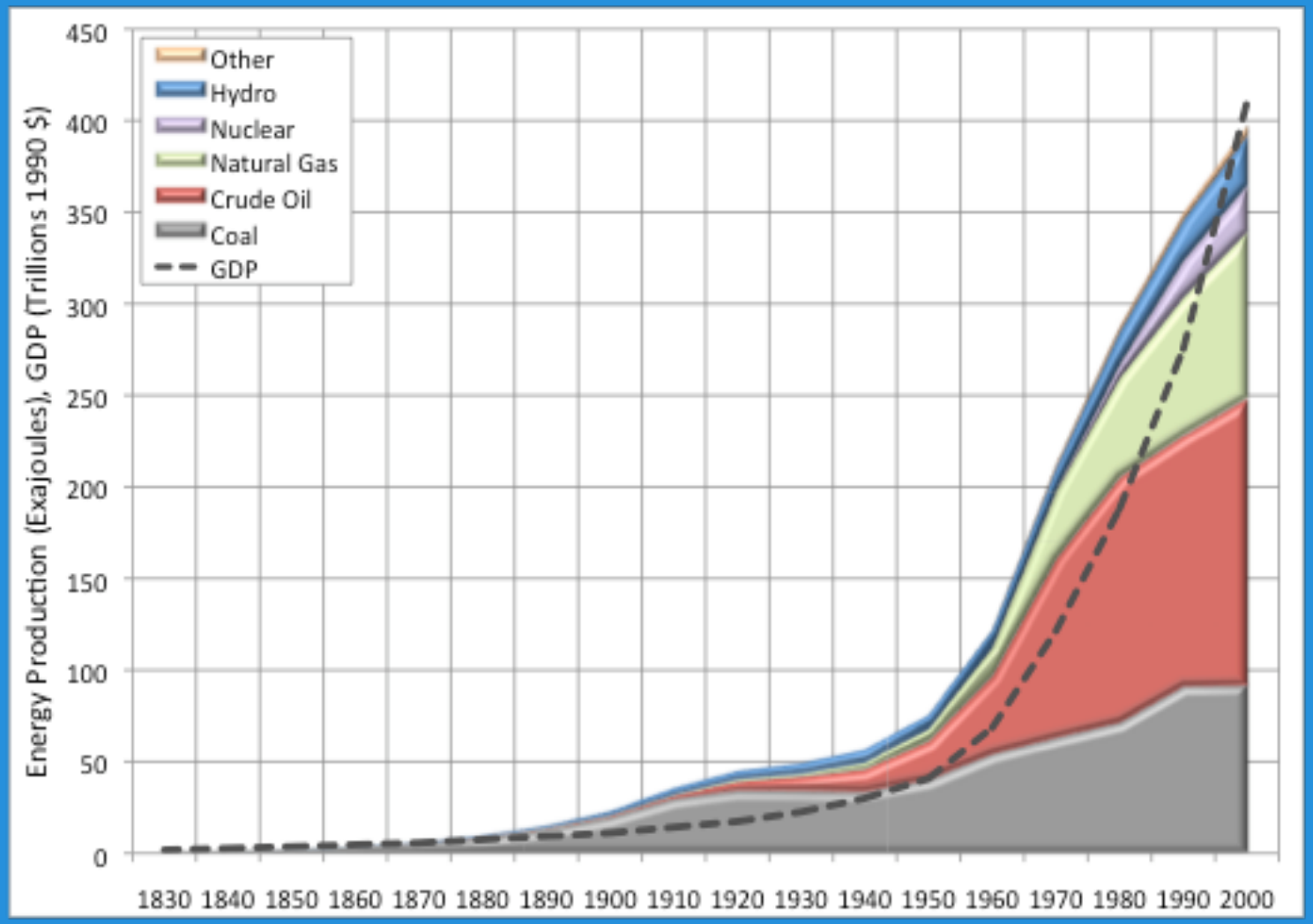
Adjusting to new energy realities in the second half of the age of oil

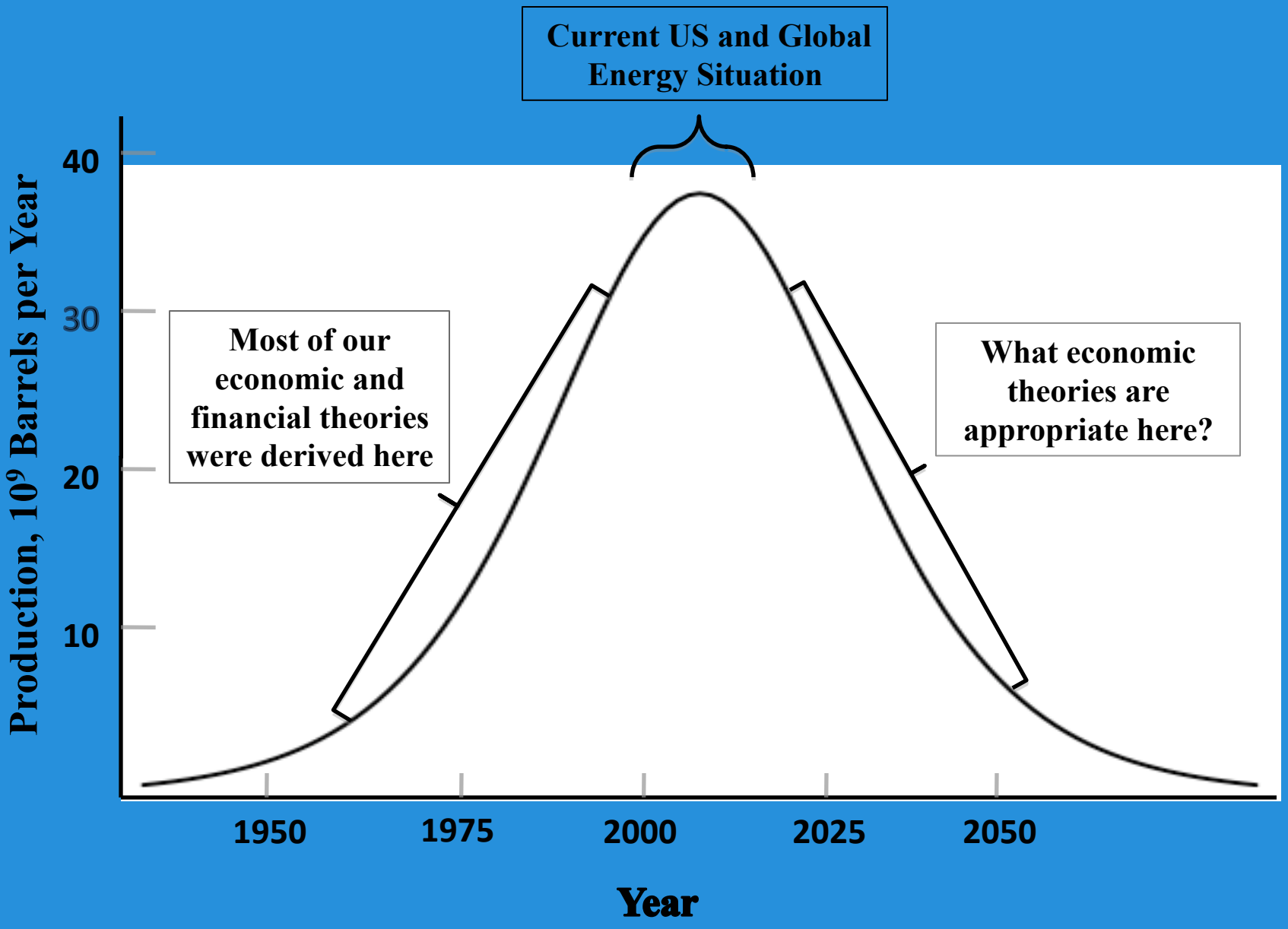
Charles Hall
David Murphy

State University of New York at Syracuse, USA

With thanks to Athena Palmer

I. Economic Production Correlates with Energy Production





C. Hall and D. Murphy

II. Stability theory:

- from General Systems Theory

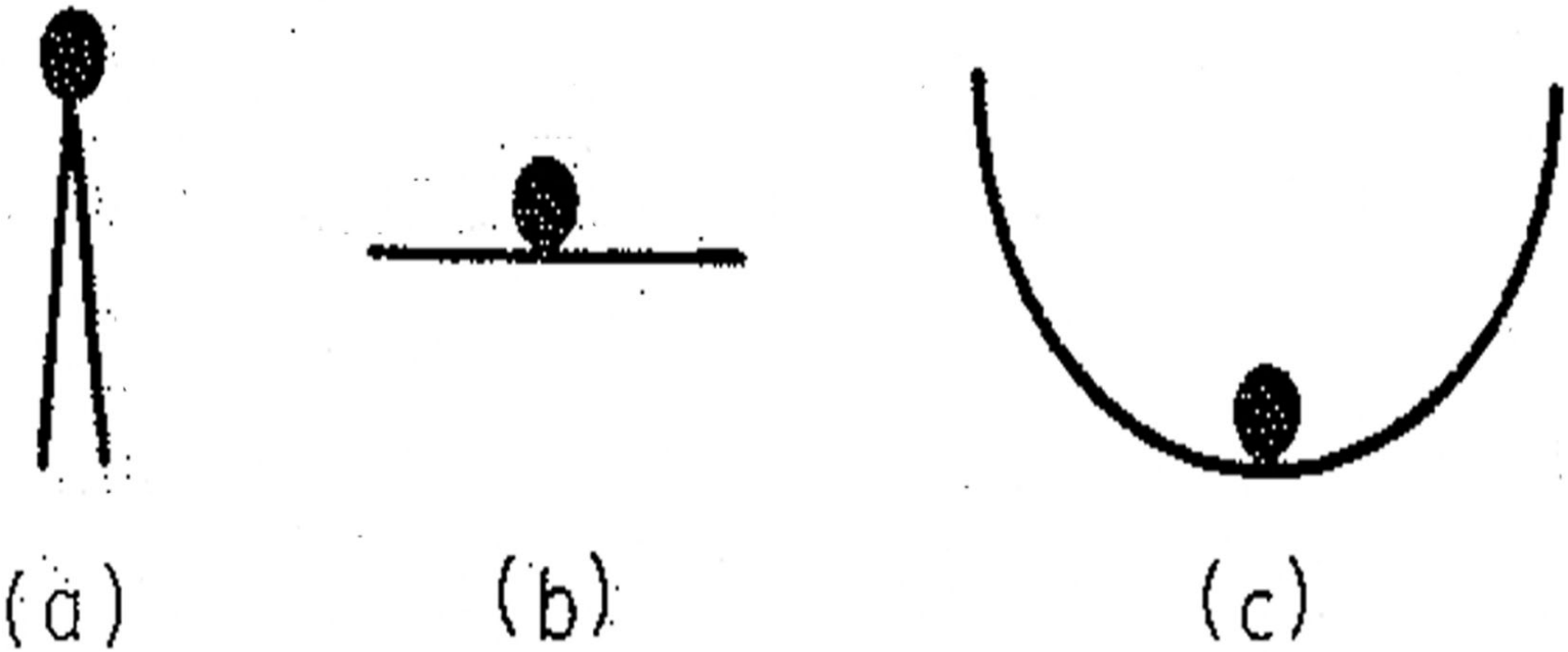


Figure 7.5. Three types of balance point.

Systems science has often been concerned with STABILITY

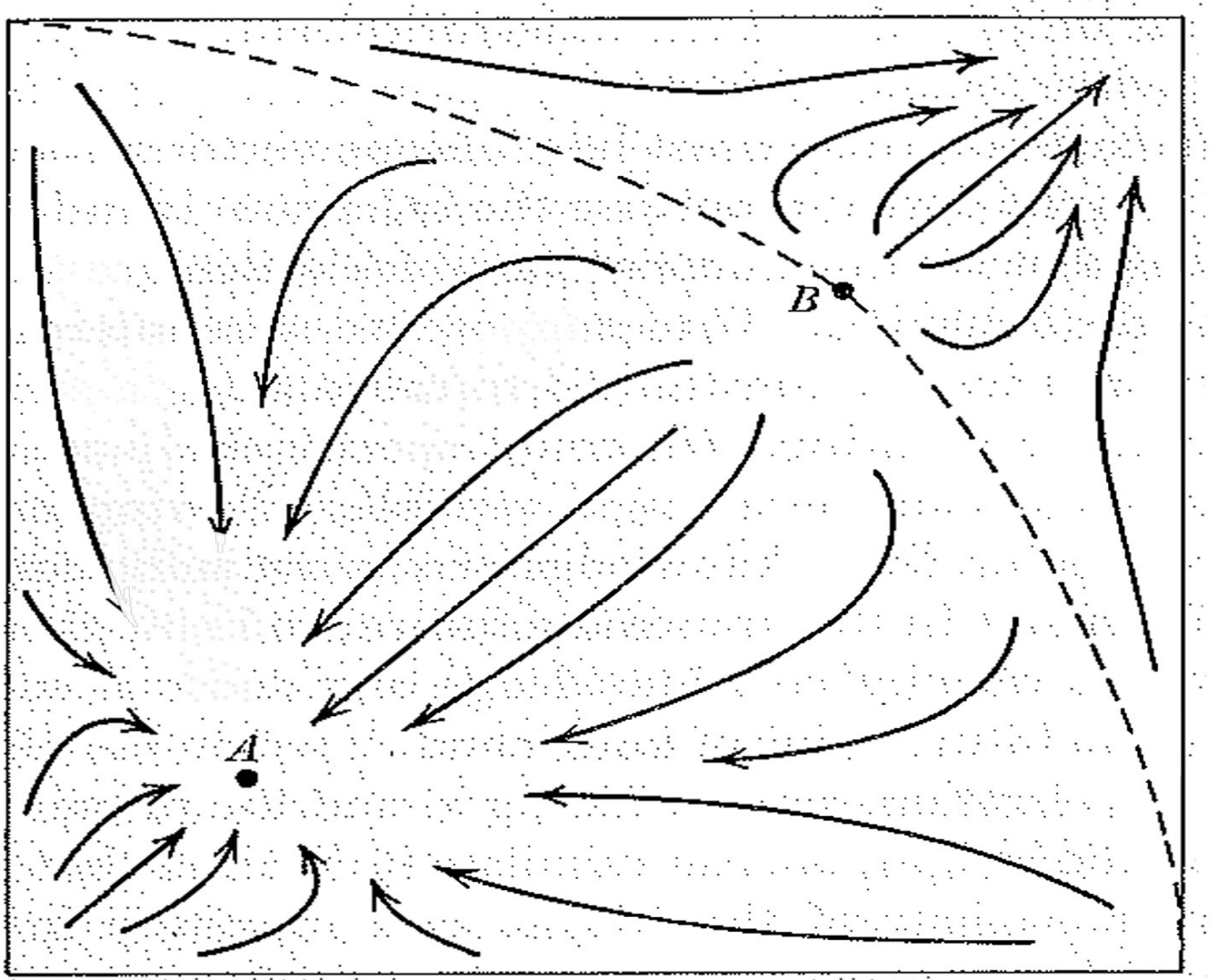
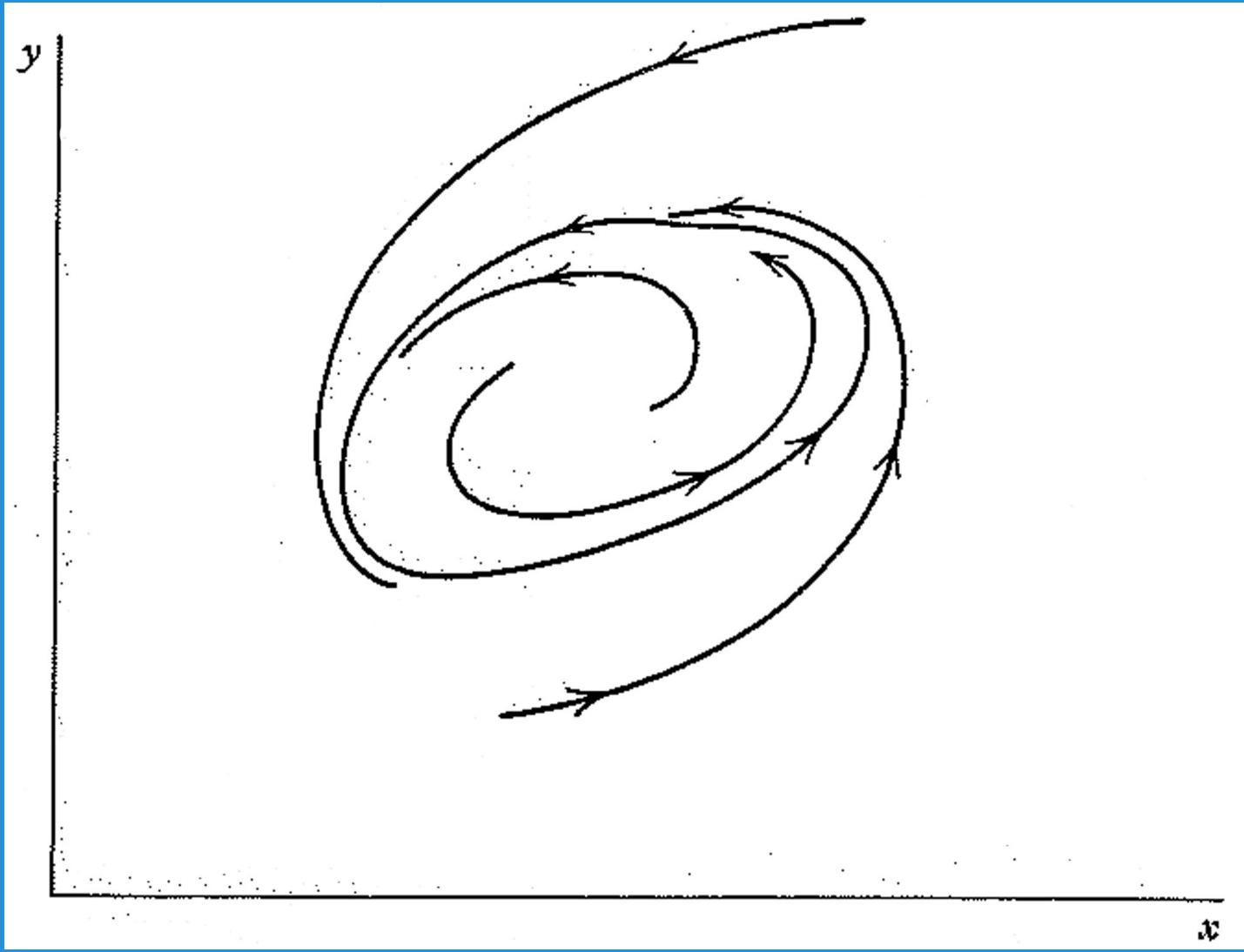


Figure 1. A system with a stable (A) and unstable (B) equilibrium point.

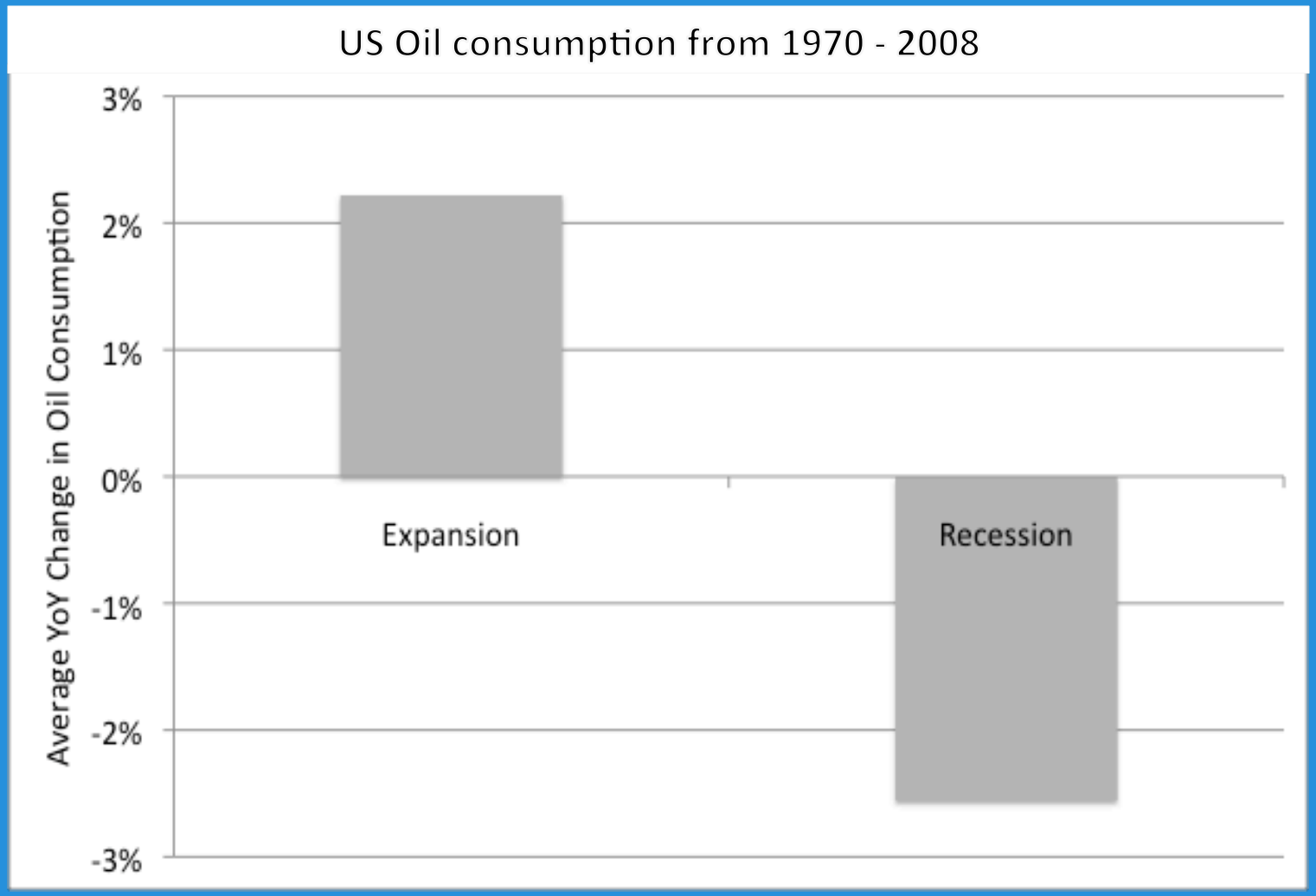


Limit Cycle Behavior

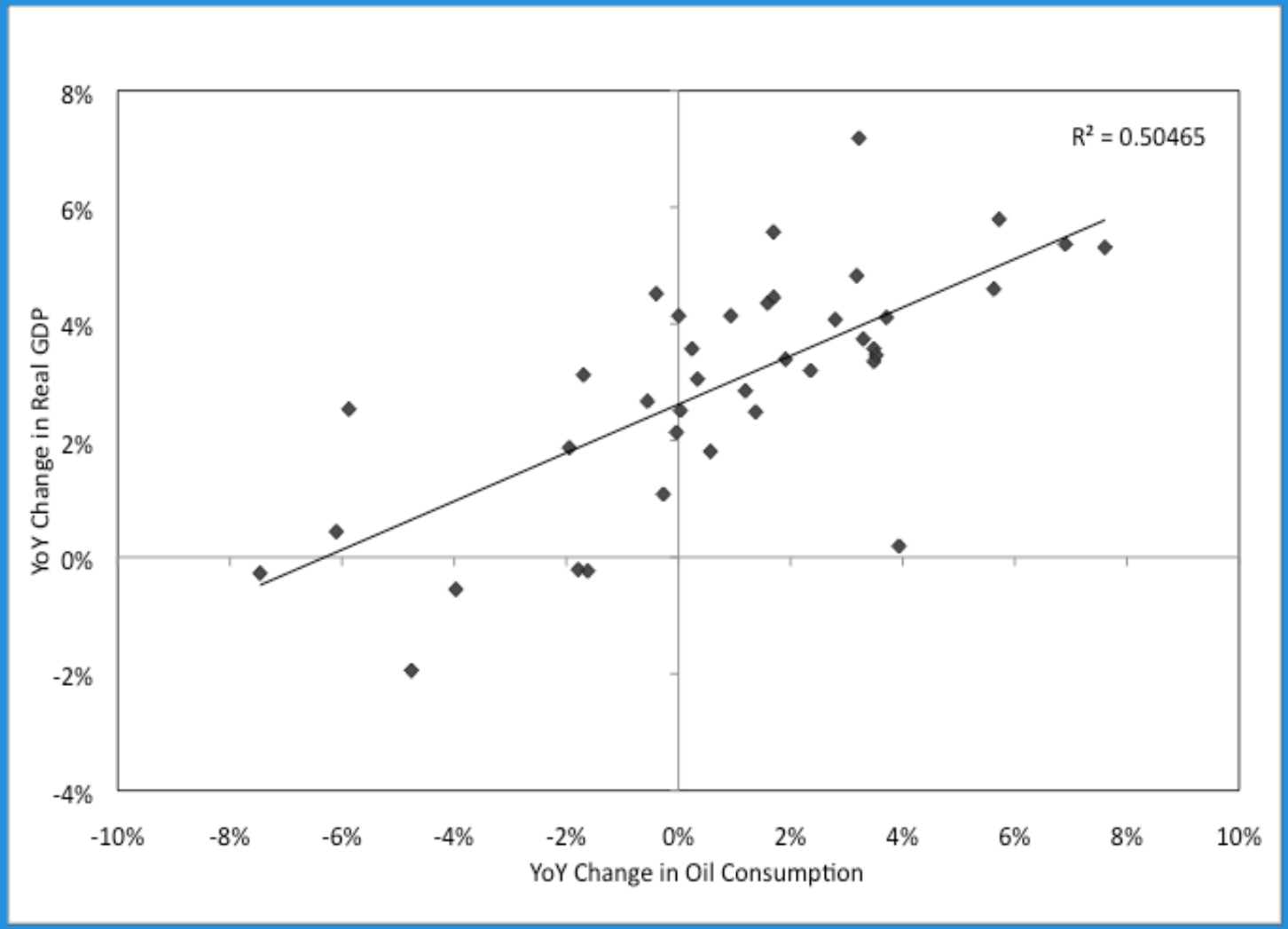
III. Does this apply to our current economic system?

- We make 8 assumptions:

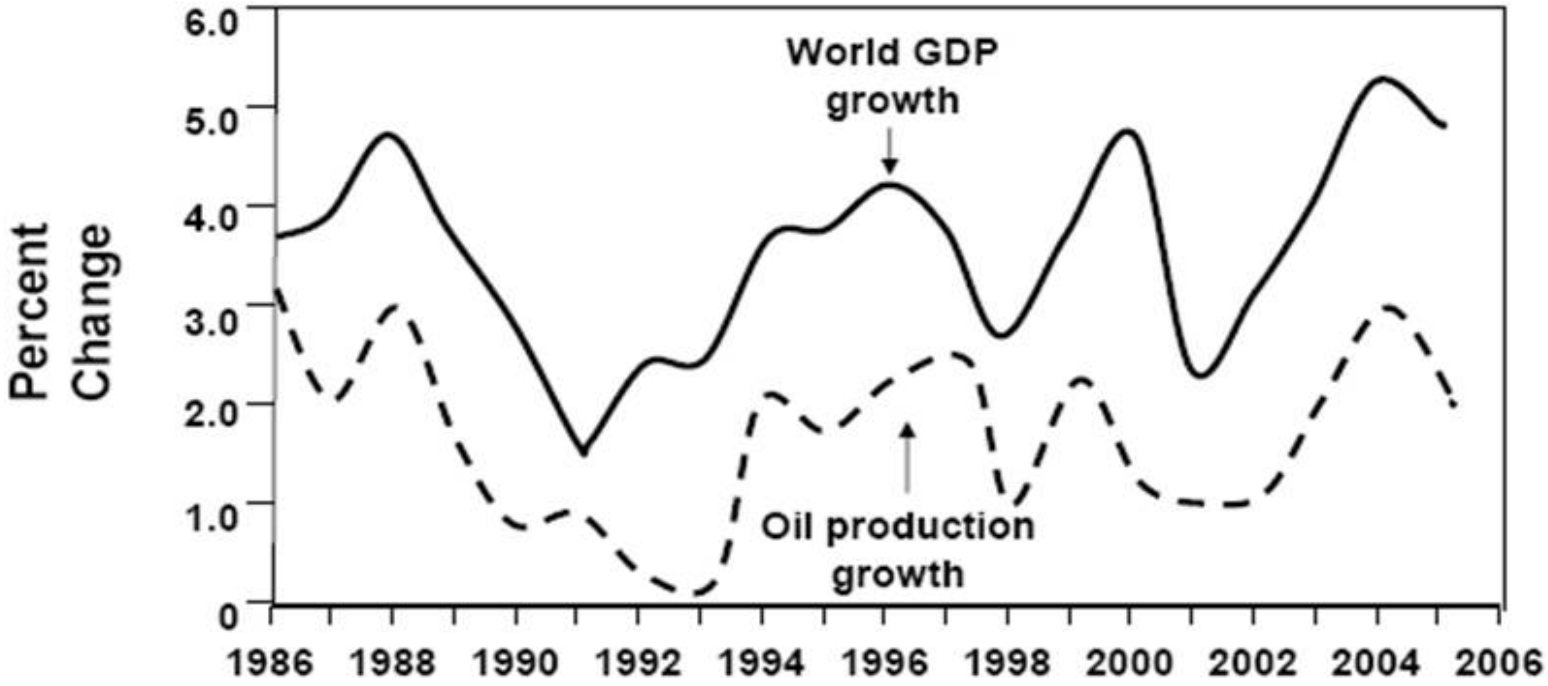
1. When oil consumption grows, so does the U.S. economy



2. 50% of the variation in GDP is explained simply by oil consumption



World GDP Growth & World Oil Production Growth Have Tracked For Decades.



For 1995-2006, Deutsche Bank calculated:

$$\frac{\%\ \text{Change in World GDP}}{\%\ \text{Change in Oil Supply}} \sim 2.5 \Rightarrow$$

Order of magnitude of 1

Is oil the chicken or the egg?

Table 1
Overview of studies on the energy-income nexus in three selected countries: India, Turkey and USA.

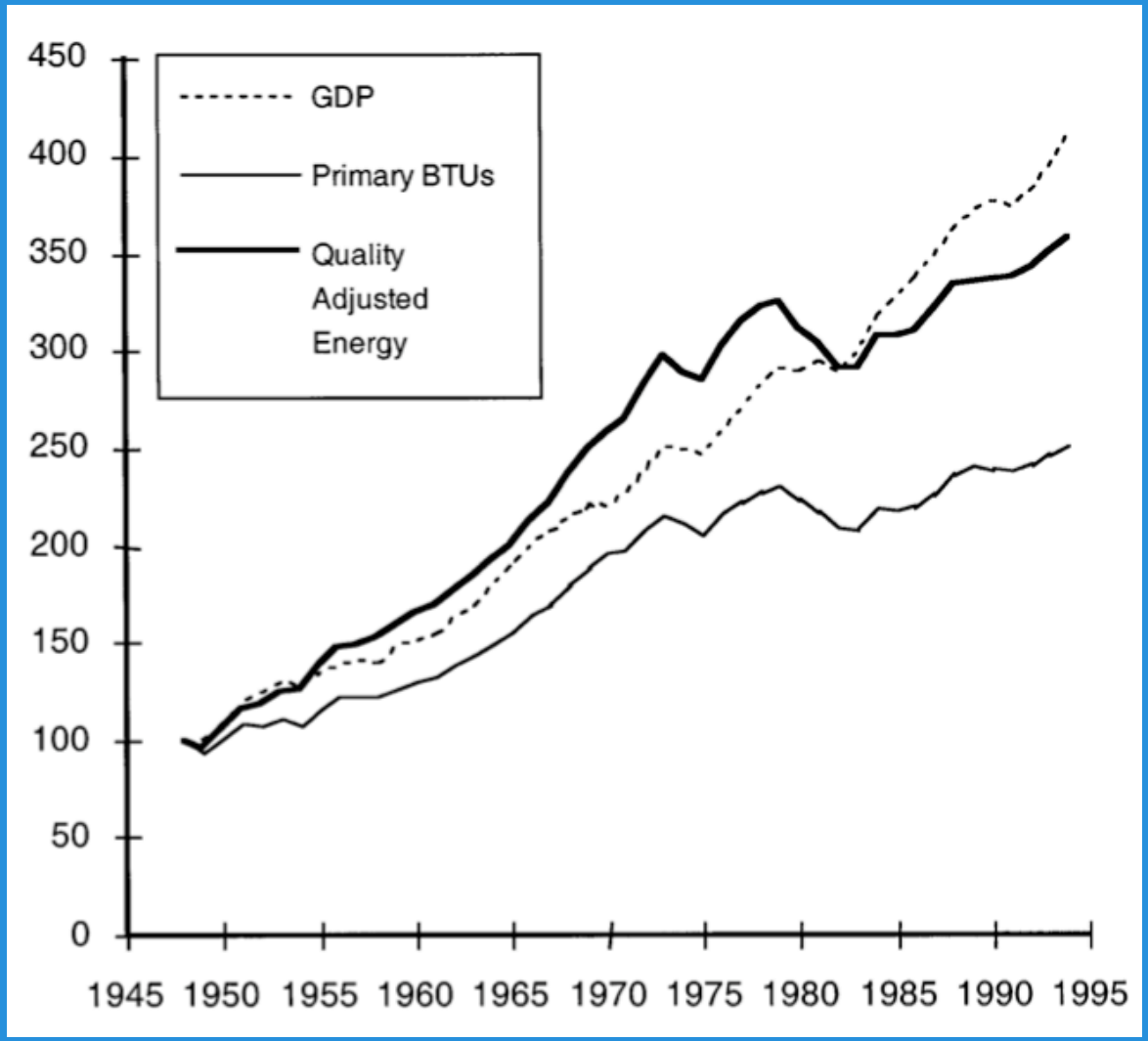
Countries	Results[a]			
	$E \rightarrow Y$	$E \leftarrow Y$	$E \leftrightarrow Y$	$E \sim Y$
India	Asafu-Adjaye (2000)	Paul and Bhattacharya (2004)	Soytas and Sari (2003)	
Turkey	Soytas and Sari (2003)	Lise and Van Montfort (2007)	Erdal et al. (2008)	Jobert and Karanfil (2007)
USA	Stern (2000)	Kraft and Kraft (1978)		Chontanawat et al. (2008)

[a] E and Y denotes energy consumption and economic growth, respectively. $\rightarrow$ and $\leftarrow$ indicate direction of the causality, while $\leftrightarrow$ means bi-directional causality and $\sim$ means no causality in any direction.

Karanfil 2009

Is oil the chicken or the egg?

4. Adjusting energy for quality differences among fuel types indicates causality running from energy consumption to GDP

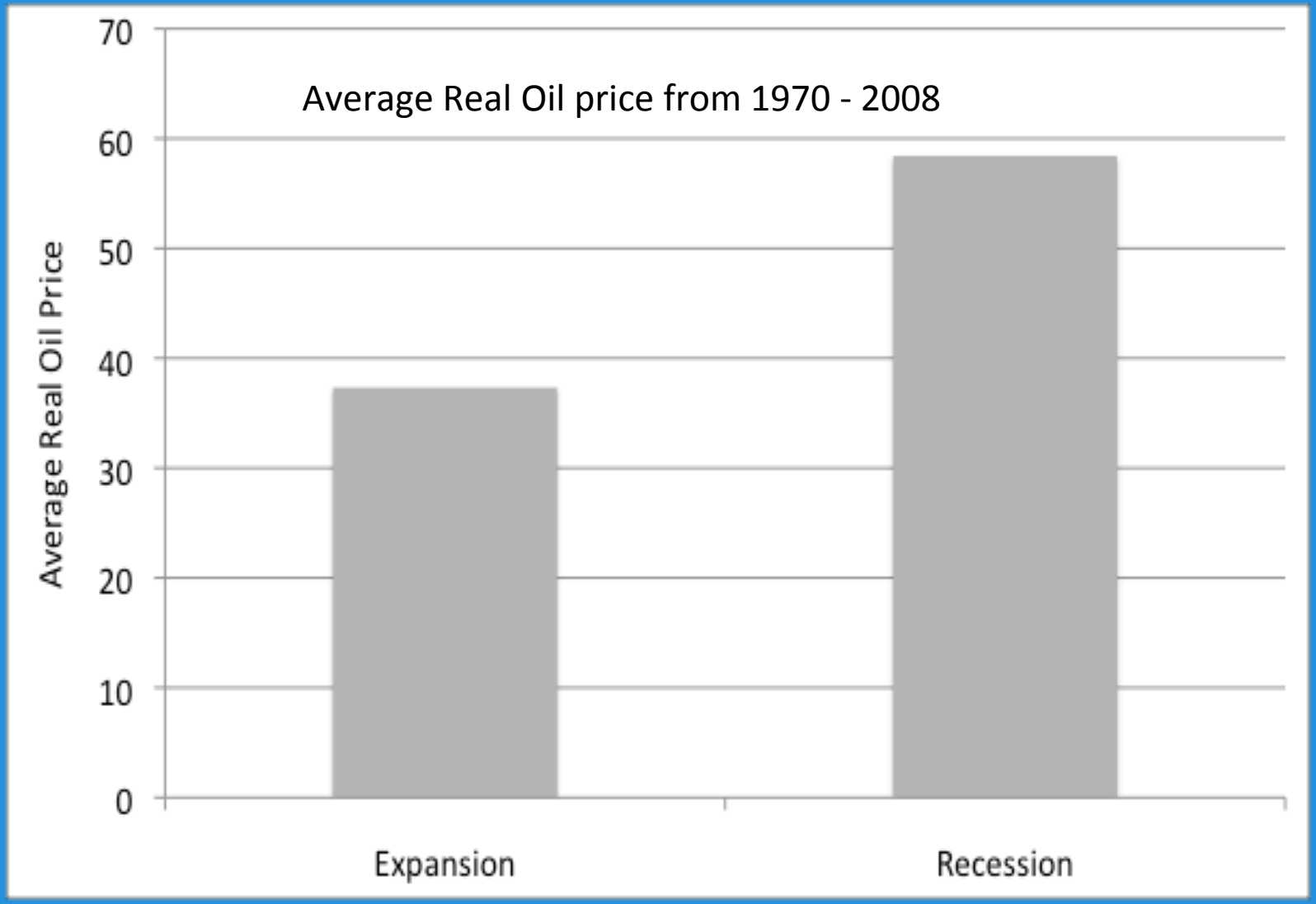


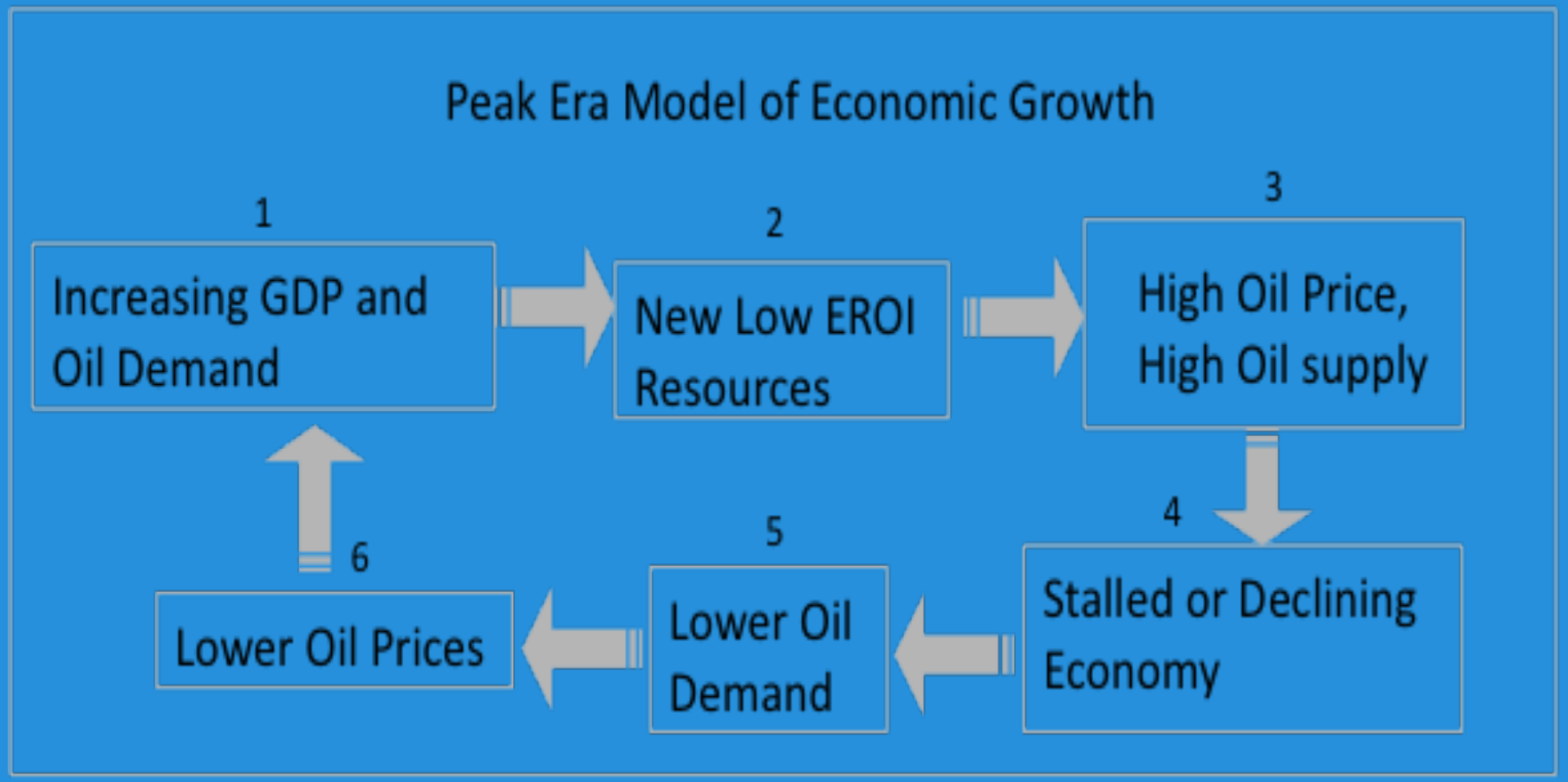
Cleveland et al. (2000)

3.But its not just energy that grows the economy

It is CHEAP energy

Oil Prices are Lower During Expansions




Peak Era Model of Economic Growth
1
Increasing GDP and Oil Demand
2
New Low EROI Resources
3
High Oil Price, High Oil supply
4
Stalled or Declining Economy
5
Lower Oil Demand
6
Lower Oil Prices

4. Every recession since 1970 has been preceded by a spike in the price of oil

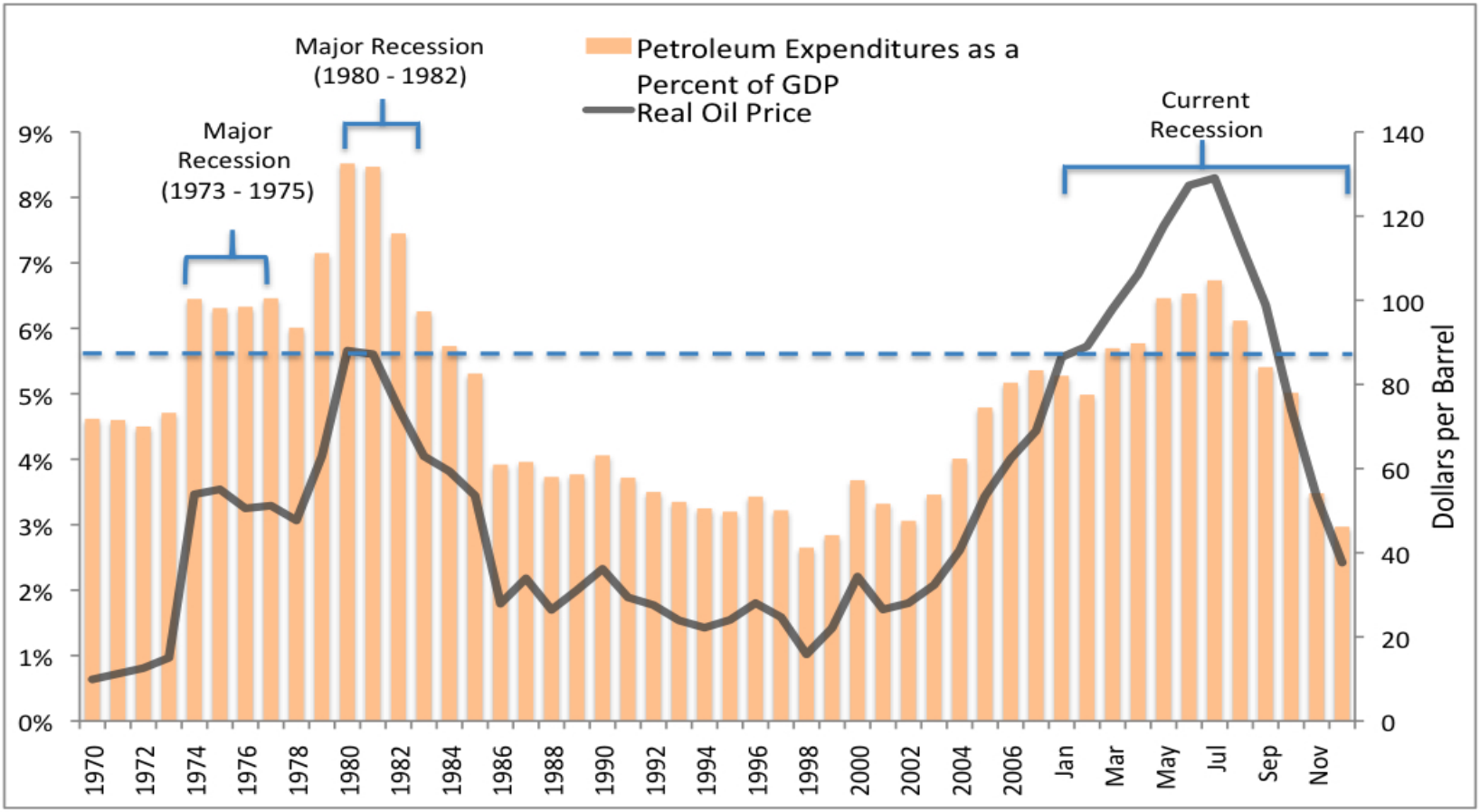
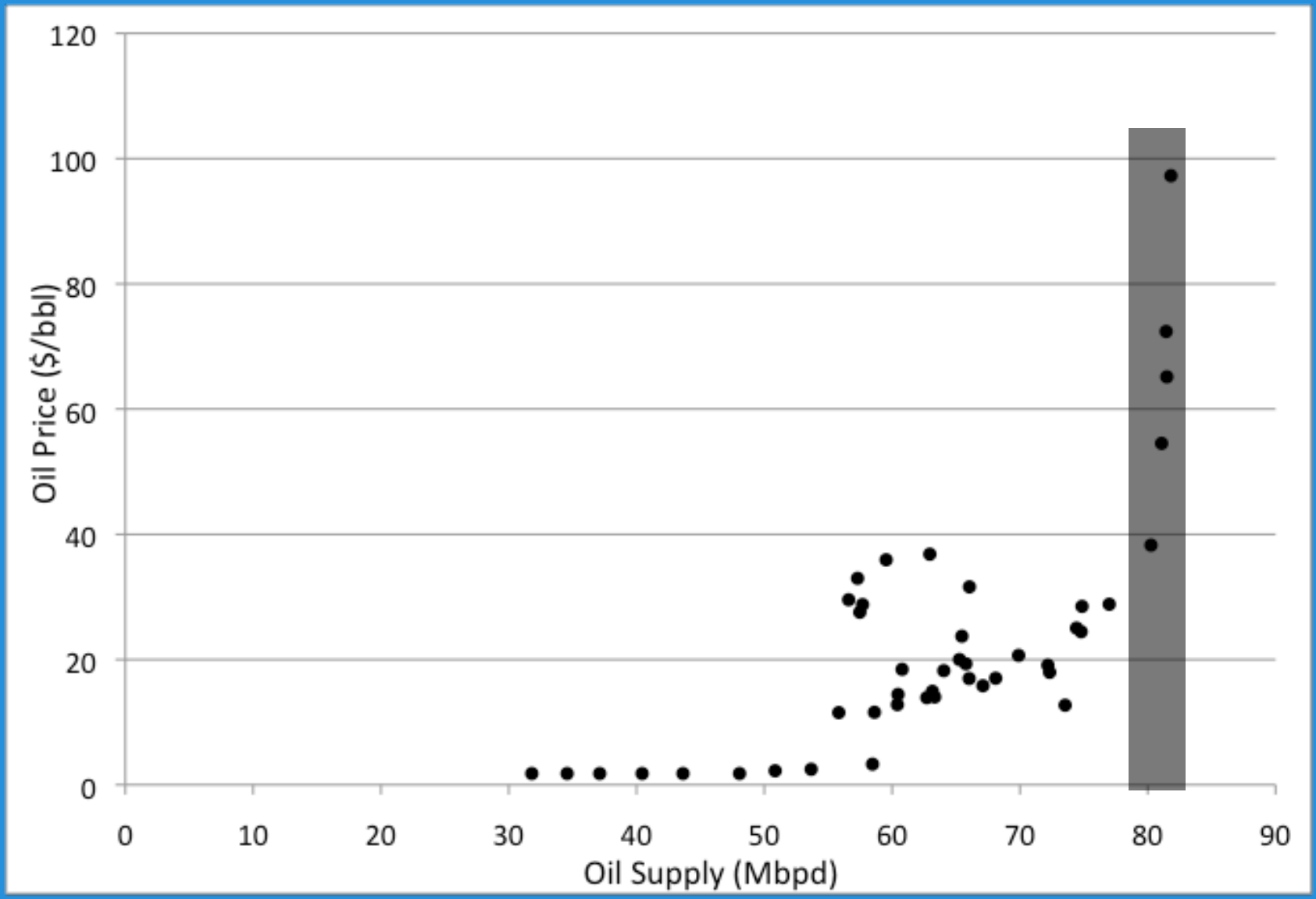
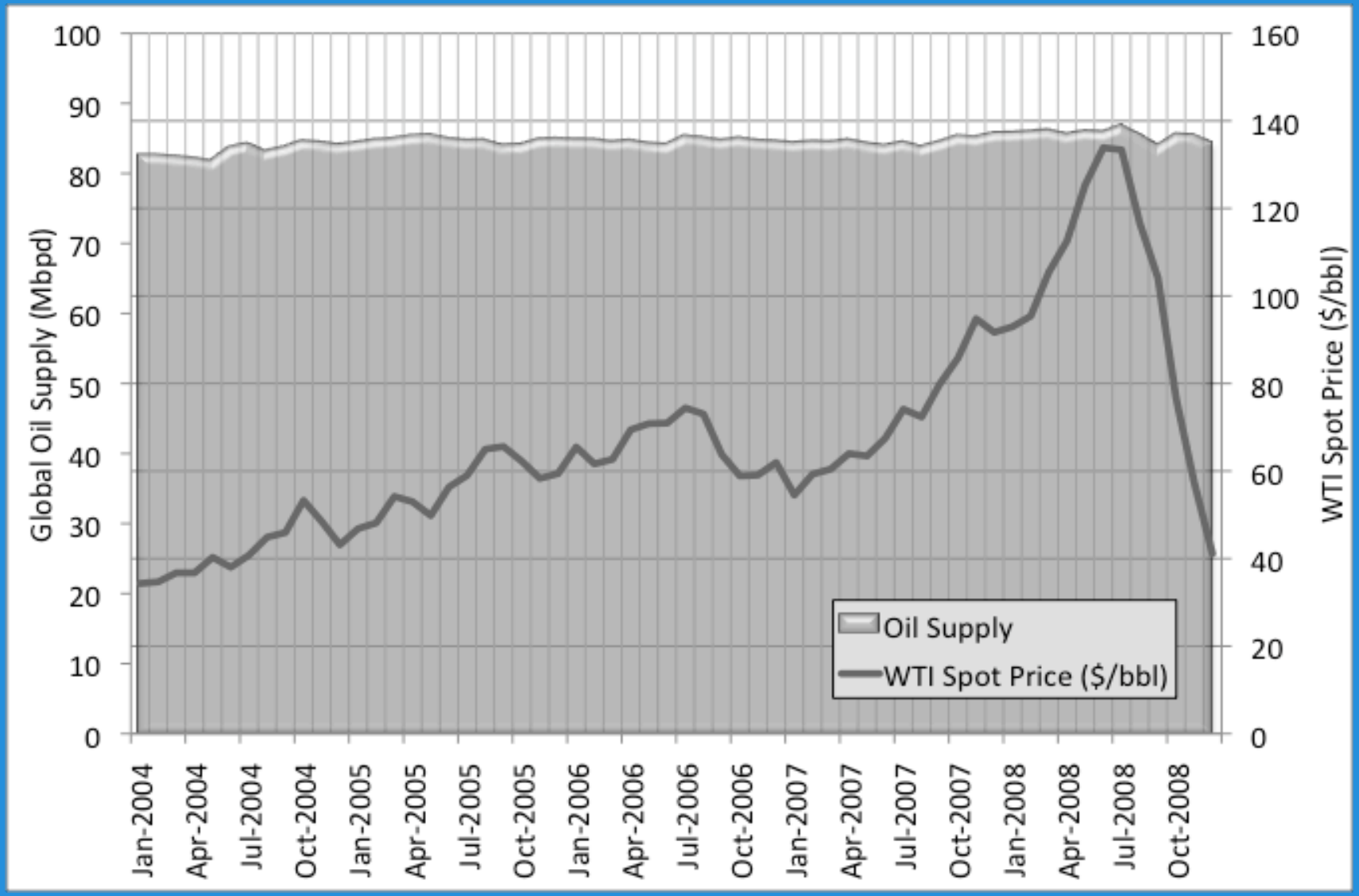


Figure 1. Petroleum expenditures as a percent of GDP in the U.S. and real oil price.

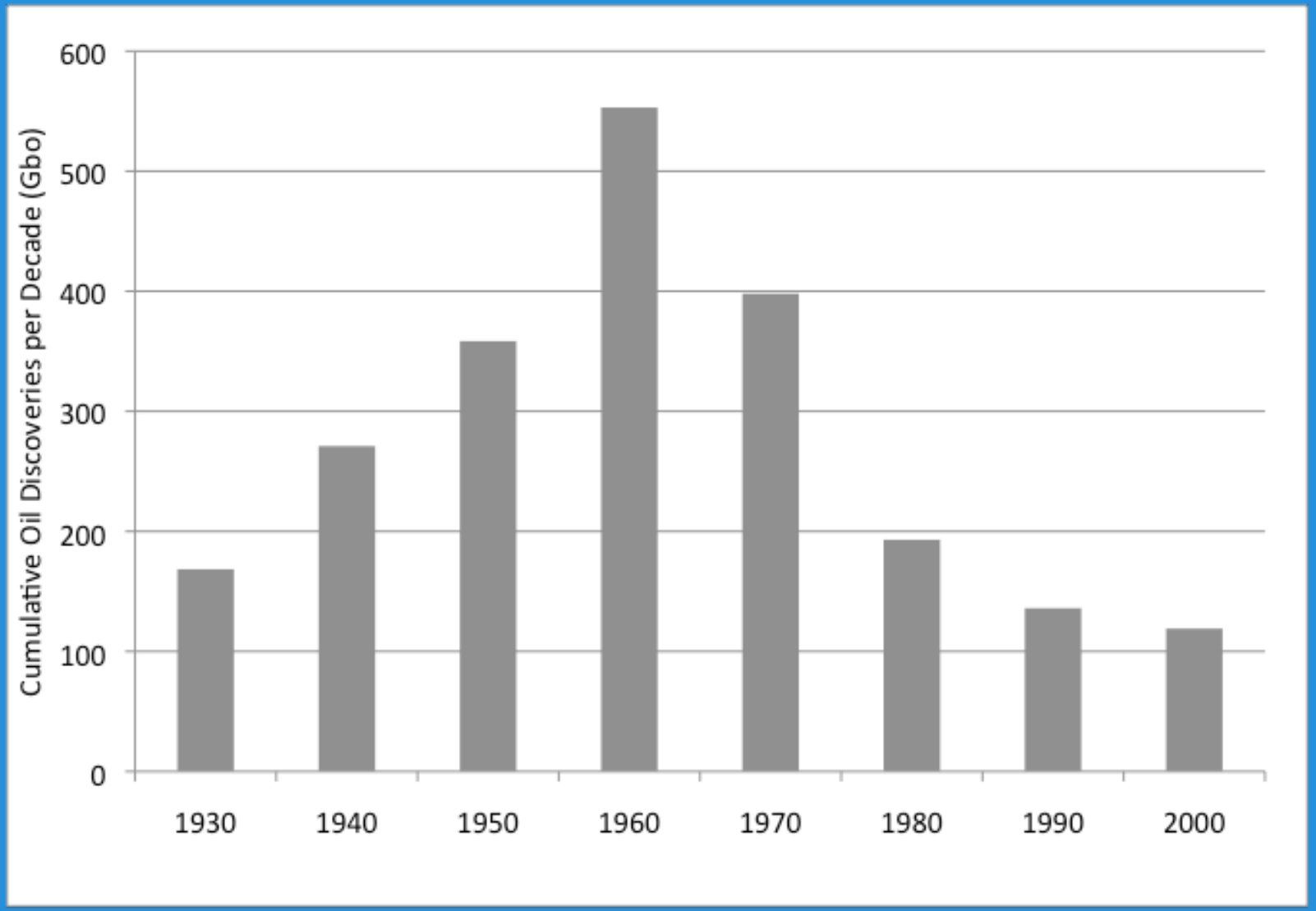
5. Supply Curve



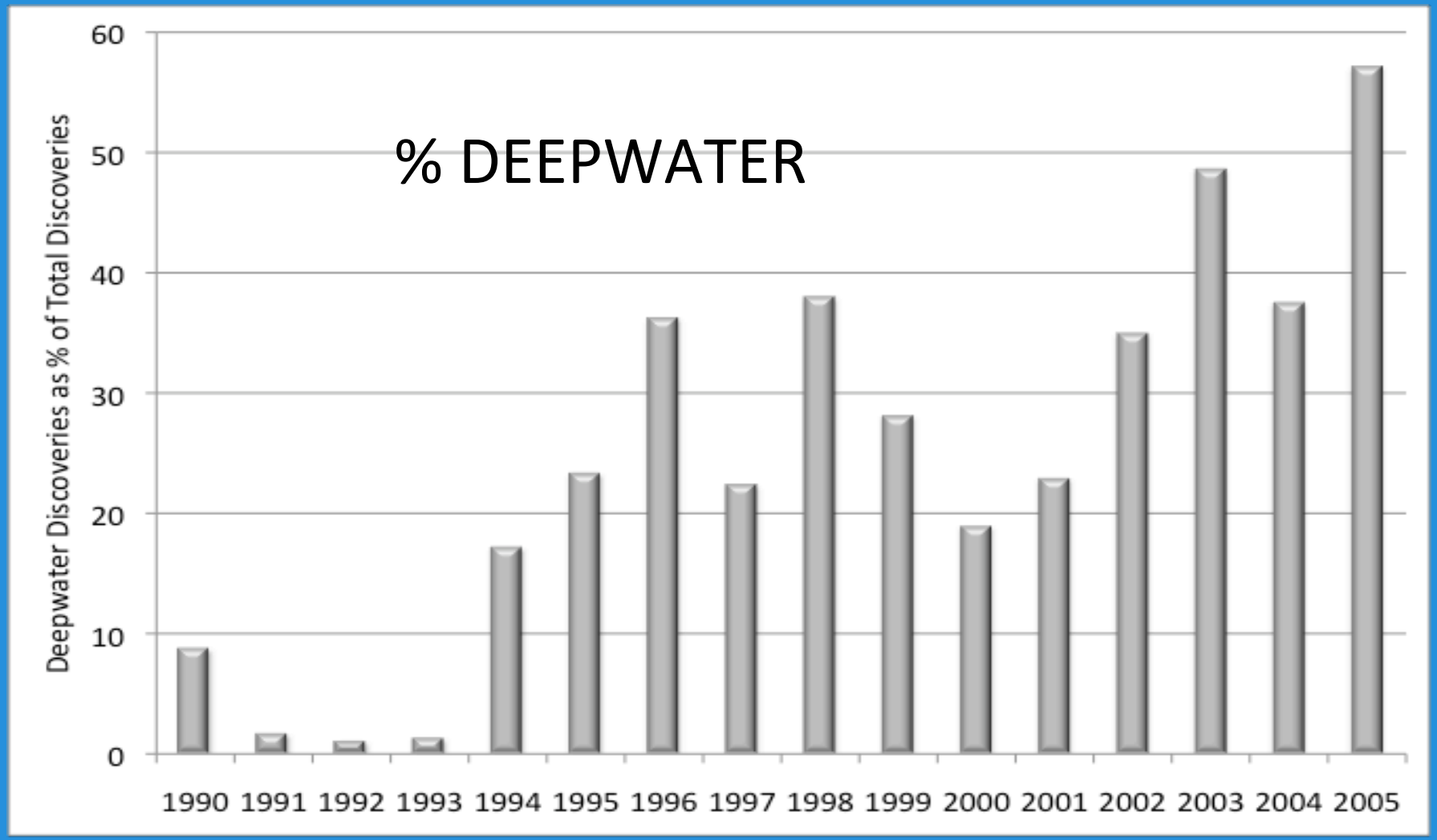
6. Supply didn't increase with Price



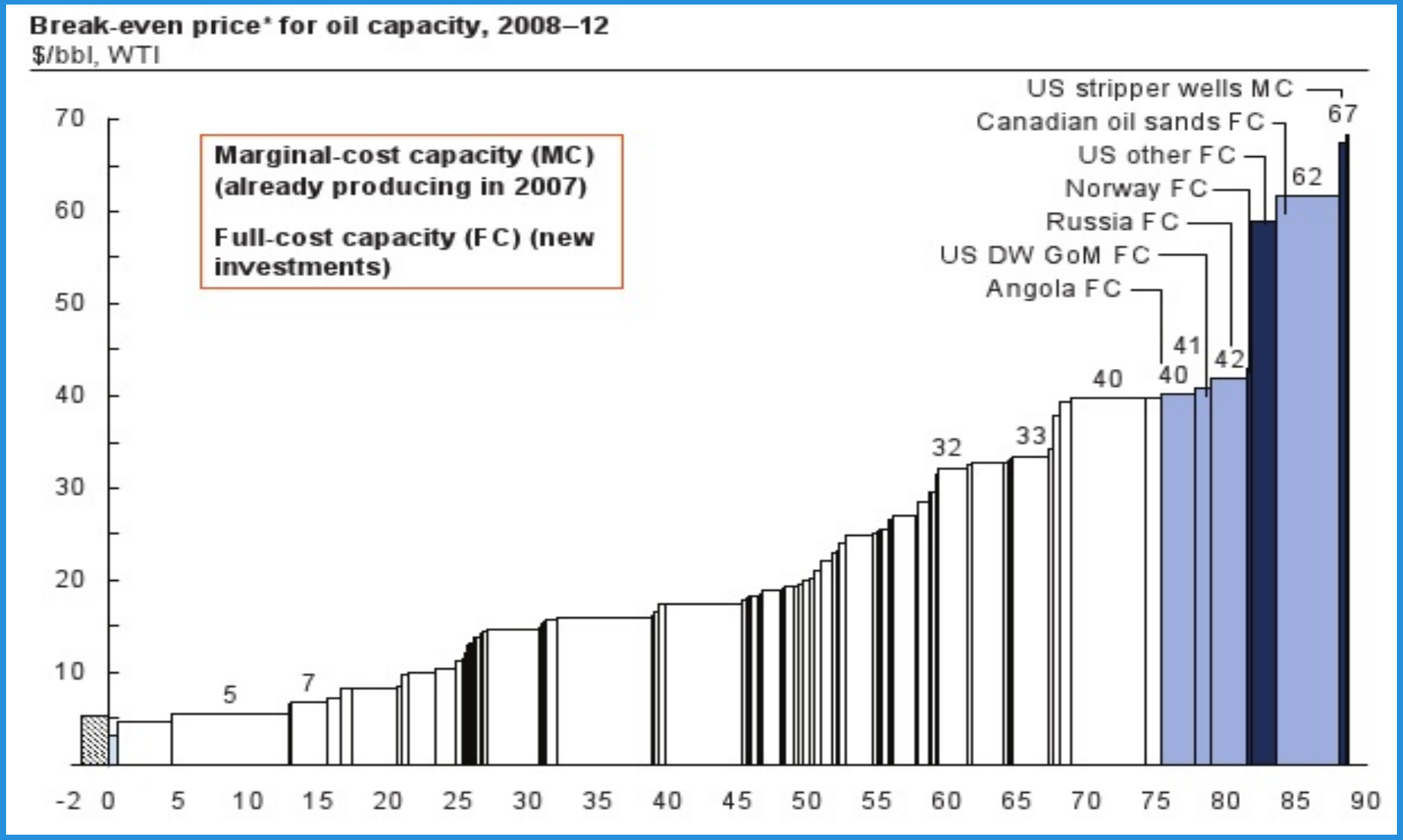
7. We are finding less oil globally



8. The oil we do find is in hard to reach places (i.e. expensive)

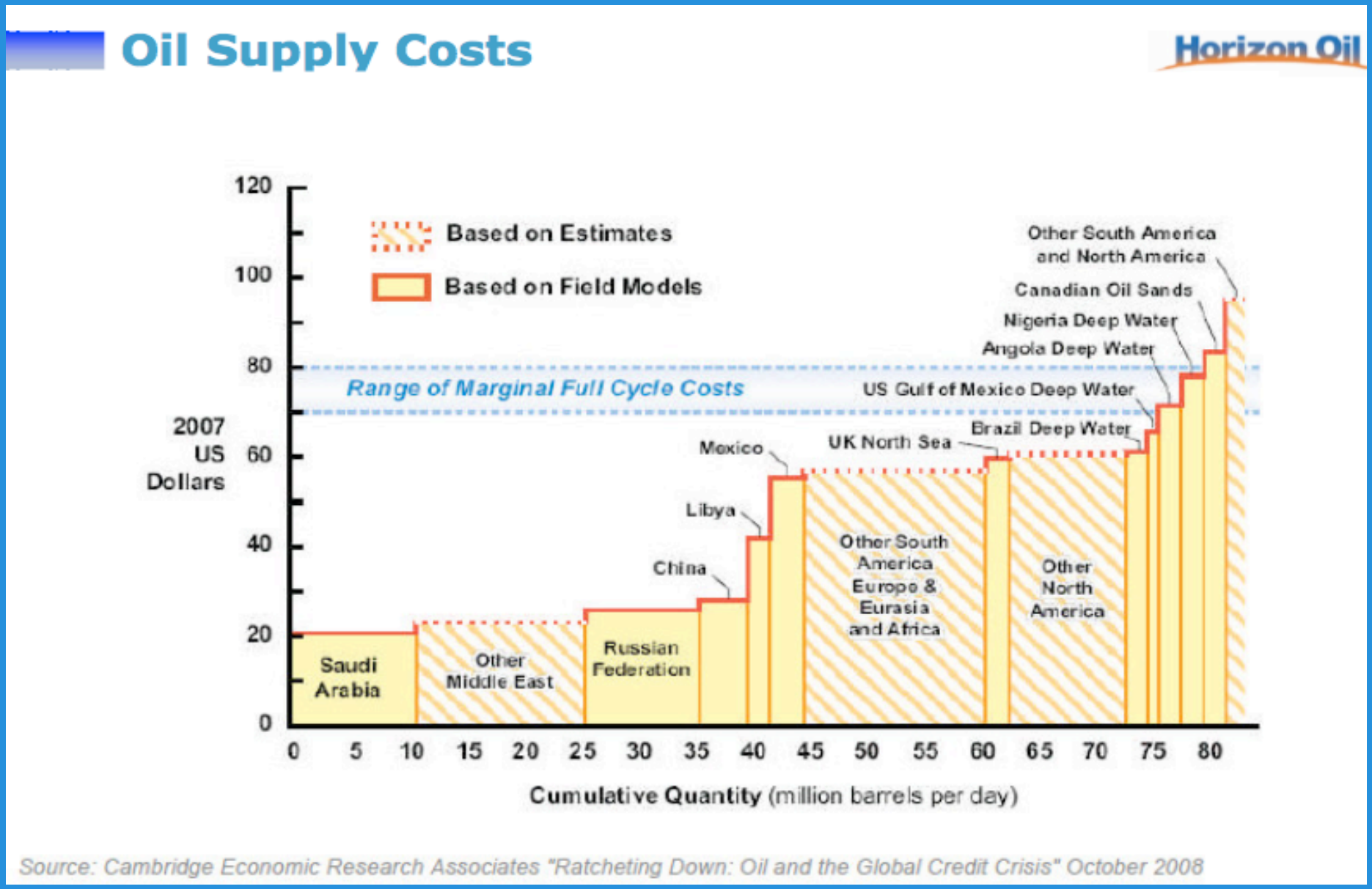


Break-Even Cost

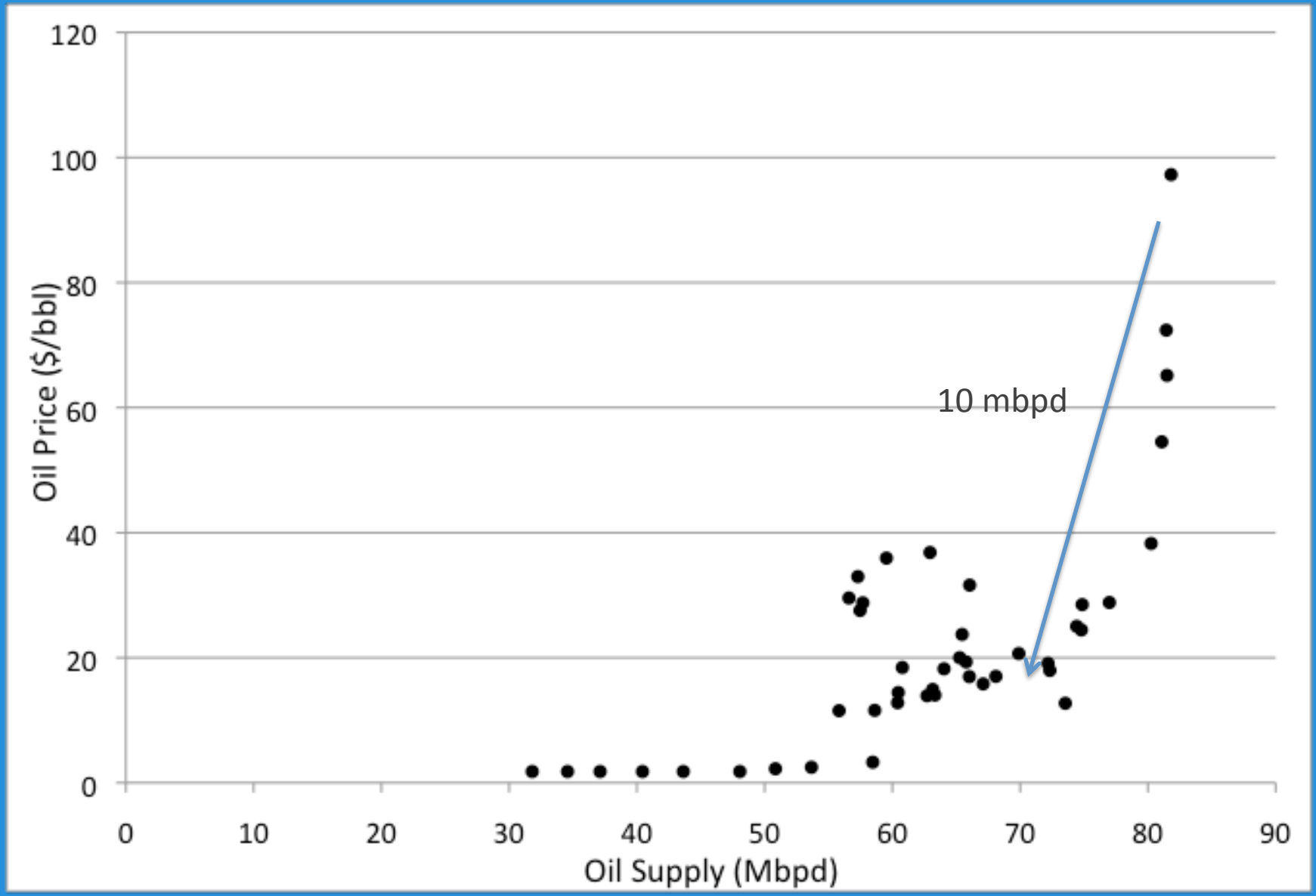


McKinsey GEM, 2010 using IEA, Wood Mackenzie, Interstate Oil and Gas Compact Commission

Where are we finding oil?

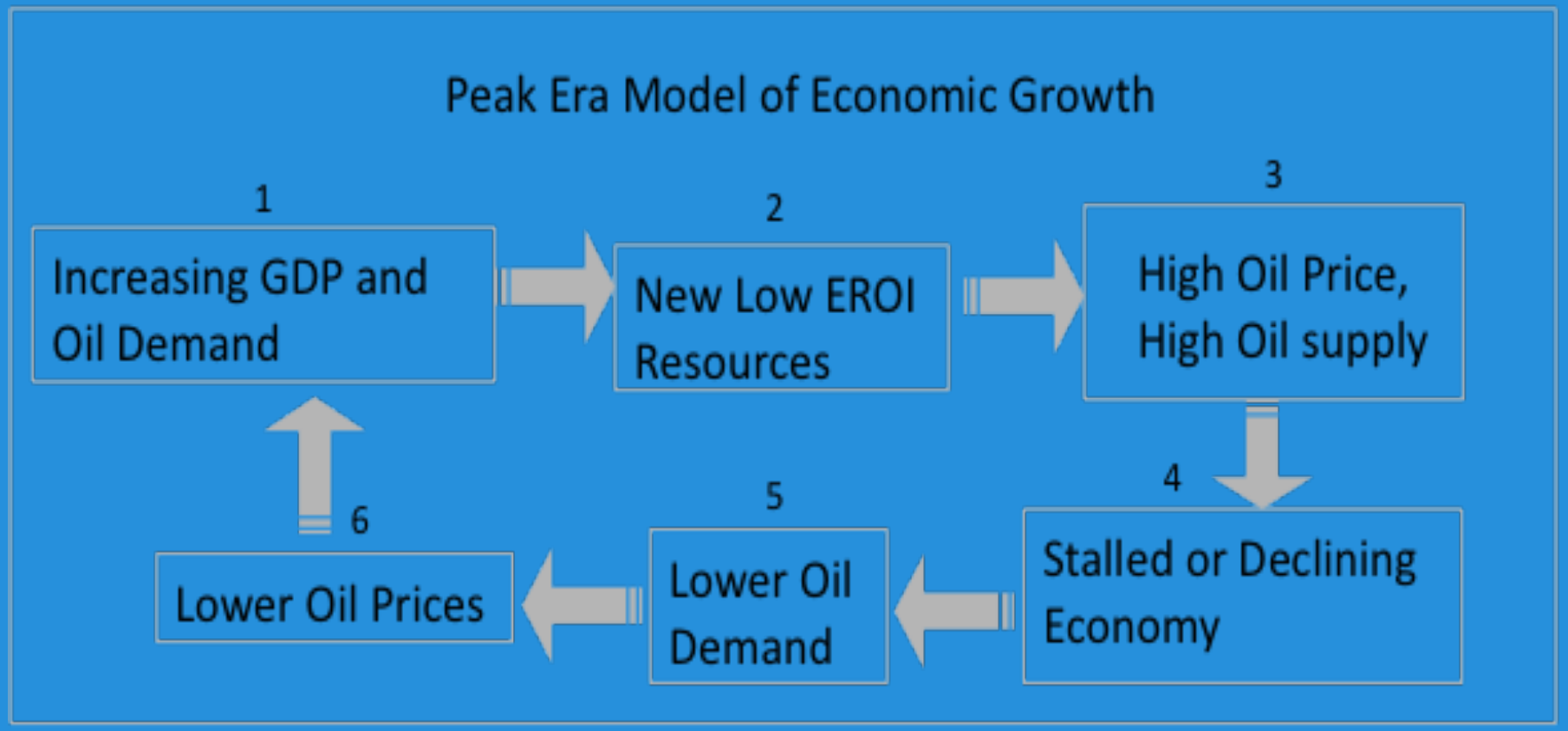


Source: Cambridge Economic Research Associates "Ratcheting Down: Oil and the Global Credit Crisis" October 2008


120
100
80
60
40
20
0
Oil Price ($/bbl)
0
10
20
30
40
50
60
70
80
90
Oil Supply (Mbpd)
10 mbpd

Summary of the Facts

- Inexpensive energy has been used to provide steady economic growth in the recent past
- We are finding less oil, and the oil we do find is expensive, creating a volatile price situation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IV. NOW WE INTRODUCE :

Economic impact of EROI

I. DEFINITION of EROI (Sometimes EROEI)

Energy return on investment for an activity:

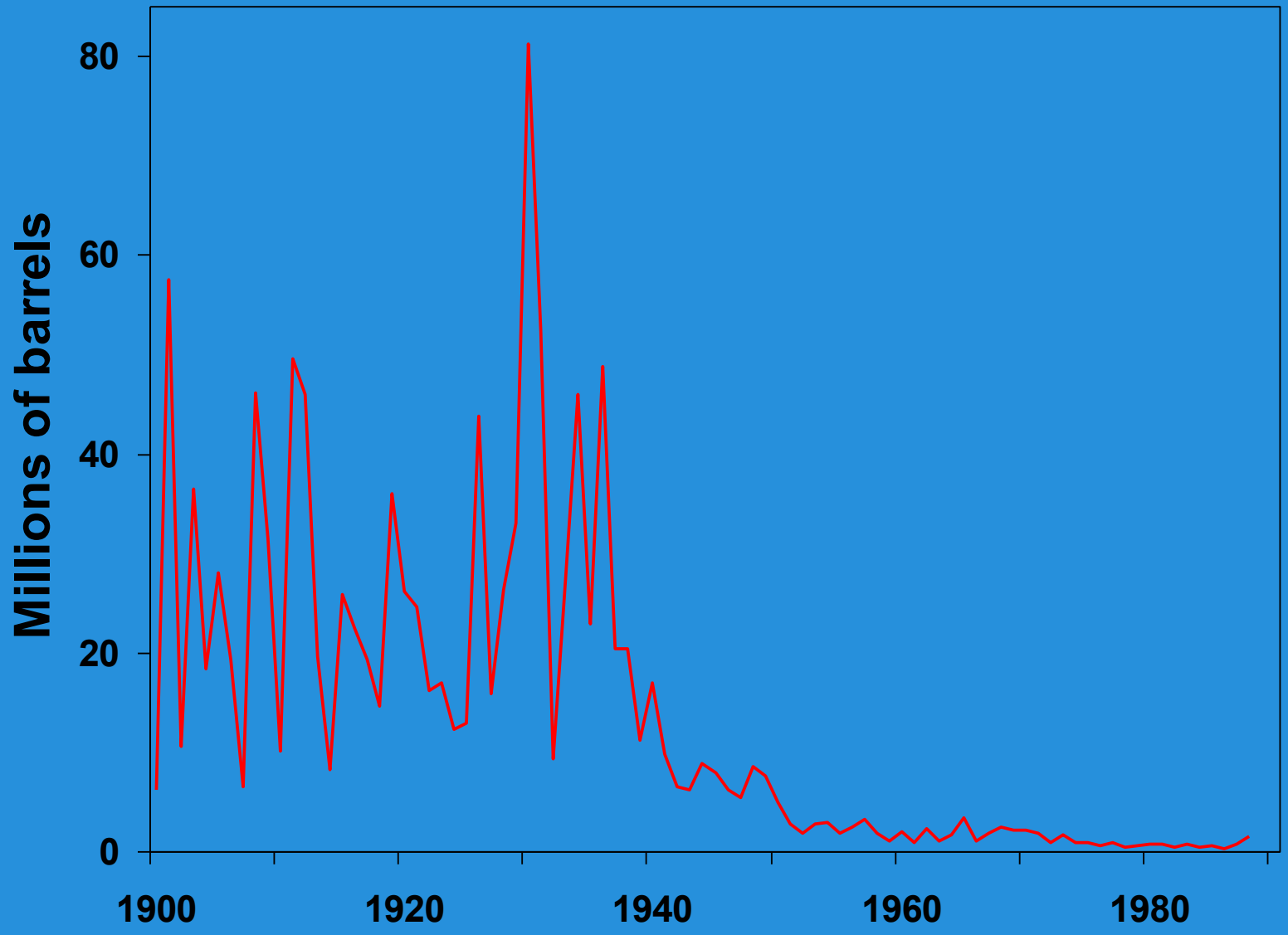
$$\text{EROI} = \frac{\text{Energy delivered to society}}{\text{Energy put into that activity}}$$

Usually consider energy invested *from society*

Best First Principle

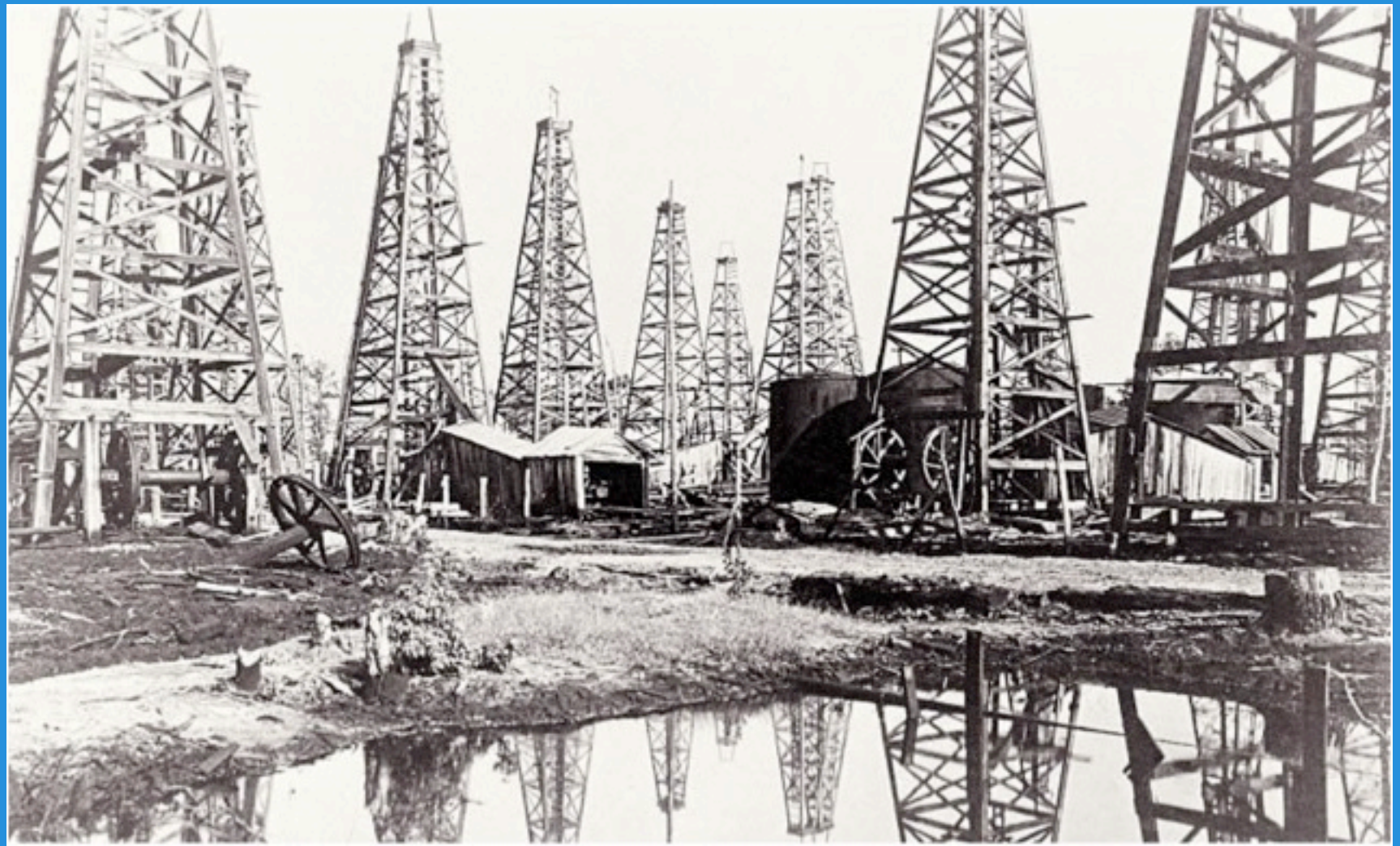
- Humans use high quality, low cost resources before low quality, high cost resources
- Best-to-worst ordering of resource exploitation

US Oil Field Size



High EROI = High Quality

East Texas Oil Field, EROI > 100:1 ??



Low EROI = Low Quality

Reprint Series
6 February 1981, Volume 211, pp. 576–579

SCIENCE

Petroleum Drilling and Production in the United States: Yield per Effort and Net Energy Analysis

Abstract. *For the past three decades the quantity of petroleum (both oil and oil plus gas) found per foot of drilling effort in the United States for any given year can be expressed as a secular decrease of about 2 percent per year combined with an inverse function of drilling effort for that year. Extrapolation of energy costs and gains from petroleum drilling and extraction indicates that drilling for domestic petroleum could cease to be a net source of energy by about 2004 at low drilling rates and by 2000 or sooner at high drilling rates, and that the net yield will be less at higher drilling rates.*

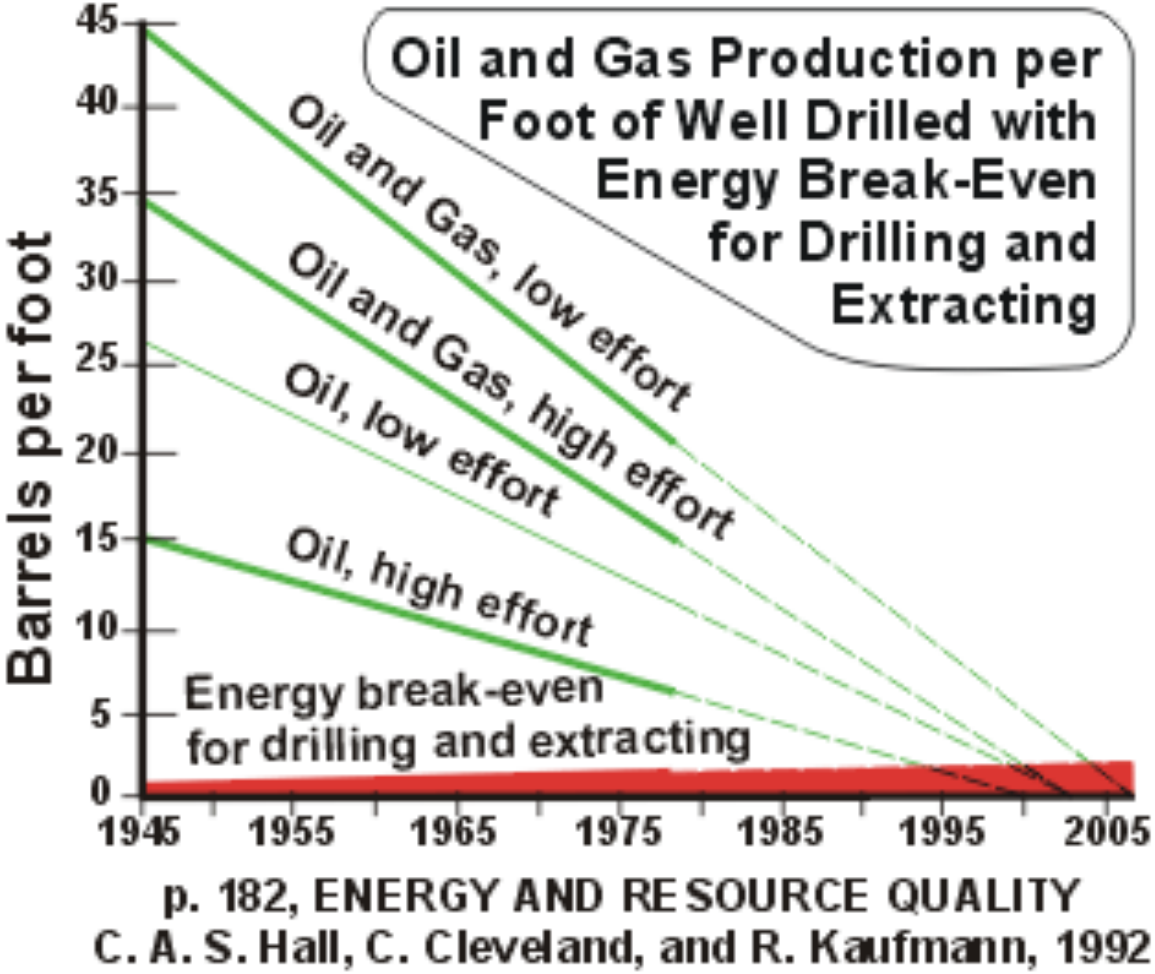
Production and reserves of U.S. liquid and gaseous petroleum peaked in the early 1970's and generally have declined since then despite considerable increases in drilling effort. Continued increases in effort are likely in the near future because imports carry a heavy economic and political price and because recent increases in oil prices have given petroleum corporations considerable quantities of new working capital. But the Carter Administration and Congress have imposed a large "windfall profits tax" on petroleum corporations, which will decrease the capital available for additional exploratory effort. On the other hand, oil industry advertisements and some politicians have promised large new exploratory efforts and oil supplies if government decreases regulation and

0036-8075/81/0206-0576$00.75/0

Hall and Cleveland 1981

We applied Yield per Effort concepts from fisheries to oil .....

For the past three years the expenditures to look for oil have been greater than the dollar returns!



p. 182, ENERGY AND RESOURCE QUALITY
C. A. S. Hall, C. Cleveland, and R. Kaufmann, 1992

NY Times Oct 10, 04

Hall & Cleveland 1981
Science

THE WALL STREET JOURNAL.

EASTERN EDITION TUESDAY, FEBRUARY 3, 1981 PRINCETON, NEW JERSEY

Increased oil drilling may not be in the national interest, a new study by two Cornell University scientists says. It predicts that industry soon may be using more energy drilling for oil than it is finding.

(Story on Page 16)

Increased Drilling for Oil May Consume More Energy Than It Gleans, Study Finds

By JERRY E. BISHOP
Staff Reporter of THE WALL STREET JOURNAL

The faster the oil industry drills for new oil in the U.S. the sooner it becomes a losing energy proposition.

That's the conclusion of a new study by two Cornell University scientists. The study appeared in a scientific journal only a few days after President Reagan decontrolled domestic oil prices to stimulate exploration for new oil supplies in the continental U.S.

Unless the oil industry finds a superior way to look for new oil pools, drilling soon will consume more energy than it unearths, the study found. The day soon will come, the researchers explained, when "the energy cost of obtaining a barrel of oil is the same as the energy in that barrel."

This break-even day of reckoning won't come for about 20 years if the industry holds drilling to its 1978 rate, the study predicted. But if that rate continues to increase, "the break-even point for oil could occur in the mid-1980s," the researchers said.

"The result of our analysis indicates that the current trend of increasing conventional exploration effort by the oil industry may not be in the best interest of the nation as a whole," Charles A.S. Hall and Cutler J. Cleveland of Cornell's section on ecology and systematics asserted in their study, published in this week's issue of the magazine Science.

The main reason is that the oil industry is becoming less energy-efficient at finding oil, they explained.

Oil observers generally reject this theory of inefficiency, although industry studies have previously demonstrated that oilmen have been finding less oil per foot drilled in recent years. Oil observers maintain that there are a number of factors that could reverse the discovery trend. They cite continuing technological improvements in the search for oil and gas, such as new direct hydrocarbon techniques. Also, industry sources say, there probably are big new oil and gas fields still to be found in the U.S. by new spurts in drilling resulting from rising prices for the fuels.

Statistical Correlation

The Cornell scientists' study statistically correlated the industry's yearly volume of drilling for exploration and development and the amount of oil found. That correlation doesn't show what is commonly assumed, however.

The team found that the amount of oil and gas (measured in equivalents of barrels of oil) discovered per foot of well drilled is dropping precipitously. They cited studies more than a decade ago by M. King Hubbert, an oil exploration consultant to both the industry and the government, that showed the industry in the 1930s extracted about 250 barrels of oil for every foot drilled. This dropped to about 40 barrels per foot drilled in the 1950s.

The trend was reversed briefly in the 1960s, causing many to cast aside Mr. Hubbert's analysis, the researchers noted. The new analysis, they said, shows that the downward trend resumed in the mid-1960s. By the late 1970s, the industry was finding only 10 to 15 barrels of oil for every foot drilled.

"Isn't When the Wells Run Dry"

At the same time, they said, the energy cost of exploring for, extracting and delivery oil has been increasing steadily. It currently equals about 1½ barrels of oil energy for every foot of well drilled.

"The time at which domestic petroleum will no longer, on the average, be a net fuel for the nation isn't when all the wells run dry but rather at some point before that time when the enery cost of obtaining a barrel of oil is the same as the energy in that barrel," they said.

If the yield of oil per foot of well drilled continues to drop—and the energy cost of drilling continues to rise—this break-even point will be reached fairly soon. How soon, they said, depends on how intensively the industry explores for oil.

If the industry slows its drilling rate to about 120 million feet of well a year, the break-even point could be staved off until the year 2004, their analysis found.

"Were we to continue to drill at the 1978 levels of about 200 million feet a year, the linear extrapolations would intersect in 2000," they added. This is for both oil and its equivalent in natural gas. "For oil alone, we could reach the break-even point in about a decade."

If the industry continues to increase its drilling rate at the pace it has in recent years, the break-even point for oil and gas could be reached in the mid-1980s, they concluded.

Reagan Adviser's Challenge

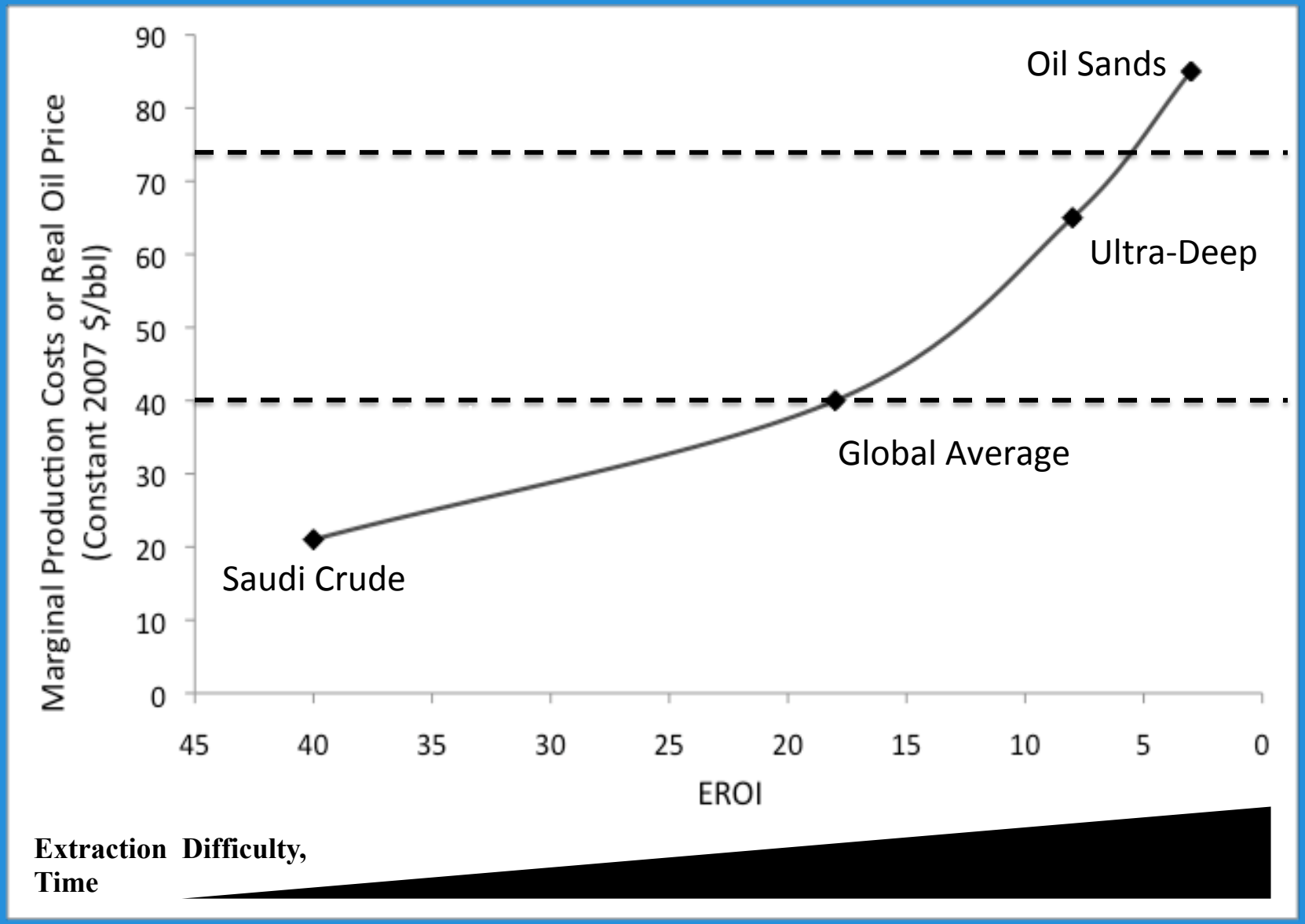
Michel Halbouty, the Houston industry consultant who was President Reagan's chief adviser on energy policies, quickly challenged the Cornell researcher's conclusions. The study, he noted, was based on the industry's drilling record since 1945. But, he said, this drilling record has been distorted by government regulation.

"We've experienced 23 years of controls and regulations that have stymied the exploration effort in this country," he said. Because of such regulation he said, many oil men have been forced to drill near old oil fields where there's a better chance of finding oil. Such drilling, he said, doesn't really add much to new oil reserves. This, he said, was one reason for the decline in the number of new barrels added to reserves per foot of well drilled.

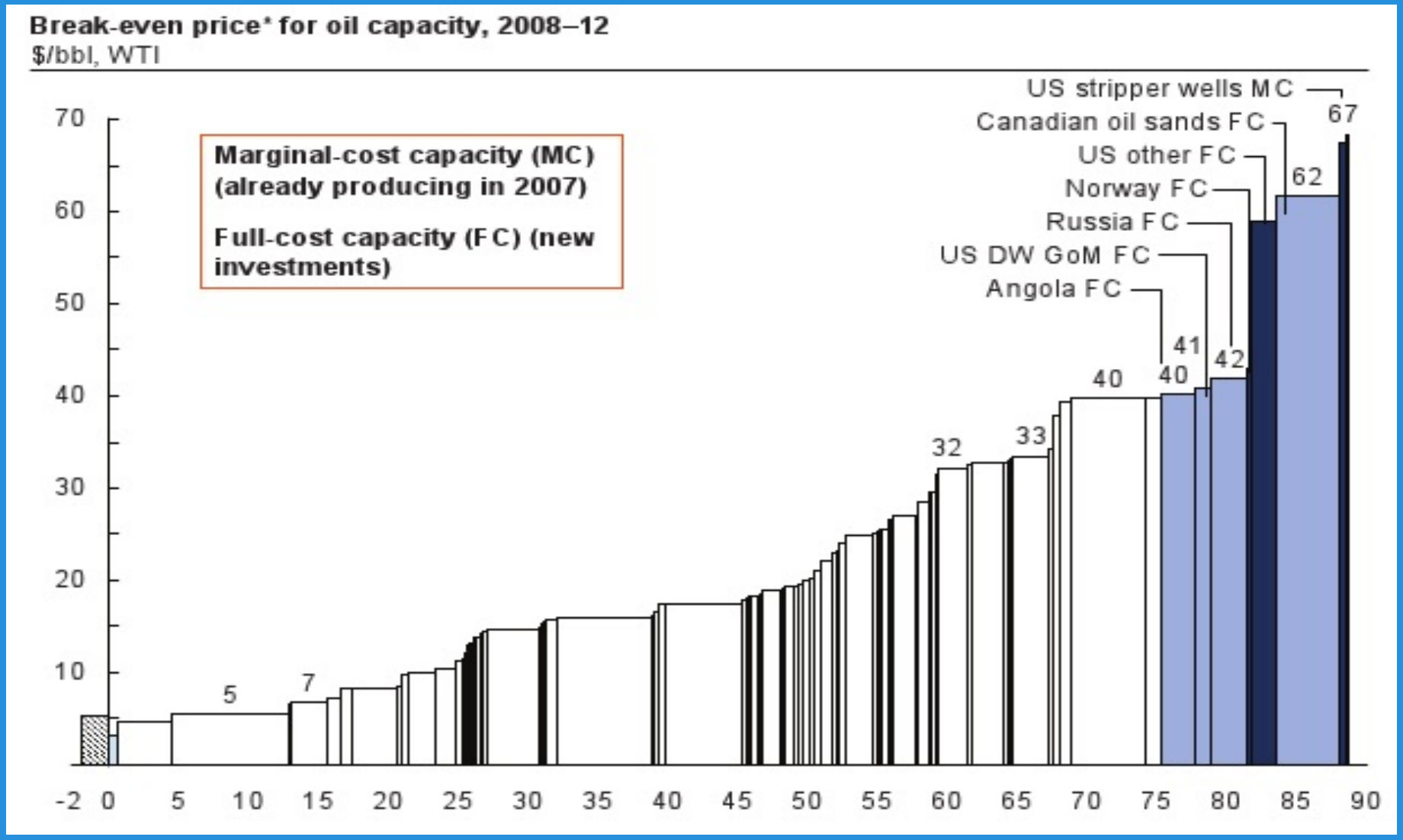
With President Reagan's decontrol order, Mr. Halbouty said, "we're going to see more real wildcatting in the boondocks."

"Most domestic oil (and presumably gas) that is now produced comes from reserves discovered before 1940," the ecologists said. "We see little hope for changing this picture very much through increased conventional drilling effort, and in fact such effort could decrease the total energy delivered to society by the petroleum industry by lowering the efficiency of that energy-intensive industry," they declared.

Price and EROI



Break-Even Cost



McKinsey GEM, 2010 using IEA, Wood Mackenzie, Interstate Oil and Gas Compact Commission

IV. We have a lot of new information about EROI

Special issue of Sustainability on EROI:

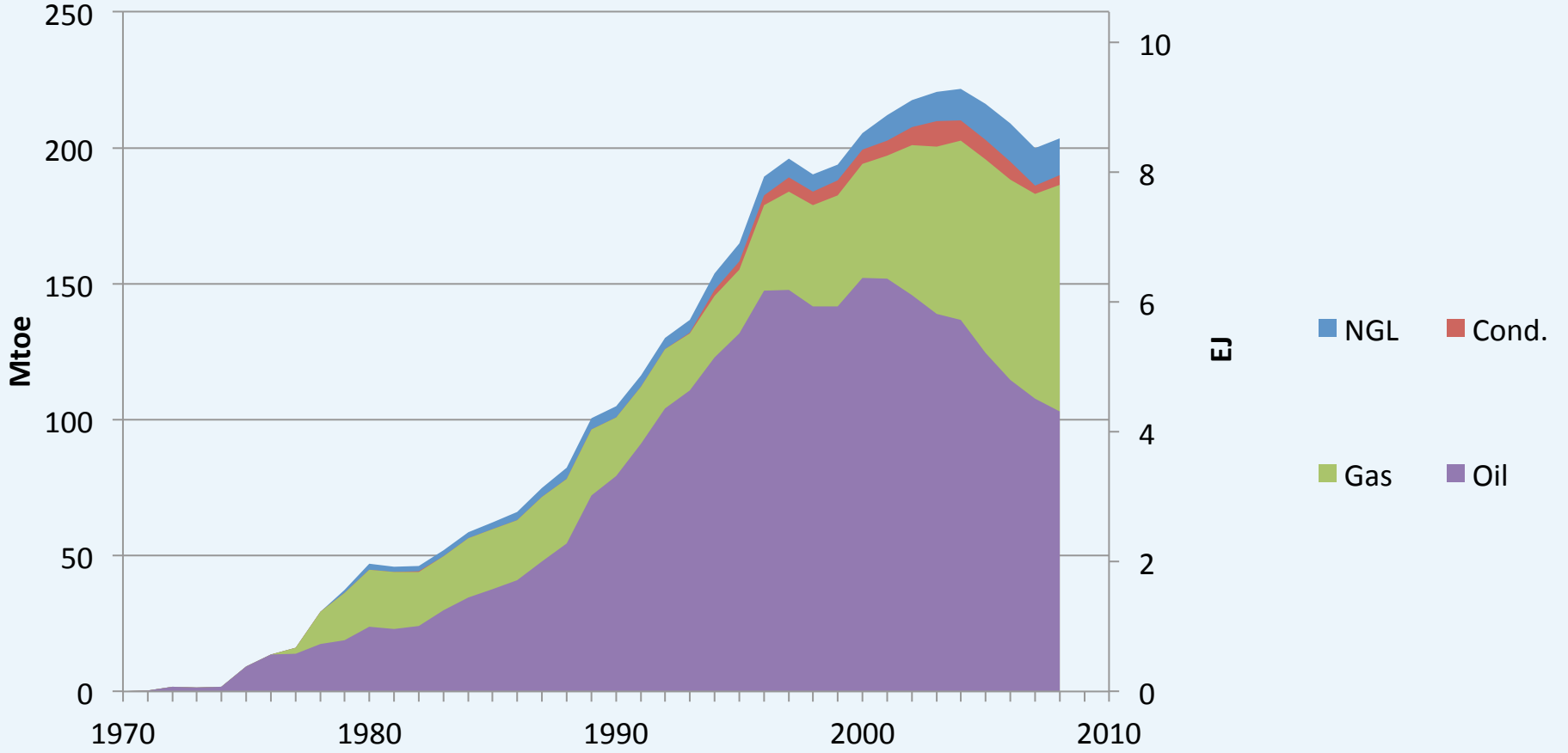
1. We have many studies now that are based on physical data

2. These studies tend to be consistent with our earlier studies

3. All show relatively high but declining EROI for conventional fuels and low but occasionally increasing values for e.g. new solar

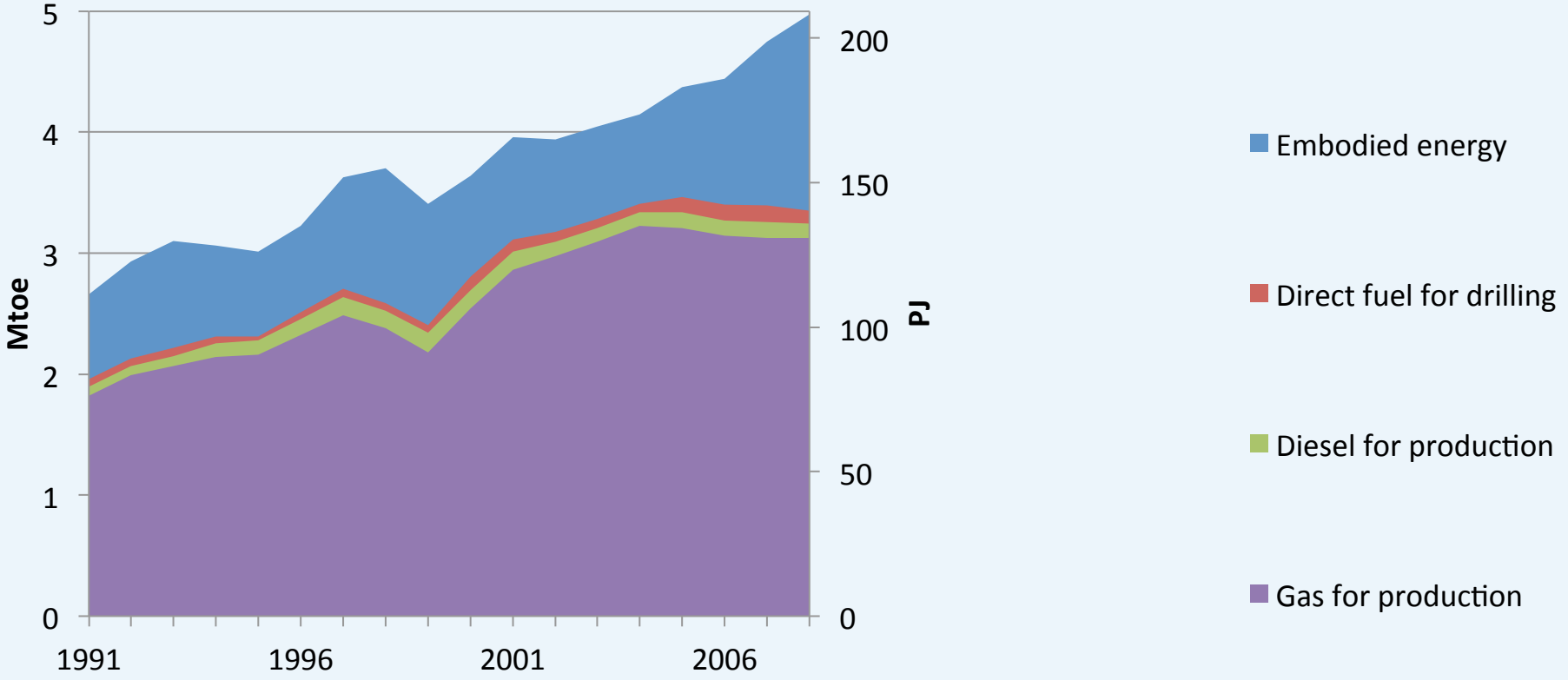
4. All show decreasing EROI when effort is high

Petroleum production in Norway in 1970 – 2008

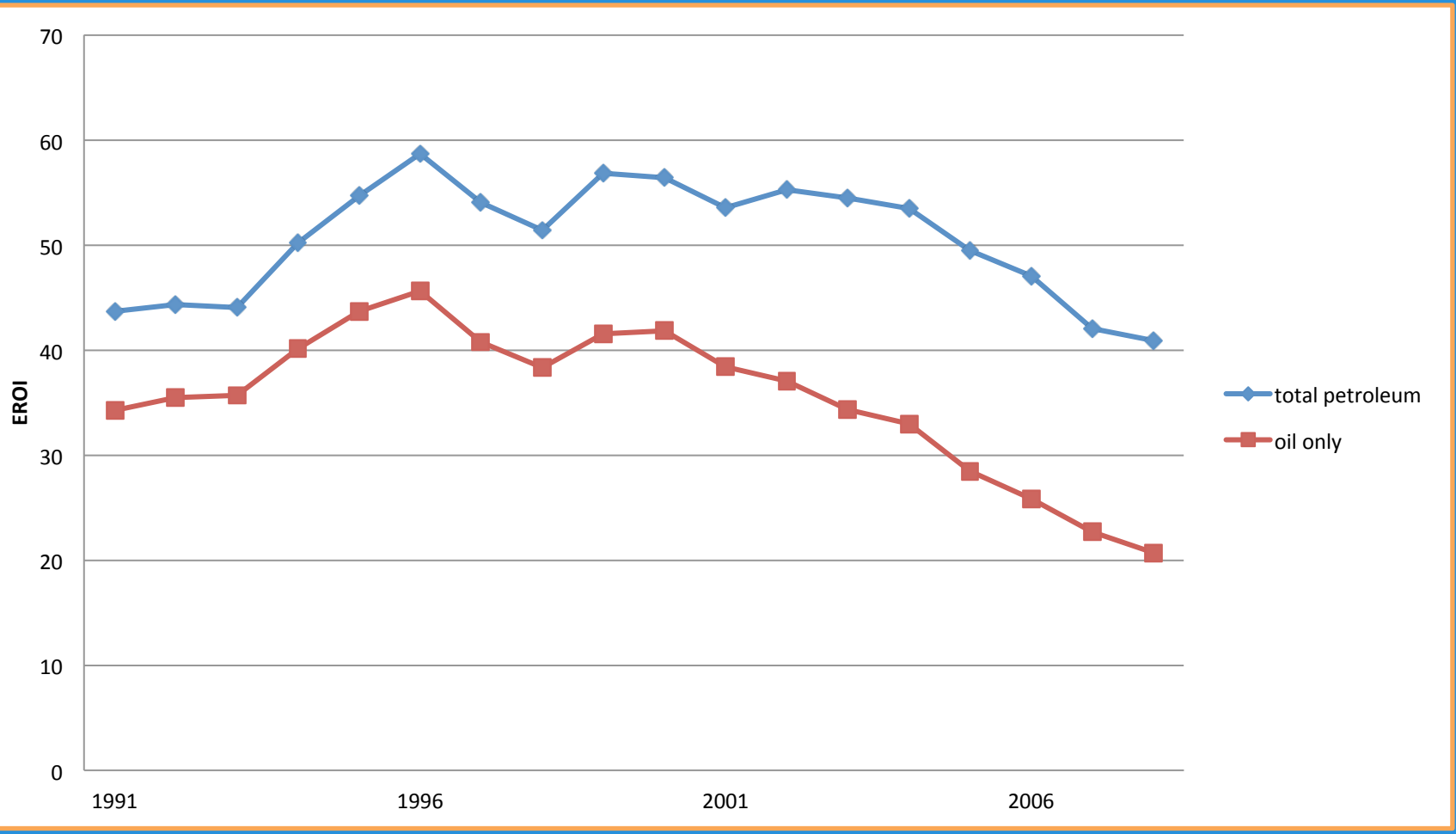


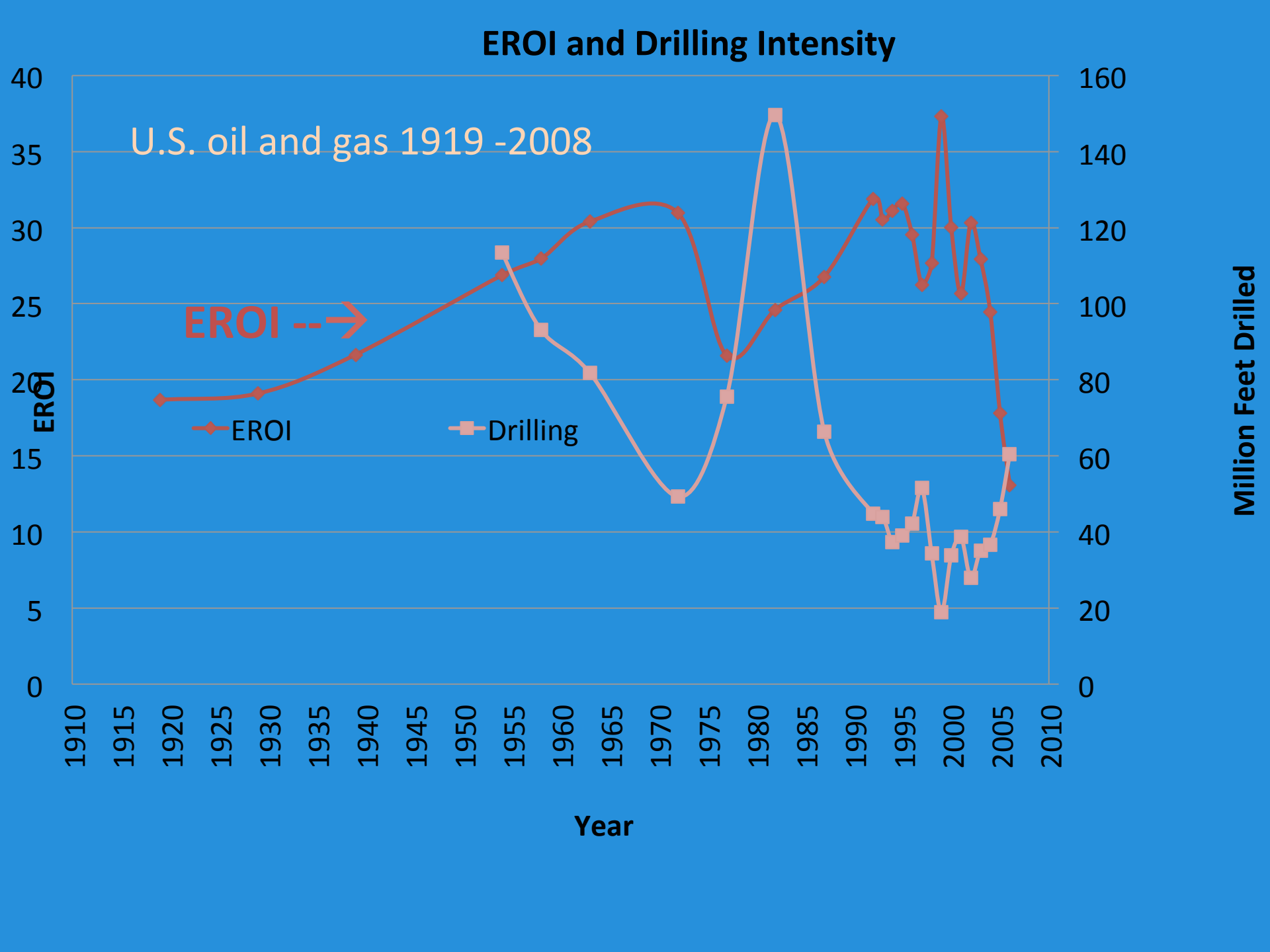
Energetic cost of petroleum production in Norway in 1991 – 2008.

Leena Grandell



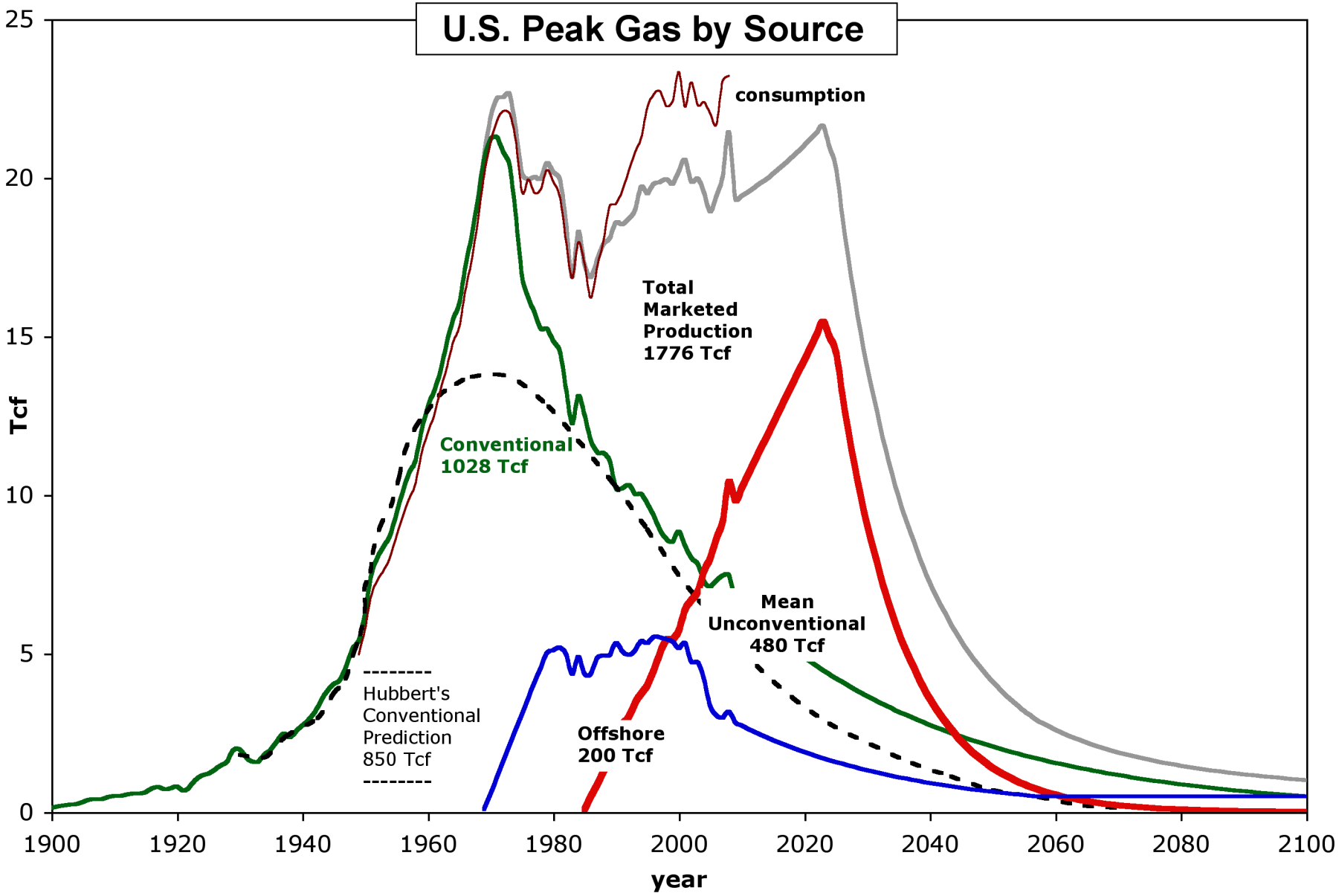
EROI of Norwegian petroleum production in 1991 – 2008




EROI and Drilling Intensity
U.S. oil and gas 1919 -2008
EROI -->
EROI
Drilling
EROI
Million Feet Drilled
Year
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120
140
160
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

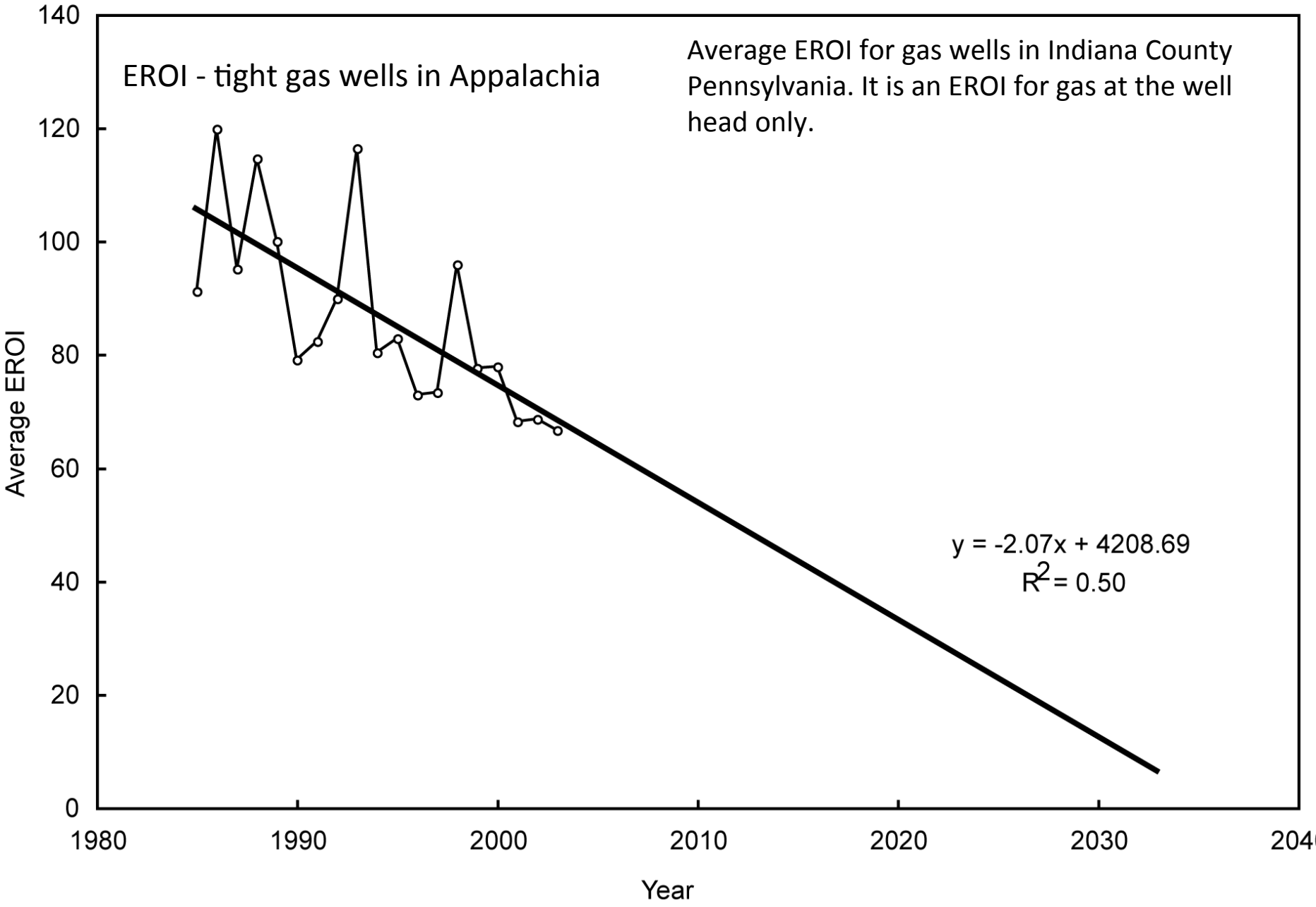
How about natural gas?

By Bryan Sell

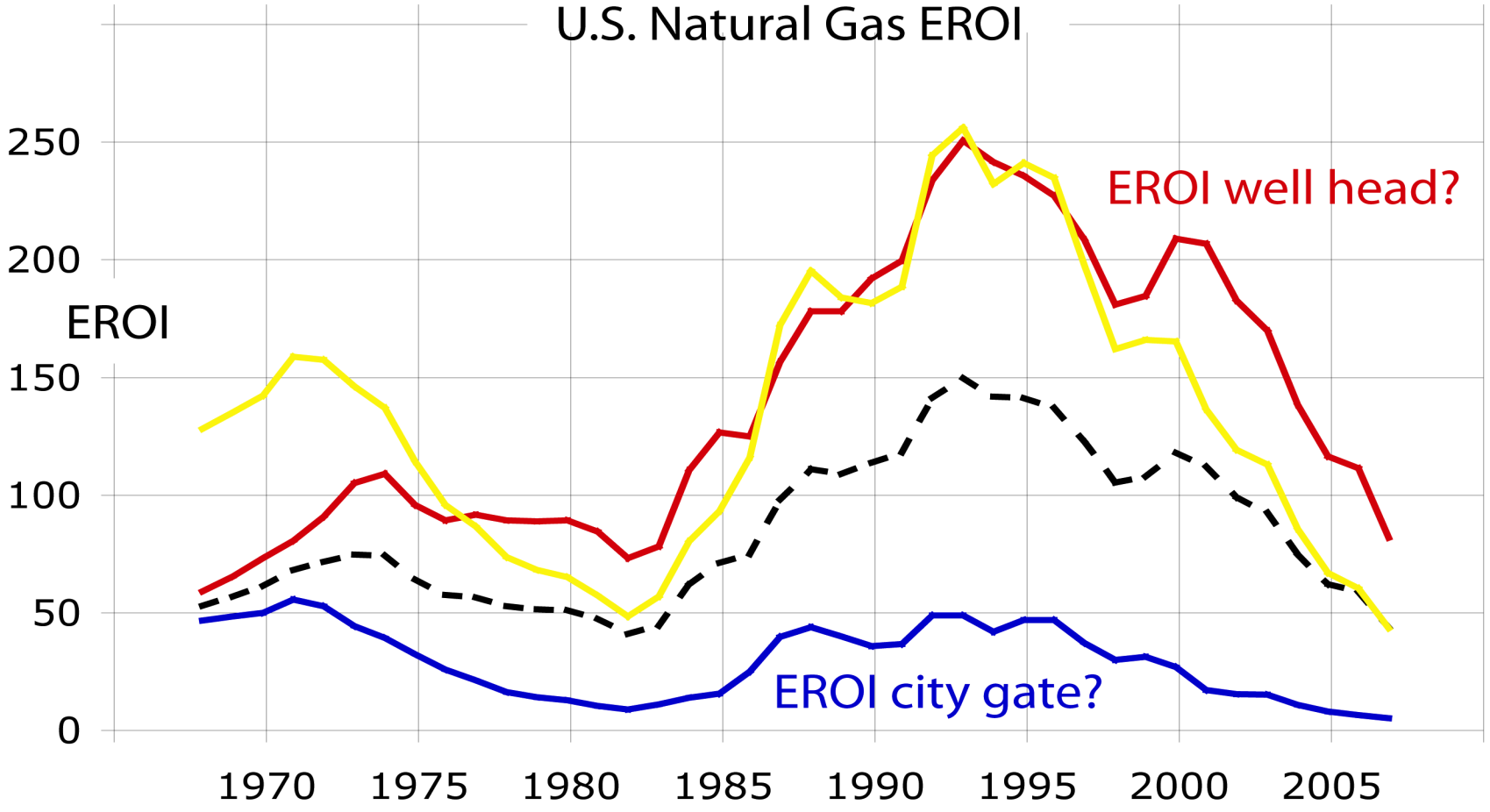

U.S. Peak Gas by Source
consumption
Total
Marketed
Production
1776 Tcf
Conventional
1028 Tcf
Mean
Unconventional
480 Tcf
Offshore
200 Tcf

Hubbert's
Conventional
Prediction
850 Tcf

Tcf
year
0
5
10
15
20
25
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100


EROI - tight gas wells in Appalachia
Average EROI for gas wells in Indiana County Pennsylvania. It is an EROI for gas at the well head only.
y = -2.07x + 4208.69
R2 = 0.50
Average EROI
Year
140
120
100
80
60
40
20
0
1980
1990
2000
2010
2020
2030
2040

US Gas– educated guess



V. Relation of these things to economics:

(We cannot run on myths)

THE ECONOMISTS' ARGUMENT

Technology will overcome depletion

THE GEOLOGISTS' ARGUMENT

Depletion is real and will overwhelm technology

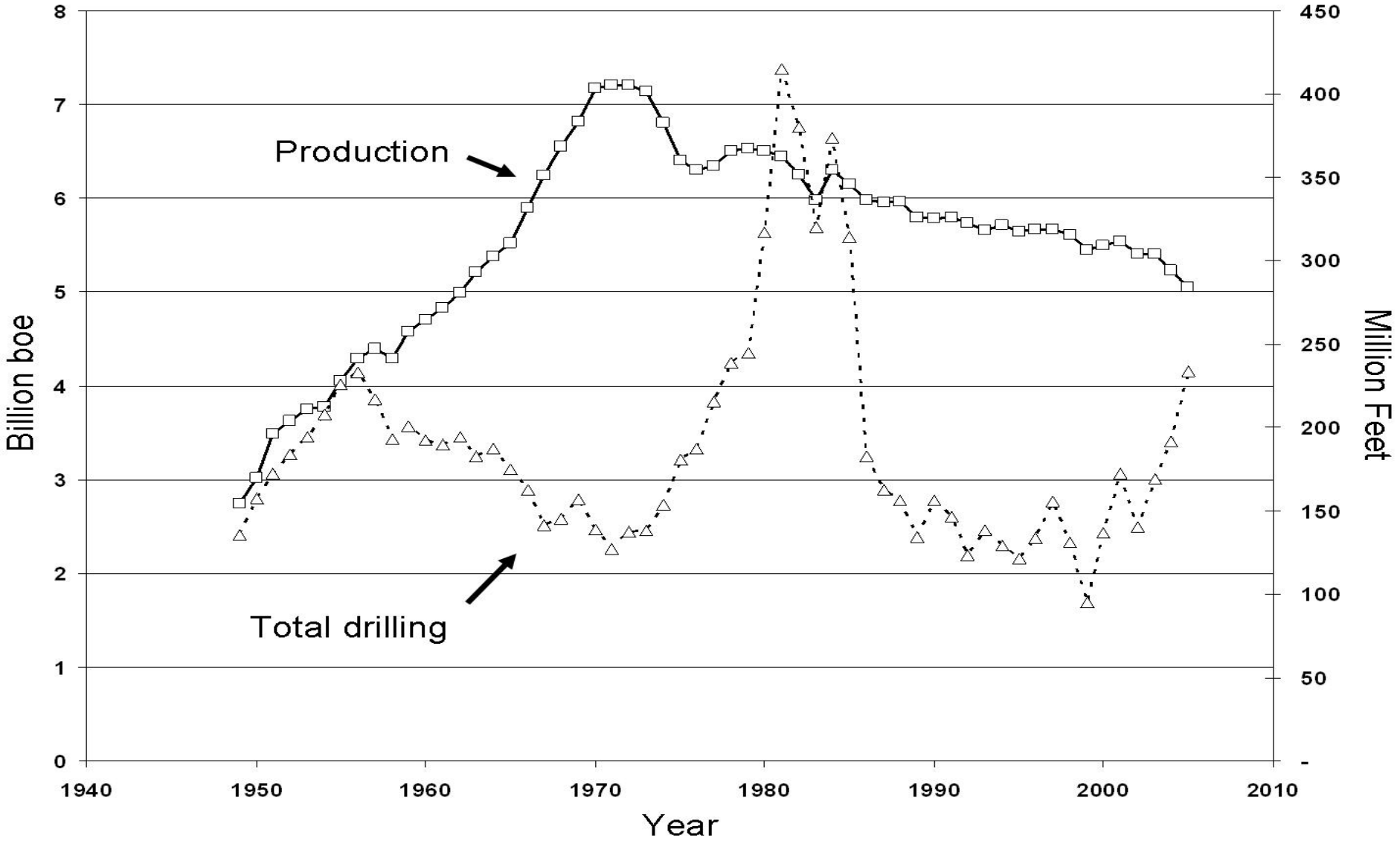
Who is right??

1. Economists say:

- We can let markets solve our problems,

Such as declining oil production

But… Increased prices does not necessarily bring forth increased production



2. ECONOMISTS SAY THIS A CYCLE, BUT CLEARLY IT IS A TREND

- Not necessarily a bad thing depending upon how we respond to it.
- We can respond to it well or poorly
- Need to live on interest, not capital
- Need to put growth aside for the time being

MY MUST HAVE A NEW ECONOMICS

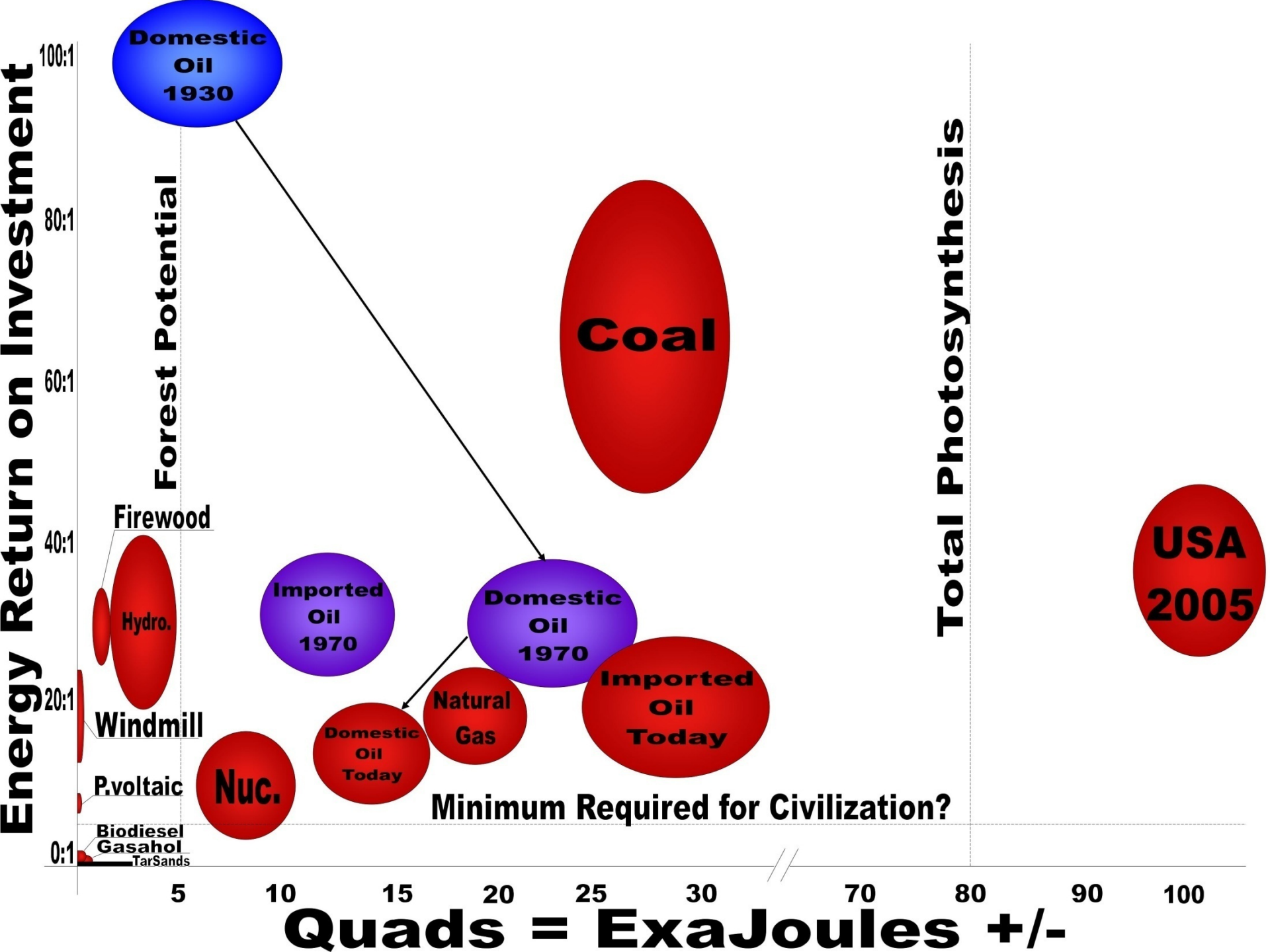
THINK! :

Why is economics now a social science, when it is about stuff????

Clearly we need a new kind of economics: Biophysical Economics

This is what we are trying to do

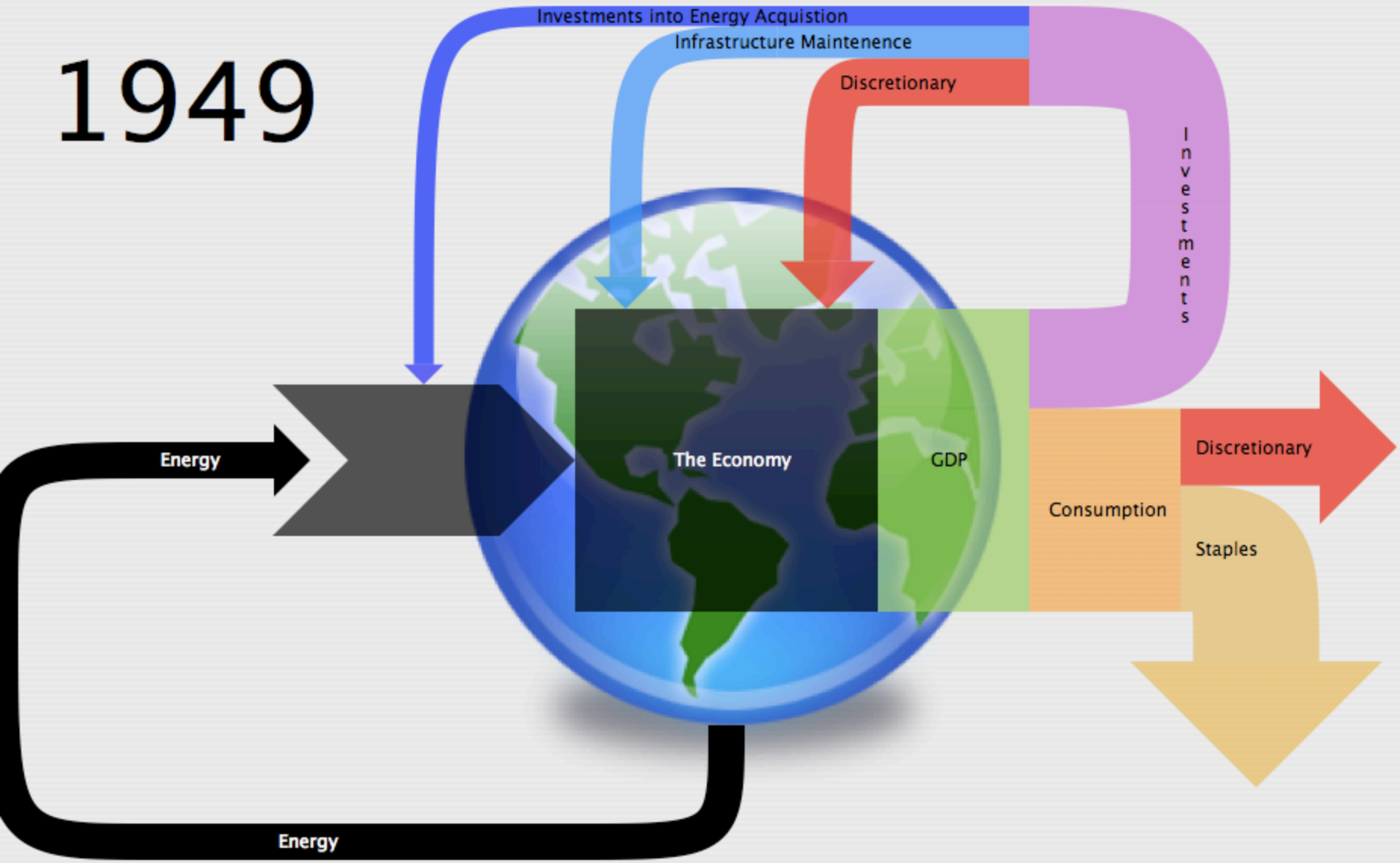
3. Alternatives are not adequate to replace oil

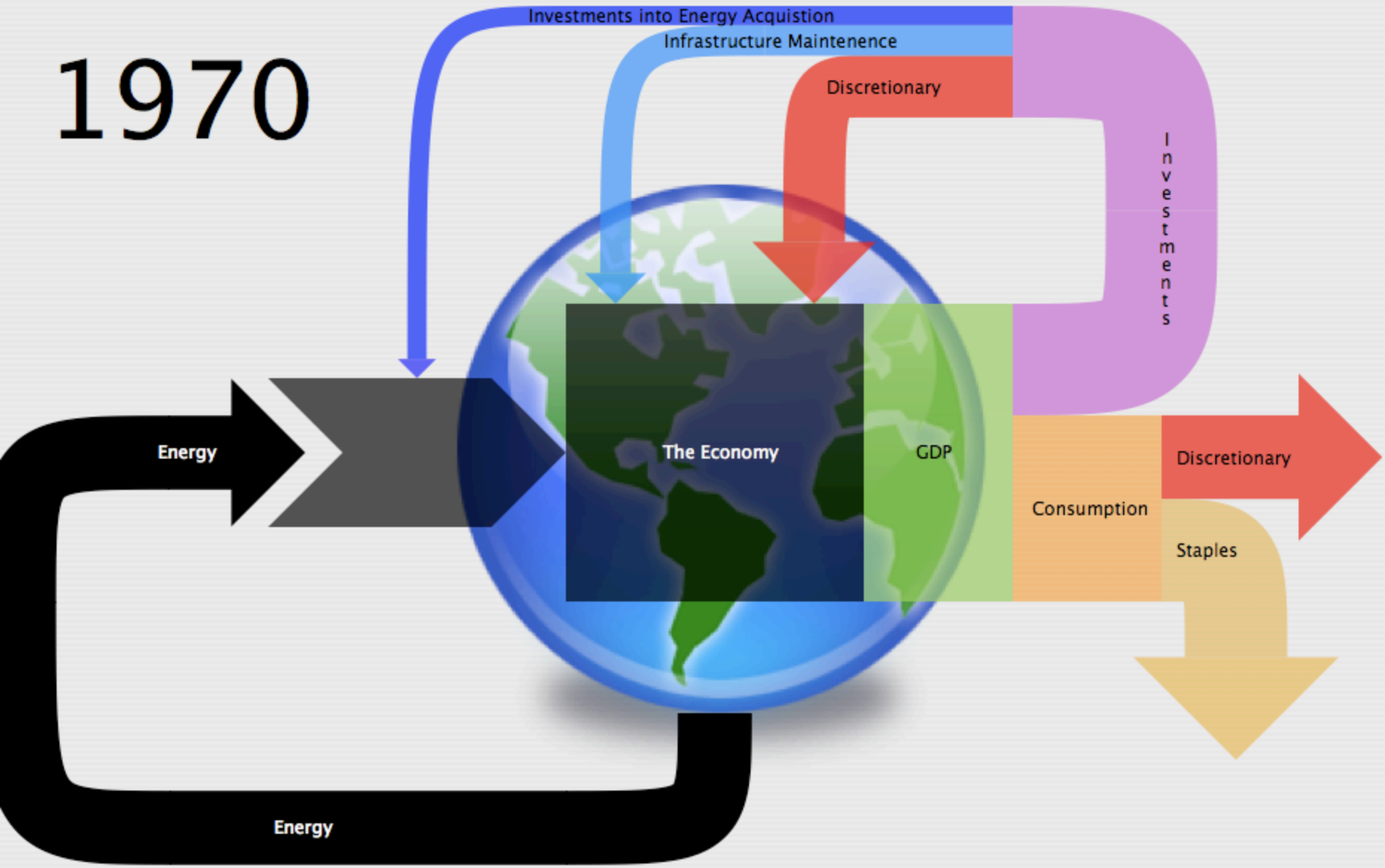

Energy Return on Investment
100:1
80:1
60:1
40:1
20:1
0:1
Domestic Oil 1930
Forest Potential
Coal
Total Photosynthesis
USA 2005
Firewood
Hydro.
Windmill
P.voltaic
Biodiesel
Gasahol
TarSands
Nuc.
Imported Oil 1970
Domestic Oil 1970
Domestic Oil Today
Natural Gas
Imported Oil Today
Minimum Required for Civilization?
5
10
15
20
25
30
70
80
90
100
Quads = ExaJoules +/-

4. Externalities can come back and bite you

How much of Katrina's cost was due to oil exploitation in S. Louisiana?

5. Declining EROI of conventional fuels and of our alternatives are likely to cause large impacts on the economy even if energy resources are large


1949
Investments into Energy Acquistion
Infrastructure Maintenence
Discretionary
Investments
Energy
The Economy
GDP
Consumption
Discretionary
Staples
Energy



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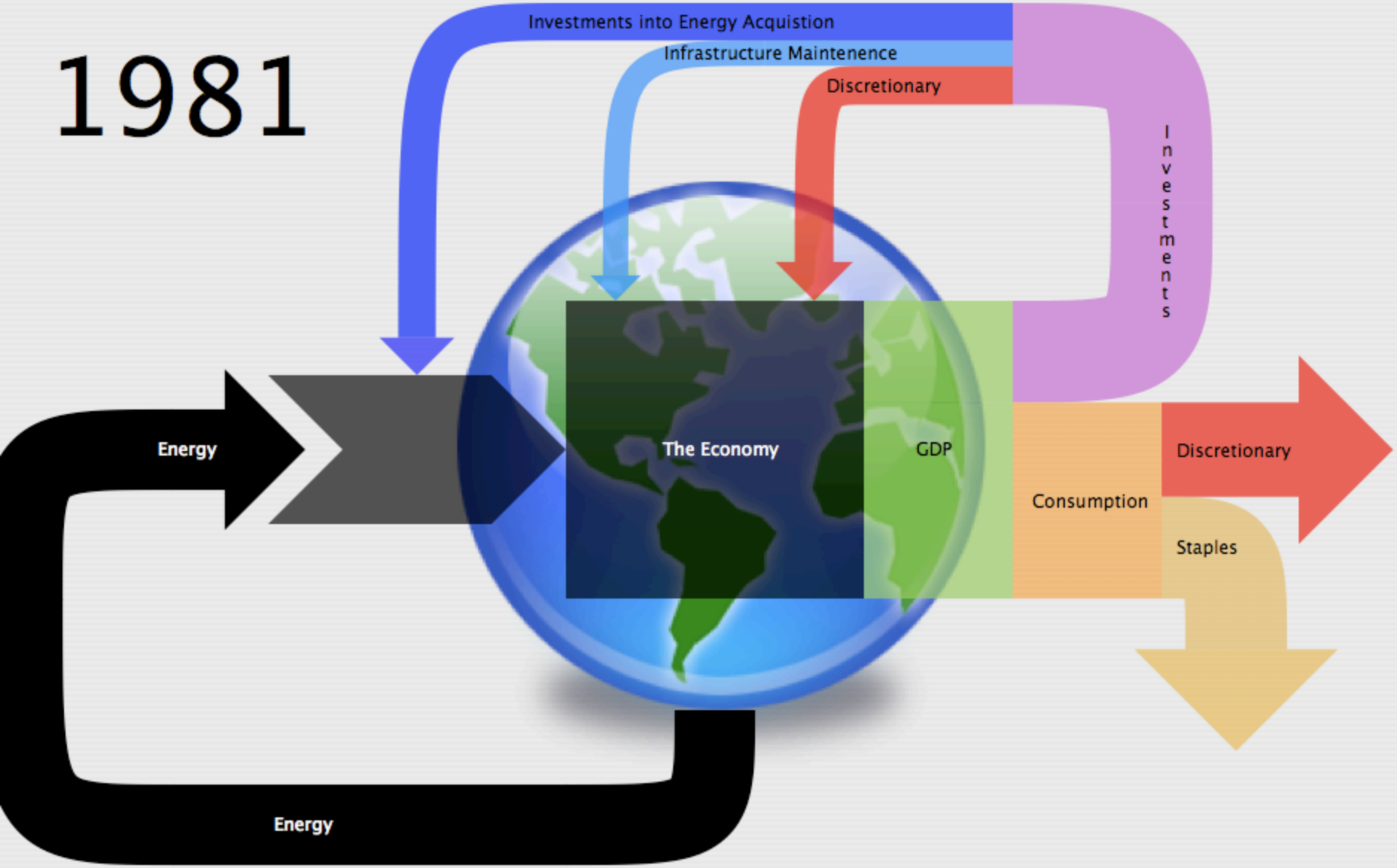
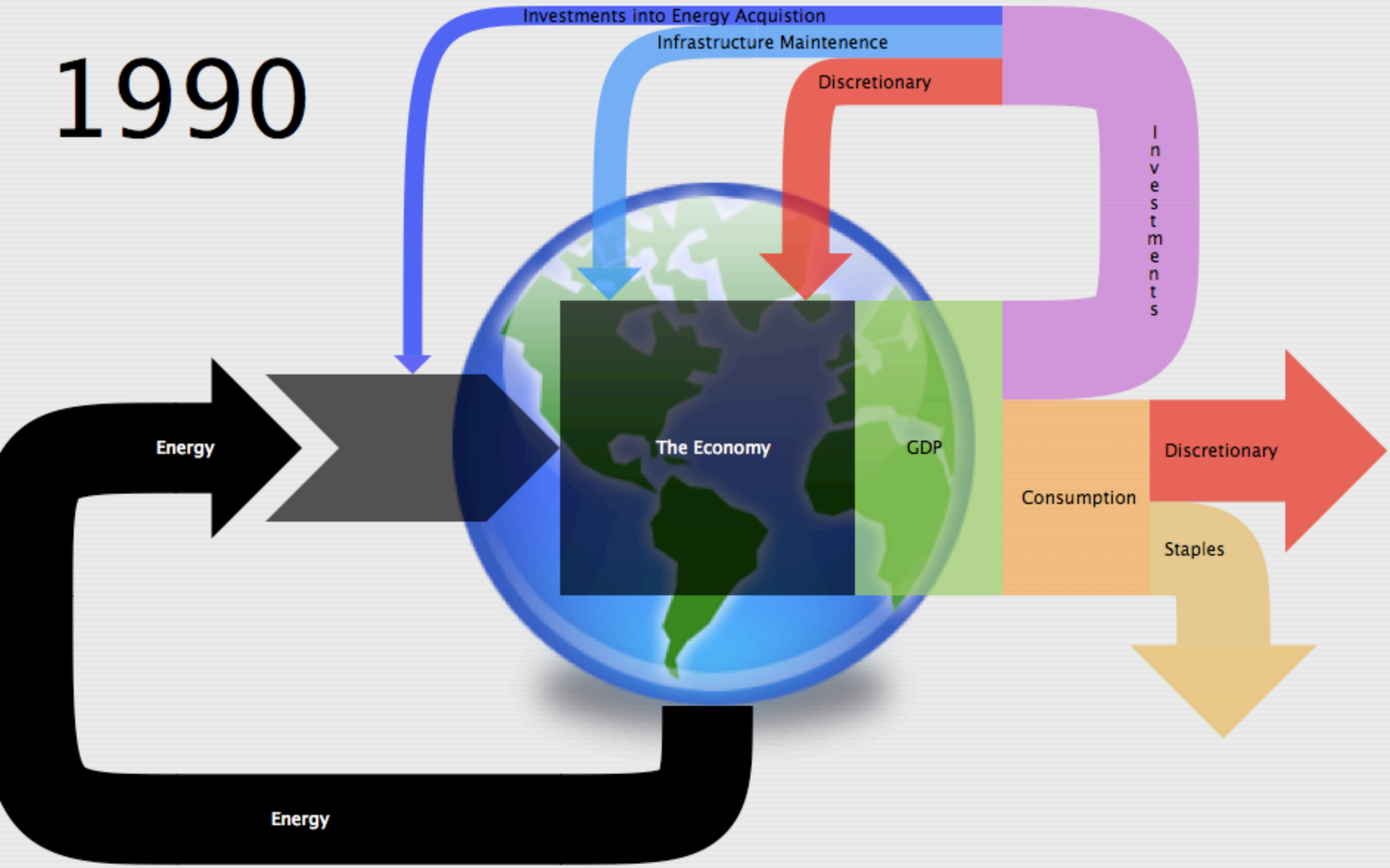
Load Data


1981
Investments into Energy Acquistion
Infrastructure Maintenence
Discretionary
Investments
Energy
The Economy
GDP
Consumption
Discretionary
Staples
Energy



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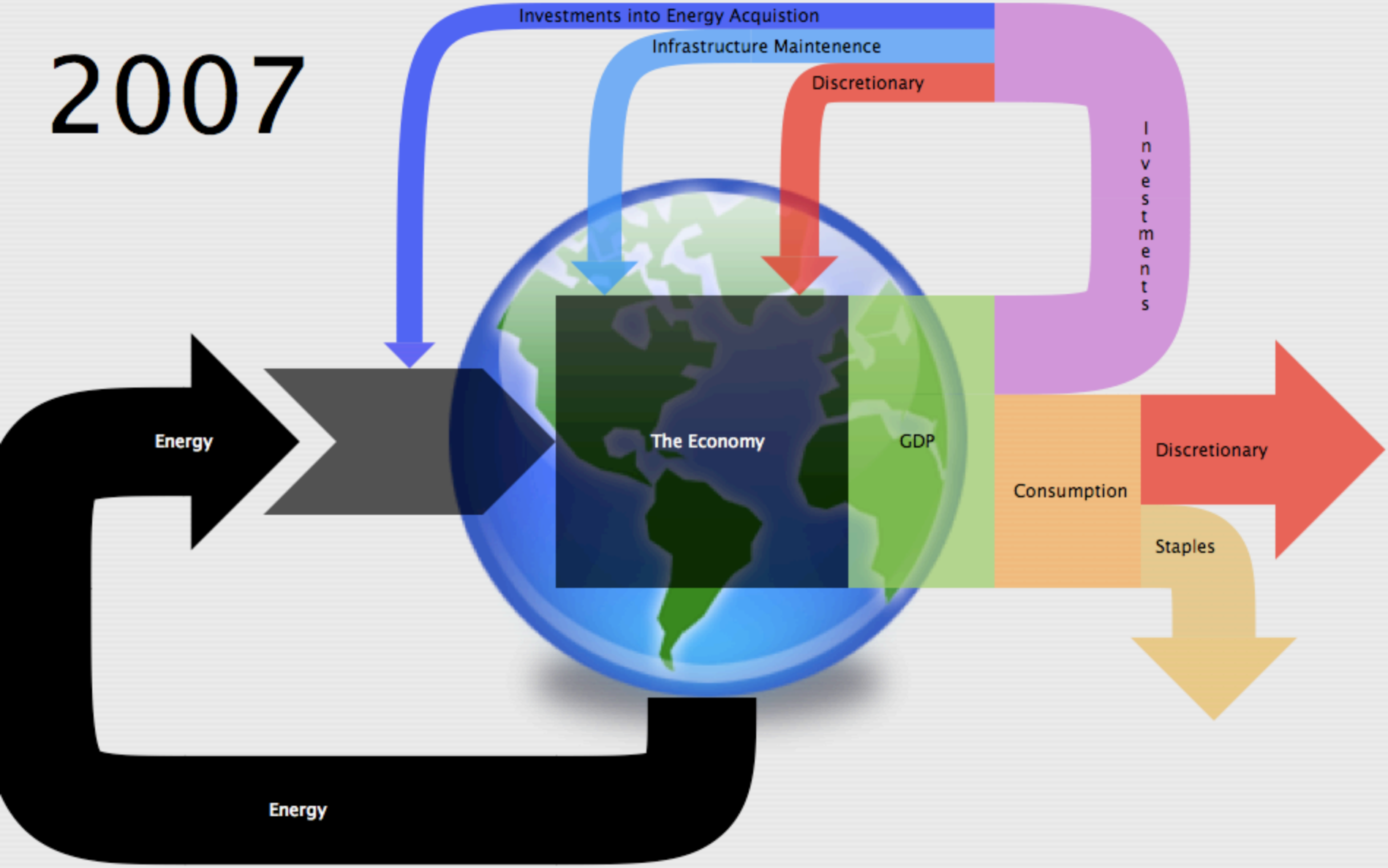
Load Data

Energy and Economy Diagram



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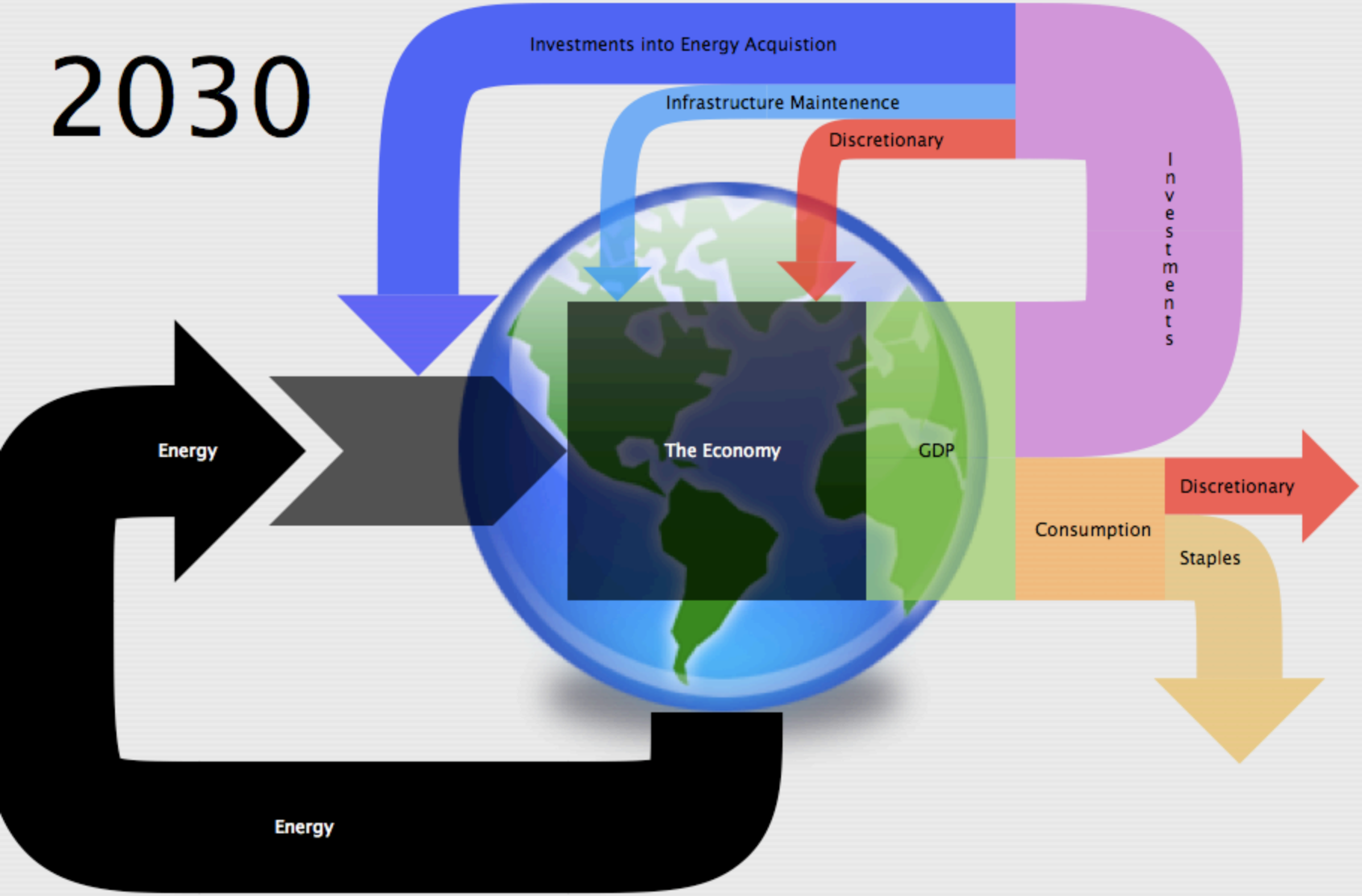
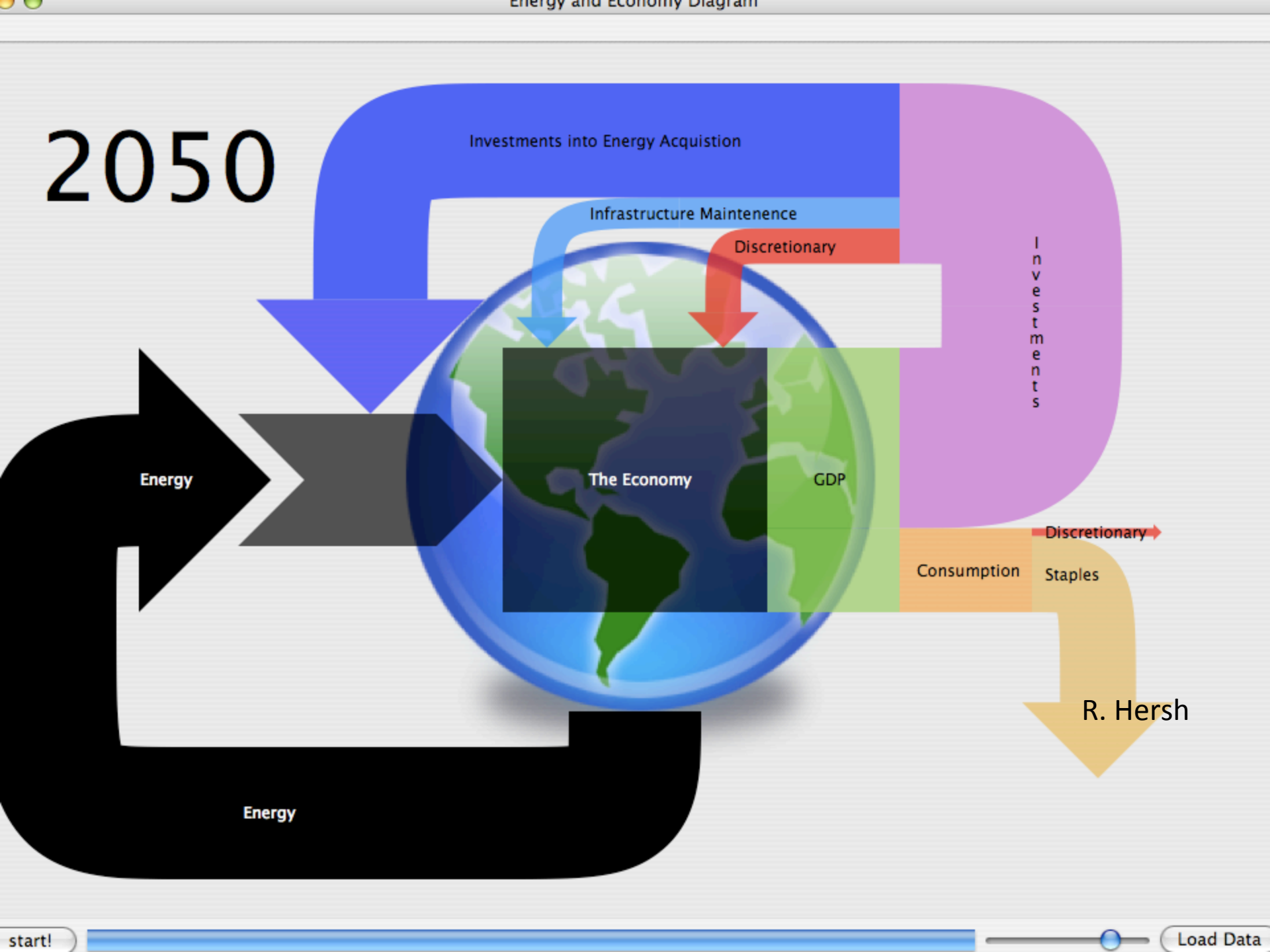

2030
Investments into Energy Acquistion
Infrastructure Maintenence
Discretionary
Investments
Energy
The Economy
GDP
Discretionary
Consumption
Staples
Energy


Energy and Economy Diagram
2050
Investments into Energy Acquistion
Infrastructure Maintenence
Discretionary
Investments
Energy
The Economy
GDP
Consumption
Discretionary
Staples
Energy
R. Hersh
start!
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SOME NEW WAYS WE WILL HAVE TO DO ECONOMICS

- 1) We will have to *reduce* labor productivity
- 2) We will have to *reduce* wages
- 3) It will impact foreign workers hugely
- 4) We cannot afford market economics
- to guide our future
- 4) It is a great time to think about redistribution

My final professional goal

THE END

Thanks to the Santa Barbara Family Foundation