Running out of and into oil: *Analyzing Global Oil Depletion and Transition Through 2050*

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Are we running out of oil?

- **“Pessimists” aka “Geologists”**
  - **Geology rules**
  - **Discoveries lag production**
  - **Peaking, not running out matters**
  - **Expect peak by 2010**
- **“Optimists” aka “Economists”**
  - **Economics & technology rule**
  - **Rate of technological progress will exceed rate of depletion**
  - **Market system will provide incentives to expand, redefine resources**
  - **Stone age did not end for lack of stones**

What if one took the optimists' view point, but quantified it?

- **How much oil remains to be discovered?**
- **How fast might technology increase recovery rates?**
- **How much will reserves grow?**
- **How fast will technology reduce the cost of unconventional sources?**
- **How much unconventional oil is there and where is it?**

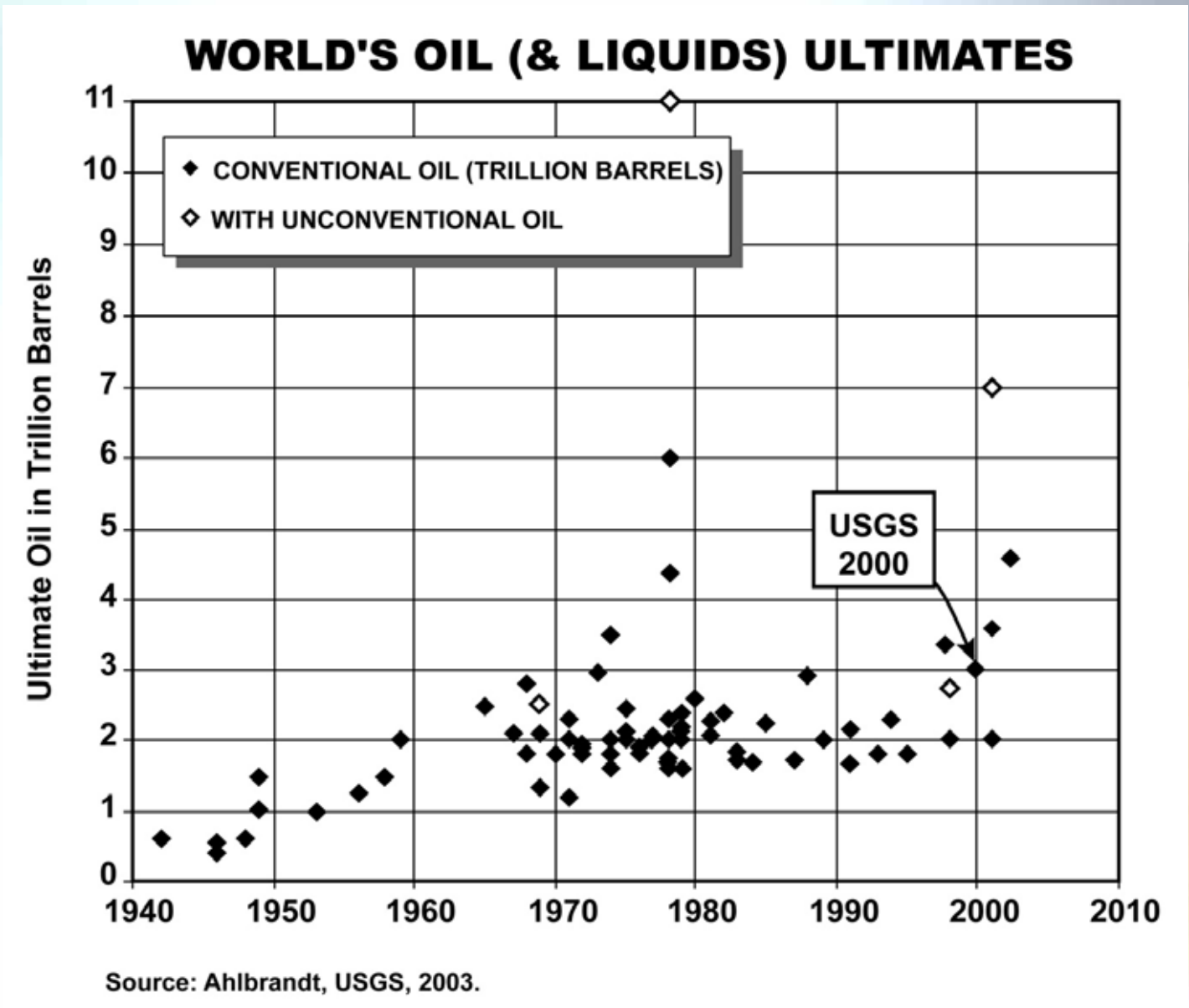
This optimists' approach is… optimistic.

- No Hubbert's curves
  - No geologic constraints on production rates
  - Costs do rise with depletion, however
- RESOURCE/Production ratio limits expansion of production
  - Analogous to a limit based on life of capital
  - No explicit calculation of capital investment
- No environmental/social/political constraints on production
  - ANWAR, etc. fair game

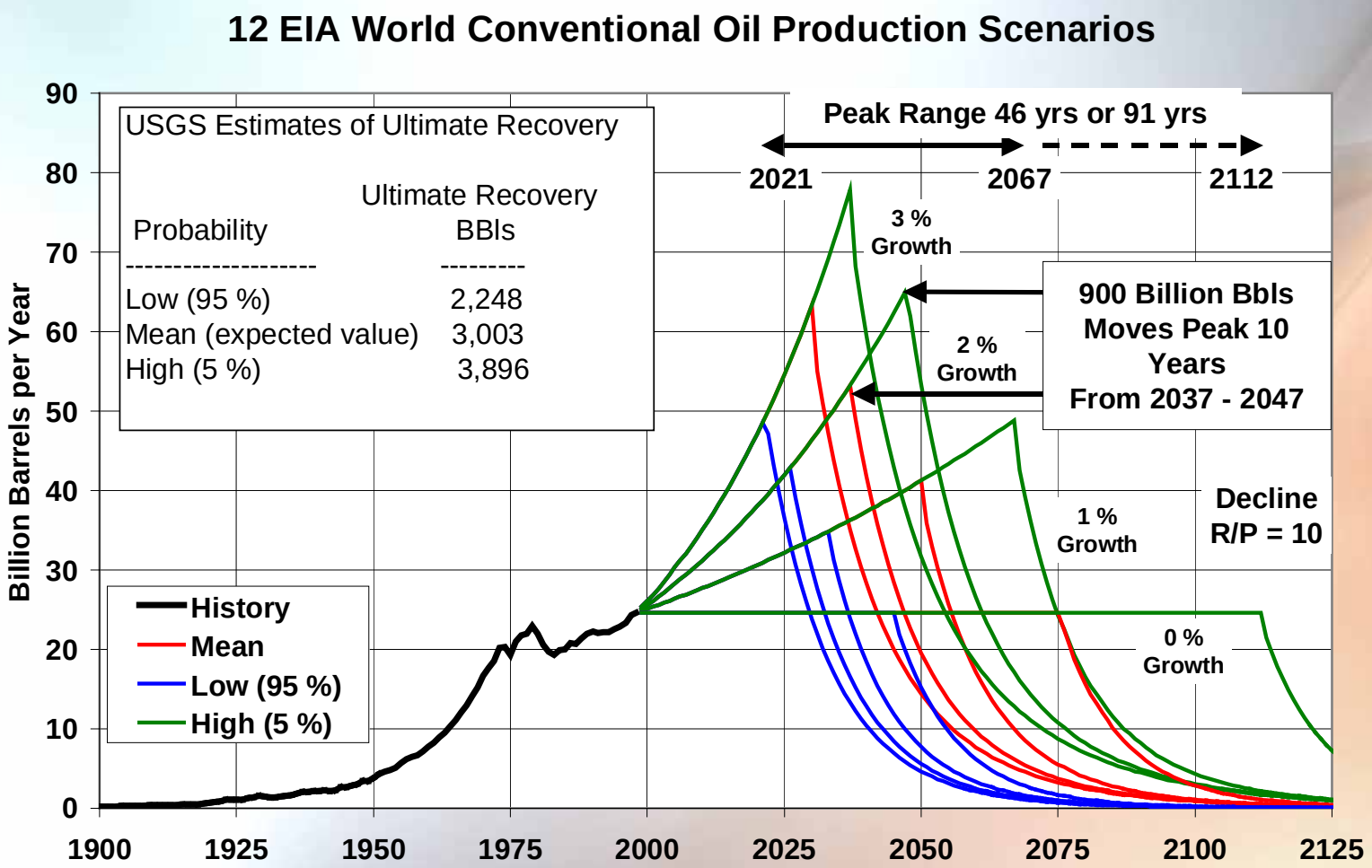
What is oil?

- **Conventional Oil**
  - **Liquid hydrocarbons of light and medium gravity and viscosity, in porous and permeable reservoirs.**
  - **Plus enhanced recovery and NGLs**
- **Unconventional Oil**
  - **Deposits of density > water (*heavy oil*), viscosities > 10,000 cP (*oil sands*) and tight formations (*shale oil*).**
- **Liquid fuels can be made from coal or natural gas (not considered here).**

Do we know how much oil there is?



EIA used a few simple assumptions to produce a range of peaking estimates.



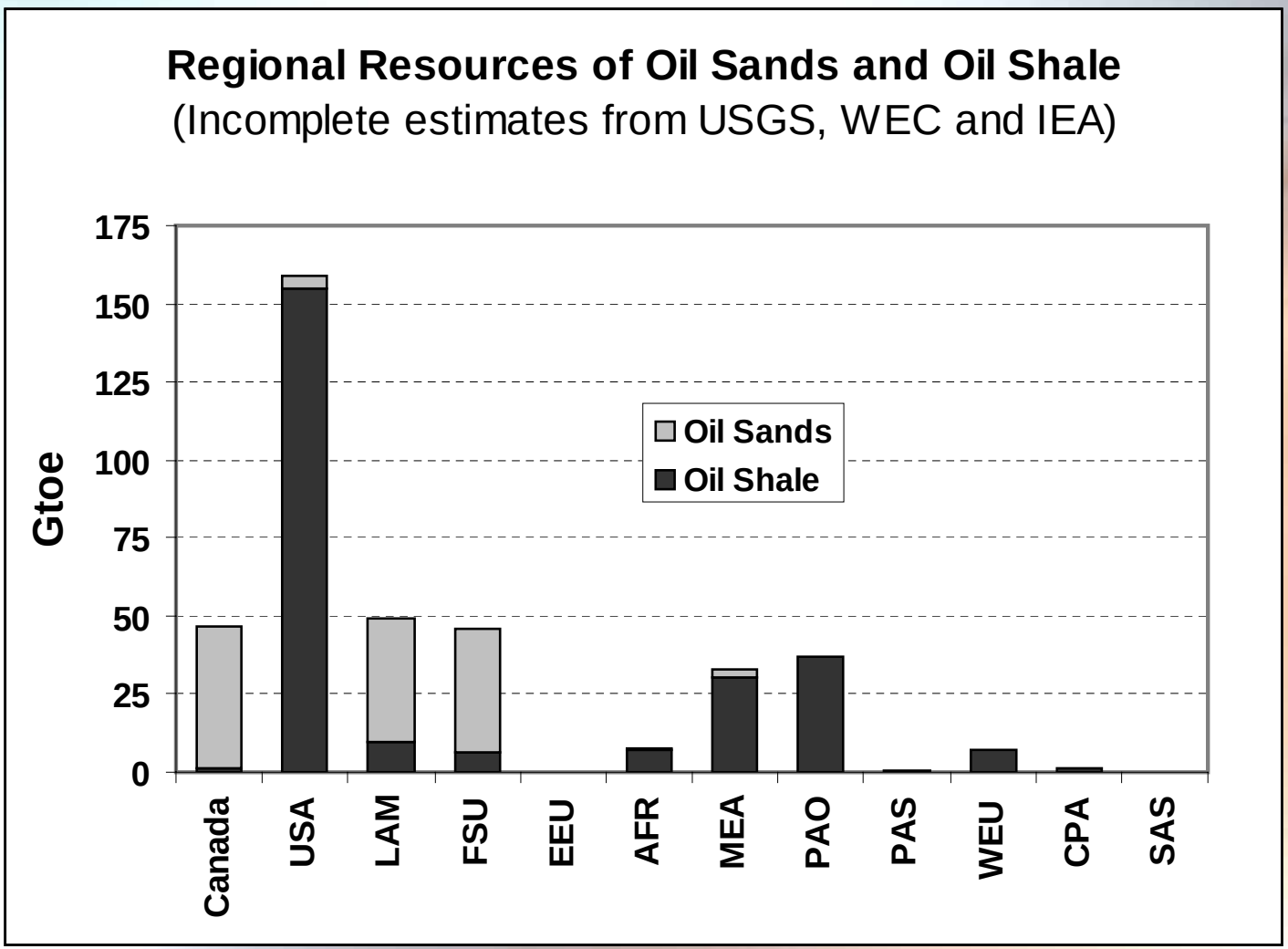
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

In 2000 the USGS published a major assessment of world oil resources, including uncertainty and technological progress.

(Billions of Barrels)

	Oil				Natural Gas Liquids				Total Petroleum			
	95%	50%	5%	Mean	95%	50%	5%	Mean	95%	50%	5%	Mean
Undiscovered	394	683	1202	725	101	196	387	214	495	879	1589	939
Res. Growth	255	675	1094	675	26	55	84	55	281	730	1178	730
Proved Res.	884	884	884	884	75	75	75	75	959	959	959	959
Cum. Prod.	710	710	710	710	7	7	7	7	737	737	737	717
TOTAL	2244	2953	3890	2994	210	334	553	351	2454	3287	4443	3345

There is even greater uncertainty about unconventional oil resources, but regions seem to divide into oil sand/heavy oil or shale oil. (1 Gtoe = 7.33 billion bbls, 20.1 mmbd)

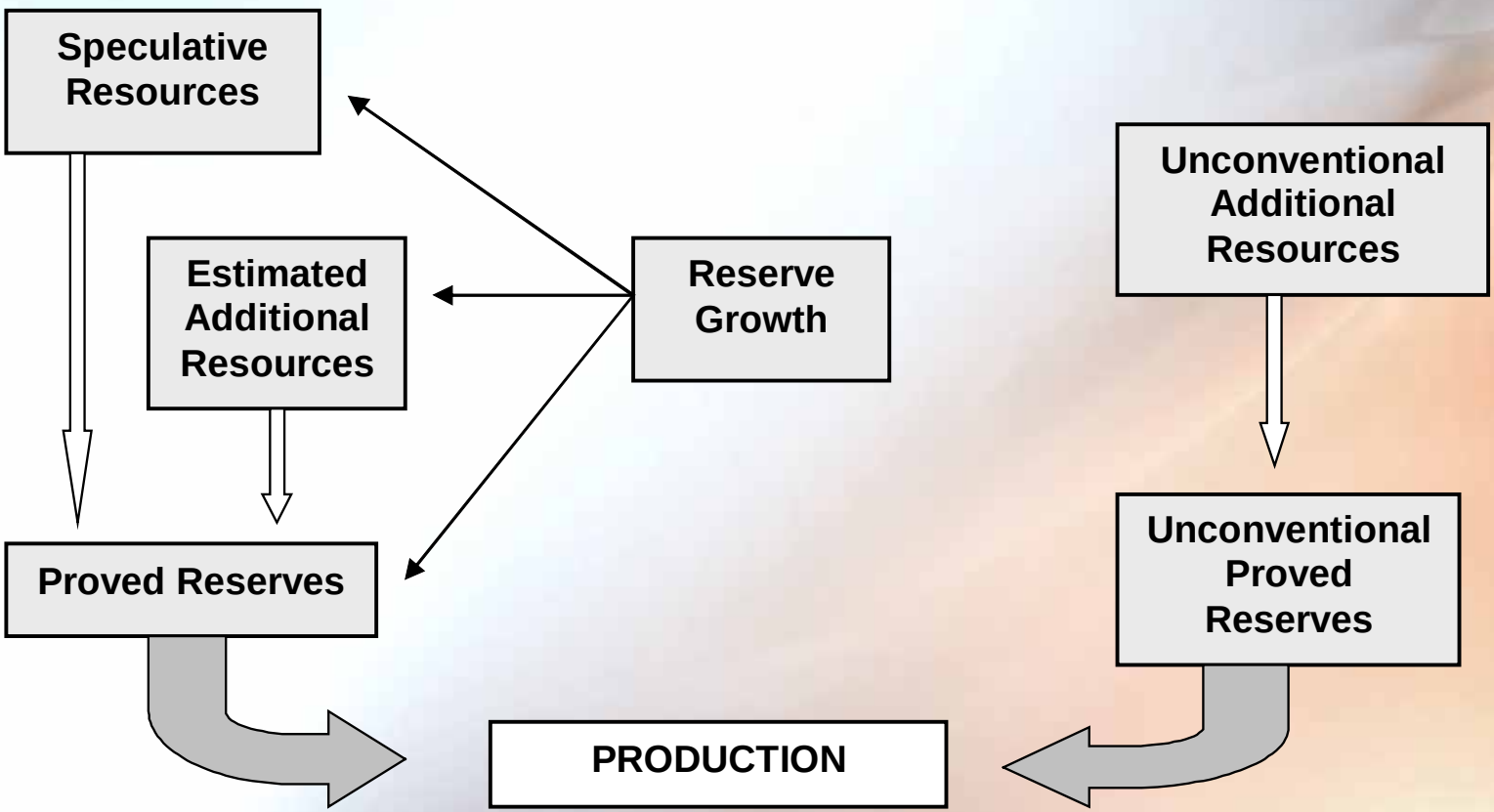


Pessimists dispute the USGS estimates with the following arguments:

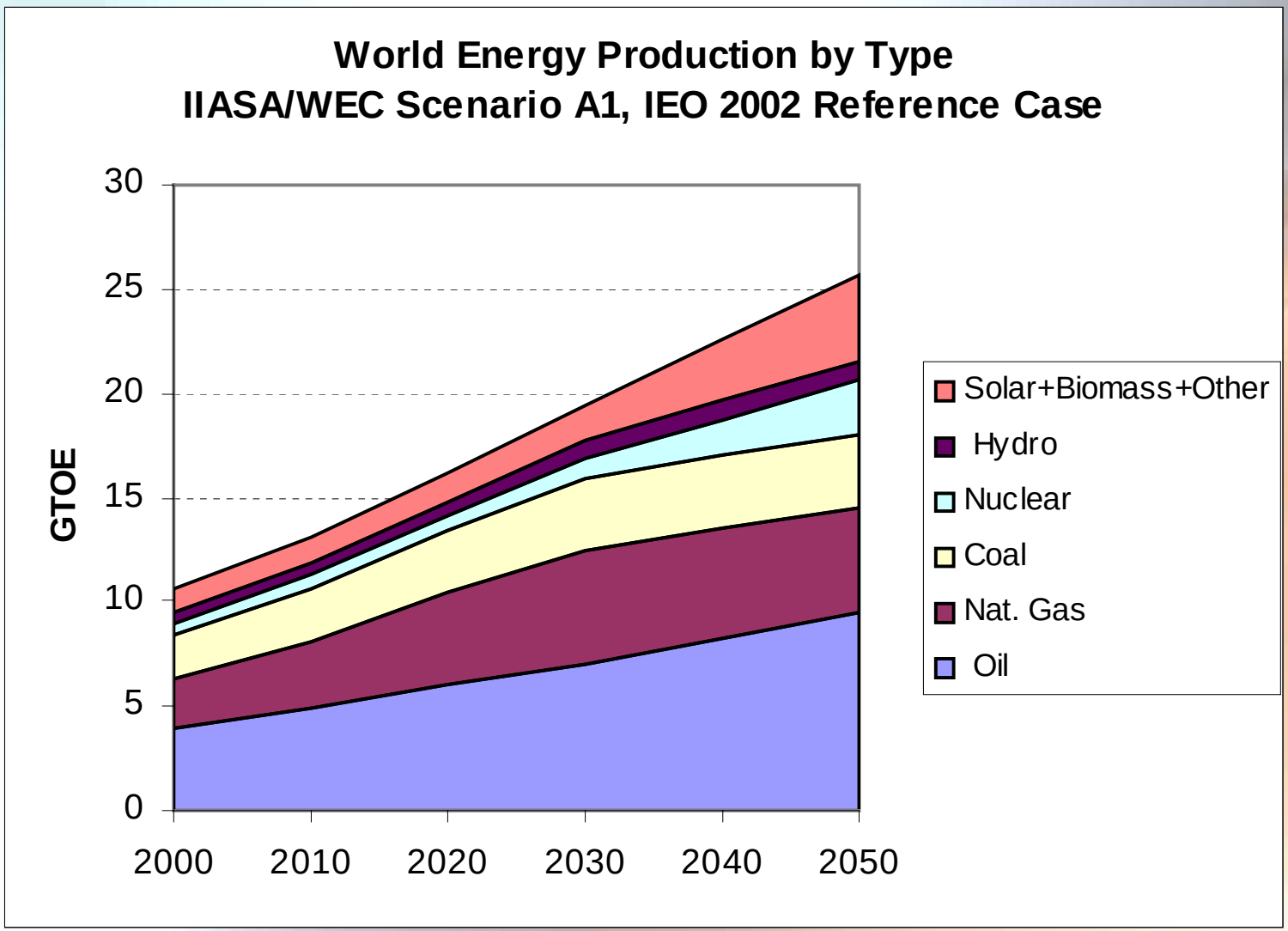
- **OPEC members overstate proved reserves**
- **Reserve growth methodology biased**
- **Range of uncertainty exaggerated**
- **Unconventional resources also much smaller than implied by my estimates**

Resource Category	Estimated Quantity (Billion Barrels)
Conventional Oil	
Known Fields Produced	896
Known Fields Future Production	871
New Fields Future Production	133
Deepwater Future	60
Polar Future	30
Gas Liquids	400
Total Conventional	**2,390**
Heavy Oil (Unconventional)	**300**

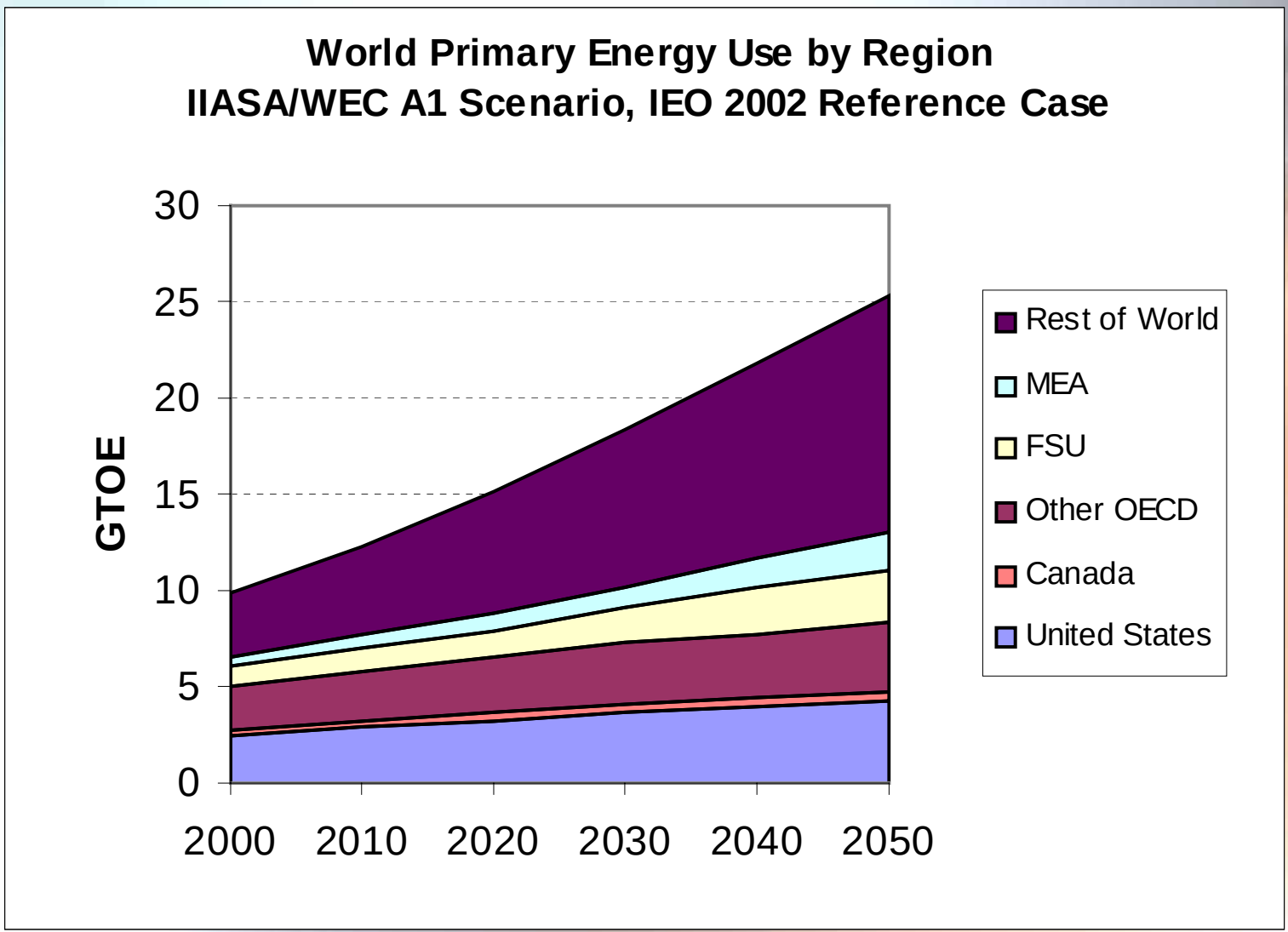
A resource accounting model was constructed to simulate oil resource depletion, expansion and transition under various scenarios. It does not include Hubbert curves. If anything, its rules are optimistic.



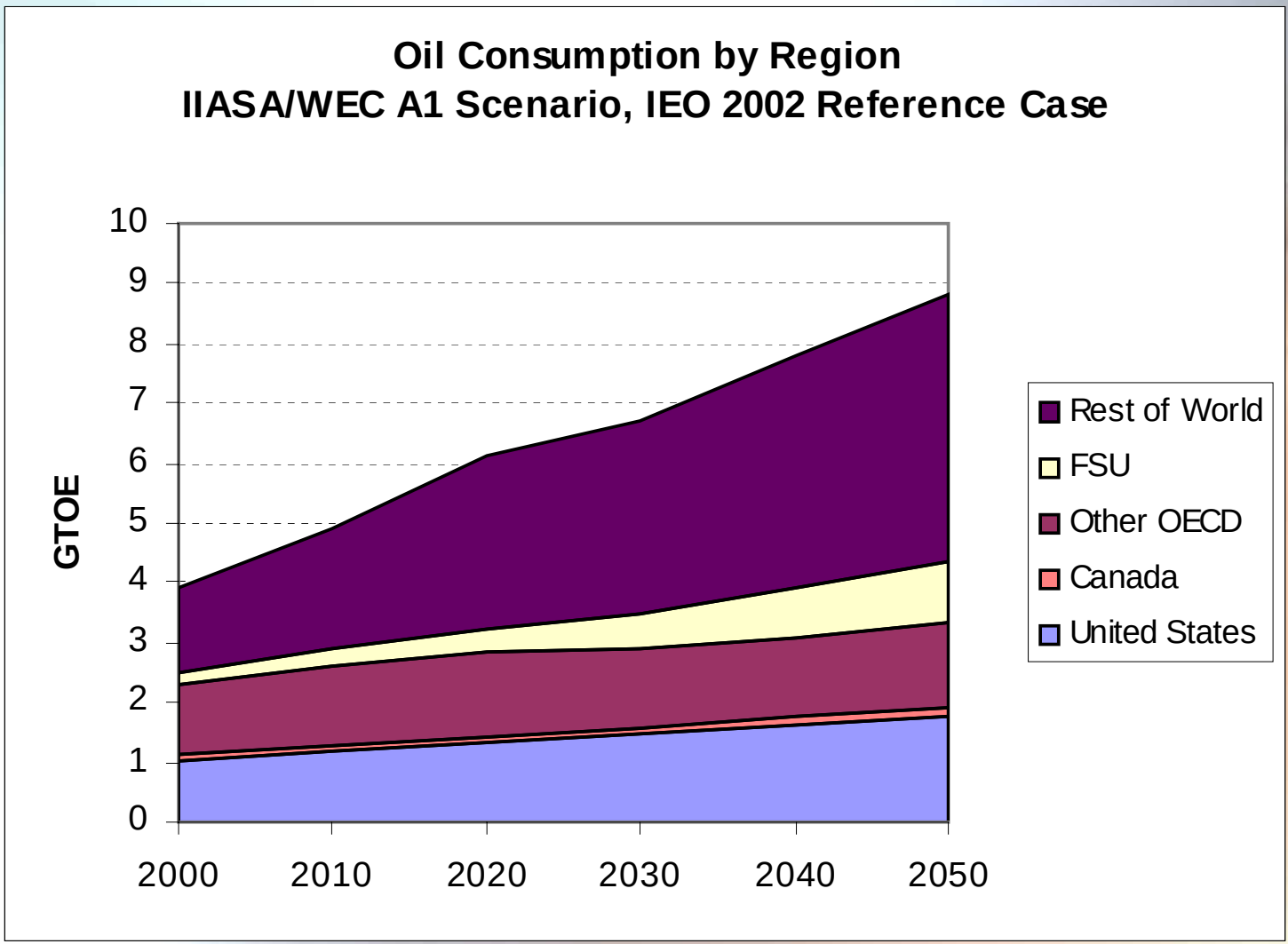
World energy scenarios were derived from existing projections. The Reference Scenario represents “business as usual”.



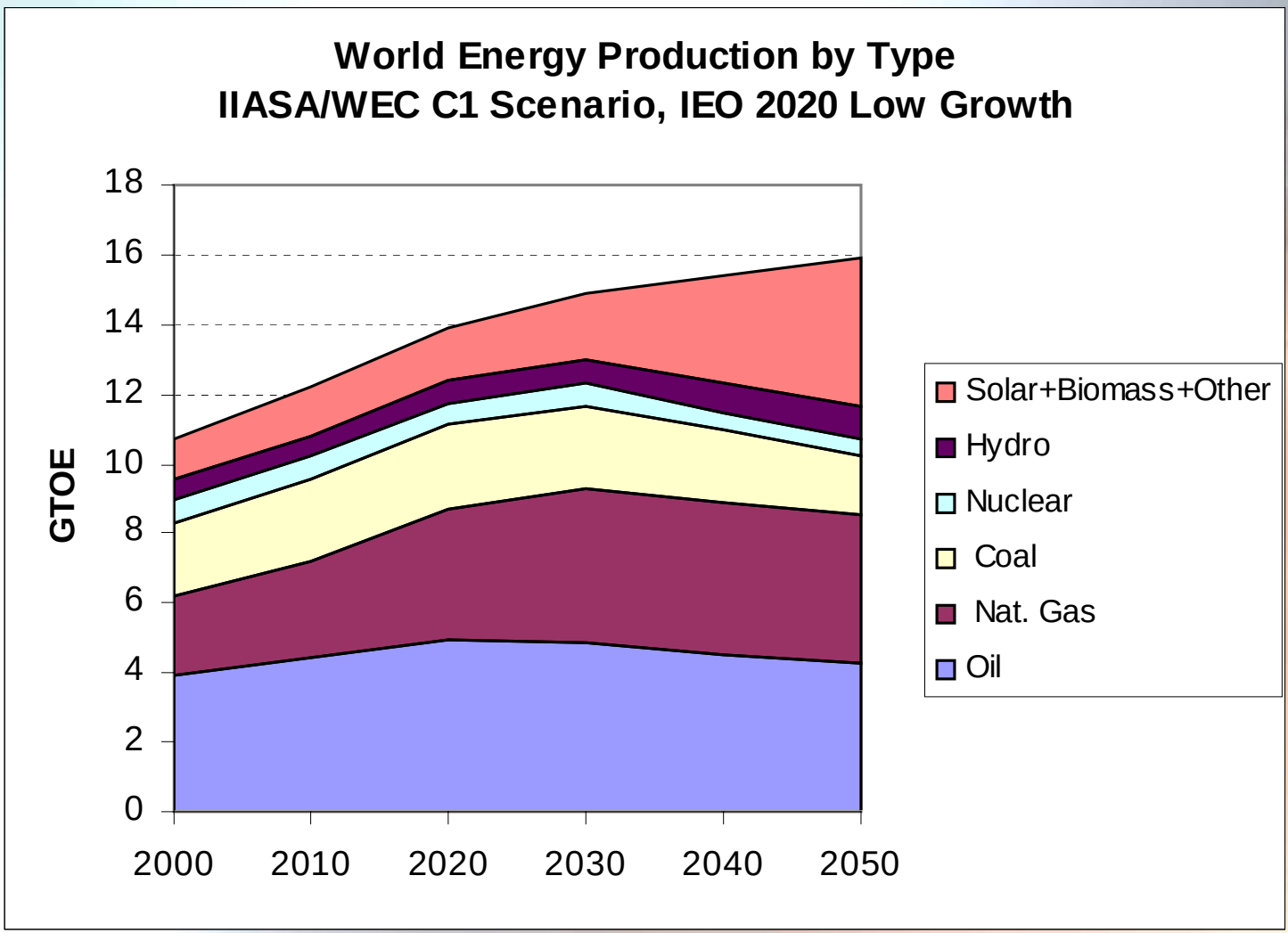
Most future growth of energy use is expected in the developing world (2.7%/yr v. 1%/yr).



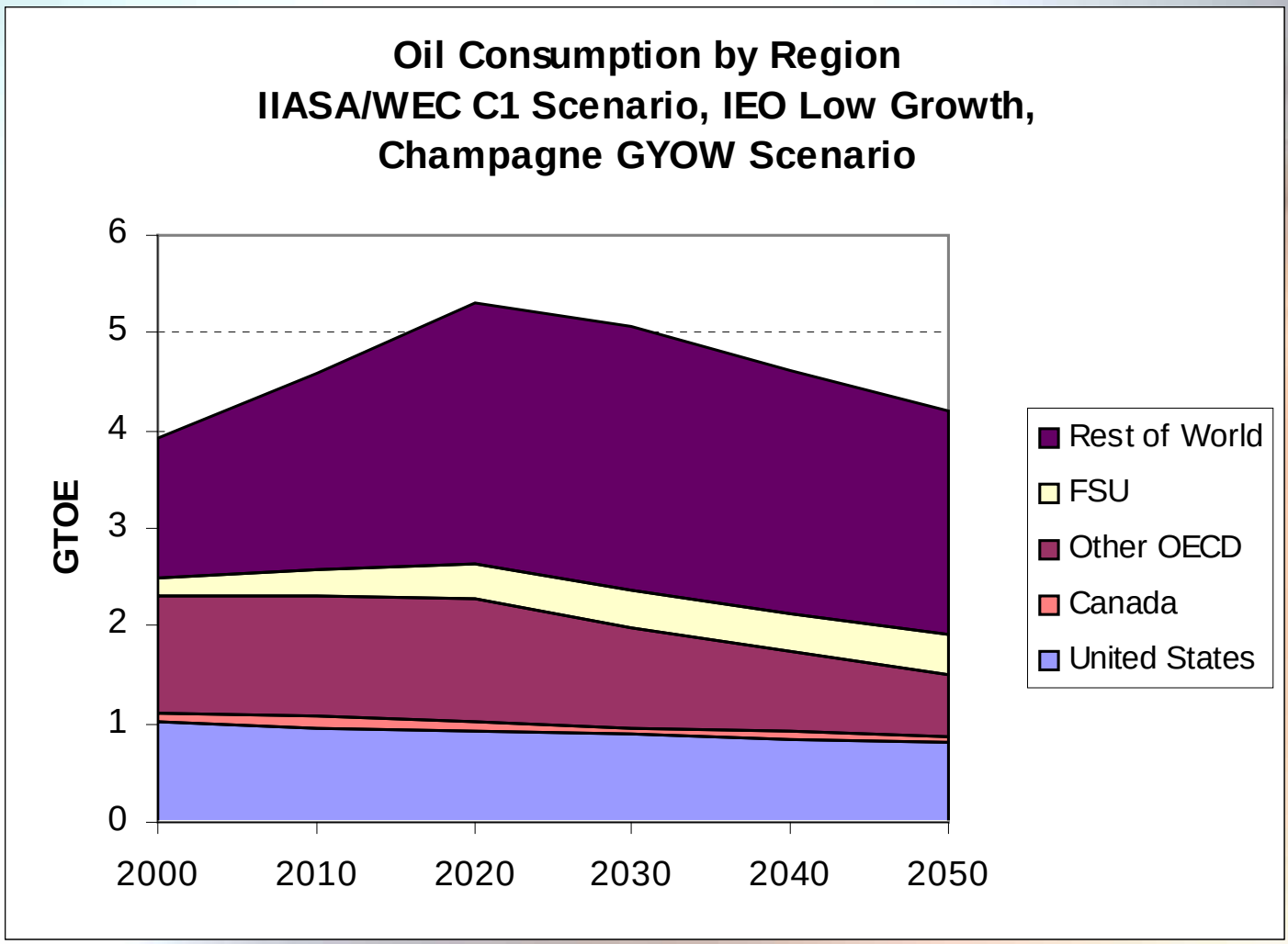
The ave. growth of world oil use is 1.9%/yr.



An “ecologically driven” scenario foresees only an 0.8% annual growth in energy use.



In this scenario, there is a demand-drive peak in oil use.



Six depletion/transition scenarios were constructed.

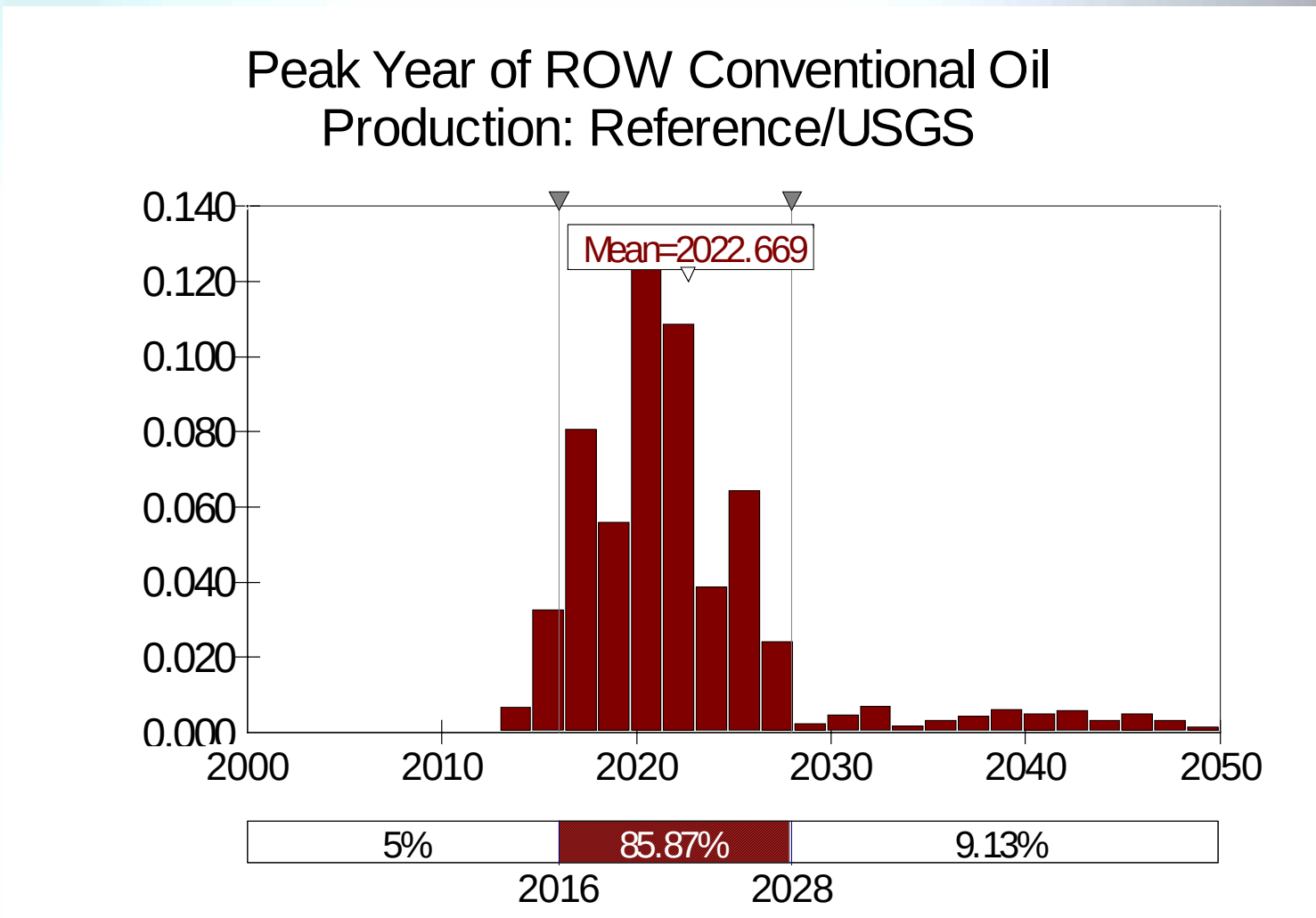
Scenario Acronym	IIASA/WEC Global Energy Scenario	IEO 2002 Projection to 2020	Champagne Model Projection	Conventional Oil Resource Estimate Source	Unconventional Resource Estimate
ARRU (1)	A1	Reference	Reference	USGS	USGS/WEC/IEA
ARRR (2)	A1	Reference	Reference	Rogner	Rogner
ARRC (3)	A1	Reference	Reference	Campbell	Campbell
AHRU (4)	A1	High Growth	Reference	USGS	USGS/WEC/IEA
CLGU (5)	C1	Low Growth	Go Your Own Way	USGS	USGS/WEC/IEA
CLGC (6)	C1	Low Growth	Go Your Own Way	Campbell	Campbell

- **Two IIASA/WEC scenarios**
- **Three EIA Int. Energy Outlook to 2020**
- **Two DOE/NRCan NA transport projections**
- **Three sources of conventional oil resource estimates**
- **Three unconventional oil estimates**

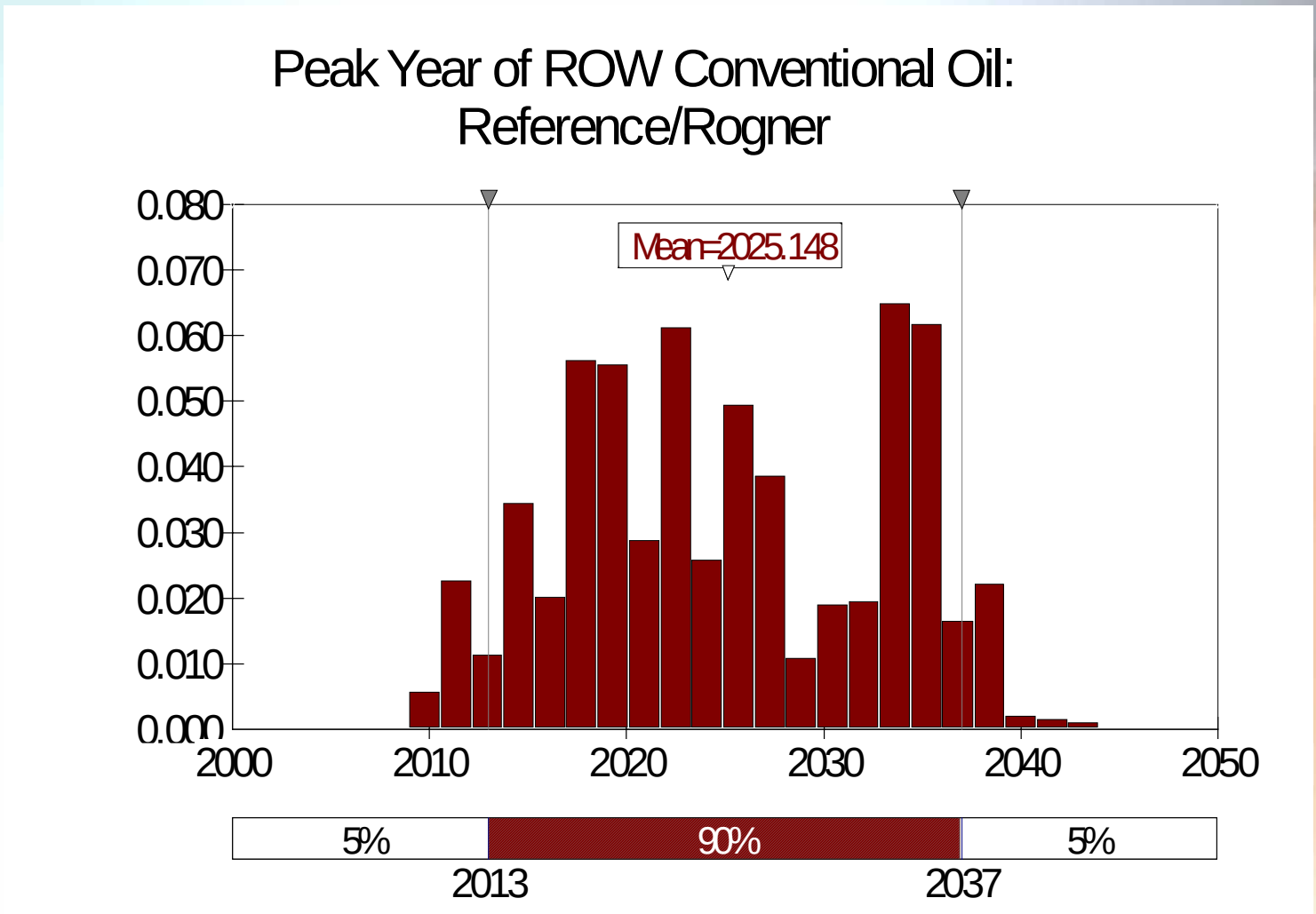
A risk analysis was carried out, defining key parameters as random variables.

Parameter	Uniform Distribution Parameters		
	USGS	Rogner	Campbell
Growth rate of Middle East production			
A1 high growth scenarios	(0.01, 0.02)	(0.01, 0.02)	(0.01, 0.04)
C1 low growth scenarios	(-0.01, 0.01)	—	—
Technological change affecting cost*			
Conventional oil	(-0.006, -0.002)	(-0.006, -0.002)	(-0.006, -0.002)
Heavy oil & bitumen	(-0.01, -0.004)	(-0.01, -0.004)	(-0.01, -0.004)
Shale oil	(-0.015, -0.005)	(-0.015, -0.005)	(-0.015, -0.005)
Base prices			
Conventional oil	$20/bbl	$20/bbl	$20/bbl
Heavy oil & bitumen	($15, $25)	($15, $25)	($15, $25)
Shale oil	($40, $90)	($40, $90)	($40, $90)
Recovery/reserve expansion	(0.002, 0.008)	(0.005, 0.015)	(0.002, 0.008)
Speculative resources parameters			
Fraction available	(0.05,0.95)	(0.05,0.95)	N.A.
Year of peak conversion	(2015, 2025)	(2015, 2025)	N.A.
Target R/P ratio	(10, 20)	(10, 20)	(10, 20)
Alpha (unconv. resource to unconv. reserve conversion rate parameter)	(-150, -50)	(-150, -50)	(-150, -50)
Supply and demand parameters			
Short run demand elasticity	(-0.08, -0.04)	(-0.08, -0.04)	(-0.08, -0.04)
Short run supply elasticity	(0.04, 0.08)	(0.04, 0.08)	(0.04, 0.08)
Adjustment rate	(0.85, 0.95)	(0.85, 0.95)	(0.85, 0.95)

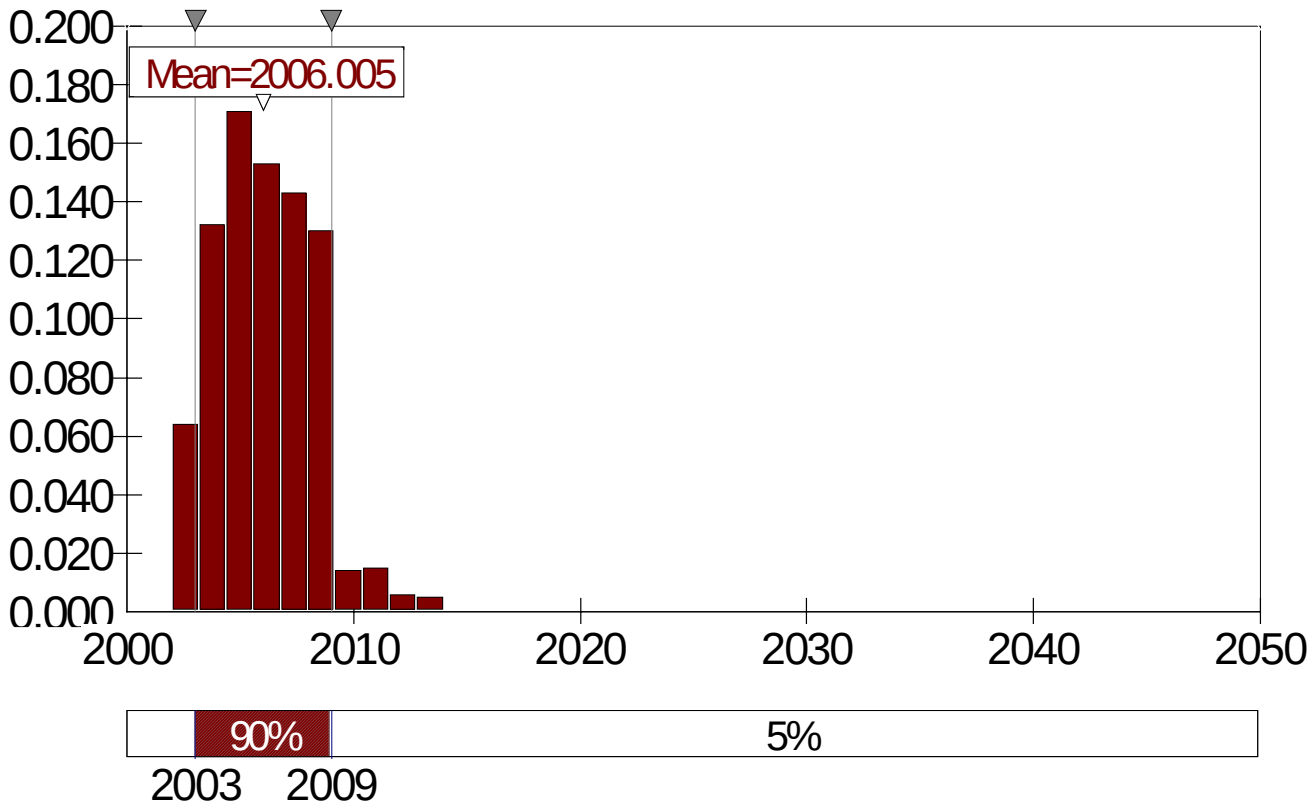
Reference/USGS: non-Middle East oil production peaks by 2030 with 90% probability.



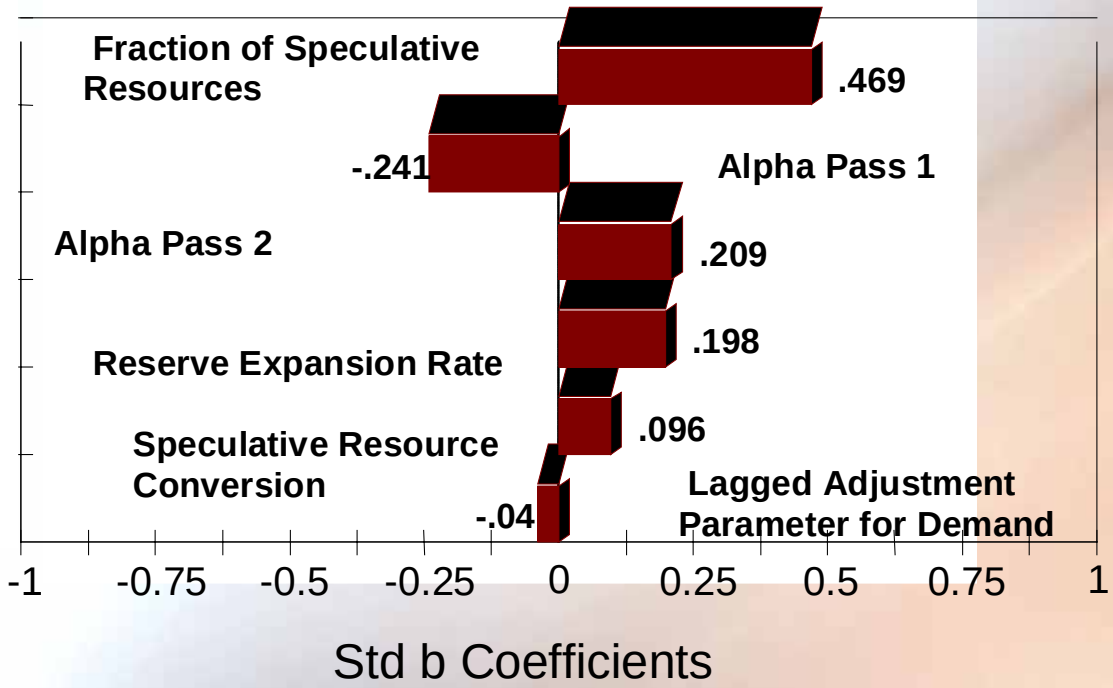
Reference/Rogner: Non-MEA peak likely anytime 2010-2040.



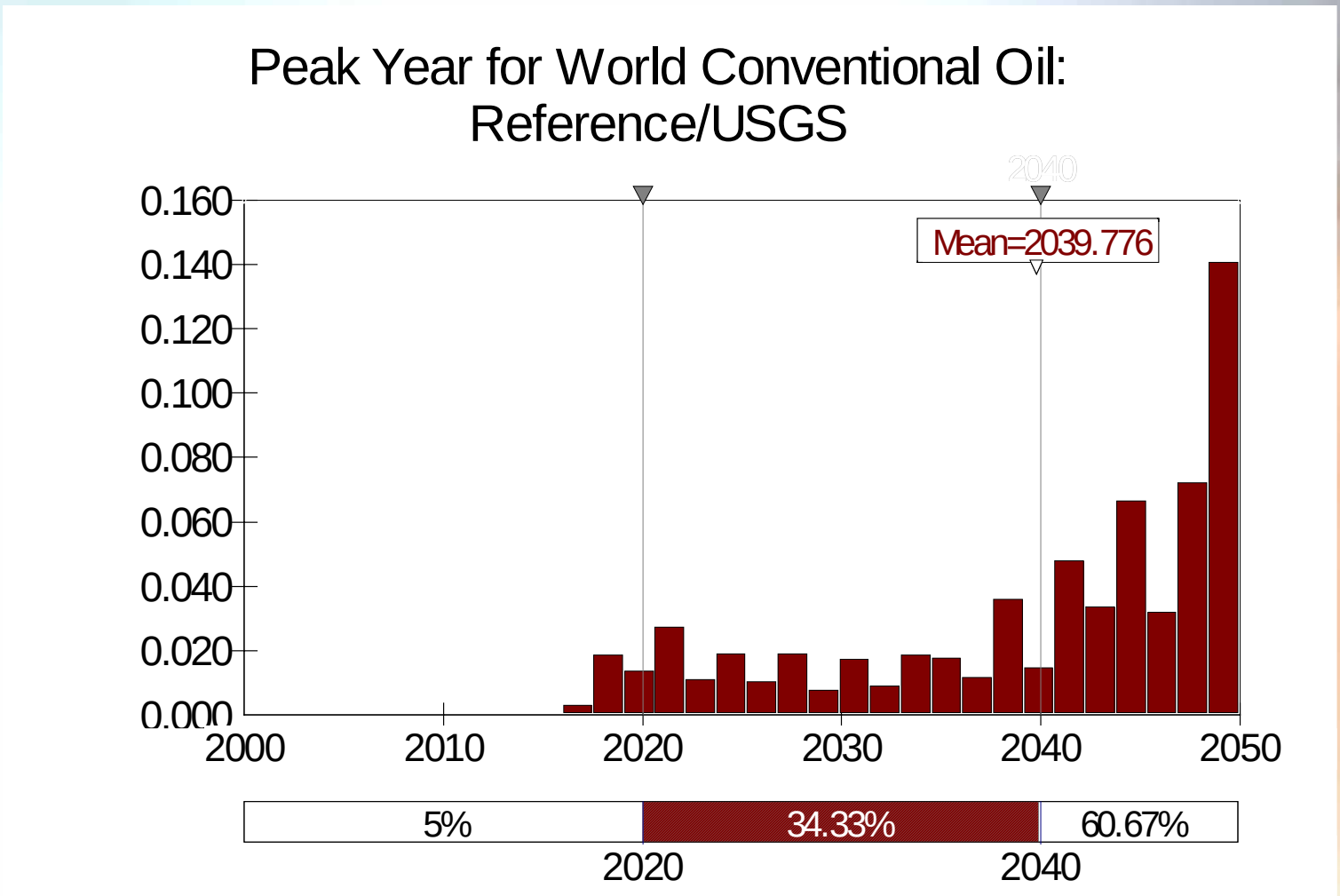
If Campbell's estimates are correct, the non-MEA peak will almost certainly occur before 2010.



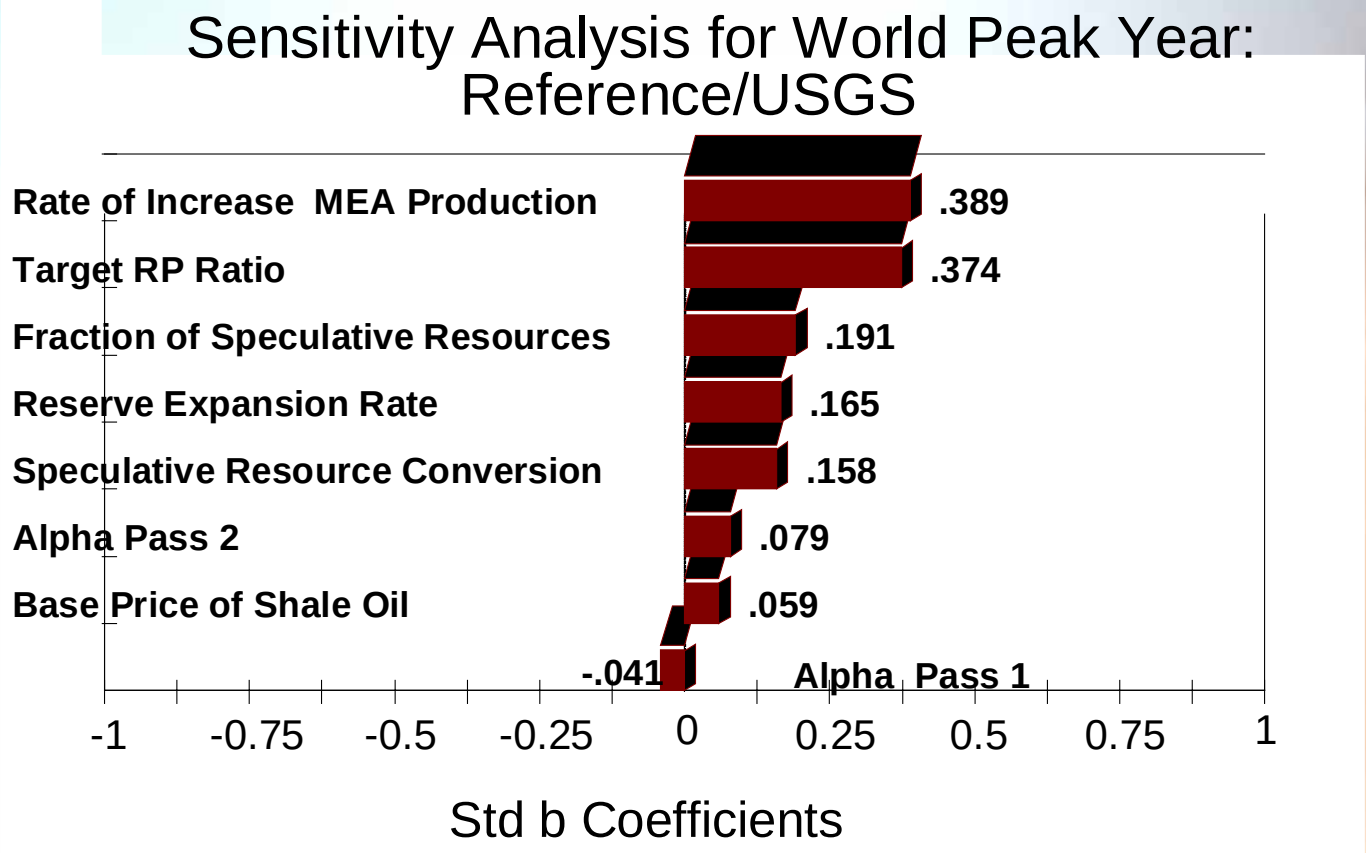
The most important determinant of the date of peaking is how much oil there really is.



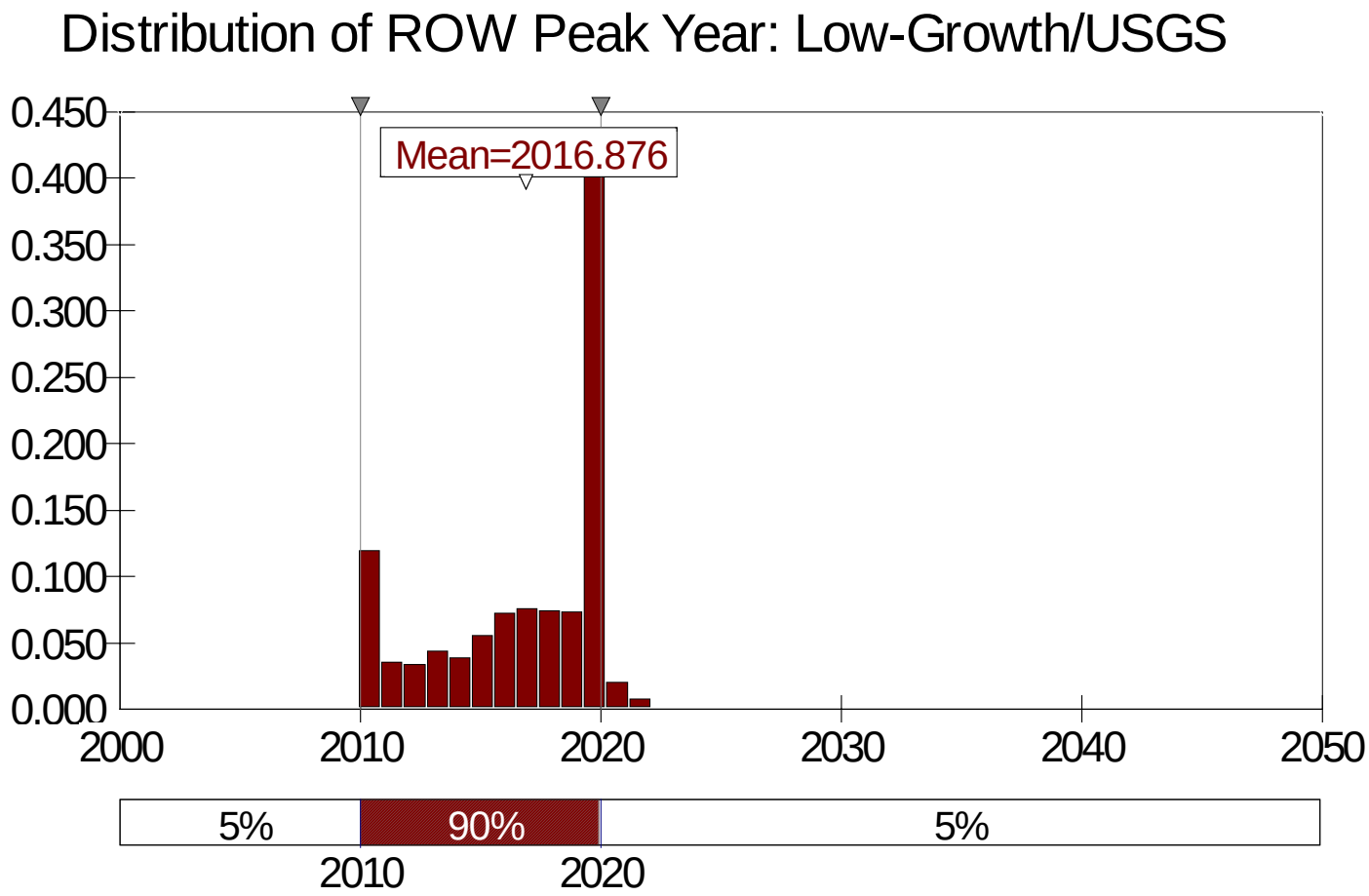
The total world oil production peak could be significantly later.



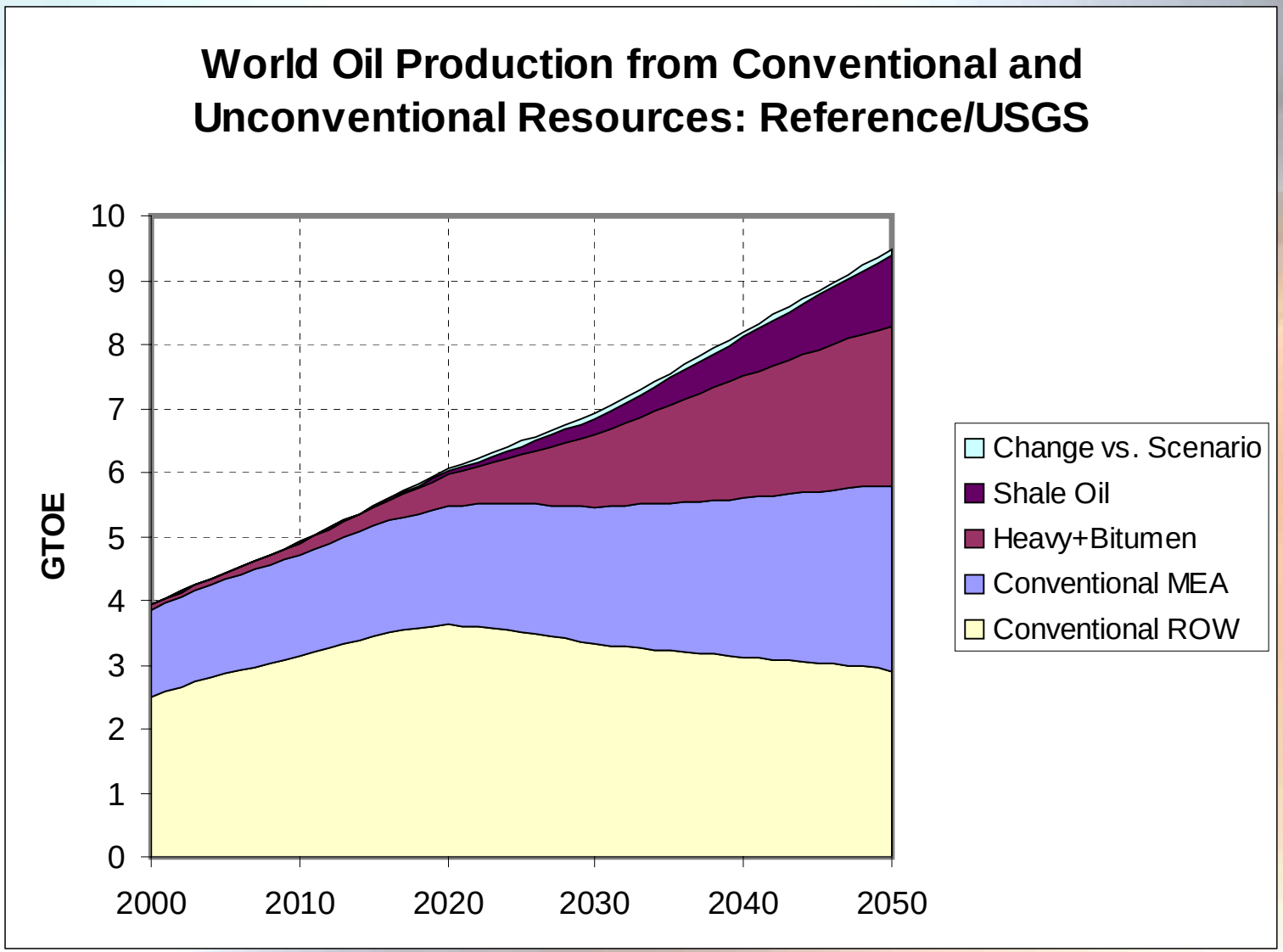
The world peaking date depends strongly on the rate of expansion of Middle East production.



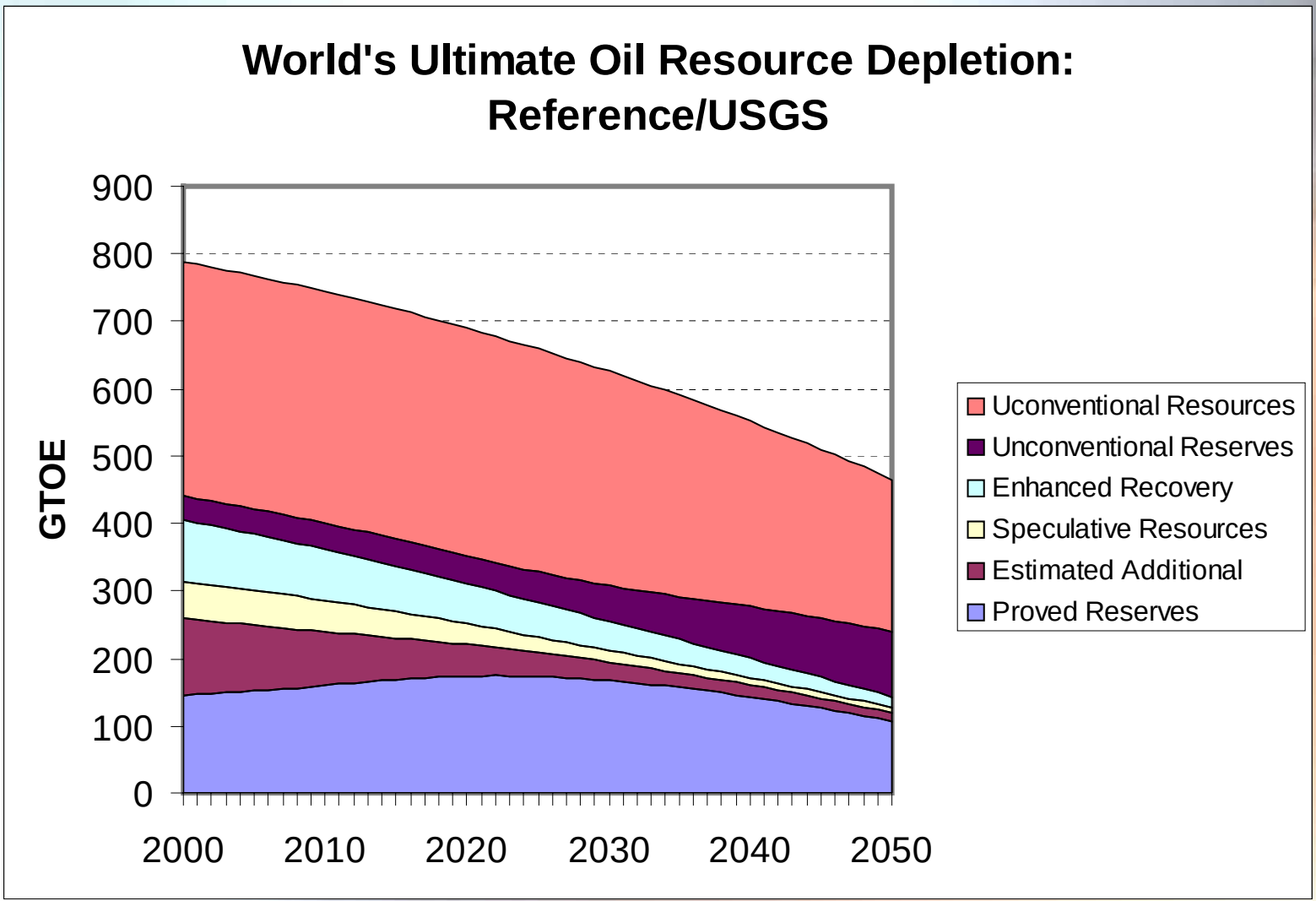
Even in the low growth scenario peaking could occur before 2020.



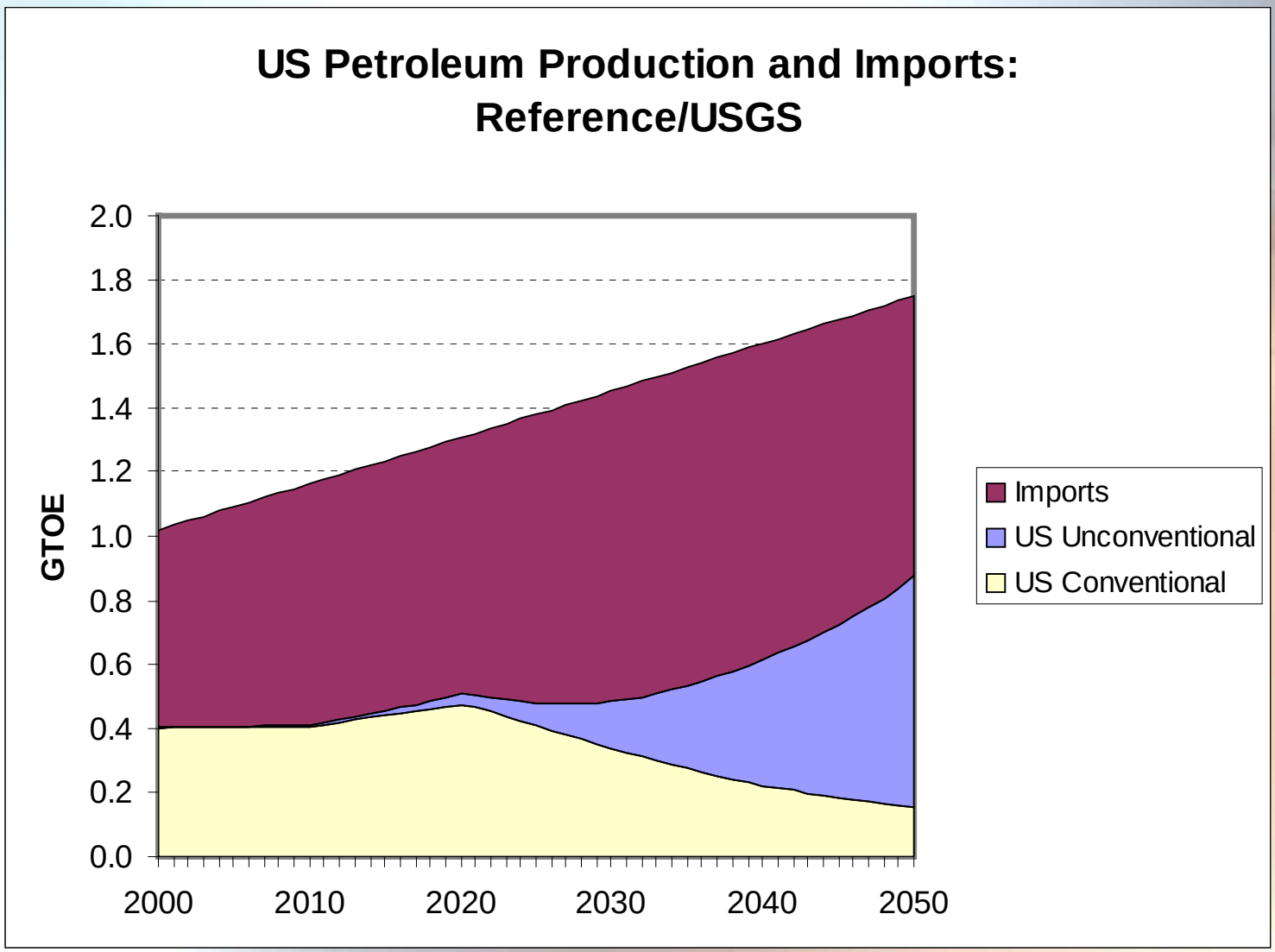
Under median assumptions, unconventional oil production must expand rapidly after 2020.



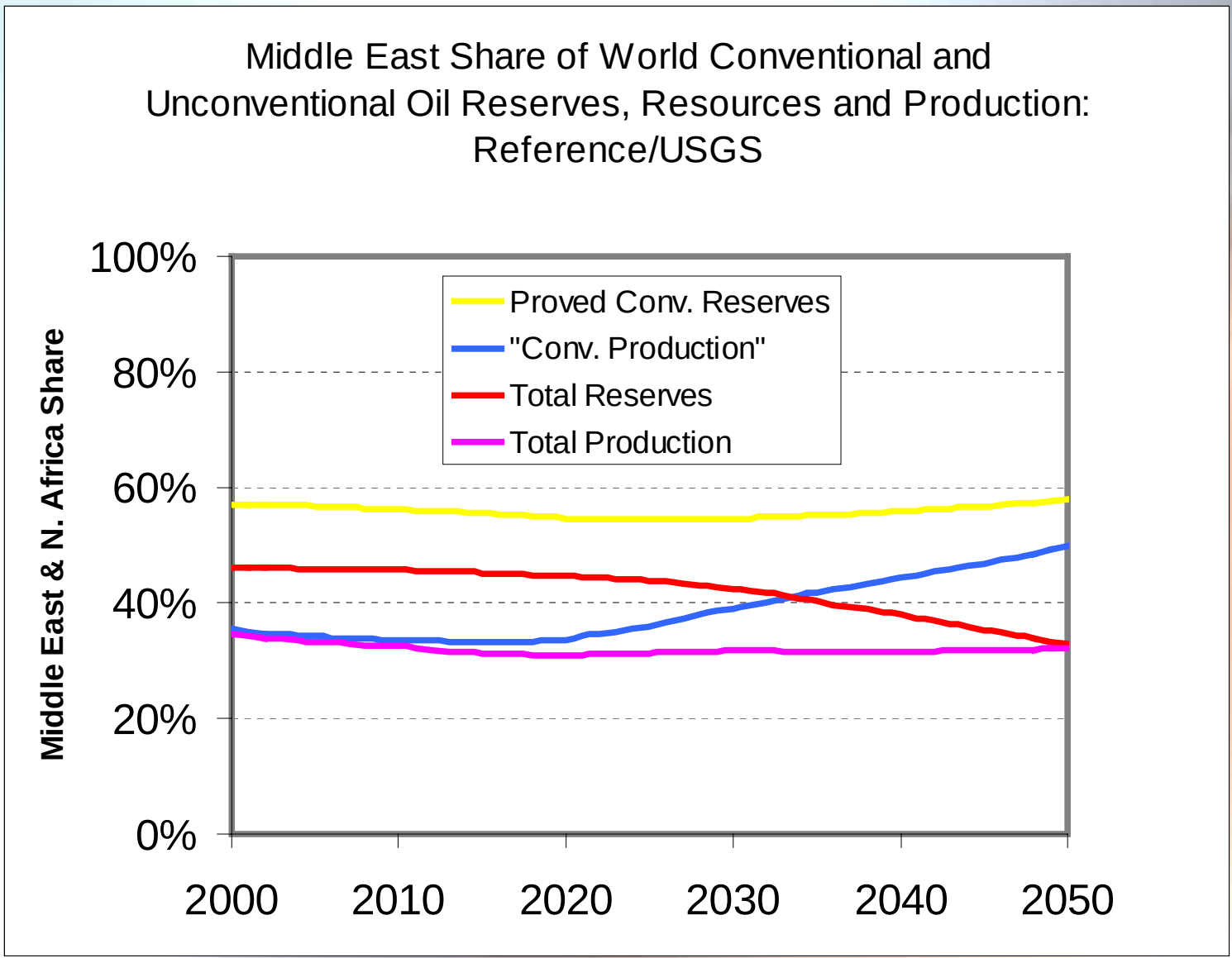
The model predicts that production may peak before proved reserves (caveat).



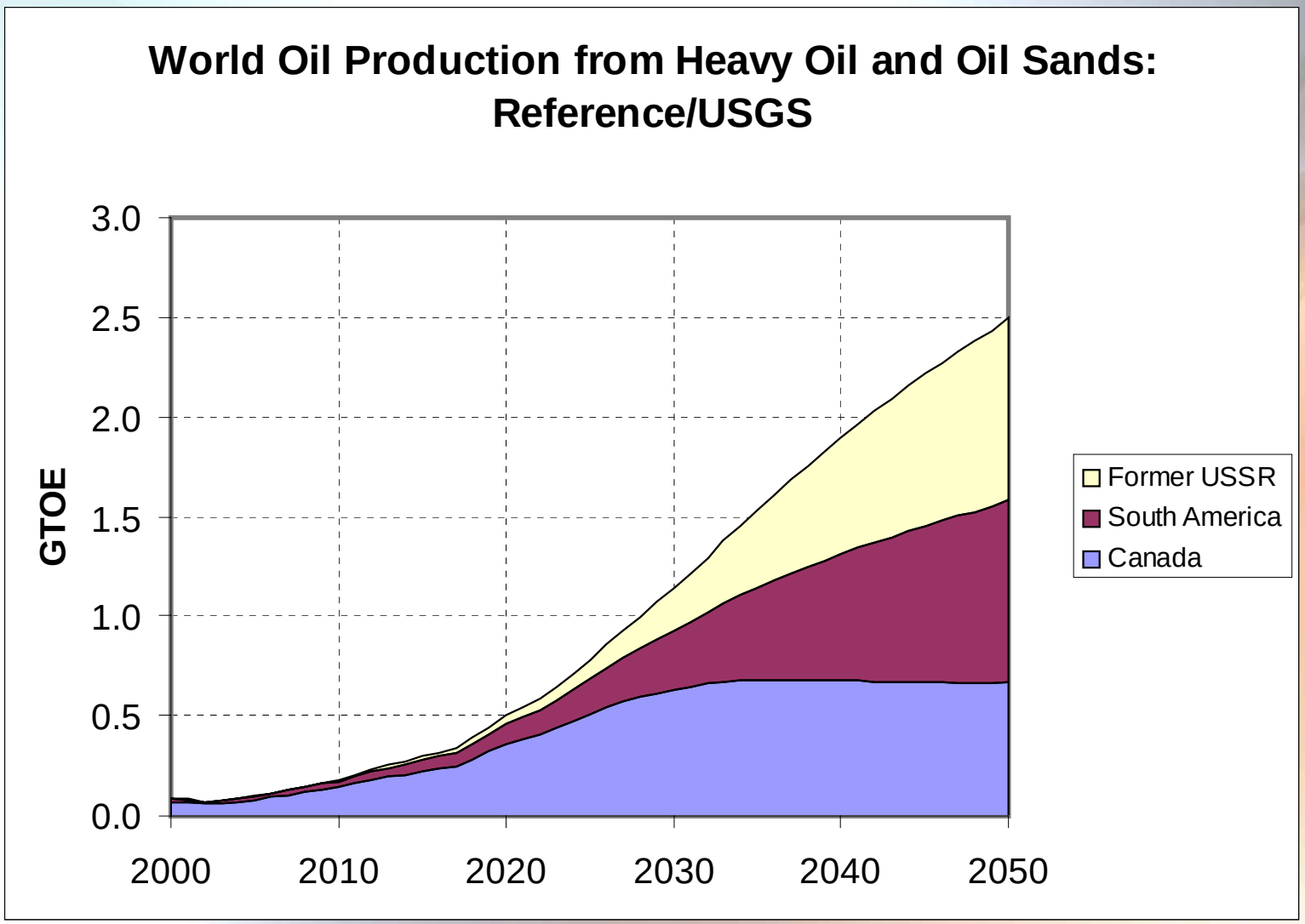
The optimism of the model is reflected in increasing US production to 2020.



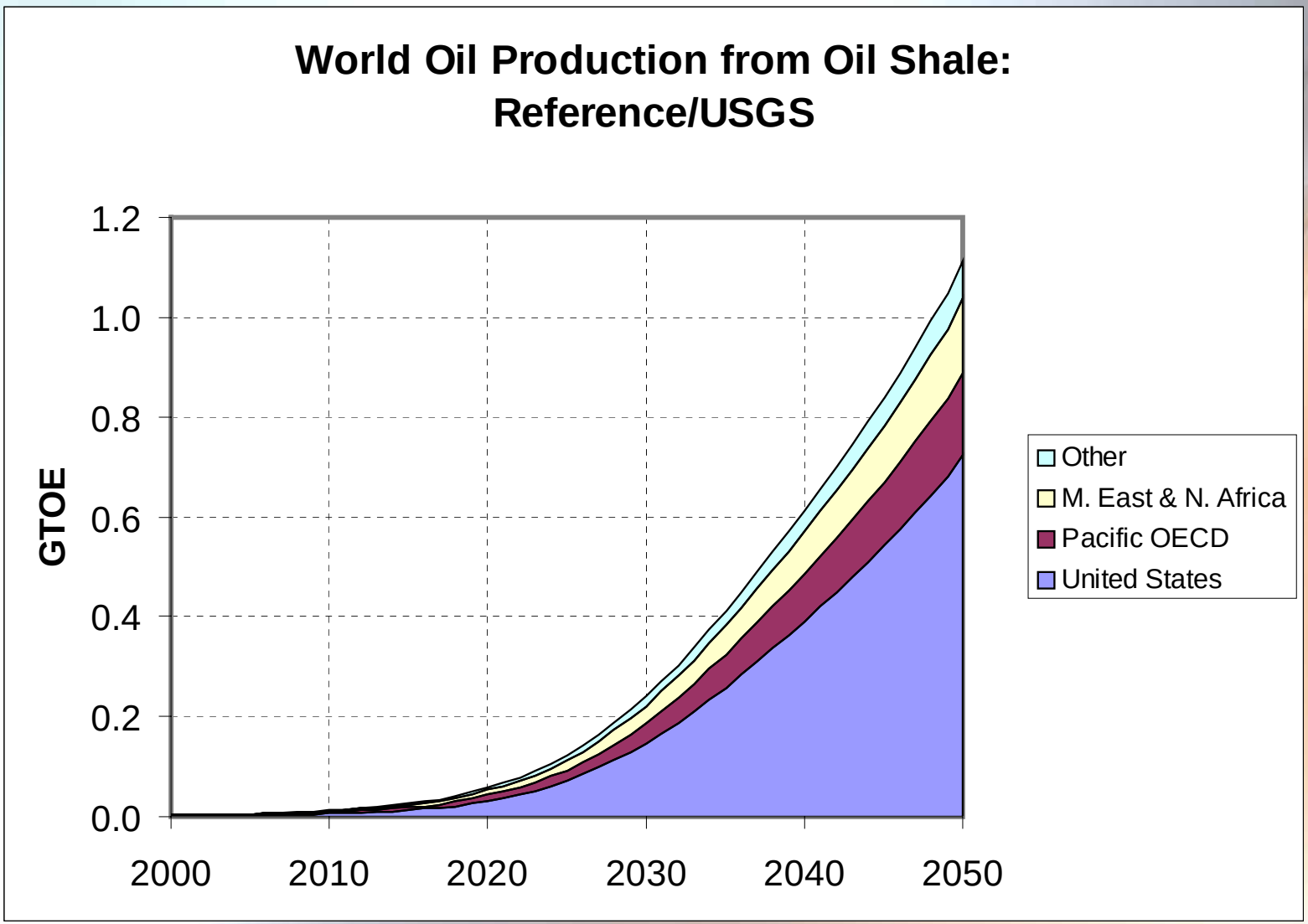
The Middle East could maintain a dominant position through 2050.



Rapid expansion of heavy oil and oil sands is needed to allow world oil use to continue to grow.



The ability to produce vast quantities of shale oil is even more uncertain.



Conclusions

- Present trends imply ROW oil peak 2010-30
- Rate of production likely to decrease after 2020 in any case
- Transition to unconventional oil may be rapid: 7-9%/yr growth
- First supplies from Venezuela, Canada, Russia
- Vast quantities of shale oil (or coal, NG) may be needed before 2050

Caveats

- Model doesn't include geologic constraints on production rates; relies on target resource-to-production ratios
- Does not include environmental or political constraints
- Does not include gas- or coal-to-liquids
- Unconventional oil resource estimates weak
- Scenario, not market equilibrium based modeling of oil demand

Thank you

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