# 1. Overview of Energy Modeling Problem

Gail Tverberg – Energy Economics and Analysis Modeling

# We are reaching limits in many ways

- Oil –moving from easy to extract oil, to hard to extract oil
- Coal – moving to lower quality coal; many pollution issues
- Water – shortages in many parts of the world
  - Needed in oil, coal and natural gas extraction
  - Also in producing electricity
- Metals – moving from high metal percentages in ores to lower ones
  - Metals used in extracting fossil fuels, making alternatives
- Population – Ever more people, needing more food and more energy supply

# Economists put their models together long ago

- Developed models as if no limits existed
  - Growth forever, never slowing or stopping
  - Pleased politicians and citizens

- In the view of economists, economic growth depends on
  - Labor
  - Capital
  - Technology improvements
  - No mention of need for energy in this view

- Connection with energy viewed as the *result of economic growth*
  - As a result of job growth, *can afford to buy energy products*

# One of economists' key views is *the way supply and demand operates*

- If there is not enough of a resource, the system will adapt
- The price of the resource in short supply will rise
  - Buyers will cut back on their use of the product
  - Substitutes will be developed
  - At a higher price, more of the scarce resource will be produced
  - The system will rebalance
- Result—there should be nothing to worry about
  - System will fix itself

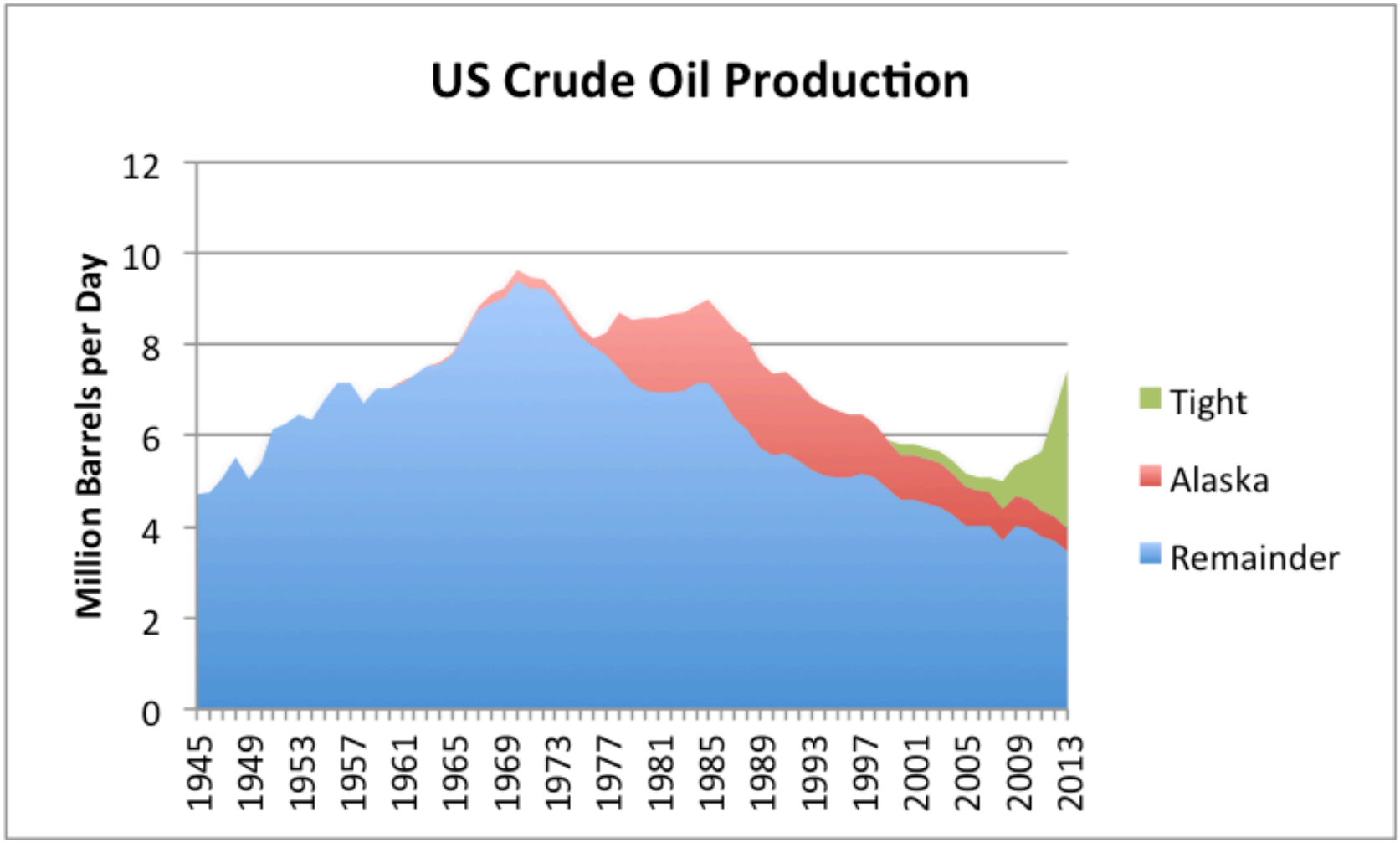
# What is the real story?

- This is the difficult question many researchers have been trying to tackle
  - What parts of the economists' story are wrong?
    - This is not obvious
  - Really need an update to the entire story of economists

- First look at a high-level view of what has happened

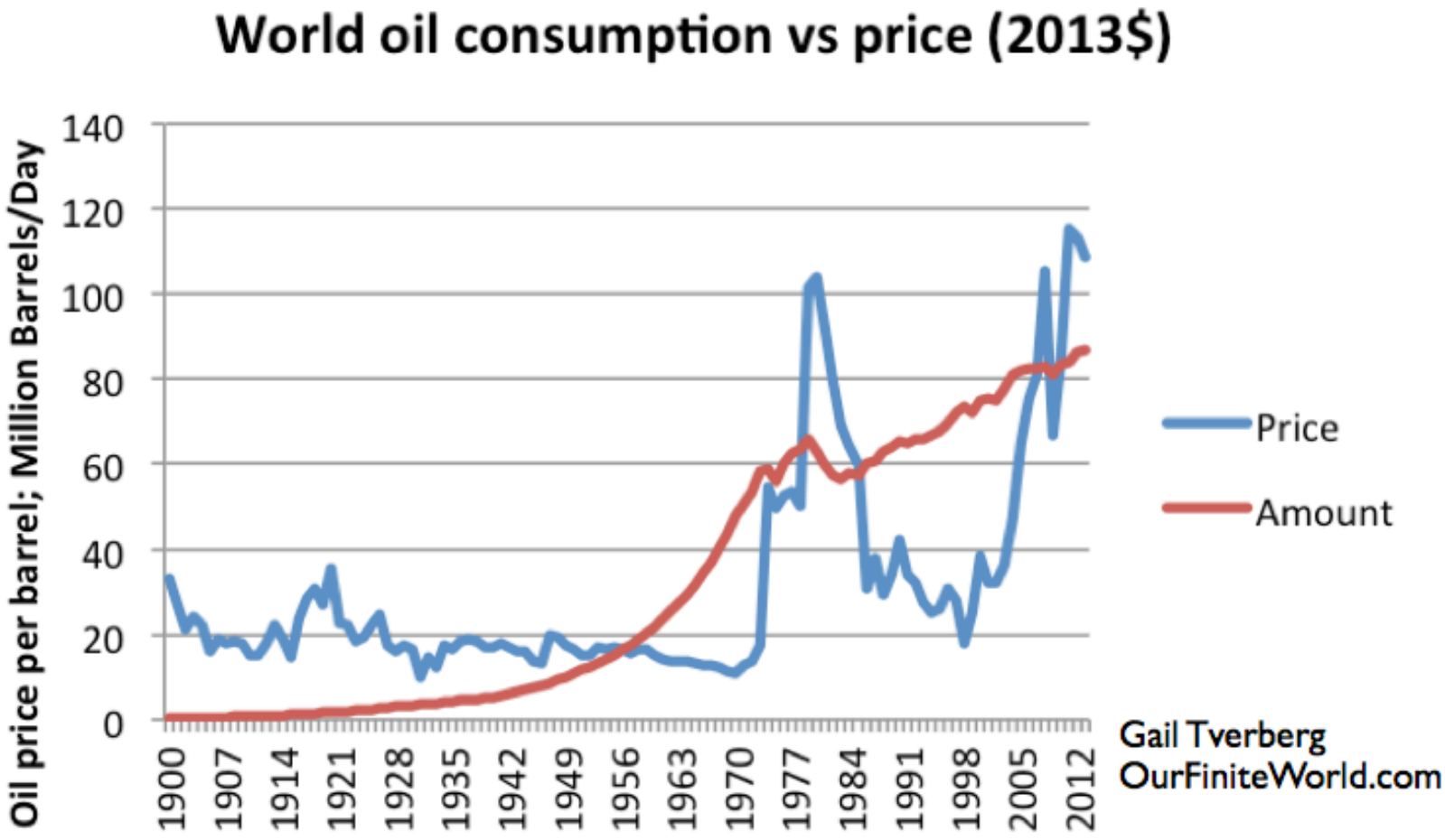
- Then look at ideas of
  - M. King Hubbert - geologist
  - Dennis and Donella Meadows - systems analysts
  - Charles Hall – ecologist

# US oil production of the type known by Hubbert began to decline in 1970



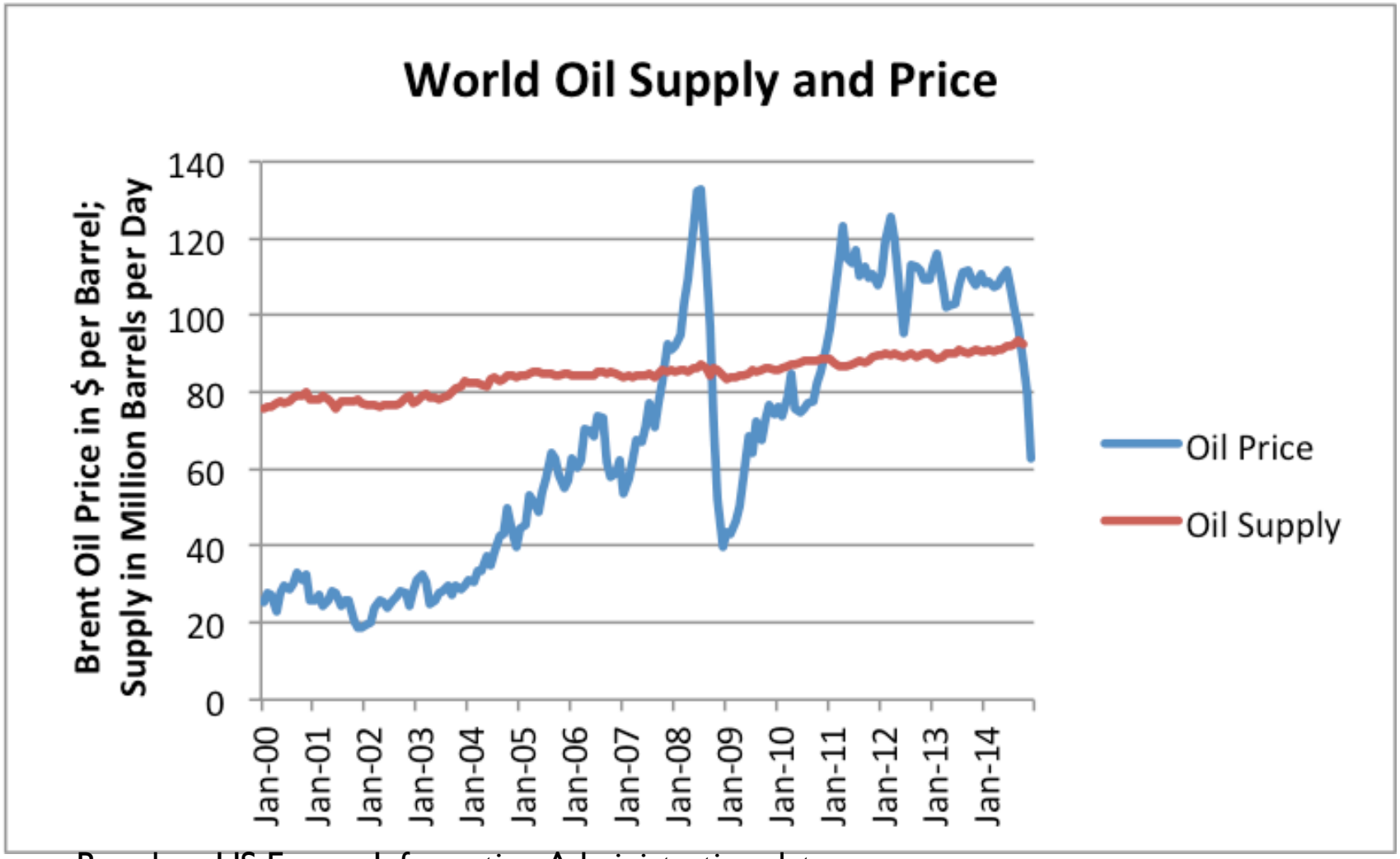

Based on US Energy Information Administration Data

# World oil supply has continued to rise, but recently oil prices are too low for producers




Based on BP Review of World Energy 2014 and Vaclav Smil data prior to 1965

# Now oil price is too low – How will this turn out?




Based on US Energy Information Administration data

# **M. King Hubbert** – Geologist, Physicist

- Worked for an oil company
- Observed that extraction of minerals of many kinds tends to follow a symmetric curve
  - Relates to the geology of the situation
- In 1956, Hubbert correctly forecast that US oil production would start decreasing about 1970
- Also forecast that world oil supply would start decreasing about 2000
  - This didn't happen
  - Didn't adequately consider new techniques; effect of higher prices

# M. King Hubbert model based on what happens in a local area

- Represents how much can be extracted under certain circumstances

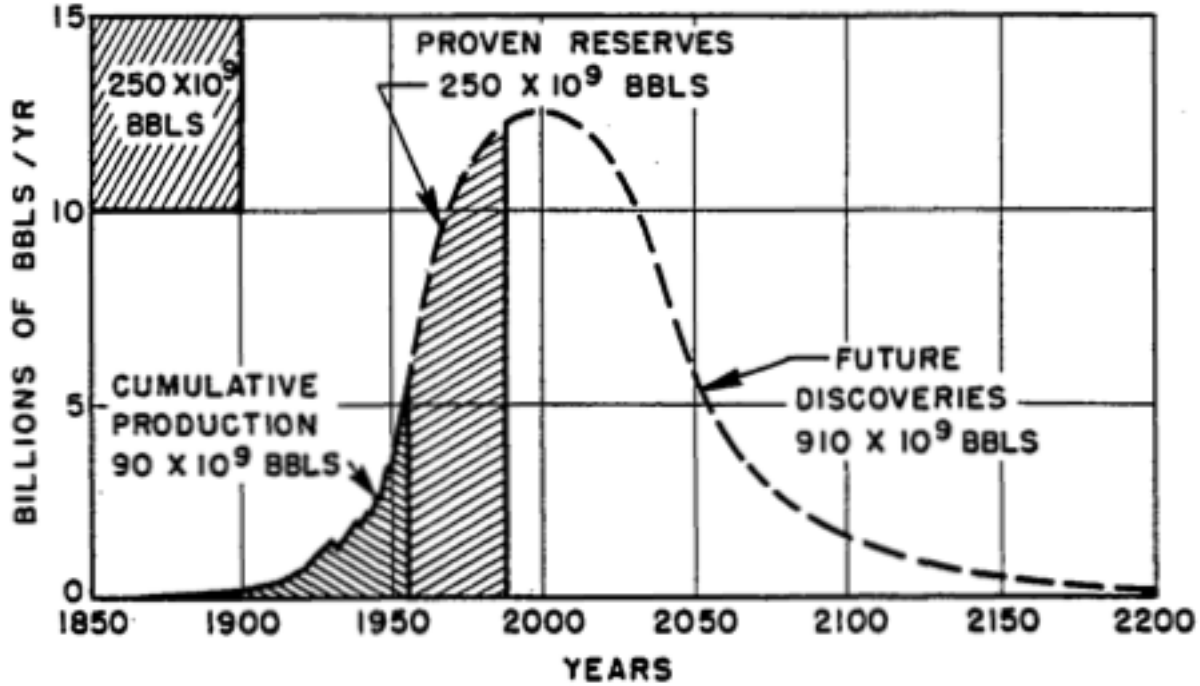



Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

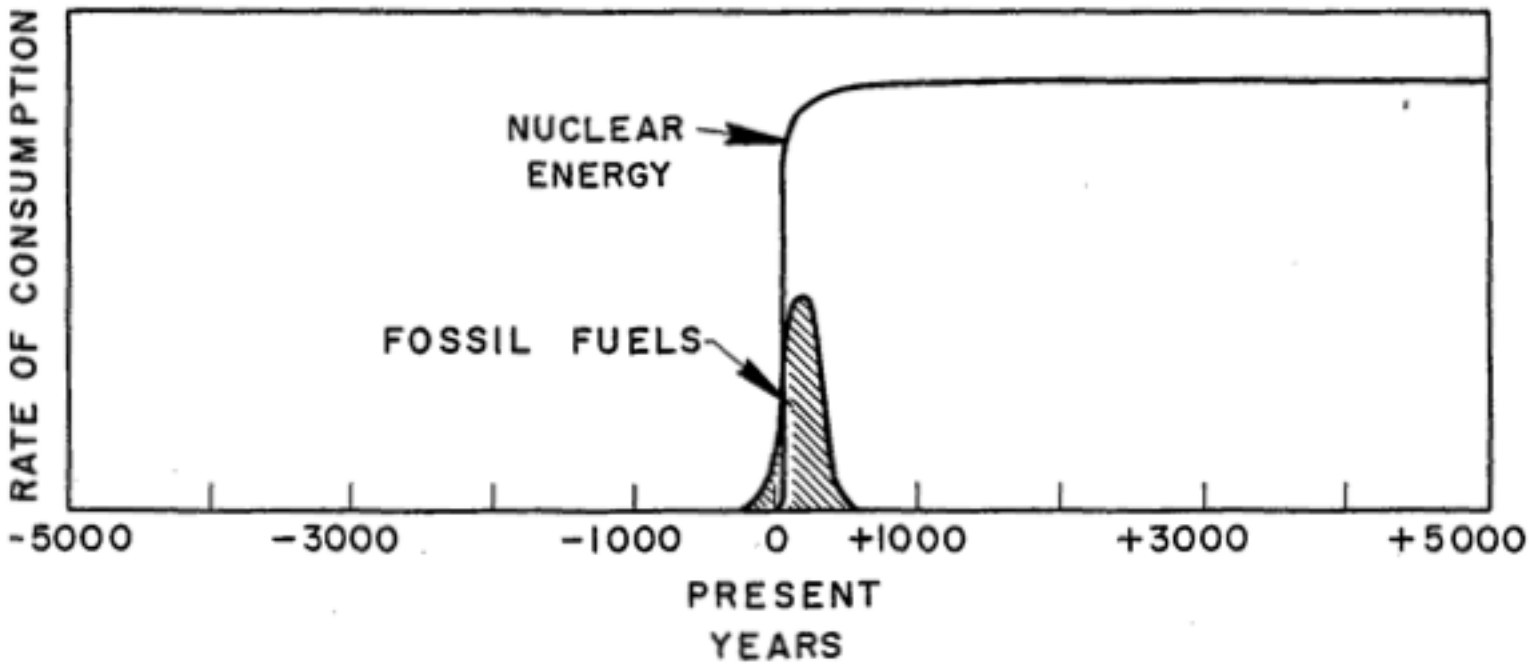
Source: M. King Hubbert's 1956 paper, Nuclear Energy and the Fossil Fuels.

# Model applies when there is a "perfect replacement" for the mineral being extracted

- Based on the situation when one field declines
  - Other fields are available to replace this field
  - The price of oil remains the same, using the new fields
  - If the economy depends on oil, there is no problem
    - Plenty of oil from other fields at same price
  - Economy can continue as in the past

- Hubbert's analysis makes it clear that world oil supply must also decline
  - The shape of the world curve may be very different, however
  - Hubbert Curve represents the slowest decline – no "above ground" problems causing decline

# Hubbert understood need for a replacement fuel to get a symmetric pattern




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

Source: M. King Hubbert's 1956 paper, Nuclear Energy and the Fossil Fuels

# Believers in "Peak Oil" have developed a set of beliefs

- Beliefs vary somewhat
  - Typically believe oil, gas, and coal production will decline, and economy will *react to this decline*
  - Economy will face a shortage of oil (and later coal and natural gas)
  - Concern is *mitigating this decline*

- Most think that the shape of the oil extraction curve will follow a Hubbert Curve
  - Only true if a cheap replacement is already available
  - Belief in slow decline of Hubbert Curve allows substitution

# Other frequent beliefs of "Peak Oilers"

- Prices will rise
  - Oil supply will decline despite the high prices
- Substitution will take place over a period of years
- Life will go on as previously
  - Will learn to adapt to lower fuel use
- These beliefs are based on economists' model of the system
  - Not really based on Hubbert's analysis

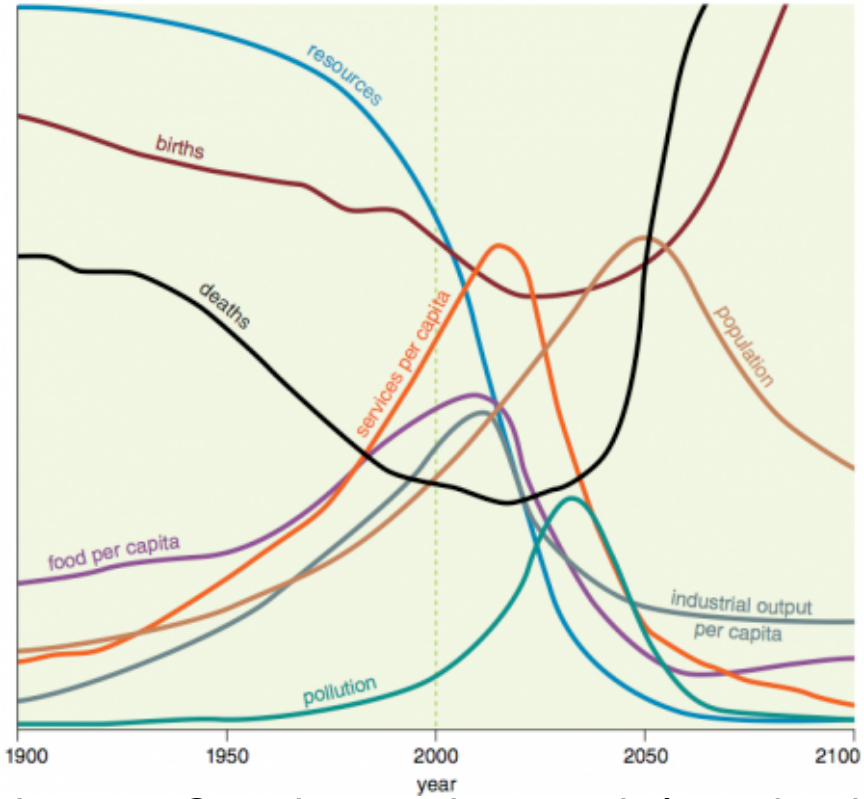
- Possible different outcome not considered by Peak Oilers
  - Fuels will become too high-priced for consumers (wages don't rise)
  - Prices of all commodities will fall because of lack of affordability;
  - System will fail quickly because of low prices
  - Substitution will not work well at all

# **Dennis Meadows**: Physical depletion of resources approach

- Dennis Meadows led team of MIT Researchers
  - Published in 1972 book "Limits to Growth"
  - Lead author was Donella Meadows, wife of Dennis Meadows
- Modeled the growing extraction of physical resources in a world with limits
- Impact these resources would have
  - Amount of food produced
  - Amount of goods produced
  - Expected growing pollution issues over time
  - Greater difficulty in extracting these resources over time
- Number of people
  - Expected births and debts

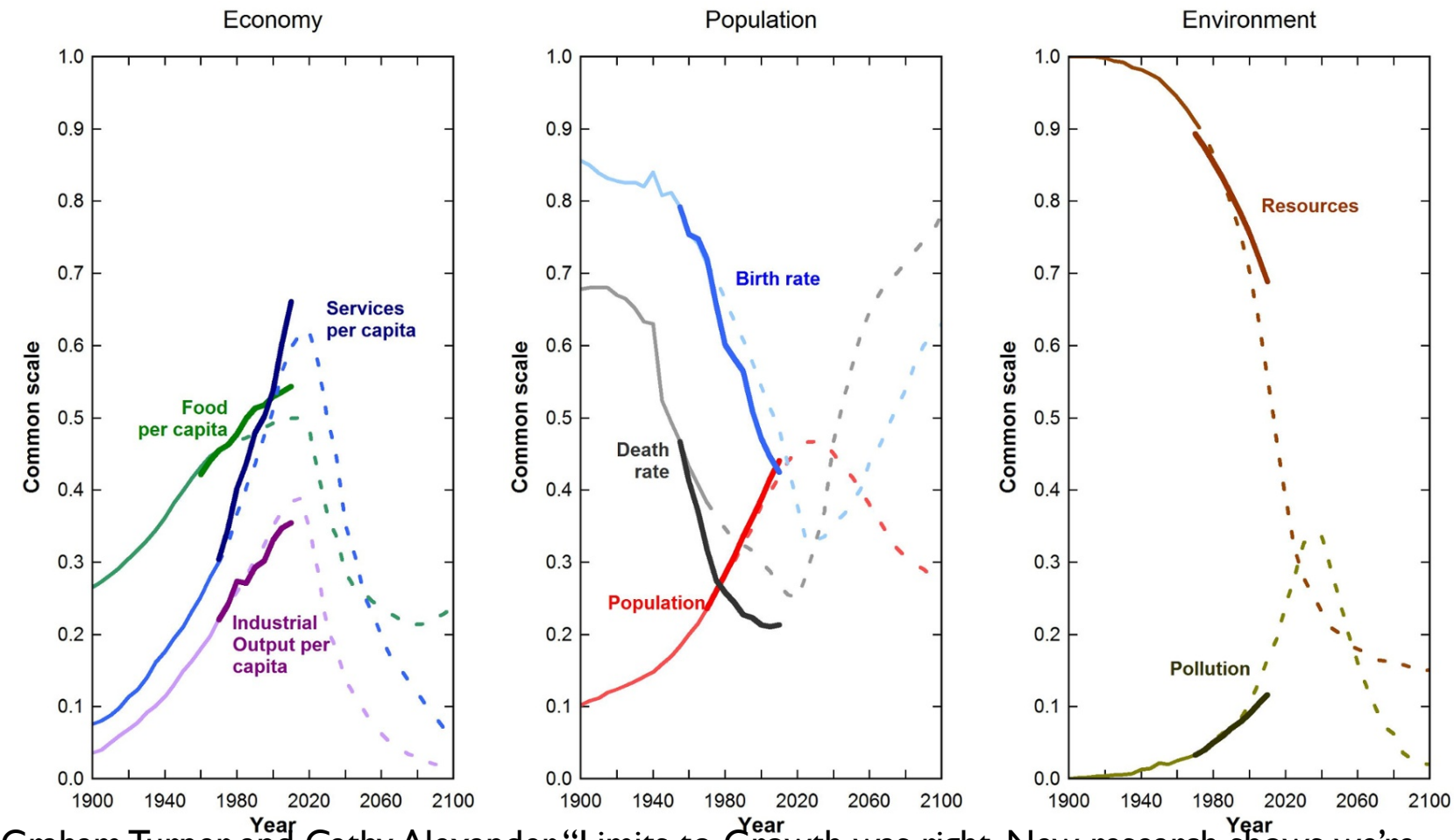
# Results published in a book called "*The Limits to Growth*"

- Base model suggested limit would be reached in 2000 – 2050 timeframe




Base scenario from 1972 Limits to Growth, printed using today's graphics by Charles Hall and John Day in "Revisiting Limits to Growth After Peak Oil" http://www.esf.edu/efb/hall/2009-05Hall0327.pdf

# Actual experience since 1972 is close to expected from "base" model




Graham Turner and Cathy Alexander "Limits to Growth was right. New research shows we're nearing collapse." The Guardian http://www.theguardian.com/commentisfree/2014/sep/02/limits-to-growth-was-right-new-research-shows-were-nearing-collapse

# How will this situation really work out?

- The collection of models was developed more than 40 years ago
- Models left out important aspects of how system really works
  - Financial system, including debt
  - How governments fare in collapse
  - Impact of countries competing with one another
- Shape of downward slope is likely wrong because of these and other omissions
  - Same bias as most peak oil analyses
  - No "above ground" problems to interfere with extraction
- What will really happen?

# Prof. Charles Hall

- Comes from the field of ecology
  - Began work in early 1970s, in response to issues raised by Meadows
- Has done much research showing that energy is necessary for economic growth
  - Refutes one of the major beliefs of economists
    - False belief that energy is not required by economy
  - Considers the thermodynamic connection between the "work" done by the oil and economic growth
- From this connection, if available energy declines, then the economy must necessarily shrink
  - Thus, shrinking oil supply should "shrink" the economy
  - Hall's writing follows the view that *economy can and will shrink*

# Prof. Hall developed metric Energy Return on Energy Invested (EROEI)

- Measure of diminishing returns in energy production
  - Energy Output / Energy Input
  - Adapted from the field of ecology—energy output of fish can't be greater than energy input

- High EROEI is good; low EROEI is bad
  - Can make energy supply go as far as possible by using high EROEI fuels
  - In theory, can rank fuels regarding how "good" they are by EROEI
    - High EROEI sort of corresponds to low-cost to produce
    - Low EROEI sort of corresponds to high-cost to produce

# Two different models of future energy supply are possible

(1) Energy supply will fall because commodity prices drop too low because of affordability issues

(1) Price of fuel rises too high for consumers—wages don't rise

(2) Producers will quit producing energy product because they can't make a profit

(3) All types of energy supplies will fall simultaneously.

(4) Substitution won't work well

(2) Peak oil view: Energy supply will fall because oil supply declines

(1) Oil prices will rise

(2) Substitutes will be possible over a long period

(3) Need to find most efficient possible substitutes

(4) Substitutes are possible, even at higher price

(1) Reason: Oil prices will be higher as well; can compete with high oil price

# Problem we are trying to mitigate is different in these two views

- In View 1, problem is *price of fuels becomes too high for consumers*
- In View 2, problem is *supply of fuel is likely to run short*

- EROEI calculation has been developed based on View 2
  - How can we make fuel supply go as far as possible?
  - Add up all kinds of energy, whether cheap or expensive
    - If Energy Out/Energy In ratio is high, will extend energy usage
  - Doesn't really matter if new energy matches built infrastructure
    - Substitution will be possible over a period of years

- View 2 is the standard view of Peak Oilers
  - No real reason to suspect this view might be wrong until 2008; 2014
  - View 2 is based on the view of economists

# If View 1 describes the real problem, then high EROEI is not the right metric

- If View 1 is right, we need *low cost fuels*
- EROEI doesn't really measure "low cost"
  - Completely omits human energy component
  - Completely omits other important aspects of cost
    - Cost of integrating new energy source into economy
    - Cost of required government services
    - Dividend and interest payments required to attract necessary capital for production of energy resource
- We already have a measure of "low cost"
  - It is cost of operating the system, with and without new energy source
    - Considers cost of integrating new energy source into existing system
    - Need types of energy that *lower the total system cost*

# EROEI Conclusions

- Changes in EROEI over time for a given fuel are useful for showing diminishing returns
  - EROEI calculation valuable from this perspective
  - Shows oil EROEI dropping from 25 =>15 => 10

- If a person firmly believes View 2 (fossil fuel supply will be low; substitution can take place over a long period), then EROEI gives an indication of what fuels might work
  - Caution: Some issues exist regarding comparability of different fuels

- If a person believes View 1, then EROEI estimates are not very helpful
  - Really need to look at the full cost of integrating the new fuel into the system—EROEI "shortcut" doesn't work

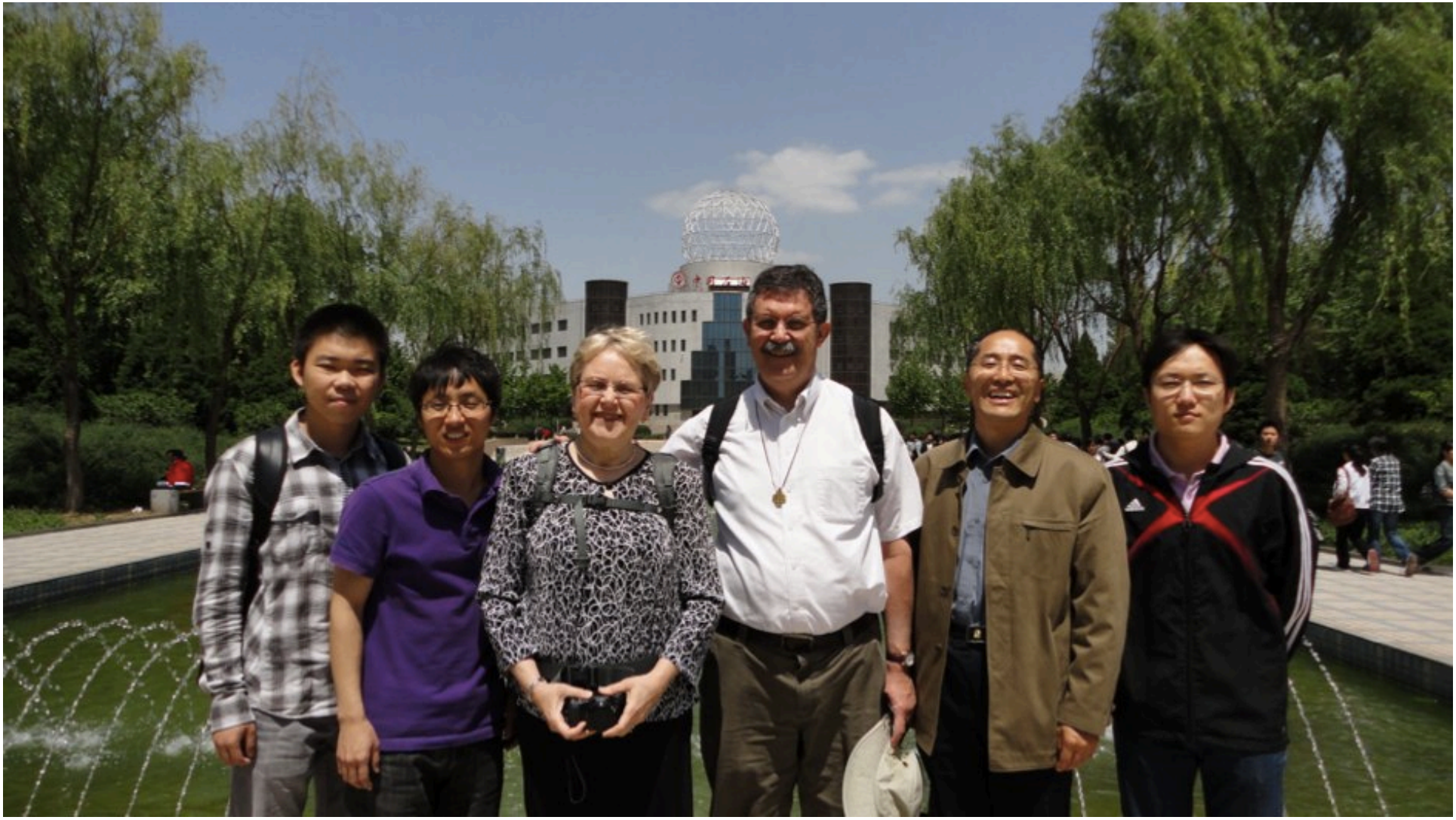
# What exactly is the correct story?

- I got involved with this story late—about 2007
- I had the benefit of the work others had done
  - I also became friends with some of the researchers involved
  - Dr. Charles Hall; Dr. Dennis Meadows
- I also had the benefit of seeing what was actually happening
- My background was different
  - I was an actuary working in insurance modeling
  - I knew first-hand what happens to financial institutions when the economy shrinks
  - I had been working in insurance in 1973-1974; saw what happened then

# In 2008, I correctly forecast the collapse that took place

- My forecast interested Prof. Charles Hall
  - Professor Hall wrote to me
  - Asked me to explain what I knew that others didn't know
- I also became an Editor at the group website TheOilDrum.com
  - Corresponded with Dennis Meadows with respect to material he submitted
- I also learned a lot about how energy system really works
  - Partly from other writers at TheOilDrum.com
  - Partly from commenters at TheOilDrum.com
  - Also from commenters on my own site OurFiniteWorld.com

Gail Tverberg, Prof. Hall and Prof. Feng in 2009, in Syracuse New York



Visiting Petroleum University of Beijing in 2011 with my husband

# Mainstream view – Economists (and, to some extent, Peak Oilers)

- Basically we have a ***supply issue***
- We start with an available supply of many resources
  - Fossil fuel energy products
  - Metal ores
  - Fresh water
- Extraction continually gets more difficult
  - In other words, it tends to use more energy products
  - Even pollution problems can sometimes be handled by using more energy products
- But prices are expected to keep rising
  - Whole system will operate as in the past, just with higher prices

# Mainstream view (continued)

- If problem is a supply issue, we should be able to adapt
  - Amount extracted in a given area tends to decline slowly
  - Everything should work out fine, if we keep adding new areas and new fuels
- Financial system is believed to determine prices
  - If prices are too low, regulators can raise the price, perhaps by "printing more money"
  - Alternatively, regulators can give consumers more ability to buy expensive goods by lowering interest rates
- Substitution is expected to be major part of solution
  - Timing is of any crisis is very distant, so substitution can take place

# My View: Problem is one of *affordability*, not *supply*

- Energy prices are likely to be *too low for producers*
  - More oil may be available than needed—a "glut"
  - Impact will look like a financial problem
    - Recession, debt defaults, inability to collect enough taxes

- Problem is very difficult to fix
  - Requires a large amount of very low-priced energy products
  - Energy products must match the built infrastructure
  - Substitution is mostly among countries
    - Sales go to the low-cost county
    - Cost considers wages, pollution control, energy costs

- If energy prices are too low, energy extraction stops