

PEAK OIL: WHY, WHEN, AND HOW

Pikes Peak Economic Club

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WHAT IS PEAK OIL?

- **The time when oil production can no longer increase**
- **After this peak, production begins to decline continuously**



WHY IS PEAK OIL A PROBLEM?

- **Oil is the world's primary energy source (36% in 2009)**
- **Primacy stems from oil's intrinsic advantages**
- **Replacing oil is huge and historically unprecedented problem**
- **No experience with major energy transitions from cheaper to more expensive**



WHAT IS THE FUTURE OF WORLD OIL PRODUCTION?

- **Two dominant contrasting viewpoints**
 - **Imminent peak**
 - **Continued growth for many decades**

These are not the only possibilities

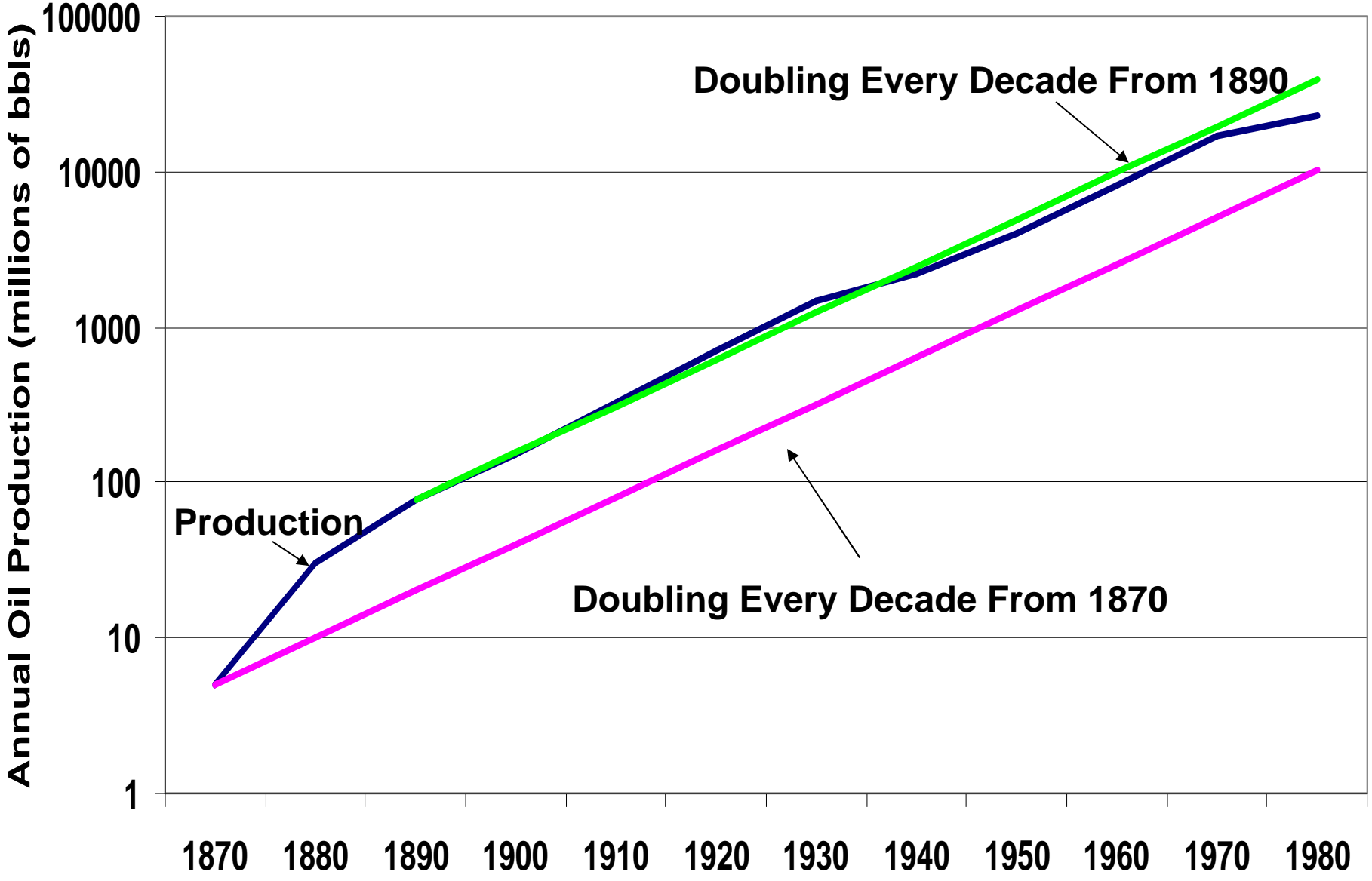


KEY POINTS ABOUT PEAK OIL

- **WHY?** – Oil resources are very large, but are being consumed at rapid rates
- **WHEN?** - Ten to thirty years from now
- **HOW?** - As a plateau lasting two to three decades



GROWTH IN WORLD OIL PRODUCTION, 1870-1980



THE SCALE OF GROWTH

- **Three orders of magnitude increase in less than one century**
 - Annual production grew from 58.5 **thousand** b/d (1879) to 58.5 **million** b/d (1973)
 - Cumulative production grew from 317 **million** barrels (1883) to 311 **billion** barrels (1973)



WHAT IS INCLUDED IN WORLD OIL RESOURCES?

- **Conventional**
 - Crude oil and NGL
 - Discovered and undiscovered
- **Unconventional**
 - Extra-heavy oil/tar sands
 - Oil from shales



HOW ARE OIL RESOURCES CLASSIFIED?

- **By discovery status**
- **By economic status**
- **By development status**
- **By technical certainty**



ULTIMATE WORLD OIL POTENTIAL

(As of 12-31-2009)

Low Medium High

(billion barrels)

Cum. Production	1205	1205	1205
Proved Dev. Reserves	700	700	700
Recovery Growth	715	1095	1585
Future Discoveries	320	750	1280
Unconventional	<u>330</u>	<u>540</u>	<u>850</u>
World Total	3270	4290	5620

ULTIMATE WORLD OIL POTENTIAL (2)

(As of 12-31-2009)	<u>Low</u>	<u>Medium</u>	<u>High</u>
	(billion barrels)		
Cum. Production	1205	1205	1205
Proved Dev. Reserves	700	700	700
Recovery Growth	(715)	(1095)	(1585)
Future Discoveries	320	750	1280
Unconventional	<u>(330)</u>	<u>(540)</u>	<u>(850)</u>
<i>Total (w/o RG & UC)</i>	<i>2225</i>	<i>2655</i>	<i>3185</i>

WHAT IS RECOVERY GROWTH?

- **Change in estimates of ultimate recovery in discovered fields**
- **Two types of changes**
 - **In-place estimates (mostly plus)**
 - **Recovery efficiency (plus)**



THE PARADOX OF RECOVERY GROWTH

- **Largest source of recent reserve additions, yet least appreciated source**
- **Why so poorly understood?**
 - **Conceptually incomprehensible**
 - **Denial**
 - **Poorly explained**



WHY DOES RECOVERY GROWTH OCCUR?

- **Past development was constrained by**
 - **Size of oil market (demand)**
 - **Cost of development (supply)**



WHY DID CONSTRAINTS EXIST?

- **Two bedrock facts**
 - Oil is concentrated in giant fields
 - Giant fields are discovered early
- Implications for undiscovered assessments are universally recognized
- Implications for recovery growth are wholly ignored



HOW PRODUCTION CONTROLS AFFECT DEVELOPMENT

- Retard discovery and development
- Make initial development less intensive
- Focus effort on least costly developments



RECOVERY GROWTH POTENTIAL

- Ranges from 715 –1095 –1585 billion barrels
- Assumes future recovery factors of 35-40-45% of c. 7 trillion barrels of known original-oil-in-place
- Includes 270-350-450 billion barrels from fields yet to be developed
- Will take 50 to 80 years to realize



IMPLICATIONS OF RECOVERY GROWTH

- **Ultimate world oil resources increase significantly, but at a slow rate**
- **Effect on peak oil production is modest**
- **Effect on duration of high oil production is substantial**



UNDISCOVERED OIL RESOURCES

- **Best understood source of future additions**
 - **Most extensively and thoroughly analyzed**
 - **Solid theoretical underpinnings**
 - **Well developed assessment methodologies**



ESTIMATING UNDISCOVERED POTENTIAL

- **Use augmented and amended USGS world assessment estimates**
- **Estimate undiscovered potential of 320 - 750 - 1280 billion barrels**

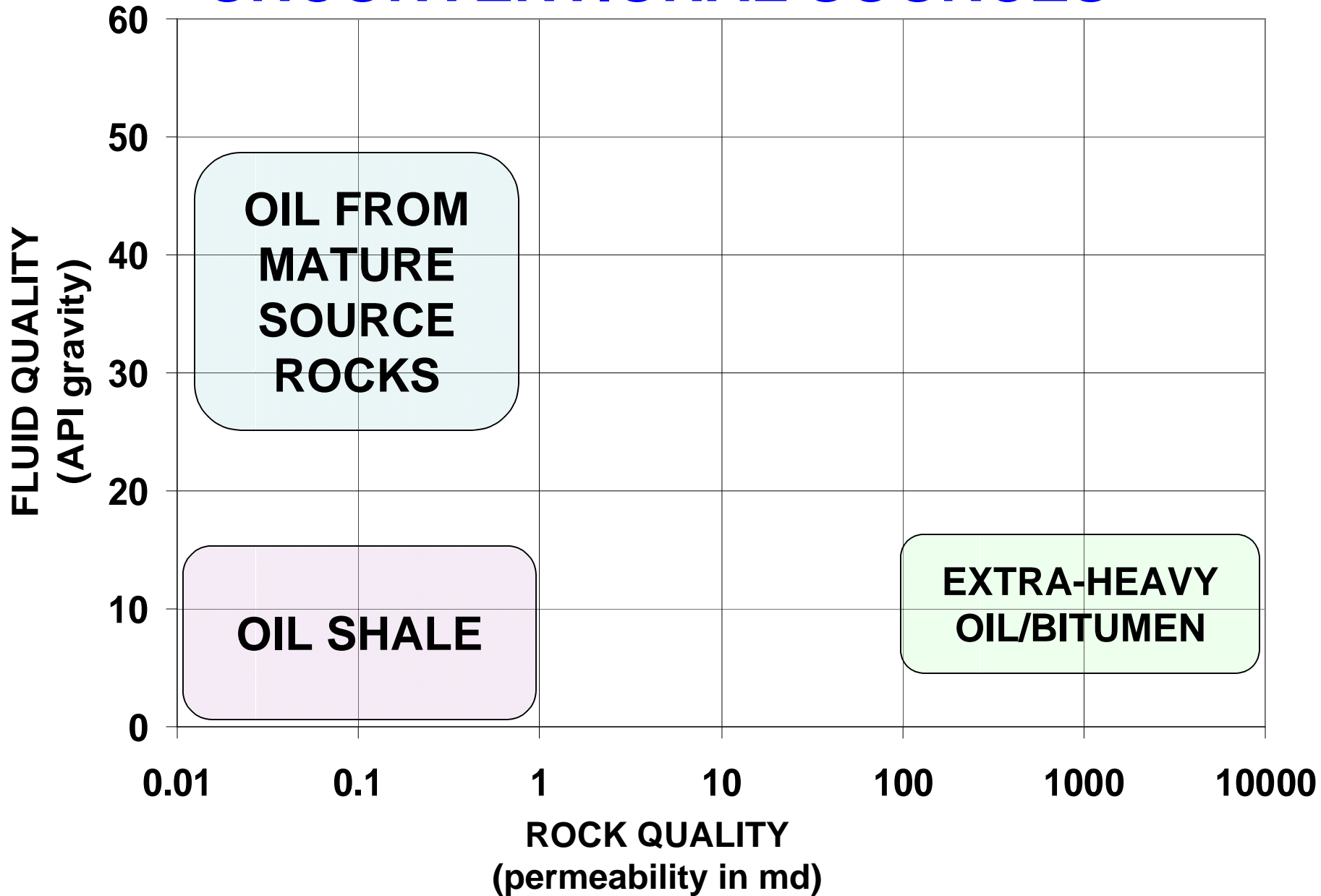


IMPLICATIONS OF THE ASSESSMENT

- **Potential concentrated in frontier provinces and Middle East**
- **Frontier provinces are at boundaries of current exploration and production technology**
- **Most are 10-40 years away from contributing to world production**



RESOURCE QUALITY OF UNCONVENTIONAL SOURCES



EXTRA-HEAVY OIL/BITUMEN

- **Extremely large identified in-place resource**
- **Concentrated in three provinces**
 - **Western Canada (Alberta)** c. 1.6 trillion bbls
 - **Orinoco (Eastern Venezuela)** c. 1.5 trillion bbls
 - **Siberian Platform (Russia)** c. 0.7 trillion bbls
 - **Others** c. 0.2 trillion bbls
- Worldwide total c. 4.1 trillion bbls



EXTRA-HEAVY OIL/BITUMEN (2)

- **Two types**
 - **EHO: High viscosity mobile oil**
 - **Bitumen: Very high viscosity immobile oil**
- **Emerging technologies minimize energy use**
- **Forecast: 10-20% recovery efficiencies without technology breakthroughs**
- **Expensive and slow to develop**



OIL FROM MATURE SOURCE ROCKS

- **Least known unconventional resource**
- **Systematic study only beginning**
- **In-place resources could be massive --
5-20 trillion barrels worldwide**
- **Forecast: Very low (1-5%) recovery of a
massive in-place resource**



“OIL SHALE”

- Not oil, but an oil precursor
- Kerogen in thermally immature source rocks
- Worldwide in-place distribution
 - Green River Shales (CO, UT, WY) 1.50 trillion “bbls”
 - Other United States 0.62 trillion “bbls”
 - Russia 0.27 trillion “bbls”
 - Other World (20+ countries) 0.51 trillion “bbls”
 - World total 3.20 trillion “bbls”



OIL SHALE RECOVERABILITY

- **Two** major challenges
 - Transforming kerogen into oil
 - Recovering the oil
- **Two** recovery technologies
 - In situ: Transformation, then recovery
 - Mining/surface-retorting: Recovery (mining), then transformation
- Slowly developing, post-2020 resource



UNCONVENTIONAL SUMMARY

- **Estimate 330 - 540 - 850 billion barrels**
- **Low recovery rates of massive in-place resources**
- **Technological breakthroughs could increase potential significantly**
- **Slow rates of development for current technologies**
- **Oil resources for both the 21st and 22nd centuries**



IF POTENTIAL OIL RESOURCES ARE SO LARGE, WHY DO WE HAVE A PROBLEM?

- High consumption rate
- Challenges of scale
- Decreasing resource quality



HIGH CURRENT CONSUMPTION

- **First trillion barrels took 140+ years to produce and consume**
- **Second trillion barrels will be produced and consumed in only 30+ years**
- **Most of world's oil resources will be consumed in the 21st century**



CHALLENGES OF SCALE/DEPLETION

- **Current scale of production is immense**
 - Four orders of magnitude growth from 1865 to 2008, doubling more than 13 times
- **3.7 million bbl/day of new capacity has to be added every year to keep production constant**



DECLINING RESOURCE QUALITY

- **Each oil source has problems**
 - Greater effort (recovery growth)
 - Challenging locations (future discoveries)
 - Poor rock and fluid characteristics (unconventional)
- **Future oil development will be more complicated and expensive**



CONCLUSIONS

- **Most world oil resources are yet to be produced**
- **World oil resources are being consumed at a very rapid rate**
- **The 21st Century - not the 20th Century - will be the Age of Oil**

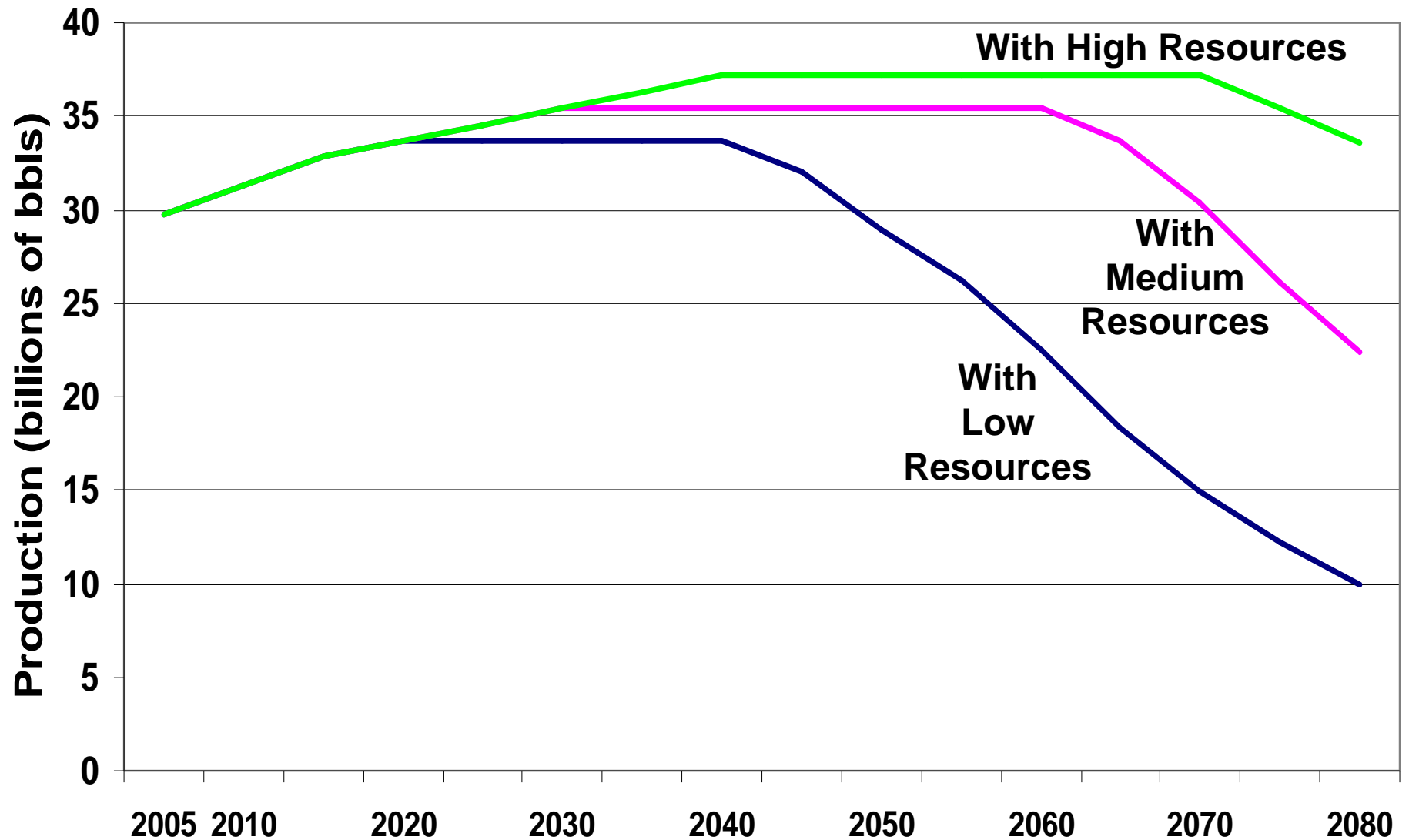


CONCLUSIONS (2)

- **The peak of world oil production is**
 - **not imminent**
 - **foreseeable**
 - **likely to be a plateau**



FUTURE WORLD OIL PRODUCTION



CONCLUSIONS (3)

- **A massive industry effort for the next 40-50 years is required**
- **An accommodating political environment is also necessary**
- **Both are essential during the long transition from oil to other sources and means of using energy**



CONCLUSIONS (4)

- **Transition from oil is a substitution process, in both demand and supply**
- **Substitution cannot be planned; it must be a discovery process**
- **Policy should emphasize creating opportunities, not mandating solutions**
- **Innovations tested in market are only viable solution**

