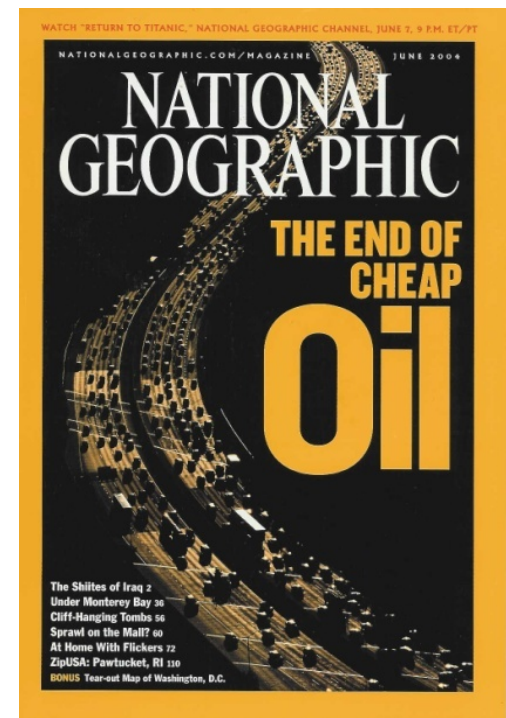


1999

# OIL PRODUCTION AND CLIMATE CHANGE

EES/IGEL Seminar  
November 12, 2014

James W. Murray  
School of Oceanography  
University of Washington

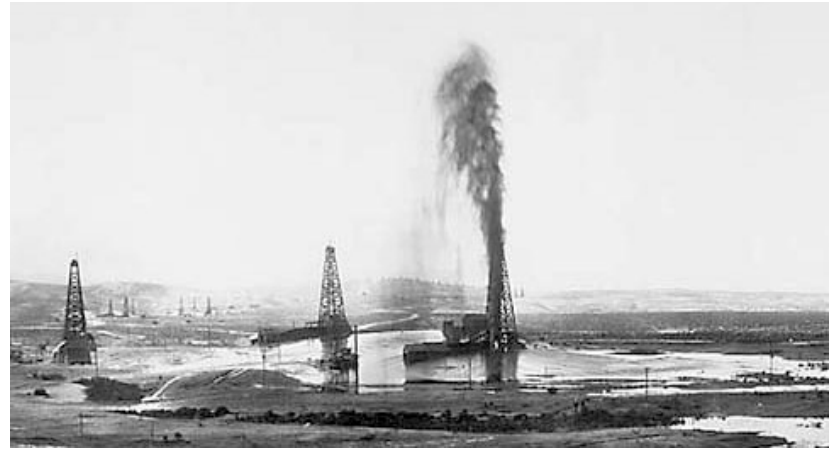


2004

**“It ain’t what you don’t know that gets you into trouble.  
It’s what you know for sure that just ain’t so”**

**Mark Twain**

**There are many, many things that the public and policymakers know for sure about energy that just ain't so.**

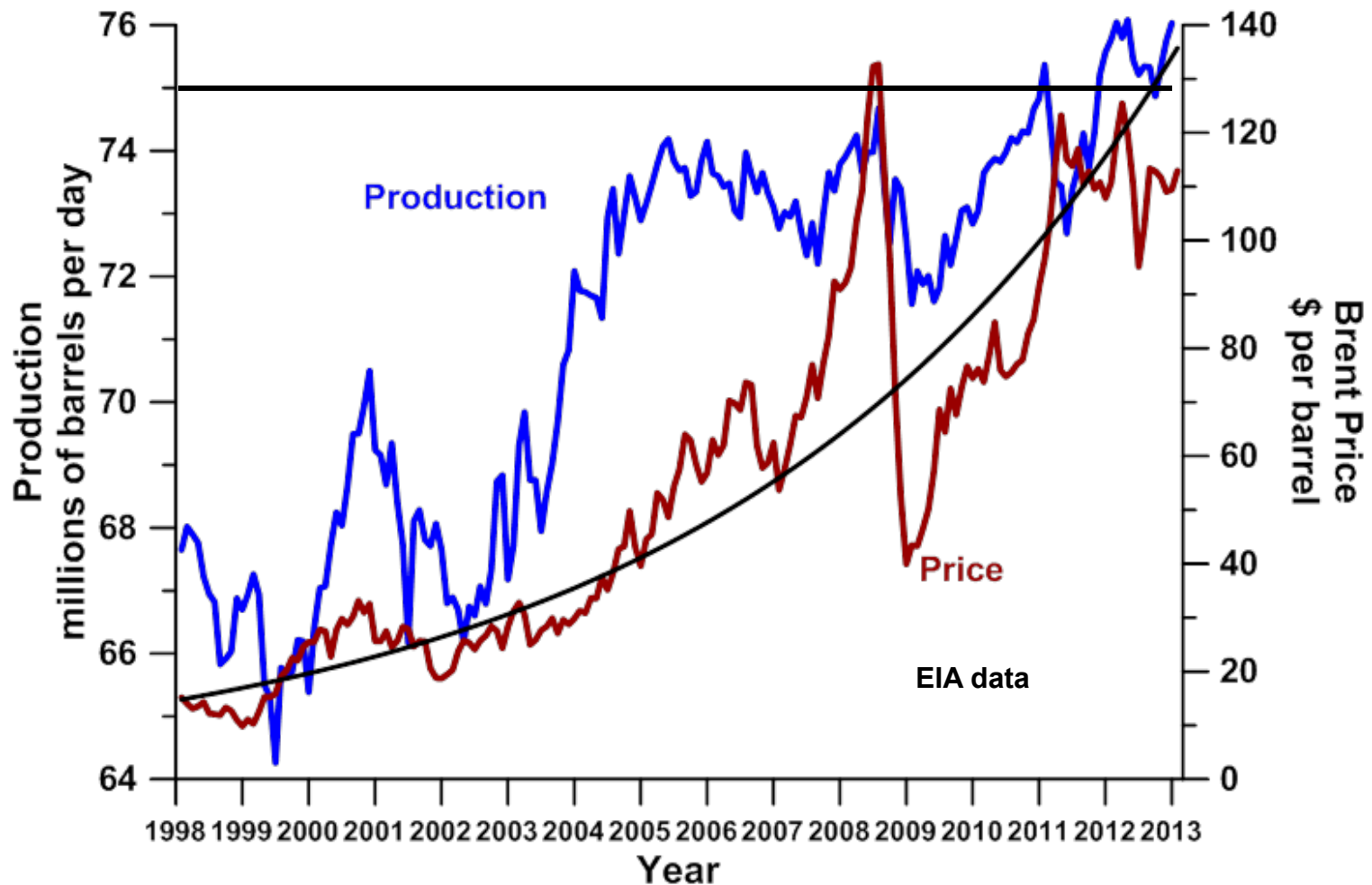


To be fair to the EIA, nobody – not the White House, not the Congress, not any elected official, not any living, breathing American — wants to hear our government tell us that there are big changes ahead and that things might be considerably worse in the years ahead. Therefore, for the most part our government tries to paint an optimistic picture of the future, with minimal concern for the consequences of bad forecasts.

**"We like to think that the reason we enjoy our high standards of living is because we have been so clever at figuring out how to use the world's available resources. But we should not dismiss the possibility that there may also have been a nontrivial contribution of simply having been quite lucky to have found an incredibly valuable raw material that for a century and a half or so was relatively easy to obtain."**

**- James D. Hamilton (Dept. of Economics, UCSD)**

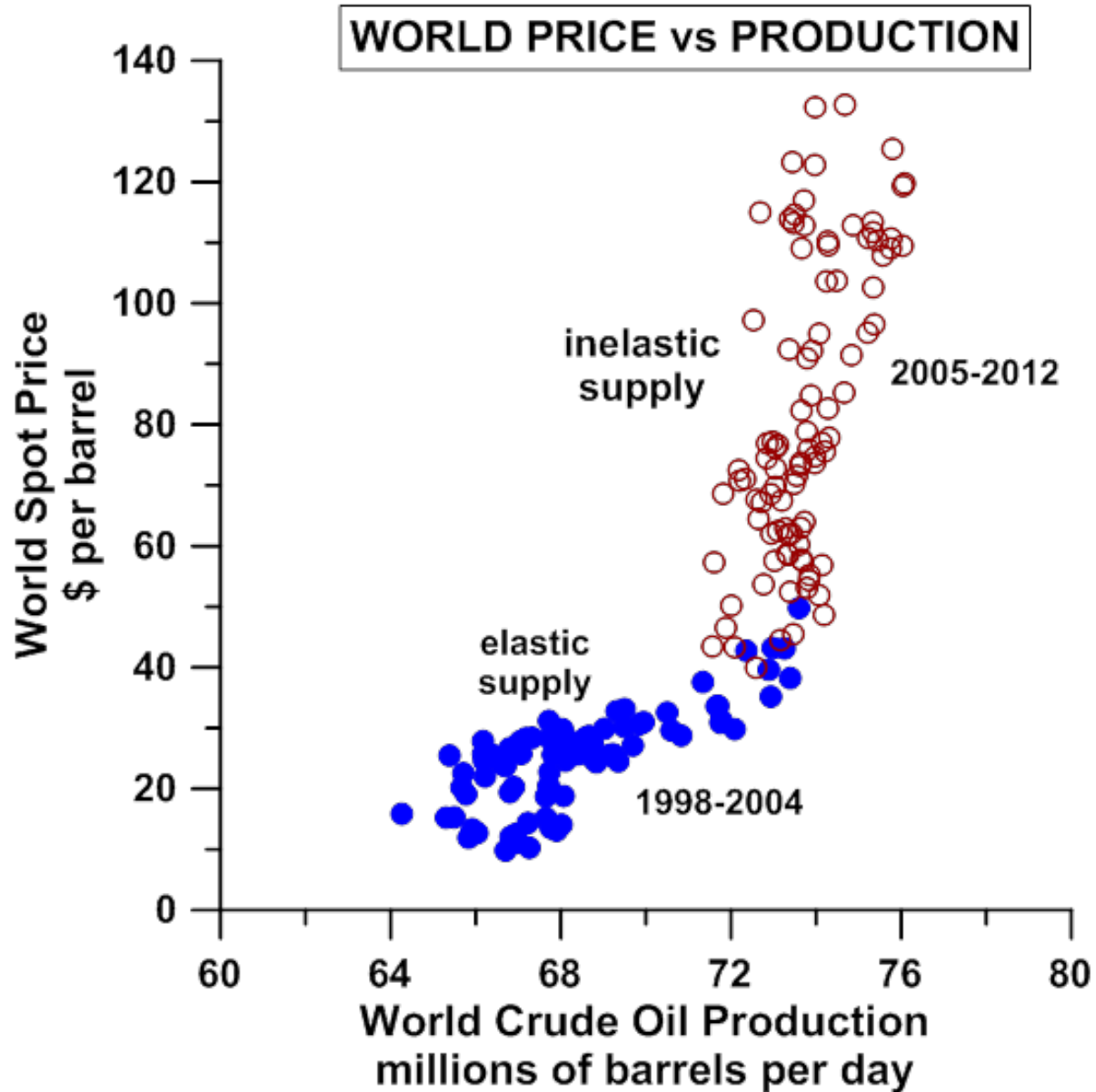
# Global oil production and price



**Oil Production has been on a plateau since 2005**

Murray and King (2012) Nature  
Murray and Hansen (2013) EOS

# A Phase Shift



**No Peak yet but ...**

**Global Oil Production has been on a plateau since 2005 in spite of a large increase in the price of oil.**

**Why the plateau?**

- 1. Existing oil fields are in decline.**
- 2. New production is just keeping pace (so far).**
- 3. No increase in total production.**

I argue that **conventional oil** has peaked  
(or will soon)!

If so the debate about “peak oil” comes  
down to what are the prospects for  
production rates from low EROI,  
expensive **unconventional sources**.

# Background geology (101)

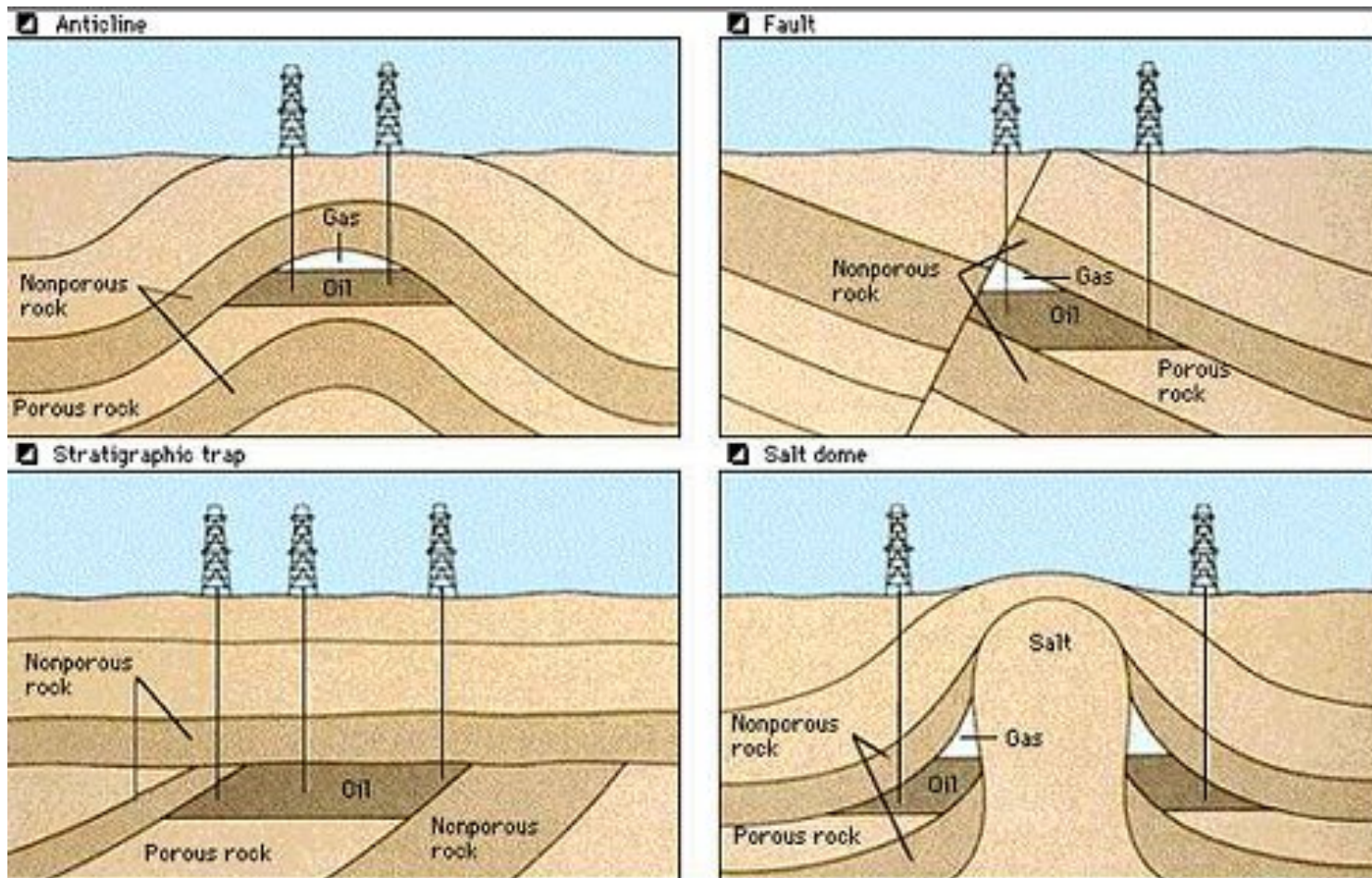
Source rocks (Marine Carbon – marine plankton) (past solar energy)

Maturation (Temperature and Pressure)

Migration from source rocks (fine grained shales) to

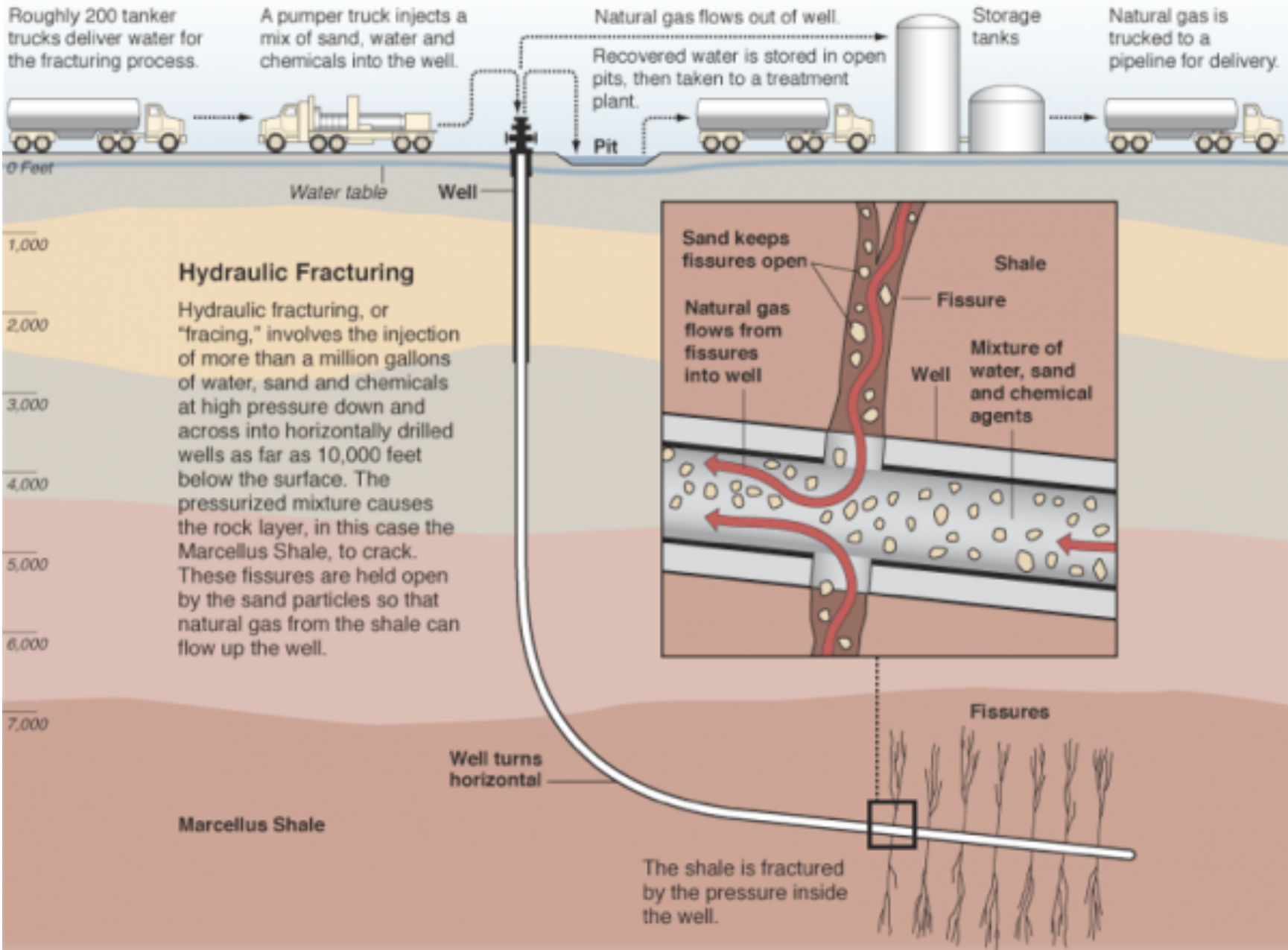
reservoir rocks (coarse grained sandstones & carbonates)

Oil and Gas Traps





# Horizontal Drilling and Hydrofracing (\$\$\$)



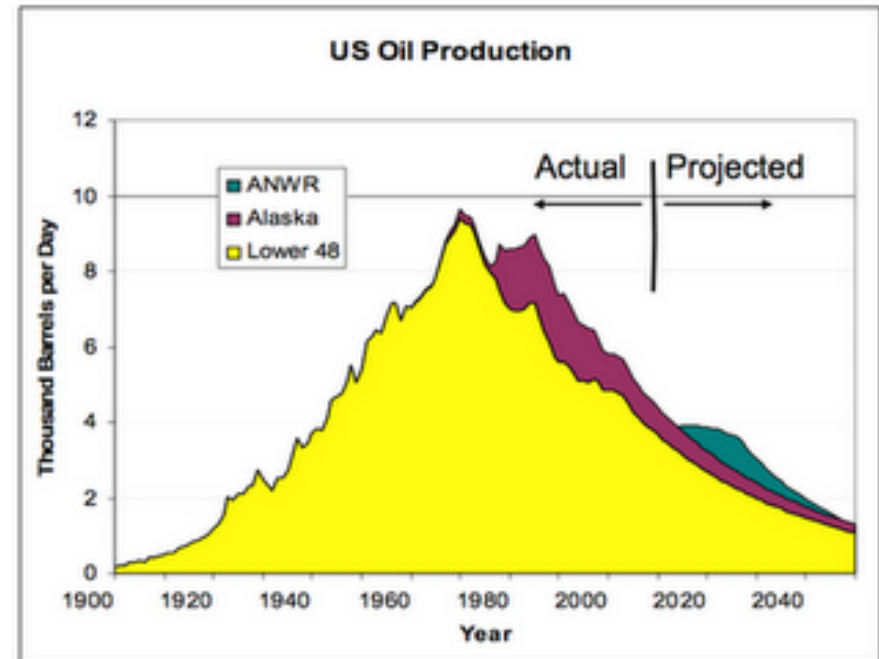
# What is Peak Oil?

## Geological Peak Oil – supply side view

Conventional oil production will reach a maximum when half the ultimate recoverable resource (URR) has been produced

US reached peak oil  
in 1970

## U.S. Oil Production



# **What is Peak Oil? Its not a theory!**

**Often misrepresented by critics.**

**It's not about Resources or Reserves!**

**It's all about maximum in Production Rate!**

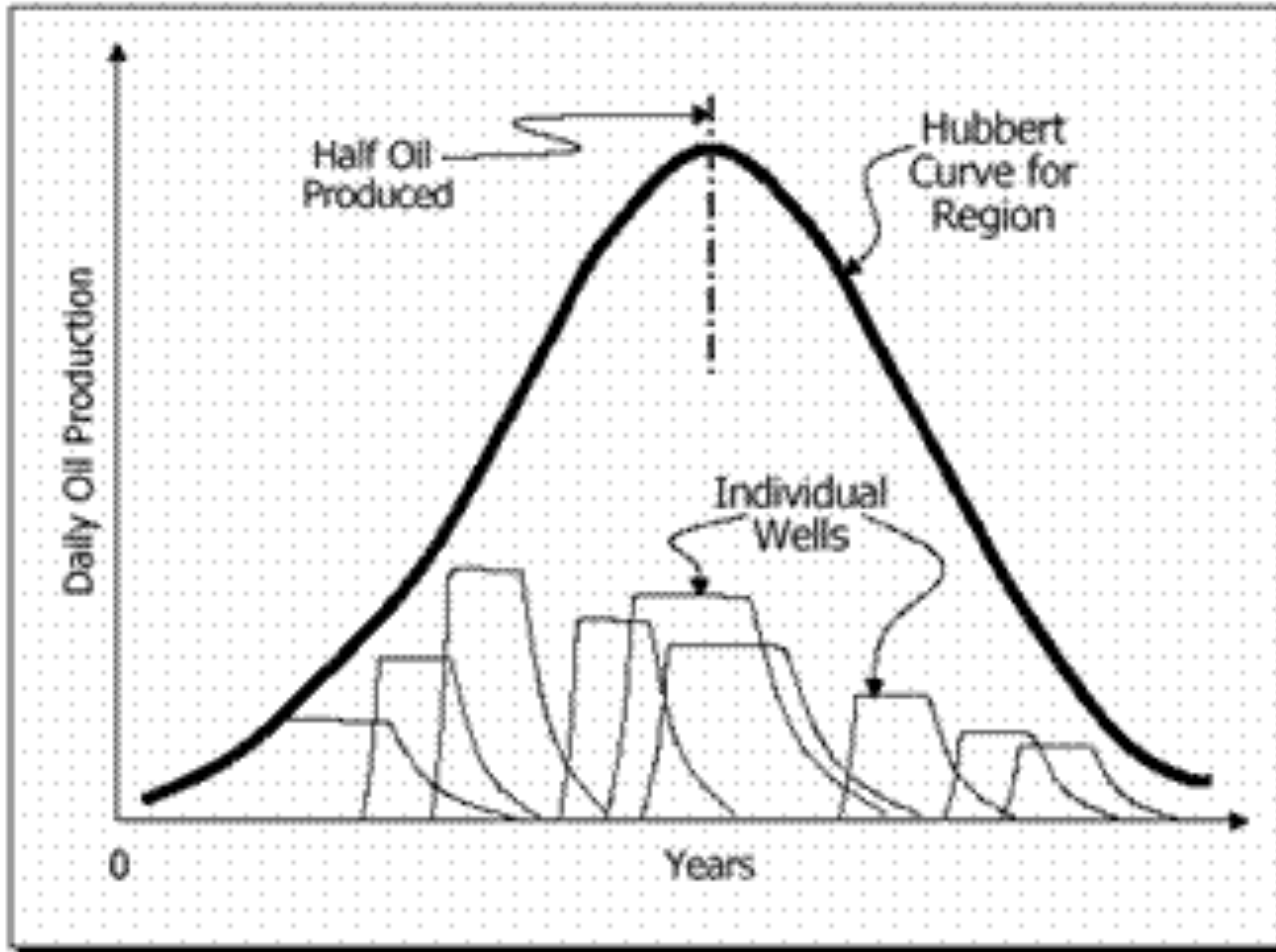
**We are not close to running out of oil.  
It doesn't mean we won't find more oil.**

**It does not mean the immediate collapse  
of modern civilization!**

# HUBBERT CURVE

## Regional Vs. Individual Wells

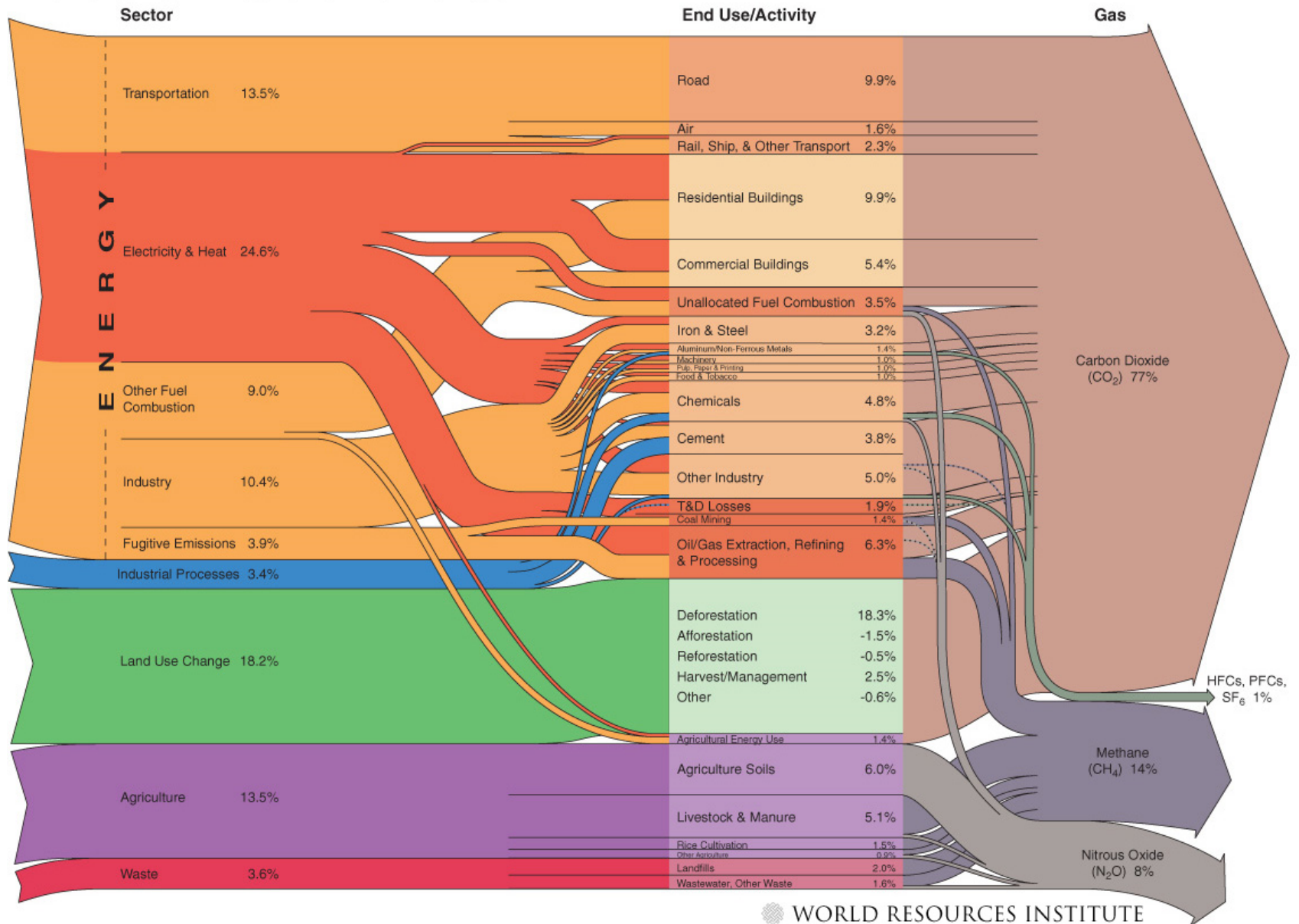
M. King Hubbert  
A model  
logistic  
distribution



**Oil Wells and Fields Peak --- Regions Peak --- The World will peak**  
**Everyone agrees that world oil will peak – controversy on the date.**  
**Fields continue to produce after peaking, but more effort and expense will be required.**

# The Link Between Peak Oil and Climate Change

## World GHG Emissions Flow Chart



# There is an ongoing Energy Policy Debate

The notion of that fossil fuel supply may be constrained has gone from being dismissed, to be partially accepted, to being vociferously dismissed.

The Teams:

**Cornucopians** – the oil and gas industry, its public relations, its bankers, official agencies (EIA and IEA) that tend to parrot industry data. Respected, get lots of press and are well funded.

“Oil production will continue to increase to meet rising demand. There is no physical limit to the global supply of oil so long as the energy industry is prepared to and allowed to apply its techno wizardry to find and produce it.”

Vs

**Peakists** – retired and independent petroleum geologists, academics, and energy analysts, US and German military think tanks, IMF

“Geological evidence suggests that rates of global oil production will soon reach a maximum then decline. The market may not be able to sustain the cost of high production of “unconventional” oil.”

## Confusing Factors

1. Definitions of oil
2. Resources vs Reserves vs Production
3. "Proven" Reserves
4. Discoveries vs Production
5. Existing oil fields in decline
6. Net Exports
7. Energy Return on Energy Invested
8. Wild Cards
  - Technology
  - Politics
  - Economy

# Definitions of Oil and Price

**IEA – International Energy Agency  
(OECD, International, Paris)**

**EIA – Energy Information Agency in US Department of  
Energy (US DOE)**

**BP – British Petroleum**

## Definitions of Oil

**IEA reports Crude + condensates + natural gas  
liquids + biofuels + processing gains = 91 mb/d**

## Oil Price

**Brent = \$86.13**

**NyMeX (WTI) = \$81.01**

**EIA reports Crude + condensates = crude oil  
= 76 mb/d**

**BP reports Crude + condensate + NGL**

**NGL = ethane, propane, butane (not liquid)**

**Condensates = low density HC liquids**

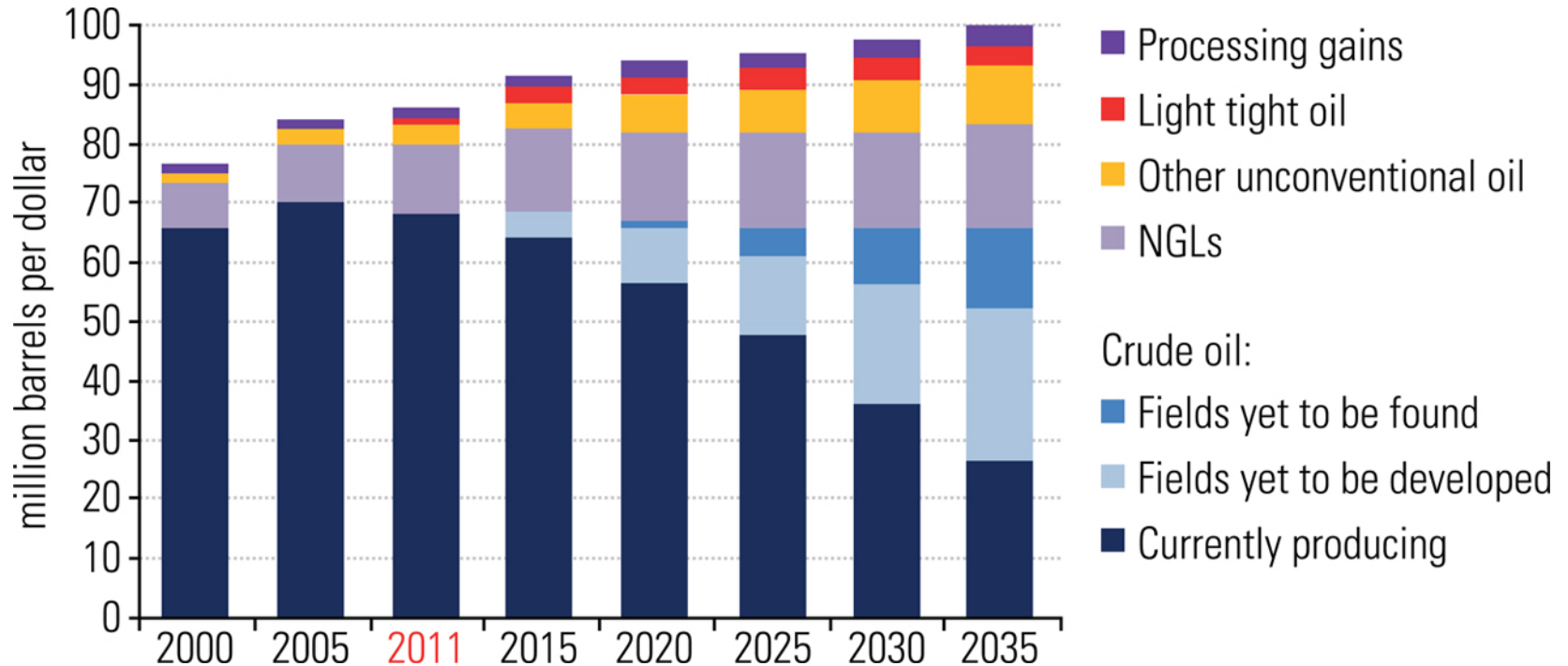
**(mostly pentane; C5 to C9)**

**No one tracks actual crude oil (API < 45)**



# 1. Worldwide oil production will grow to 2025

## The IEA actually admits to “Peak Oil”



**The decline rates of all conventional crude-oil fields producing today is spectacular**

Here's what's being added to underlying crude oil production and labeled as oil by the oil companies and reporting agencies:

**Biofuels** - Essentially ethanol and biodiesel.

**Natural gas plant liquids** - Butane, ethane, pentanes, propane and other non-methane components of raw natural gas.

**Lease condensate** - Very light hydrocarbons (C5-C9) gathered on production sites from both oil and natural gas wells, often referred to as "natural gasoline" because it can in a pinch be used to power gasoline engines though it doesn't have the octane (30 to 50) of gasoline produced at refineries.

**Refinery gain** - The most puzzling addition of all to crude oil supply calculations. This is merely the increase in the volume of refinery outputs such as gasoline, diesel and jet fuel versus the volume of crude oil inputs. It is due entirely to the expansion of the liquids produced, but indicates no actual gain in energy. In fact, great gobs of energy are EXPENDED in the refinery process to give us what we actually want.

**Actual oil (oil with an API gravity of 45 or less per RBN Energy) production numbers are hard to find.**

From Jeff Brown: Estimated crude oil production (mb/d)

2002 – 60	2006 – 65	2010 - 66
2003 – 62	2007 – 65	2011 - 65
2004 – 65	2008 – 66	2012 - 67
2005 – 67	2009 - 64	

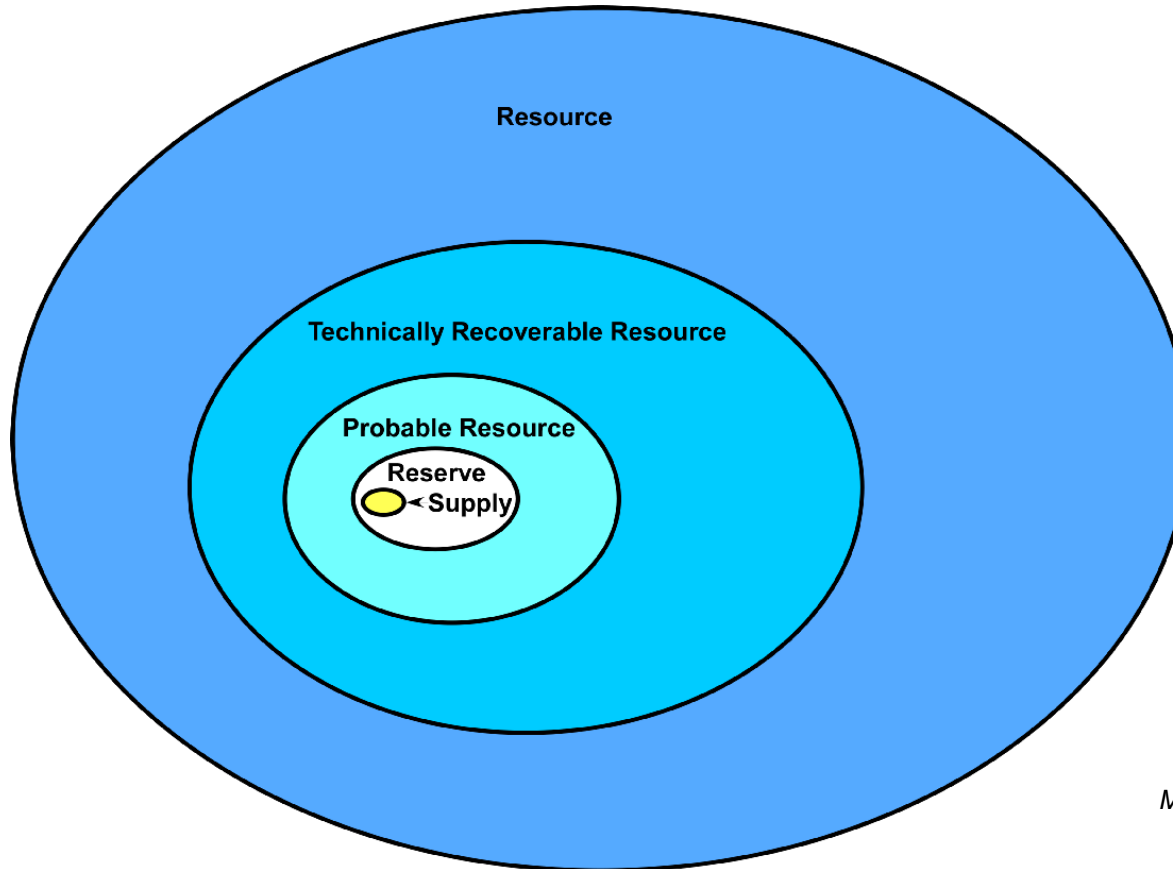
## **Crude Oil vs “Crude Oil”**

**When the industry and the government talk about the price of oil sold on world markets and traded on futures exchanges, they mean one thing. But, when they talk about the total production of oil, they actually mean something quite different--namely, a much broader category that includes all kinds of things that are simply not oil and that could never be sold on the world market as oil.**

**If what you're selling cannot be sold on the world market as crude oil, then it's not crude oil!**

# Resources $\neq$ Reserves $\neq$ Supply

2

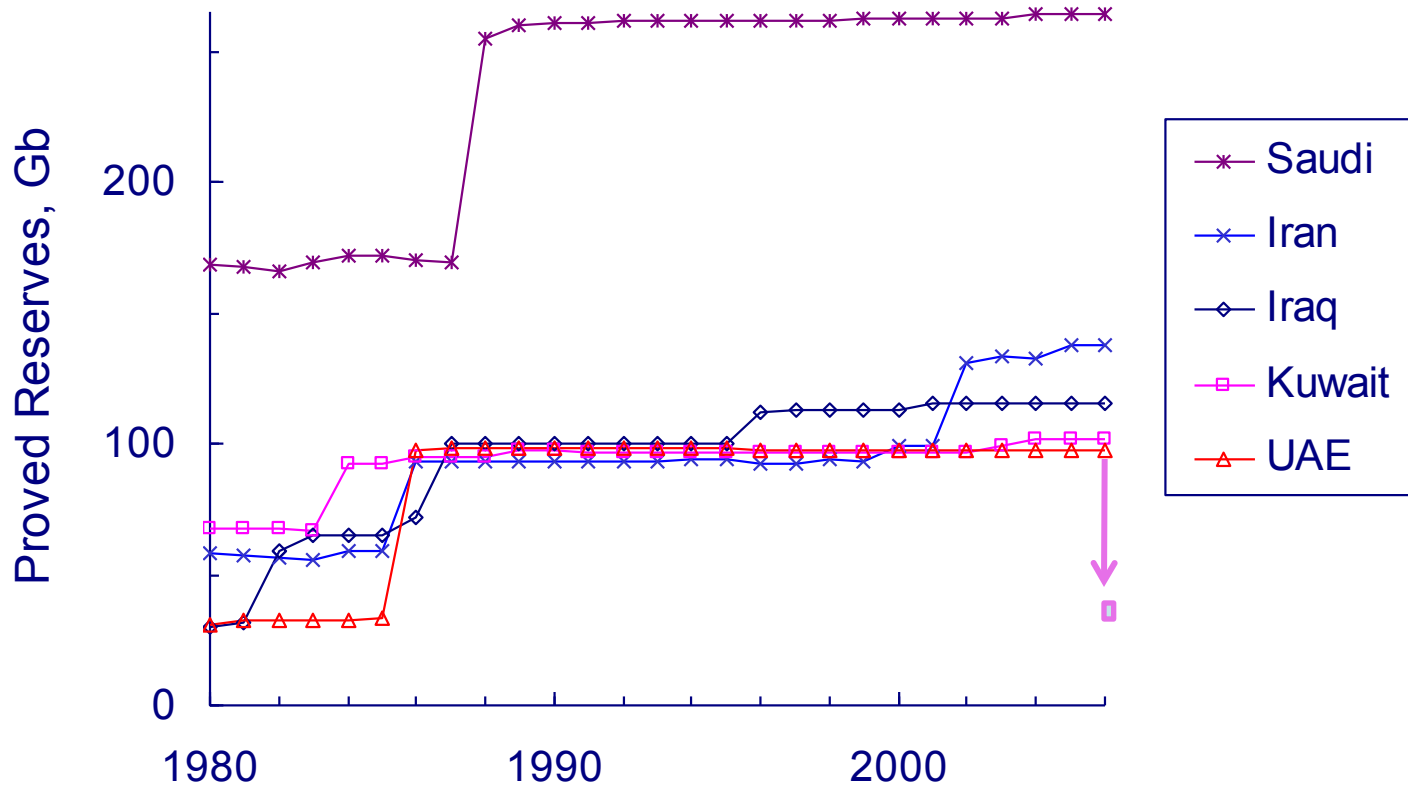


*Modified from Medlock (2010)*

- Reserves are a very small sub-set of resources (oil in place) (**overstated**).
- Reserves take years of development drilling to become supply.
- Proved undeveloped reserves may never be developed.
- **Reserves (an amount) are irrelevant for production (a rate)**
- It is the production that is used by society

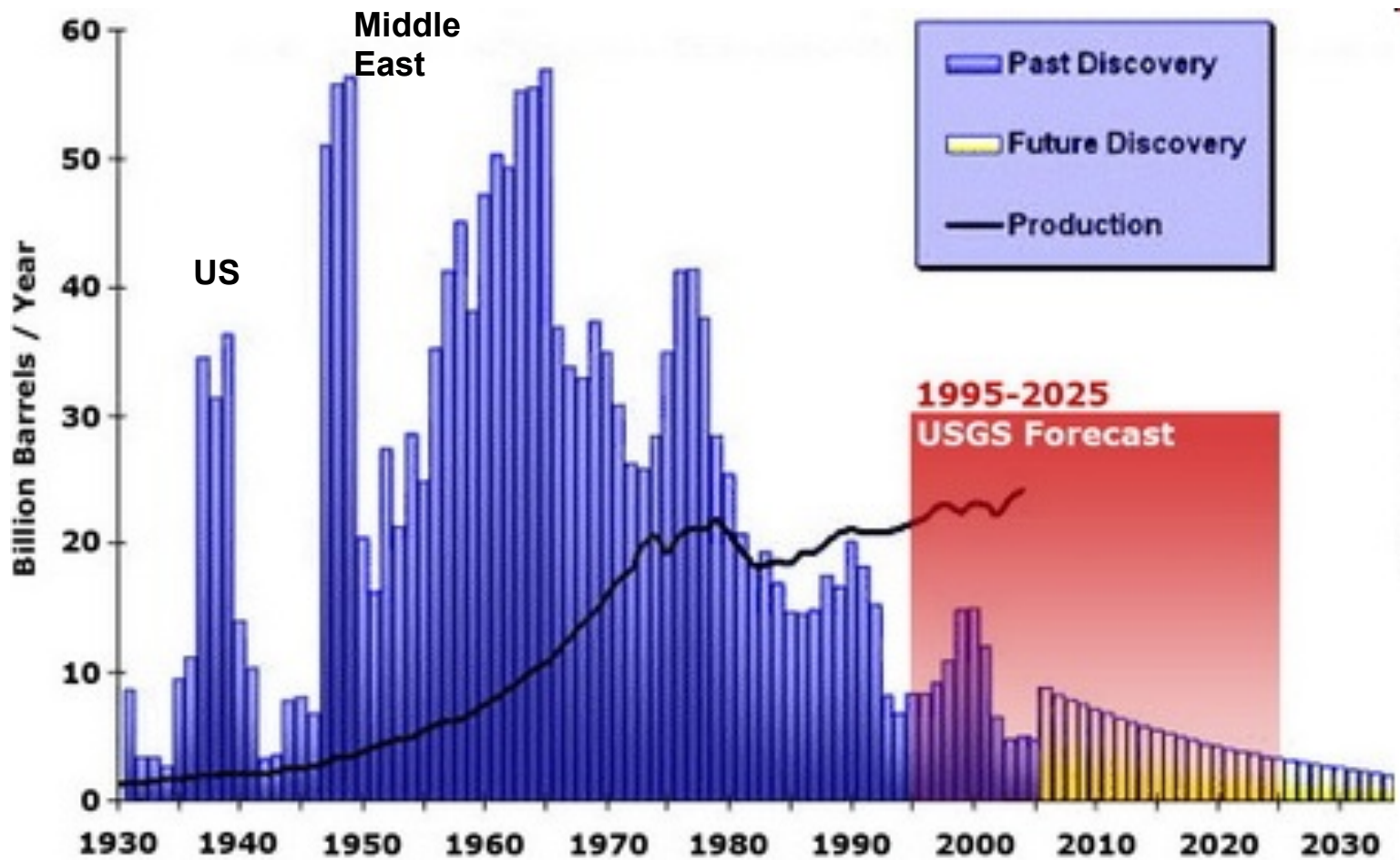
# OPEC Oil “Proven” Reserves!

Not proven  
by anybody!



- Accurate reserve estimates for OPEC countries are state secrets
- Values for 1983 are accurate
- No adjustment for 193Gb produced since 1980
- **Kuwait Example:** A recent leak of Kuwait Petroleum Company documents showed the actual reserves are only **48Gb** (official reserves are **102Gb**). 1980 Kuwait reserves adjusted for production since then are **55Gb**

# Oil discoveries have been declining since 1964.



The red box shows the average amount estimated to be discovered by the **USGS** each year between 1995 and 2025. **USGS Forecast is way off base.**

# Existing Oil Fields are in Decline

Existing oil fields are declining at **5%** per year  
(IEA, EIA, Exxon, CERA, ASPO)

For 2010 to 2030 the world needs **46 mb/d** of new production  
– just to maintain flat production

The IEA forecasts in 2008 projects a 10% increase in  
oil production between now and 2030 (from 87 to 96 mb/d)  
( $\Delta = +9$  mb/d).

The projected growth requires discovery and  
production of  $46 + 9 = 55$  mb/d of new oil!

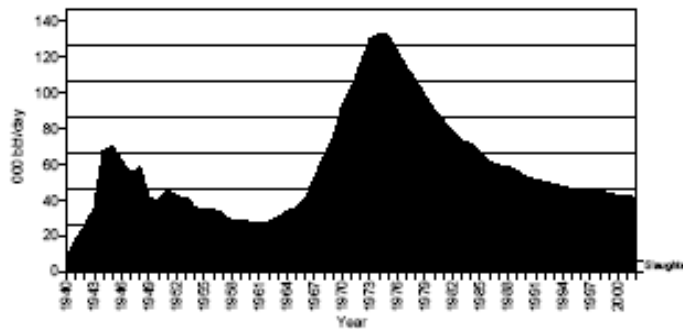
$55 \text{ mb/d} \div 9 \text{ mb/d} = \sim 6$  new Saudi Arabias



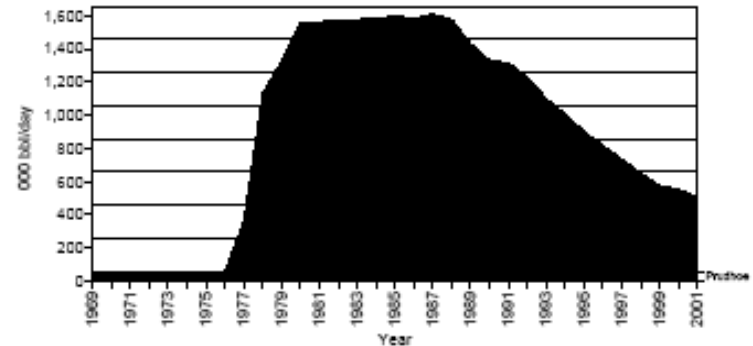
# Examples: Peak and Depletion is Normal

## When Giant Oilfields Deplete, They Fall Fast

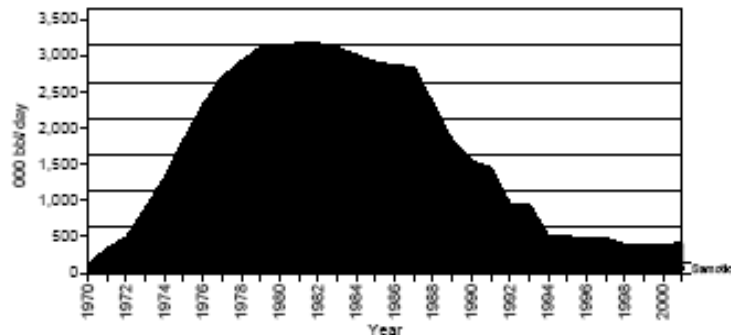
Slaughter, Texas



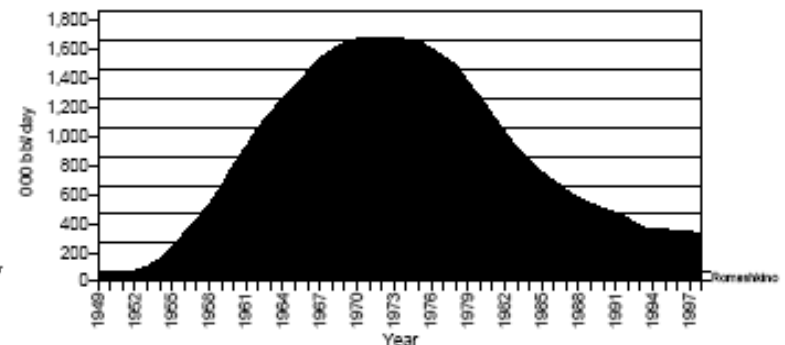
Prudhoe Bay, Alaska



Samotlor, Russia

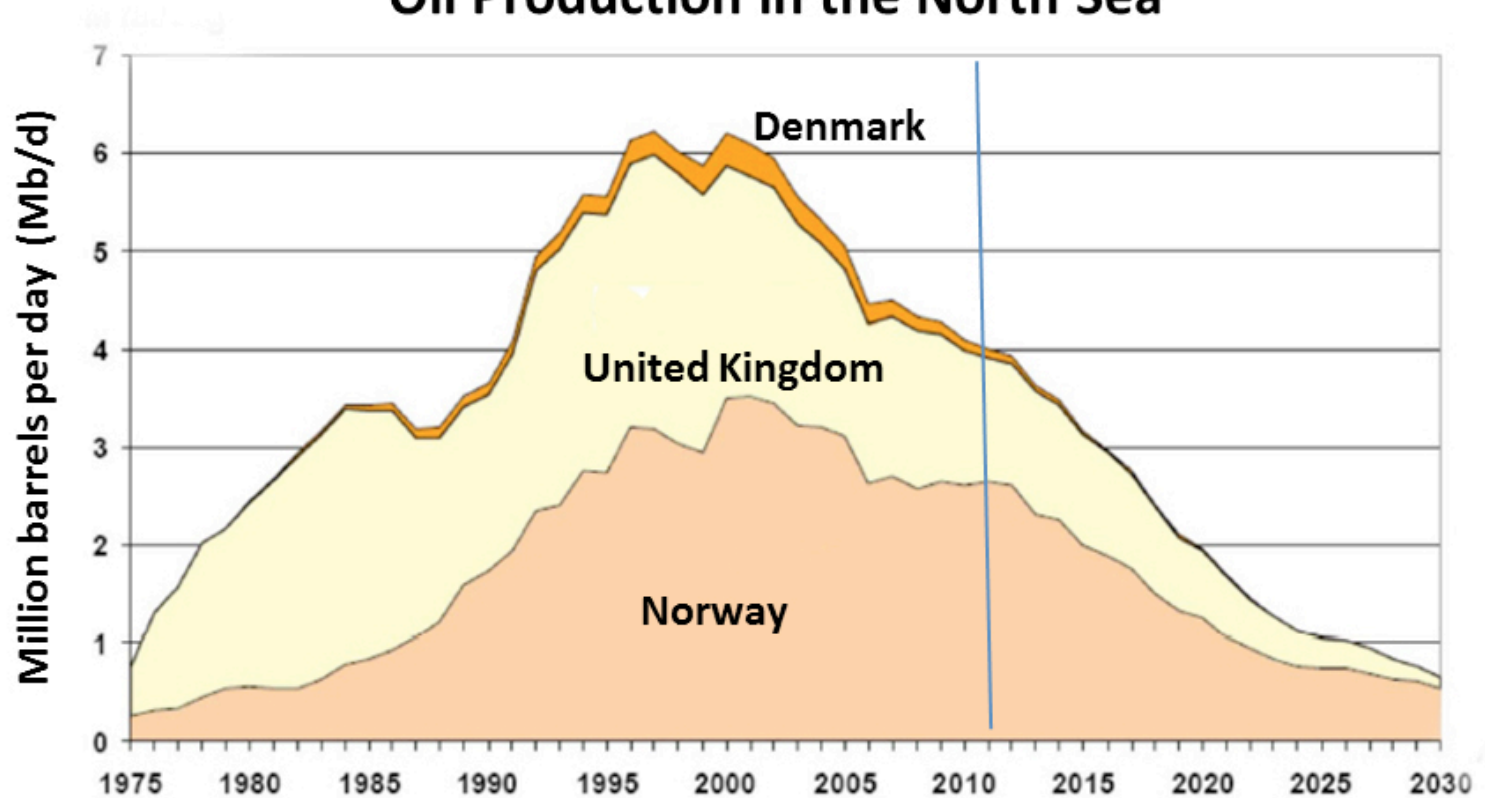


Romashkino, Russia



# Peak and Depletion in Regions

## Oil Production in the North Sea



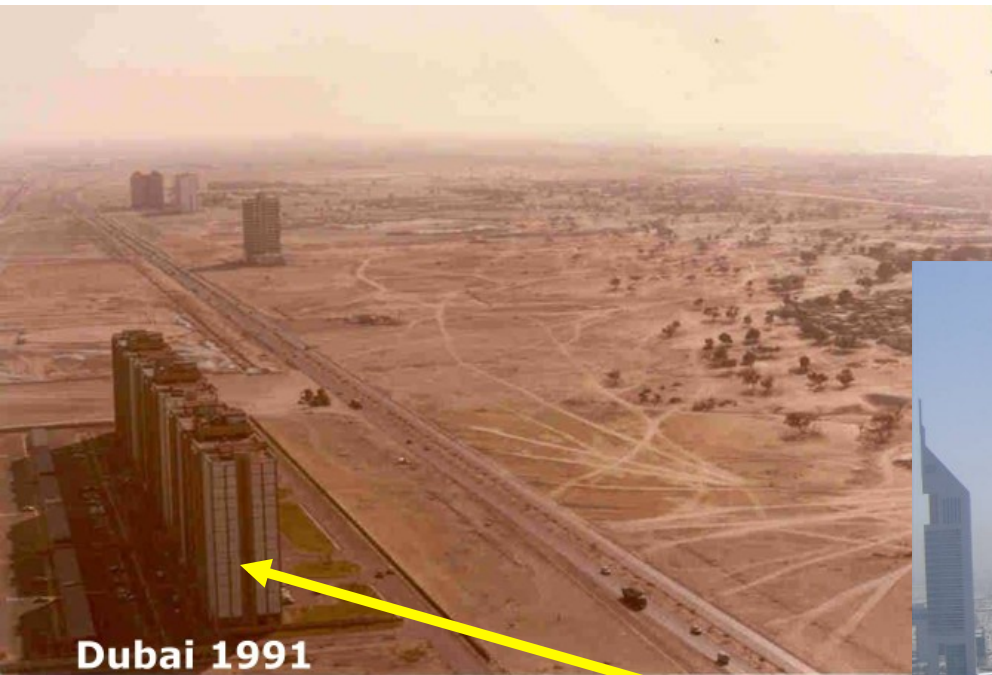
Data Preem 2012

Only 14 of the 54 oil producing nations in the world do not have decreasing oil production.

**Q. When will the world peak??**

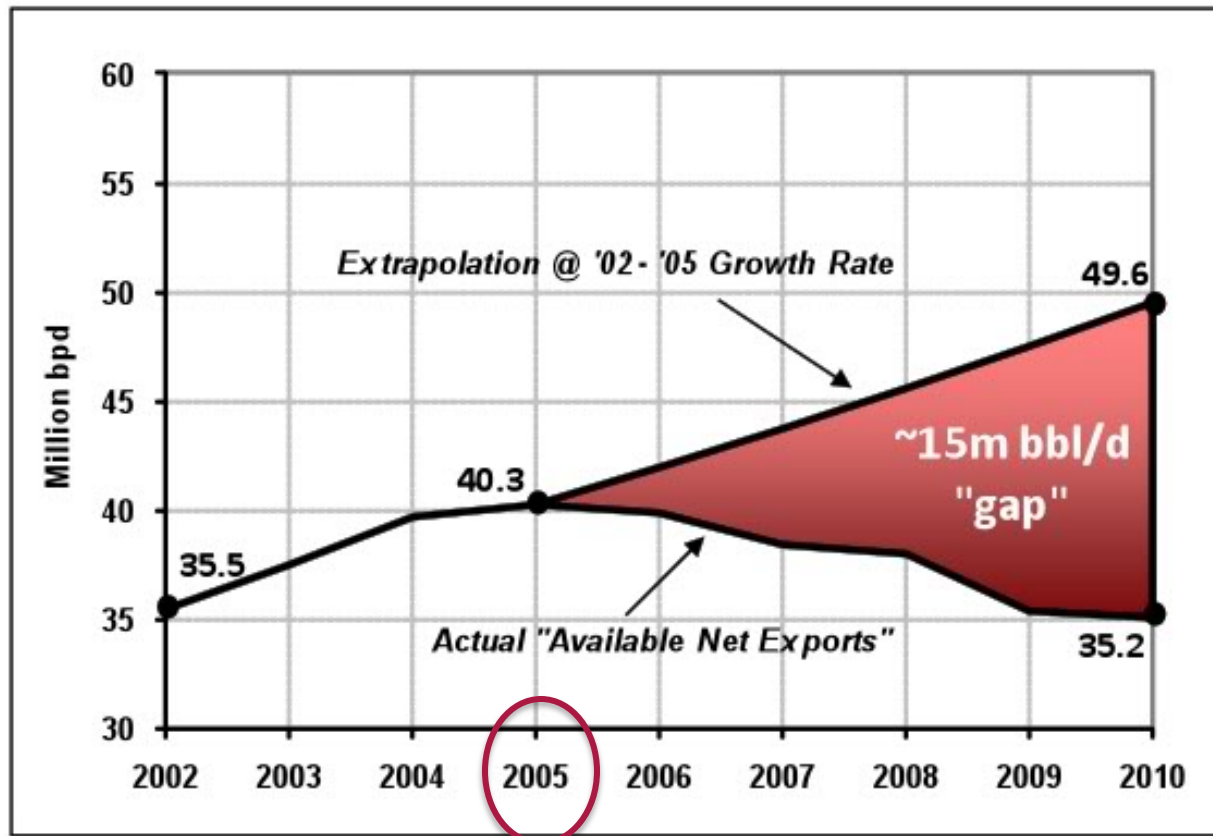
# *Net Exports are going down*

6



*Over the last three years, consumption inside of OPEC has grown at an astounding  $>5\%$  average annual rate.*

# “Available Net Exports”

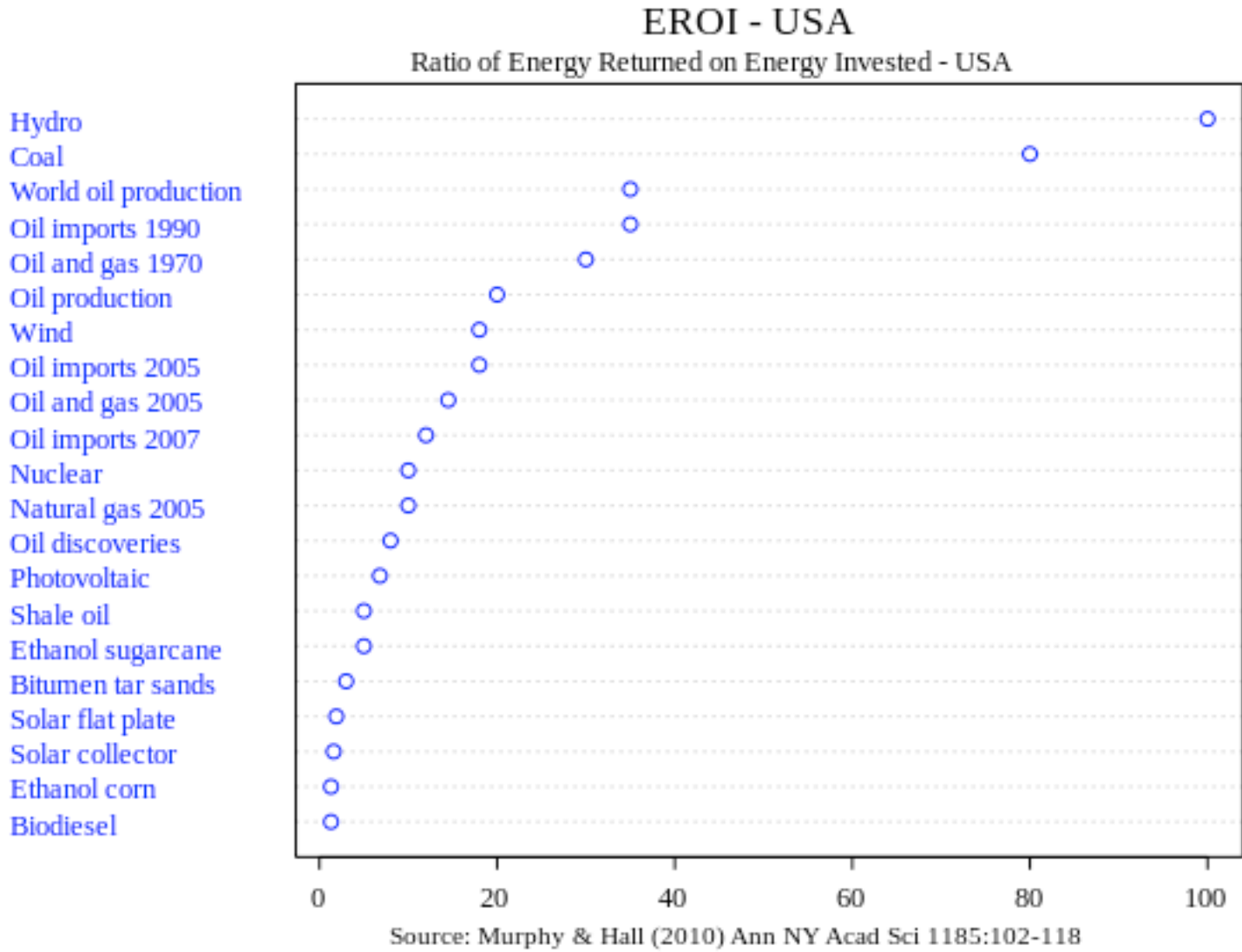


Note: Available Net Exports defined as "Global Net Exports" less China & India net imports.

**Peak Oil has come to the export market**

**Citigroup (2012) – Saudi Arabia will become an oil importer in 2030**

# EROI = Energy Return on Invested

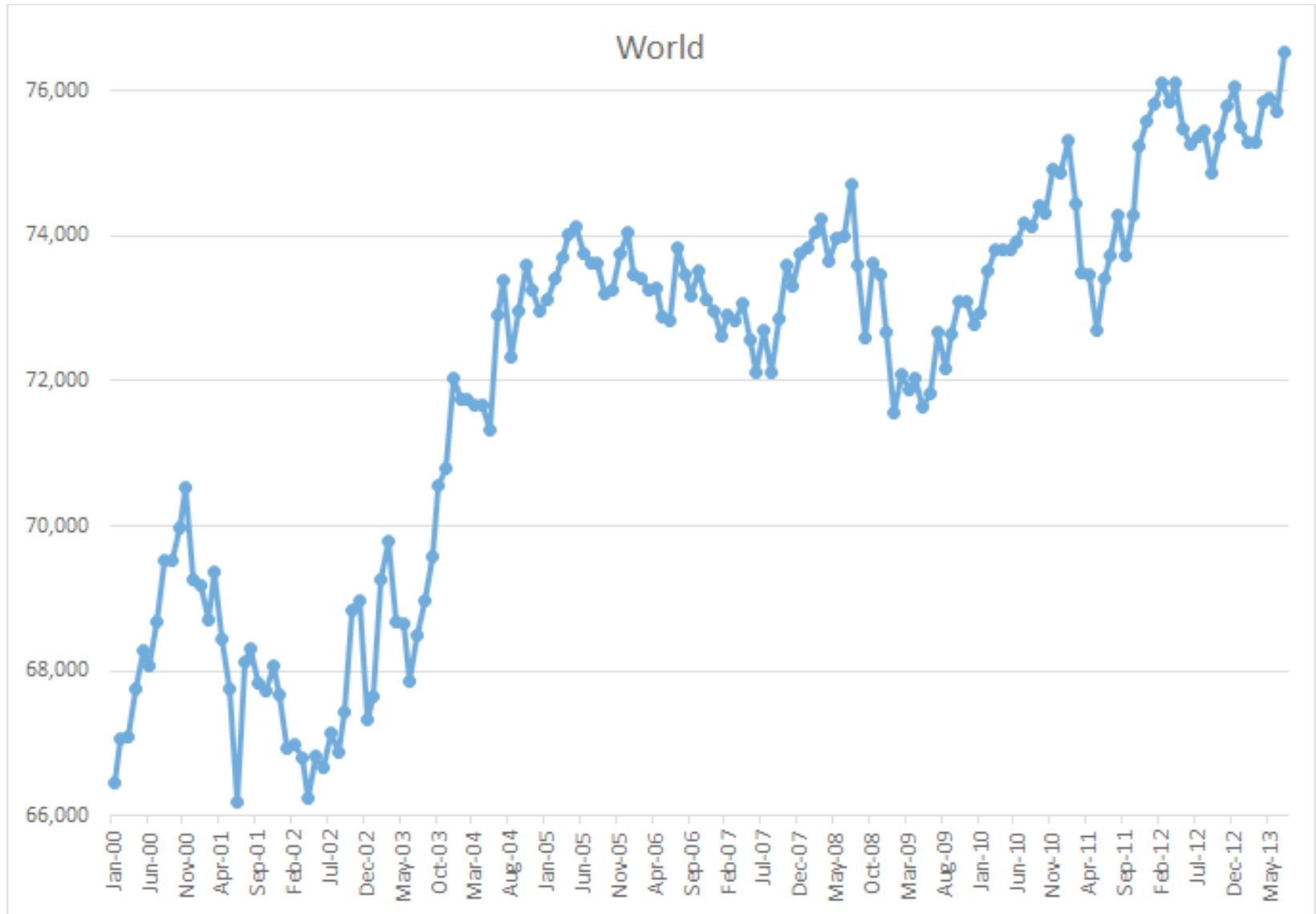


$$\text{Net Energy} = E_{\text{out}} - E_{\text{in}}$$

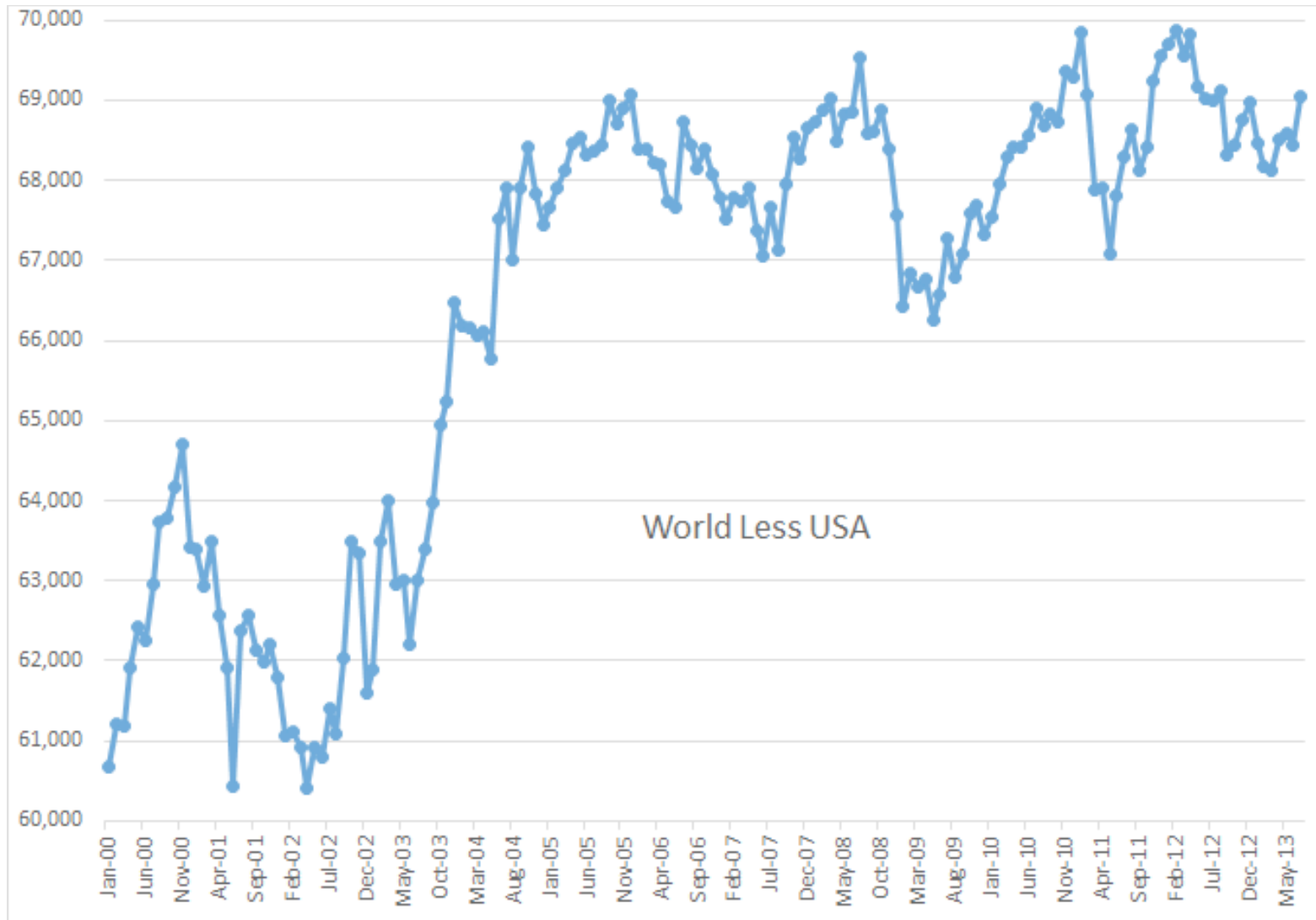
$$\text{EROI} = E_{\text{out}}/E_{\text{in}}$$

Soaring Capex!

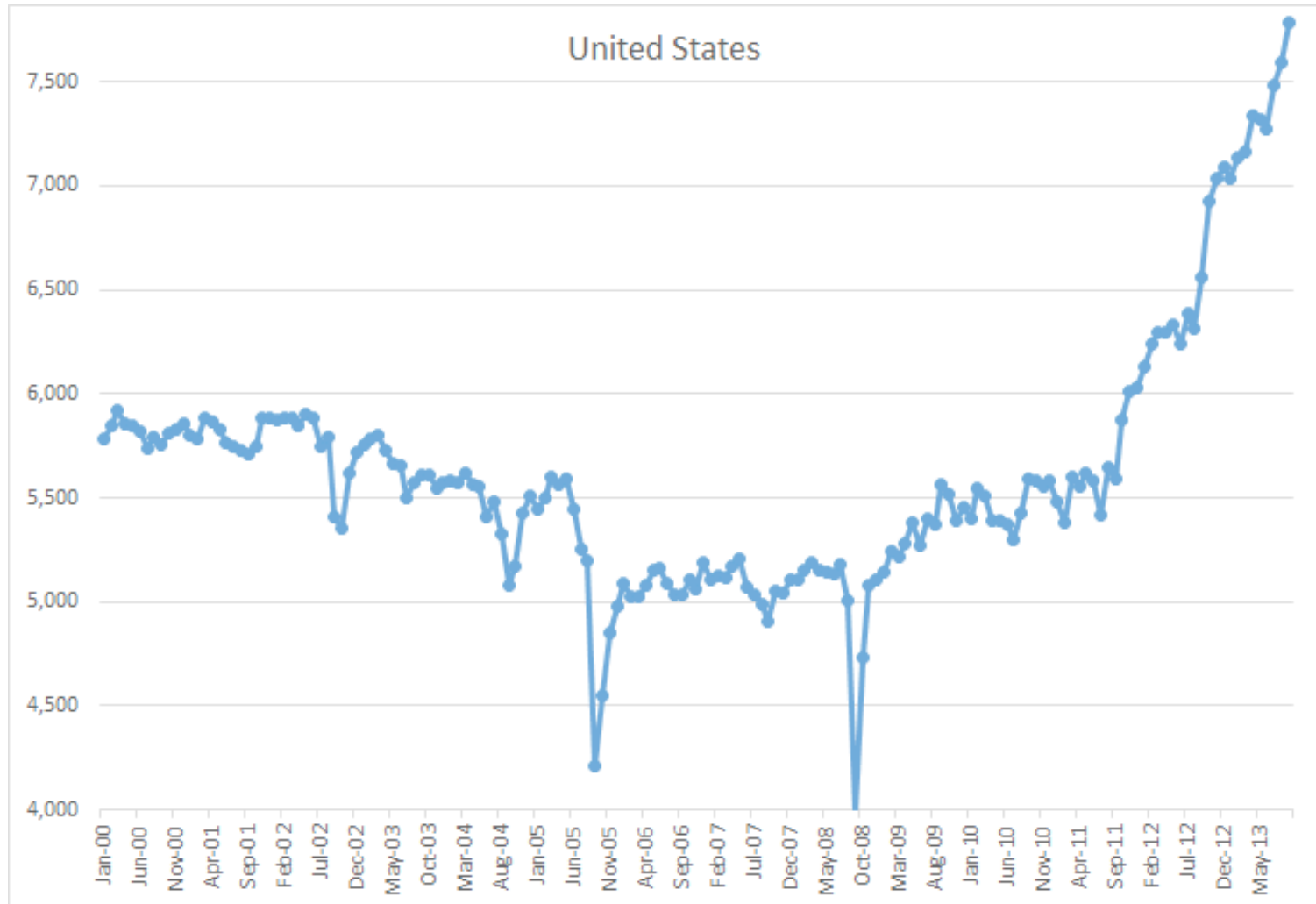
# World Oil Production



# World Oil Production – US Production



# USA Production



**Increase due to tight oil**



# The Miracle of Tight Oil



**What is shale?**

**= organic rich mud to fine grained source rock**

**= with high porosity and low permeability**

# Oil Train in Wyoming



# **Are shale gas and tight oil game changers?**

Detailed analysis by **David Hughes (2013, 2014)** (Post Carbon Institute) shows:

**Spectacularly high early decline rates**

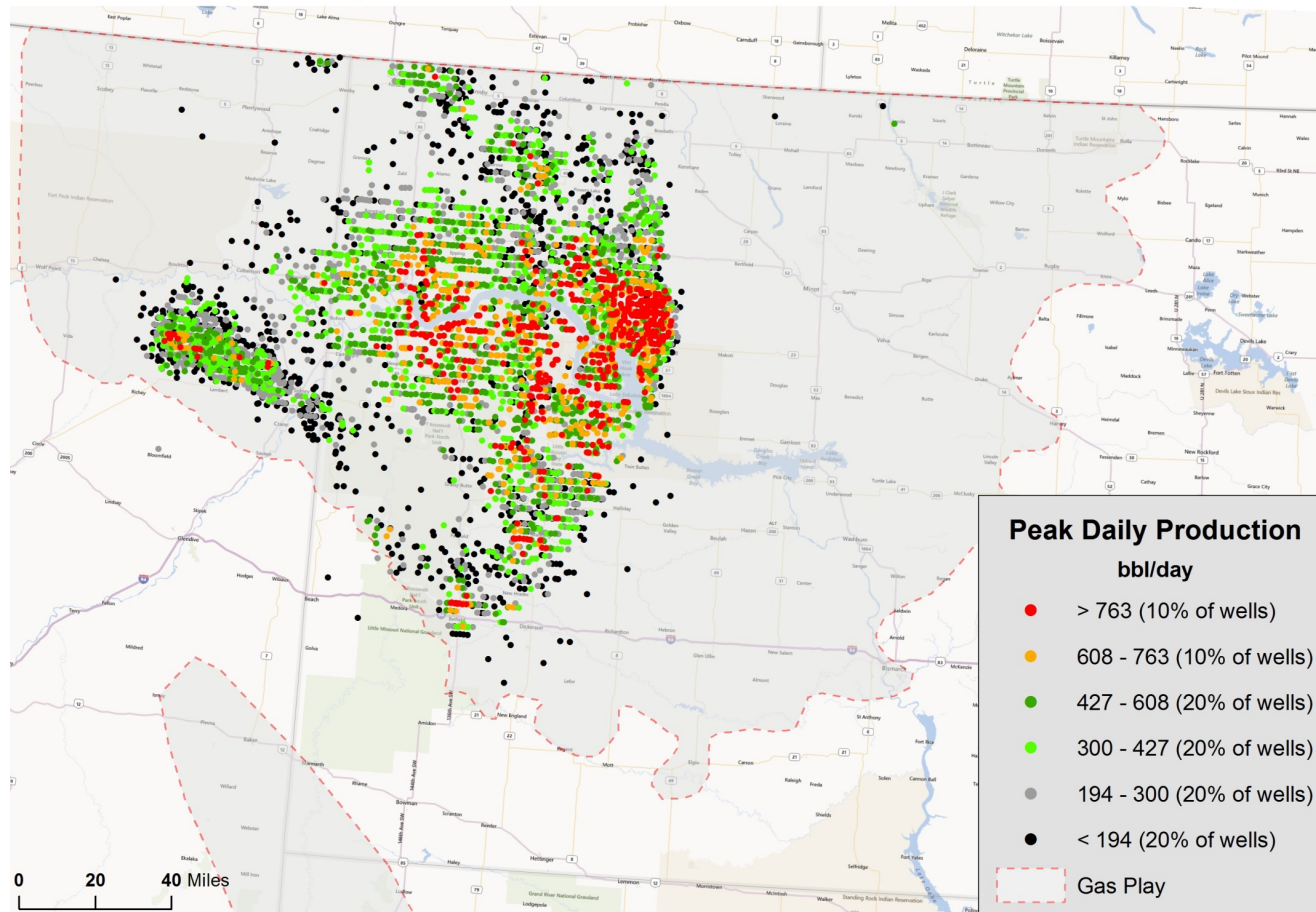
**“sweet spots” become exhausted**

As a result, shale-gas production is already dropping in several key drilling regions, and production of tight oil in the top two regions is likely to peak as early as 2016 or 2017. These two regions, in Texas and North Dakota, comprise 74% of total US tight-oil production.

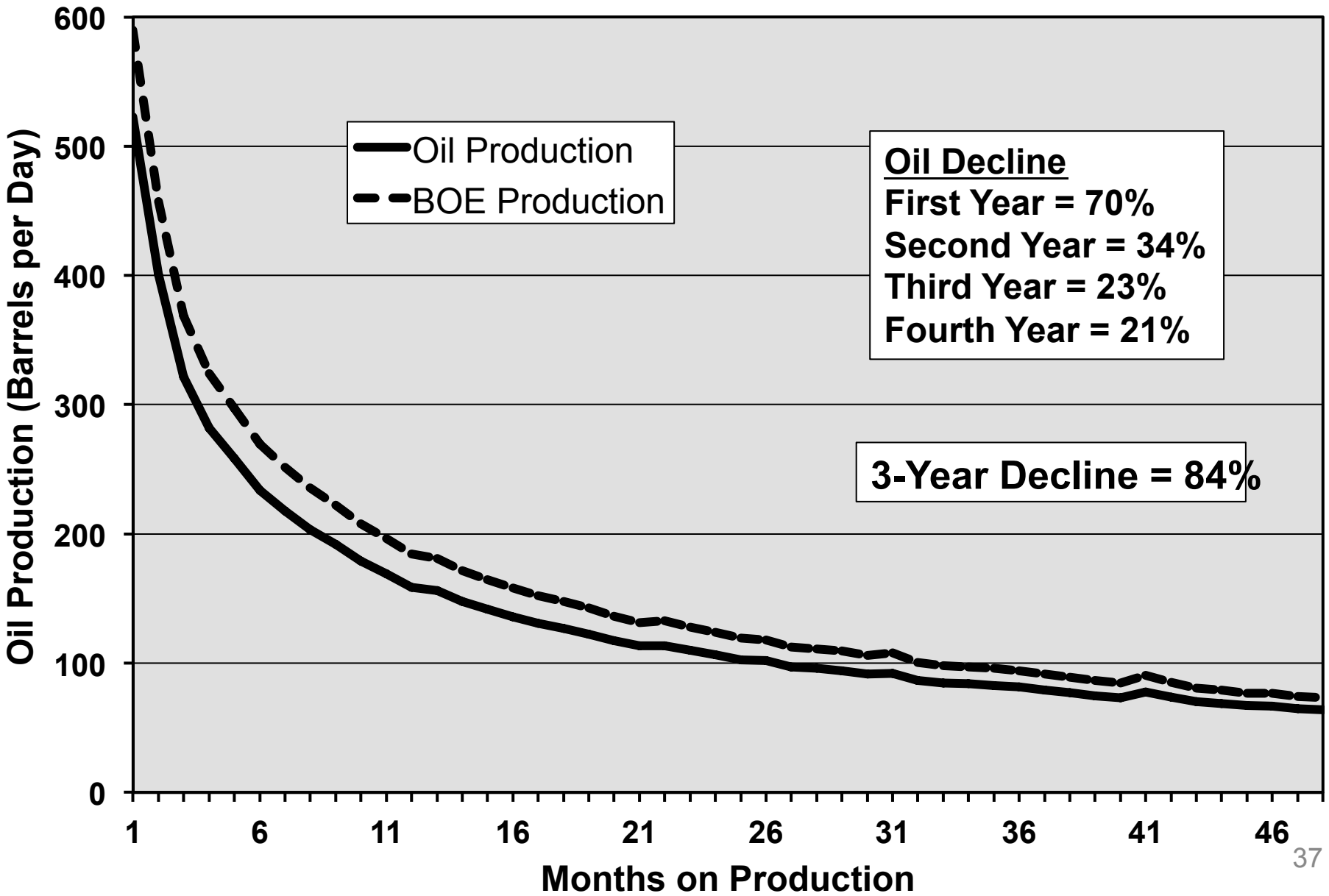
# Bakken Formation – Hot Spots drilled first

As of March 2013, 5,047 wells  
Producing 0.70 mbd  
**140 Bbls/day/well !!**

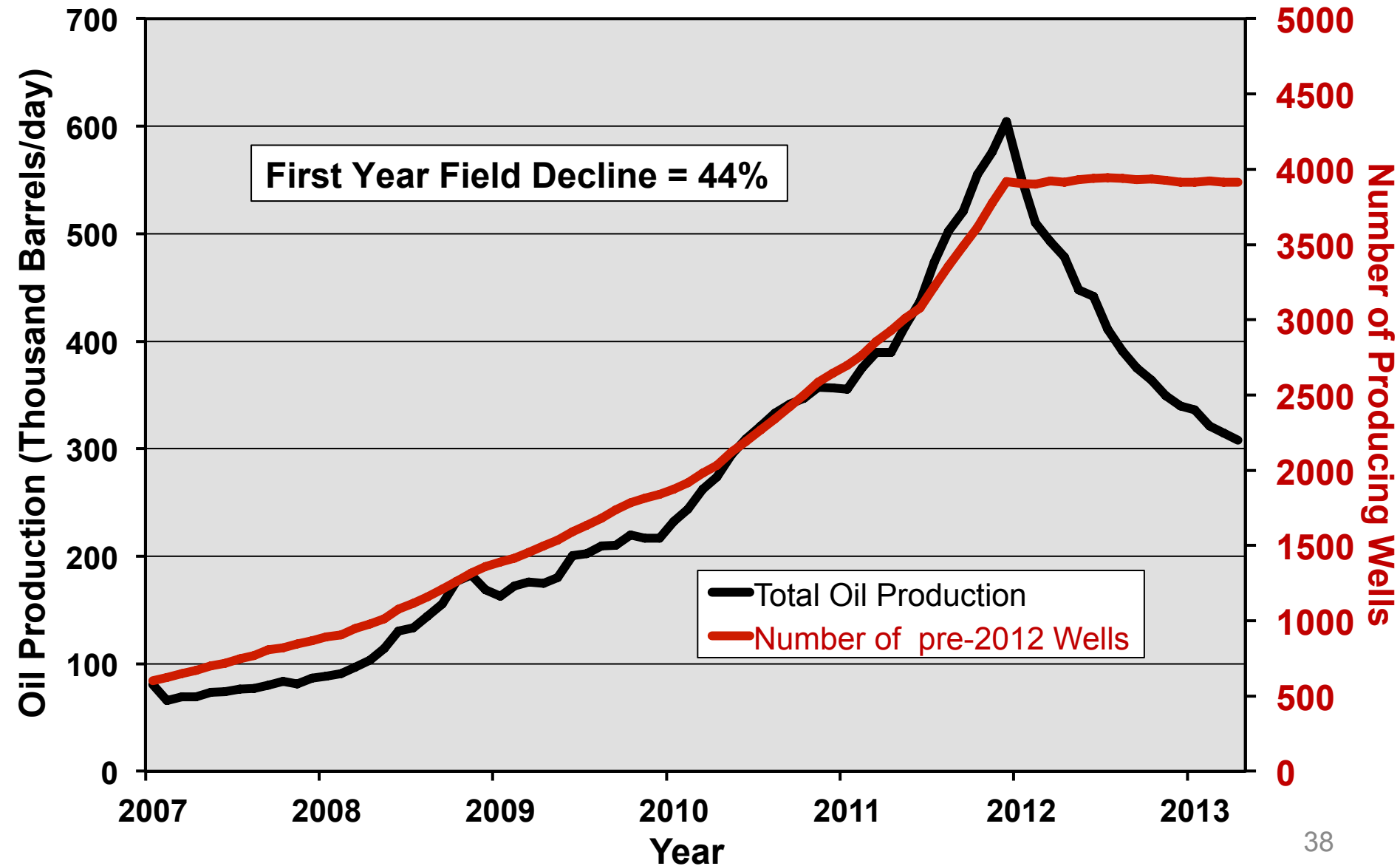
**Bakken Well Quality**  
Spatial Distribution of Peak Oil Production



# Bakken/Three Forks Type Oil and Barrels of Oil Equivalent Well Decline Curves Including Montana and North Dakota



# Bakken Field Production Decline – Oil Production from all Wells Drilled Prior to 2012



# Red Queen Effect

**A drilling treadmill required just to stay constant.**

The steep declines in production require an ever increasing treadmill of new drilling just to stay constant. This **Red Queen Effect** (from Lewis Carroll's "Through the Looking Glass") states that **"It takes all the running you can do, to keep in the same place!"** (Likvern, 2013)



**"The Red Queen has to run faster and faster in order to keep still where she is. That is exactly what you all are doing!"**

**To maintain production of 1 mb/d from Irag requires 60 new wells/year. For the same production from the Bakkan requires 2,500 new wells @ ~\$10M each. Remember EROI!**

## **Here are there are five main things to know about the shale plays.**

1. They deplete very quickly. The typical shale, or tight rock, well production declines by 80% to 90% within three years.
2. They are expensive. All oil and gas coming form them is several times more expensive than what we got from conventional oil plays.
3. They are environmentally damaging because the fracking fluid is highly toxic and much of it escapes during the blowback process and sometimes water wells are contaminated.
4. Because each well has low flow and depletes quickly, massive numbers of wells must be drilled creating significant infrastructure damage to roads and bridges. Currently no state or municipal authorities are capturing anything close to the total cost of the infrastructure damage from the shale operators which means taxpayers are gong to be left paying those bills.
5. Not all shale plays are created equal – some are vastly superior to others. And even within a given play there are sweet spots and dry holes which can only be determined by punching a well in and seeing what comes out. Some call this the ‘mapping by braille’ approach.



## Negative cash flow

Firm	Free Cash Flow (millions of dollars)			
	2010	2011	2012	2013
Noble	-66	-567	-881	-936
Anadarko	11	-3,408	804	737
Range	-556	-831	-1,072	-396
Devon	-1,279	-1,588	-3,593	-1,670
Chesapeake	-3,435	-1,459	-3,373	-3,398
EOG	-3,026	-2,539	-2,300	70
Continental	-430	-968	-2,486	-1,176
Cabot	-385	-402	-291	-195
Kodiak	-171	-495	-1,080	-1,232
Encana	-5,369	-1,271	-957	-824
Exco	-731	-1,343	-56	-990
Quicksilver	-311	-437	-272	-64
Hess	-1,093	-2,158	-2,306	-1,205
Sandridge	-687	-1,385	-1,600	-889
Newfield	-341	-1,055	-642	-650
Concho	-1,482	-546	-1,536	-517
PDC	-169	-314	-485	-235
Petroquest	23	-81	-66	-246
Carrizo	-225	-314	-497	-389
Bill Barrett	-1	-479	-577	-182
Diamond Back	N/A	-57	-52	-144
Pioneer	N/A	-397	-921	-493

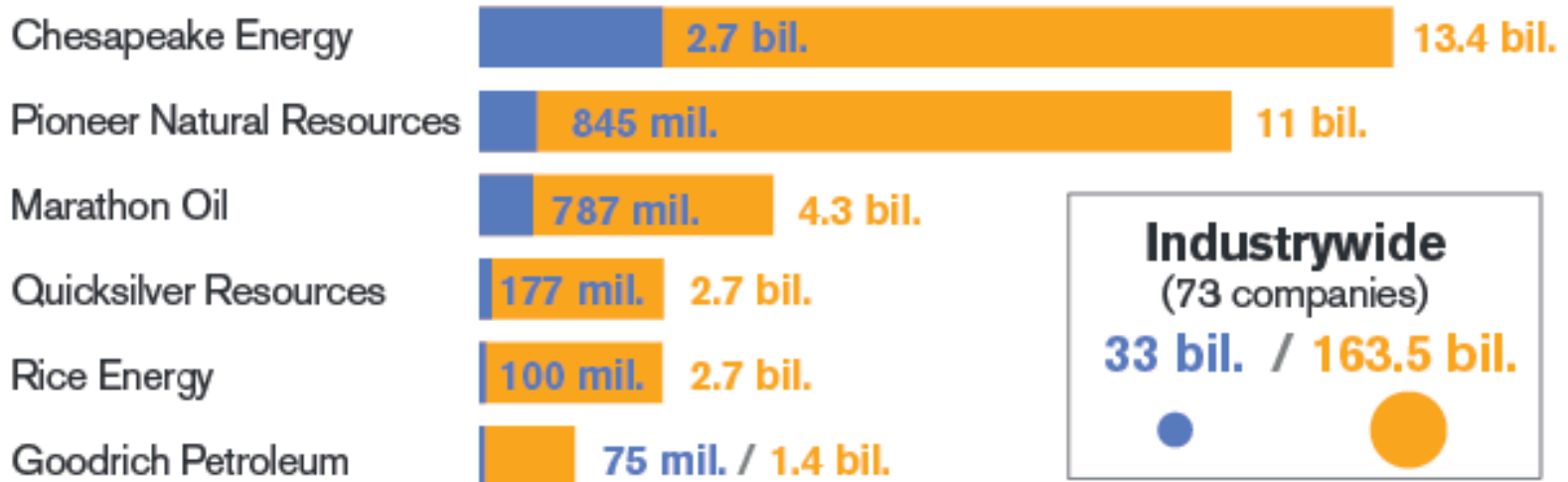
# **The issue of data reporting – a serious ethical issue**

**Sixty-two of 73 U.S. shale drillers reported one estimate in mandatory filings with the Securities and Exchange Commission while citing higher potential figures to the public, according to data compiled by Bloomberg.**

## **Selling the Shale Boom**

An analysis of 73 shale drillers found that almost all reported higher oil and gas prospects to investors than to the Securities and Exchange Commission (SEC). These six companies illustrate the range of estimates within the industry.

**■ Reserves reported to the SEC**     **■ Resources presented to investors**  
(selected examples in barrels of oil equivalent)



# Shale Takeaways

- Tight oil production from the top two plays is likely to peak in the 2016-2017 timeframe (both Hughes and EIA)
- Shale oil production has a high condensate content (~12%)(more volatile)
- High well- and field-decline rates mandate sustained high levels of drilling to maintain production.
- Sweet spots become exhausted early on in field development hence drilling rates must continually escalate to maintain production levels.
- High quality plays are not ubiquitous:
  - 74% of tight oil production comes from 2 plays.
- Environmental concerns with fracking are widespread and will likely escalate with the escalating drilling treadmill needed to maintain, let alone grow, shale gas and oil production.



**The shale revolution did not begin because it was a good idea but**

**1. because more attractive opportunities were exhausted**

**and**

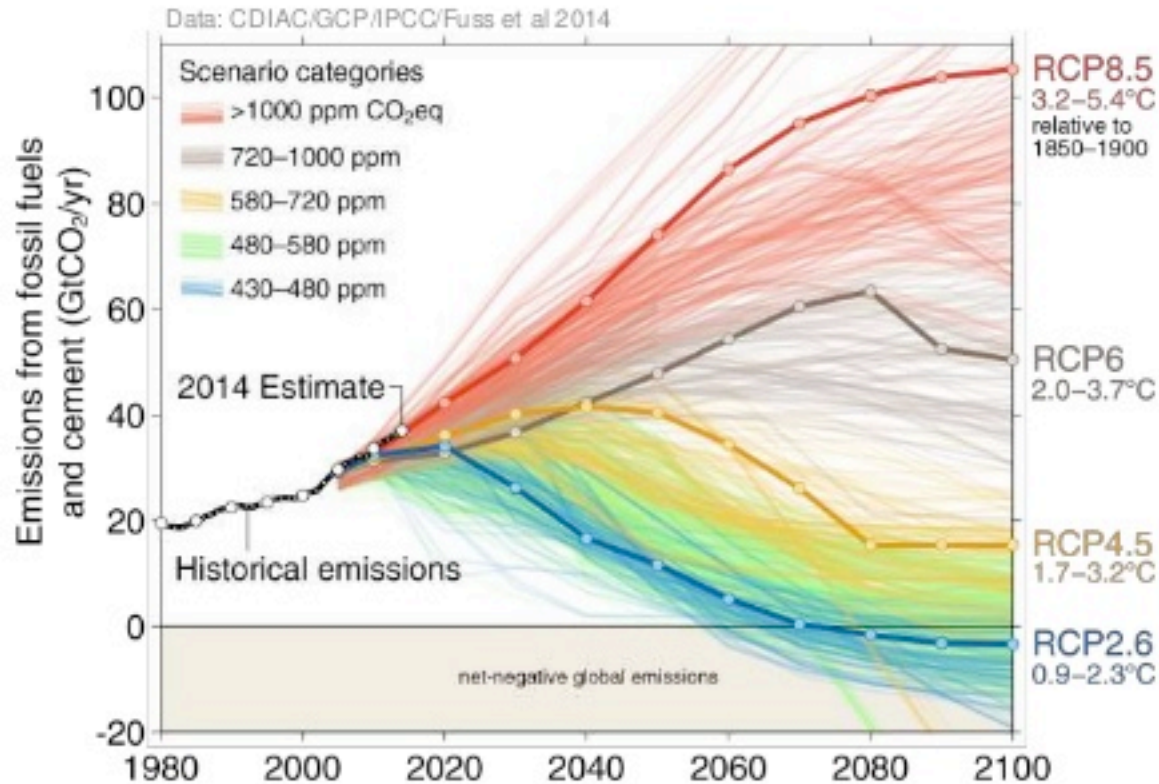
**2. because the market price climbed to support the cost of extraction**

**The prospects for crude + condensate oil production to exceed 75 mb/d are not good.**

# Peak Oil and Climate Change

## Observed Emissions and Emissions Scenarios

Emissions are on track for 3.2–5.4°C “likely” increase in temperature above pre-industrial  
 Large and sustained mitigation is required to keep below 2°C



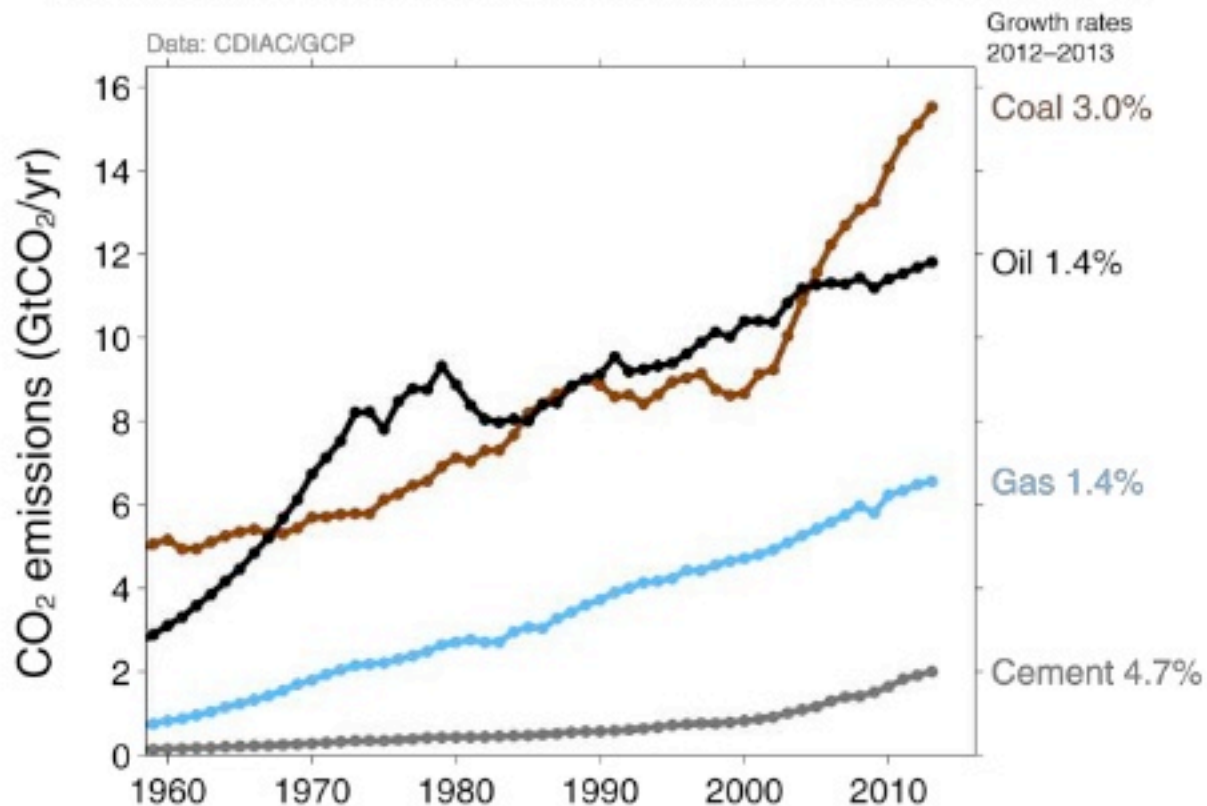
Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: [Fuss et al 2014](#); [CDIAC](#); [Global Carbon Budget 2014](#)



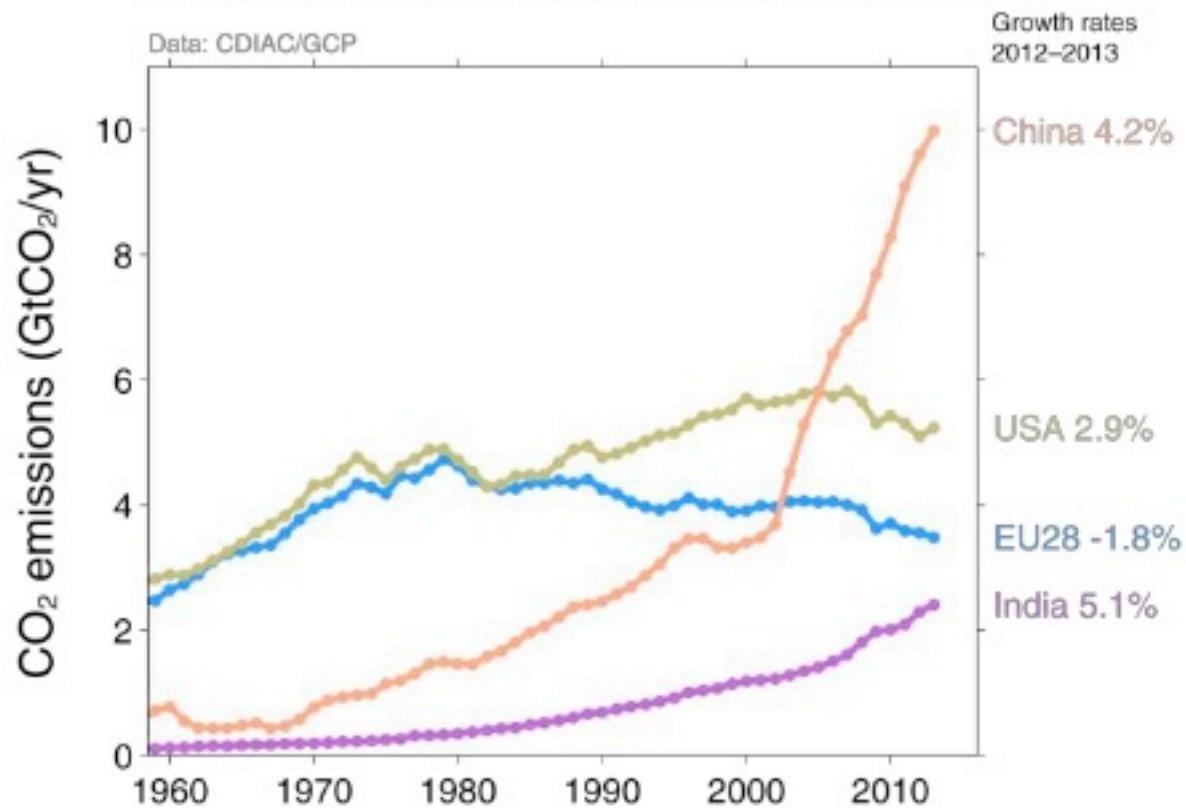
## Emissions from Coal, Oil, Gas, Cement

Share of global emissions in 2013:  
 coal (43%), oil (33%), gas (18%), cement (6%), flaring (1%, not shown)



## Top Fossil Fuel Emitters (Absolute)

The top four emitters in 2013 covered 58% of global emissions  
 China (28%), United States (14%), EU28 (10%), India (7%)



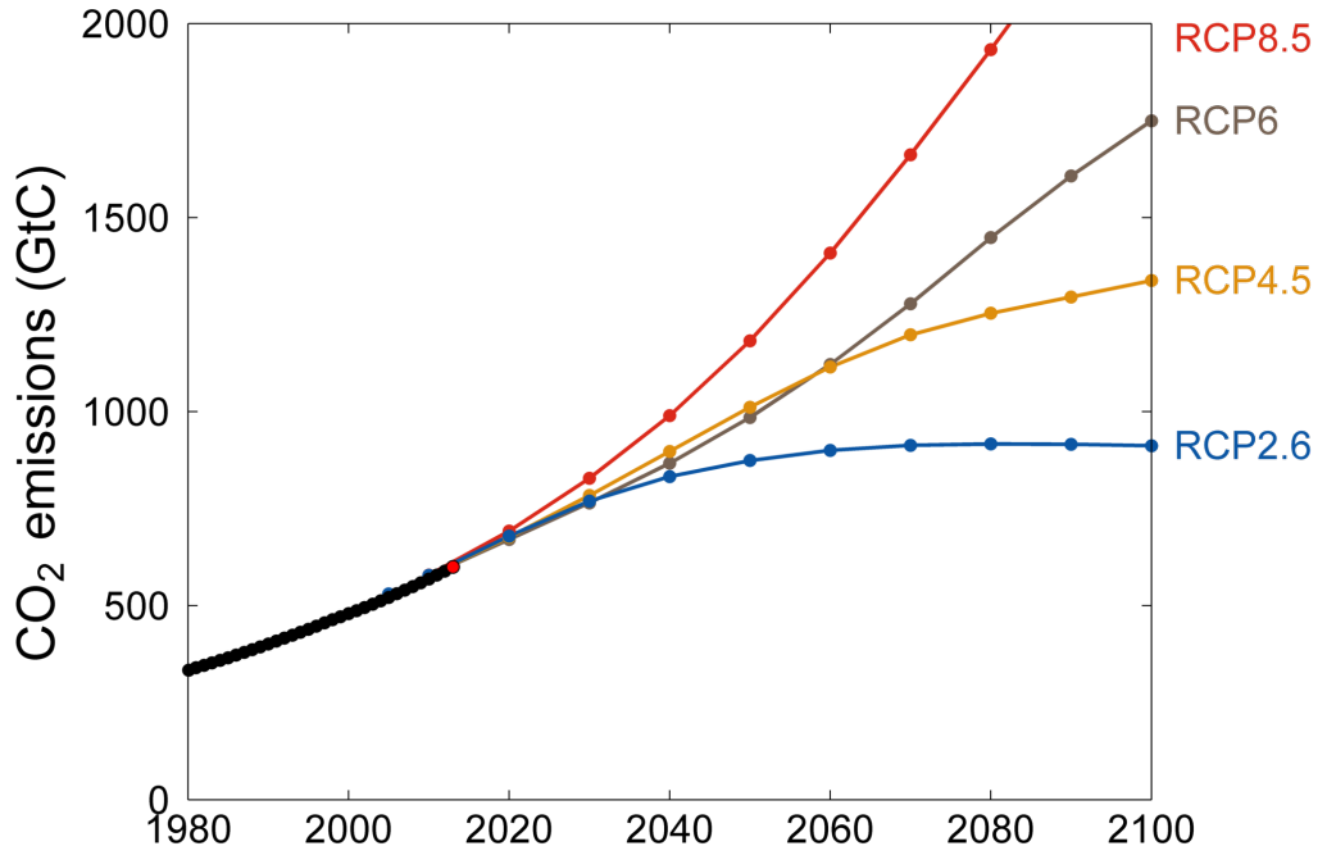
Bunkers fuel used for international transport is 3% of global emissions

Statistical differences between the global estimates and sum of national totals is 3% of global emissions

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

# Cumulative Emissions and Scenarios

For a “likely” chance to keep warming less than 2°C since the period 1861–1880, requires cumulative CO<sub>2</sub> emissions to stay below 1000GtC, or 790GtC when allowing for non-CO<sub>2</sub>

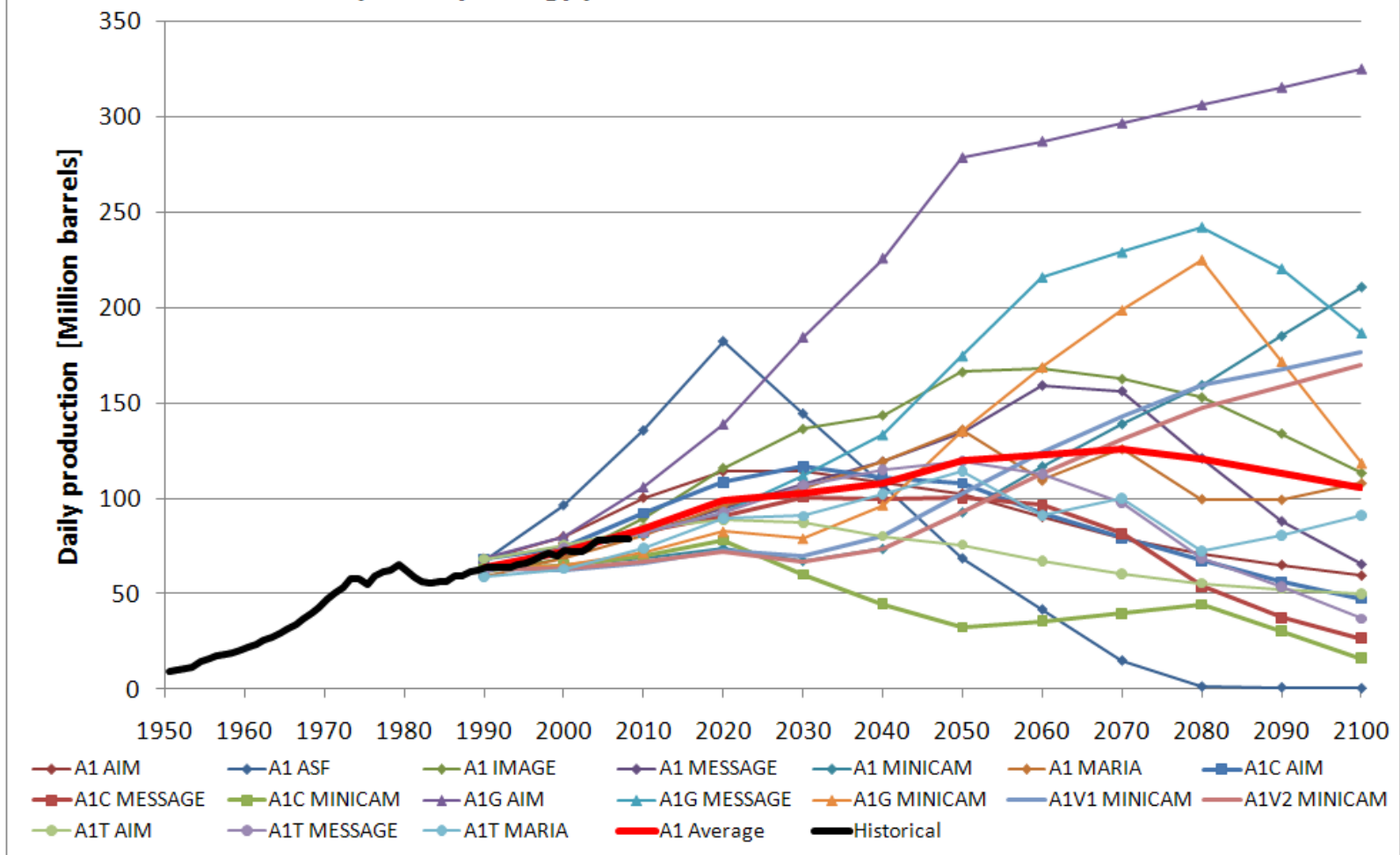


Cumulative emissions 1870–2013 are 550 ±60 GtC; 70% from fossil fuels and cement, 30% from land-use change  
 Cumulative emissions from 1750–1870 are highly uncertain, with about 50 GtC with 90% from land-use change

Source: [CDIAC Data](#); [Le Quéré et al 2013](#); [Global Carbon Project 2013](#)

**Such trajectories are unsustainable.**

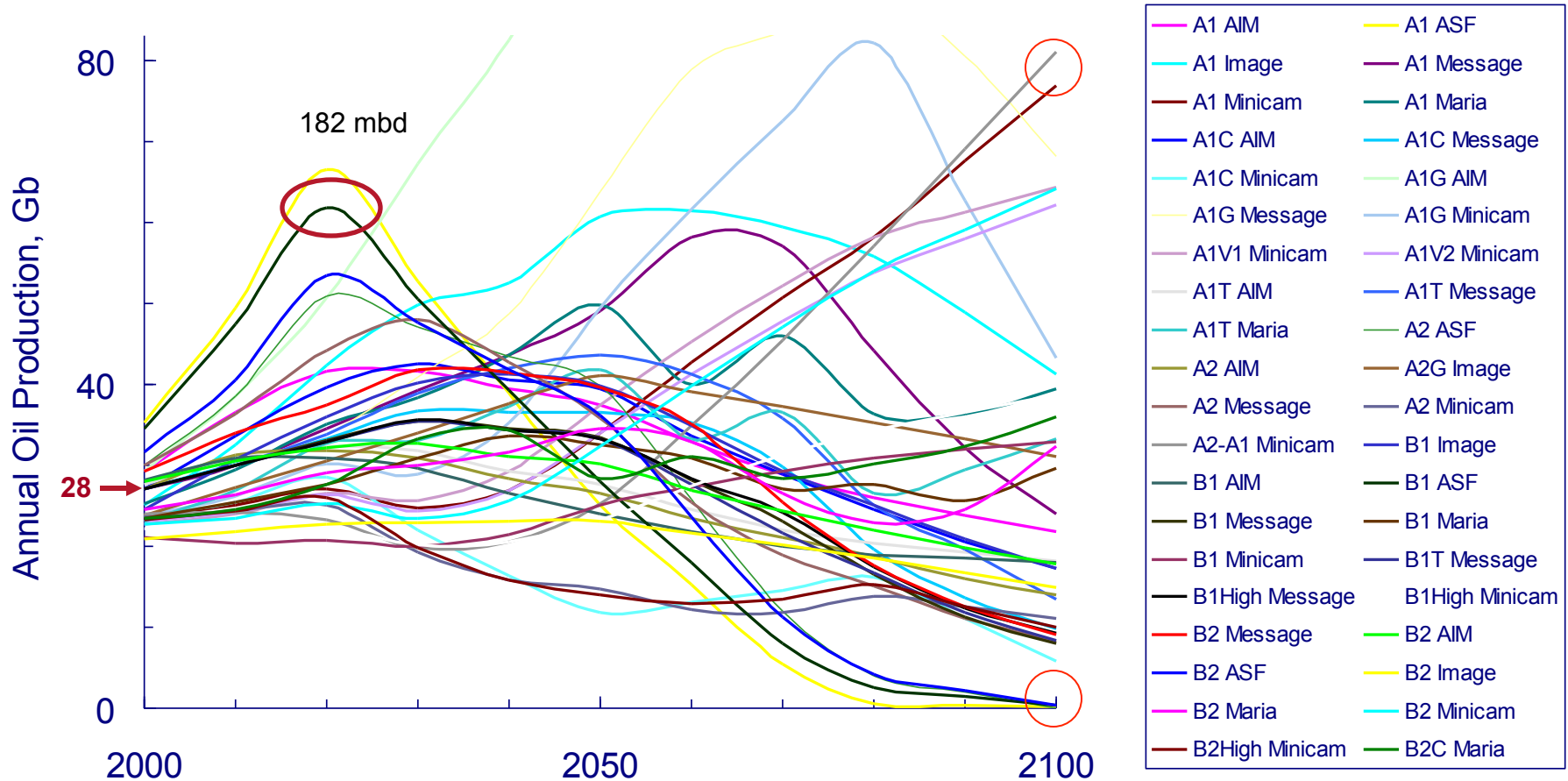
World primary energy production from Oil in the A1 scenarios



**Oil consumed by the SRES emission scenarios range up to 325 mb/d (for A1G AIM) in 2100 with an average maximum of 126 mb/d (Hook et al., 2010).**

**With present oil production on a plateau of 75 mb/d it is very unlikely that such production rates would ever be reached.**

# Oil Production in the IPCC Scenarios



- In 13 scenarios, oil production is still rising in 2100
- **In none of the scenarios did oil production decrease because of resource limitation**
- **Today's Crude Oil Production is 28 Gb yr<sup>-1</sup>**



**The total ultimate CO<sub>2</sub> emissions may not be as large as some estimates project.**

**An updated estimate of the total ultimate carbon emissions from all fossil fuels (including coal) sums to 885 Gton C (Tans and Rutledge, in prep) which is much smaller than the upper limit of 6,000 Gton C estimated by Nakicenovic (2004).**

# **We need an energy transition to a society based on renewable energy.**

**We need to do it fast , but we are way behind.**

**Today Germany's electricity is 22% renewable and solar is about 25% of that or 5.5% of the total**

**We can't drill out of this problem.**

**We need to reduce consumption drastically.**

**Example: Globally we get  $55 \times 10^{18}$  joules of useful energy from  $475 \times 10^{18}$  joules of primary energy. 11% efficiency**

**By increasing efficiency we can get the same energy by burning less fuel**

**EIA projects a transition of 70 years. YIKES**



