Lec #4: Consumption of Finite Resources

LAST TIME: Population Growth

- Discussion of Population Growth Growth

TODAY: History of Energy Use and Predicting the Future

- Expiration of Finite Resources
- Per Capita Consumption and GDP

THURSDAY: What Causes an Oil Crisis?; When?

- History (and Future) of US Oil Consumption
- What will cause the next "energy crisis"
- What can we do about it?

How Do We Estimate Lifetime?

1. assume resource is infinite
   - discoveries must keep pace with consumption
2. deplete at constant amount (current use rate)
   - must decrease per capita use at same rate as population increases
   - production must maintain current pace
3. exponential growth until resource expires
   - production *rate* must also *increase* exponentially
4. Hubbert model
   - early exponential rise
   - production slows & peaks when 1/2 resource is consumed
   - steady decline in production rate
   - symmetric, bell-shaped curve

Exponential Expiration Time

- $T_{exp} = (1/k) \ln \{kN_T/N_0 + 1\}$
  - comes from integrating exponential growth:
  - $dN(t)/dt = k*N(t)$
  - $N(t)=N_0e^{kt}$
  - $N_T = \int^{Texp} N_0 e^{kt} dt$
- Must be able to extract resource as fast as it is needed. But...

"oil doesn't come from a hole in the ground, it comes from rocks" (Kenneth Deffeyes)

Example 2: Constant

T_{exp} = amount left / current rate

per capita use must *decrease* exponentially if population *grows* exponentially

Example 3: Exponential

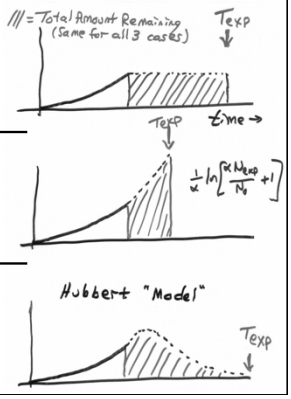
$T_{exp} = (1/k) \ln \{kN_T/N_0 + 1\}$

but nature and economics won't allow it!

Example 4: Hubbert

$T_{exp} = \infty$!!

but, that's not the issue!



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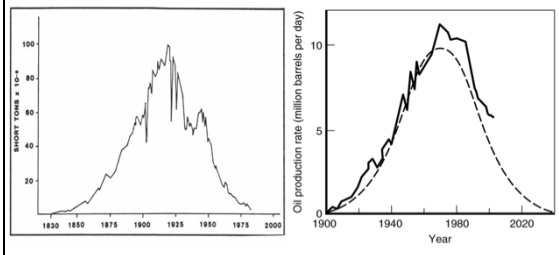
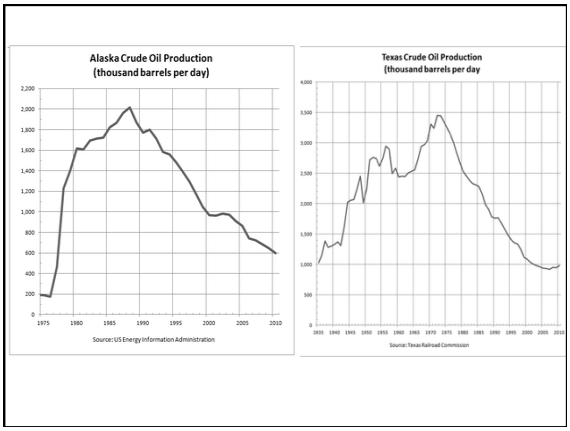
Hubbert Curves

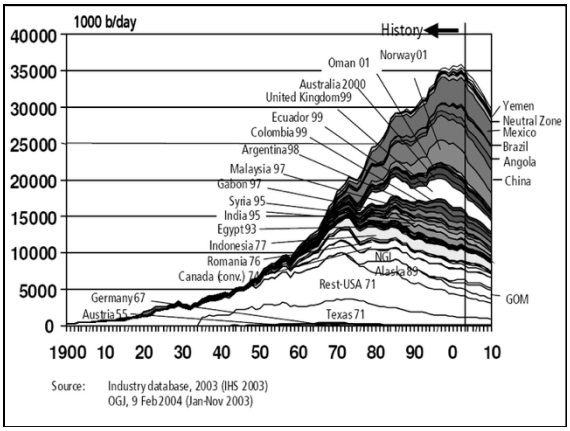


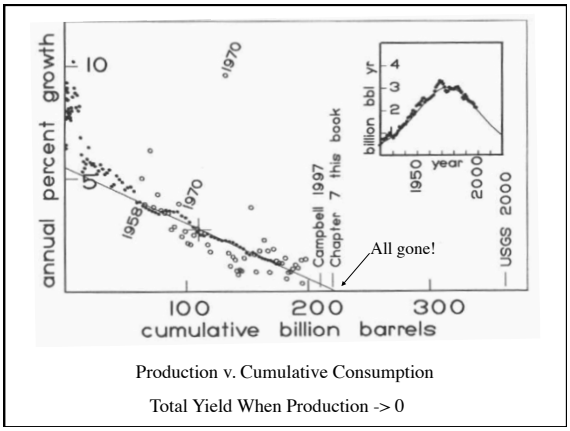
PA Anthracite Coal

US Petroleum

"Hubbert's Peak: The Impending World Oil Shortage" (Deffeyes, 2001)

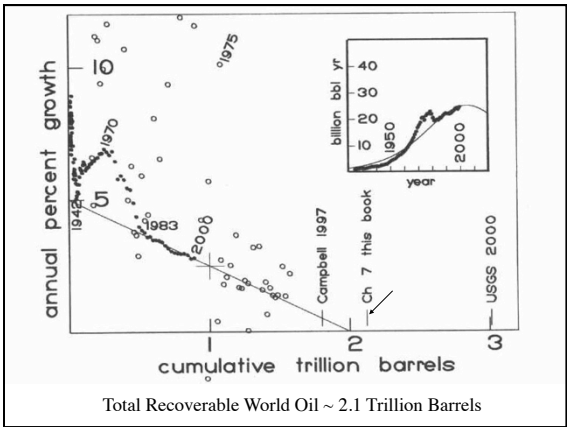




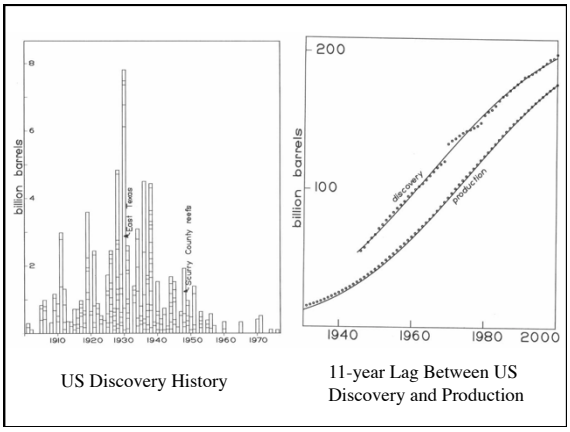


Production v. Cumulative Consumption

Total Yield When Production -> 0

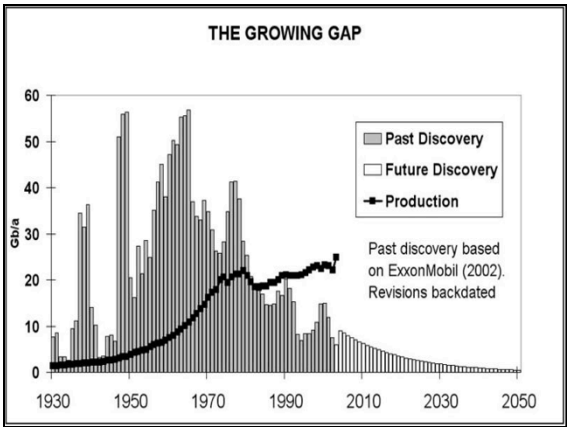


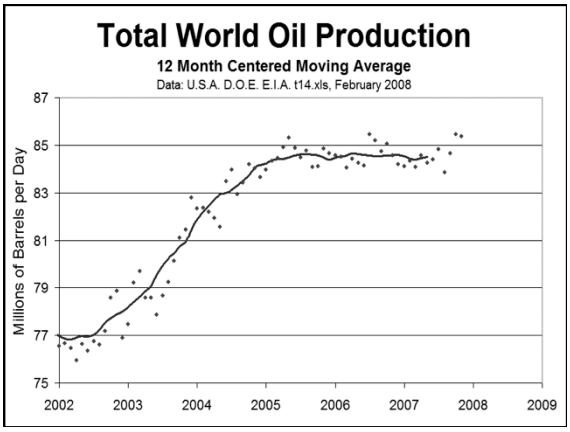
Total Recoverable World Oil ~ 2.1 Trillion Barrels

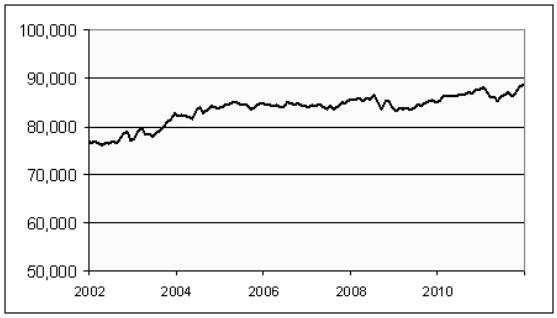


US Discovery History

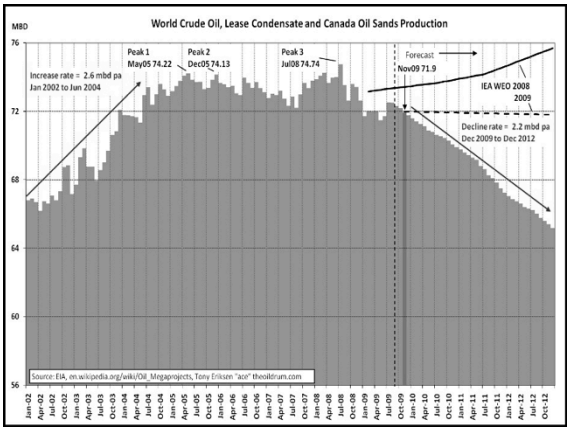
11-year Lag Between US Discovery and Production

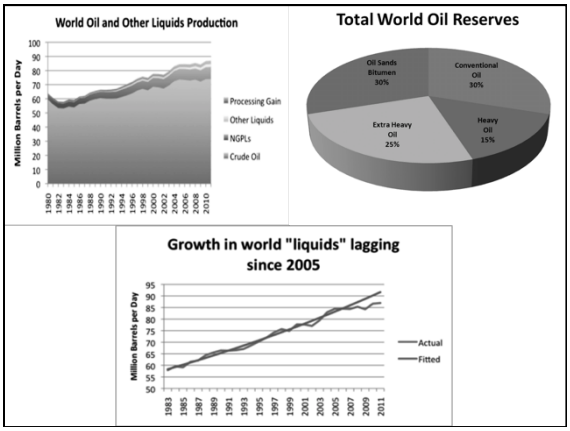




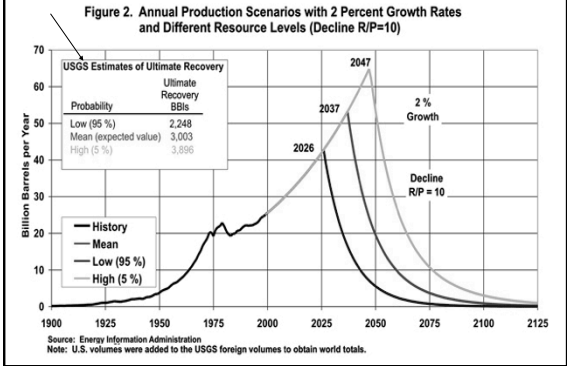


Choice of Zero Point Can Make A Big Difference!





You Be The Judge; How Optimistic Are You Now?



What Causes a Crisis?

- Different assumptions give different T_{exp}:
  - exponential expiration is shortest
  - "@ current rate" is much longer
  - Hubbert curve -> ∞, but forever *decreasing*
- When does the "crisis" occur?
  - Population growth is slowing [but still growing exponentially]
  - Can per capita rate drop fast enough to keep pace with population growth?
  - Finite resources becoming *increasingly difficult* to exploit (hence the Hubbert peaks)
  - *Running out* of the resources is NOT the problem!