



**INTERNAL AND BIOPHYSICAL LIMITS
TO GROWTH IN THE SECOND HALF OF
THE AGE OF OIL**

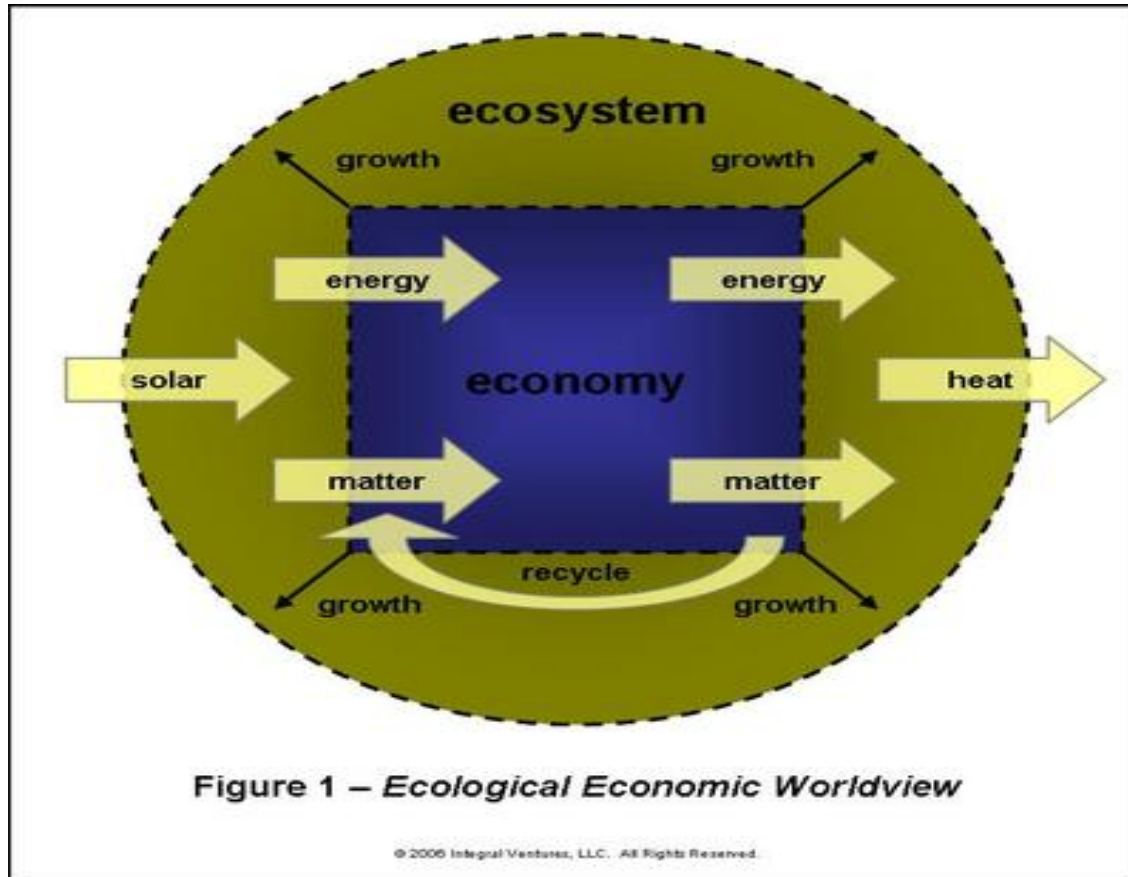
**Kent A. Klitgaard
Wells College
Aurora, New York, USA**

THE DILEMMA OF ECONOMIC GROWTH

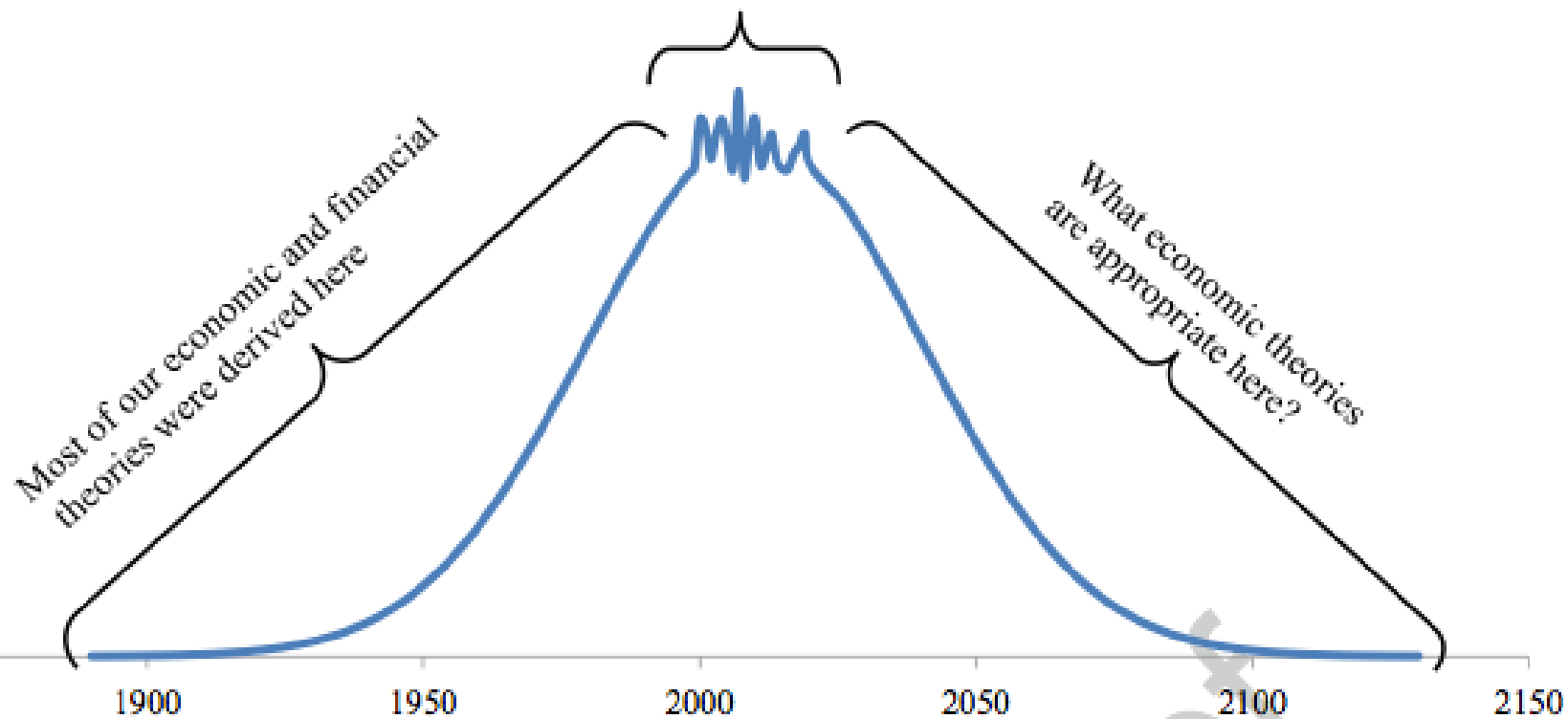
- Are We growing too fast and too slowly at the same time?
- Too fast to reduce carbon emissions?
- Too slowly to reduce unemployment and poverty?



LIMITS TO GROWTH AND THE BASIC ECOLOGICAL ECONOMICS MODEL



Current U.S. and Global Oil/Energy Situation



I. DEFINITION OF EROI (SOMETIMES EROEI)

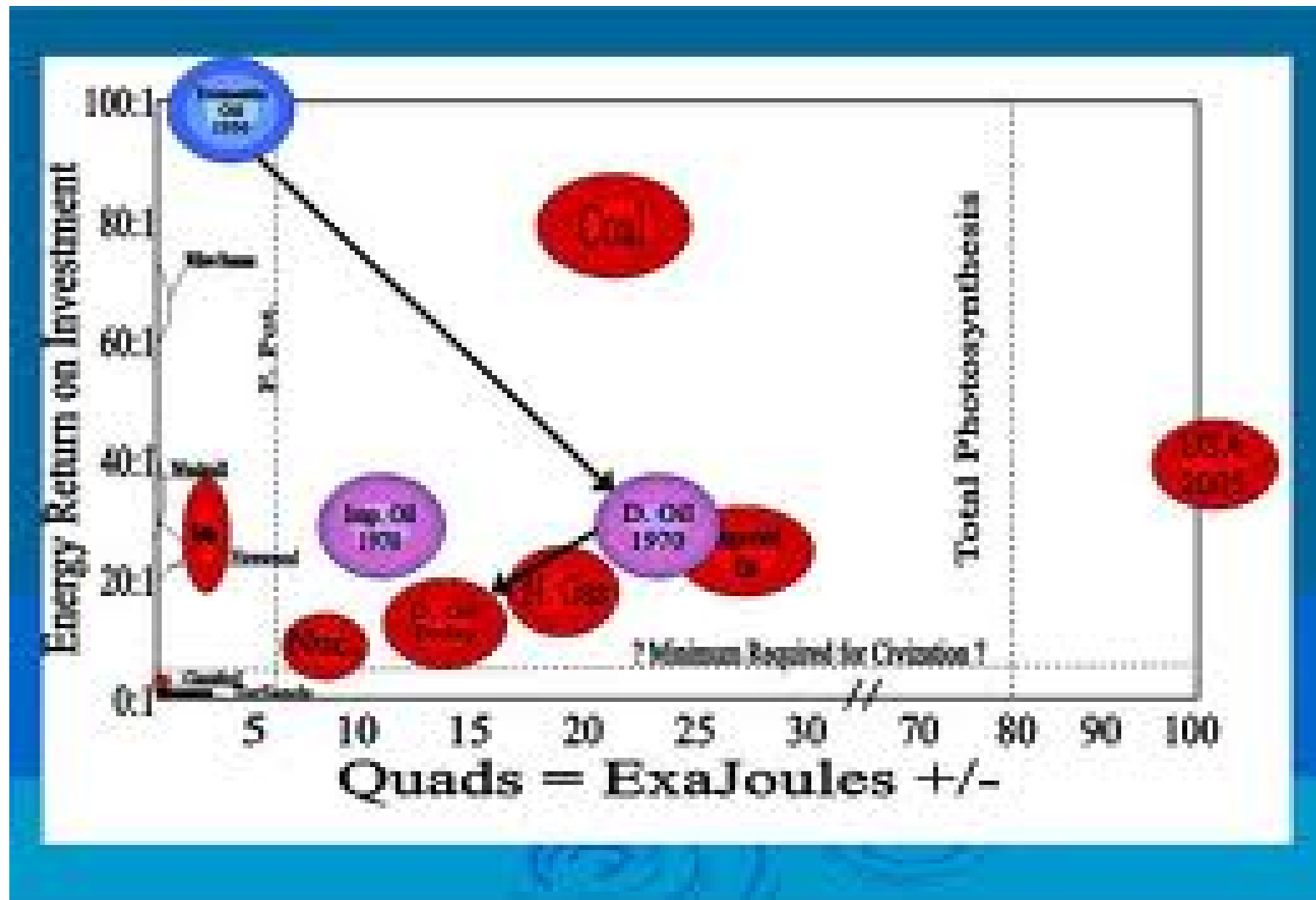
Energy return on investment for an activity:

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

Usually consider energy invested *from society*



DECLINING EROI



ECONOMIC THEORIES OF SECULAR STAGNATION

- A Fossil Fuel-Driven Economy (with a large energy surplus) Produces a large economic surplus
- $ES = \text{Value of Output} - \Sigma$ (subsistence consumption + replacement investment)
- This surplus seeks investment
- Inability to absorb surplus leads to short-term recessions and long-term stagnation (slow growth)
- Statistical Trace: unemployment and excess capacity

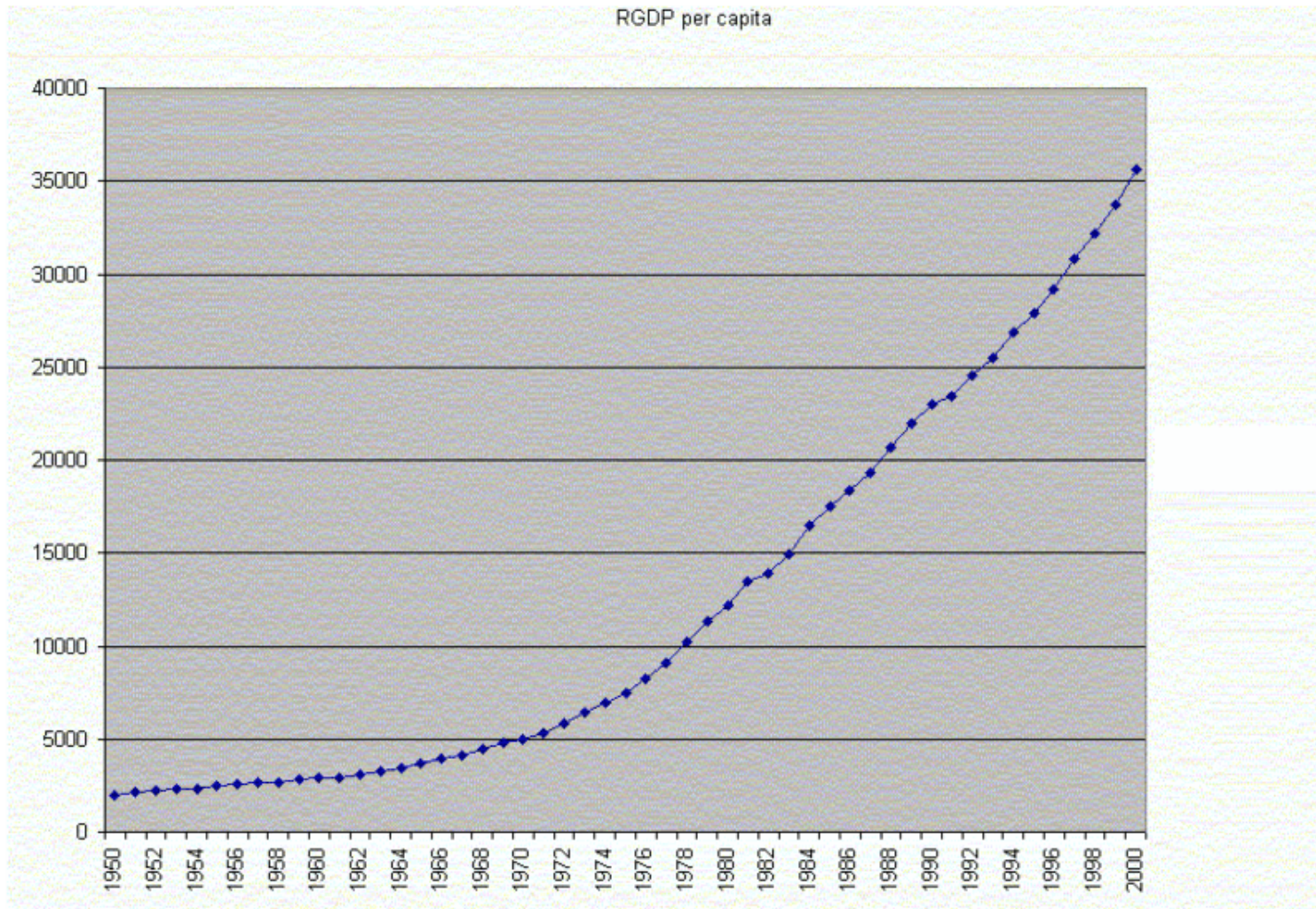


EXPLANATIONS OF PERIODS OF PROSPERITY

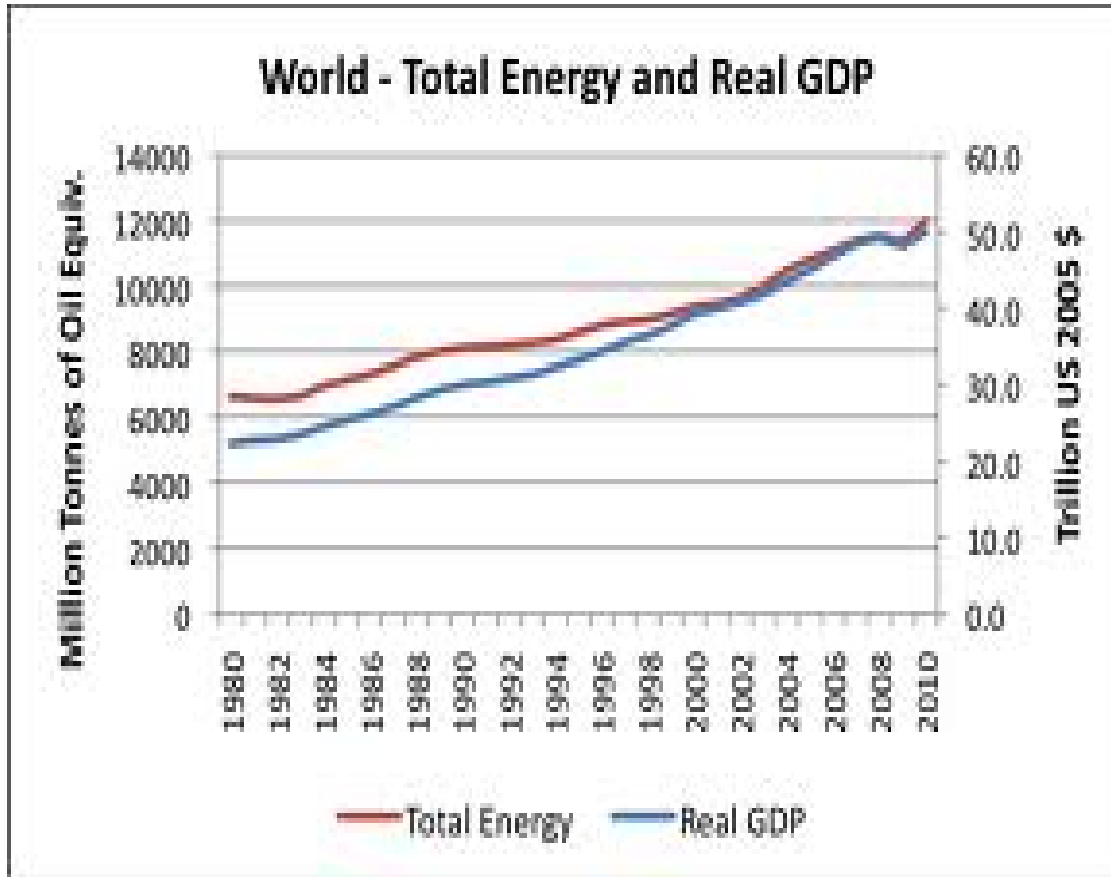
- 1. Epoch-making Innovations
 - -Absorb large amounts of economic surplus
 - -spin-off industries
 - -Examples
 - --steam engine
 - --railroad
 - --automobile
 - ----all fossil-fuel intensive
- 2. War and its aftermath



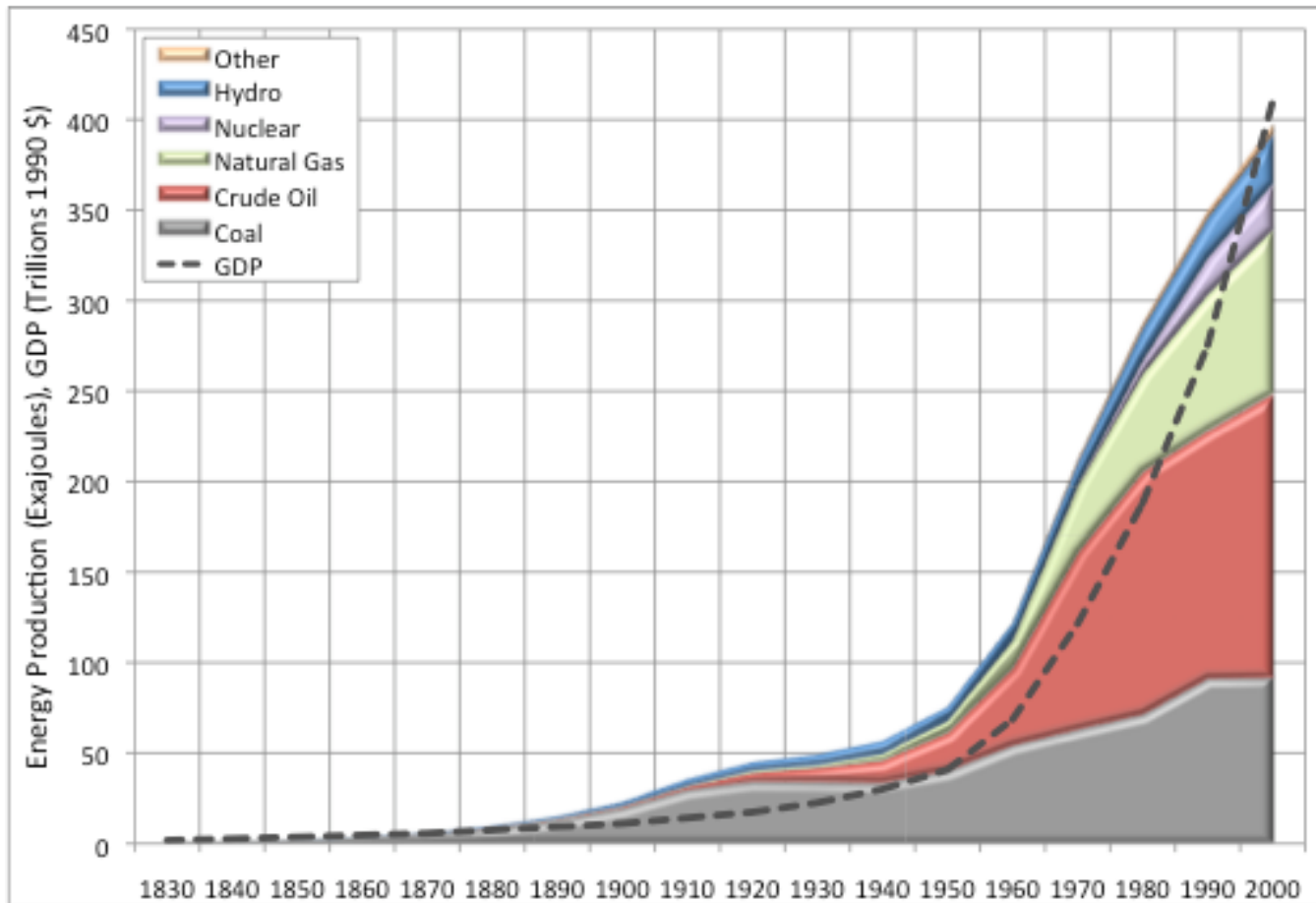
REAL GDP GROWTH



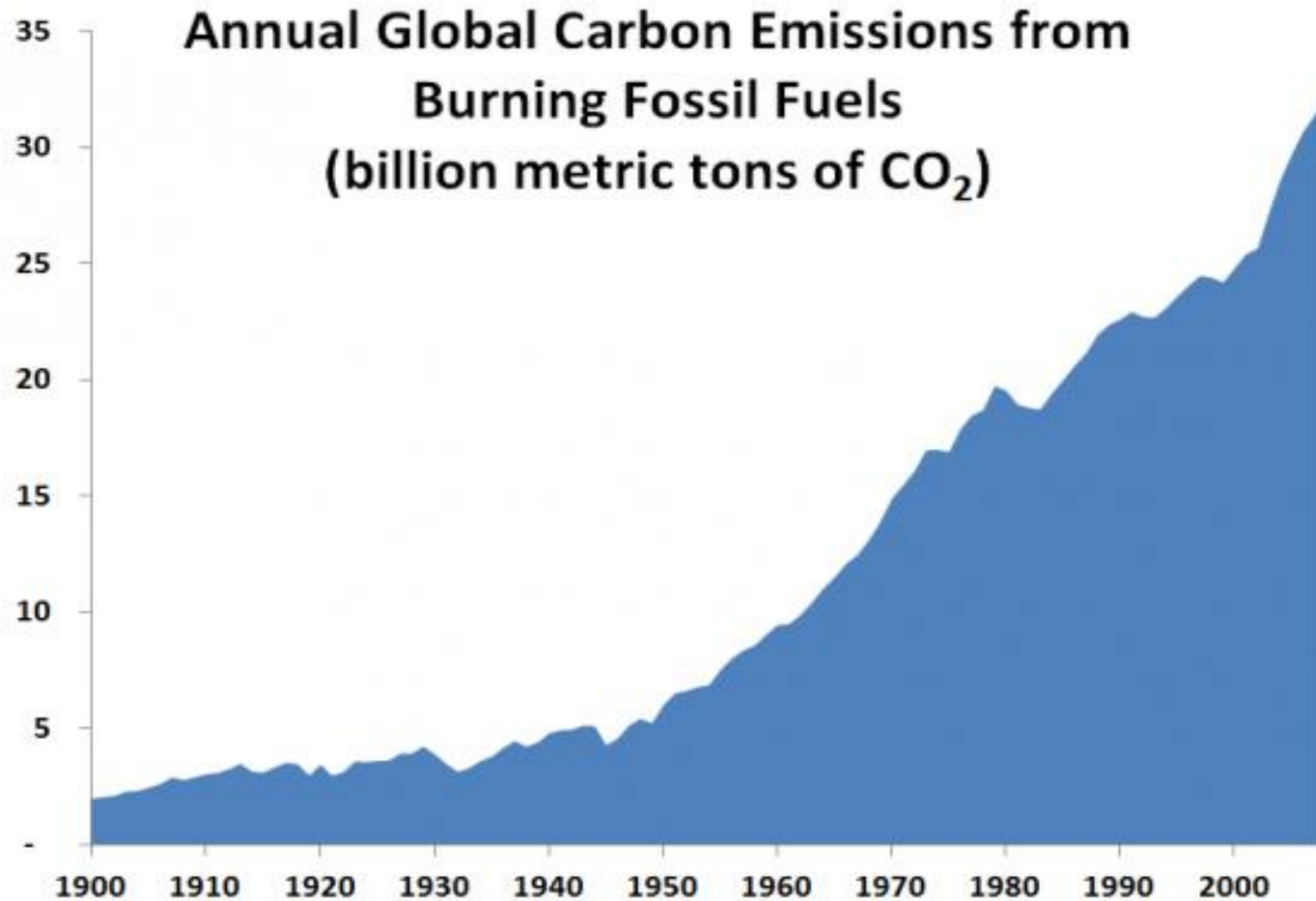
ENERGY AND GDP GROWTH



GDP AND THE ENERGY MIX



CARBON DIOXIDE EMISSIONS

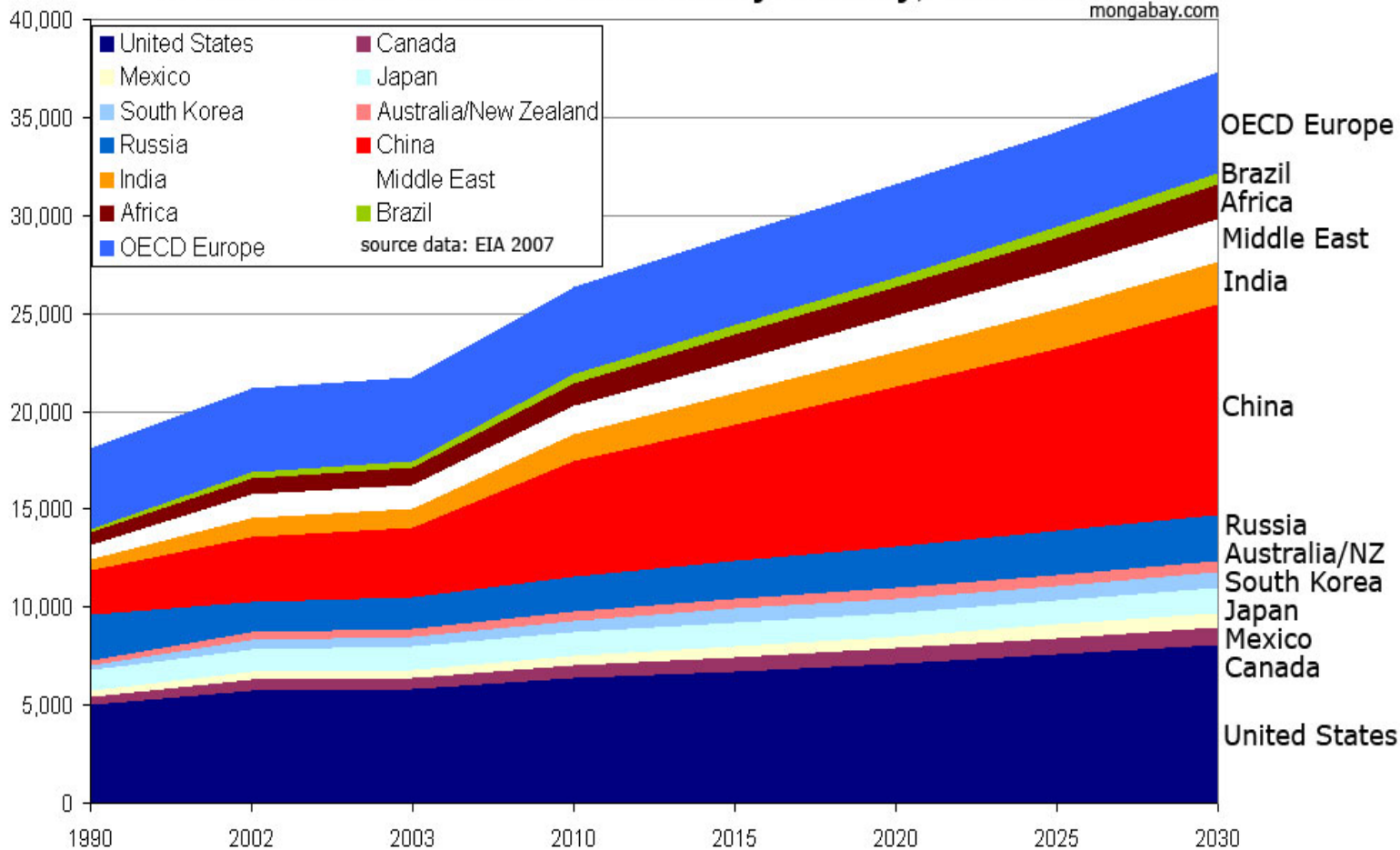


Data Source: U.S. Department of Energy, Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov/trends/emis/tre_glob_2008.html

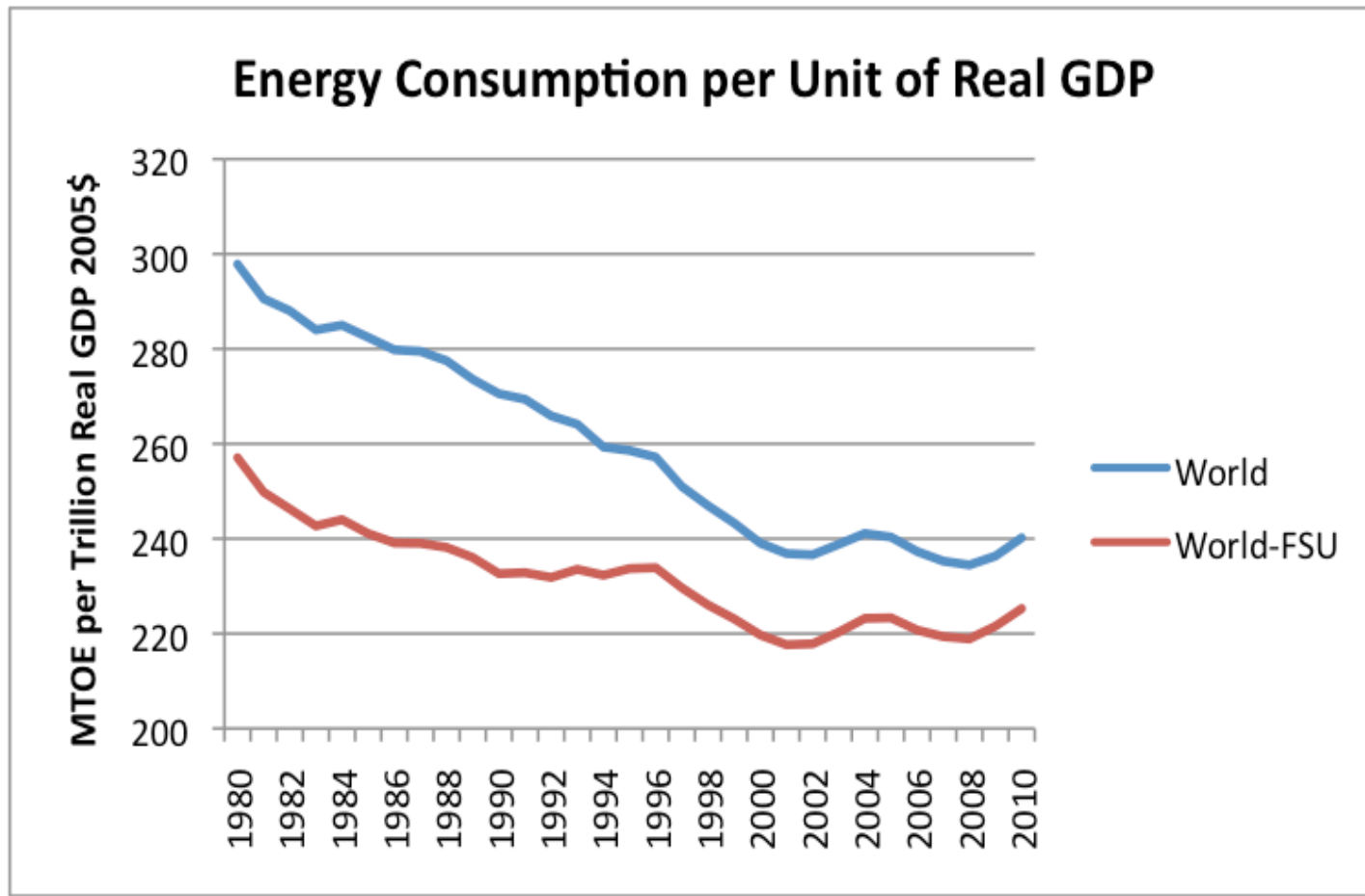


CARBON DIOXIDE EMISSIONS BY COUNTRY

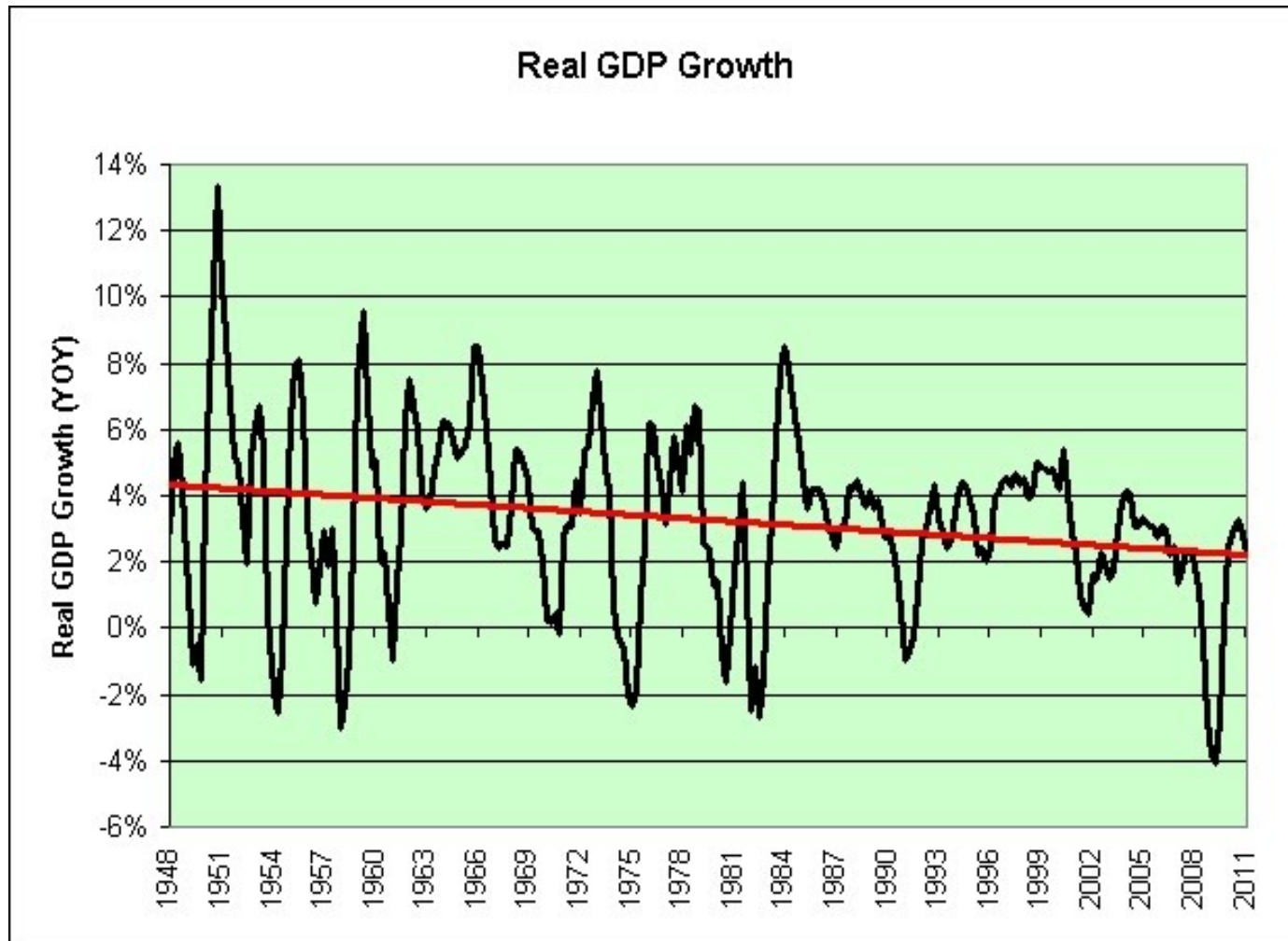
World Carbon Dioxide Emissions by Country, 1990-2030



CARBON EMISSIONS PER UNIT OF GDP



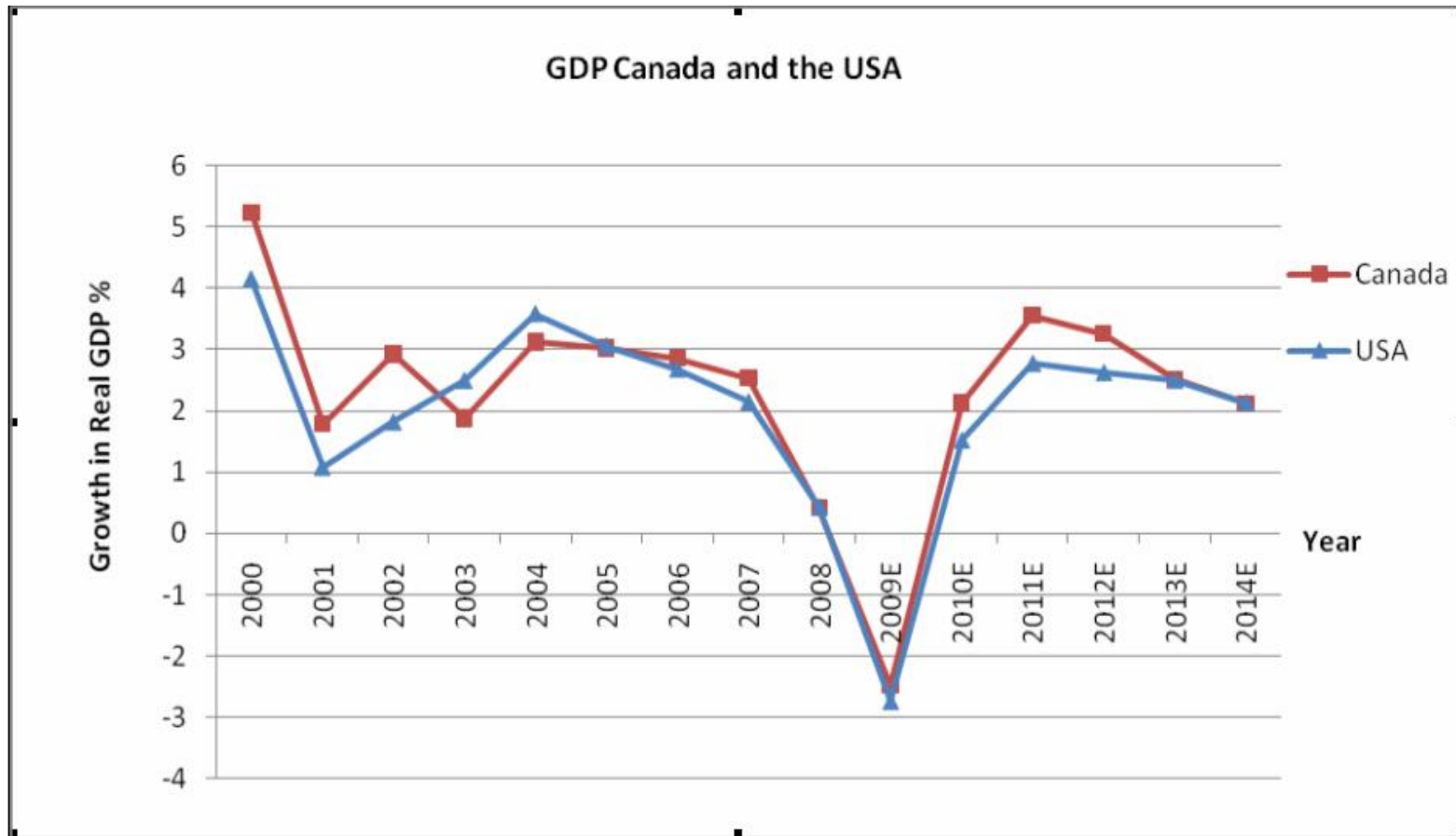
PERCENTAGE CHANGE IN GDP



PERCENTAGE CHANGE IN GDP: US & MEXICO



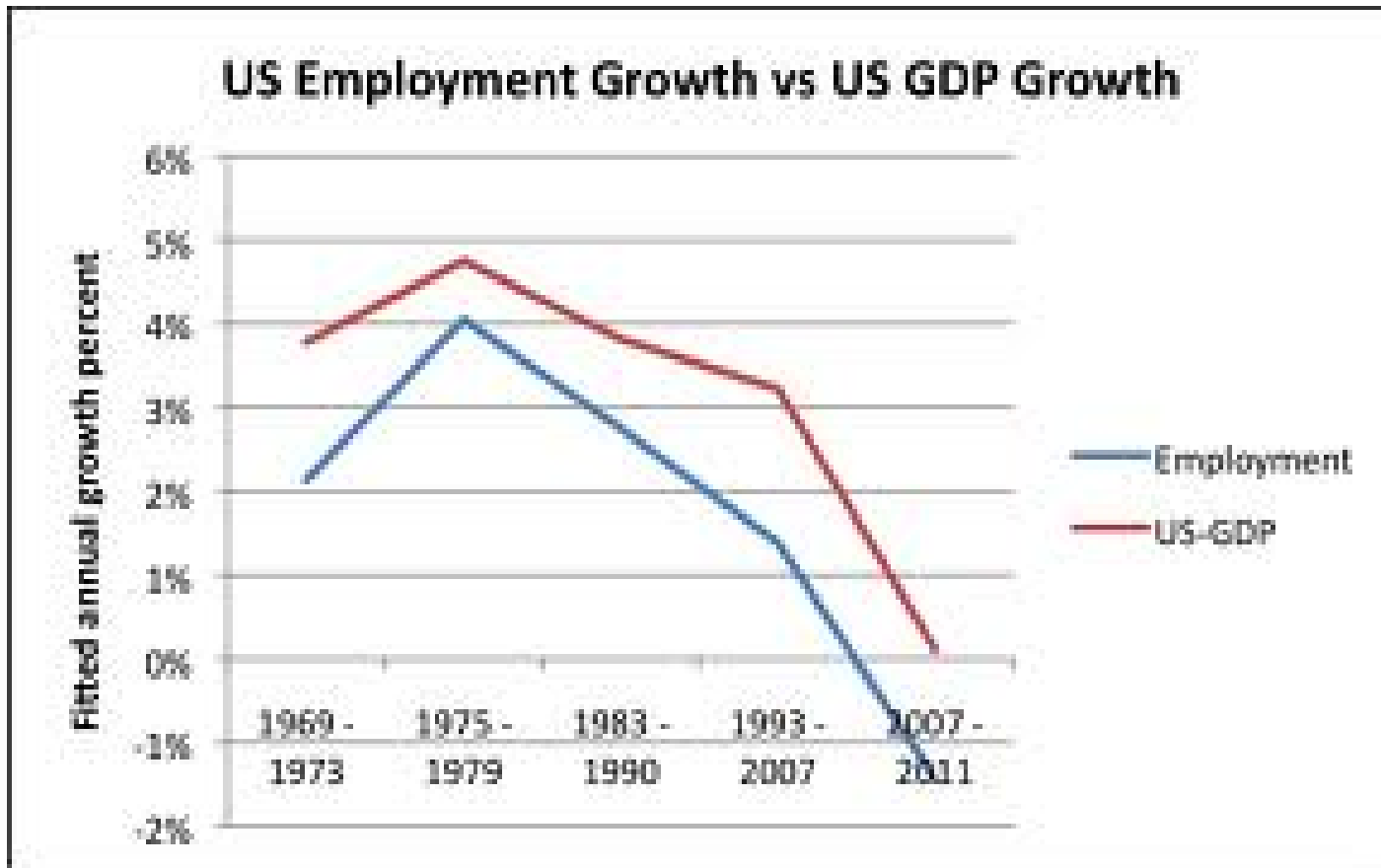
PERCENT CHANGE IN GDP: US AND CANADA



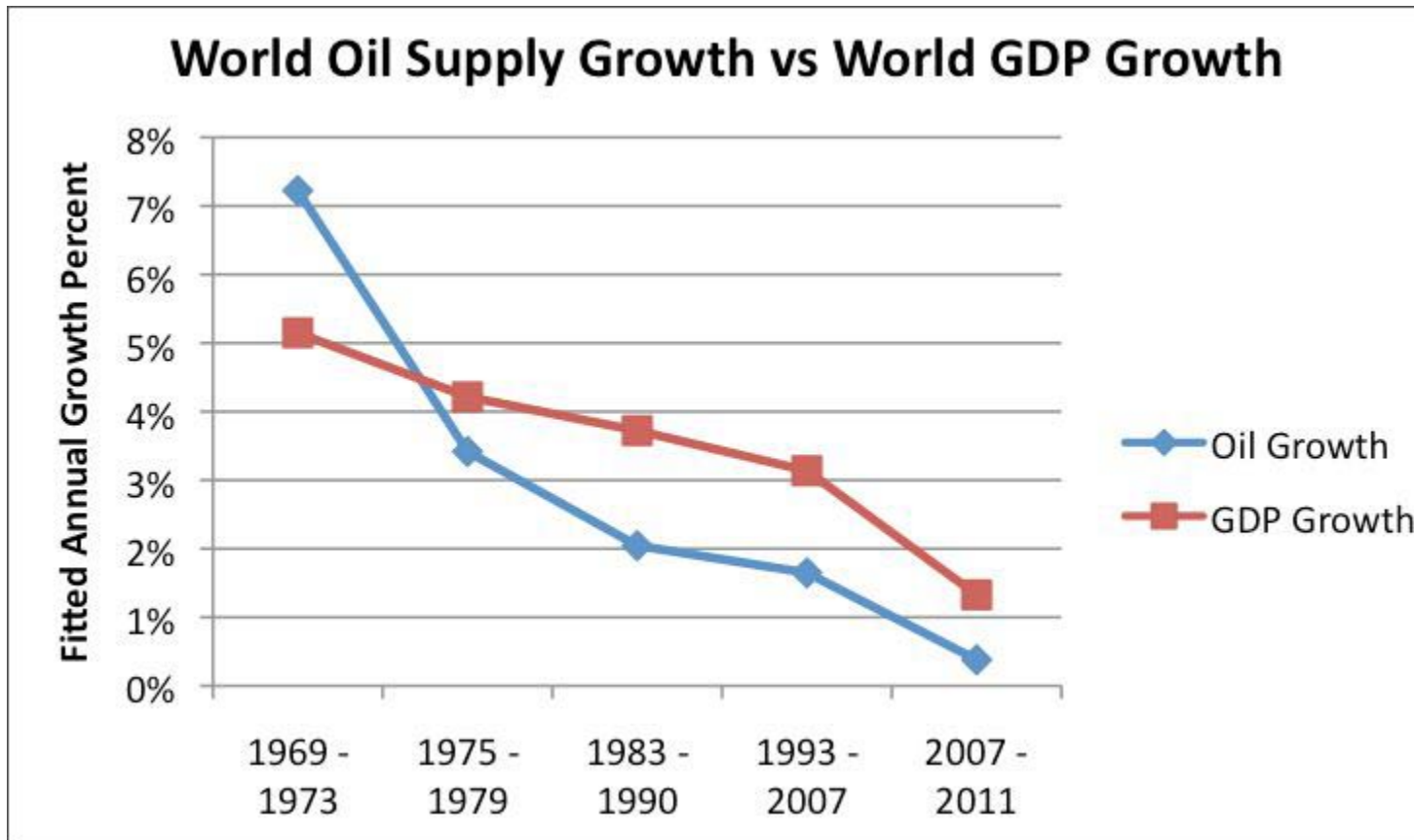
Source: IMF website



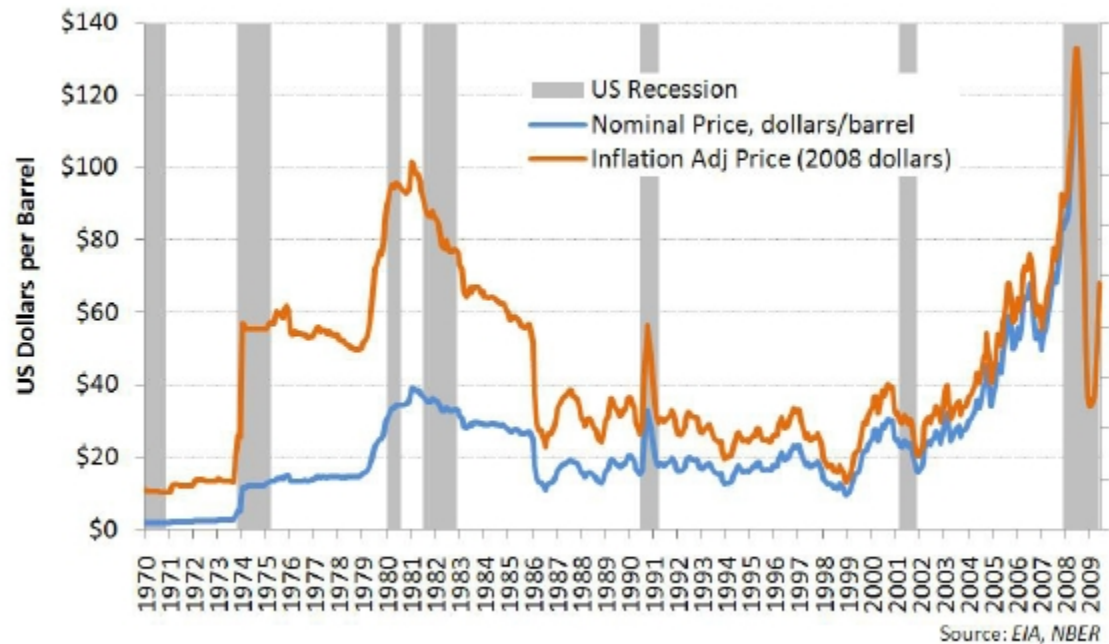
EMPLOYMENT AND GDP GROWTH



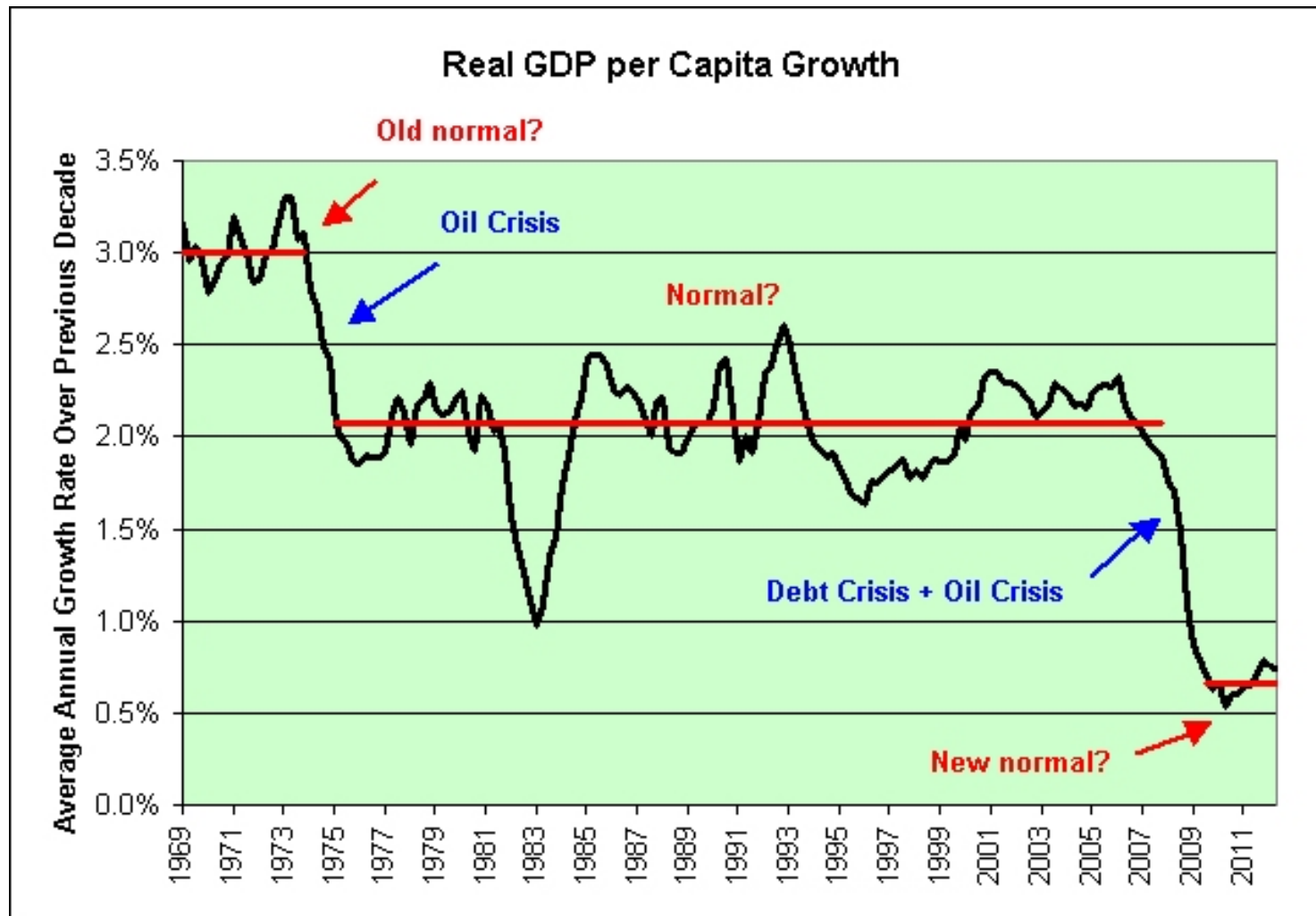
PERCENTAGE GROWTH IN GDP AND ENERGY



OIL PRICES AND RECESSIONS



THE NEW NORMAL?



A PRESCIENT QUOTE?

- *“When we, systems dynamicists, see a pattern persist in many parts of a system over long periods, we assume that it has causes embedded in the feedback loop structure of the system. Running the same system harder or faster will not change the pattern as long as the structure is not revised”*
 - *--Donnella Meadows, Dennis Meadows & Jorgen Randers*
 - *The Limits to Growth 30 Year Update*



WHAT STRUCTURAL CHANGES CAN NORTH AMERICA BRING ABOUT?

- Smaller scale, more local production
- Limits to speculative finance
- Work sharing
- More equality (internationally and intranationally)
- Getting by on less energy
- Sustainability can be neither Soviet-style heavy industry nor globalized monopoly finance capitalism

