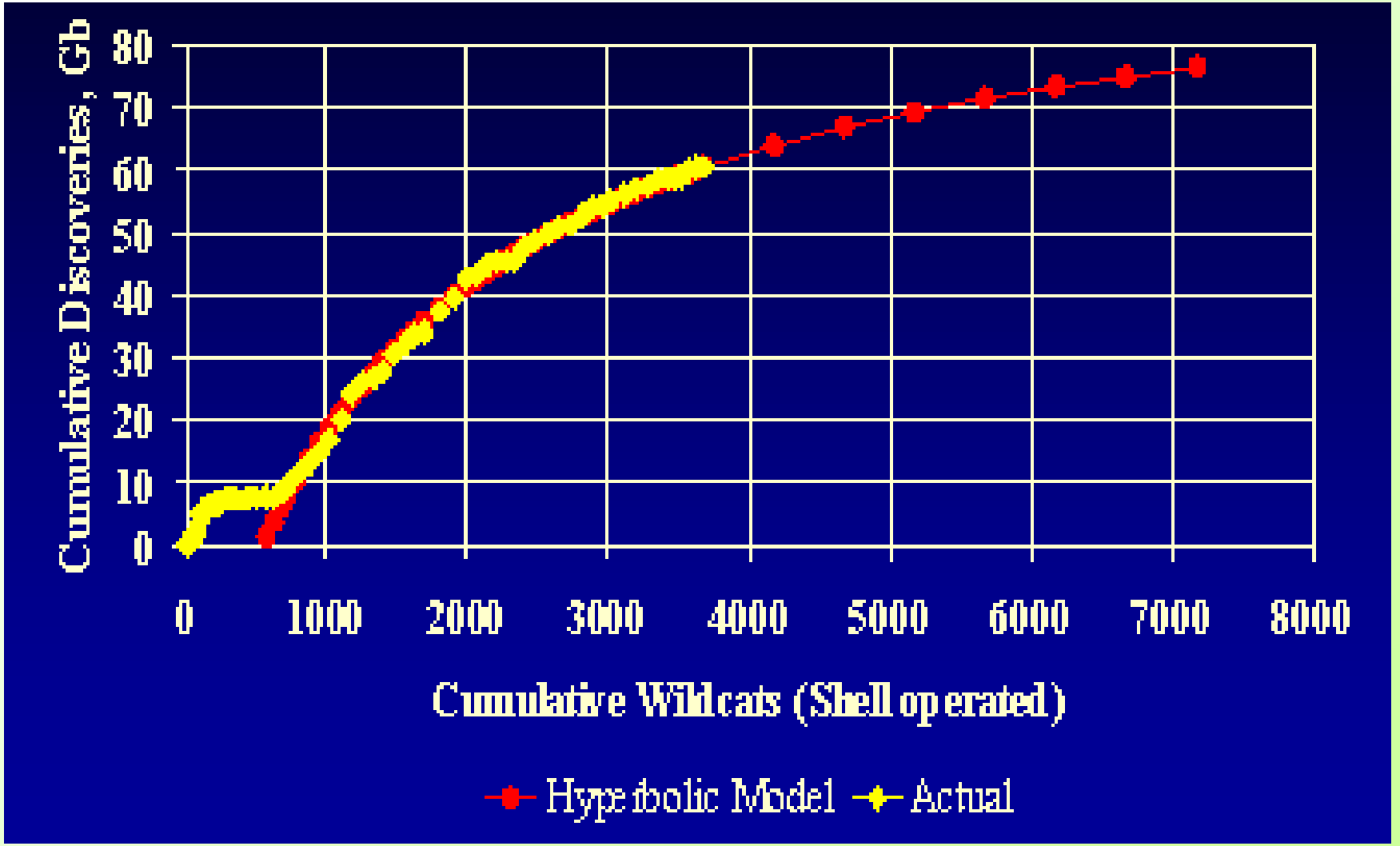
Wildcats and Resource Base



From C. Campbell's Dec 2000 presentation in Clausthal, Germany

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Drilling More Production Wells

- Can we simply drill more producing wells in existing conventional oil fields?
- To a degree this helps, but doubling wells may only add an extra 20-25%, maybe less
- OOIP in a field is a fixed quantity
- Recovery improvements gradually add to reserves, by 20-30% in conventional oil
- This is easily factored into predictions
- Hence, more wells is not a solution

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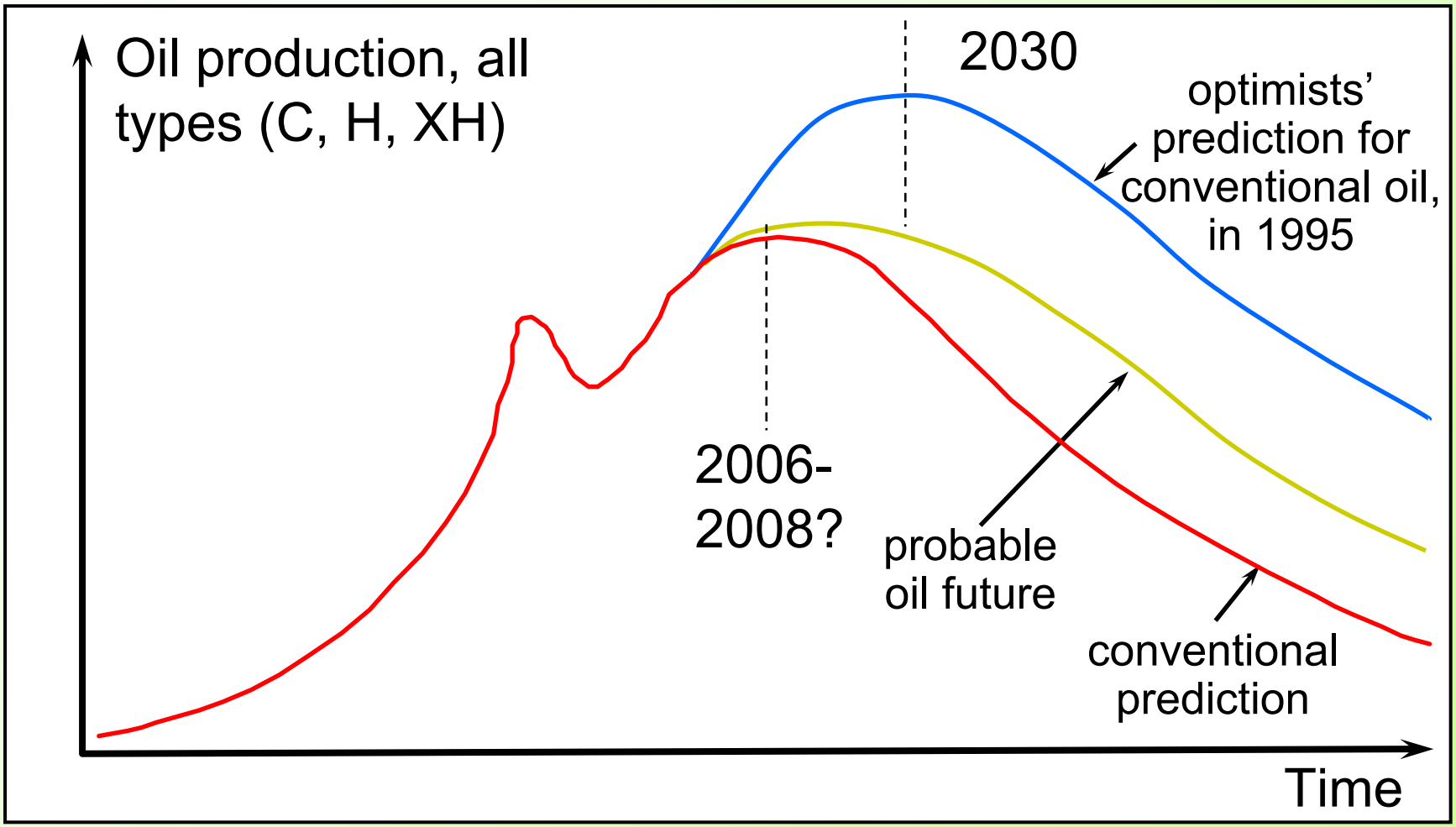
Future of Conventional Oil



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Optimists vs. Pessimists

- Optimists use USGS data (~3 trillion instead of ~2 trillion barrels conventional)
- Pessimists fail to account for the new emerging technologies that will help slow down the decline rate
- However, the "peak" production of conventional oil is imminent (2-5 years?)
- Demand will have to be met by higher prices and heavy oil…
- Let's study some data…

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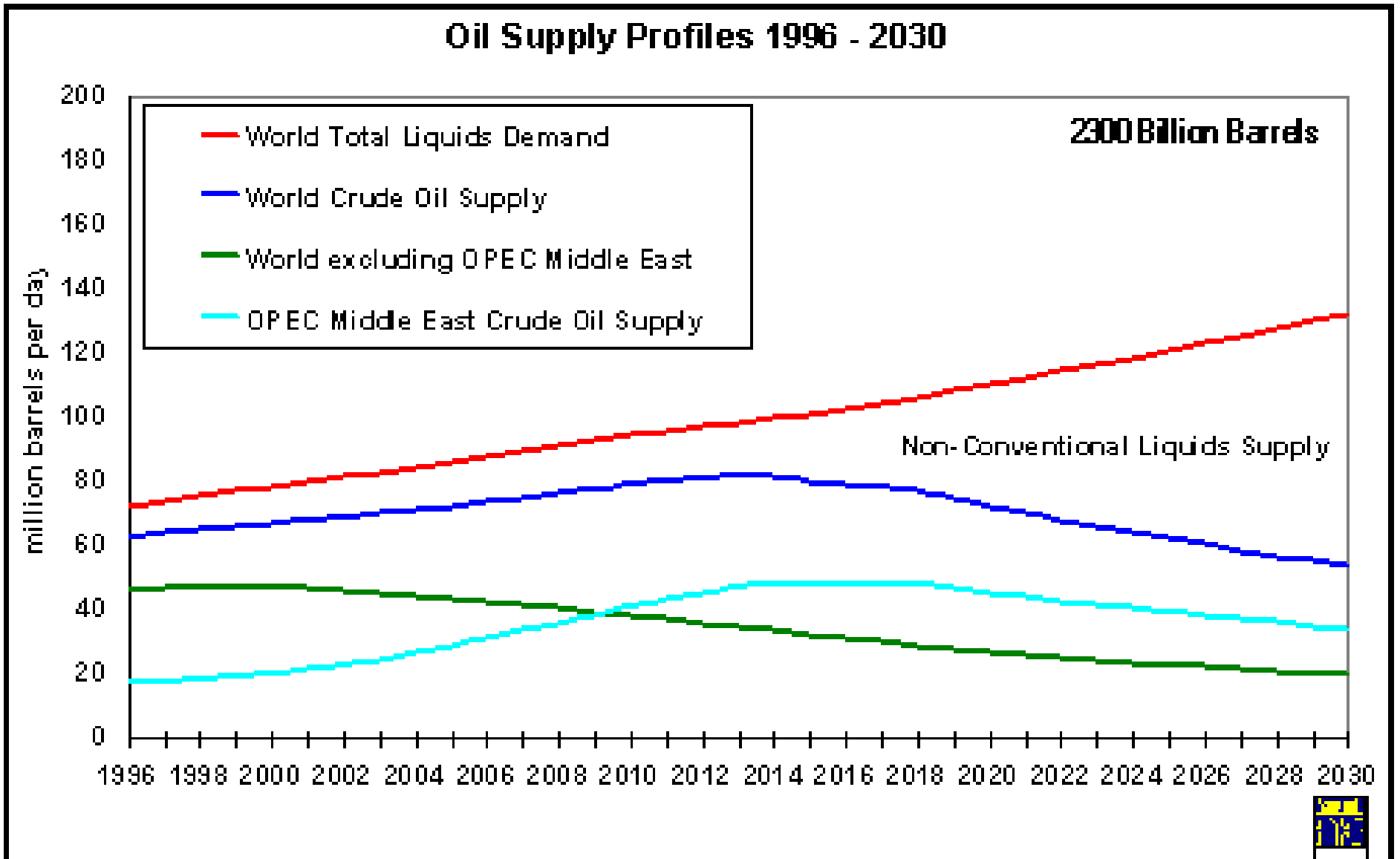
World Oil Supply Predictions…



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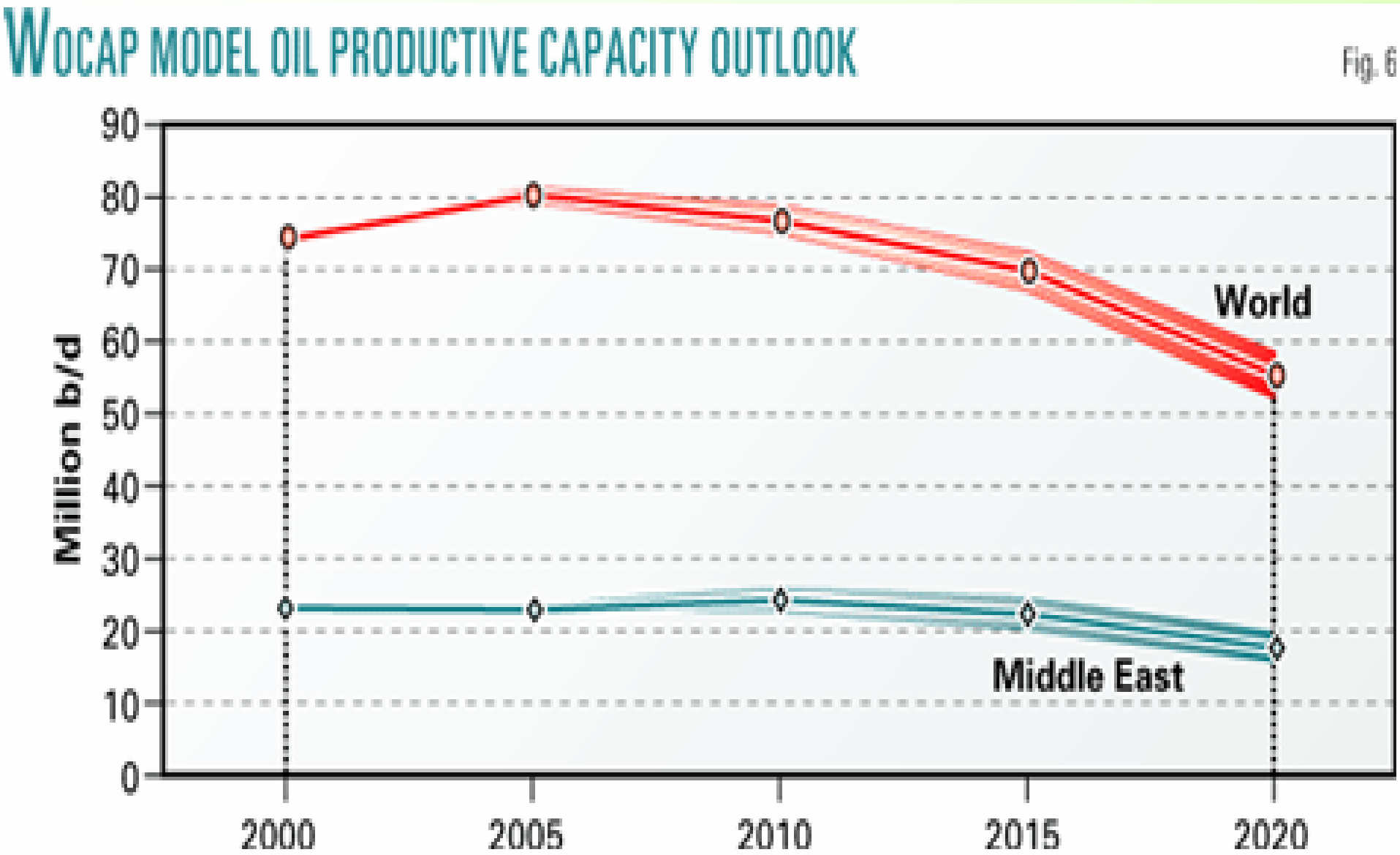
Bakhtiari's Model Predictions…



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Robustness of Predictions

- In a logistics curve for oil, the following behavior seems to apply:
  - Predicting the peak is impossible at early t
  - Once past the inflection point, predicting the peak of the curve becomes increasingly easy
  - Post-peak decline will occur, inevitably…
  - Rate of decline is open to discussion
- Peak in conventional oil production appears to be imminent…
- What happens after is less certain…

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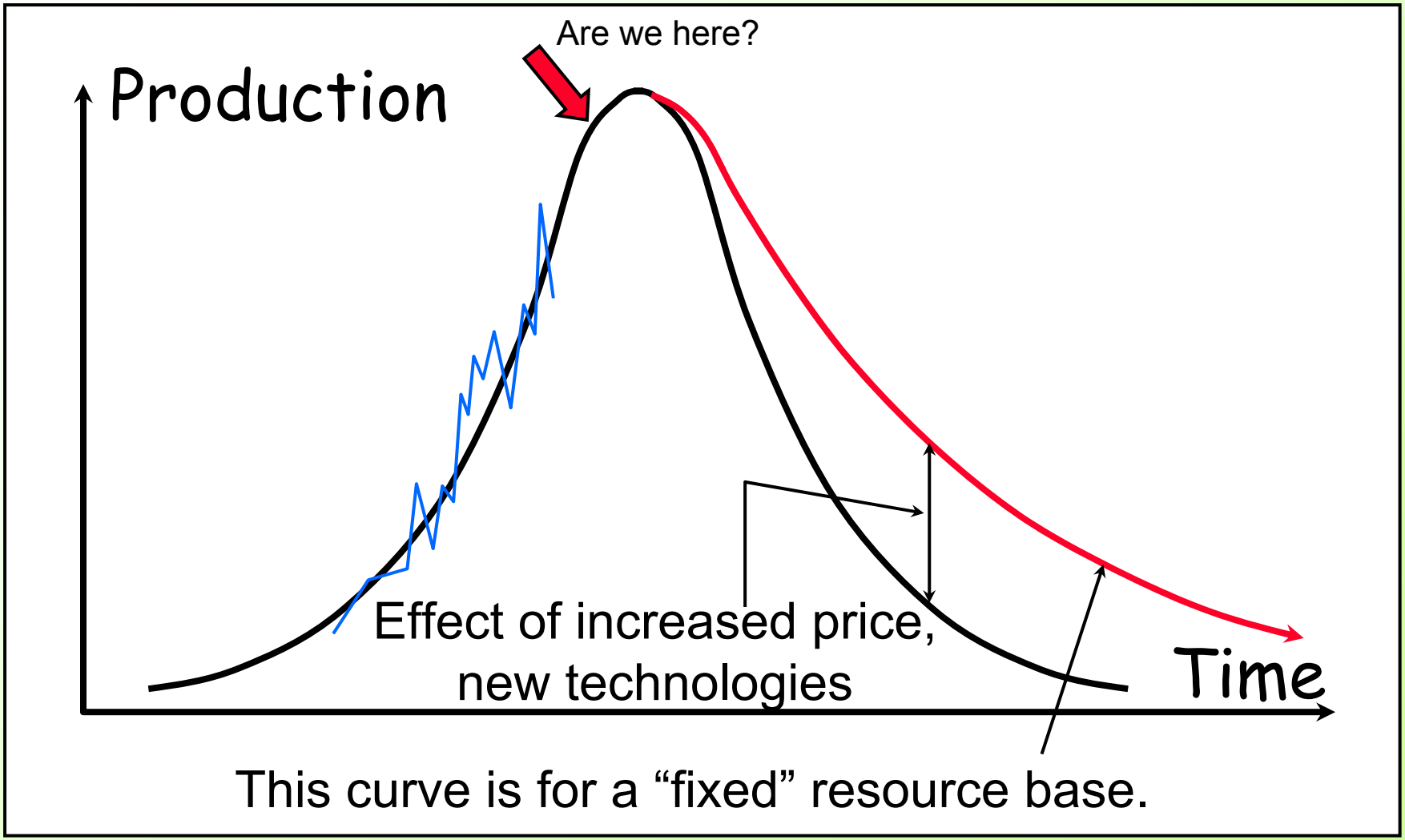
"Hubbert Curves"



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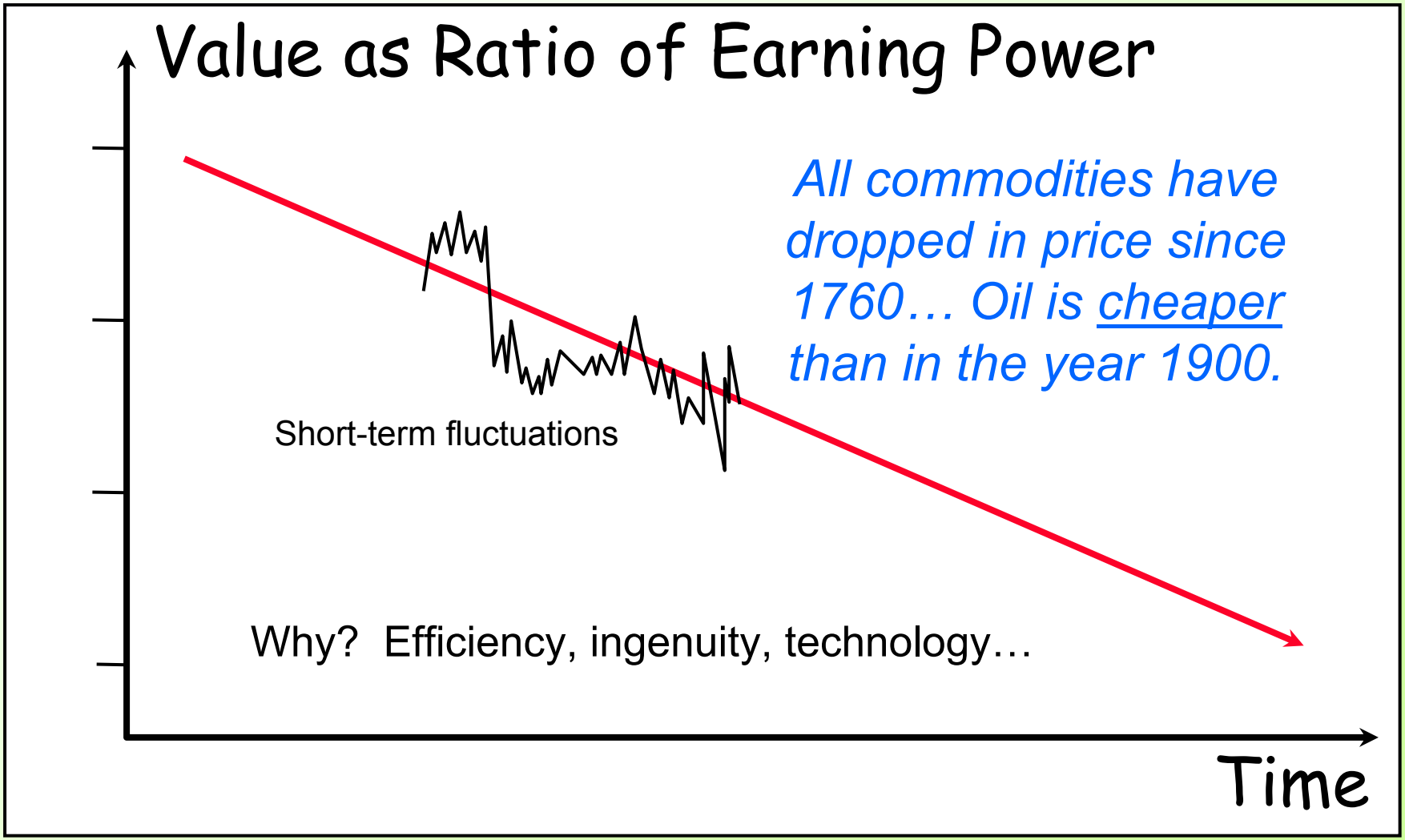
HOWEVER!



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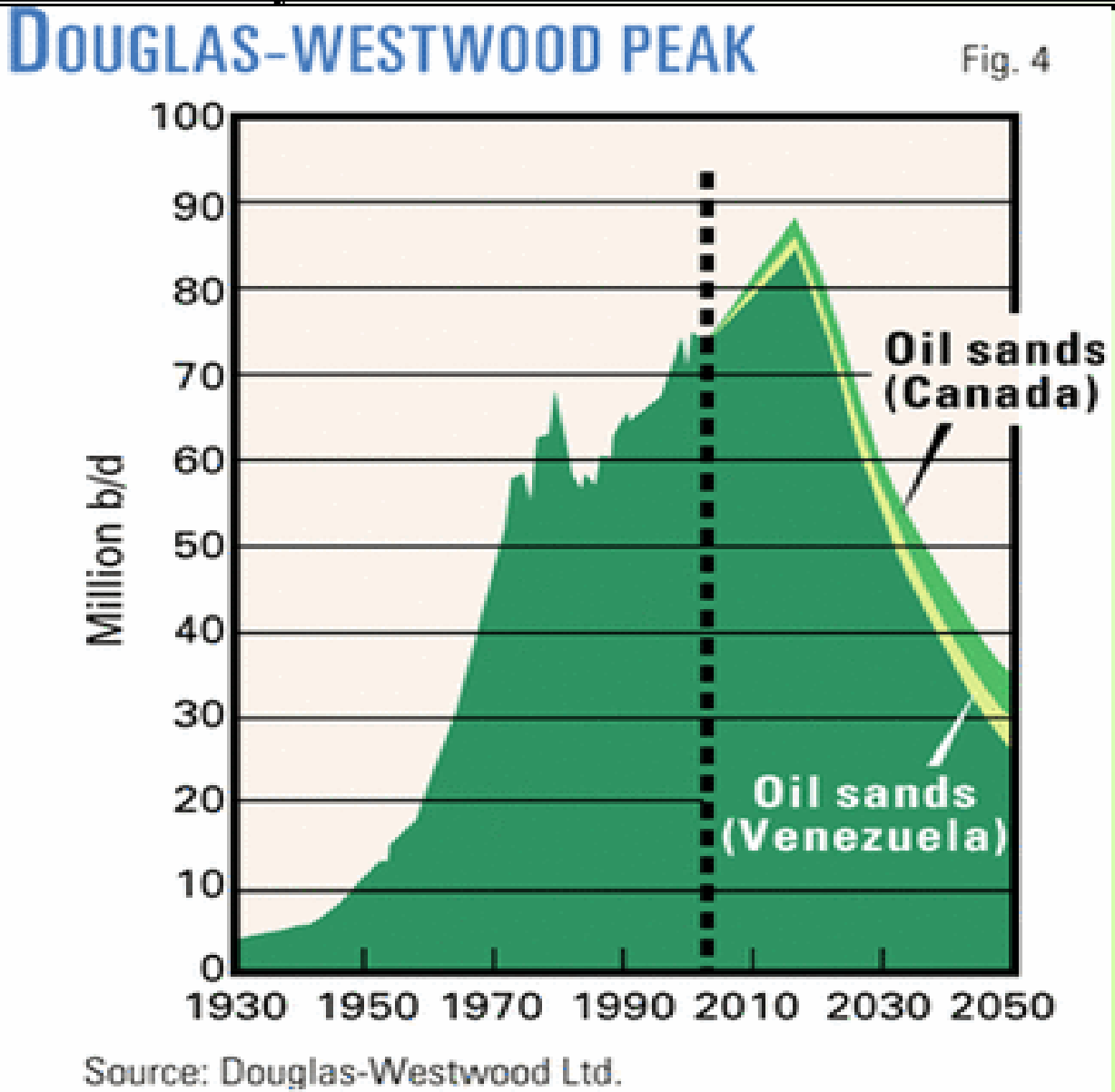
Other's Predictions…



I believe that this underestimates Canadian and Venezuelan Heavy Oil and Oil Sands potential, as well as the potential for other heavy oil deposits in other countries…

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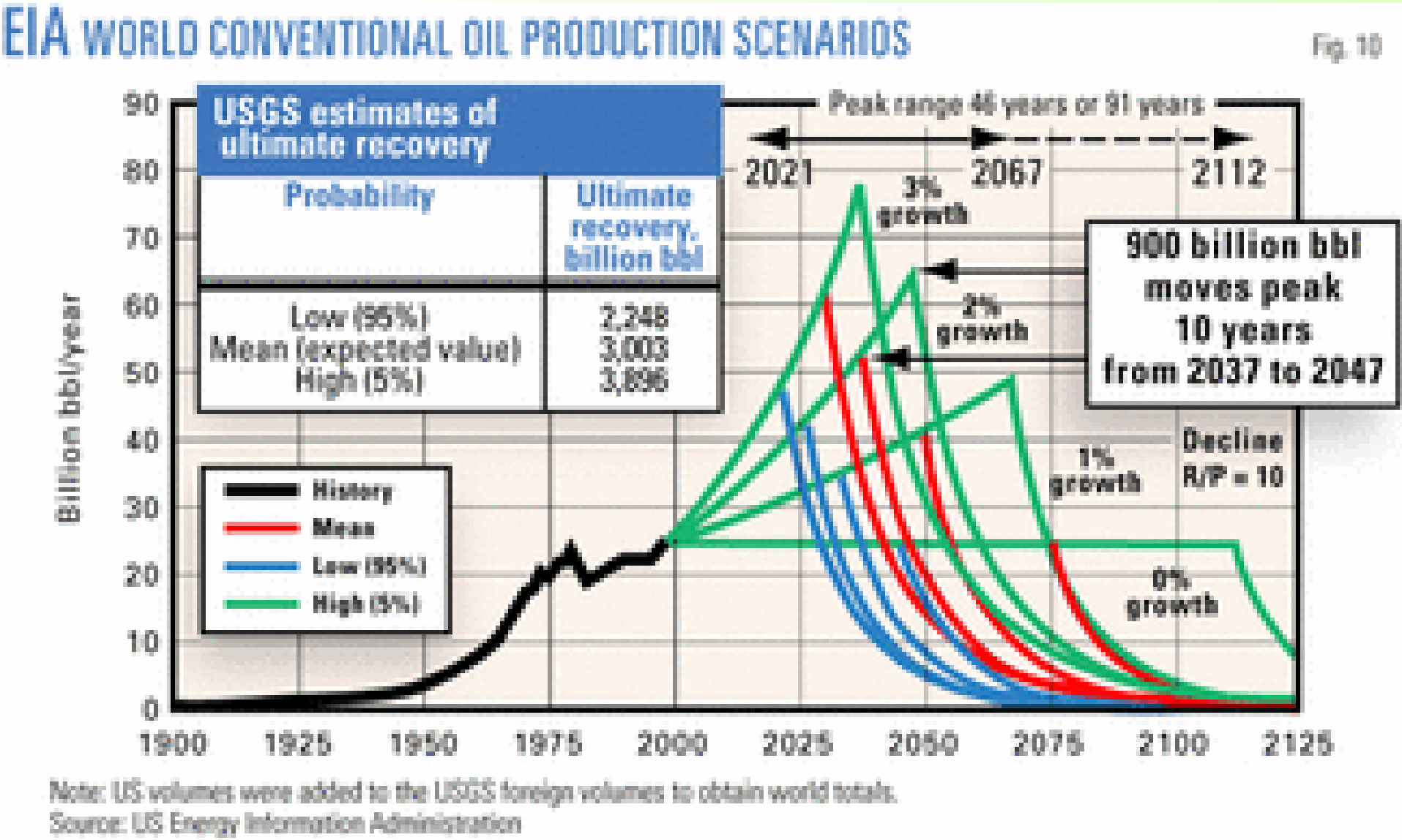
EIA: Perennial Optimists…



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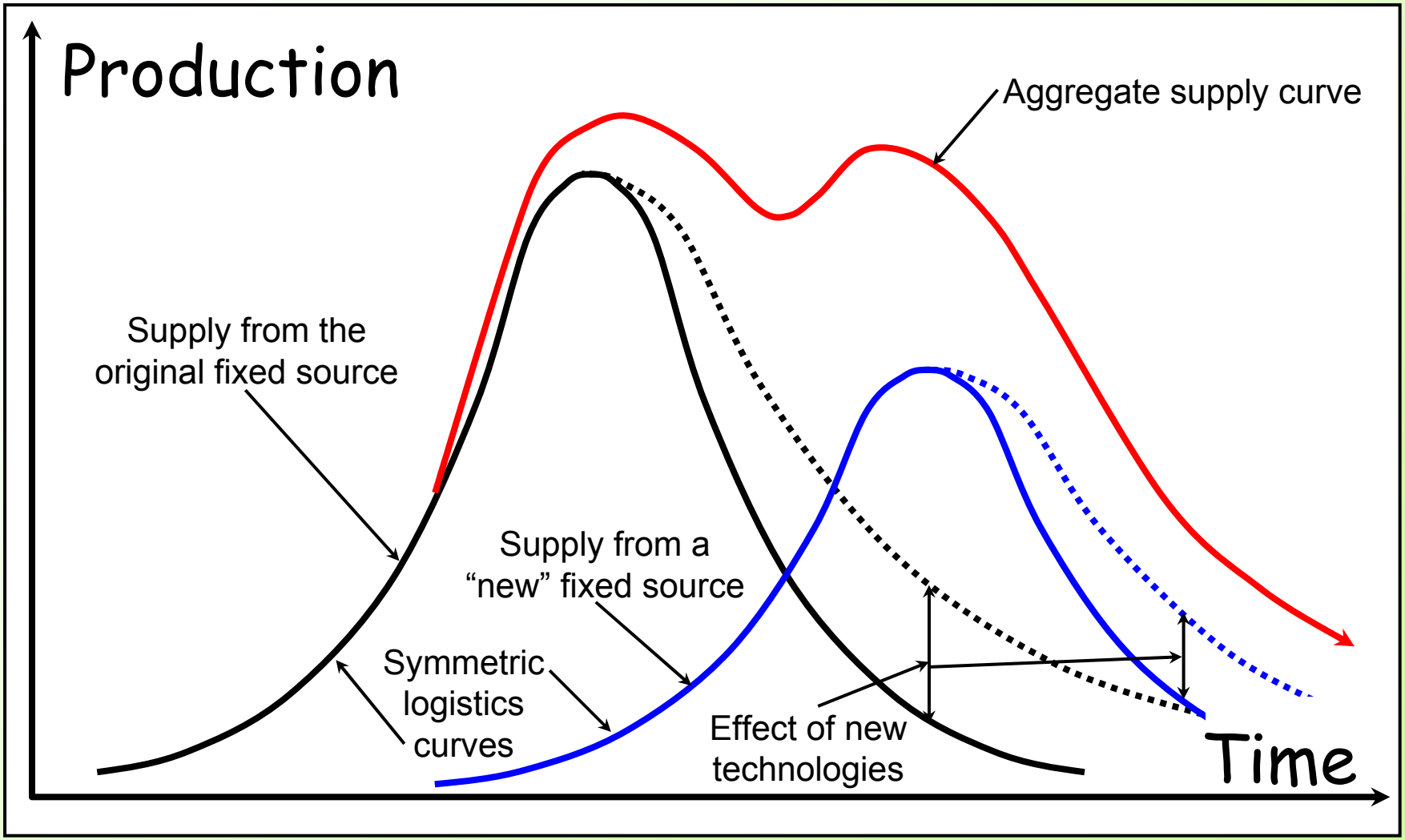
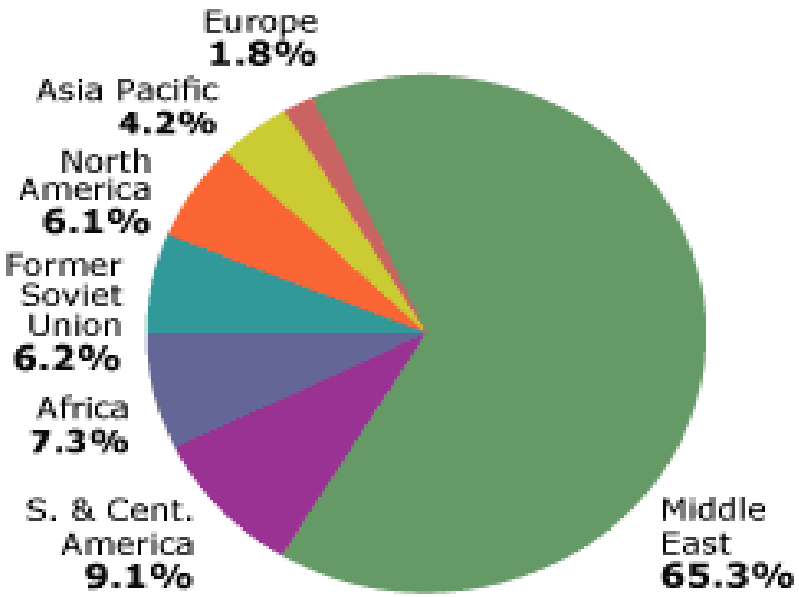
"Hubbert Curves" & "New" Oil



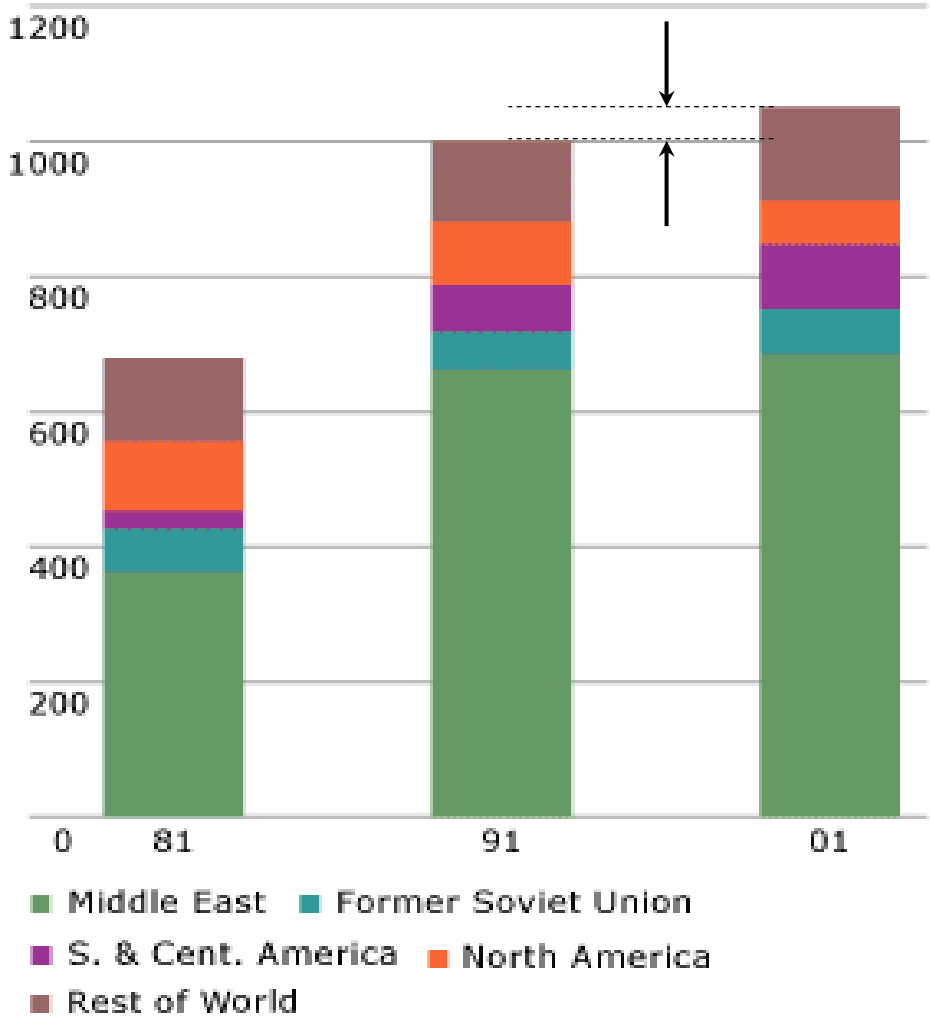
charts of distribution of proved oil reserves 2001

Thousand million barrels %



Thousand million barrels

Note growth, despite production!



(Conventional oil only!!)

BP web site, 2002

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Reserves Growth, Oil Endowment

- Data show reserves growth despite oil use!
- The depletionists "readjust" their curves
- The commodity-ists crow that reserves will increase if the price goes up
  - They assume that reserves growth will increase over time as a function of high prices
  - They assume that there is much more oil to be found if the price is right
  - Are these assumptions correct?

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World Oil Production

- I believe the peak in conventional oil production is imminent (next 2-3 years)
- Peak in total boe will be much later
  - Natural gas replacement effect
  - New production technologies
  - Effect of heavy oil in Canada, Ven., elsewhere
  - Prices will remain high (> $35 average)
- The position justified by careful assessment of all factors is "between" the two camps
- A typical compromise position…

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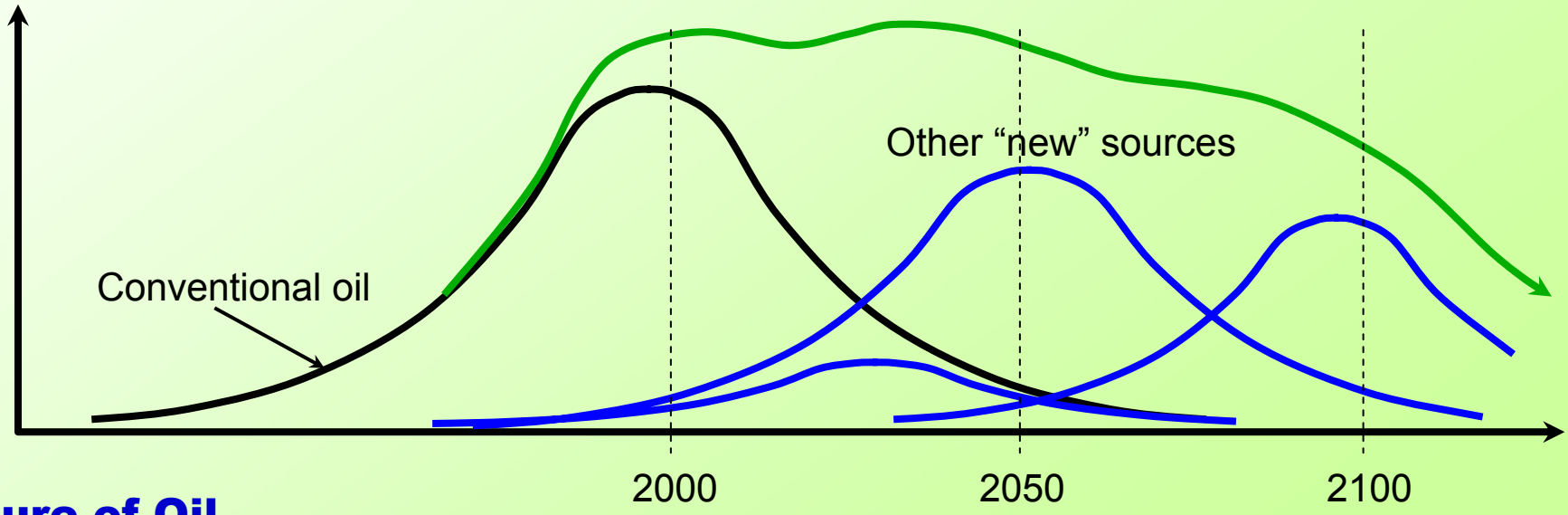
The Whole Picture…

- Conventional oil is a "fixed" quantity
- Heavy oil & bitumen (<20°API) now are recoverable (20-30% of OOIP?)
- Also, …
  - ➔ +Shale Oil, + Coal-to-oil, +CH_4 Hydrates……



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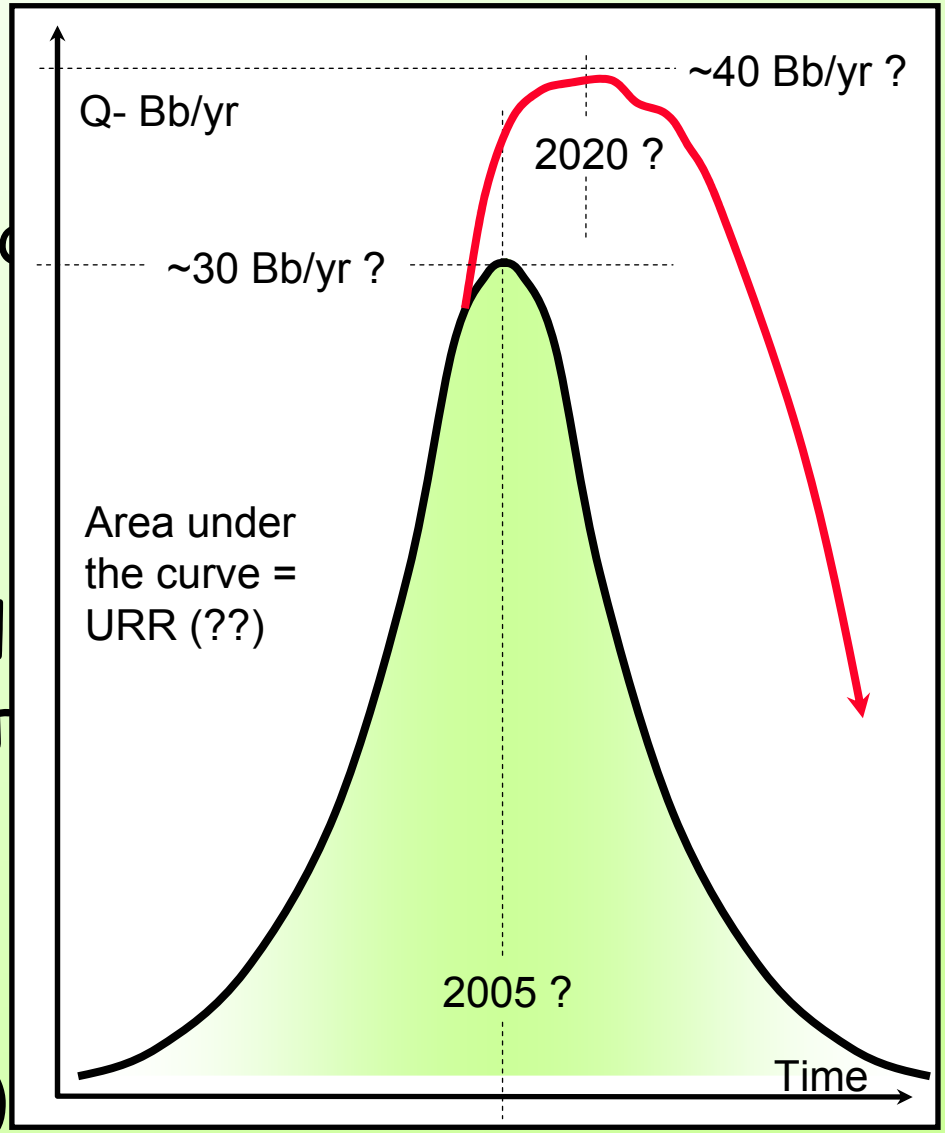
Nevertheless…

- Exploration era at an end
- There will be sustained pressure on oil supply
- Everyone in China and India wants a car!
- There is a fixed fossil fuel resource, it is not infinite as *f*($)
- The era of the "oil factory" is to begin (tar sands, heavy oil…)



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What Are Our Options?

- Conventional oil peak is imminent
- We can make up the difference by developing heavy oil and oil sands
- High prices affect demand (as in 1980's)
- Make oil from CH_4 (not a good idea)
- We can convert wood, plants, coal
- We can go to a H_2 or an ethanol economy
- Carbon may impact future technologies (carbon taxes, sequestration…)
- Other options?

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Limits to Hydrocarbons

- Conventional oil ~ 2% of natural "HCs"
- Heavy oil ~ 3-5% of total HCs
- Natural gas ~ 3-8% of HCs
- Coal + shale oil ~ >50% of non-gas HCs
- Methane hydrates may comprise >30%!
- We can synthesize oil from coal, wood…
- We can make oil from elements (C + H)!
  - e.g.: H_2 from electrolysis (solar power)
  - C from various sources, then combine them!

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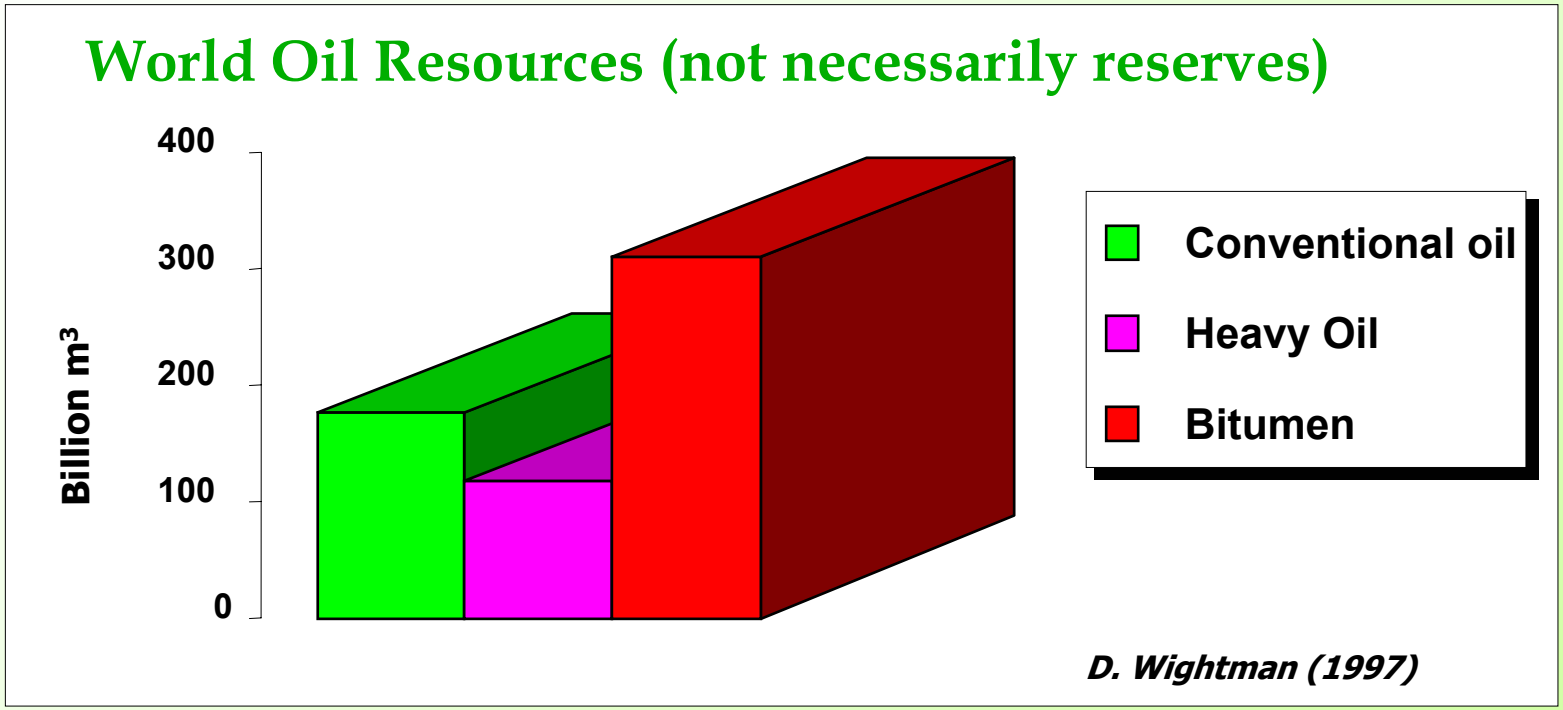
How Much Fossil Oil is There??



- Saudi Arabia claims ~40 billion m^3 (#1 in 2000)
- With New Heavy Oil Technologies, Canada claims >35 billion m^3 of reserves (new #1 in the future?)

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New Fields in Basins

- The largest fields are the "easiest to find", and are therefore discovered first
- Most of the World's recoverable light oil is found in the 50 largest fields
- There is an economic limit to the size of field that can be economically developed
- Technology, high price can alter economic limits, but can't create more oil in a basin
- So, the depletionists have a good point
- IOR = economics; Primary = geology!

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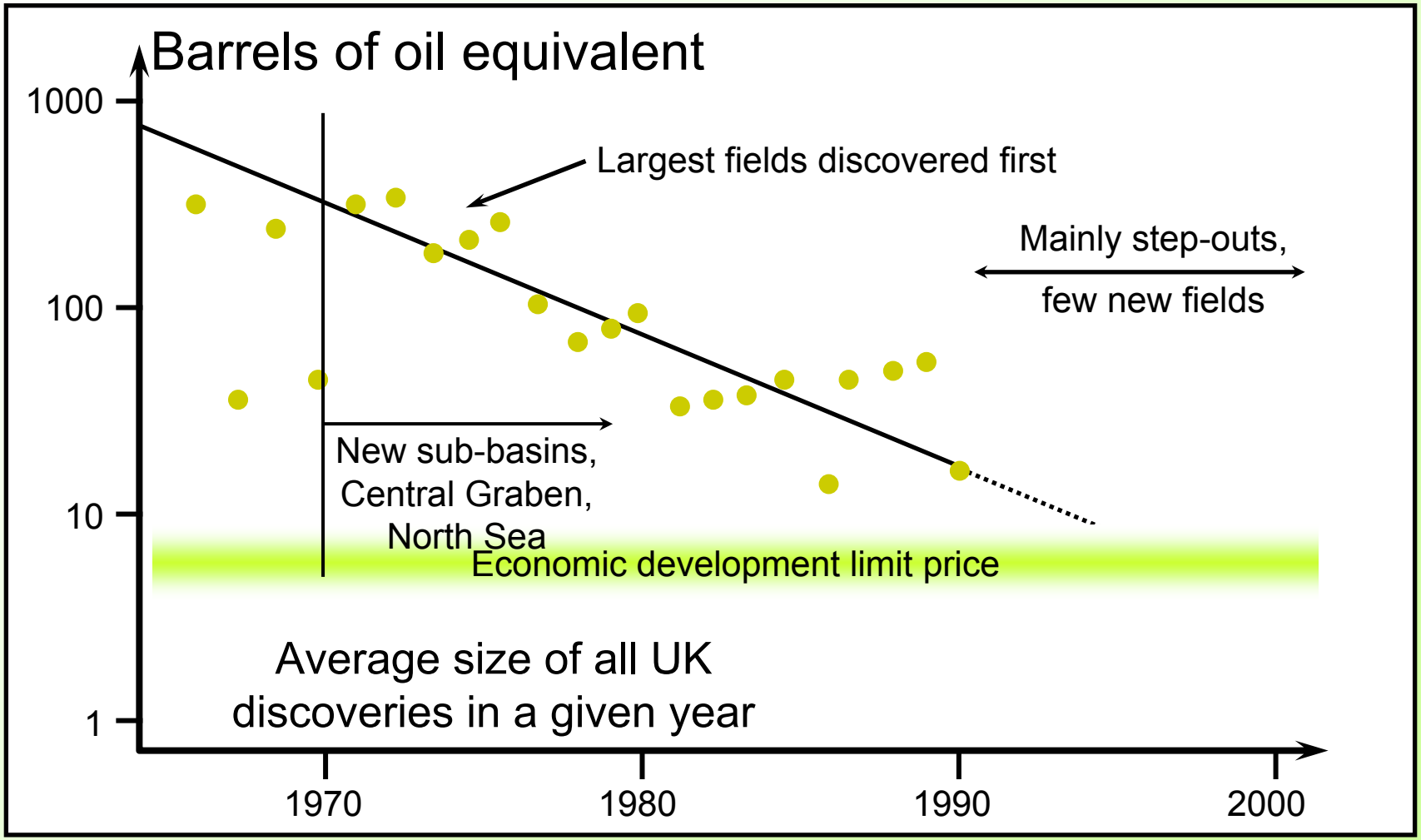
Typical Basin Discovery Pattern



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Oil Sands – Canada and Venezuela

Core from Venezuela

Weathered surface looks almost white

Oil sand slopes in Canada

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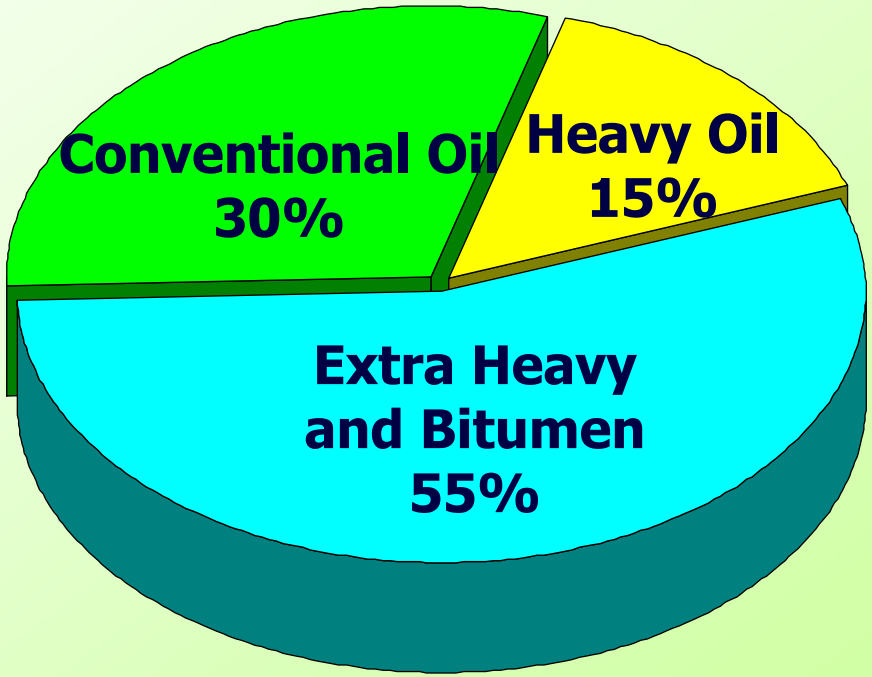
World Oil Endowment

Probably the total endowment is 11-13 trillion barrels Venezuela and Canada together have ~35% of this. The key question is: How much is recoverable? How much can we reasonably book now as URR? Will this grow?



Source: MacGregor, 1996 and UNITAR, 1998

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But, Will Oil Run Out?

- Natural cheap conventional oil must run out
- But, oil from heavy oil deposits, shale, coal conversion… depends on $ + technology
  - At $25/BBL, heavy oil is quite profitable
  - At $45/BBL, oil from coal (SASOL), gas?
  - At $55/BBL, shale oil projects?
  - At $85/BBL, wood conversion is possible!
  - At some price, gasoline from chemistry (C+H)
- Oil is thus "**infinite**", depending on price

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Middle East Oil…

GUEST COLUMN

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Oil is NOT Like Gold!

- Fixed gold amount in the earth's crust
- Richest mines are always exploited first
- Can't create gold
- Gold is stored as well as used (i.e. a buffer against high prices)
- Gold cannot be destroyed (in principle, always recyclable)

- Only fossil HC is a "fixed" quantity
- Politics often dictate differently (e.g. USA)
- Oil can be "created"
- With minor exceptions all produced oil is consumed, no storage
- Oil is destroyed when used, and cannot be recovered in any way

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Let's Make Oil

- Biodiesel (Canola converted to diesel, good for Canada, but for the environment??)
- Coal conversion
- Destructive distillation of wood
- Ethanol and methanol (poor fuels because of low combustion temperatures)
- Jojoba bean…
  - High oil content, grows in salty arid soil
  - Future generations → large oil farms

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Hubbert, etc.

- Hubbert was right, to a point
- Economists are right, to a point
- We will never run out of oil because we can grow it (oil from wood, biodiesel)
- We are running out of cheap conventional oil, but heavy oil and oil sands will massively cushion the shock
- There are limits to long-term oil price, set by the "next cheapest technology"…
- Permanent $100/bbl oil? Likely never…

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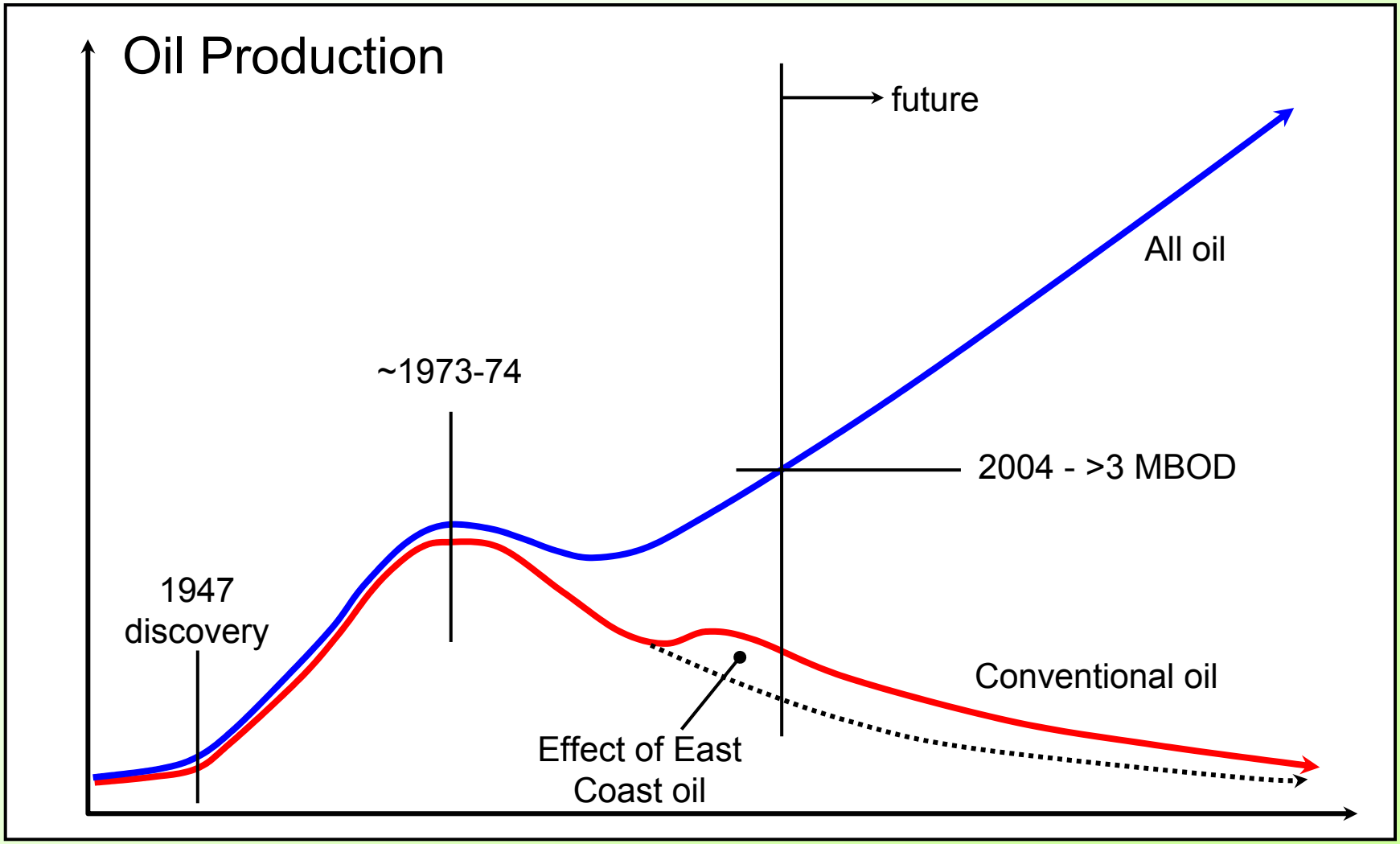
Canada's Oil History



Future of Oil

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World HO in Place

- Venezuela ~ 1.4 trillion barrels
- Canada ~ 2.0 trillion bbl
- Other countries – less heavy oil
- With new and future technologies for heavy oil, Canadian optimism is warranted:
  - Reasonable 20% recovery (existing methods)
  - Perhaps 30% recovery (evolving methods)
  - Eventually 40% recovery (+future methods?)

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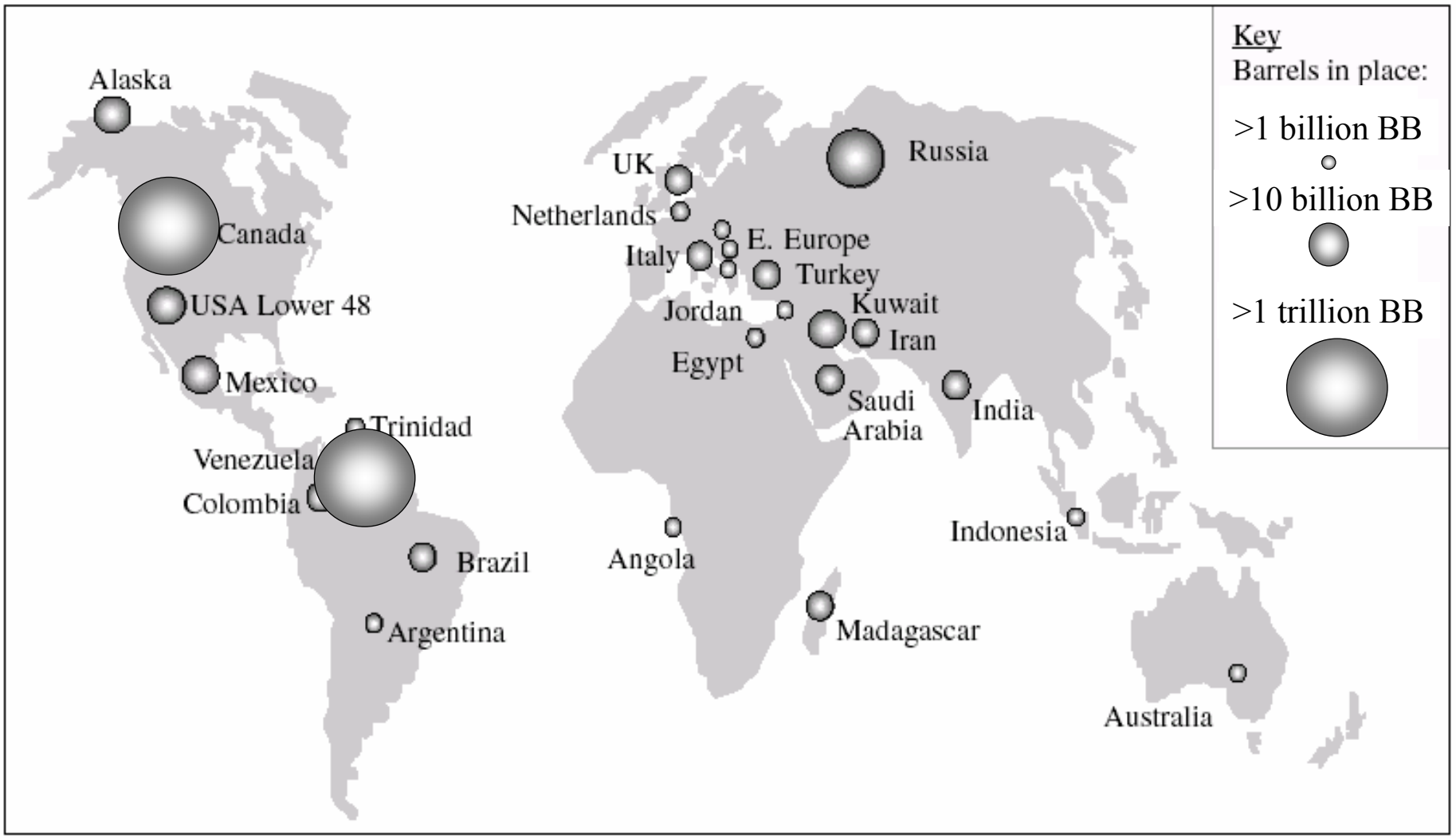
Where is the Viscous Oil??



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The Big Resource Holders…

- Canada ~2.0 x 10^{12} bbl
- Venezuela ~1.4 x 10^{12} bbl
- Russia ~0.4 x 10^{12} bbl (?)
- Others (total) 5-6 x 10^{12} bbl (?)
- Compare these with the 2.1 x 10^{12} bbl estimated recoverable conventional oil
- If 20% heavy+ oil can be recovered economically = conventional resource size
- Clearly, technology impact is large

map of proved oil reserves at end 2001

Thousand million barrels

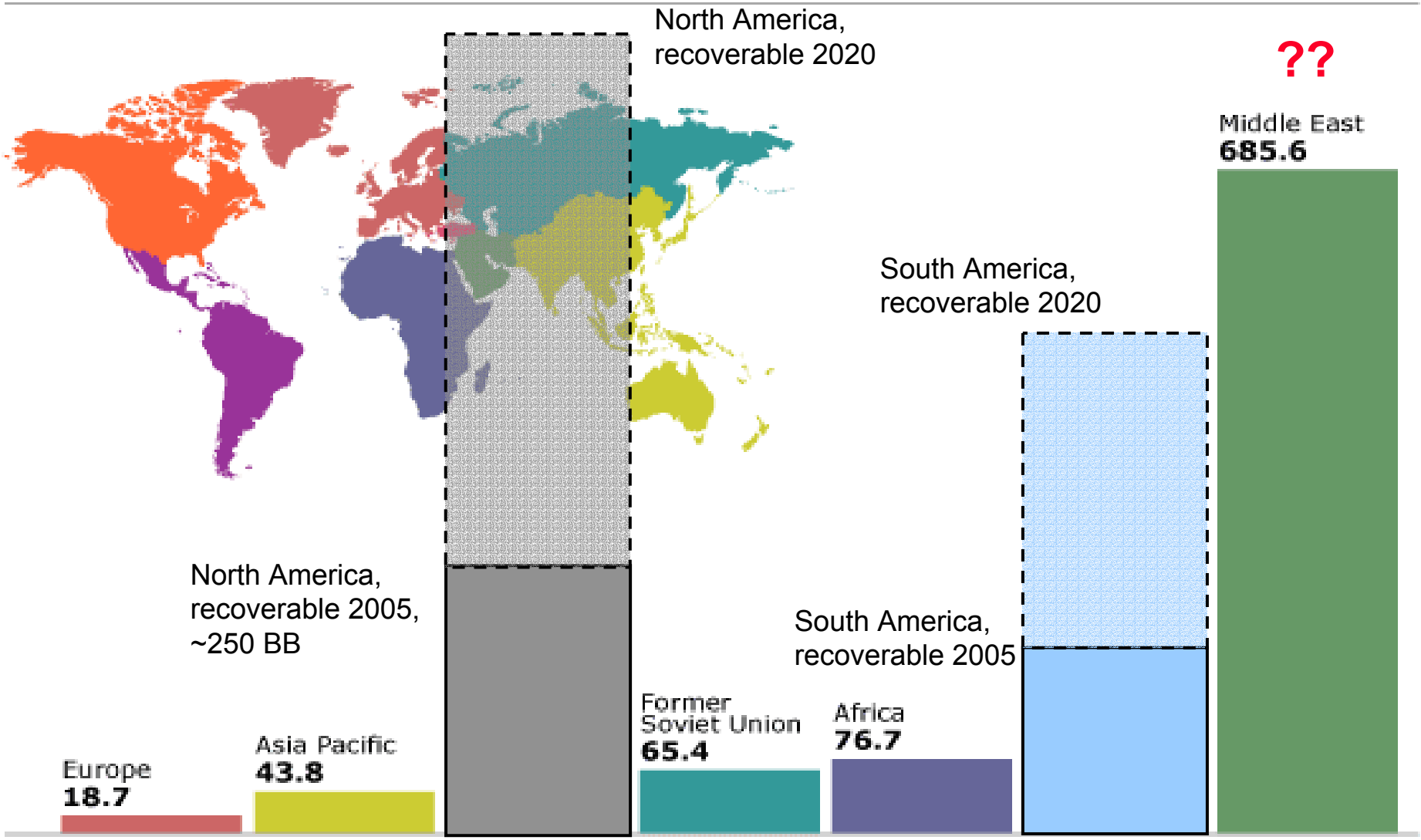
The Old Reality

(Conventional oil)

BP web site, 2002

map of proved oil reserves at end ~~2001~~ ~2005

Thousand million barrels



The New Reality

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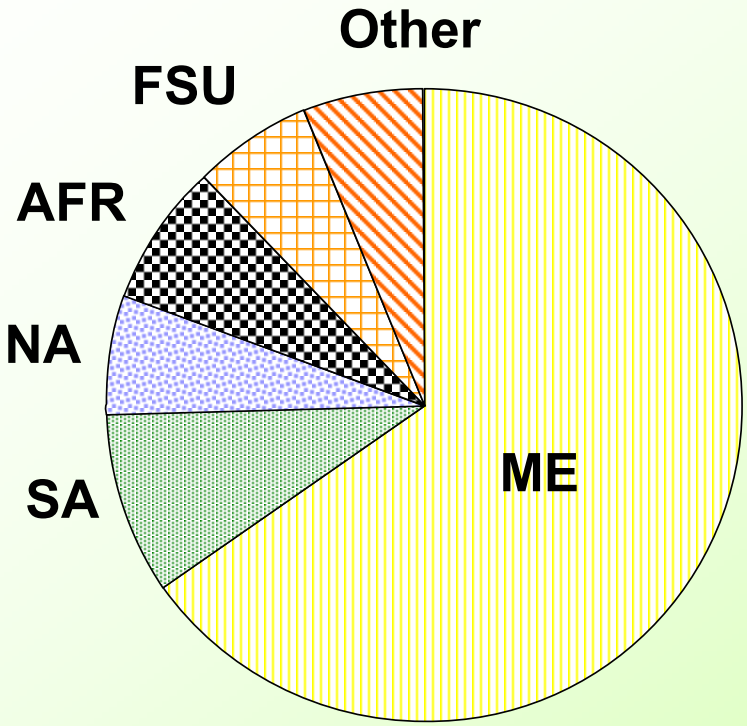
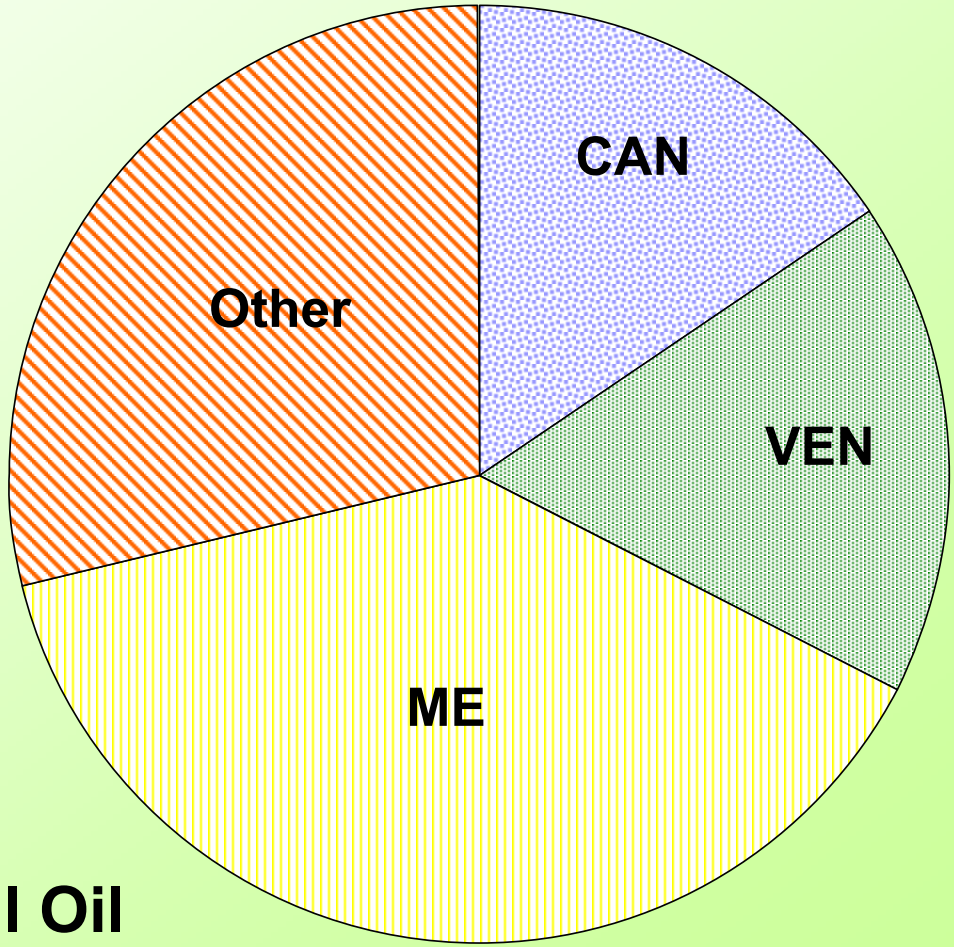
World Recoverable Oil Disposition



Conventional Oil
~1-1.5 × 10^{12} B



All Oil
~2.5-3.5 × 10^{12} B

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Further Comments

- Many countries (Libya, Saudi, Iran…) are currently not interested in heavy oil
- Likely, their reserves of heavy oil are underestimated
- The great majority of the heavy oil is found in high-porosity, unconsolidated sandstones
- The great majority are relatively shallow (<1500 m depth)

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Canadian Heavy Oil & Bitumen…

Project	2004 Prod	2012 Prod
Syncrude	235,000 b/d	>500,000 b/d
Suncor	240,000 b/d	>500,000 b/d
Shell Muskeg	>110,000 b/d	>300,000 b/d
2 other mines	0	~400,000 b/d
SAGD projs.	80,000	>500,000 b/d
Others (CSS, CHOPS…)	850,000 b/d	1,200,000 b/d
	~1,500,000 b/d	**>3,400,000 b/d**

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Implications for North America…

- Assume 30% of Canada's resource can eventually be extracted
- Assume stable US + CAN consumption at 20 MBOD (daily ~ 27% of world in 2000)
- Assume 2.0 trillion BO in place
- This can meet 100% of USA and CAN consumption for the next ~80 years
- **Thus: We are only running out of cheap conventional oil, not oil *per se*…**

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Oil Predictions…

- Conventional oil will peak in ~2004-2008
- Total oil consumption (+NG liquids, heavy oil, synthetic, …) later (2010 – 2020?)
- Flat plateau in period 2015 – 2030 at about 5.5-5.8 Bm^3/yr (peak ~100 Mb/d)
- In ~40 yrs, all major oil companies will be mainly heavy oil companies
- In ~40 yrs, Canada & Venezuela will be among the world's top three oil producers

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Oil Predictions…

- The era of finding "Elephants" is over
- The "exploration era" is largely over
- The era of technology-driven oil company activity will soon become dominant!
  - New production technologies
  - The "Smart Reservoir", carefully monitored…
  - New refining and upgrading for low H oils
- Companies who quickly acquire good heavy oil properties and technology will prosper.
- Your grandchildren will drive "oil" cars

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Energy Predictions… (~2050)

- Nuclear will be "reborn" (no CO_2)
- Coal-to-energy conversion, no emissions, will be perfected (2025 - 2040)
- Hydrogen fuel cells will be limited to "city cars", and will not revolutionize the world
- Ethanol will be a modest source of energy
- GMO plants that have high oil content
- We will still be arguing about CO_2, oil…

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Argentina…

- Little upside potential in conventional oil
- However – new IOR methods!
- The time to start HO development is now
  - Quantify the reserves & their quality
  - Establish an Applied HO R&D facility
  - New technology demonstration projects
- Change the royalty structure for HO
- These efforts will help a "soft landing"
- Energy subsidies are very dangerous