



Energy and the Economy: Twelve Basic Principles in a Finite World



Gail E. Tverberg, October 10, 2014

A finite world works differently from one without limits



We are familiar with the problem with maps.
But how about economics?

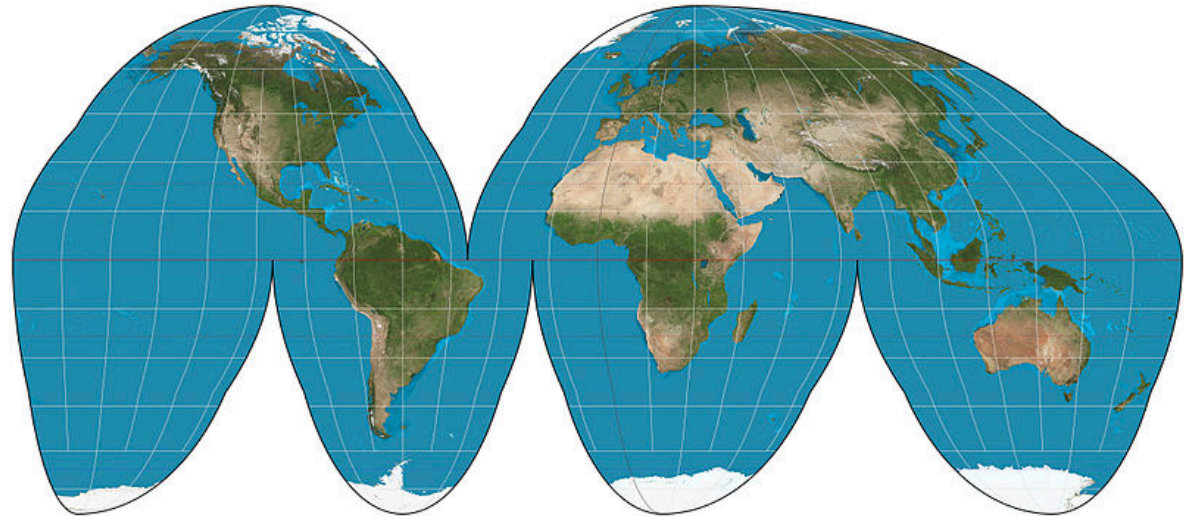
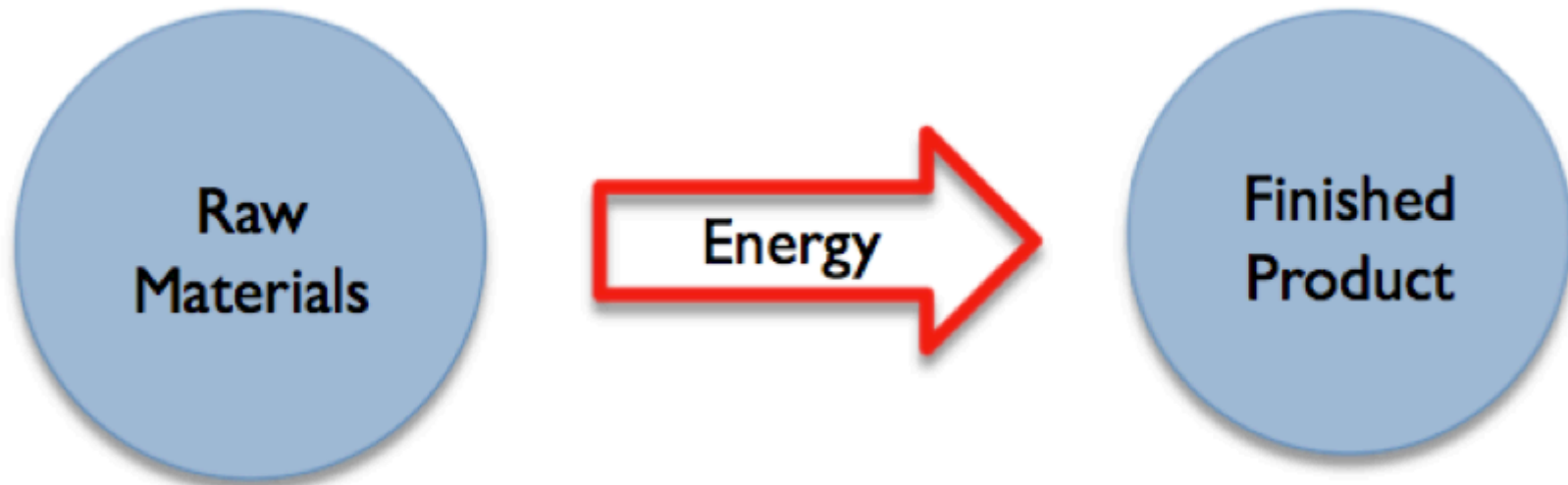


Image source: Wikipedia

Principle 1. Energy and physical resources are integral to the economy.



- ▶ Energy transforms raw materials (resources) to finished products

Examples of kinds of energy:



Human
\$\$\$\$\$\$\$\$\$\$\$\$



Electricity
\$\$\$



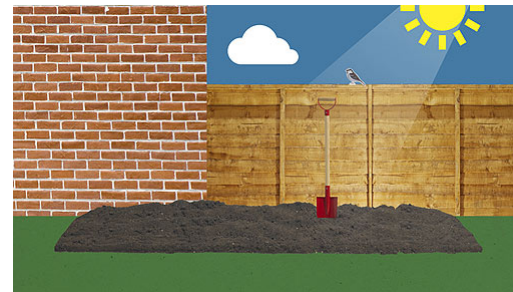
Animal
\$\$\$\$\$\$\$



Coal
\$



Oil
\$\$\$\$\$



Sun
FREE

Sources: McIntosh clip art; Wikipedia; BBC-UK http://www.bbc.co.uk/gardening/digin/your_space/patch.shtml

Principle 2. Energy consumption is integral to “holding our own” against other species

- ▶ All species reproduce more than needed to replace the parents
 - ▶ Natural selection determines which live
 - ▶ Humans circumvent with *external energy*
- ▶ Humans learned to control fire > 1 million years ago
 - ▶ Cooked food
 - ▶ Less chewing
 - ▶ Shrinking teeth, gut
 - ▶ Growing brain
 - ▶ Could live in colder areas
- ▶ Later trained dogs to hunt

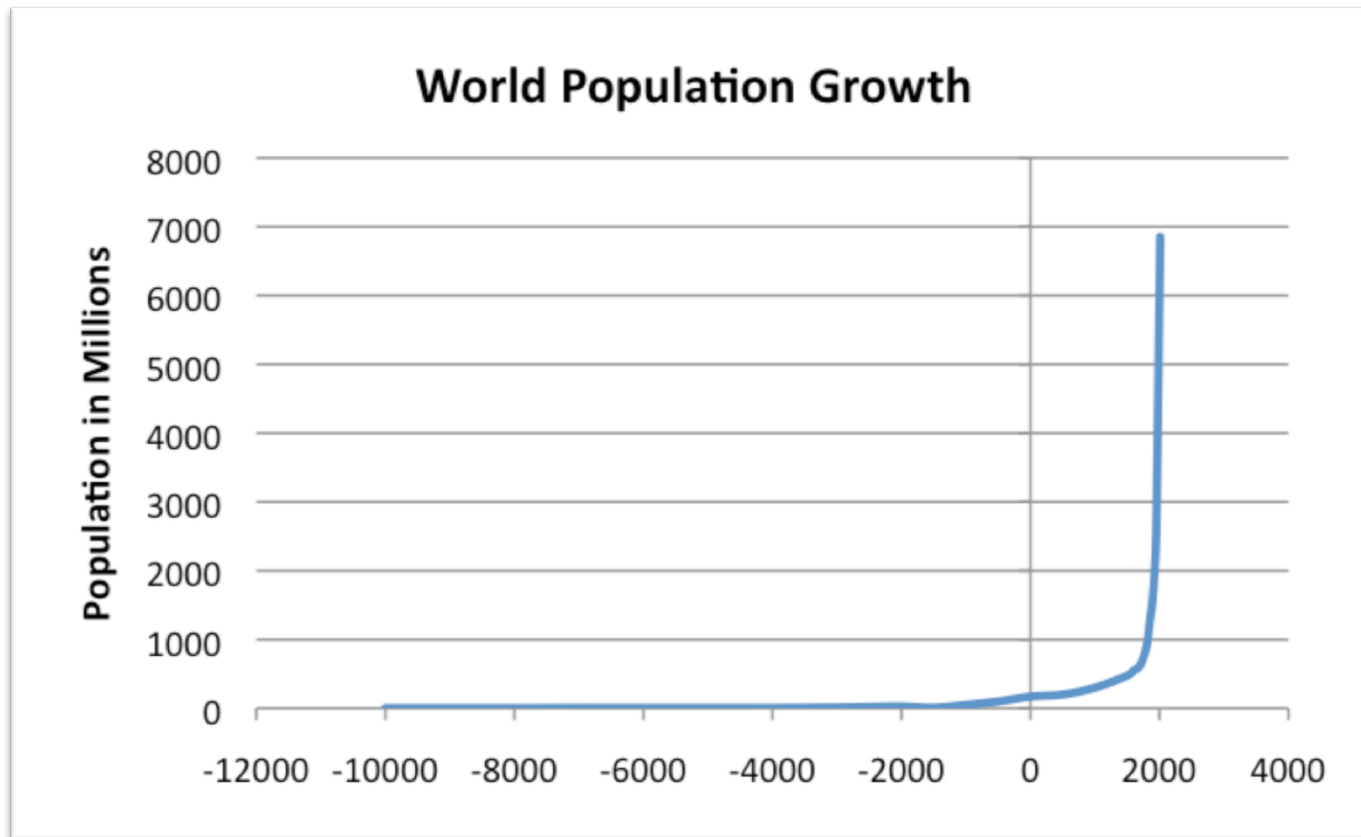
Humans vastly outnumber chimps, our closest relative

Chimps
300,000



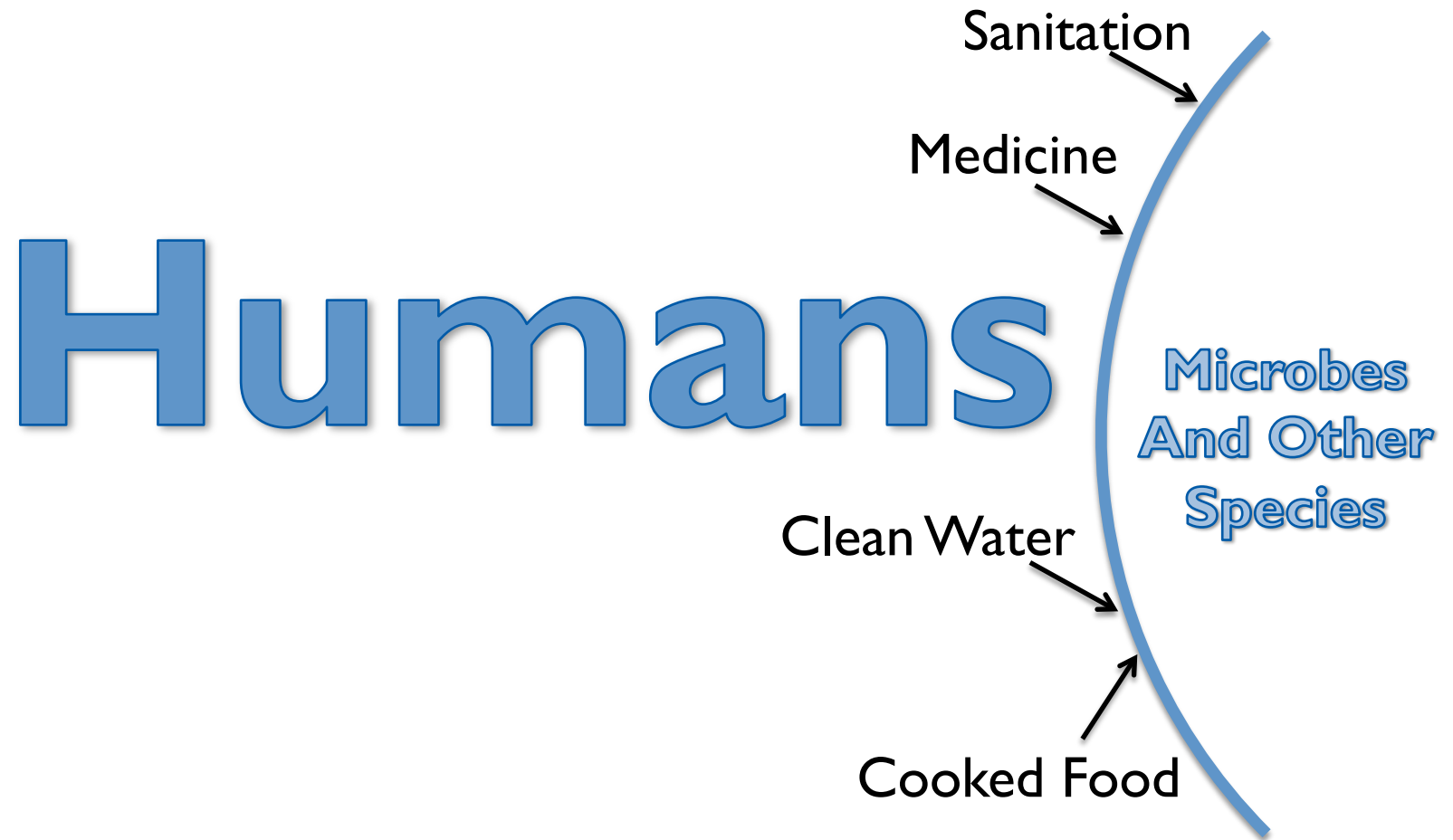
Maximum chimp population 3 million- McEvedy and Jones,
Atlas of World Population History

Population increased greatly as fossil fuels were added in last 200 years



Based on US Census Bureau information

To keep our place in the world, we need to keep using energy



Principle 3. It takes a *networked economy* to produce energy resources (including food)

- ▶ Hunter-gatherers
 - ▶ Built fires for cooking
 - ▶ Shared meals--time for collaboration
 - ▶ Who hunts; who gathers; who makes clothing; who cooks?

- ▶ Self-organized economy grew over time
 - ▶ In settled state, needed
 - ▶ Land “ownership”
 - ▶ Specialization in crops; animals raised
 - ▶ Dispute resolution
 - ▶ Ability to trade goods
 - ▶ Roads

Economy can be thought of as a self-organized network



Dome constructed using Leonardo Sticks <http://www.rinusroelofs.nl/structure/davinci-sticks/gallery/gallery-01.html>

**Includes consumers, businesses, governments,
laws, financial system, trade system**

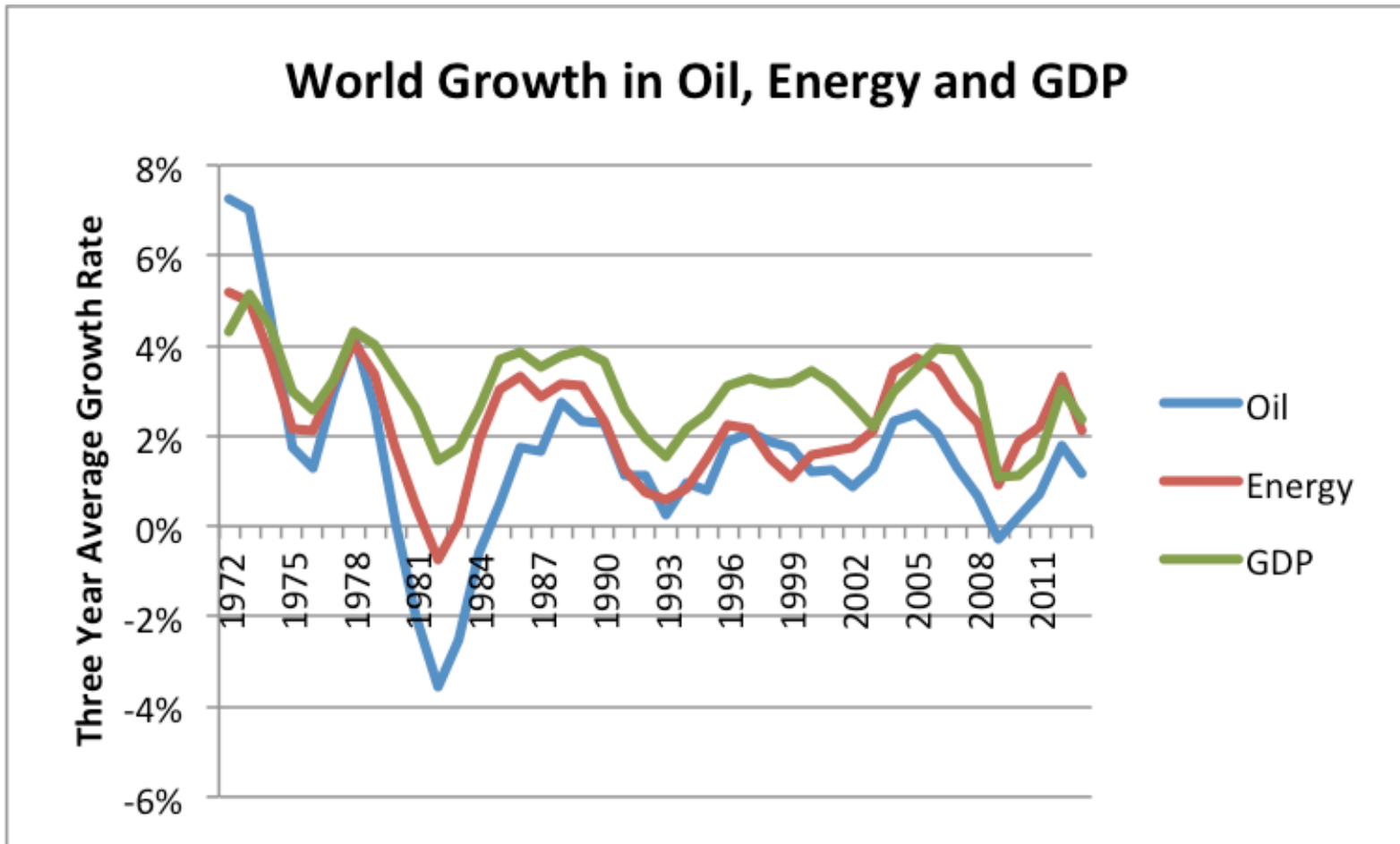
Important points about networked economy

- ▶ Economy doesn't shrink well
 - ▶ Old methods disappear – can't go backward
 - ▶ Don't make buggy whips
 - ▶ Reason economy is illustrated as hollow
 - ▶ Shrinking economy => Debt defaults
 - ▶ Shrinking economy => Profits disappear
- ▶ Production and wages are linked
 - ▶ If economy becomes more efficient, *wages tend to rise*
 - ▶ If economy becomes less efficient, *wages tend to fall*

Networked economies are fragile

- ▶ Many have collapsed
- ▶ Reach “diminishing returns”
 - ▶ Higher inflation-adjusted cost of goods
 - ▶ More human labor to create same goods
- ▶ Economy shifts from growth to shrinkage
 - ▶ Economies can collapse if they shrink

Principle 4. *Economic growth is tightly linked to both oil and total energy consumption.*



Source: Real GDP based on USDA values in 2005\$, oil and total energy supply from BP Statistical Review of World Energy, 2014.

(Energy use)-(economic growth) link goes two ways

- ▶ Two ways because this is a networked system
- ▶ More energy use => More goods produced; more economic growth
 - ▶ It takes energy to make goods (Principle 1)
 - ▶ Oil is often specifically required
 - ▶ Substitution is slow, expensive

(Energy use)-(economic growth) link goes two ways (cont.)

- ▶ More economic growth => Can *afford* more energy use
 - ▶ Higher wages
 - ▶ Higher wages=>More ability to borrow
 - ▶ Consumers prosper=>Governments and businesses prosper
 - ▶ Higher demand=> Higher prices of oil and energy products
 - ▶ **Extraction becomes economic** for high-cost oil resources

- ▶ Higher demand = greater *affordability*

Affordability affected by debt availability

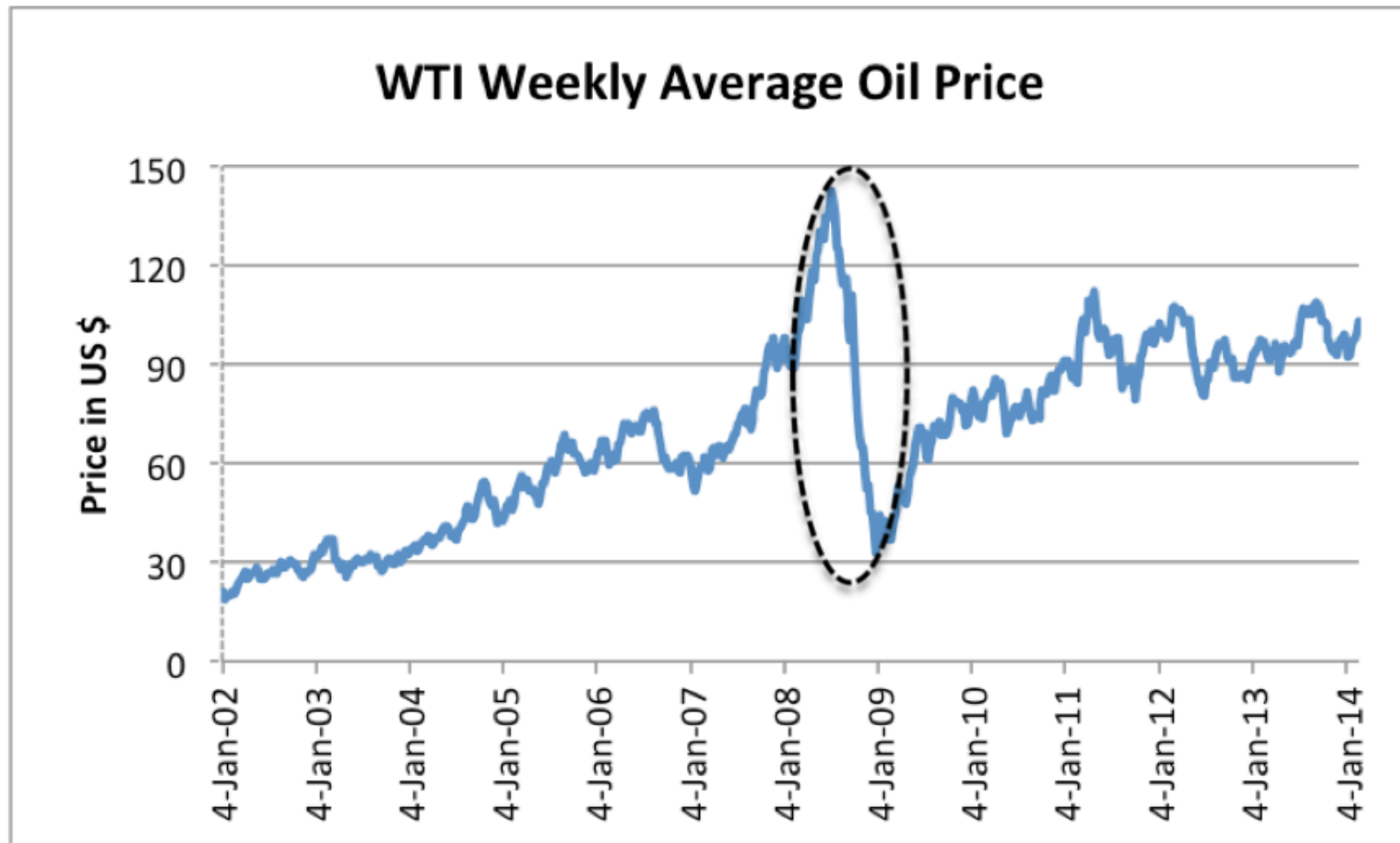
Repaying loans is easy in a growing economy



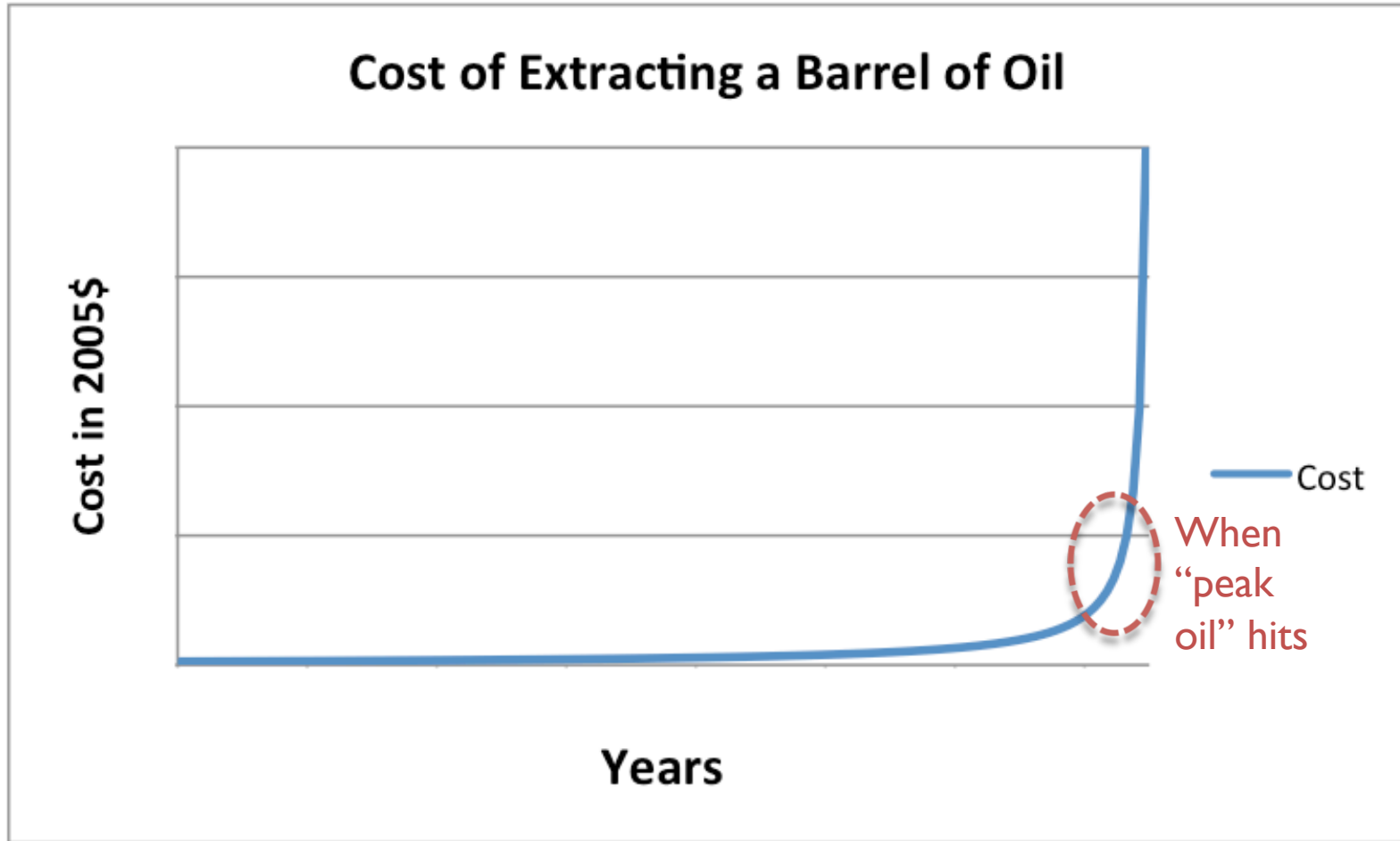
Repaying loans is much more difficult in a shrinking – or flat - economy



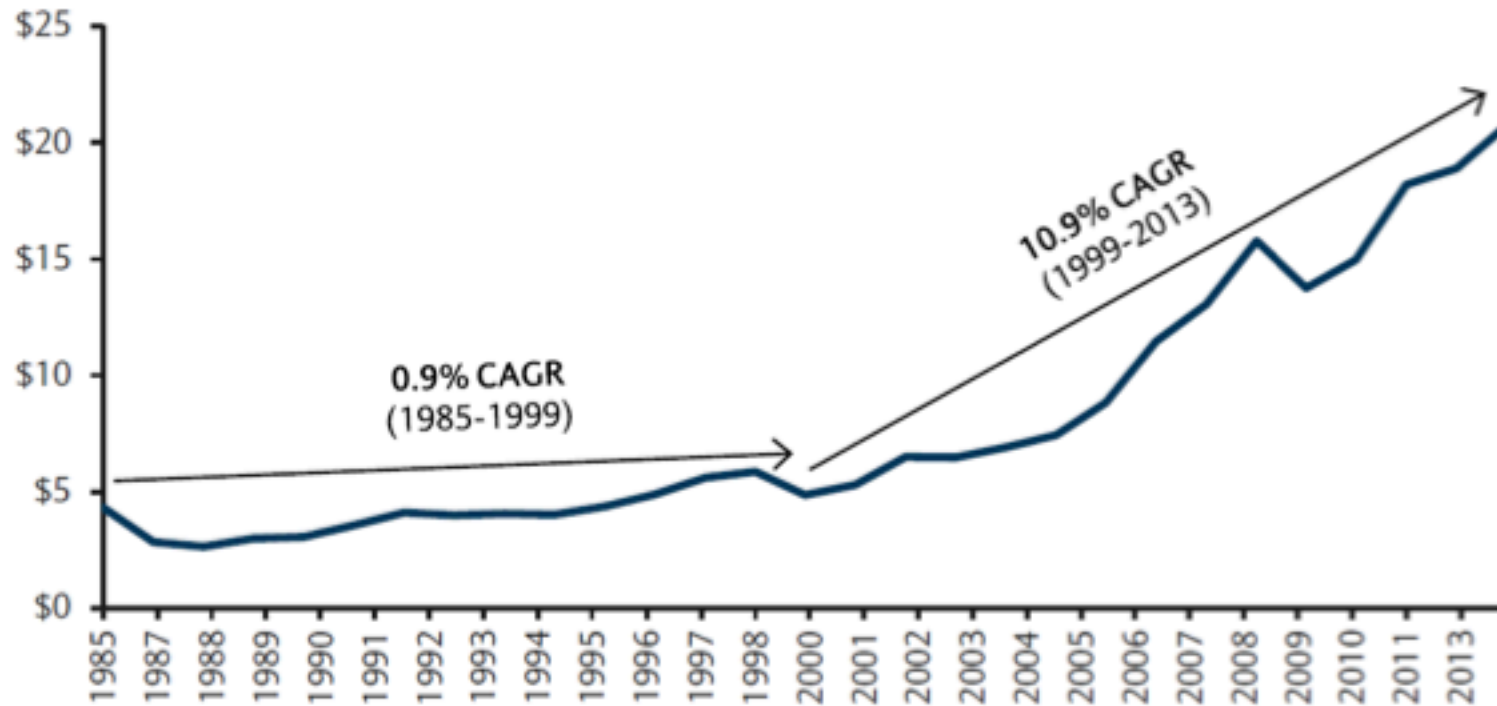
2008 price drop occurred when debt expansion turned to contraction



Principle 5: Reaching limits eventually leads to *sharp cost increases*



Oil extraction costs increasing rapidly since 1999—hitting “diminishing returns”



Source: IEA, Barclays Research

E&P Capex per Barrel

Source: Barclays Capital

Source: S. Kopits of Douglas-Westwood, Feb 11, 2014, <http://energypolicy.columbia.edu/events-calendar/global-oil-market-forecasting-main-approaches-key-drivers>

“Bend” in costs produces distinctly different effects

- ▶ Early low cost increases (<1%) can be offset by technology changes
 - ▶ Inflation-adjusted cost of products falls
 - ▶ Workers can afford more products
 - ▶ Standard of living rises

- ▶ Large cost increases cannot be offset by technology changes
 - ▶ Inflation-adjusted cost of goods rises
 - ▶ Workers can afford less
 - ▶ Networked economy needs to shrink
 - ▶ Oops!

Principle 6. Limits of a finite world happen in many areas at once

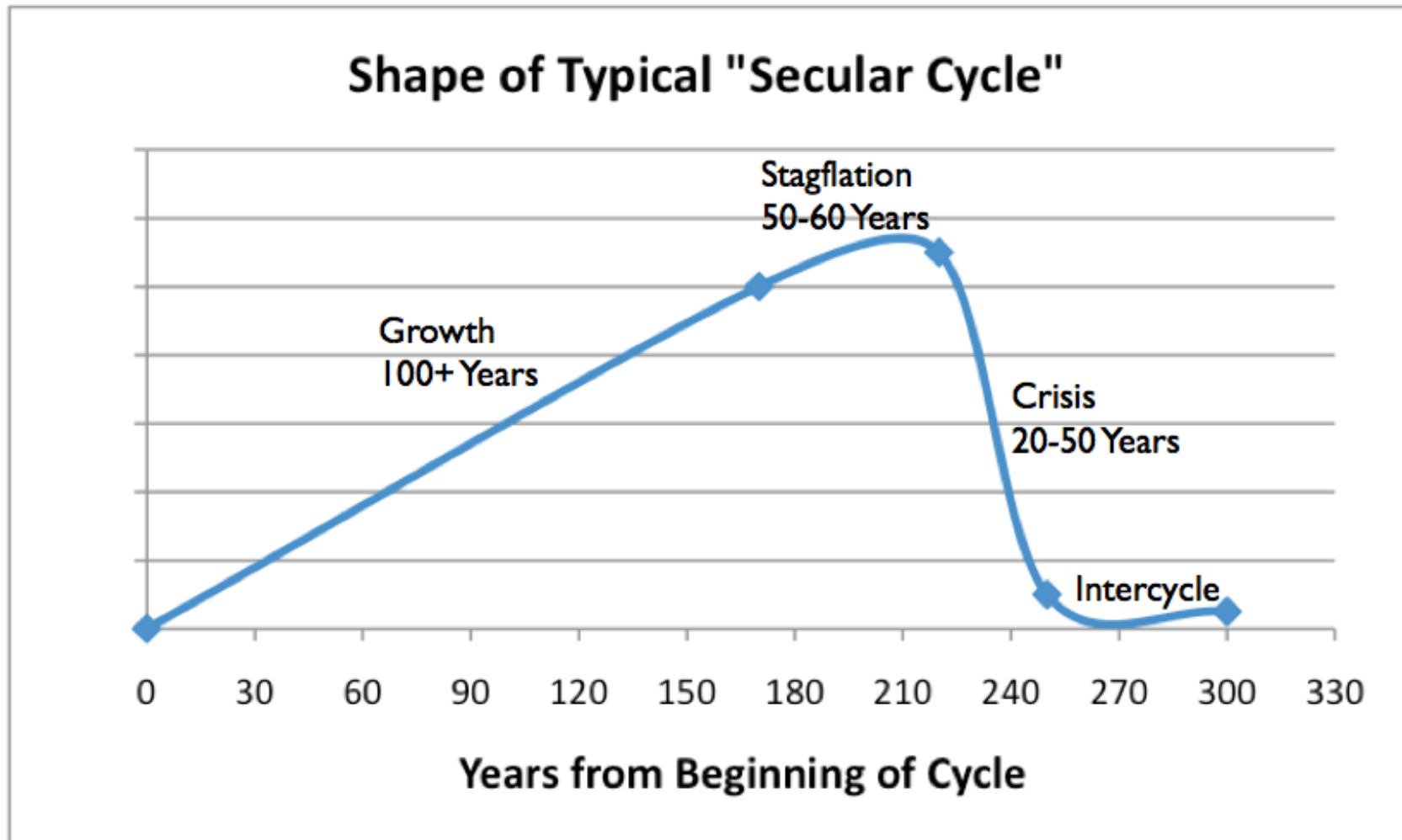
- ▶ Rising costs happen in multiple areas (diminishing returns)
 - ▶ Oil: Higher extraction costs
 - ▶ Water: Desalination
 - ▶ Metals: Lower ore concentrations
 - ▶ Fish: Fewer and smaller
 - ▶ CO2 Pollution: Need to change technology

- ▶ More population per hectare
 - ▶ Need more intensive agriculture
 - ▶ More pressure on water use
 - ▶ More pressure on minerals

Limits hit many areas at once (continue)

- ▶ Built infrastructure deteriorates
 - ▶ Need fixes to roads, pipelines, schools
 - ▶ These all take limited mineral, energy resources
- ▶ Governments need an increased share of resources
- ▶ Effect is to lower standard of living
 - ▶ Fewer resources left to produce “economic growth”
 - ▶ Economy shrinks

Principle 7. Our situation is similar to those of previous civilizations that collapsed



Based on *Secular Cycles* by P. Turchin and S. Nefedov, Princeton Univ. Press, 2009.

Similarities to previous civilization

- ▶ Hit diminishing returns—more labor, less output
 - ▶ Wages of common workers fell
 - ▶ Greater disparity in wages
 - ▶ Spiking food prices
 - ▶ More debt
- ▶ Government called on to do more
- ▶ Government had difficulty collecting enough taxes
 - ▶ Because of low wages
 - ▶ Couldn't grow army, add benefits

Eventually civilization collapsed

- ▶ Method varied
 - ▶ Inability of army to defend against invaders
 - ▶ Unsuccessful resource wars
 - ▶ Impoverished workers unable to buy adequate food
 - ▶ Epidemics reduced population
- ▶ Collapse took period of years
- ▶ Rebuilding also took period of years
 - ▶ But prior collapses were not built on fossil fuels
 - ▶ Forests could regrow; eroded soil could regenerate

Principle 8. *Limits to Growth* modeling suggests other ways limits are hit.

- ▶ **First way: Run short of resources**
 - ▶ Try to solve many problems at once (oil, water, etc.)
 - ▶ Each takes resources
 - ▶ Resources to grow the economy end up “short”
 - ▶ Economy shrinks

Limits to Growth modeling suggests other ways limits hit (cont.)

- ▶ Second way: Run short of physical capital
 - ▶ Cannot create enough new factories, pipelines, etc
- ▶ Example—Looks like there is lots of very heavy oil available
 - ▶ Reserves / Annual production is high
 - ▶ But our ability to install enough equipment to ramp up oil production quickly is lacking
 - ▶ Much of this oil will be left in the ground

Principle 9. Hubbert curve models special case when a replacement fuel is available

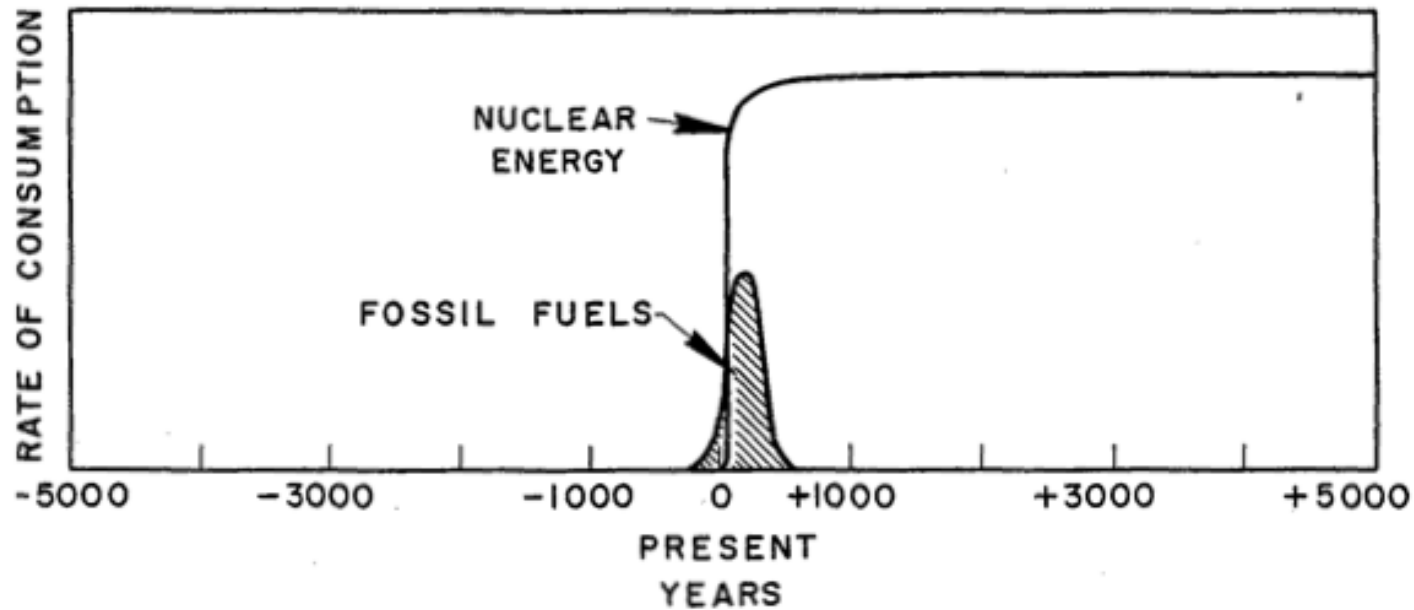


Figure 30 - Relative magnitudes of possible fossil-fuel and nuclear-energy consumption seen in time perspective of minus to plus 5000 years.

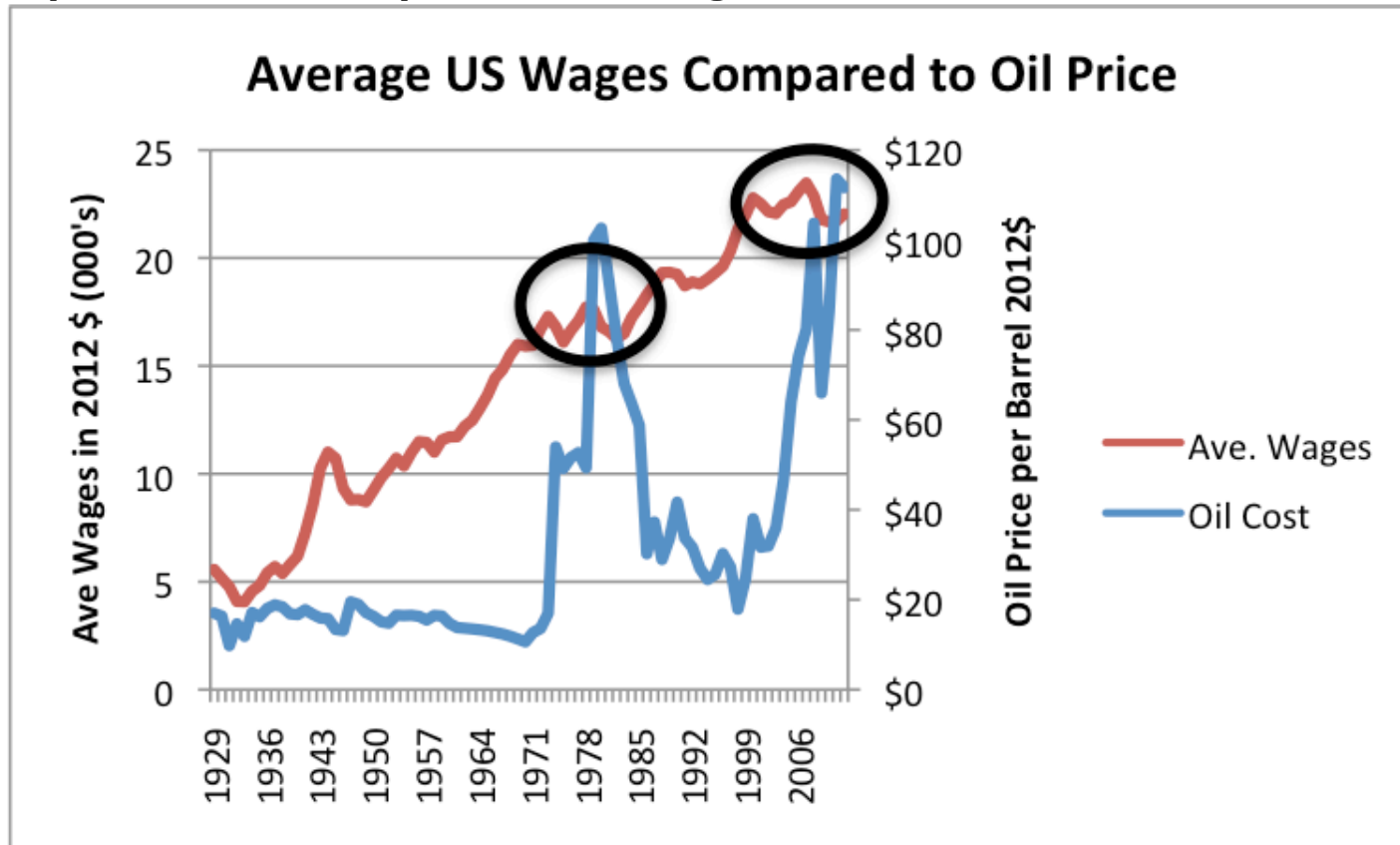
Source: M. K. Hubbert, *Nuclear Energy and the Fossil Fuels*, 1956.

Replacement fuel is *not* available today

- ▶ Above-ground factors become important
 - ▶ Food for 7+ billion, with declining oil
 - ▶ Financial system breaking
 - ▶ Disrupted trade system
- ▶ Oil drop-off likely to be much steeper
 - ▶ Like collapse scenario
- ▶ Other fuels likely to drop off simultaneously
 - ▶ Dealing with disrupted *networked economy*

Principle 10. We need a growing supply of *cheap* energy to maintain economic growth.

▶ High-priced oil depresses wages



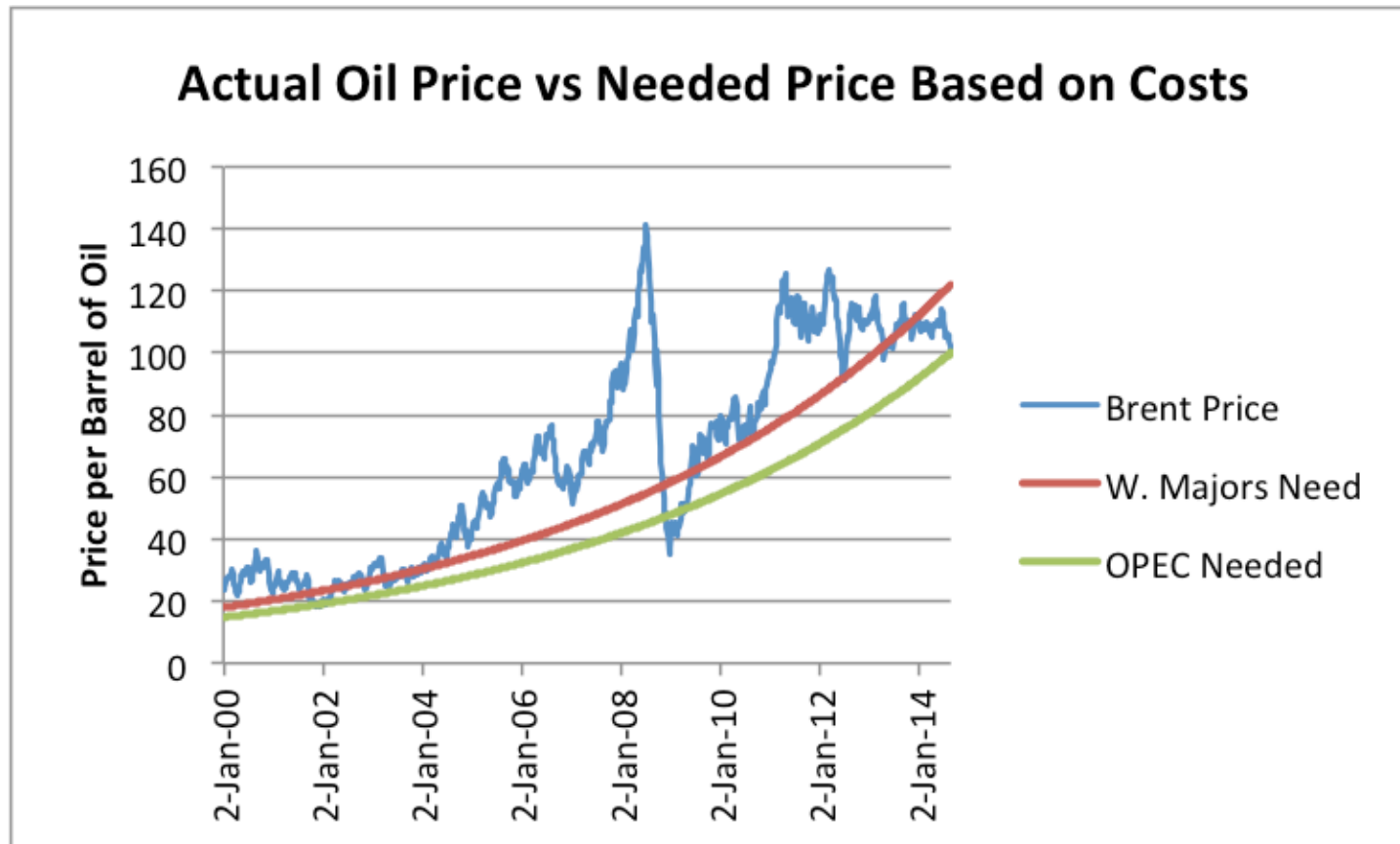
Source: Wages are total wages from BEA adjusted by CPI urban, divided by total population. Oil is Brent oil in 2012\$ from BP Statistical Review of World Energy 2013.

There are many reasons energy needs to be cheap

- ▶ Competition with other countries
 - ▶ High priced oil or renewables makes uncompetitive
- ▶ Competition with free energy from sun
 - ▶ Cold countries have extra costs
 - ▶ Hard to compete with warm countries
 - ▶ High energy prices makes problem worse
- ▶ When energy cost is high, tends to squeeze out other costs
 - ▶ Wages and interest costs

Principle 11. *Low oil prices* are as much of a problem as high.

- ▶ Conflict between oil price needed and market price



Actual price is Brent weekly spot price from EIA. Needed by Western Majors and by OPEC based on "Higher Long-Term Prices Required by a Troubled Industry," Goldman Sachs, April 12, 2013

Rising oil prices are a problem for oil importers – as we saw in 2008

- ▶ **Cost of oil products and food rises**
 - ▶ Wages do not
 - ▶ Consumers cut back on discretionary items
 - ▶ Layoffs in discretionary sectors
 - ▶ Result Recession!

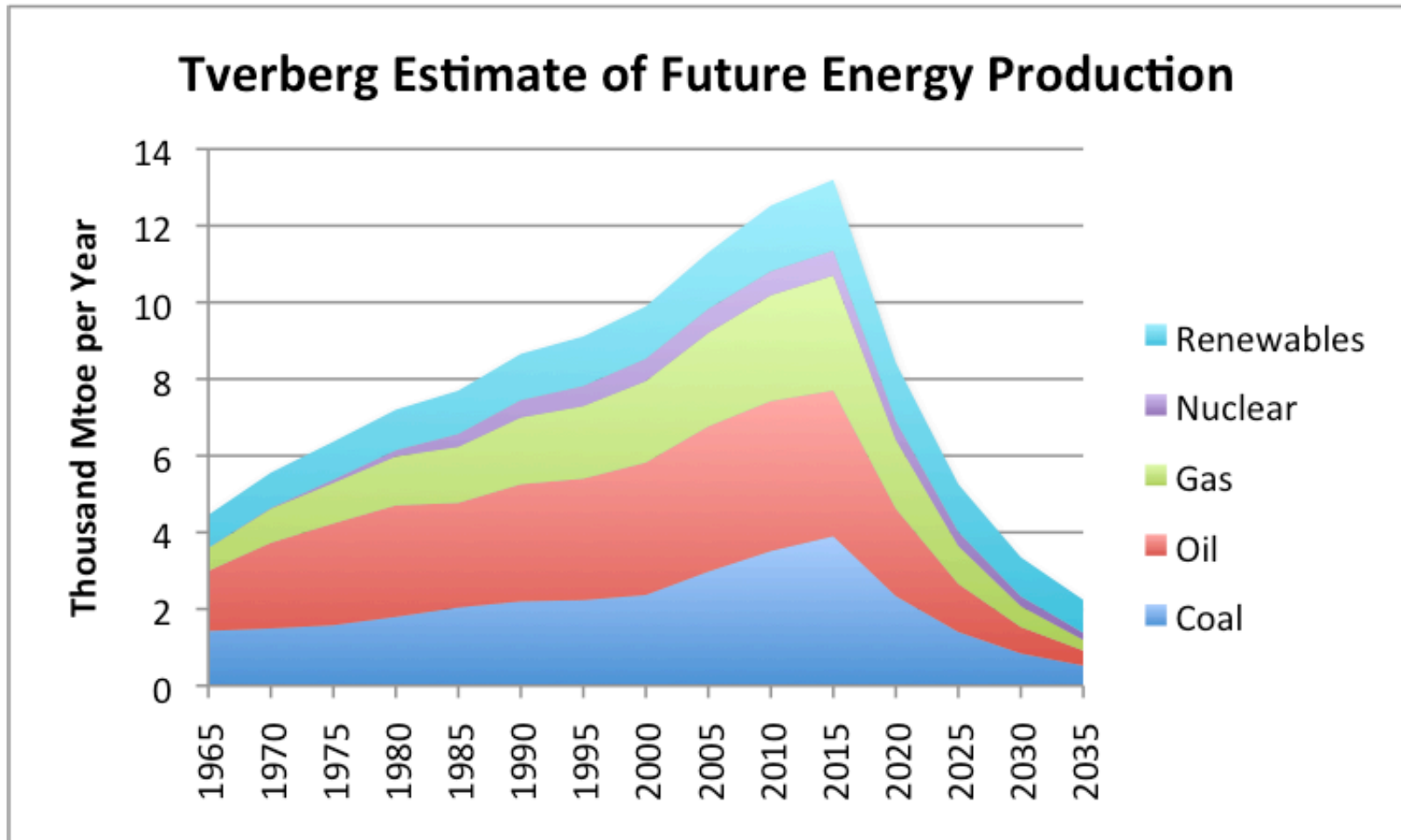
- ▶ **Also, defaults on debt**
 - ▶ Particularly severe by those laid off
 - ▶ Leads to financial problems for banks

- ▶ **Price of homes tends to fall**
 - ▶ Homes are a discretionary item

In 2014, oil prices are *too low for producers*

- ▶ **Western oil companies**
 - ▶ Cutting back on new development
 - ▶ Sell land
 - ▶ Maintain dividends without more debt
- ▶ **Oil exporters**
 - ▶ Cannot collect enough tax revenue
 - ▶ Can't afford food subsidies, new desalination
 - ▶ More war in Middle East
 - ▶ Russia policies affected
- ▶ **Falling oil prices also lead to deflation**
 - ▶ Makes debt hard to repay

Danger is serious drop off in production, as prices of all fossil fuels drop too low.



Historical based on BP 2013 Statistical Review of World Energy, adjusted to IEA groupings.

Principle 12. Old economic models are no longer valid, as we approach limits.

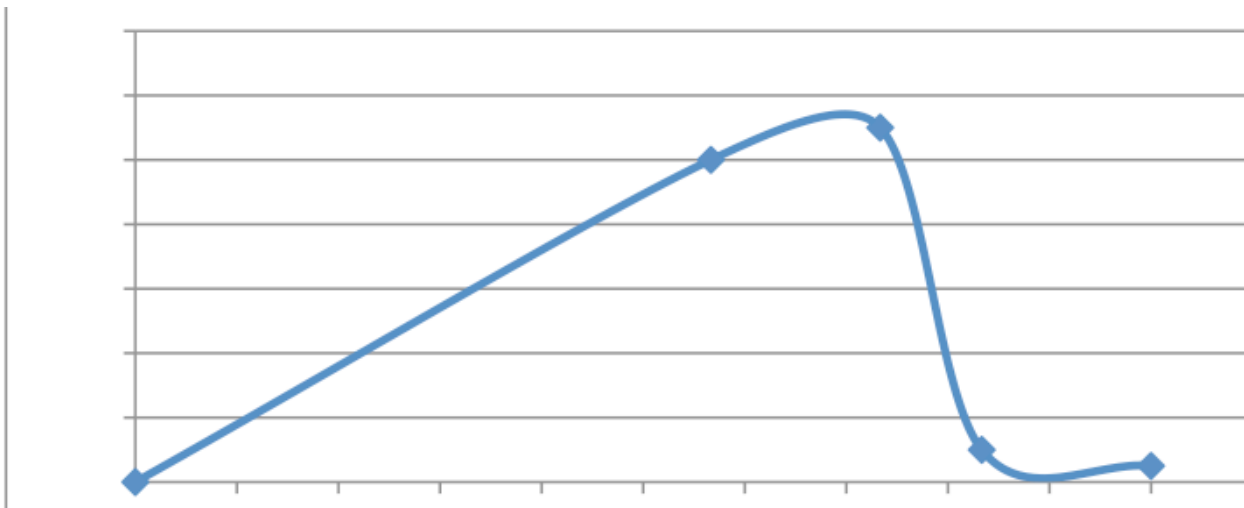
- ▶ Problem: Economy works differently *away from limits* than *close to limits*
- ▶ Past economic models set up for *away from limits*
 - ▶ Usual mode is expansion
 - ▶ Prices rise with shortages
- ▶ But at some point, inflation-adjusted costs start rising
 - ▶ Shrinkage starts taking over
 - ▶ Wages tend to fall and more are unemployed
 - ▶ Energy prices drop because affordability is low
 - ▶ Very different situation than prior models considered

Conclusions

- ▶ The “peak oil” story isn’t quite right
 - ▶ We do reach limits
 - ▶ But not with the rounded slow decline of Hubbert’s Curve
- ▶ The story that energy prices will rise isn’t true
 - ▶ Any rise is likely to be brief
 - ▶ High-cost energy *of any type* tends to push the economy toward contraction
- ▶ A steeper crash in fossil fuel production may make climate change less of an issue

Conclusions (cont.)

- ▶ Even though a man-made economy looks like it is easily replaced, this is an illusion
 - ▶ Economy + trade system is a self-organized system
 - ▶ Some physicists consider the economy to be a dissipative system
 - ▶ Like animals and hurricanes



Conclusions (cont.)

- ▶ The world has much more order to it than any of us would expect
 - ▶ There seems to be a plan behind it
 - ▶ Starting with the “big bang”
- ▶ Perhaps Nature has more plans than we are aware of
 - ▶ Both for the world and for humans

<u>Issue</u>	<u>View of Some Peak Oilers</u>	<u>Tverberg View</u>
Cost of oil extraction	Tends to rise	Tends to rises
Price of oil to consumer	Rises	May fall; depends on wages, debt
Wages of consumer	Oil prices assumed not to affect wages	High oil prices depress wages
Supply or Demand	Supply shortage	Lack of affordability (demand)
Point of View	Importance of holding imports down	Exporters require revenue or system falls apart
EROEI	Very important	Measures one aspect of problem
Hubbert's Peak	Very likely	Very unlikely—represents best case scenario



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