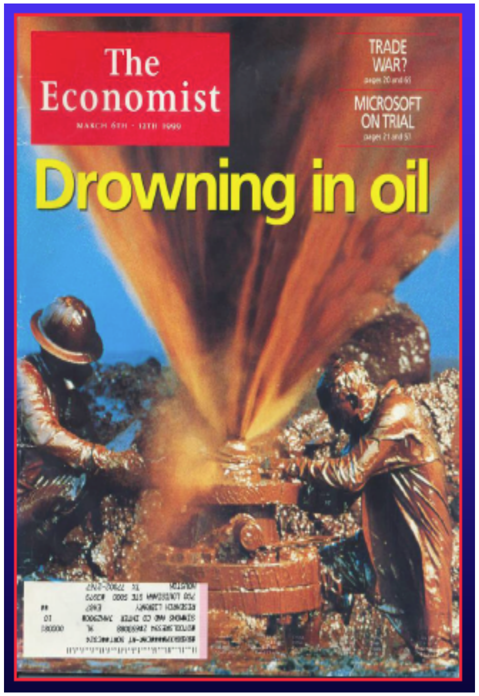
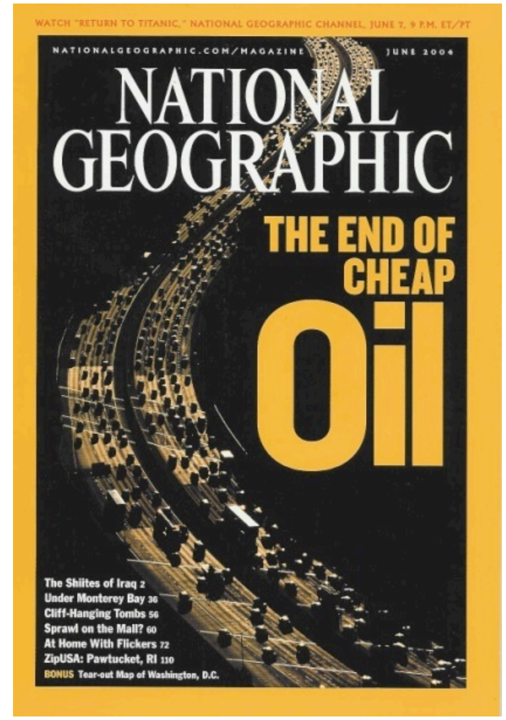


1999

Peak Oil and Climate Change

UBC TRIUMF
January 2010

James W. Murray
School of Oceanography
University of Washington



2004

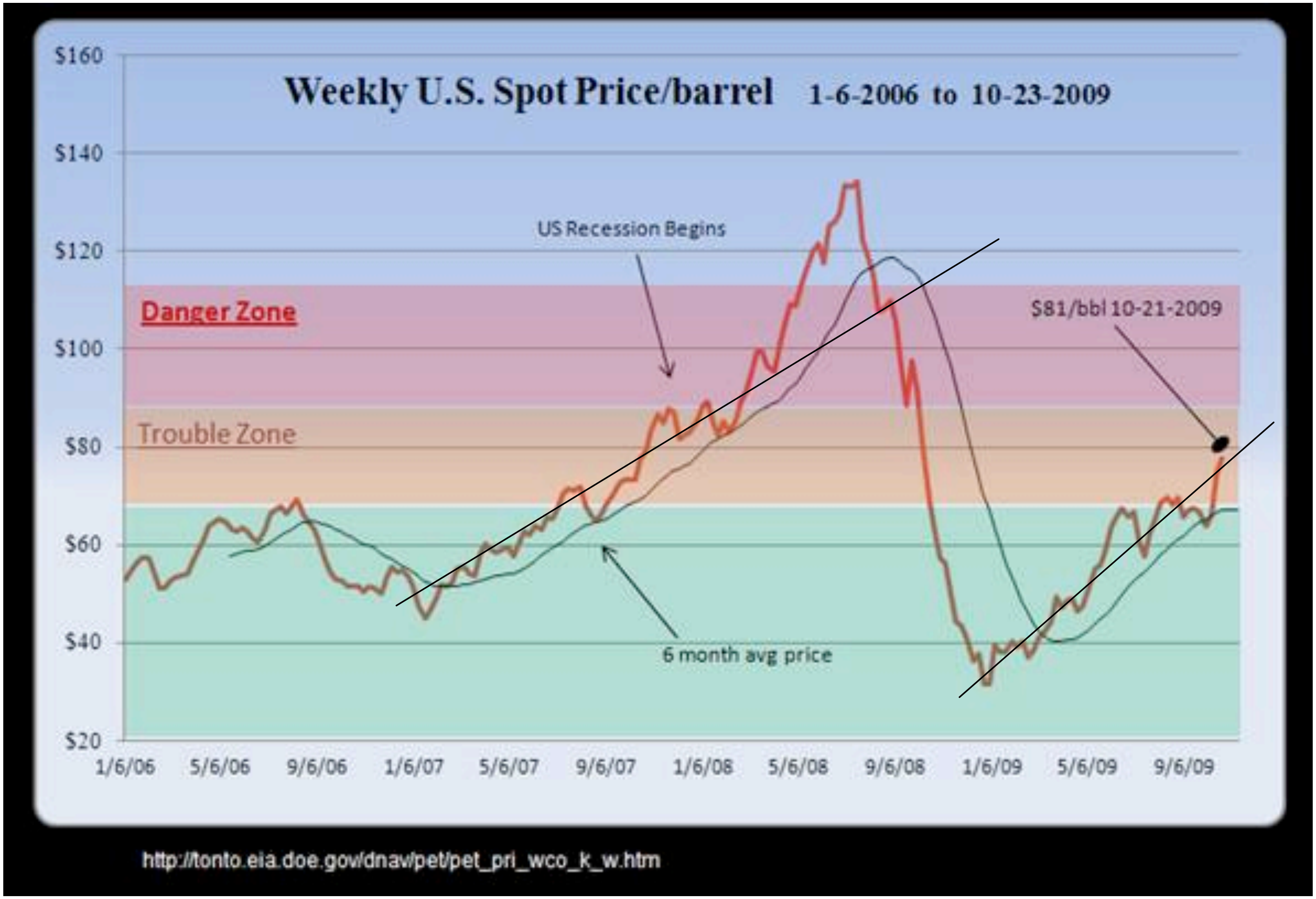
IEA World Energy Outlook - Nov 2008

"The world's energy system is at a crossroads. Current global trends in energy supply and consumption are patently unsustainable — environmentally, economically, socially. What is needed is nothing short of an energy revolution."

with special acknowledgement to David Rutledge (Cal Tech), Jim Hansen (Seattle)
See today's Globe and Mail (business section) – about Peter Odell

The price of oil has increased almost continuously since 1999.

If oil gets too high the economy becomes unstuck
If oil gets too low new investment is halted



Ali al-Naimi – Sweet spot for oil prices ≈ $75
But the price will be difficult to control.

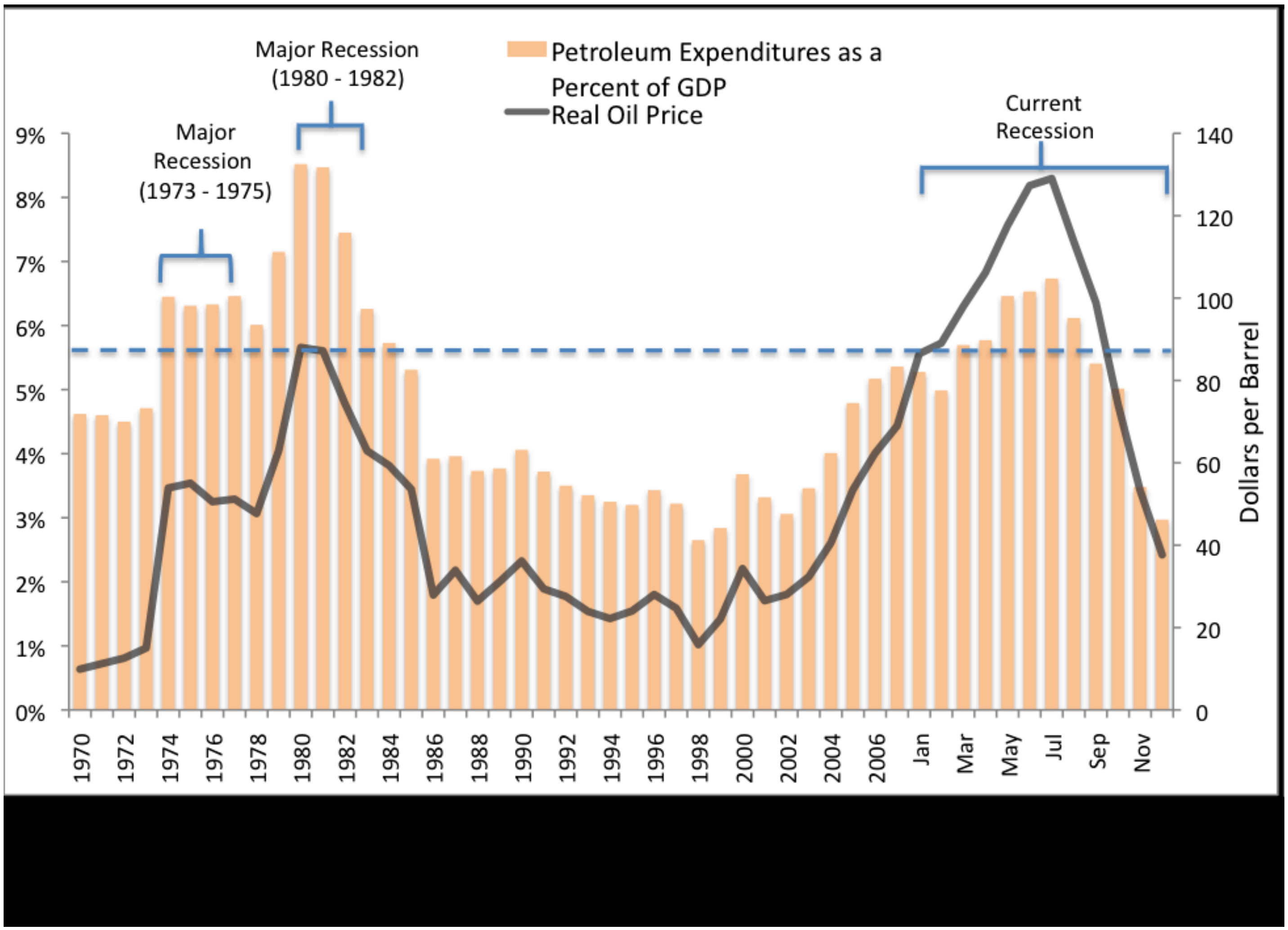
Expect the economy to zig-zag in the future with the lows getting progressively higher

Energy as a buffer on economic growth

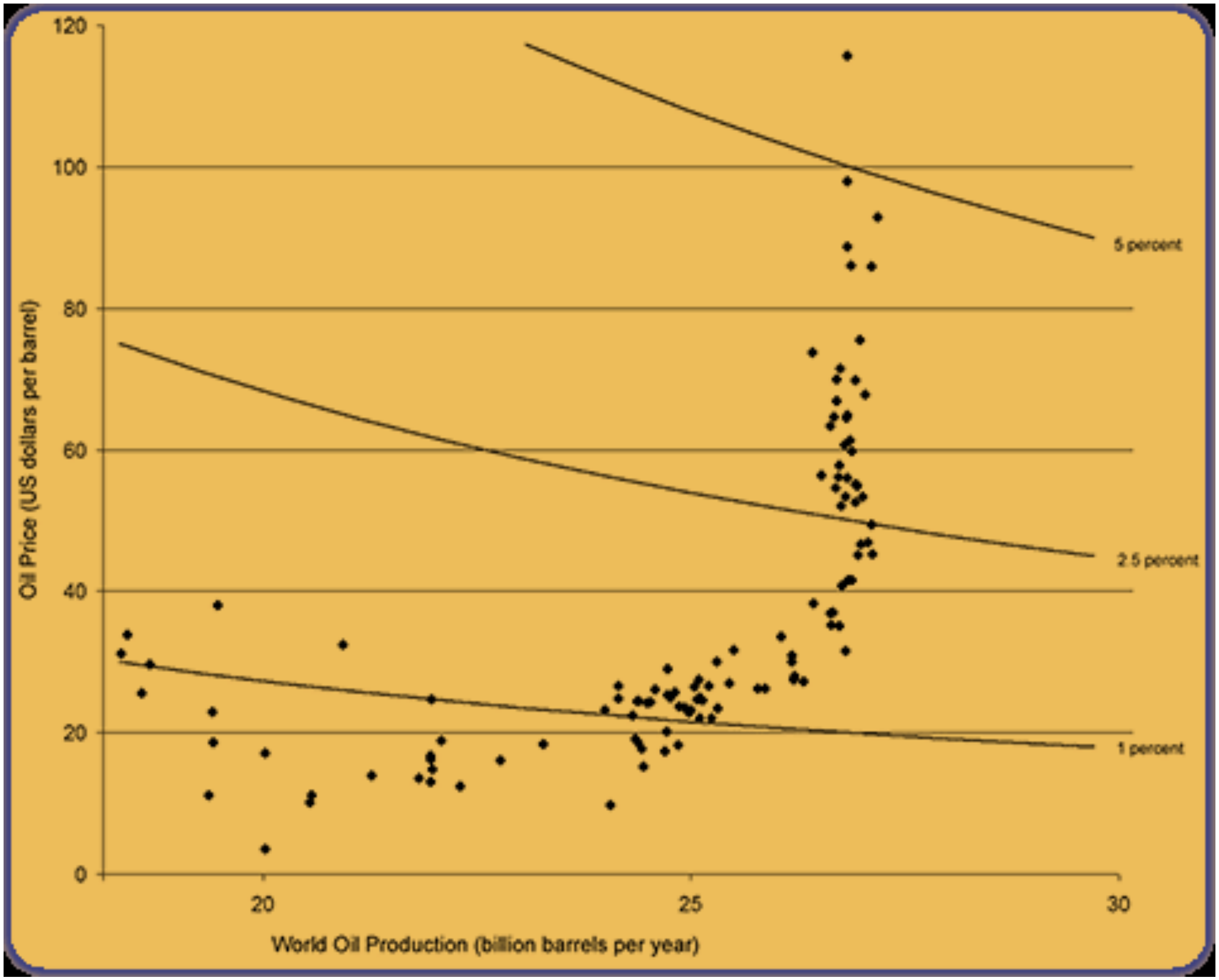
James Hamilton (UCSD) – Recessions generally correlate with the price of oil.
If energy expenditures rise faster than income, then the share of income for other things must decline

Oil Expenditures as a % of GDP

5.7% is the key

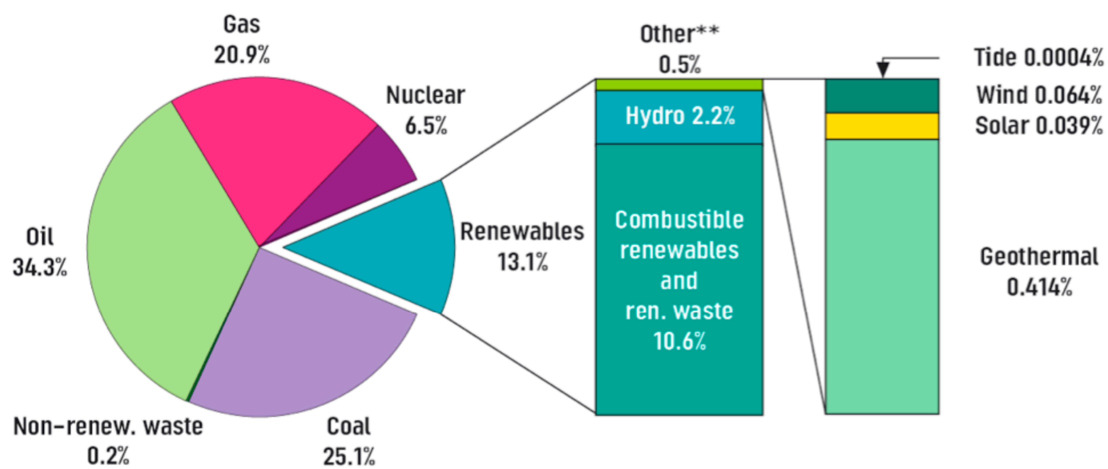


The Price Elasticity of Demand has become virtually zero.
It's a supply limited market.



from Kenneth Deffeyes

Can there be economic growth without growth in energy?



Source: IEA, 2007

Fuel Share of World Primary Energy Supply

David Fridley - LBNL

Changing Perceptions of Peak Oil

During 2009 the most significant story about peak oil was published by *The Guardian* (UK) on November 9th

Whistleblower #1, still with the IEA, said "The IEA in 2005 was predicting oil supplies could rise as high as 120 million barrels a day by 2030 although it was forced to reduce this gradually to 116m and then 105m last year [2008]. The 120m figure always was nonsense but even today's number is much higher than can be justified and the IEA knows this. Many inside the organization believe that maintaining oil supplies at even 90m to 95m barrels a day would be impossible but there are fears that panic could spread on the financial markets if the figures were brought down further." Such honesty isn't tolerated by IEA member state USA, which apparently leaned hard on the Agency to bury this hard truth for years.

There was a similarly strong warning from a heavy-weight within the oil industry. **Christophe de Margerie, CEO of oil super-major Total SA**, had previously issued warnings about world oil supply constraints. In 2007, he stated that "production of 100 million barrels a day will be difficult." He upped the ante during 2008, claiming that "world oil production would peak at or below 95 million barrels per day." On February 10th, 2009, the CEO's statement could have been issued by ASPO-USA: "world oil production may plateau below 90 million barrels per day."

Oil optimists like **Daniel Yergin and Michael Lynch** pushed back against the peak oil story on op-ed pages of several major US newspapers. Reporters wrongfully continued to link peak oil to "running out of oil,".

A fog of sorts still plagues the issue in the media.

Todays Conclusions

Evidence is strong suggesting that energy resource limitation will be a serious issue.

Peak Oil has occurred or will occur soon.

Why? existing oil fields are declining at ~5-7% (~5 mbd)

New discoveries are not keeping up.

Oil and Coal Reserves are much less than assumed by the IPCC.

We know enough to see that Resource Limitation needs to be an IPCC Scenario

Outline

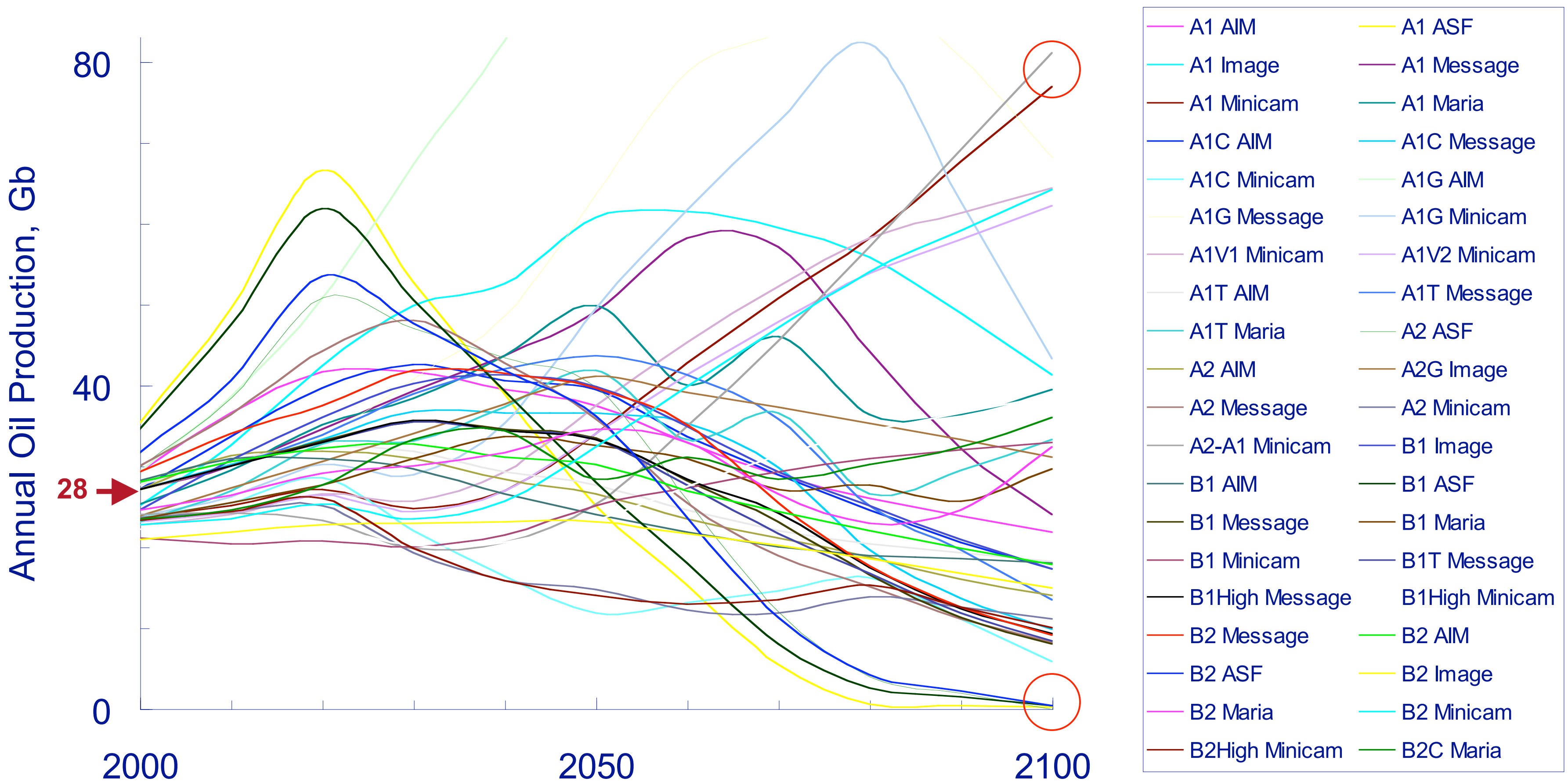
- The 4th UN IPCC Assessment Report SRES Scenarios
- Oil Reserves
- Hubbert's peak
  - The history of US oil production
  - How much oil and gas will the world produce?
- The Coal Question
- Discussion
  - Future carbon-dioxide levels and temperatures
  - Summary

The UN Panel on Climate Change (IPCC)

- The UN Intergovernmental Panel on Climate Change publishes **assessment reports** that reflect the scientific consensus on climate change
- The **4^{th} report was released in 2007**
  - Over one thousand authors
  - Over one thousand reviewers
  - Nobel Prize
- Updated measurements show that the global temperature is rising 0.013°C per year for the last 50 years
- Report discusses climate simulations for fossil-fuel carbon-emission scenarios
- There are **40 scenarios**, each considered to be equally valid, with story lines and different government policies, population projections, and economic models

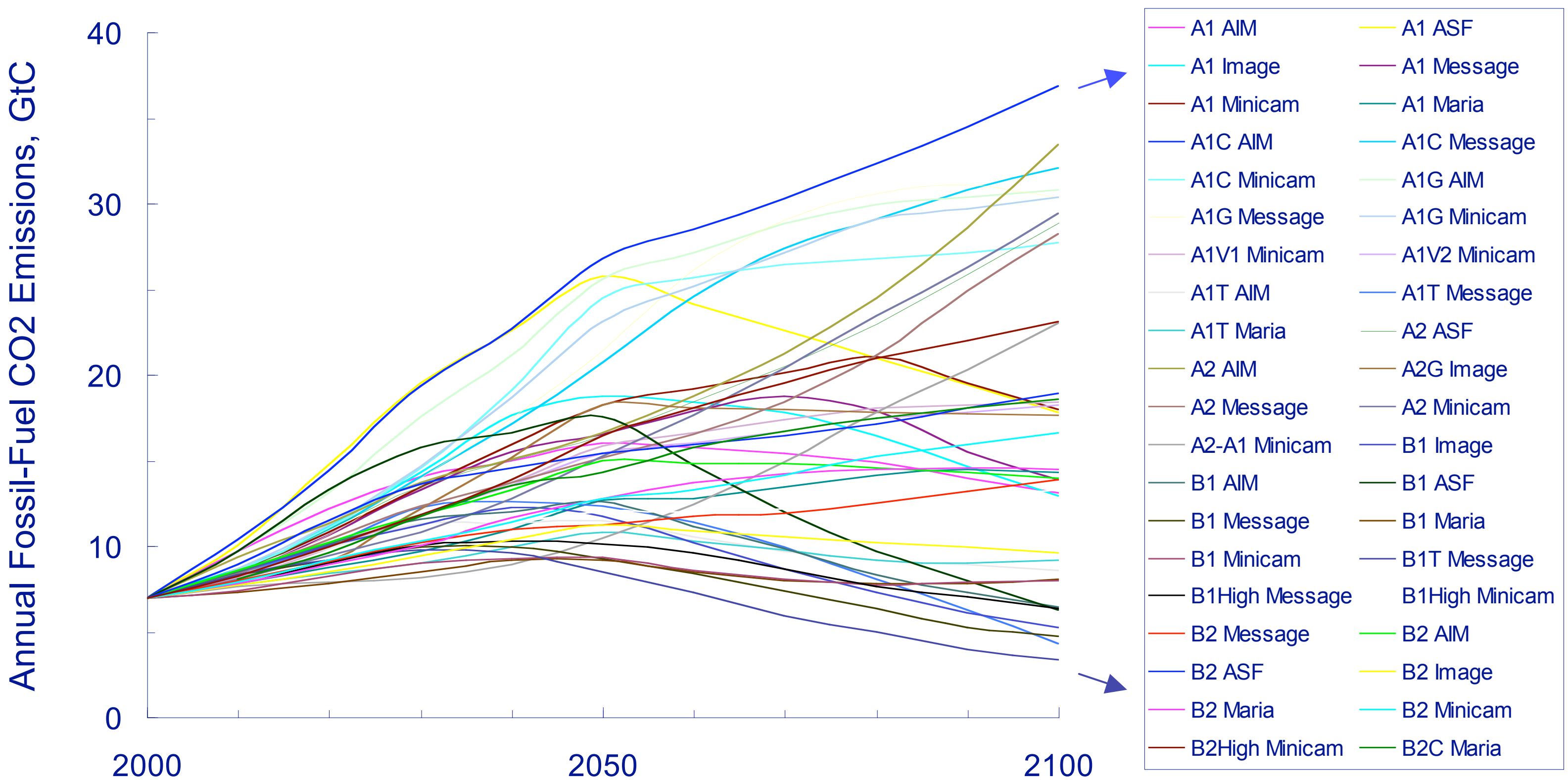
AR5 will only have 3 scenarios

Oil Production in the IPCC Scenarios



- Gb = billions of barrels   1 barrel = 42 gallons = 159 liters
- In 13 scenarios, oil production is still rising in 2100
- **In none of the scenarios did oil production decrease because of resource limitation**
- **Oil Production is never going to be more than today (28 Gb)**

CO_2 emission Scenarios



From Oil + Gas + Coal
These scenarios drive almost all climate change research

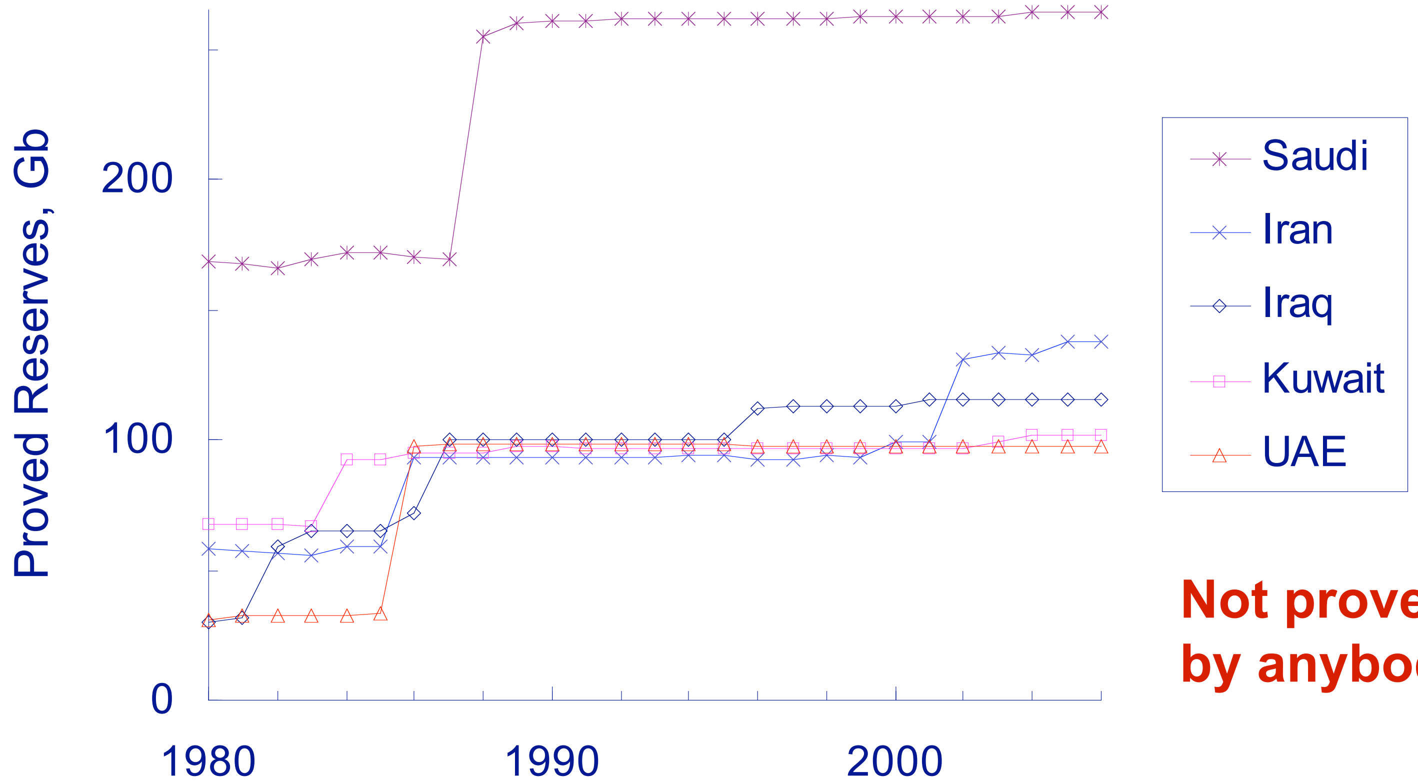
What is Peak Oil?

It’s not about Reserves!

It’s all about the Production Rate!

We are not close to running out or oil

OPEC Oil "**Proven**" Reserves!



Not proven by anybody!

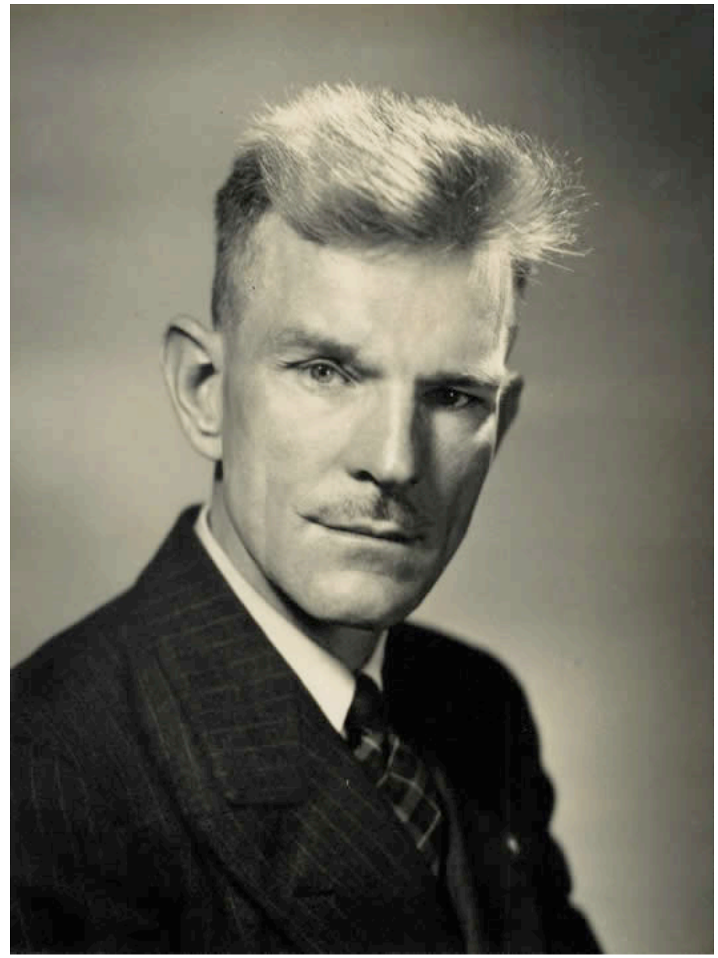
- **Accurate reserve estimates for OPEC countries are closely guarded state secrets**
- **Values for 1983 are probably accurate (for 1983)**
- **430Gb rise in reserves, no adjustment for 193Gb produced since 1980**
- **These questionable reserves are 45% of world oil reserves used by IPCC!**
- **A recent 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**

From BP Statistical Review

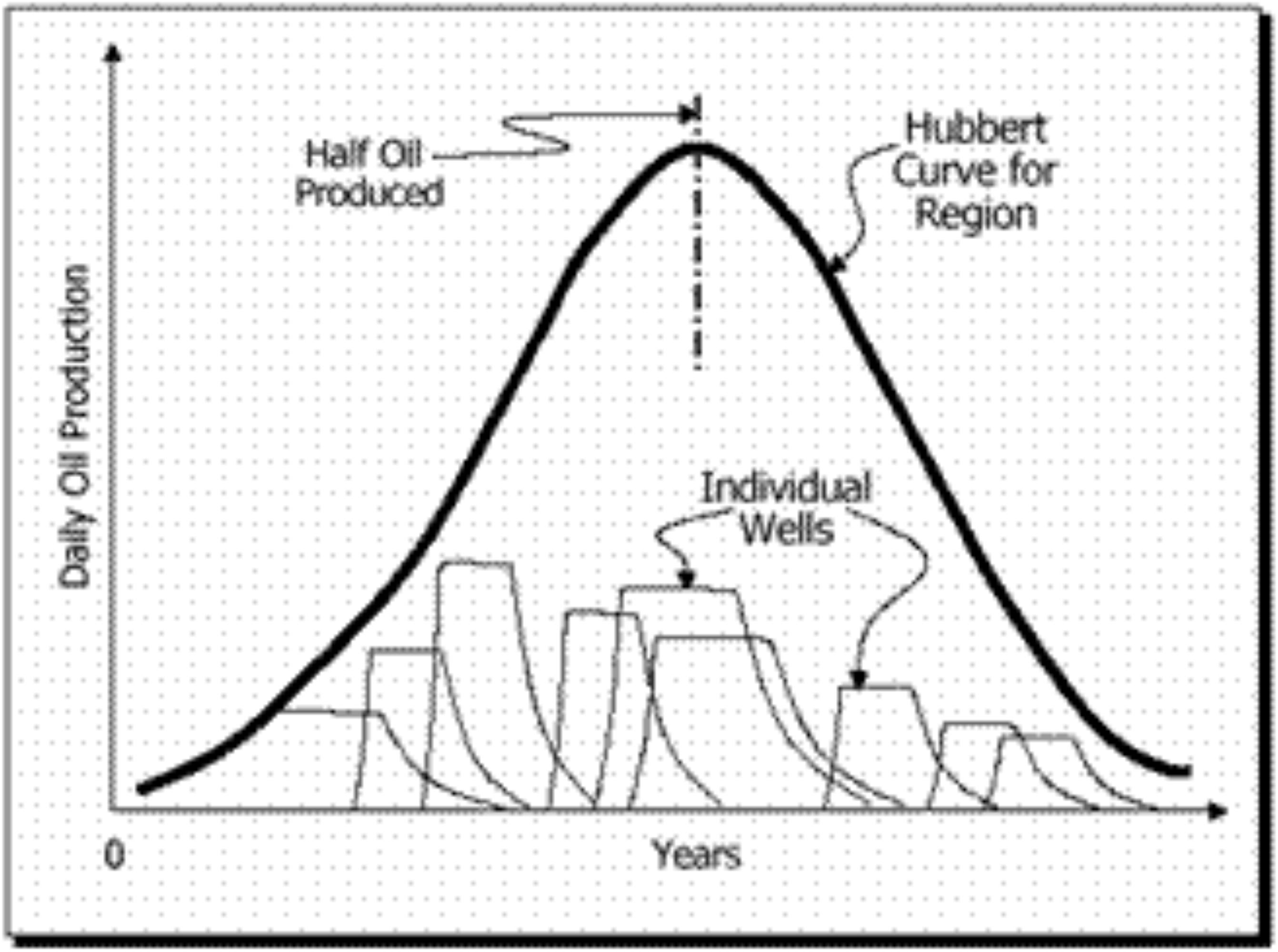
Gb = billions of barrels

M. King Hubbert

- Geophysicist at the Shell lab in Houston
- In 1956, he presented a paper with predictions for the peak year of US oil production



HUBBERT CURVE
Regional Vs. Individual Wells

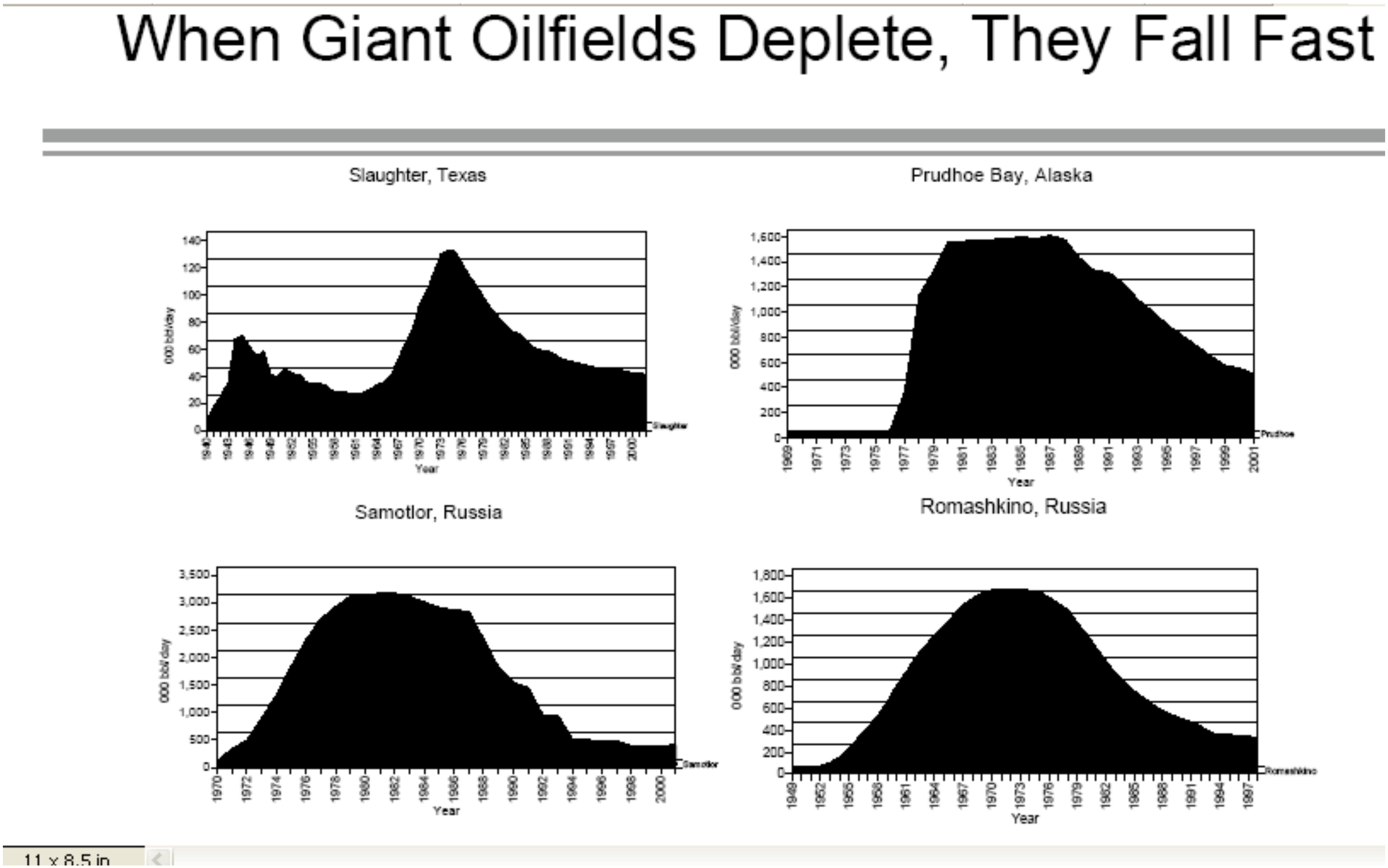


A model
logistic
distribution

Oil Wells and Fields Peak --- Regions Peak --- The World will peak

Everyone agrees that world oil will peak – controversy on the date

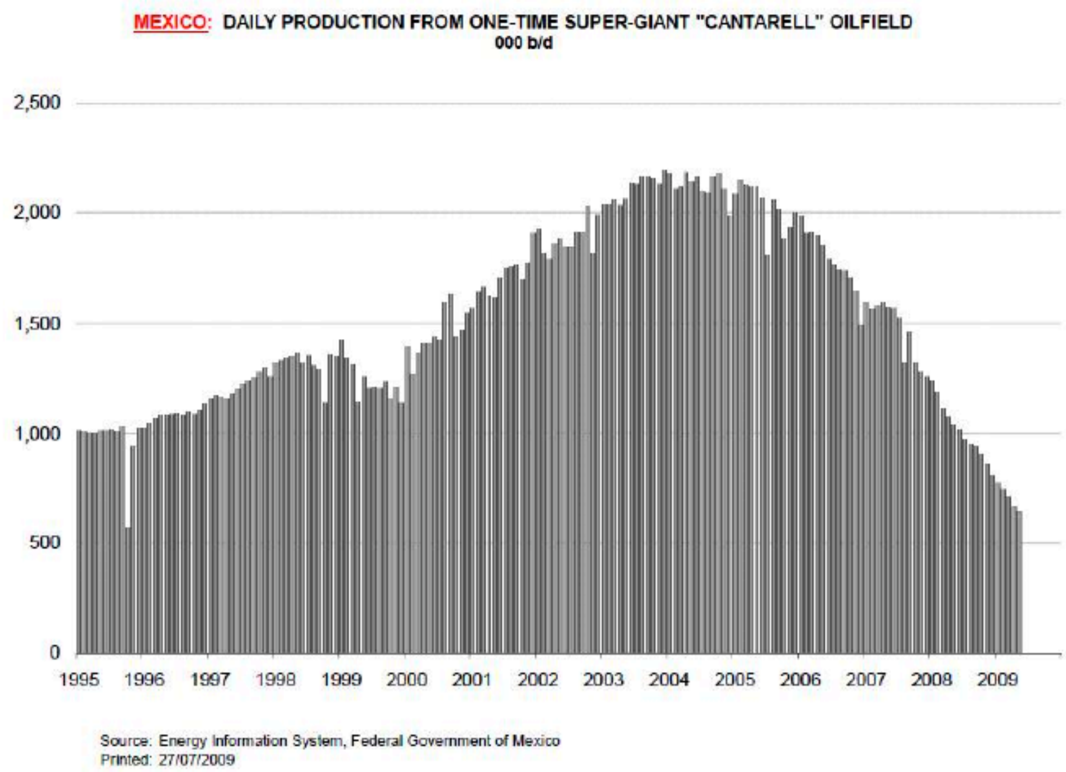
Examples: Rapid Depletion is Normal



Mexico

Was the #2 supplier of oil to the US
Now is #4

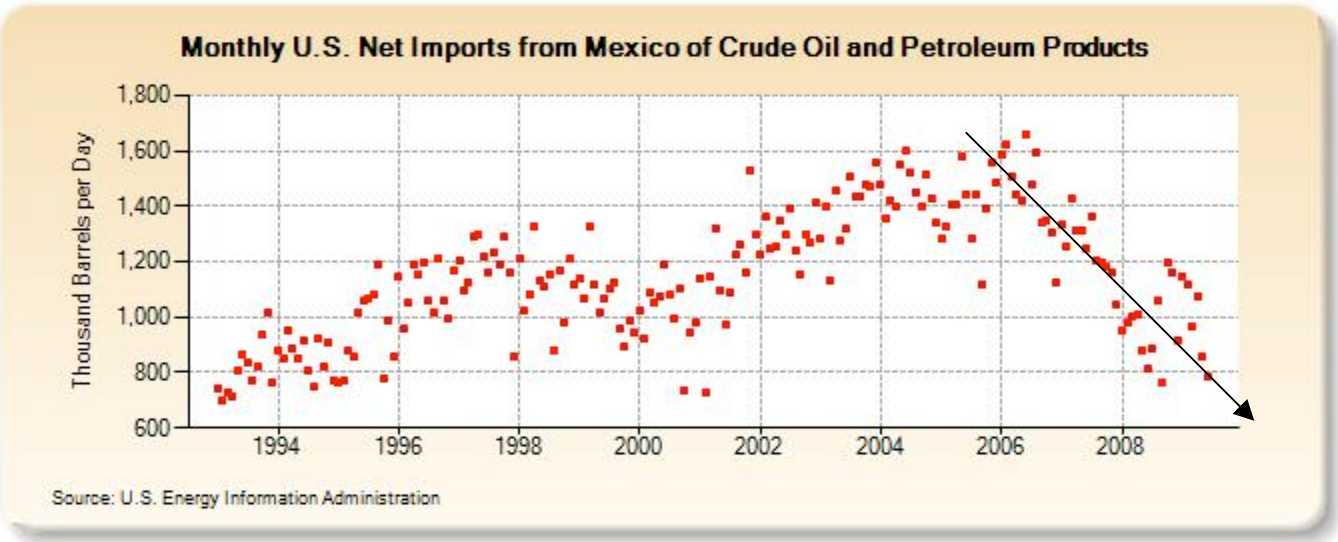
Cantarell from >2,000 in 2005
to 860,000 in Jan 2009
to 588,000 in July 2009



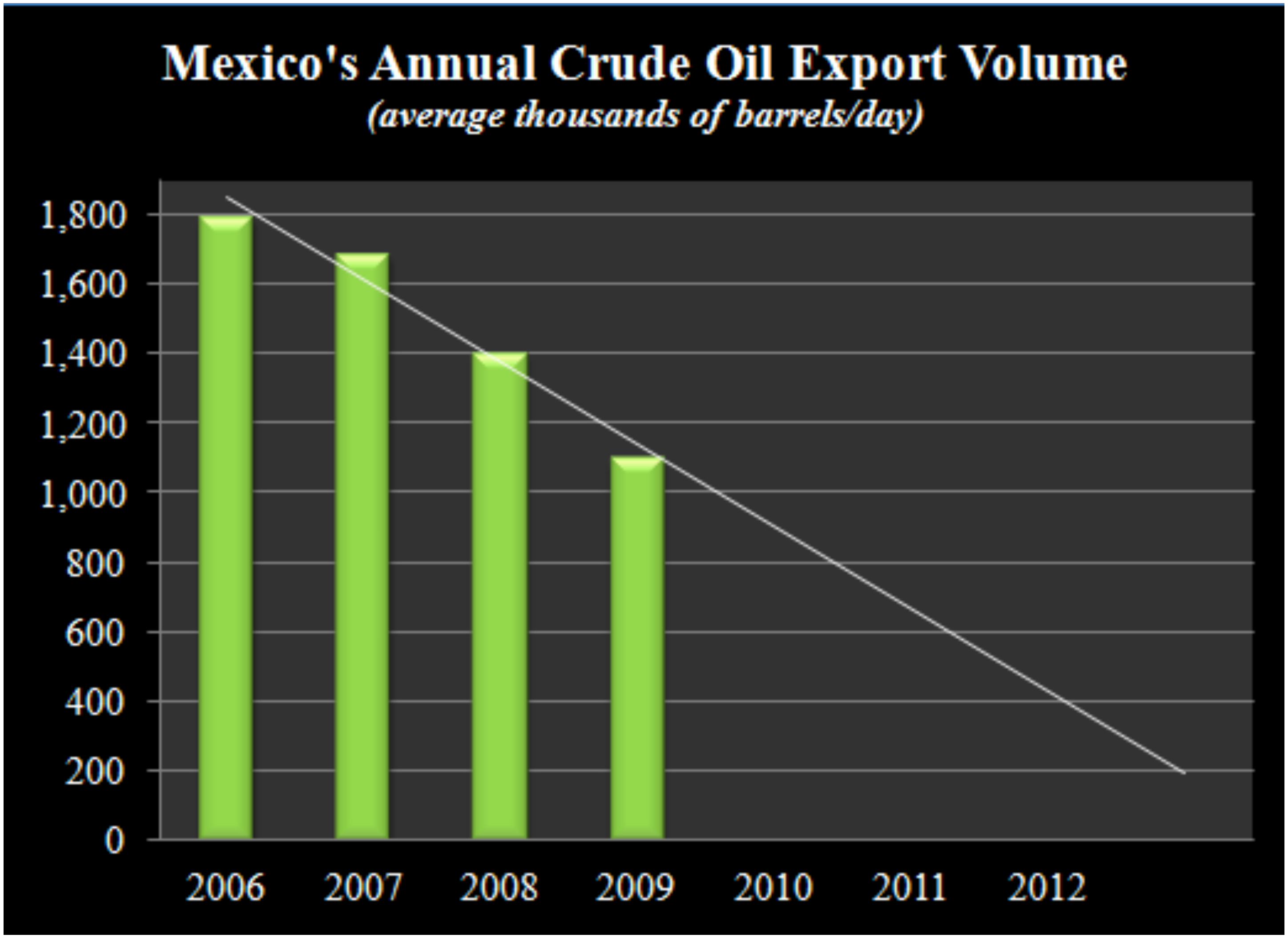
Both Mexico and the US are in trouble.

Mexico:
Sale of oil = 40% of federal budget

US:
Net exports go to 0 in ~2014

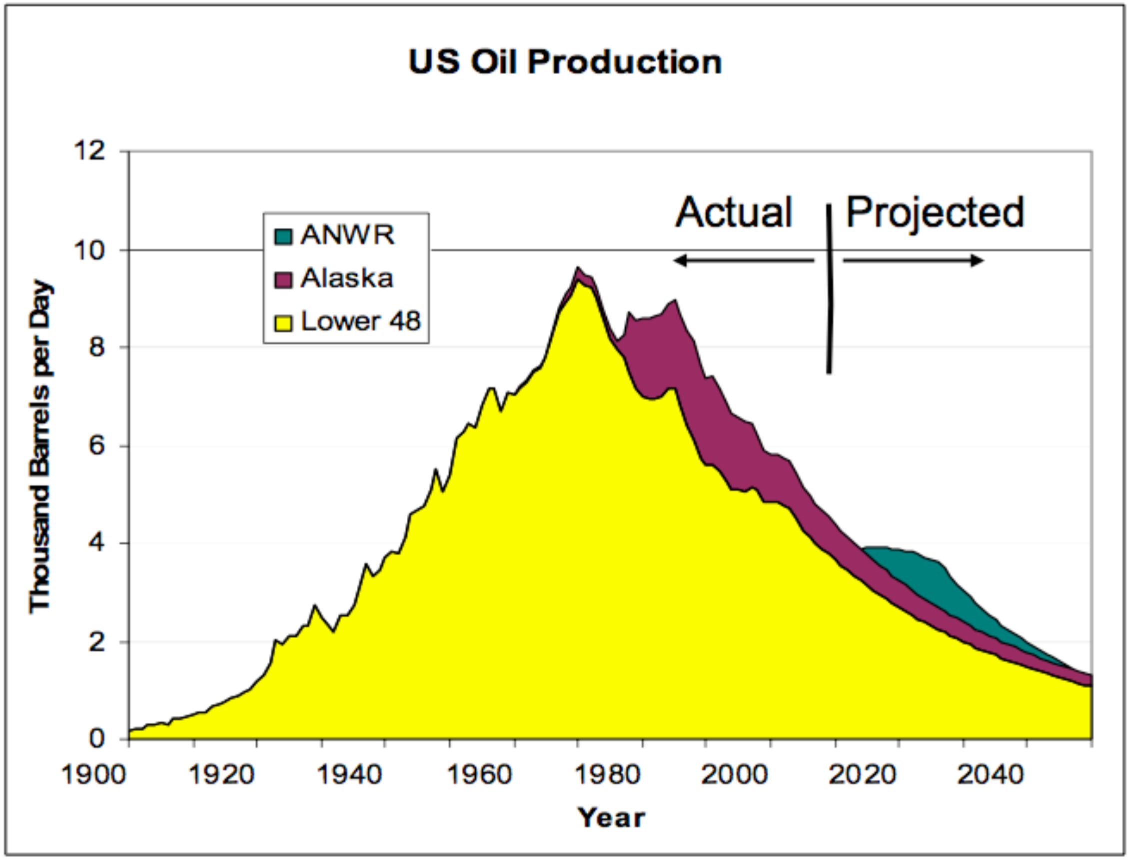


Net Export Production



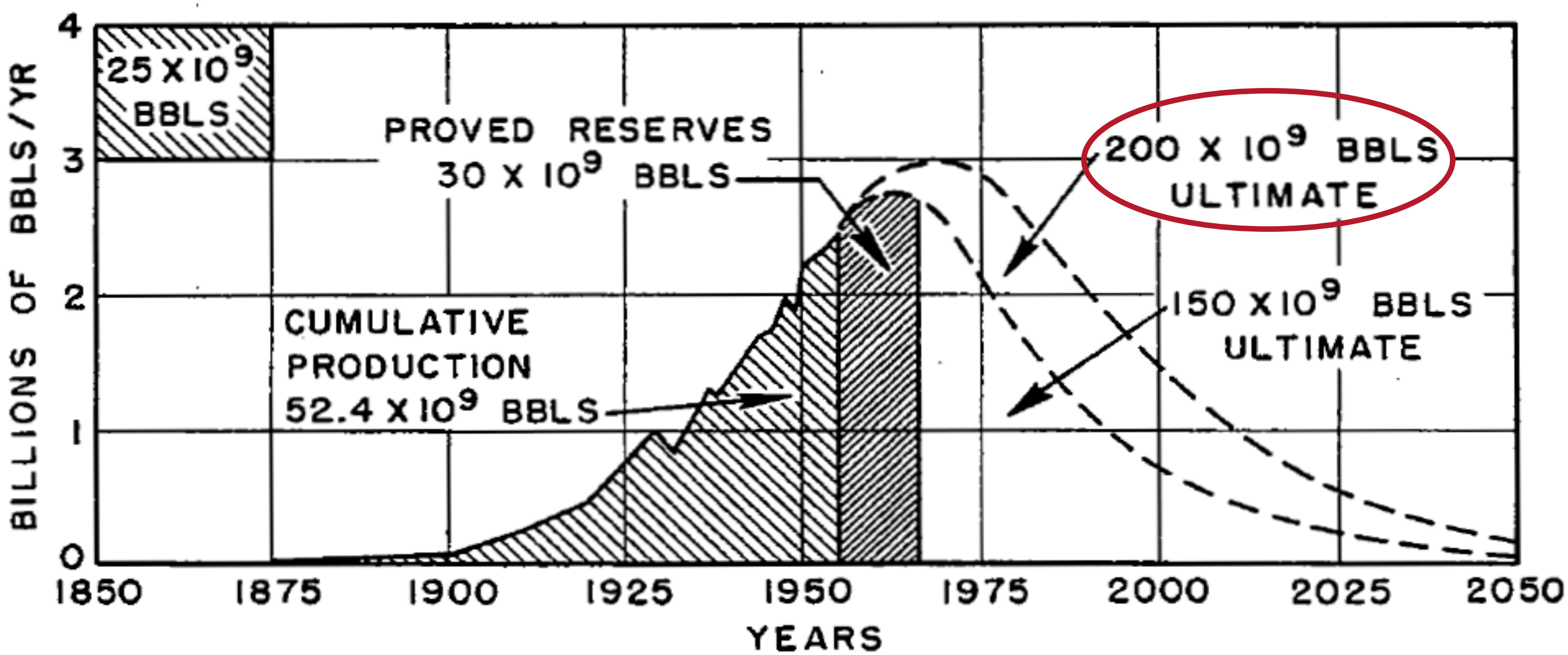
U.S. Oil Production

Typo:
Million!



US Oil Consumption today is about 20 million barrels of oil/day
ANWAR will not save us!

Hubbert's Peak

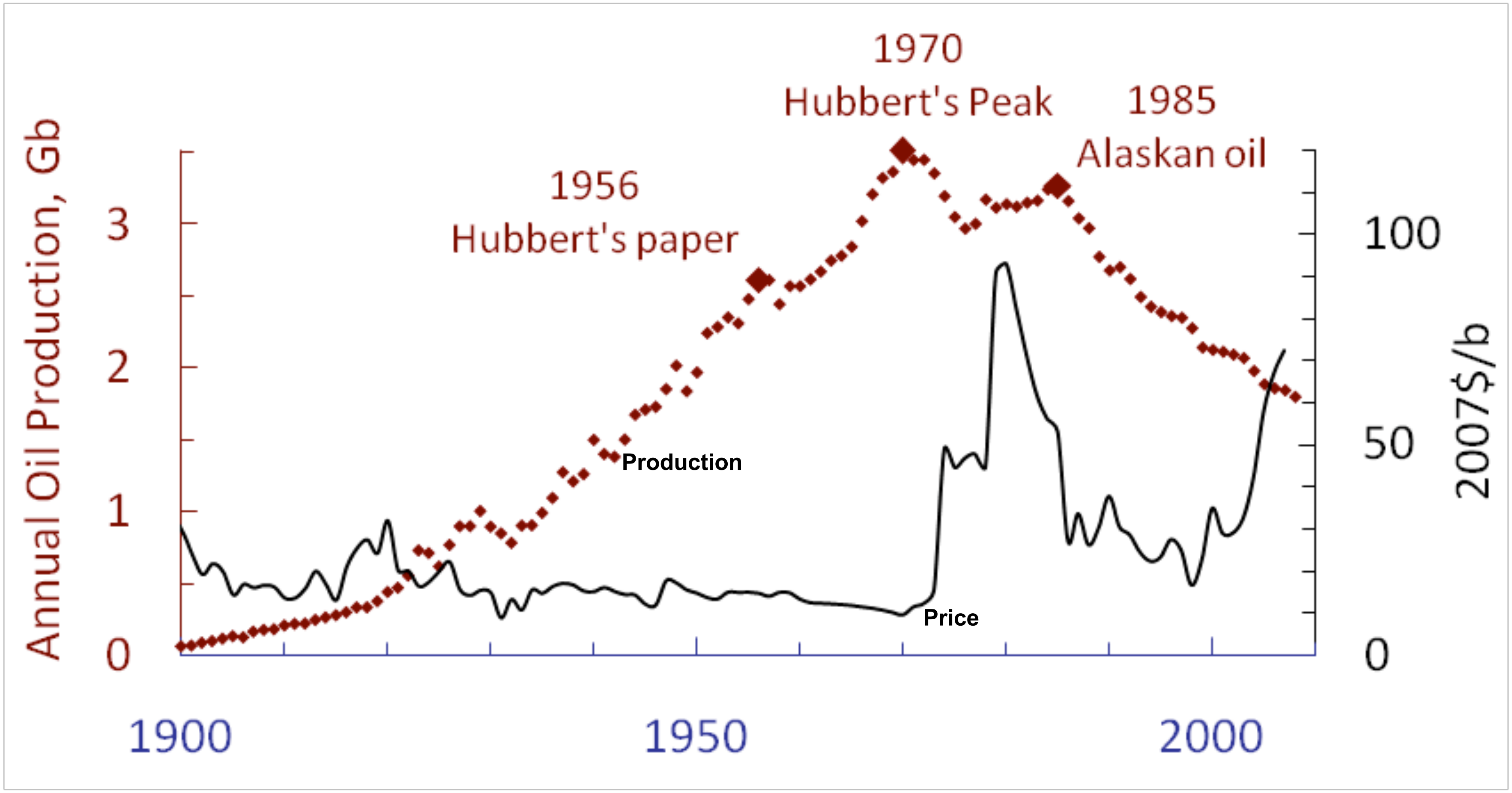


- From Hubbert's **1956** paper
- Hubbert drew bell-shaped curves by hand, and added up barrels by counting squares
- For the larger estimate, **he predicted a peak in 1970**
- Hubbert has been much criticized — there is no consideration of supply and demand curves, prices, or policy, and new technologies

Case Study:

Apply the Principals of Hubbert's Model to the US to see how this works

US Crude-Oil Production



- Production is bell-shaped, like the curves Hubbert drew
- Average price after the peak is 2.6 times higher than before

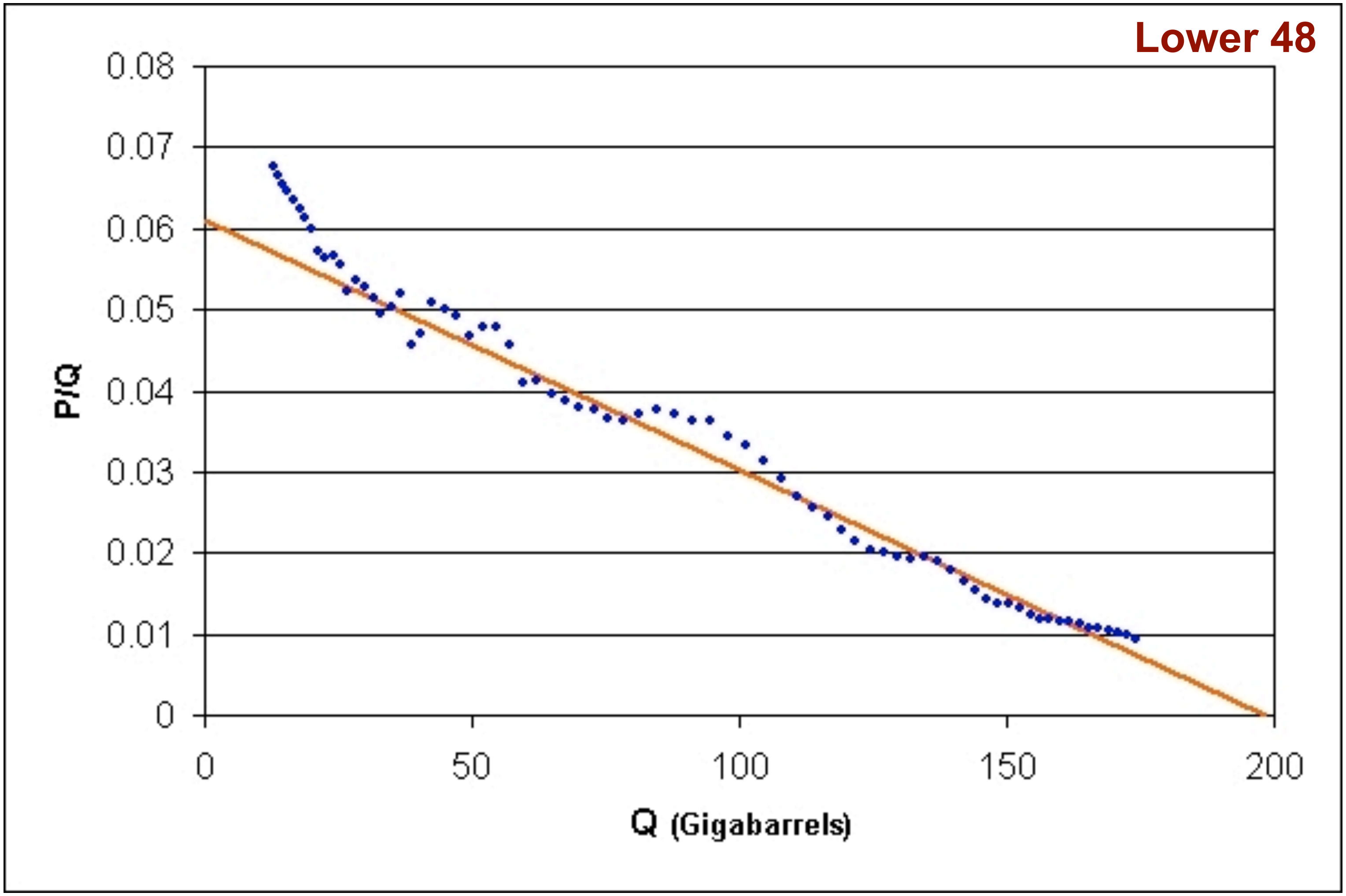
The Logistic Curve or Rate Plot

$P/Q = mQ + a$

Q for which $P/Q = 0$ is 198 gigabarrels of oil.

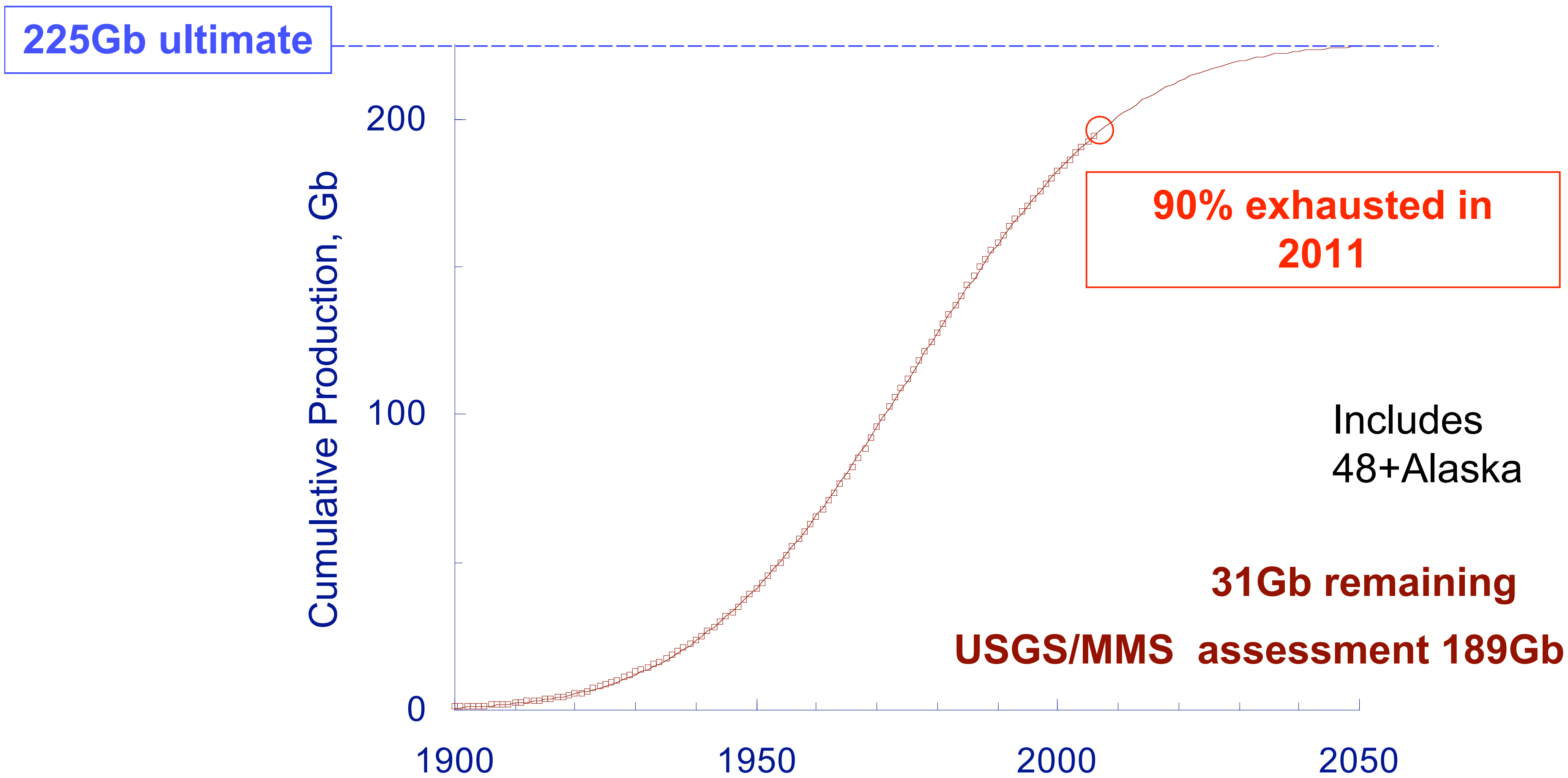
Also called **Q_t (maximum cumulative production)**

Half of this is 99 which occurred in 1973



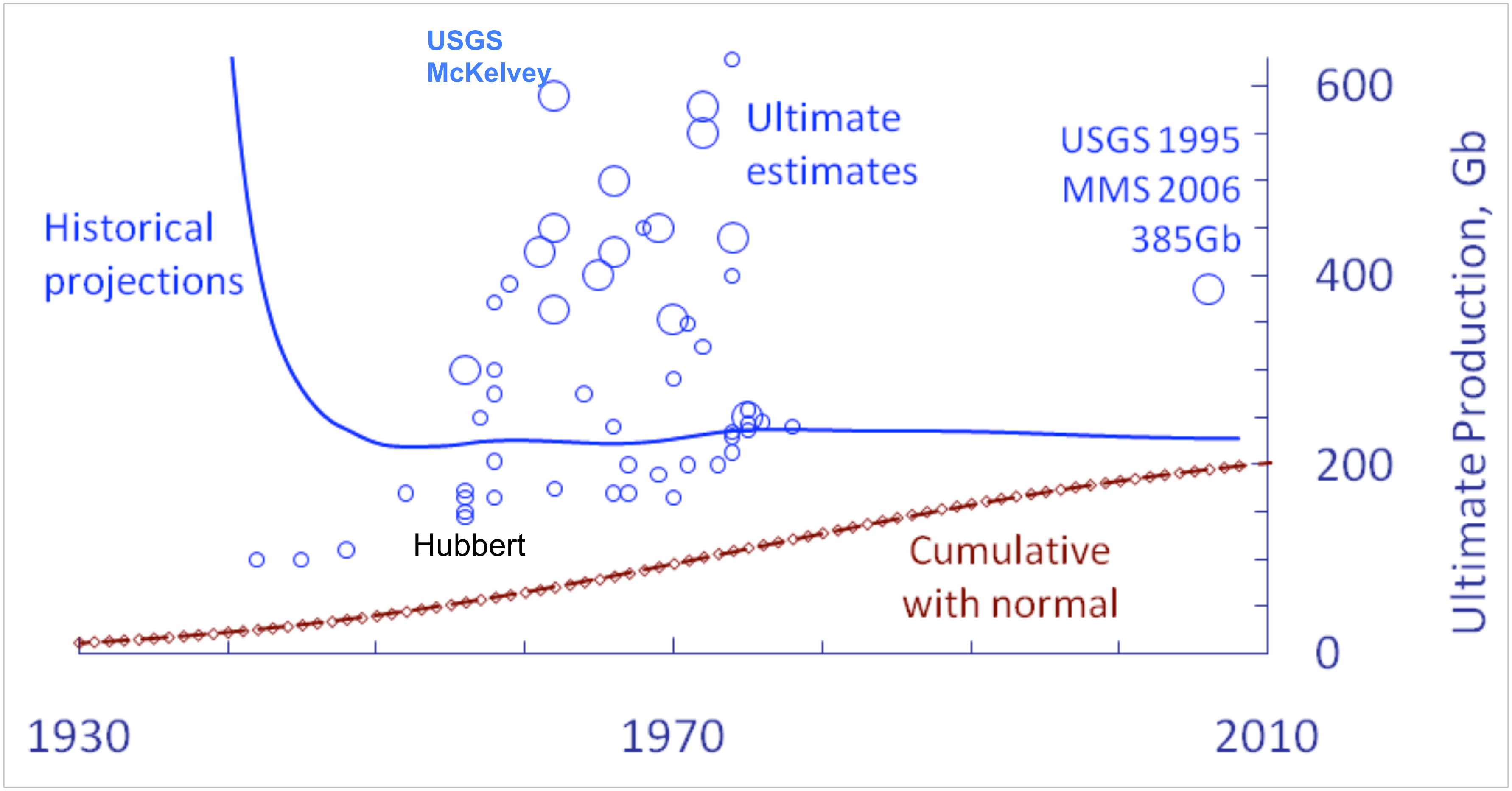
A model for exponential growth in a finite system

Another Approach: Cumulative Oil Production



- **EIA data from 1859**
- **Fit for cumulative normal gives the ultimate production and the time for 90% exhaustion**

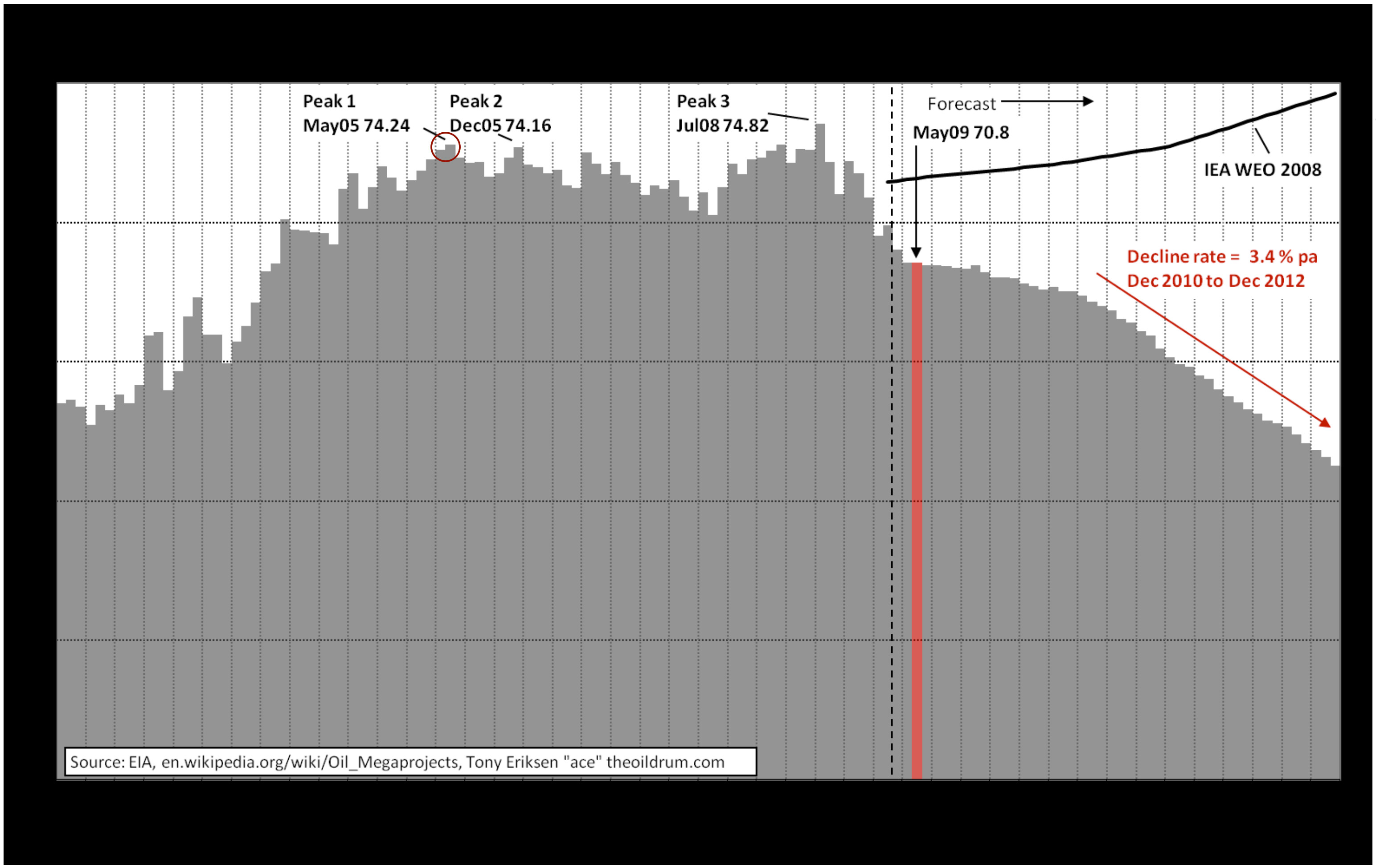
Historical Projections for US Oil



The power of Hubbert Linearization is that it uses past behavior of a system to indicate possible future performance rather than relying on the overoptimistic opinions of resource "experts"

Can we apply this approach to estimate ultimate global oil production?

World Oil Production Peaked in May 2005
non-OPEC Peaked in 2004
Saudi Arabia peaked in 2005,
Russia appears to have peaked

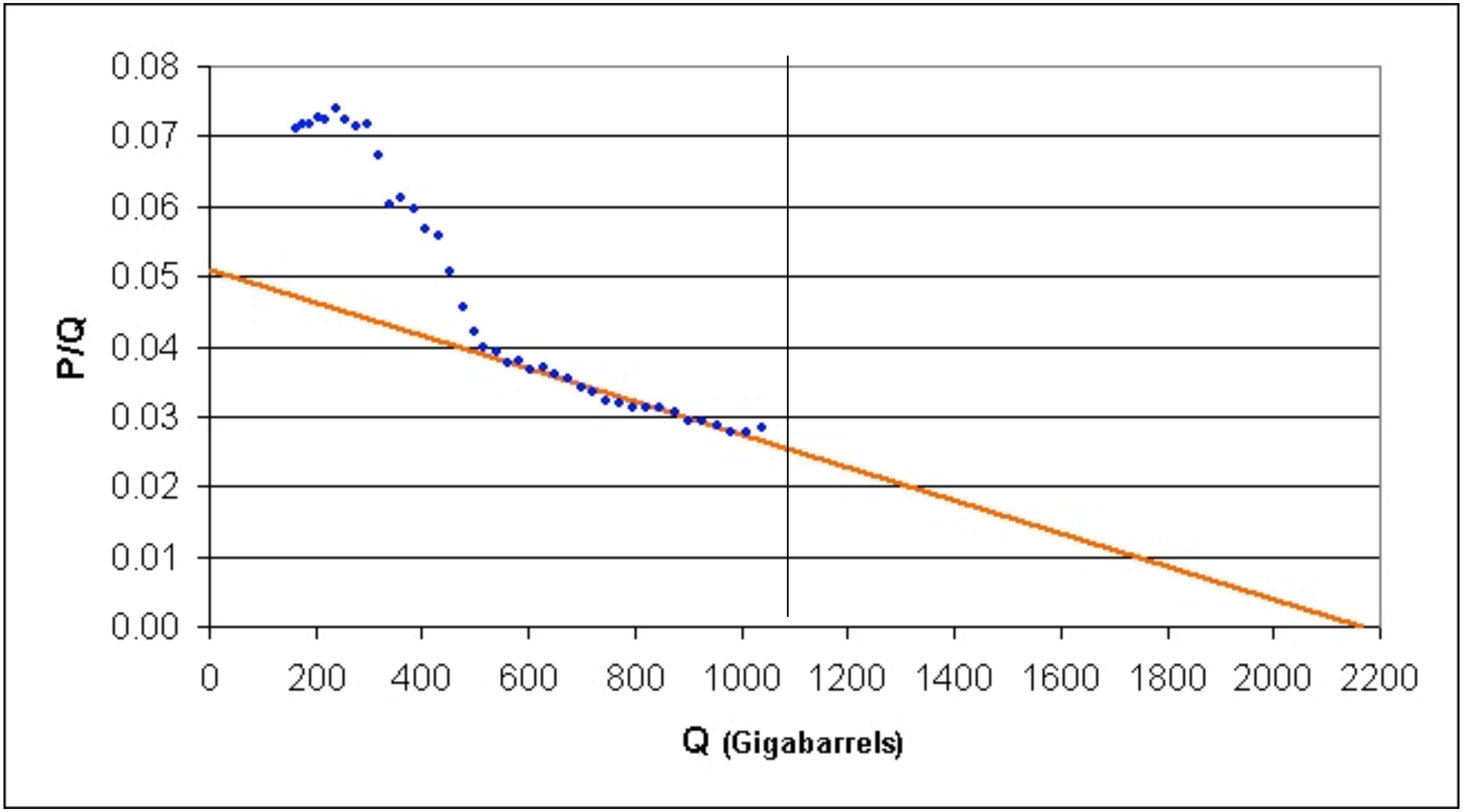


IEA still predicts an increase (May 19, 2009)

MBD

Year

Rate Plot:
Maximum Cumulative Production (Q_t) = 2165 Gigabarrels



½ Q_t = 1083 Gb

Who are the experts that IPCC turn to?
Energy Information Agency (EIA) - DOE
International Energy Agency (IEA) – Paris
US Geological Survey (USGS) - Washington

Their economic models for future emissions are driven by demand (not supply).

EIA, IEA and IPCC assume that supply will meet demand
USGS assumes much oil yet to be found

The EIA forecasts in 2008 projects a 30% increase in oil production between now and 2030 (from 85 to 97 mb/d) (Δ = +12 mbd).

The hard truth is that increasing energy supply at all will be difficult.

To have growth we need to balance
decline of exisiting fields
with discovery of new oil

Existing Oil Fields are in Decline

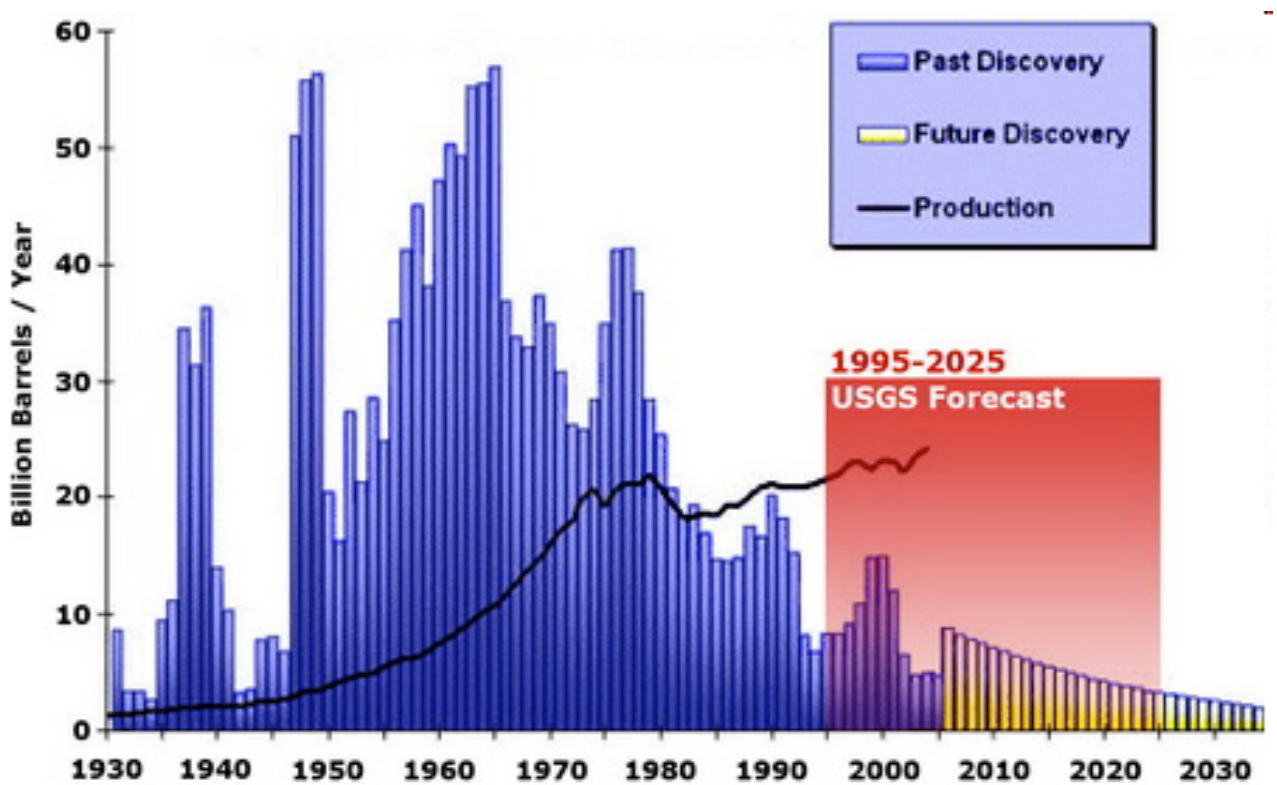
Existing oil fields are declining at - 6.7% per year (IEA 2008)

For 2005 to 2030 the world needs 45 mbd of new production – just to maintain flat production

The projected growth requires discovery of 45 + 12 = 57 mbd of new oil!

57 ÷ 9 = ~6+ new Saudi Arabias

Urban Legend – we can drill more to get more oil
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.

The world's oil provinces have been well explored.
Future discoveries will be limited to smaller structures and deeper formations

Canadian Oil/Tar Sands

bitumen
API Gravity = 8-10 (cold molasses)
viscosity = 10,000
high sulfur = 5%

Hugh resource = 1.7 trillion barrels
but at most 0.3 tb available for extraction

surface mining (~20%)
in-situ (SAGD) (~80%)

1.2 mbd in 2008; projected 2.4 mbd in 2020
4 barrels of water for each barrel of oil
2 tons tar sands = 1 barrel
Oil Junkies Last Fix – Big energy demand
Law of Receding Horizons
EROI = ~6:1 gold (natural gas) to lead (oil)

Neither scaleable nor timely

What about coal?

There are supposed to be hundreds of years of supply of coal!

Big 3 Reserves:
US (27%)
Russia (17%)
China (13%)
then
India, Australia, South Africa

Remarkably the data-quality is very poor globally but especially for China (last update 1992) and SE Asia and FSU

World Energy Council = WEC

The reserves to production ratio (R/P)

"It has been estimated that there are over 984 billion tonnes of proven coal reserves worldwide…This means that there is enough coal to last us over 190 years." The Coal resource, *World Coal Institute*, 2005

Future Supplies are often discussed in terms of the reserves-to-production (R/P) ratio.

Sounds sensible but supply forecasts of nonrenewable resources based on R/P ratios are always wrong!

Three main reasons..

1. Rates of consumption of energy are never constant - they increase
2. It is physically impossible to maintain a constant rate of extraction until the resource is exhausted
3. Reserves are not static, but can increase as a result of new discoveries and new technologies.

The R/P approach is useless – but now five independent groups have attempted an to determine when peak coal will occur.

These include the Energy Watch Group (EWG), Institute for Energy, Aleklett (Uppsala University), Rutledge (Cal Tech)

We have a big problem with coal. The reserves may not be as large as We've been led to believe.

"Present estimates of coal reserves are based upon methods that have not been reviewed or revised since their inception in 1974, and much of the input data were compiled in the early 1970s. Recent programs to assess reserves in limited areas using updated methods indicate that only a small fraction of previously estimated reserves are actually minable reserves."

from the National Academy of Sciences
***Report on Coal,* June, 2007**

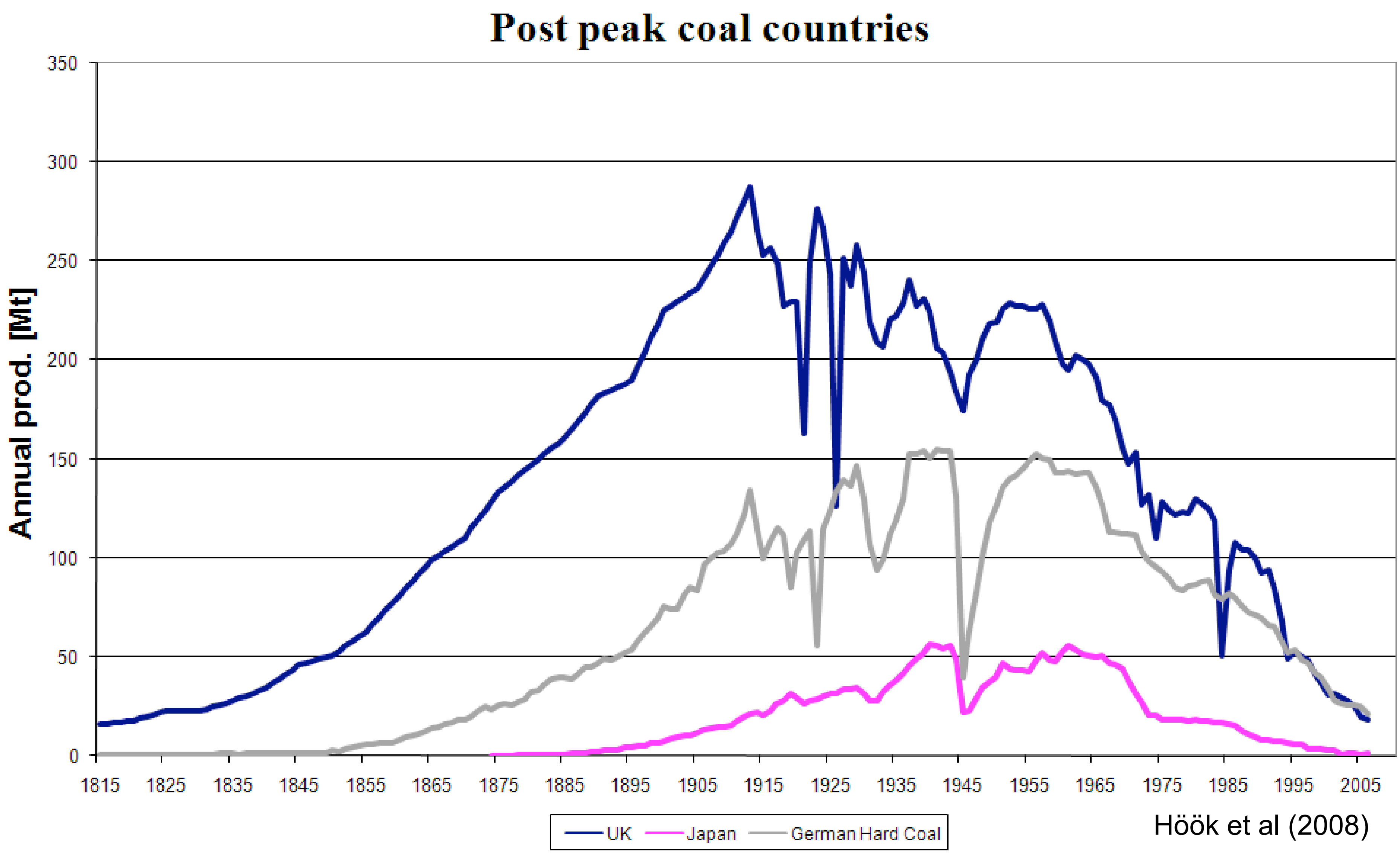
Another Problem is Energy Content
IPCC reports energy units (ZJ)

Types of coal (four types – different energy content)
Anthracite (30 MJ/kg)
Bituminous (19 – 29 MJ/kg)
Sub-bituminous (8-25 MJ/kg)
Lignite (5-14 MJ/kg)

The high energy coal is running out

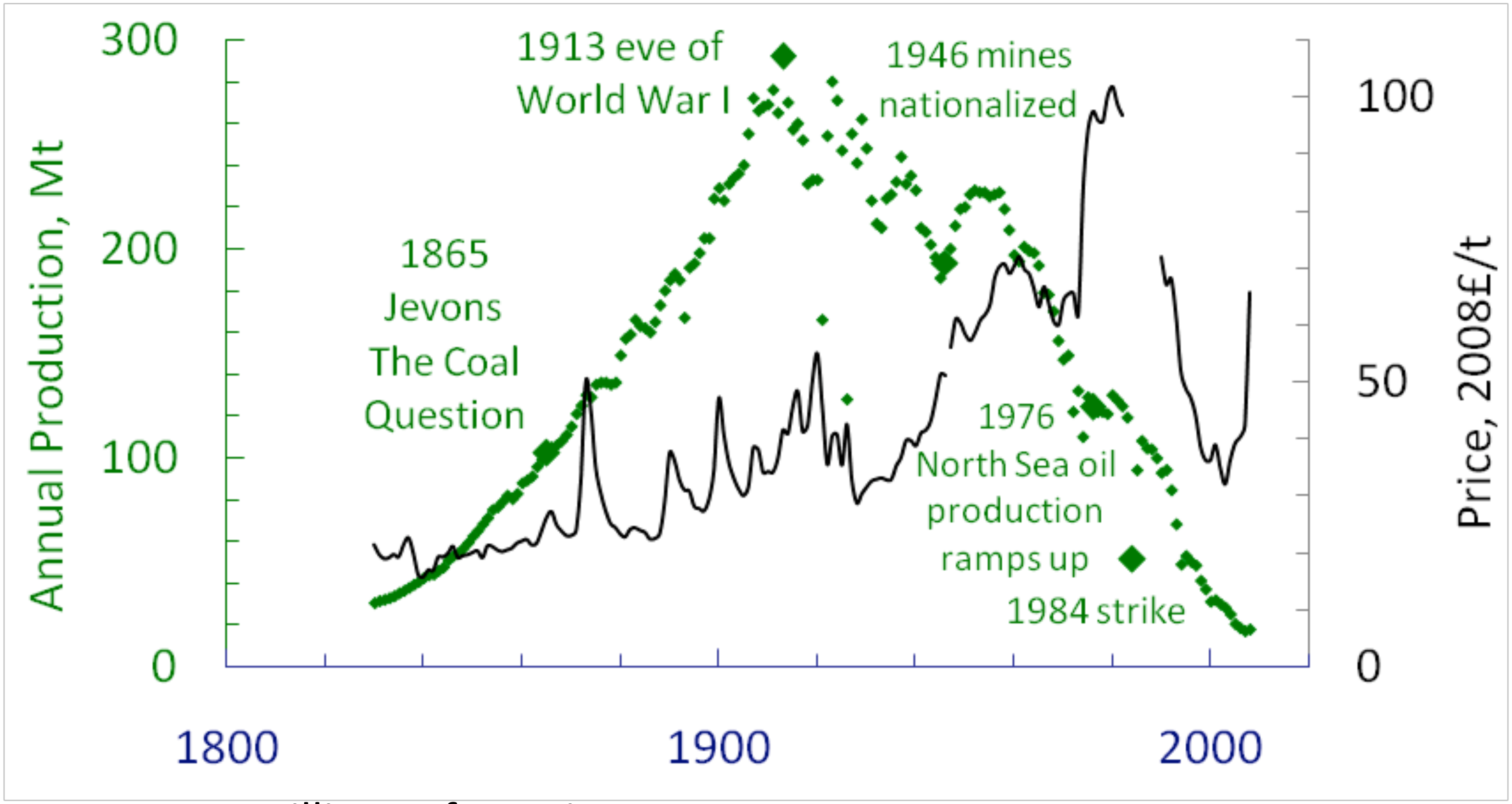
US passed peak anthracite in 1950
peak bituminous in 1990

Total energy content of US coal peaked in 1998
Total energy content of world coal should peak in 2025



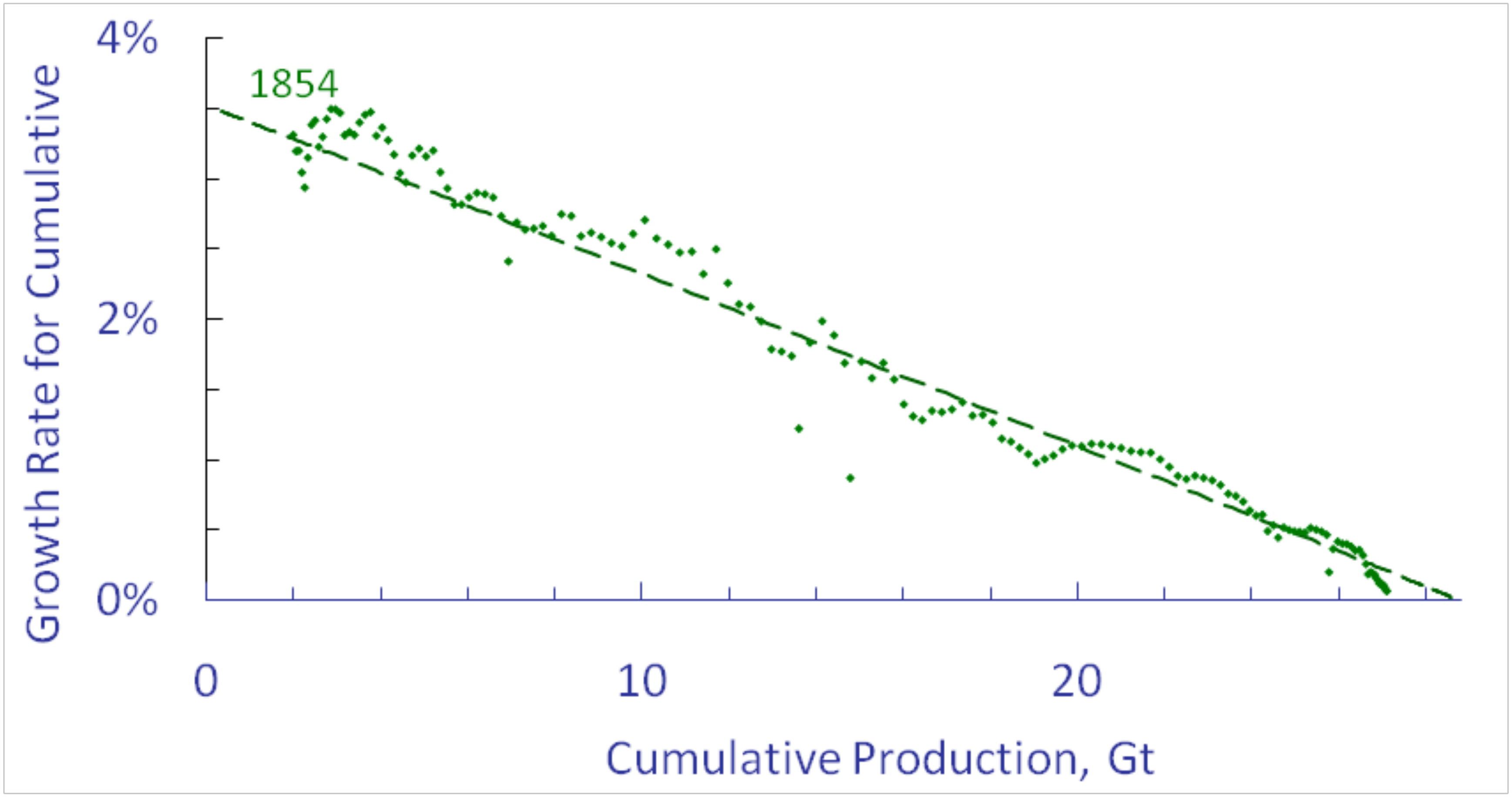
Can we apply Hubbert approach to coal?
You can make a strong case using UK, Japan, France, Pa anthracite

UK Coal Production



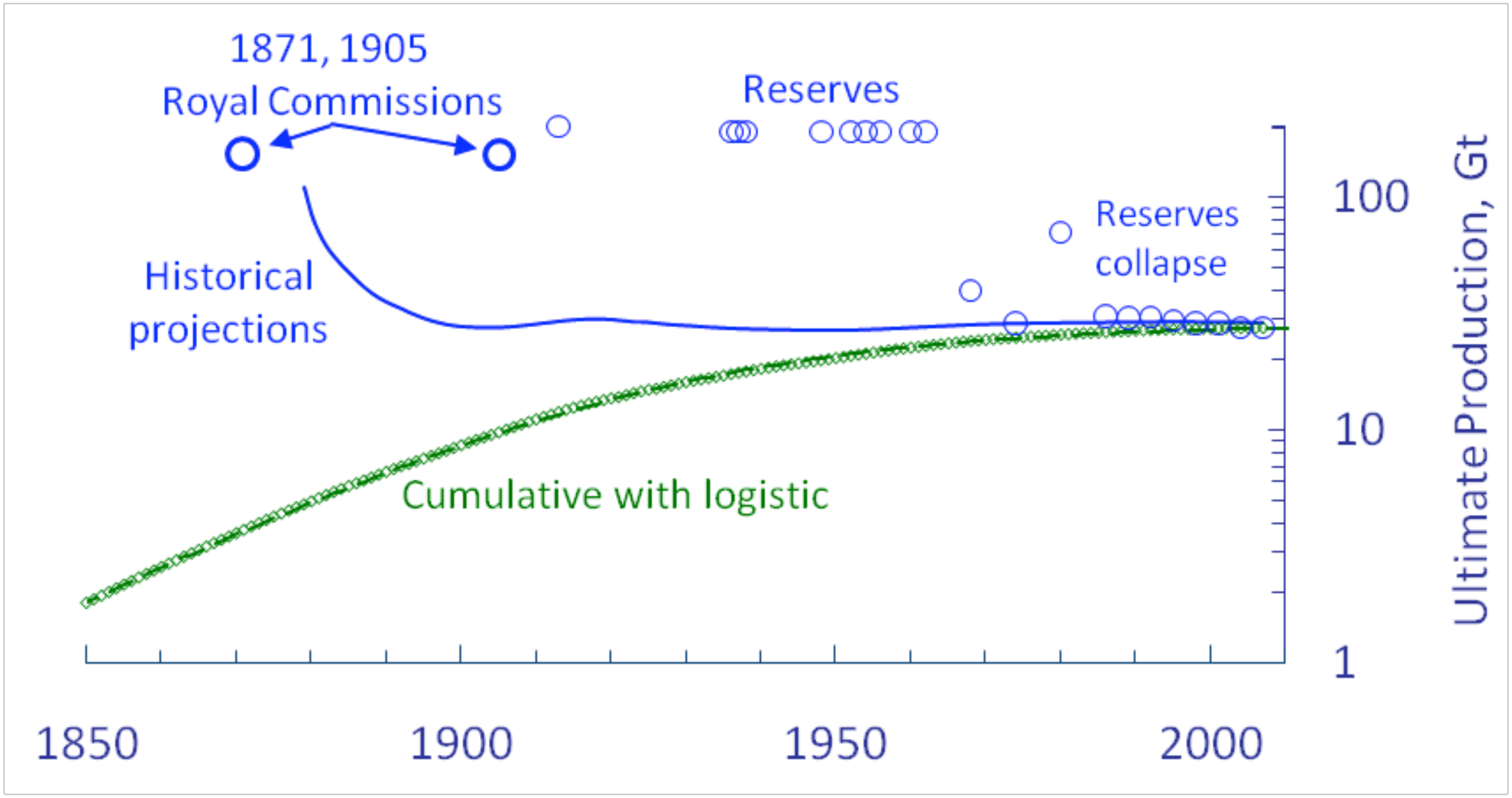
- Mt = millions of metric tons
- Production is now 16 times less than the peak, while the average price after the peak is 2.4 times higher than before
- In 1913, Britain exported 27% of its production, now it imports 74% of the coal it burns

Rate Plot for British Coal



- Rate plot does not curve, fit to a logistic rather than normal

Historical Projections for UK Coal



- Reserve numbers are available before projections stabilize
- Produced 18% of the 1871 Royal Commission reserves + cumulative
- Criteria were too optimistic — 1-ft seams, 4,000-ft depth (Deffeyes' law)

The world's proven reserves of coal are decreasing fast!

Whenever coal reserves are updated the reserve estimates
are revised downward (significantly).

Not due to production, but rather more thorough geological surveys.

Example: World Reserves by WEC decreased from 10 trillion tons
to 4.2 trillion tons in 2005

Example: Gillette in Wyoming from 20.9 billion tons to 9.2 billion tons (2009)

The energy content of coal mined is decreasing.

Projections vs Reserves for World Coal

Region	Projection Gt	Reserves Gt
Eastern US	37	96
Western US w/o Montana	33	79
Montana	$\boxed{68}$	
Central and South America	$\boxed{16}$	
China	88	189
South Asia	$\boxed{68}$	
Australia and New Zealand	50	77
Former Soviet Union	36	226
Europe	21	44
Africa	16	30
World (at 3.6boe/t)	$\boxed{\text{435 (1.6Tboe)}}$	903

- **UN IPCC scenarios assume 18Tboe is available for production**

from D. Rutledge

Where Does the IPCC Get Its Coal Numbers?

World Energy Council survey	Proved recoverable reserves, Gt	Additional recoverable reserves, Gt
1992	1,039	702
1995	1,032	680
1998	984	3,368
2001	984	409
2004	909	449
2007	847	180

- The scenario report SRES (2000) references the 1995 and 1998 WEC surveys
- Downward trend in proved recoverable reserves
- The IPCC chose to use additional recoverable reserves and they also chose 1998 (3,368Gt) instead of 1995 (680Gt) — additional recoverable reserves are now 19 times smaller than in 1998

Regional Fits vs Reserves, Gt

Region	Fits for Ultimate	WEC Reserves plus cumulative
Europe	155	195
US and Canada	141	316
China (with Japan, South Korea)	115	159
South Asia and Middle East	78	78
Russia	74	219
Australia and New Zealand	59	86
Africa	22	57
Latin America	19	19
World	663	1,129

850 left to be mined

IPCC range is
355 to 3500 in 2100

Many independent groups are coming to the same conclusion

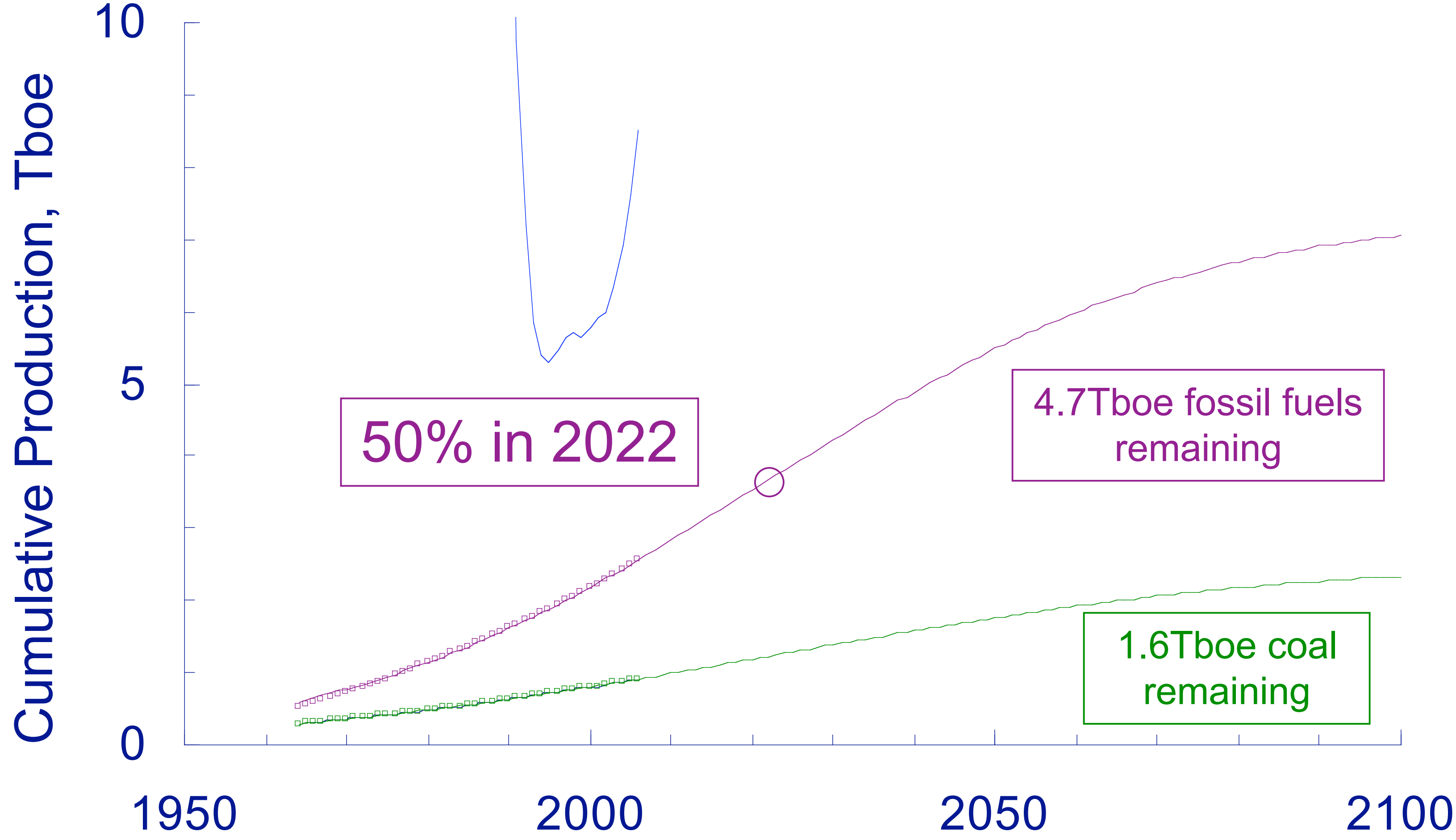
Uppsala – Kjell Aleklett Peak Coal in 2030 (examples follow)
http://www.tsl.uu.se/uhdsg/Publications/Coalarticle.pdf

Energy Watch Group (EWG-Germany) Peak Coal in 2025
http://www.energywatchgroup.org/files/Coalreport.pdf

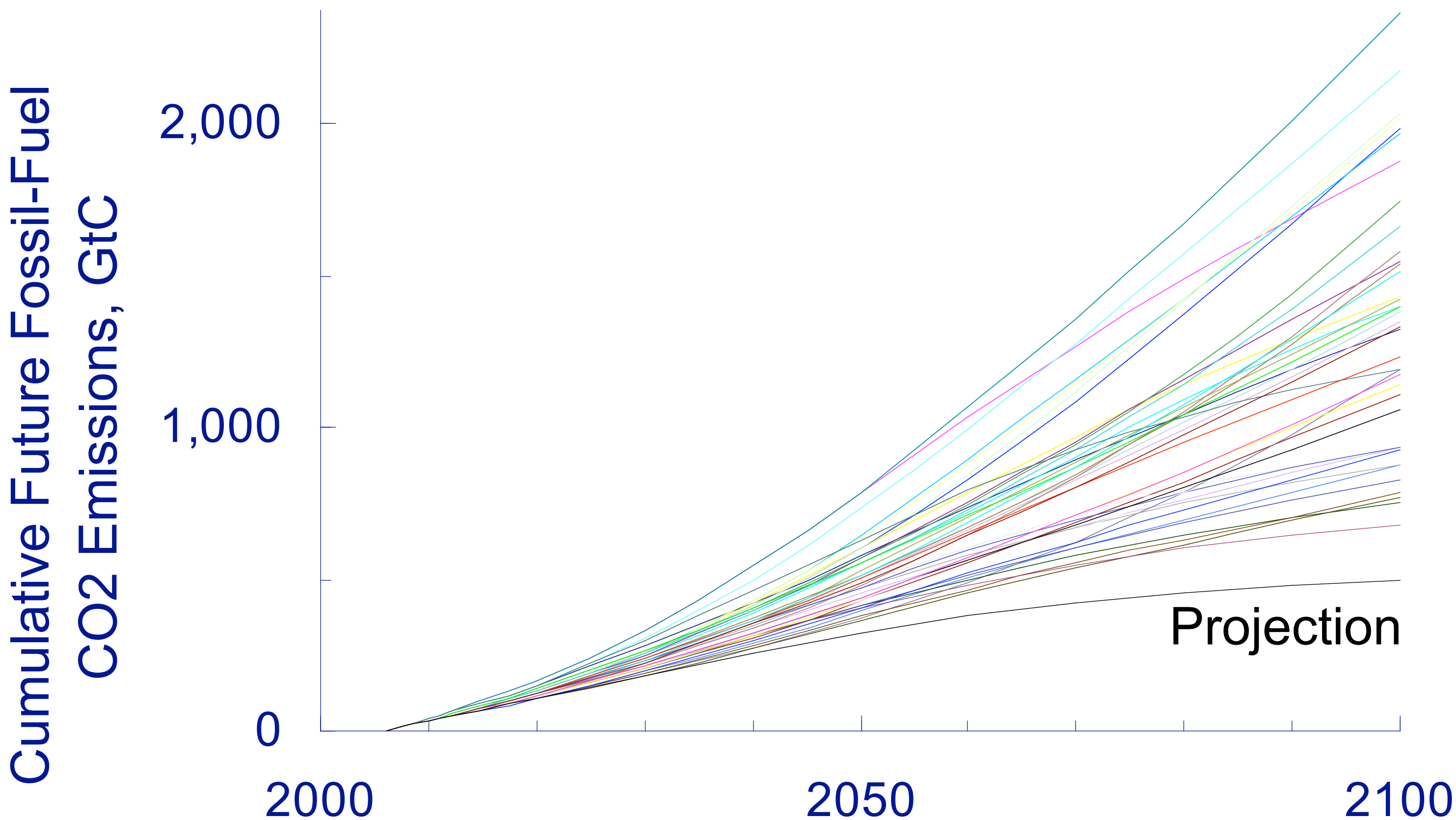
Institute of Energy (IFE)
Kavakov and Peteves (2007) The Future of Coal
http://ie.jrc.ec.europa.eu/

Richard Heinberg Post Carbon Institute (2009)
“Blackout : Coal. Climate and the Last Energy Crisis”
New Society Publishers

Future Fossil-Fuels Production



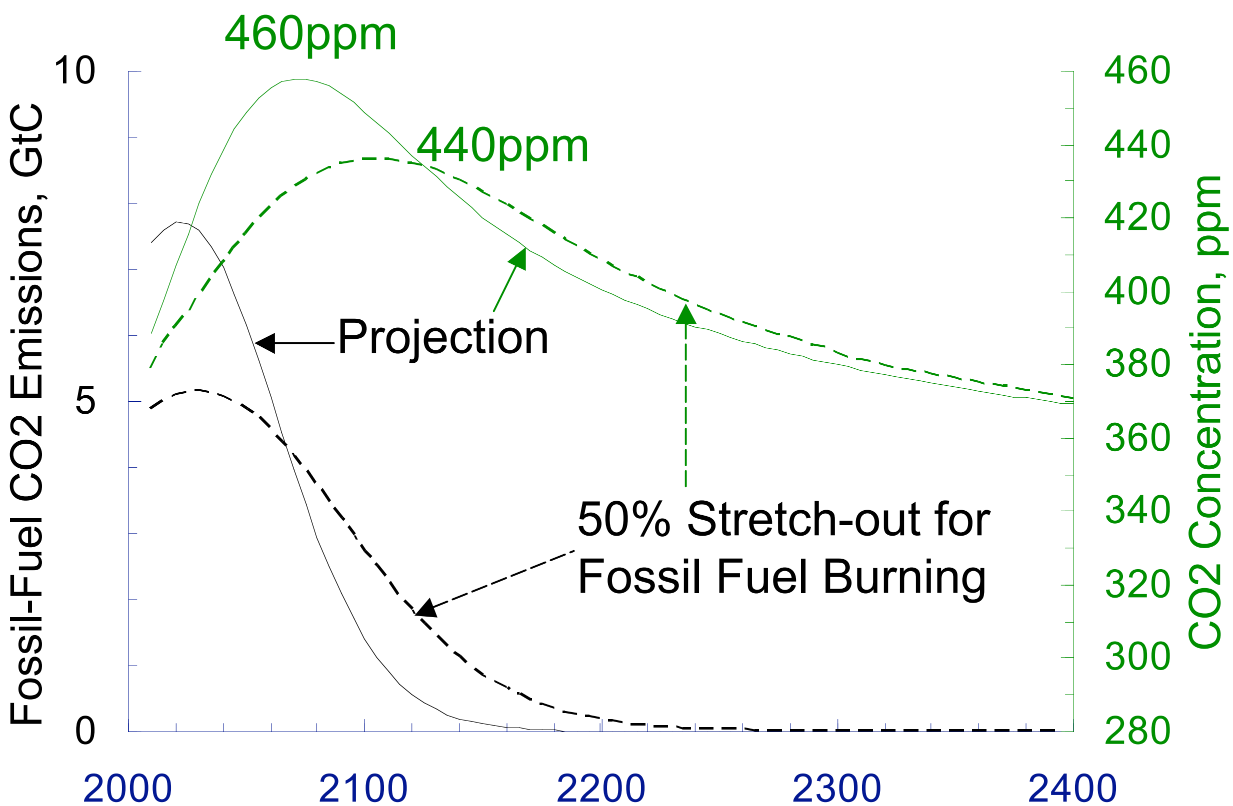
Comparing with the IPCC Scenarios



- This projection has lower emissions than any of the 40 IPCC scenarios
- This is still true even with full coal reserves

D. Rutledge

Carbon-Dioxide Levels



- Simulations with the program MAGICC from Tom Wigley at the National Center for Atmospheric Research (NCAR) in Boulder
- This program was used in the earlier UN IPCC Assessment Reports
- profiles that come with the program are modified to use our projection for fossil-fuel emissions
- profiles are business-as-usual for other greenhouse gases

Why Doesn’t The Government Tell this Story?

Quote of the day:

**“(Steven Chu, US Secretary of Energy) was my boss.
He knows all about peak oil, but he can't talk about it.
If the government announced that peak oil was threatening our economy, Wall Street would crash.**

He just can't say anything about it.

-- David Fridley, scientist at Lawrence Berkeley National Laboratory

Conclusions:

1) Supply Limitation will be serious

Existing scenarios and energy policies are based on emissions - not supply

2) Coal is thought of as a solution to energy needs –

This will be a disaster for climate change without CO_2 sequestration.
Is CO2 sequestration realistic?

3) Energy will pass climate change as the hot button issue

We have to get our energy plan in order before we can move forward
on climate change

4) Energy Supply Limitation will Buffer Economic Recovery.

5) Security Issue:

Seven nations control 75% of world's oil exports. There will be shifts
in global power and wealth

Once it is clear that oil production has peaked is there are reason to
believe that exports will not be limited?

Extra Slides

Is geological CO2 sequestration a realistic strategy for solving climate change?

There are only two really serious strategies for mitigating climate change – switching to alternative non-carbon based energy sources (nuclear, wind, solar) or sequestrating carbon dioxide underground as we continue to use fossil fuels. See Science, September 25, 2009 issue of Science.

There are three main issues that are usually underappreciated.

Energy Cost

energy consumption
= roughly 20-30% of the gross starting energy in the coal. One "carbon wedge"
= 855 coal power plants of 1000 megawatts.

Timing

Only 3 or100 carbon storage demonstration projects are representative of future large scale systems.

Scale

A storage volume of 30,000 km^3/yr required.
Niagara Falls = 50 km^3/yr.
We need to store 600 Niagara Falls of liquid CO_2.