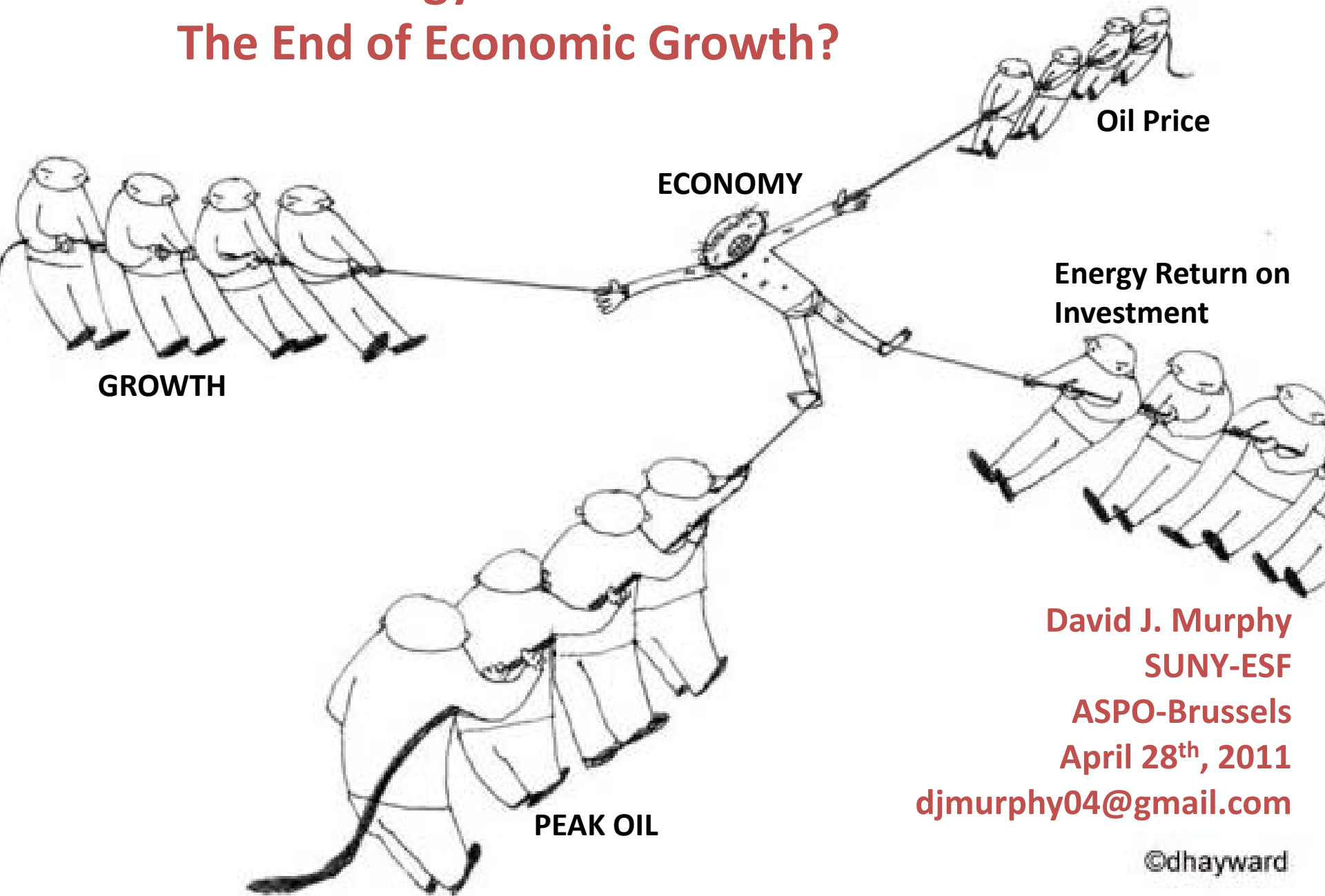
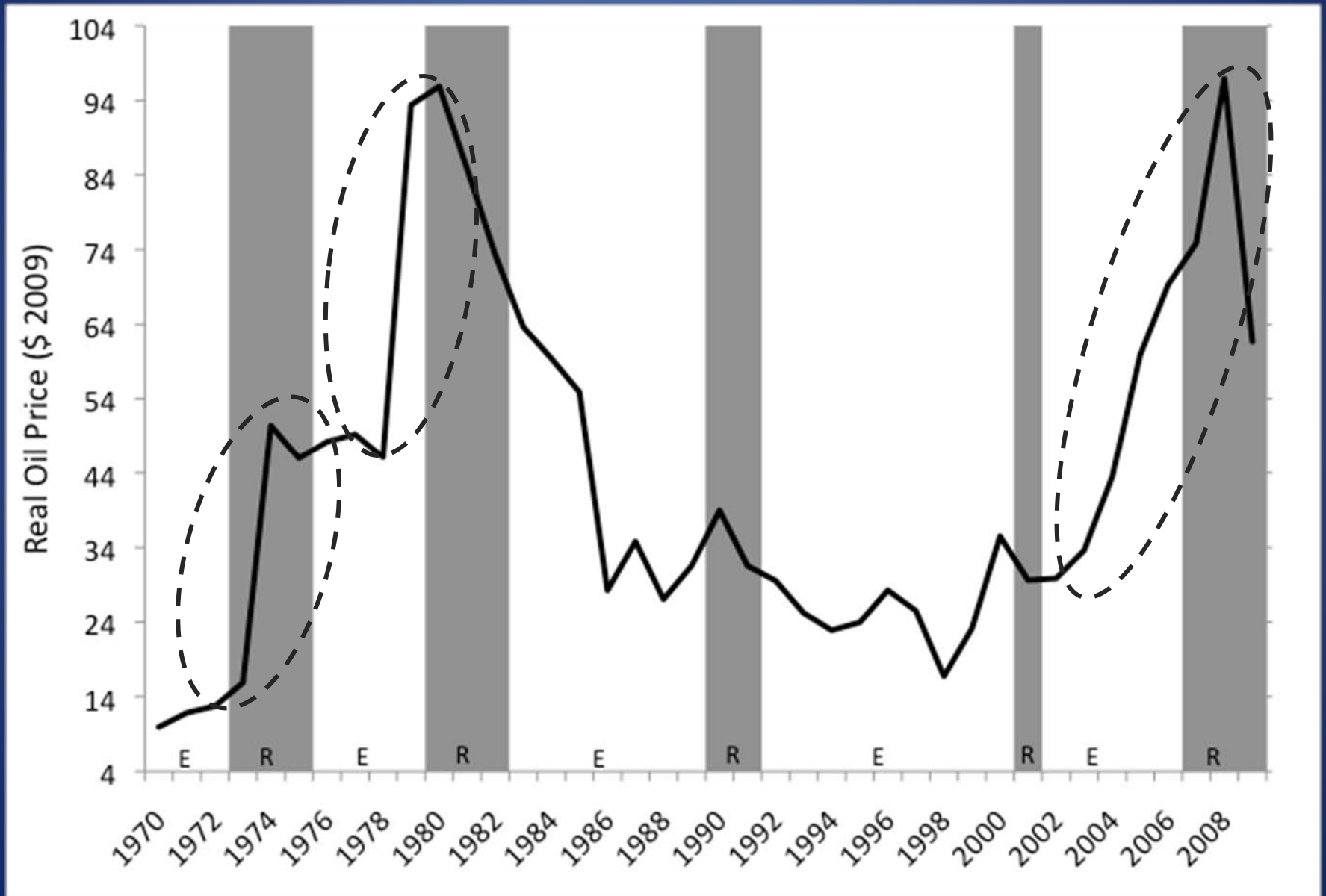


# Peak Oil and Energy Return on Investment: The End of Economic Growth?



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ASPO-Brussels  
April 28<sup>th</sup>, 2011  
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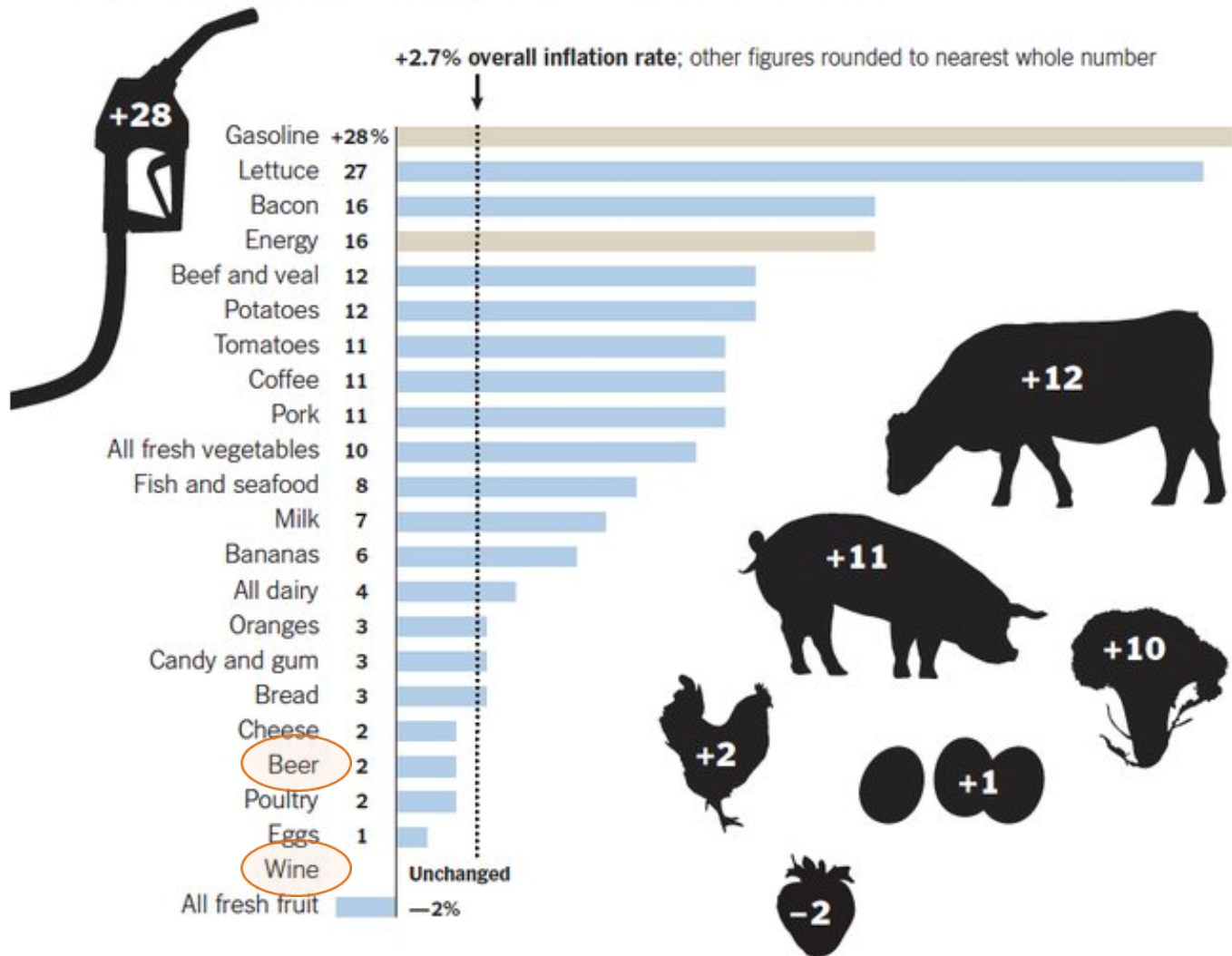
# Every Recession since 1970 correlates with a spike in the price of oil



# A Rising Tide Lifts All Boats...?

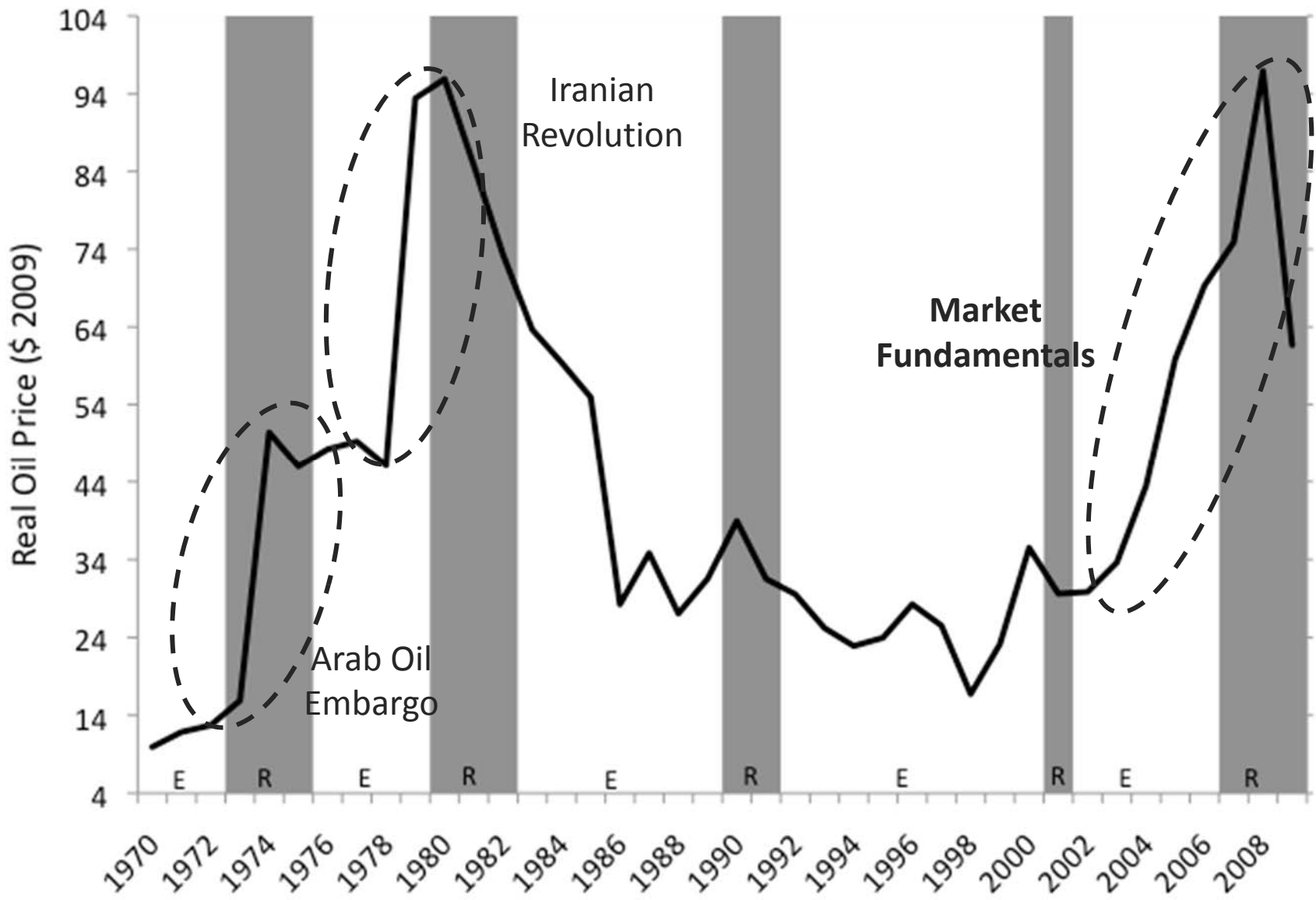
## Paying More for Filling Up

A year's change in food and energy costs, March 2010 to March 2011.

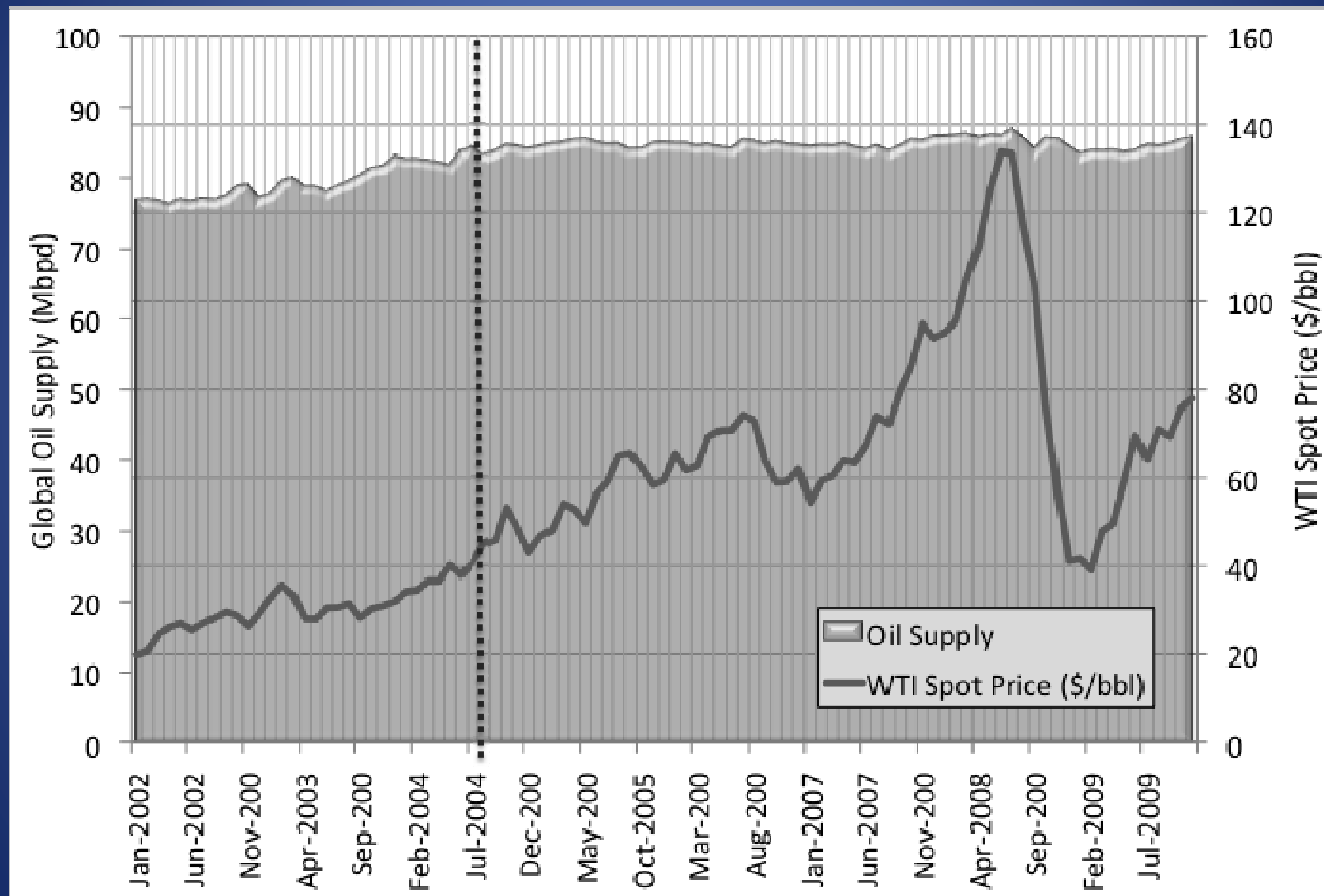


Source: Bureau of Labor Statistics

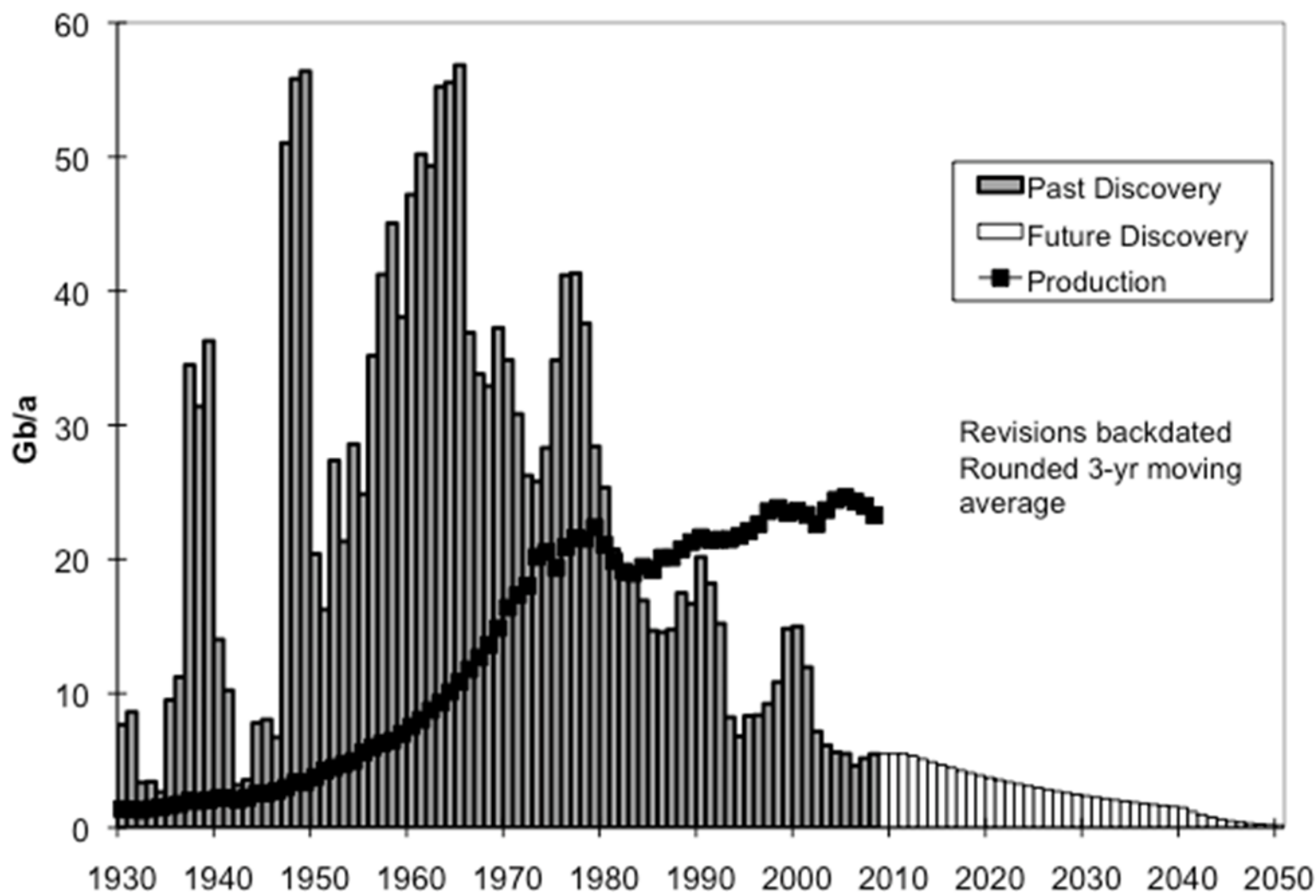
THE NEW YORK TIMES  
The New York Times



# The 2008 price spike was different: Supply didn't increase with price



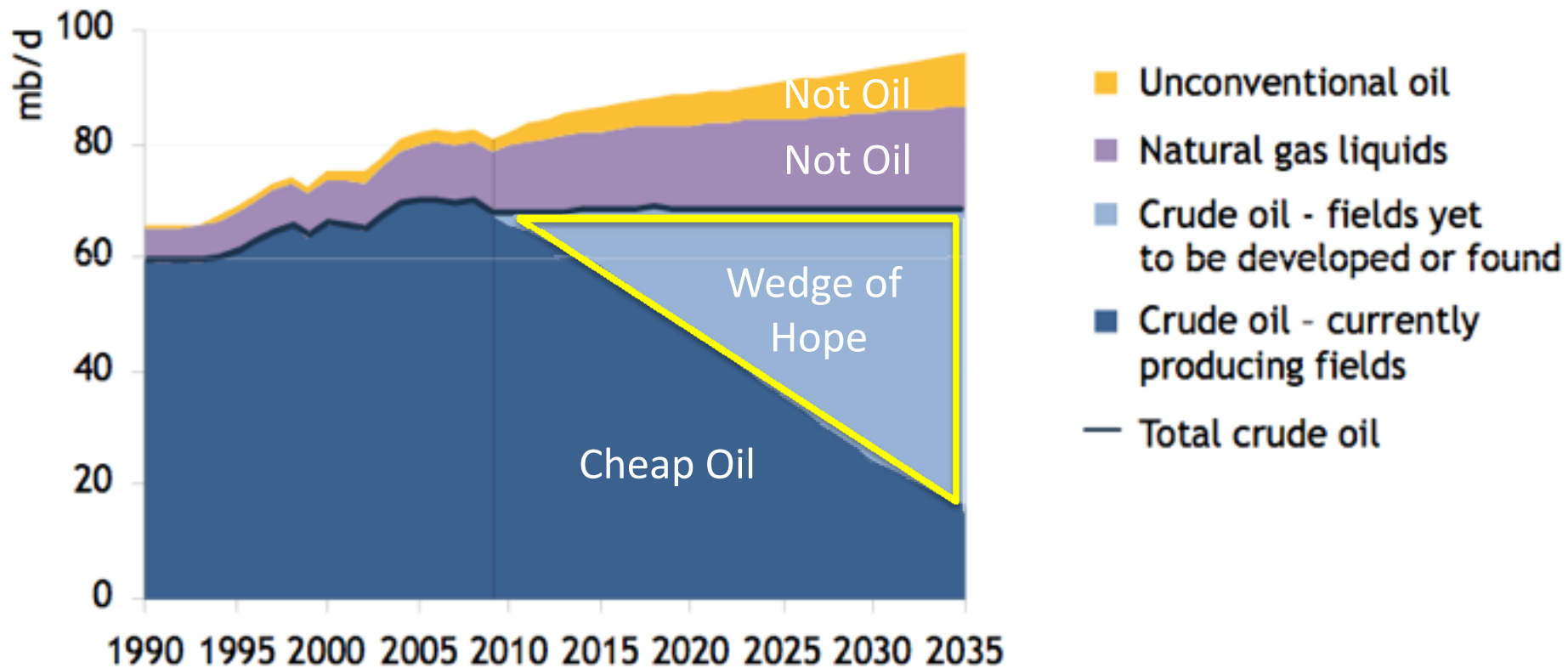
## The Growing Gap Regular Conventional Oil



# Peak oil is here

***“Crude oil*** output reaches an undulating plateau of around 68-69 mb/d by 2020, but ***never regains its all-time peak of 70 mb/d reached in 2006***, while production of natural gas liquids (NGLs) and unconventional oil grows strongly.”

(IEA WEO 2010)



Peak oil means peak **CHEAP** oil

i.e. the **QUALITY** of “oil” is declining as well

1930's: 1 barrel of oil invested would yield 100 barrels of oil out of the ground



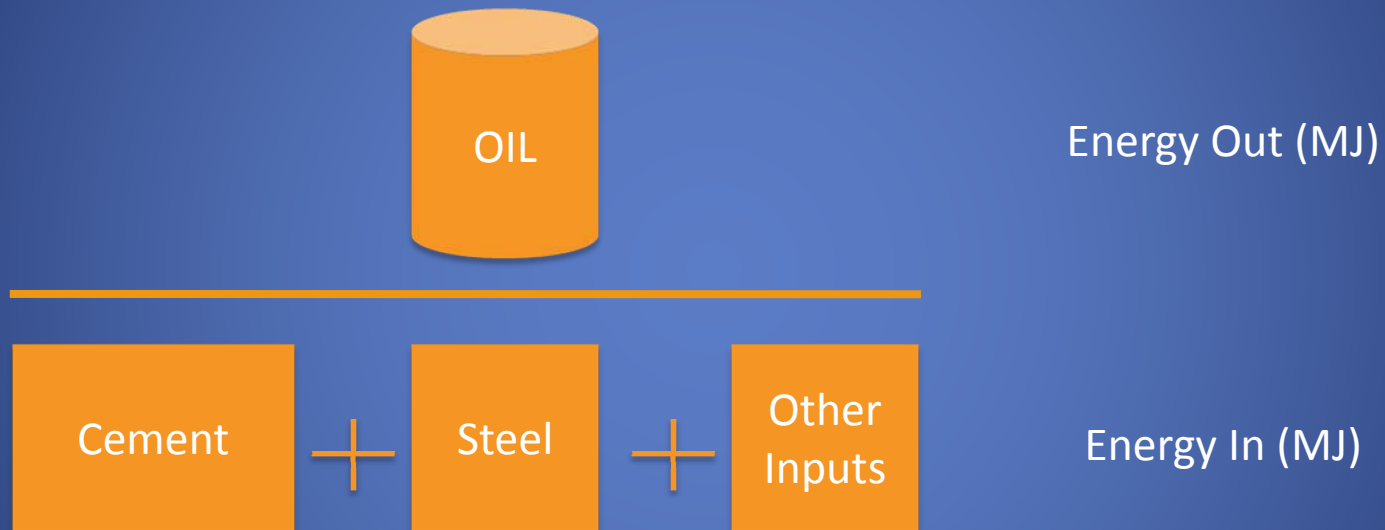
Today: 1 barrel of oil invested yields less than 10 barrels out for most recent discoveries



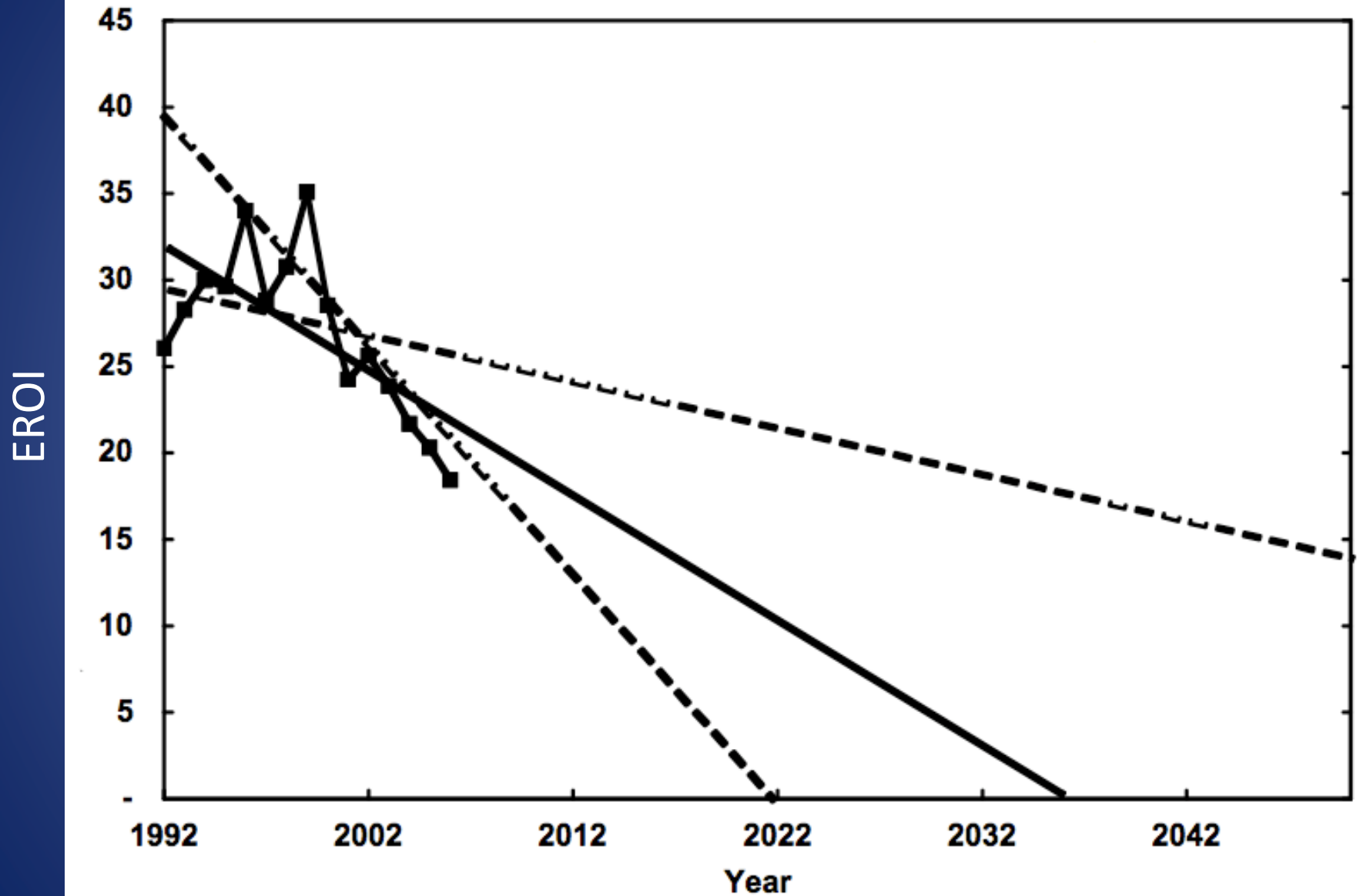
Today: 1 barrel of oil invested yields roughly 3 barrels out in the Alberta Tar Sands



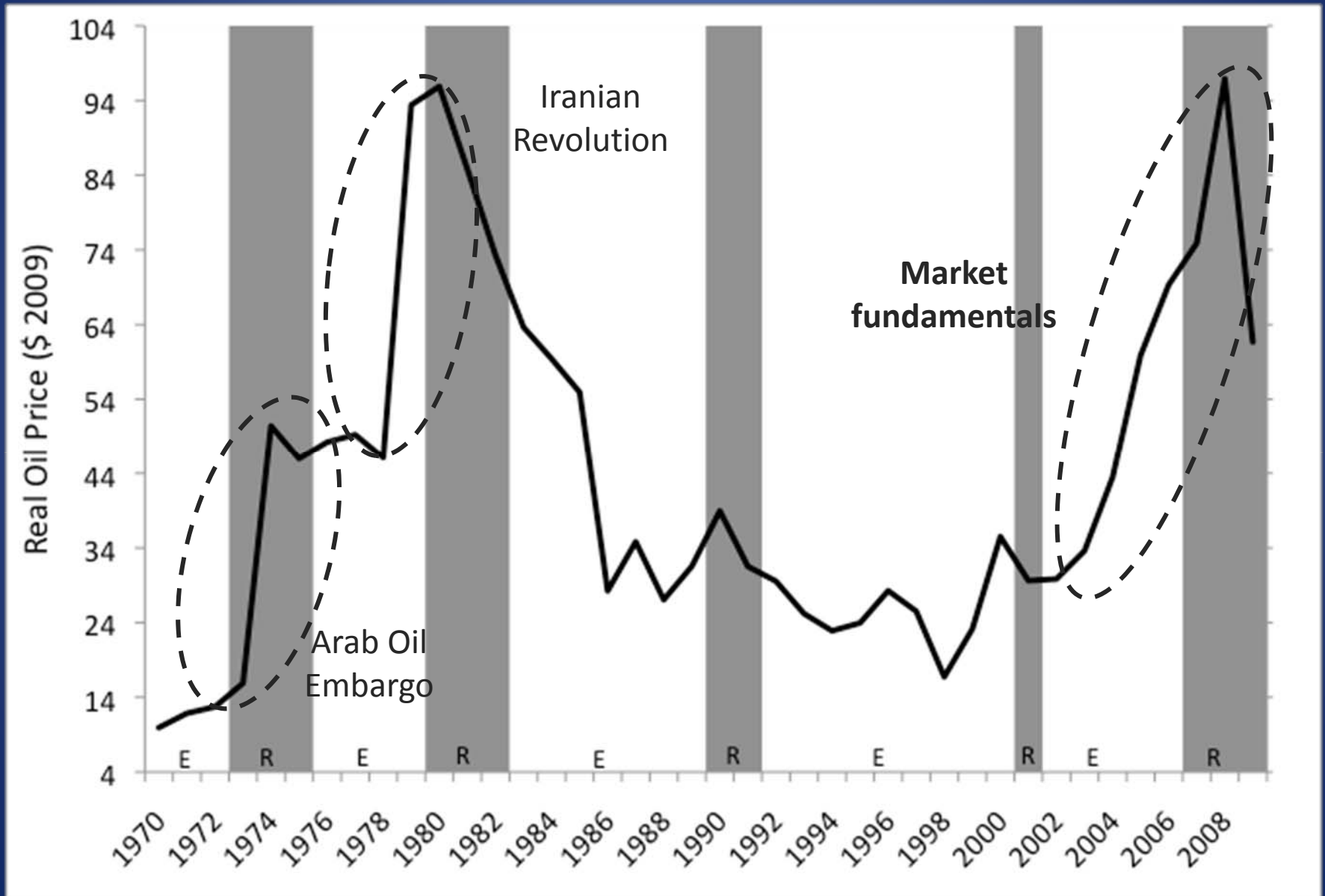
# Energy Return on Investment (EROI)



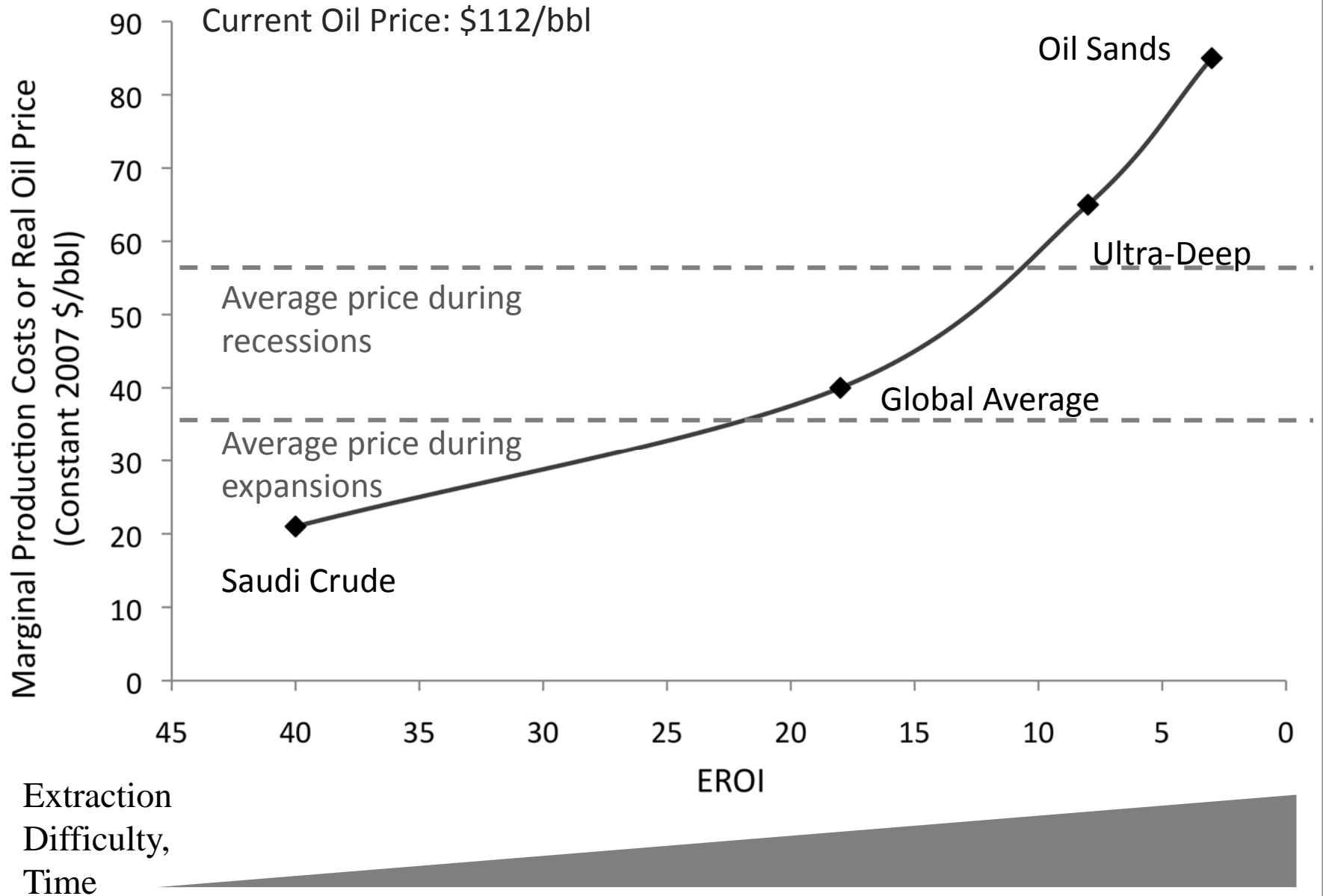
# EROI of Global Oil and Gas Production



# How does EROI relate to economic growth?



# Price and EROI

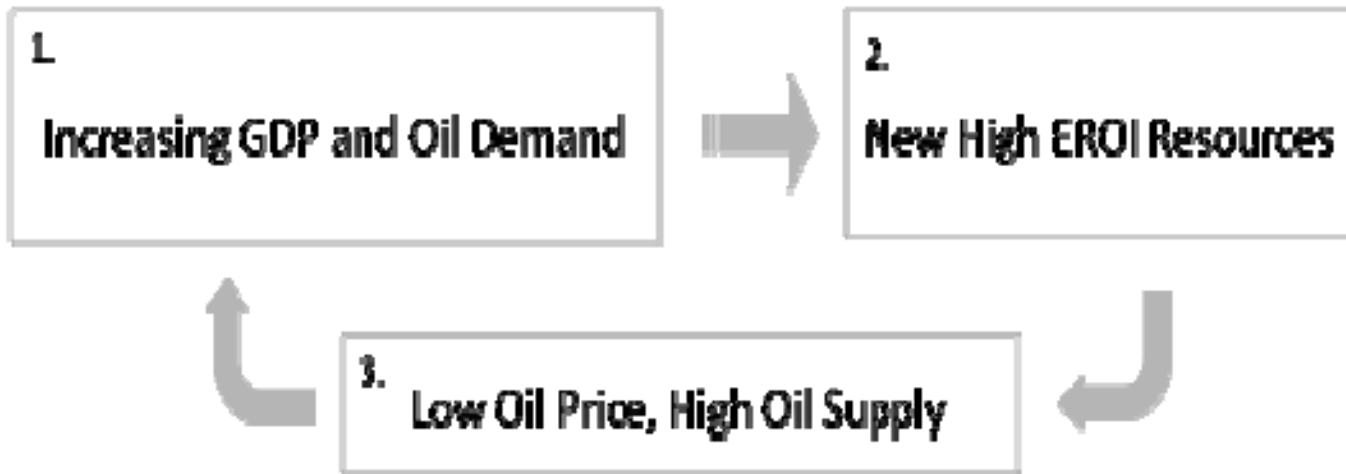


# What does all this mean for economic growth?

For the first time in the past 140 years we will try to grow the economy on a supply of oil that is declining in **quantity** and **quality**



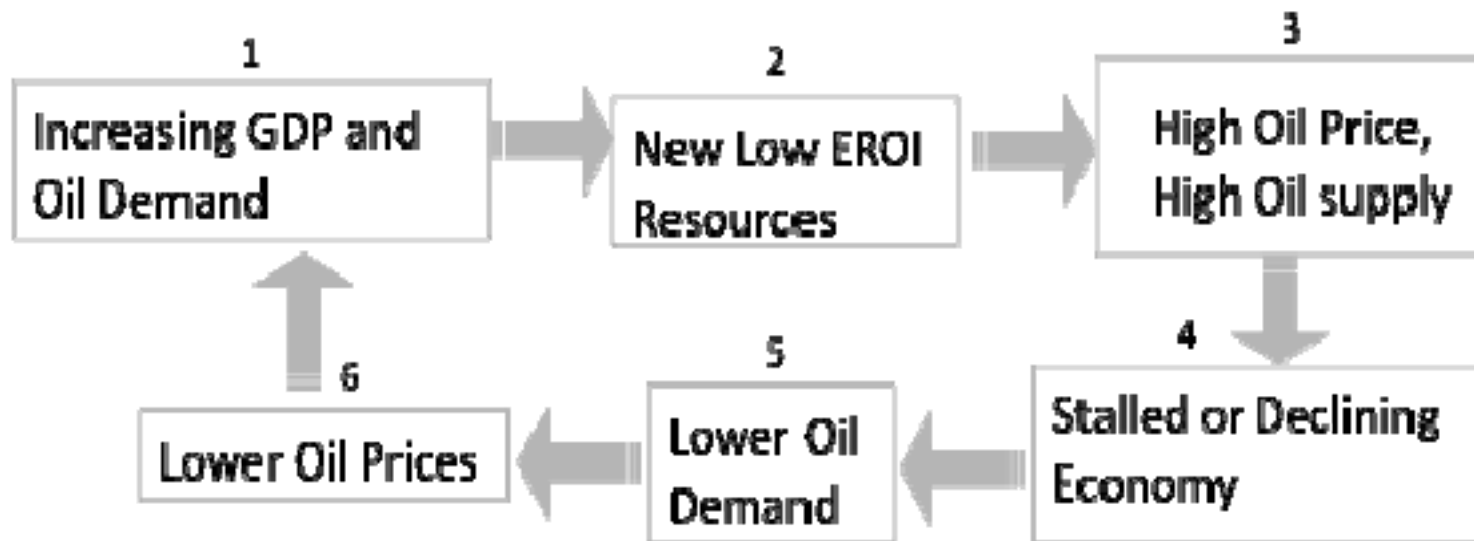
## Pre-Peak Model of Economic Growth



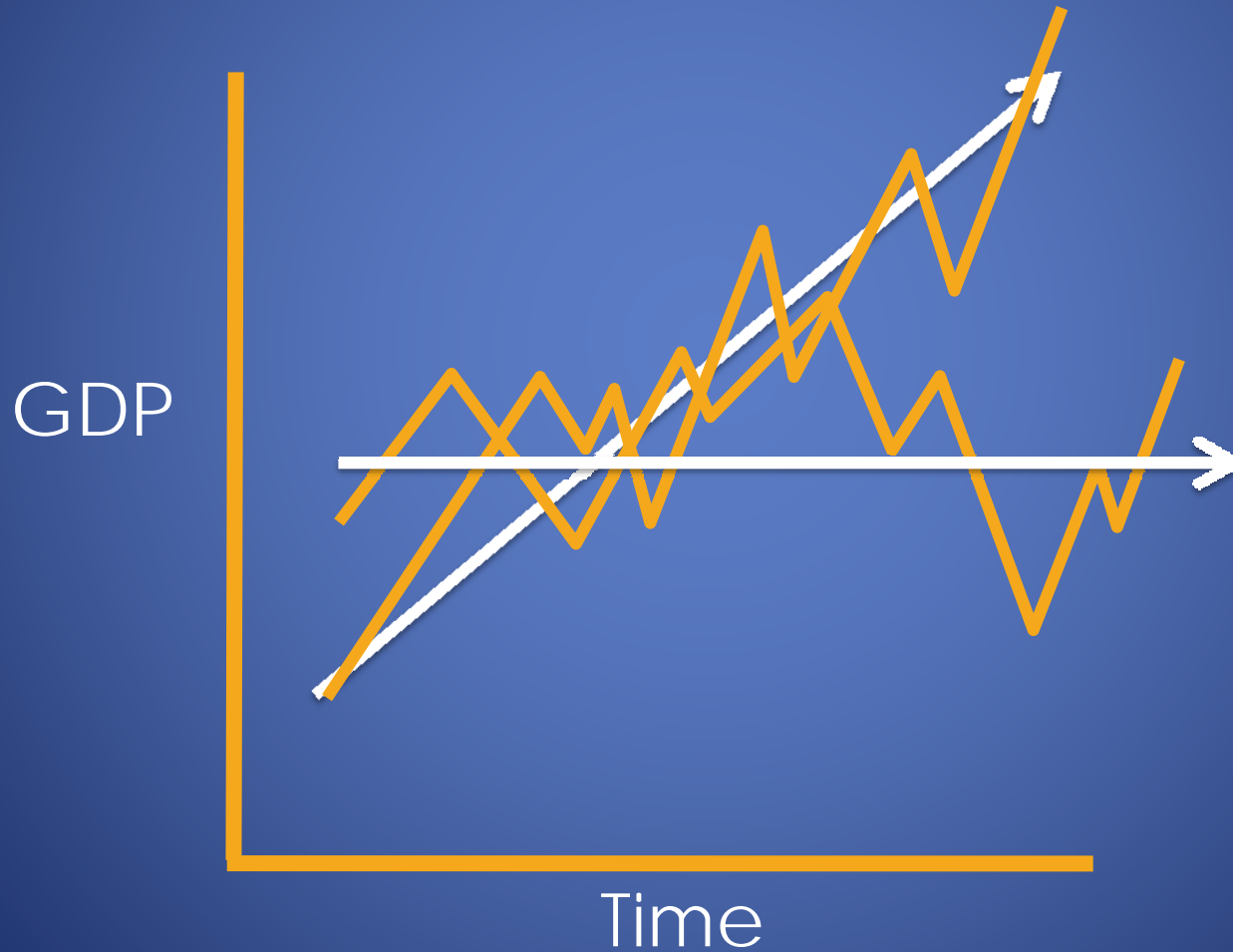
This model continued until resource extraction became difficult due to depletion



## Peak Era Model of Economic Growth

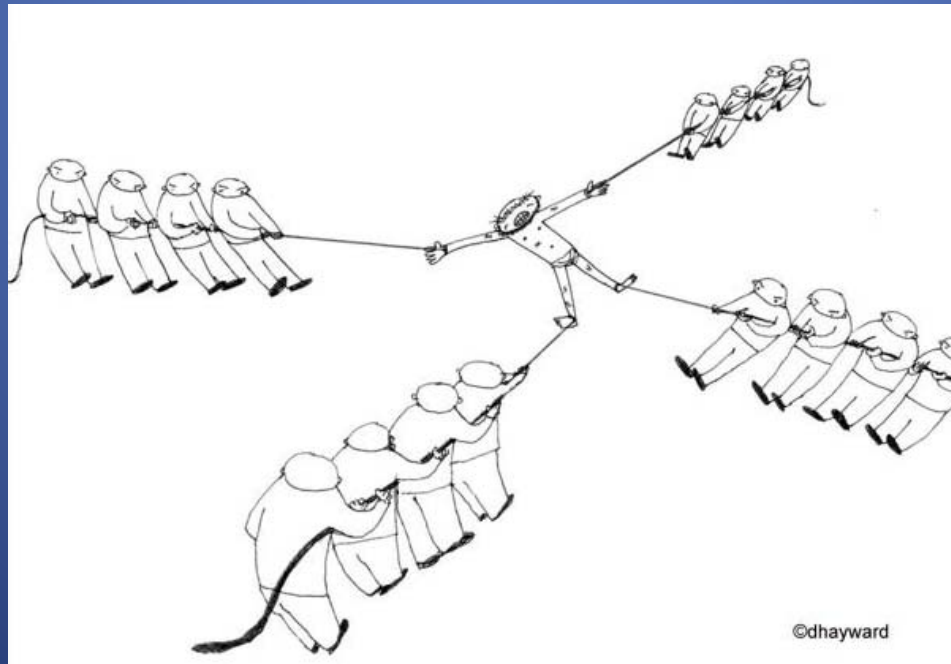


# Peak-Era Growth Model



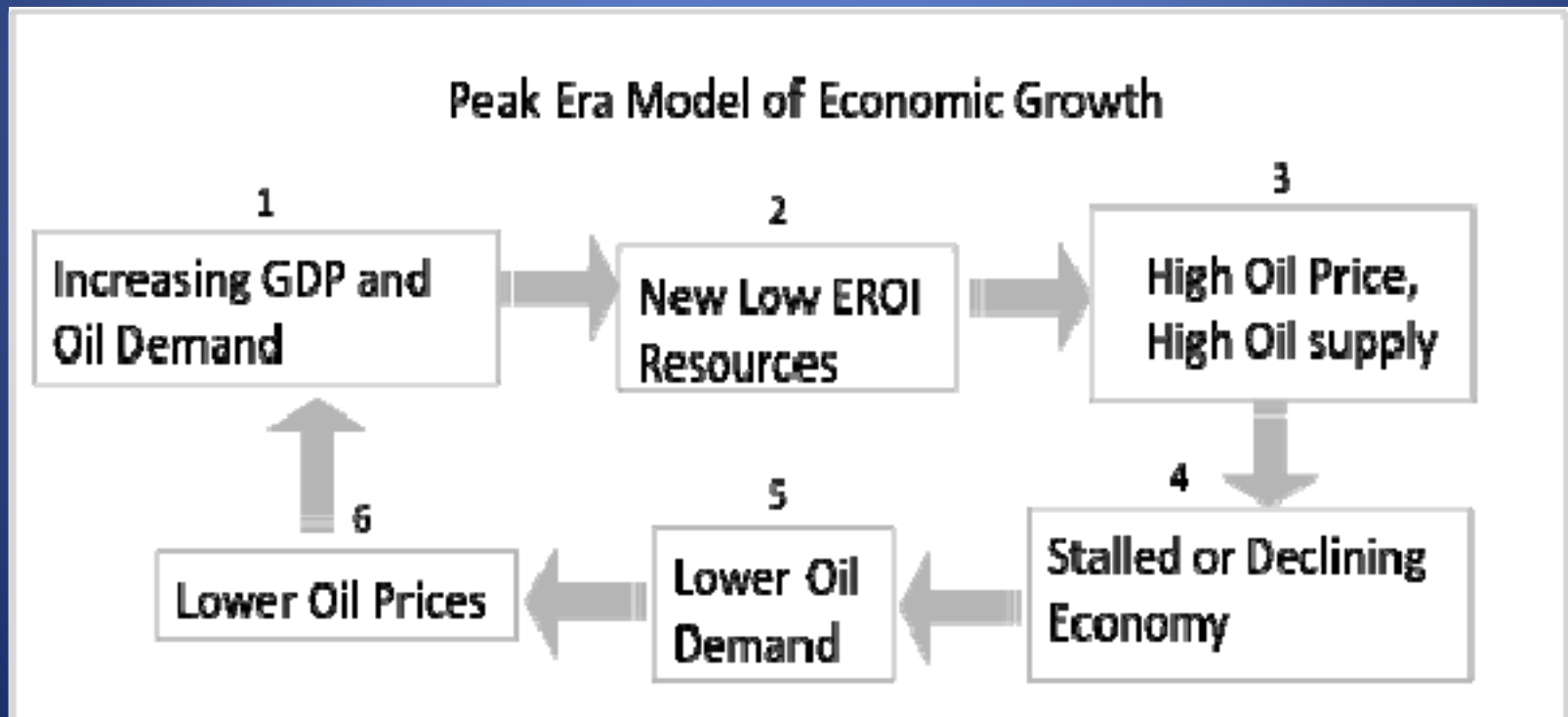
# A Growth Paradox?

- Maintaining business as usual economic growth will require the production of new sources of oil, yet the only sources of oil remaining require high oil prices, thus hampering economic growth

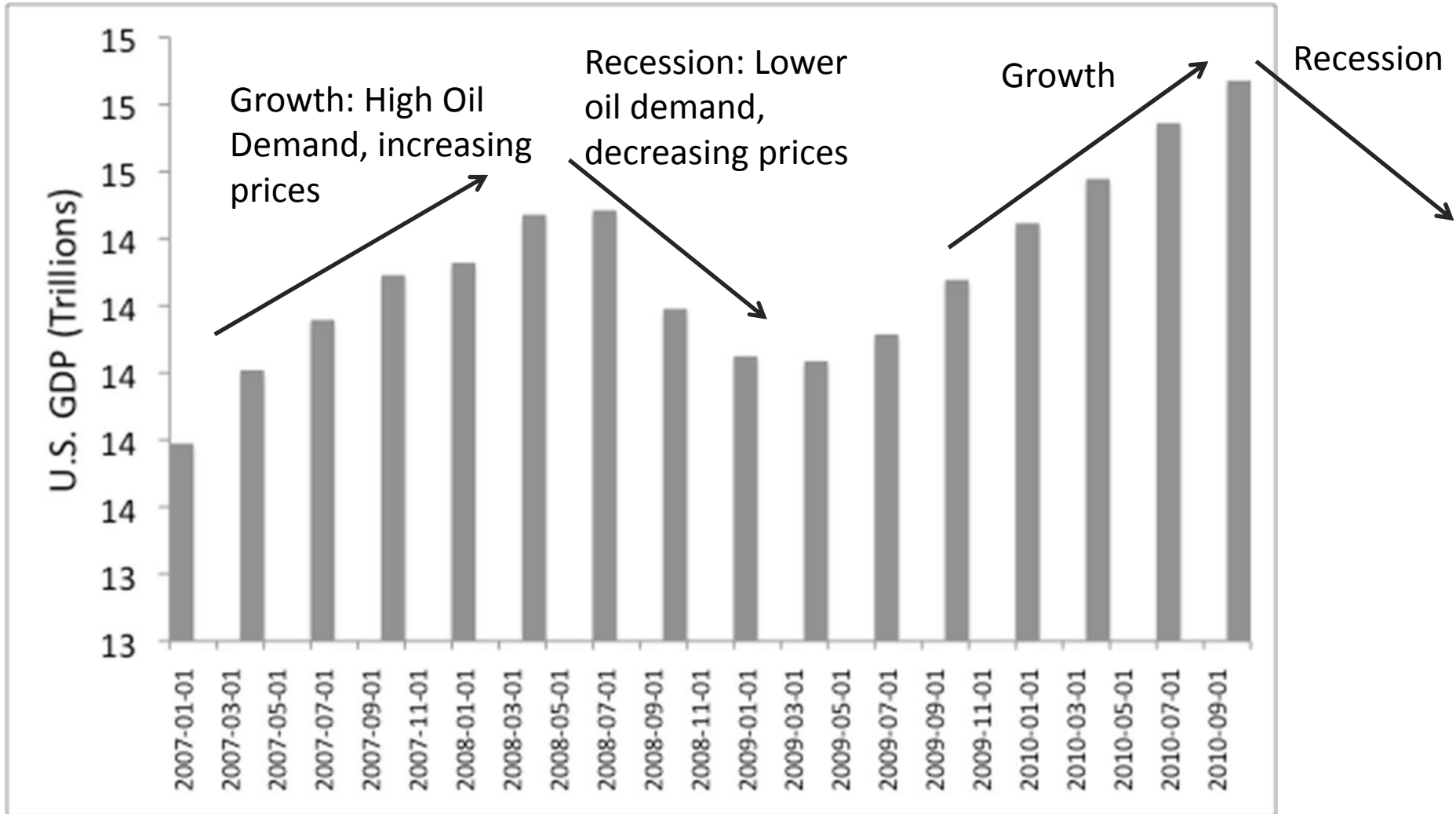


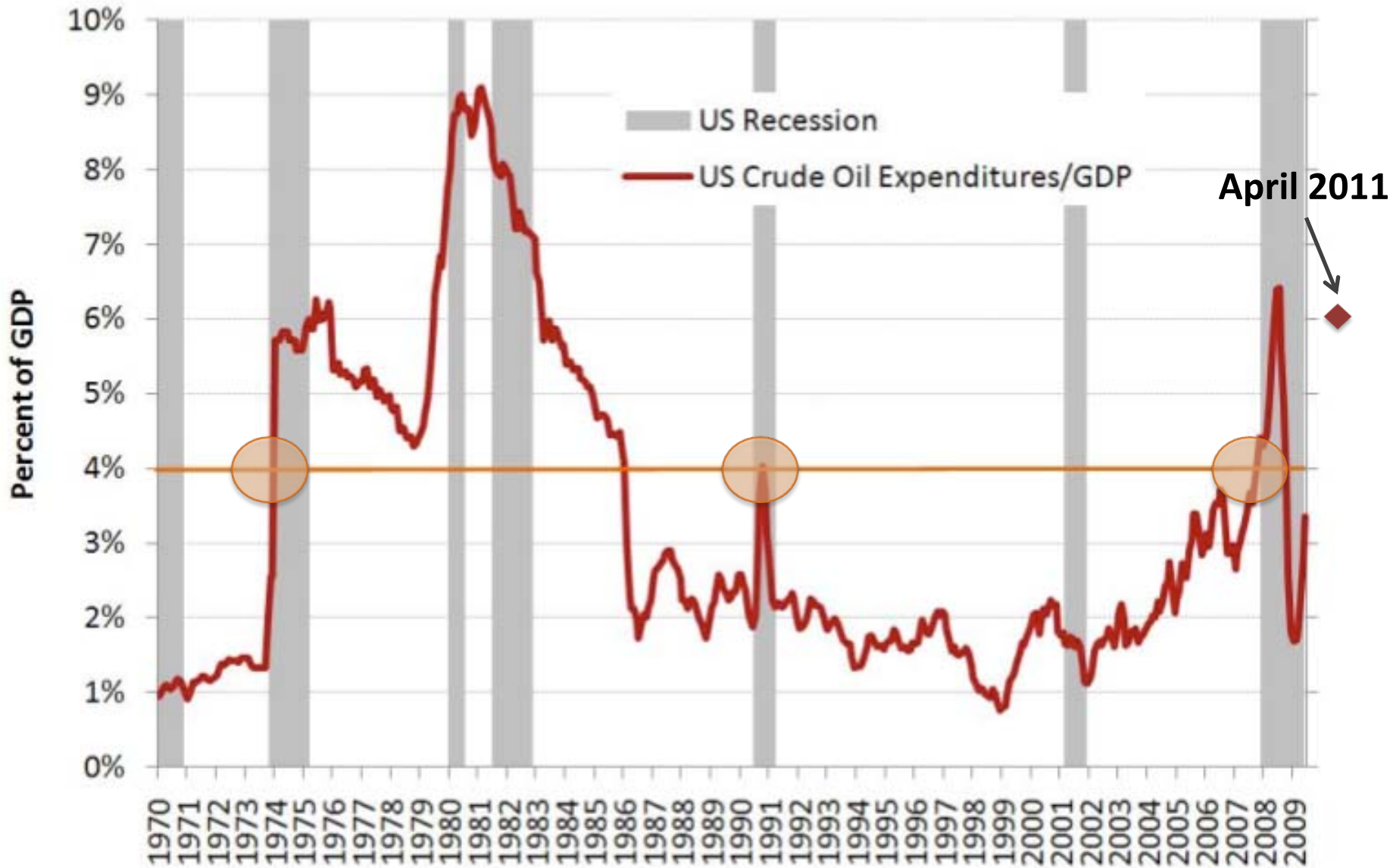
# Impacts of Peak-Era Growth Model

- Oscillations between growth and recession – i.e. the “Economic Undulating Plateau”



# The “Economic Undulating Plateau”

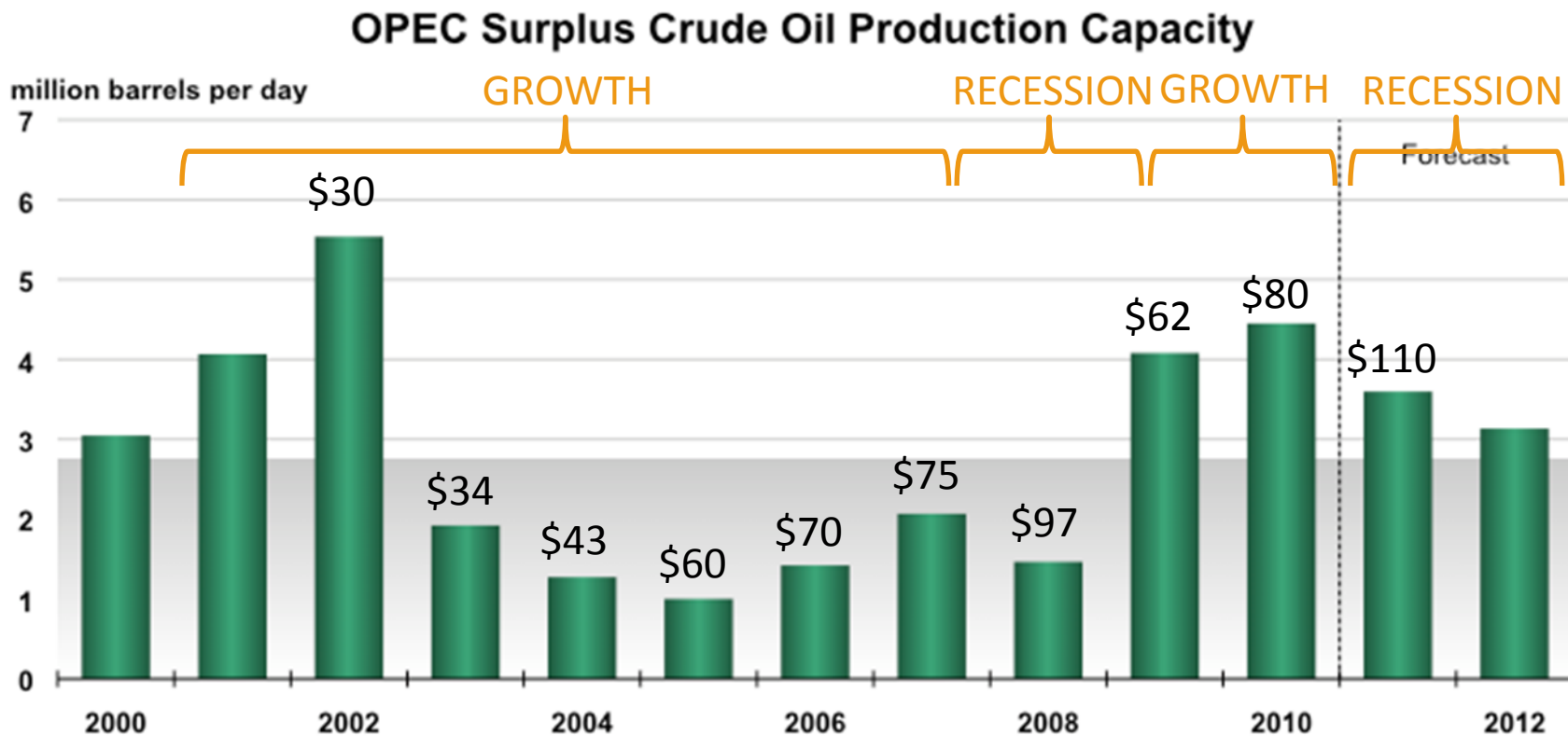




Source: EIA, NBER

...tends to occur around \$80/bbl

# Impacts of Peak-Era Growth Model



Note: Shaded area represents 2000-2010 average (2.8 million barrels per day)

Source: Short-Term Energy Outlook, April 2011



# Can Technology/Substitution Make a Difference?

- “As resources become scarce and relative costs change, substitutions will occur to ameliorate effects of diminishing returns”

Barnett and Morse, *Scarcity and Growth* (1963)

Resource	Year	Magnitude (EJ/yr)	EROI (X:1)
<b>Fossil fuels</b>			
Oil and gas	1930	5	>100
Oil and gas	1970	28	30
Oil and gas	2005	9	11 to 18
Discoveries	1970		8
Production	1970	10	20
World oil production	1999	200	35
Imported oil	1990	20	35
Imported oil	2005	27	18
Imported oil	2007	28	12
Natural gas	2005	30	10
Coal (mine-mouth)	1950	n/a	80
Coal (mine-mouth)	2000	5	80
Bitumen from tar sands	n/a	1	2 to 4
Shale oil	n/a	0	5
<b>Other nonrenewable</b>			
Nuclear	n/a	9	5 to 15
<b>Renewables</b>			
Hydropower	n/a	9	>100
Wind turbines	n/a	5	18
Geothermal	n/a	<1	n/a
Wave energy	n/a	<<1	n/a
<b>Solar collectors</b>			
Flate plate	n/a	<1	1.9
Concentrating collector	n/a	0	1.6
Photovoltaic	n/a	<1	6.8
Passive solar	n/a	n/a	n/a
<b>Biomass</b>			
Ethanol (sugarcane)	n/a	0	0.8 to 10
Corn-based ethanol	n/a	<1	0.8 to 1.6
Biodiesel	n/a	<1	1.3

Average EROI = 22  
(Oil, Imported Oil, Nat. Gas,  
Coal, Tar Sands, Shale Oil)

Nuclear = 5-15

Wind = 18 (ish)

Solar = 3.5

Biofuels = 1.2

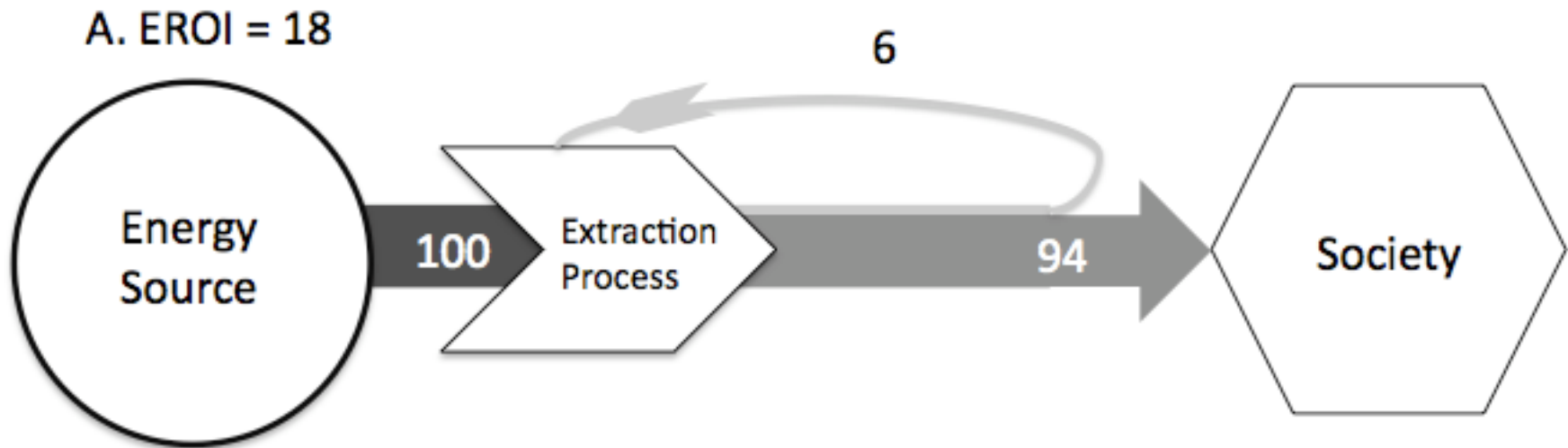
# Why is EROI Important?

Can corn ethanol substitute for gasoline?



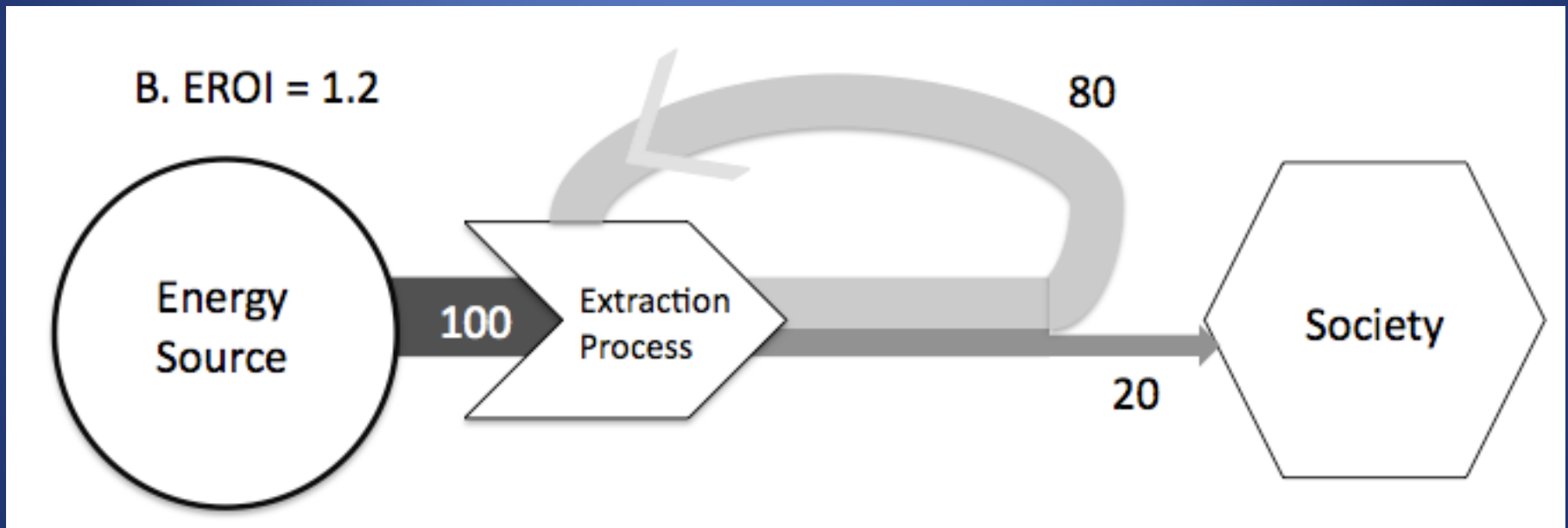
# A Tale of Two Systems: Oil vs. Ethanol

## HIGH EROI SYSTEM (Oil)



# A Tale of Two Systems: Oil vs. Ethanol

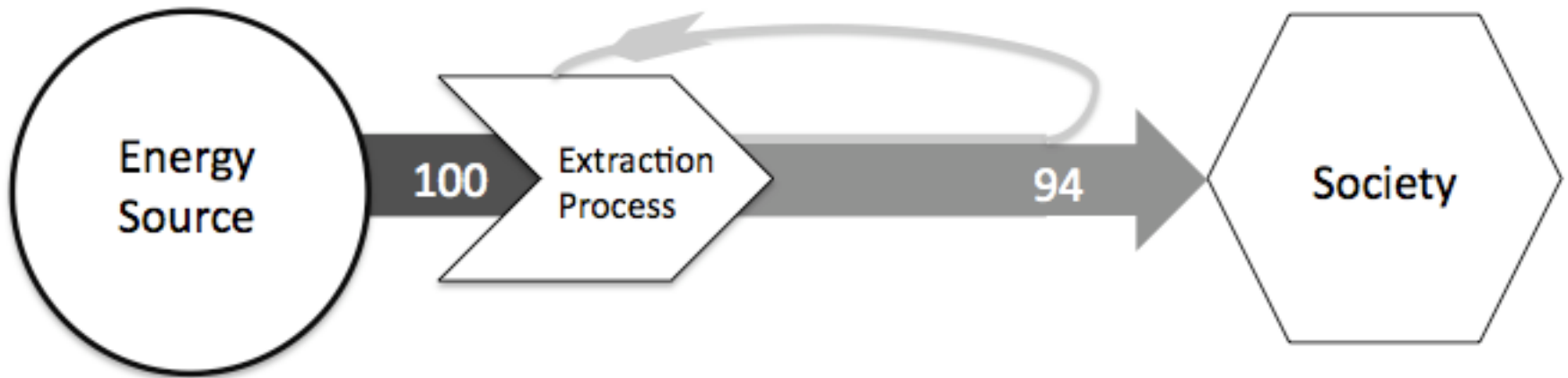
## LOW EROI SYSTEM (Ethanol)

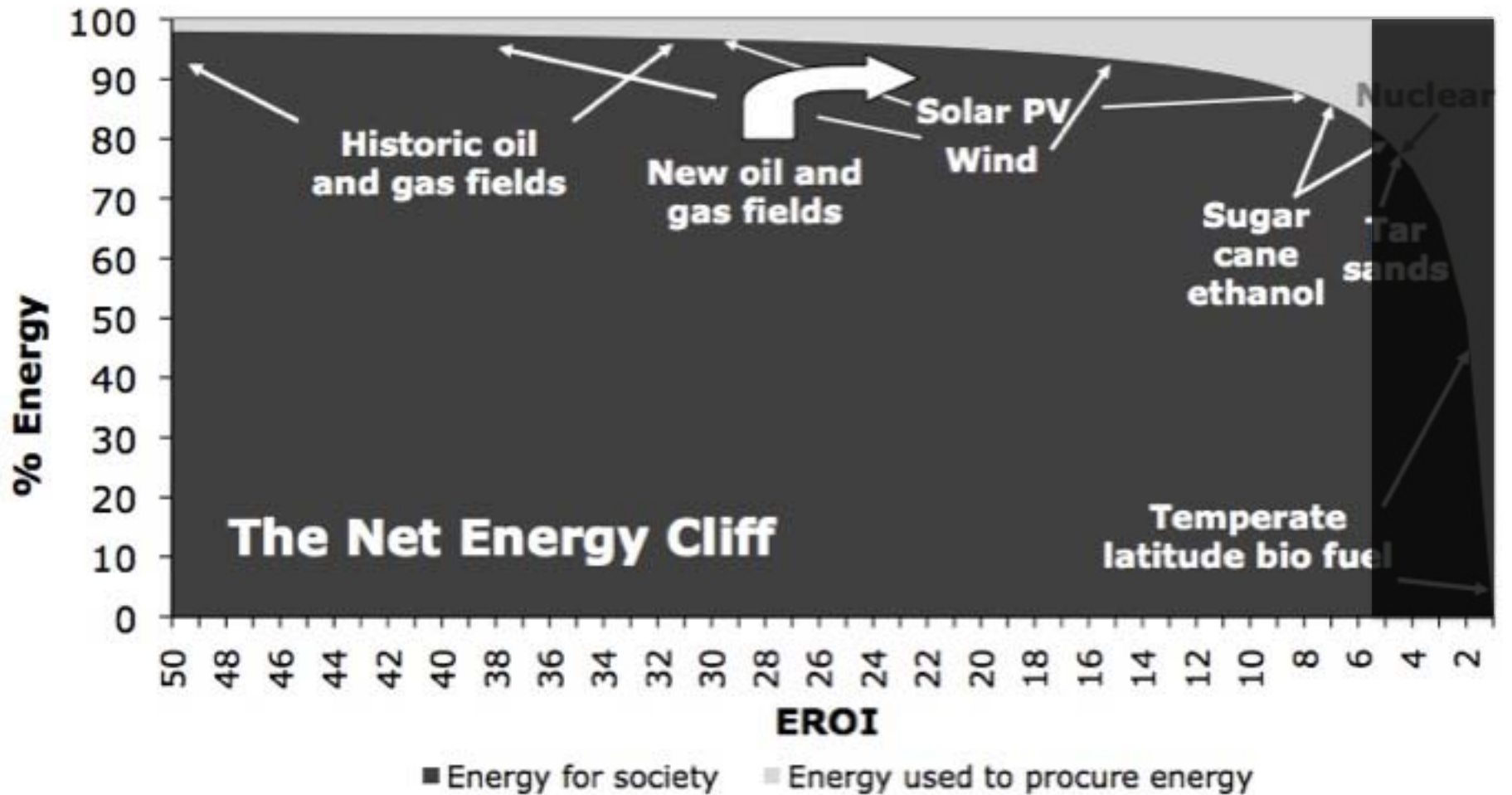


# Some alternatives have higher EROIs

## Wind and Natural Gas

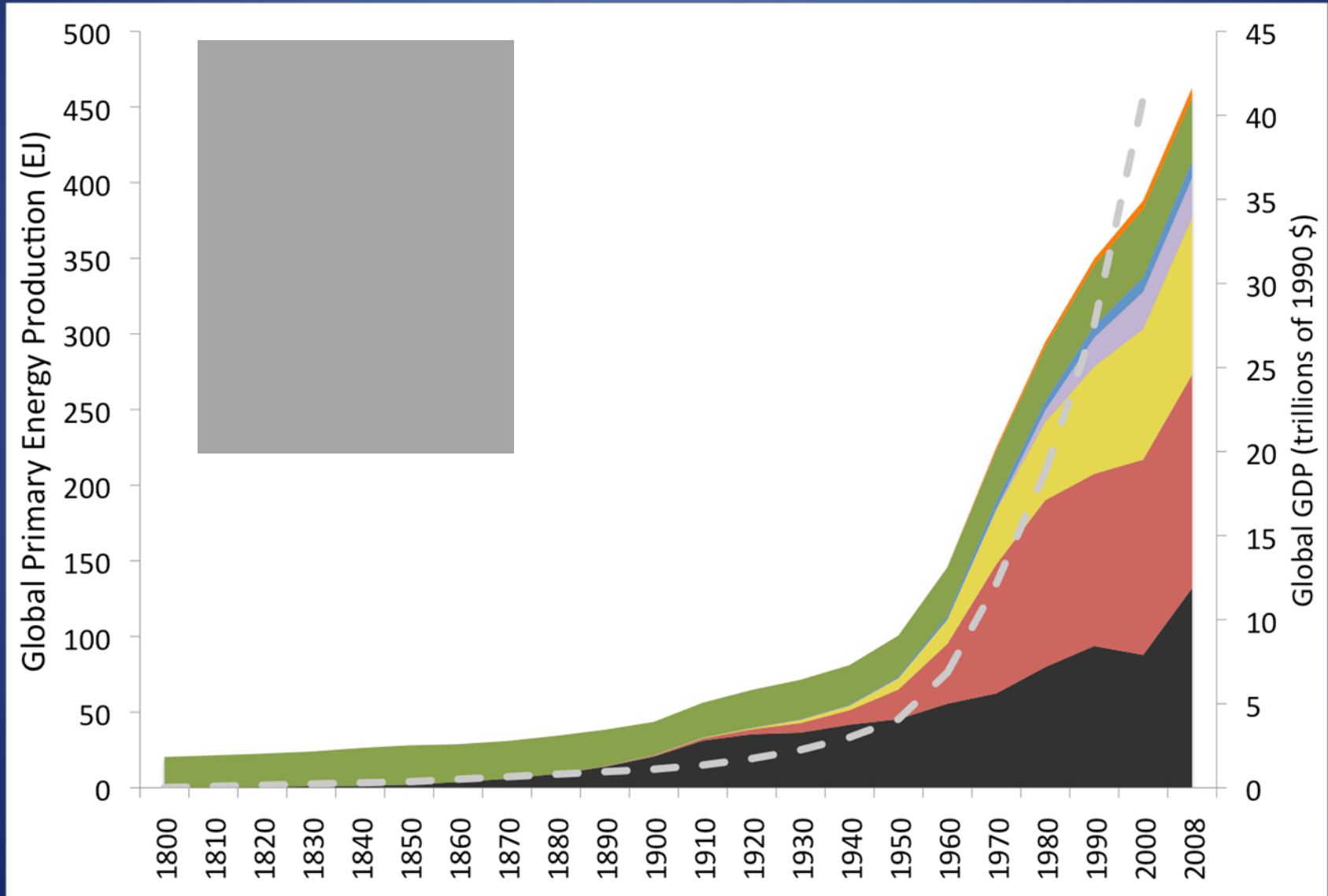
A. EROI = 18





# What is the scale of substitution?

## Can you spot the alternatives?



# What is the time scale for substitution?

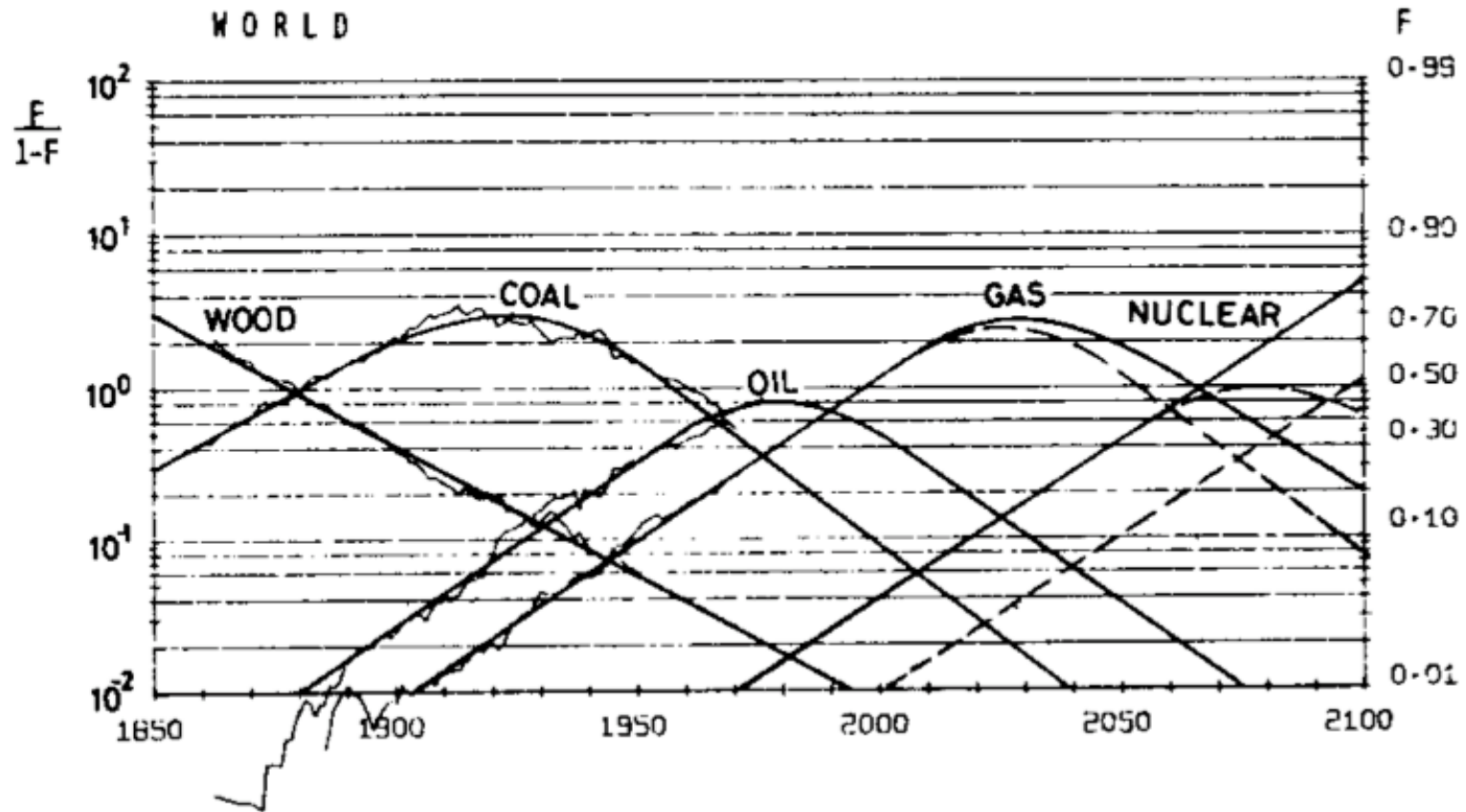


Fig. 7(a). Historical evolution of the primary energy mix for the *world*. Wiggling lines are statistical data, smooth lines computed. Some values for the actual market fractions are given on the right side of the figure. The effect of introducing a new source of primary energy (1% in year 2000), solar, fusion or else, is indicated by the dashed lines. This effect appears minimal on conventional sources, and dramatic only on nuclear, but in the second half of the next century.

# Final Thoughts

- Economic Growth as we know it has required increasing supplies of cheap oil
- Peak oil and declining EROI have created a growth paradox
- The growth paradox will likely cause the economy to oscillate between growth and recession in the short term
- In the long term, substitution will help, but this will be a very slow transition
- Alternatives are the future, but we must choose them wisely, and EROI can help
- Of course the easiest option is to simply consume less energy...

# Demand: An Ace in the Hole!

- The average European consumes half the energy of the average American
- Half of our oil consumption ~ 9 mbpd (roughly 10% of global production)

# Thanks!

## Questions/Comments?

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