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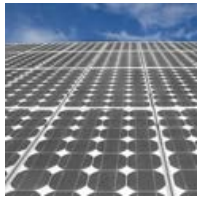

Fossil Fuel Supply and Energy Security

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How should we expect fossil fuel supply to evolve?

- Can we expect market forces to lead to reductions in fossil fuel supply?
  - Related, can we expect the demand for fossil fuels to fall?
  - **"We could use up all the proven reserves in the entire world by the end of the next decade"**

- How does this interact with energy security?

Running out of supply

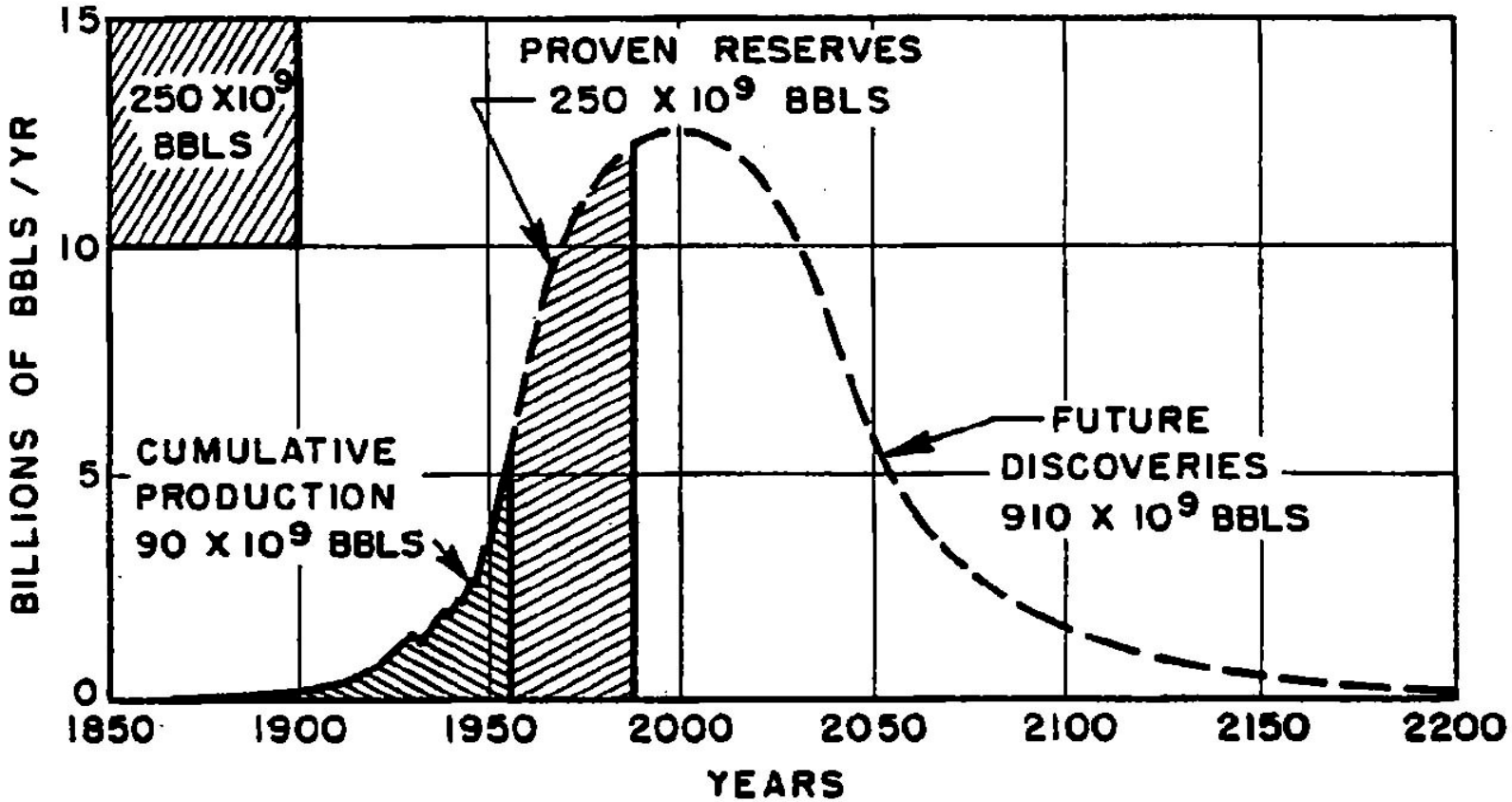

Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

Running out of supply

- Fossil fuels are, by definition, in ***finite supply***
  - *eventually* we will run out of them
- Capacity to produce at a given price must *eventually* diminish
  - supply curve must *eventually* shift upwards and backwards
- Without changes in demand, supply reduction leads to:
  - higher prices
  - lower quantities
  - *(eventually)*
- When is *eventually*? Are we close?

Running out of demand

- Technology of all kinds, including *alternatives to fossil fuel production and/or consumption*, tends to get better over time
  - energy efficiency, batteries, wind, PV
  - All getting cheaper to produce, with improved quality
- Improving *alternatives* to fossil fuels reduces demand for them
- Without changes in supply, demand reduction leads to:
  - lower prices
  - lower quantities
- Are alternatives improving *fast enough*?

We've run out of demand before

Recent work:

- Will we run out of supply?
  - examine historical record of fossil fuel reserves, exploration and development risk, technology
  - look for signs that progress is decelerating
  - are we near a version of Hubbert's peak?

- Will we run out of demand?
  - examine historical record of alternative power generation technology and electric vehicle battery development
  - look for signs that progress is accelerating

- (More in the paper, available on my website)

Recent work:

- **Will we run out of supply?**
  - **examine historical record of fossil fuel reserves, exploration and development risk, technology**
  - **look for signs that progress is decelerating**
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Are investments in supply slowing down?

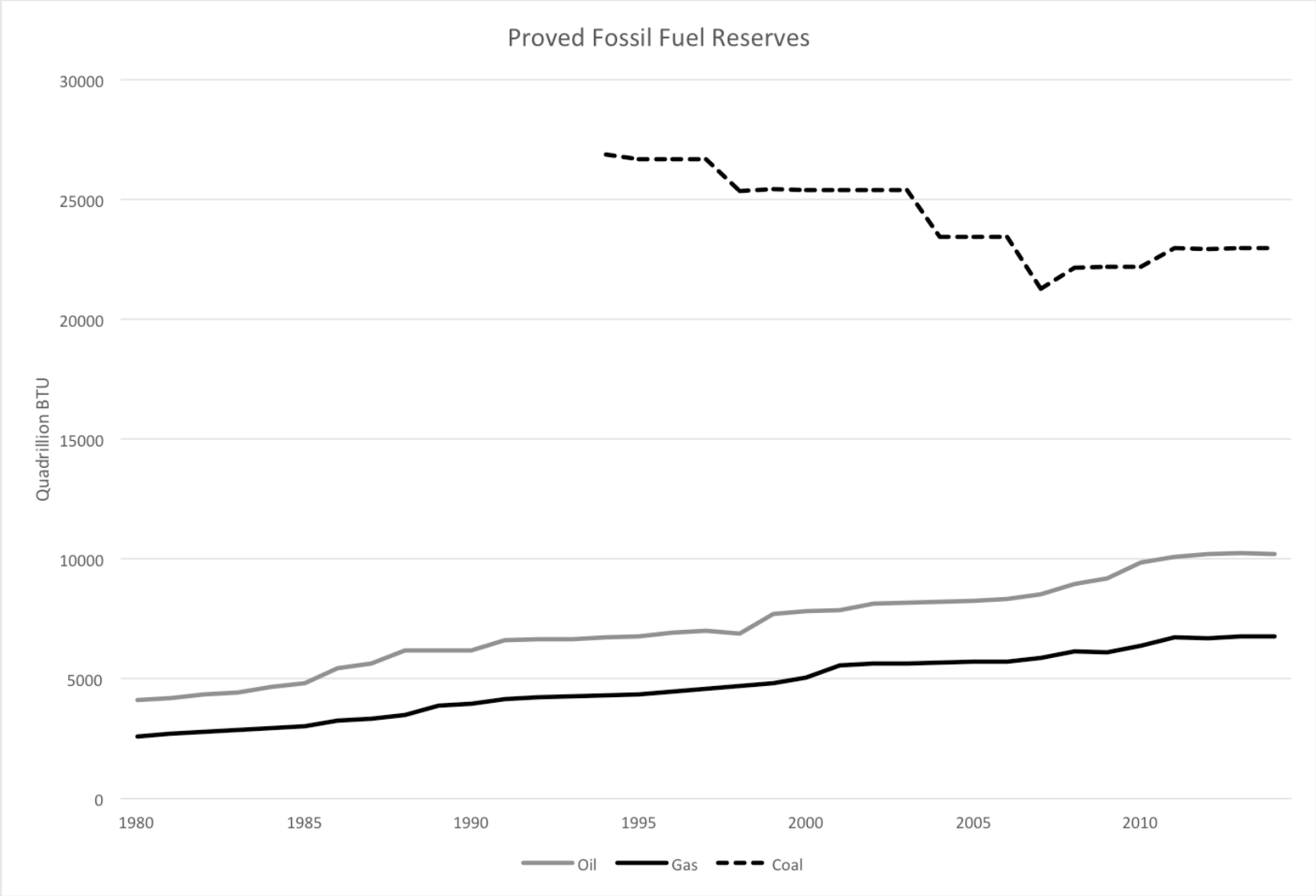
- Focus on reserve data from the BP Statistical Review, back to 1950s

- What are ***reserves***?
  - *"quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions"*

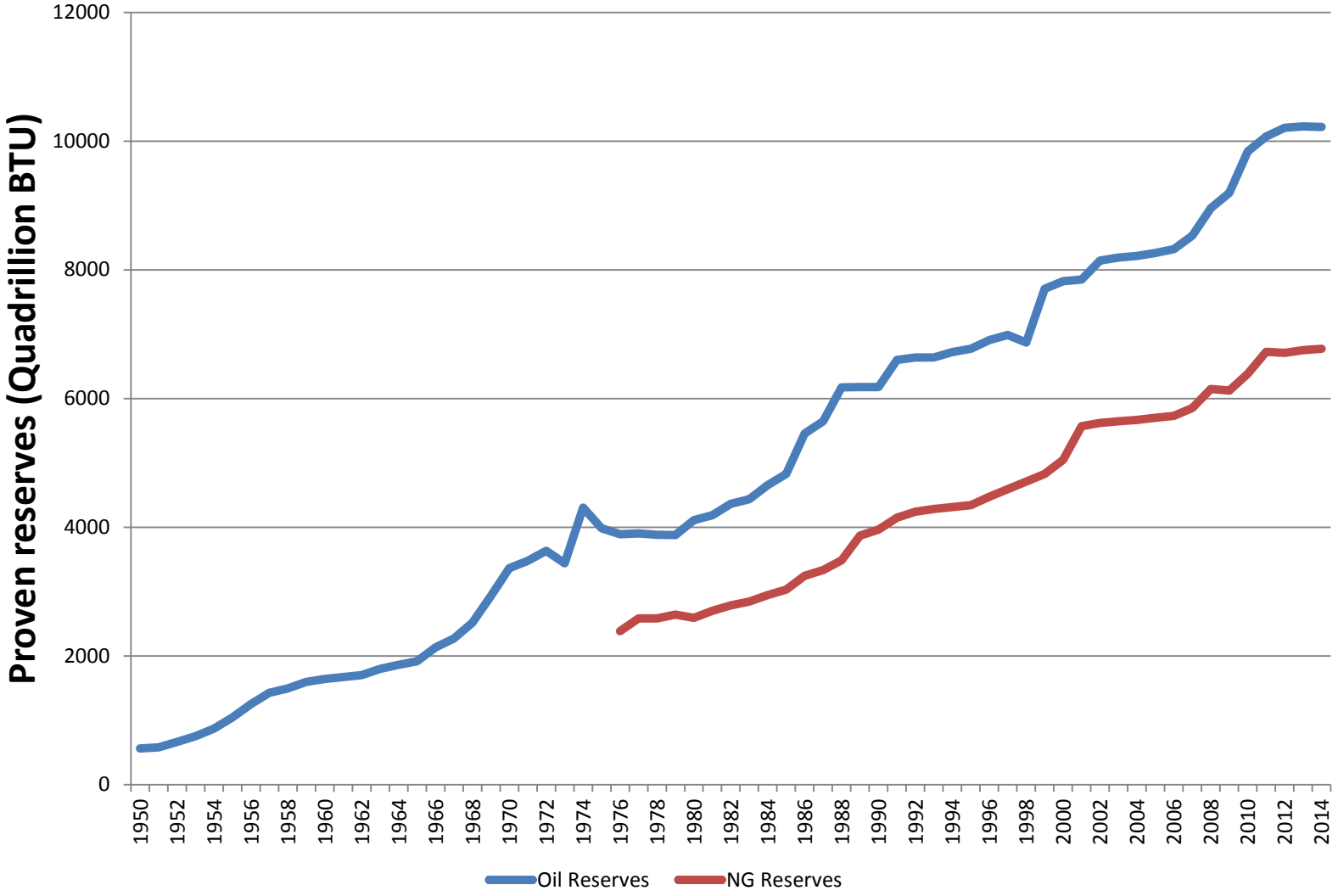
- Reserves change for three reasons

1. new reserves are discovered and proved
2. old reserves are produced and consumed
3. old reserves become uneconomic (prices fall or costs rise)

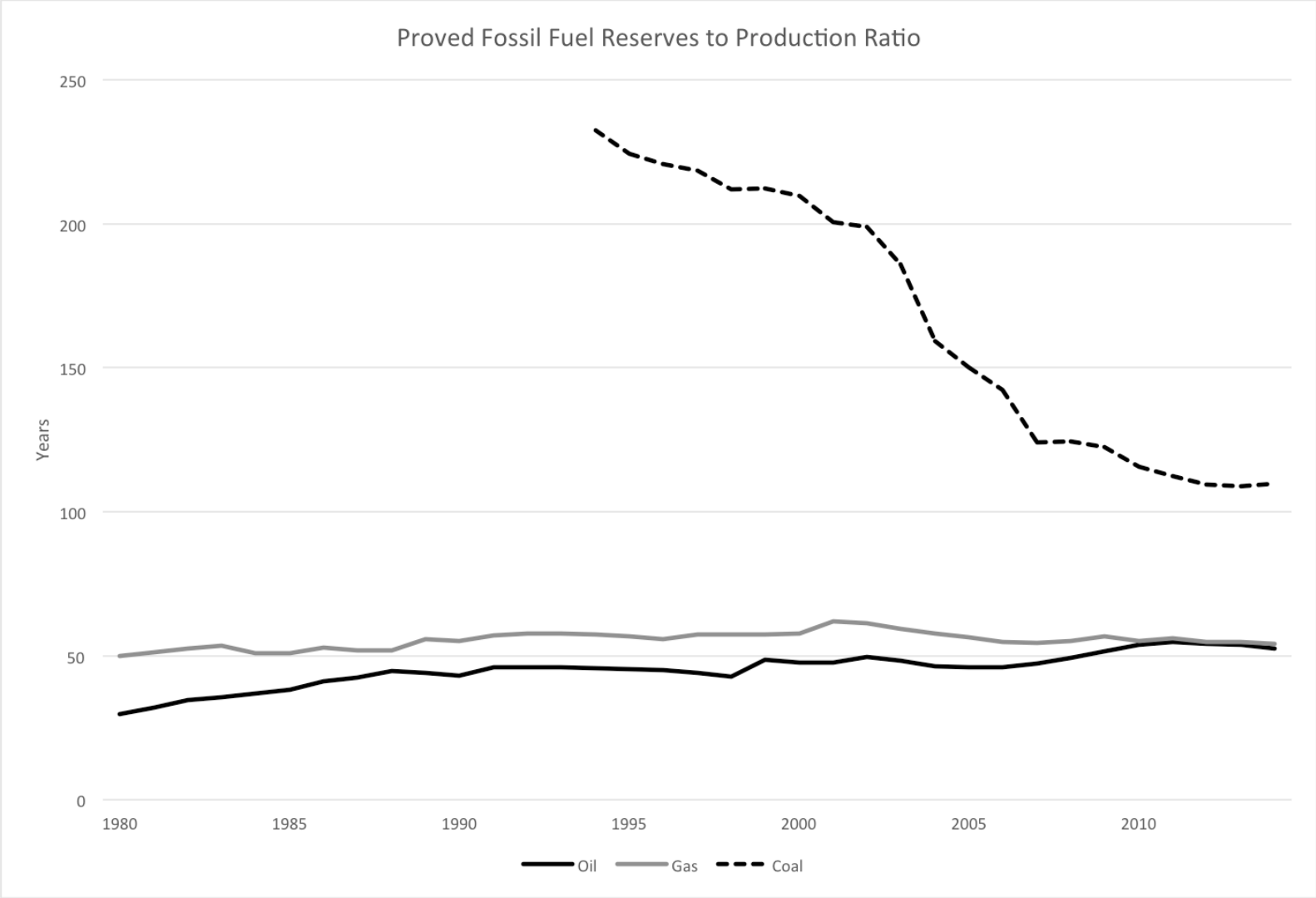
Proven reserves over time



Over a longer time



Oil/NG: Empirical regularity?



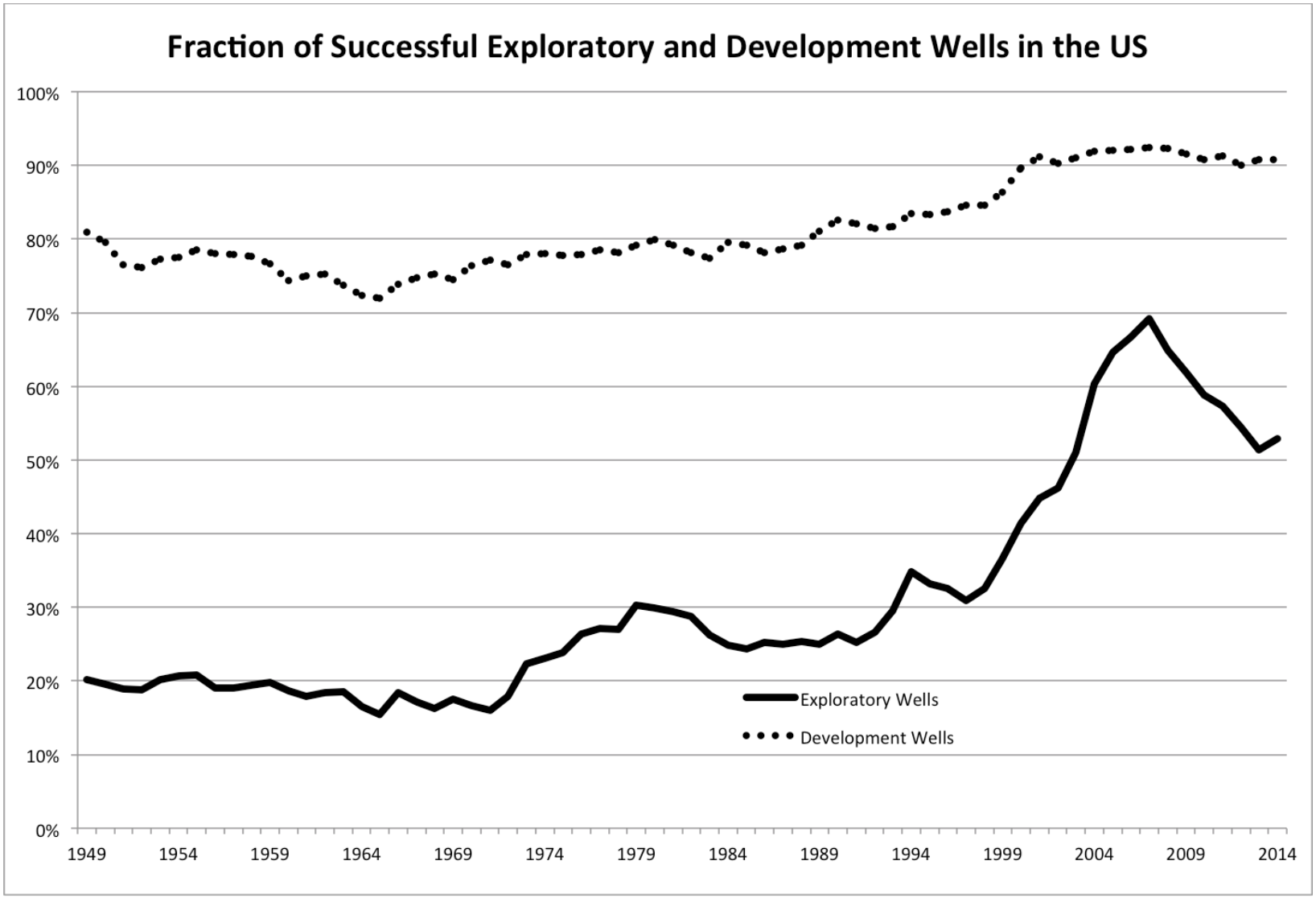
Why is future supply consistently growing?

– Two possible ways this could happen

1. We are getting better at finding/developing new deposits
   - pushing the boundaries of “geological information” and “known reservoirs”

2. We are getting better at developing technology to commercialize deposits that were previously uneconomic
   - pushing the boundaries of “engineering information”

This wasn't always oil!


Fraction of Successful Exploratory and Development Wells in the US
100%
90%
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70%
60%
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10%
0%
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1984
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1999
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2009
2014
Exploratory Wells
Development Wells

Improving ability to find new resources

- Exploratory drilling success went from 20% to 60% in 50 years
  - seismic technology (2D->3D, onshore->offshore)
  - offshore drilling (shallow in the 50s, deep water in the 80s)
  - horizontal drilling and hydraulic fracturing today
- Development drilling success went from 80% to 90%
  - also important: 10-20 times as many development wells!

Development of "impossible" resources

- Two major events in reserve growth

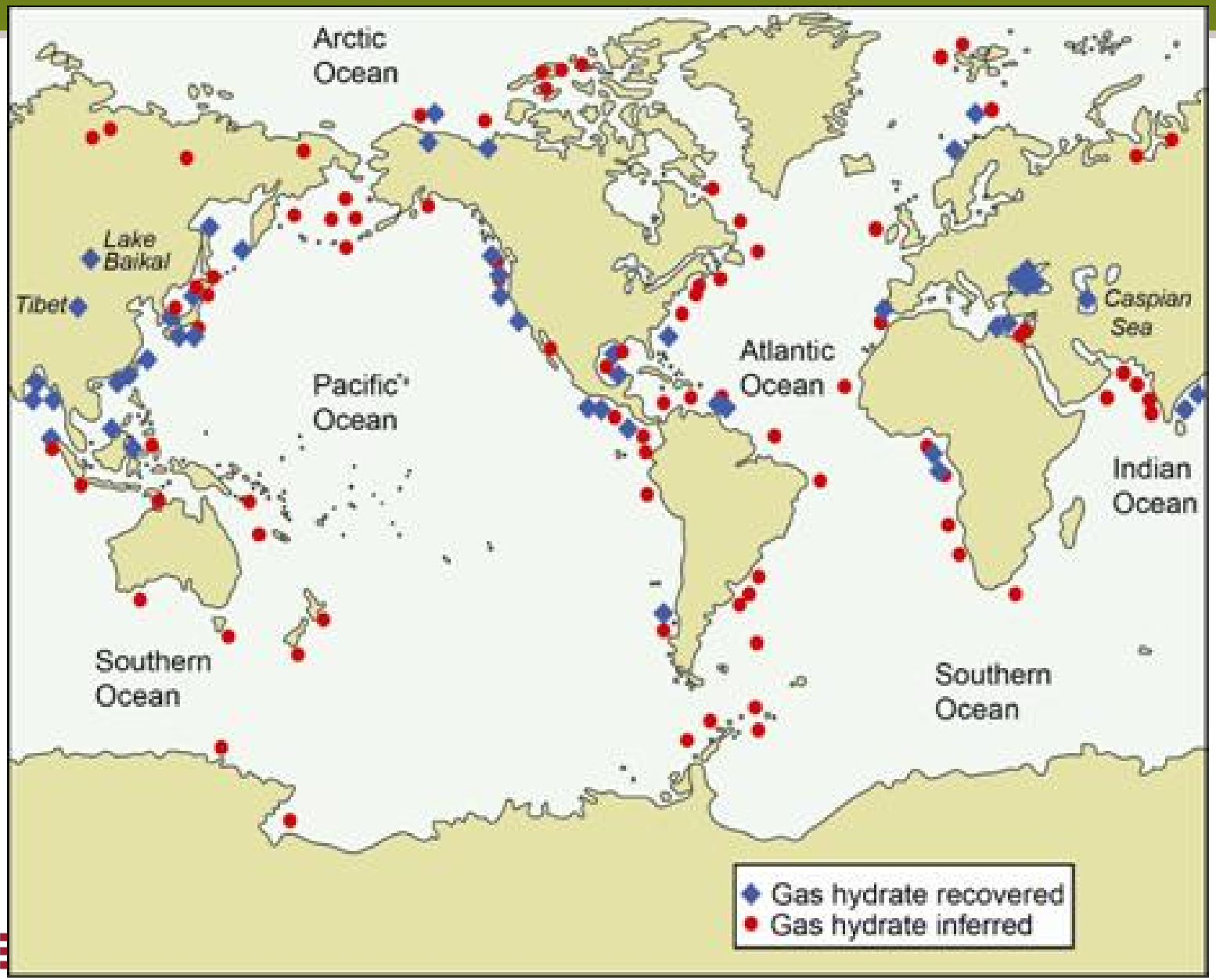
1. Canadian tar sands in the late 1990s
   - **triples** Canadian oil reserve estimates
   - 10% increase in world oil reserves from this alone
2. North American shale gas and oil (2005-present)
   - 50% increase in oil reserves, 60% increase in gas
   - ROW only grows 16% in the same time

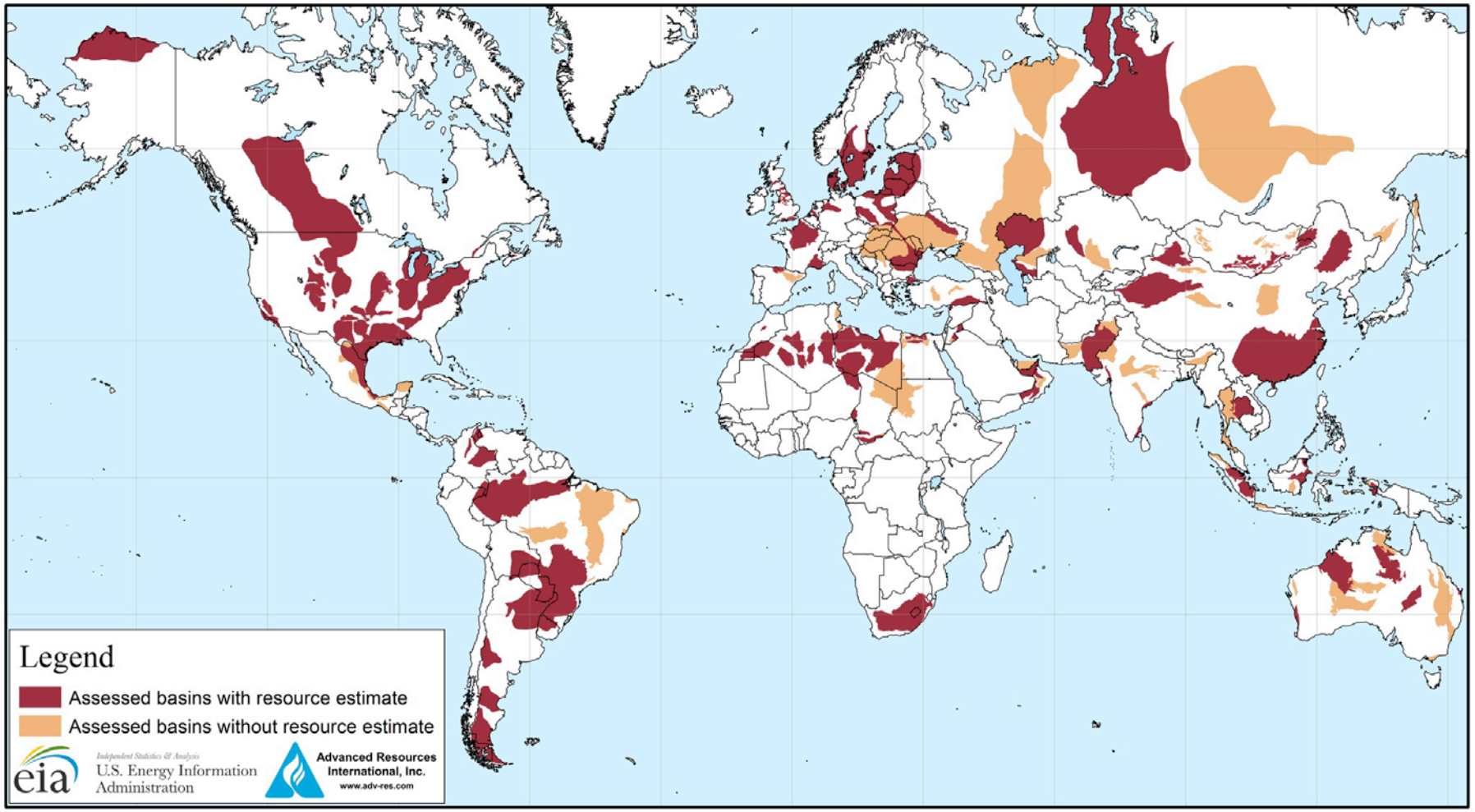
- Both resources were long known to be large, but previously thought to be technologically/economically infeasible

Future development of “impossible” resources

- Oil shale (not to be confused with shale oil)
  - similar to tar sands technology, but more viscous
  - USGS estimates 2.8 trillion bbls of oil shale *resources*
    - compare to 4-6 trillion bbls of “conventional” oil *resources*

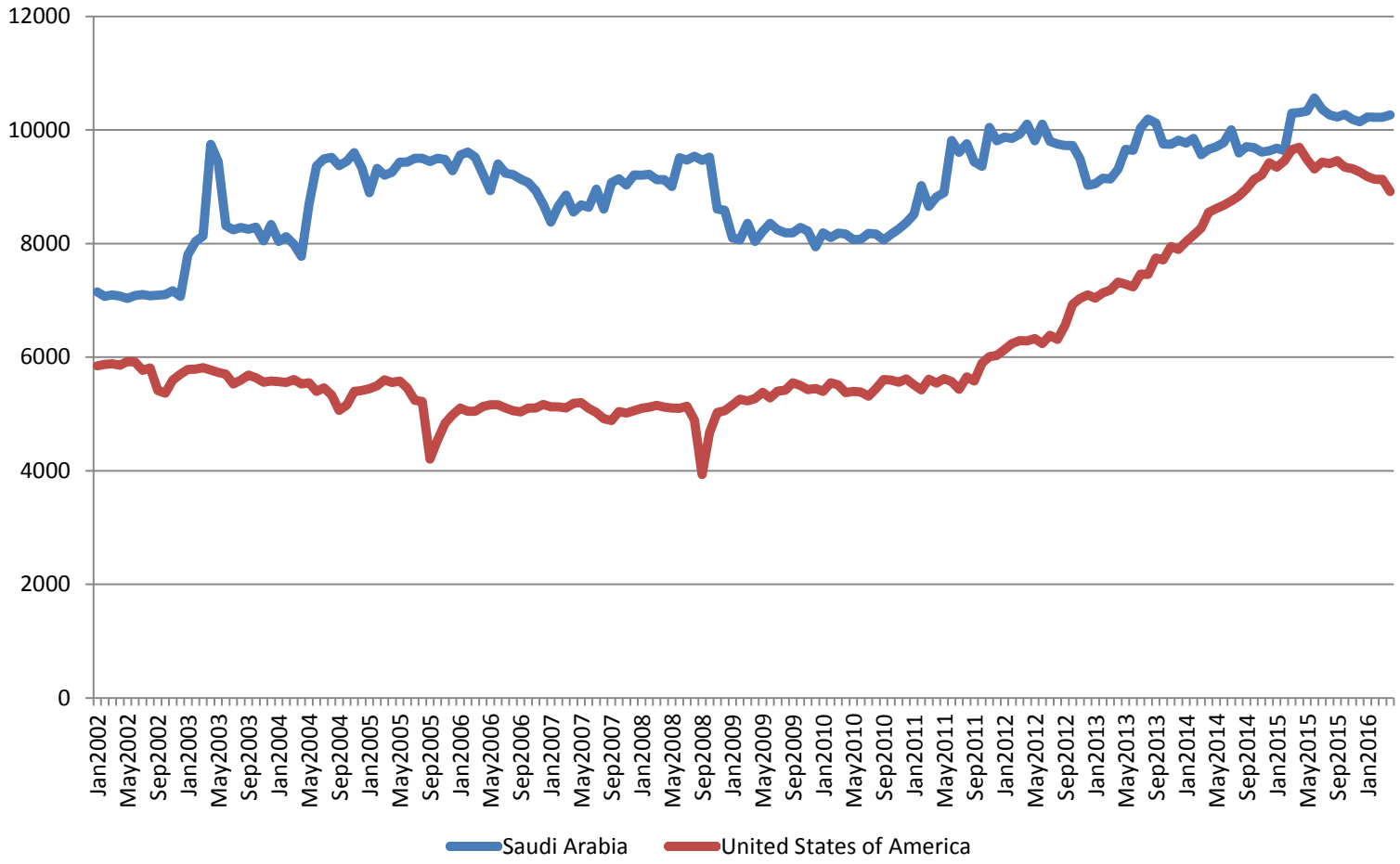
- Methane hydrates
  - solid mixture of natural gas and water, trapped in high pressure, low temperature environments, beneath seafloors
  - USGS estimates 10-100 trillion cubic feet of natural gas *resources* in methane hydrates
    - compare to 28-410 trillion cubic feet of “conventional” natural gas *resources*


Arctic Ocean
Lake Baikal
Tibet
Pacific Ocean
Atlantic Ocean
Caspian Sea
Indian Ocean
Southern Ocean
Southern Ocean
Gas hydrate recovered
Gas hydrate inferred


Legend
Assessed basins with resource estimate
Assessed basins without resource estimate
eia
Independent Statistics & Analysis
U.S. Energy Information Administration
Advanced Resources International, Inc.
www.adv-res.com

Huge implications for energy security

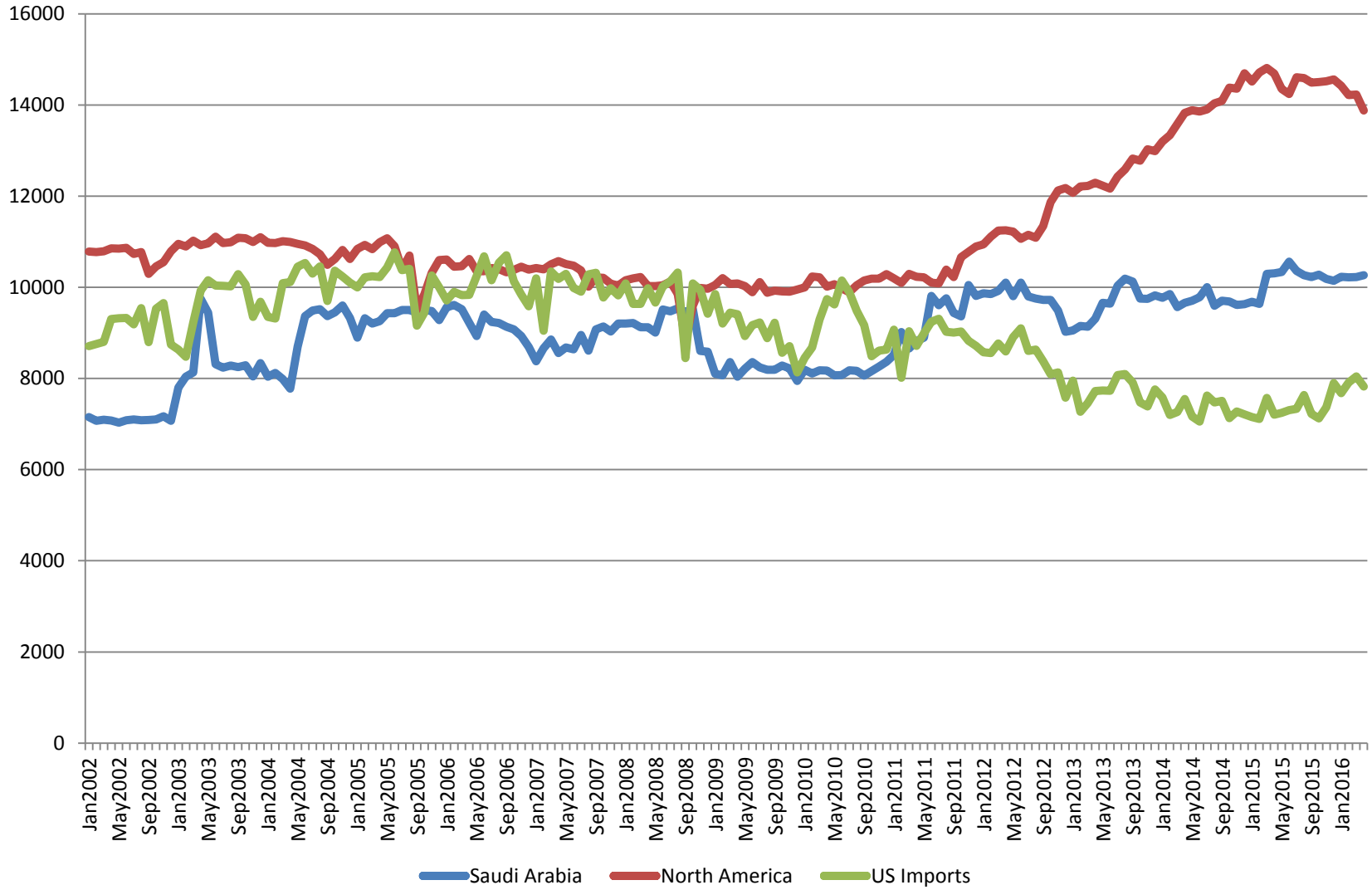
- Fracking has fundamentally changed geopolitics around oil



Energy security

- Energy security takes two forms:
  - 1. The possibility of major disruptions in the supply of oil
  - 2. The macro-economic risks associated with oil price spikes

- Both of these risks are greatly reduced by the increase in domestic production
  - Looking at North America...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Saudi Arabia
North America
US Imports

Wrapping up

- 1. We should expect world fossil fuel supply to continue to grow
- 2. While the amount of fossil fuels in the ground is *technically* falling, it is a race against technological progress and demand
  - Technological progress is winning this race
- 3. The changing location of this supply is transforming geopolitics