Our Finite World
Exploring how oil limits affect the economy

Overview of Our Energy Modeling Problem

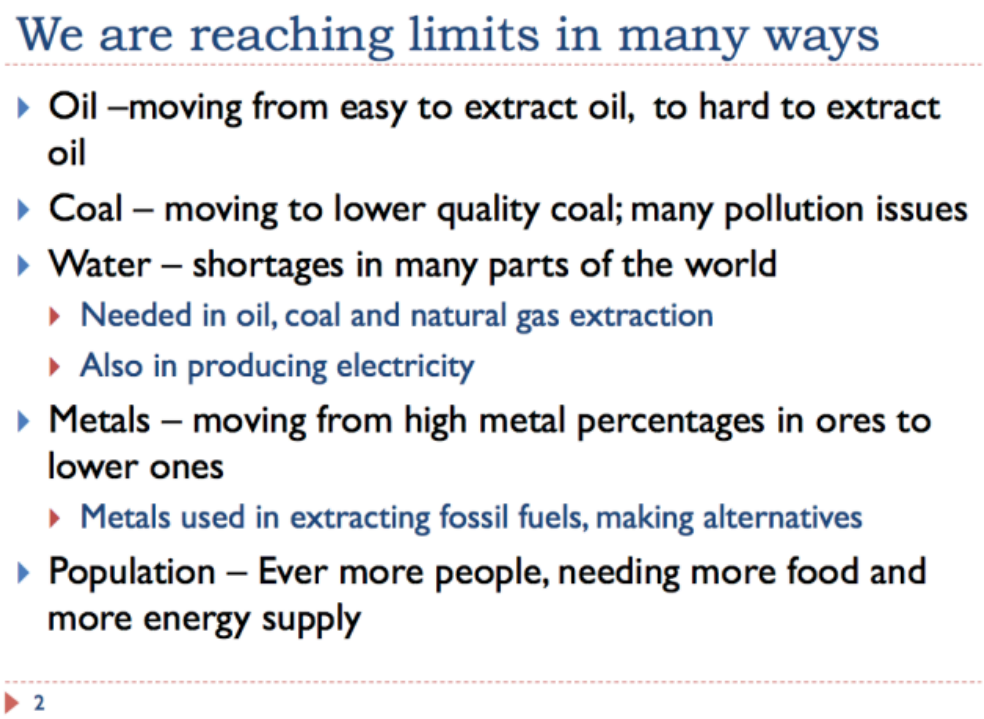
Posted on April 23, 2015 by Gail Tverberg

We live in a world with limits, yet our economy needs growth. How can we expect this scenario to play out? My view is that this problem will play out as a fairly near-term financial problem, with low oil prices leading to a fall in oil production. But not everyone comes to this conclusion. What were the views of early researchers? How do my views differ?

In my post today, I plan to discuss the first lecture I gave to a group of college students in Beijing. A PDF of it can be found here: 1. Overview of Energy Modeling Problem. A MP4 video is available as well on my Presentations/Podcasts Page.

Many Limits in a Finite World

We live in a world with limits. These limits are not just energy limits; they come in many different forms:



All these limits work together. We can work around these limits, but the workarounds are higher cost–for example, substituting less polluting energy resources for more polluting energy resources, or extracting lower grade ores instead of high-grade ores. When lower grade ores are used, we need to process more waste material,

raising costs because of greater energy use. When population rises, we must change our agricultural approaches to increase food production per acre cultivated.

The problem we reach with any of these workarounds is *diminishing returns*. We can keep increasing output, but doing so requires disproportionately more inputs of many kinds (including human labor, mineral resources, fresh water, and energy products) to produce the same quantity of output. This creates higher costs, and can lead to financial problems. This phenomenon is one of the major things that a model of a finite world should reflect.

Economists Views

Economists developed their views of the economy long ago, when limits seemed to be far in the distance. Thus, the models they built do not reflect the expected impact of limits. They are missing variables that would be needed to adjust for changes in the economy's behavior as limits are reached.

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

4

The story in Slides 3 and 4 tends to be true if we are far from limits, but is it really true when we are close to limits? Perhaps diminishing returns as we approach limits changes the results.

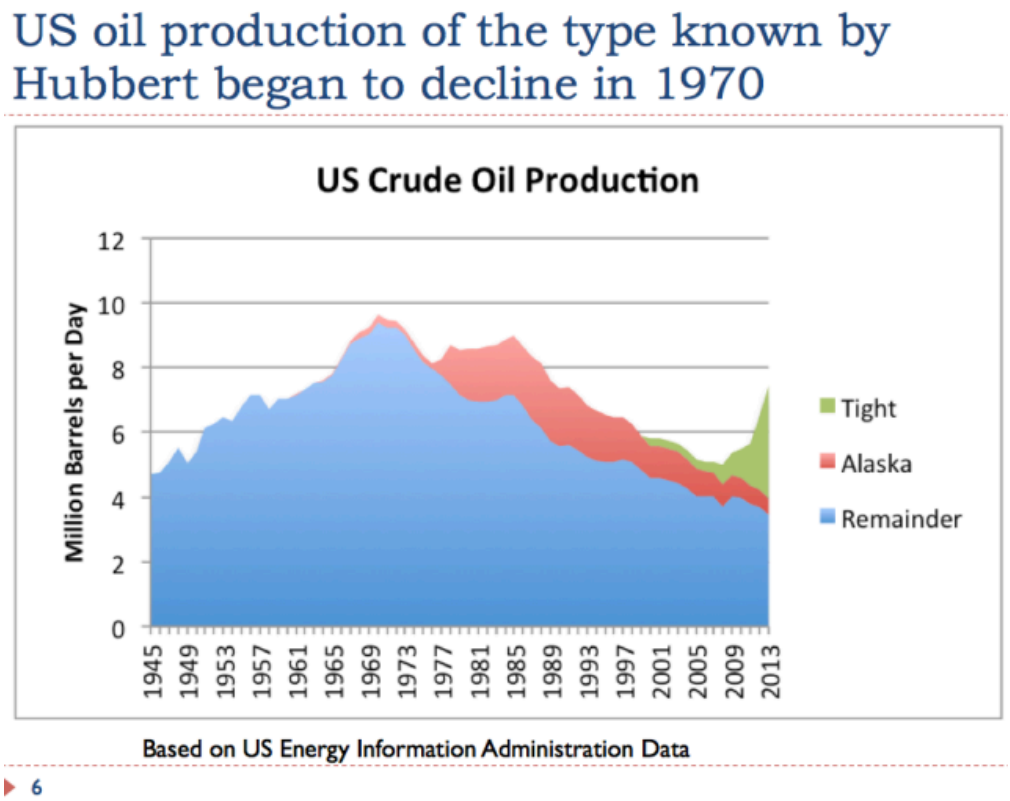
What is the real story?

- 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

5

World Oil Situation as We Approach Limits

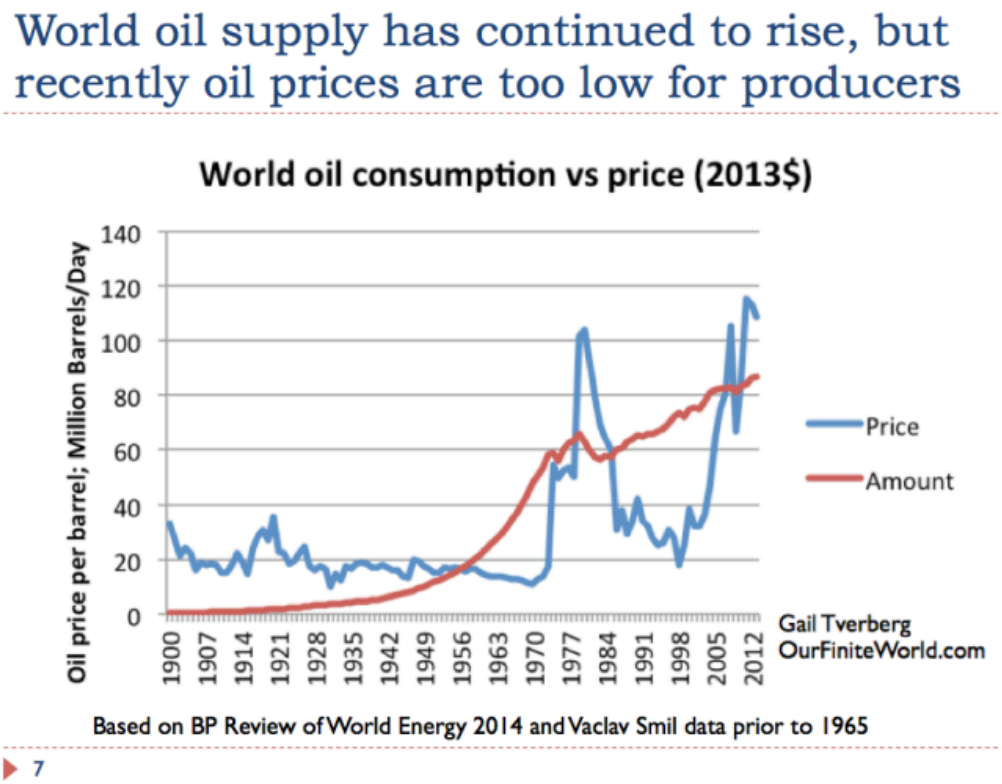
Perhaps we can get some indication of how diminishing returns are affecting the economy by looking at historical oil supply and prices. Up until 1970, US oil production grew quite steadily.



After 1970, oil production suddenly began to decline. Oil companies did not expect such a decline; they assumed that oil production would rise endlessly. Once oil production began to decline, oil companies quickly began trying to find ways to fix their problems. One of these approaches was quickly to ramp up production in areas that they knew contained oil, but hadn't previously been drilled. These included Alaska (northern United States), Mexico, and the North Sea. Oil production in these areas is now in decline.

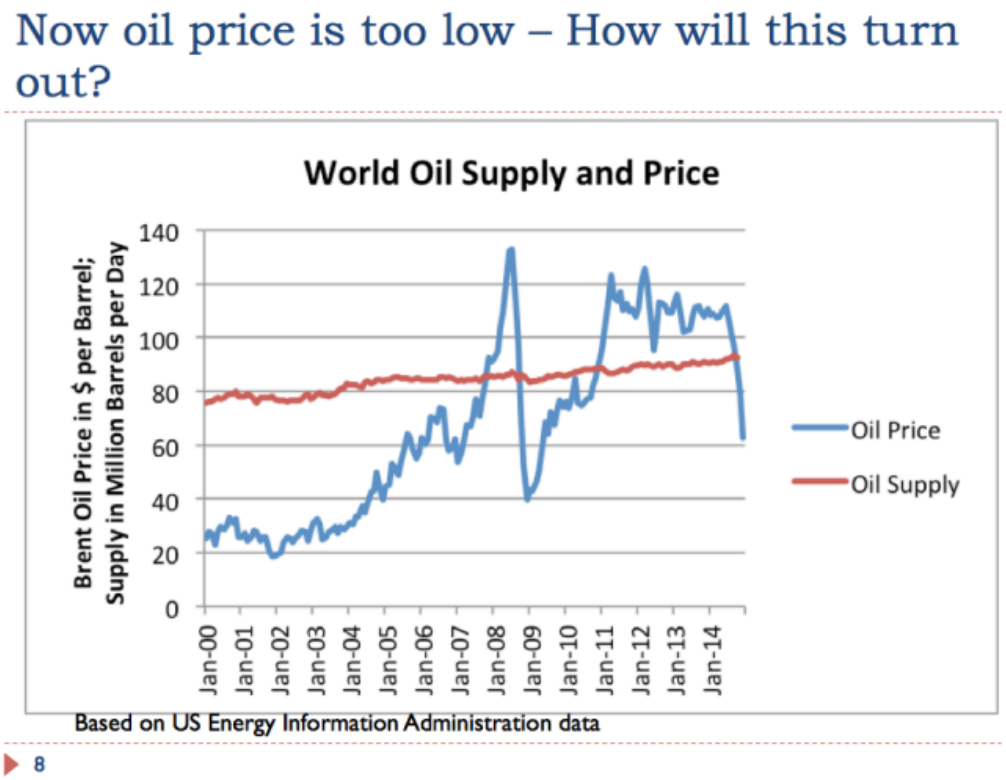
Several ways were also found to reduce oil usage. These included change from oil to alternate fuels for electricity generation and home heating, and offering smaller, more fuel-efficient cars. With this combination of approaches, oil prices were brought down, most of the way to the $20 level (Slide 7).

The inflation adjusted level of oil prices is important because oil is the single largest source of energy use in both the US and world economy. If oil prices are cheap, it easy to grow food cheaply, and manufacturing and transport can be done cheaply. Because of this, the economy tends to grow. If oil prices rise, economic growth tends to slow, because the cost of many types of goods (including oil products, food, and building new homes) tends to rise faster than wages. It becomes more expensive to replace infrastructure such as roads and pipelines as well. The higher cost of oil effectively acts as a "tax" inhibiting economic growth.



Oil prices again reached a high level in the early 200os as we again began to reach limits of the amount of oil that could be extracted at the then-available price. This time we weren't able to cut back on world demand, so prices tended to stay high. Instead, the big change made was in oil supply, with higher oil prices enabling (after a several years time-lag) greater production both from US oil from shale formations (called "tight oil" in Slide 6 above) and from the oil sands in Canada.

The question becomes: can the economy really function adequately on $100+ barrel oil? Or do the negative feedbacks from these high oil prices have too adverse an impact on economic growth?



Slide 8 shows more detail regarding production and prices for recent years. We see that oil prices were generally rising up until mid 2008, and then dropped steeply. Prices rose again after several types of economic stimulus were added. More government spending was added, interest rates were dropped to very low levels and a program called quantitative easing (QE) began.

Prices stayed at a level a little over $100 barrel from January 2011 though mid-2014. More recently, oil prices have dropped to a little more than half of their previous level. This decline in oil prices appears to correspond to a time when world debt is not rising as rapidly: the US stopped its QE program, and China's debt no longer rising as rapidly. Thus, some of the economic stimulus that helped hold oil prices up is disappearing.

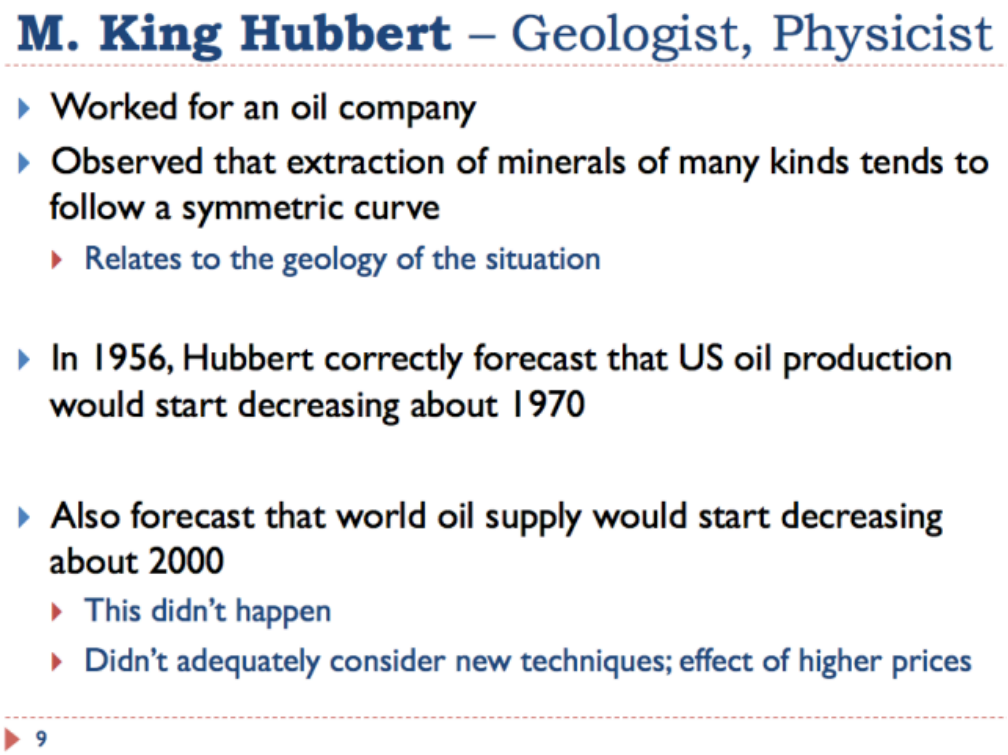
The problem we are now encountering is not the high price problem that economists thought would bring on more supply. Instead, we are encountering a problem with oil prices that are too low for oil producers to make a profit. Such low oil prices can quite possibly bring down world oil production, because investment in oil production is no longer profitable. A person might ask: Is the low price situation we saw in 2008 and are encountering again in 2014-2015 what diminishing returns really looks like? *Is the problem we encounter as we reach limits one in which oil prices drop too low, rather than rise too high?*

In 2008, huge stimulus efforts were required to bring oil prices were brought back up to the $100+ level. Perhaps one point raised by economists (Slide 3) was correct: Maybe there is a connection between economic growth and oil demand. *Perhaps the issue as we reach limits is that world economic growth sinks too low*, and it is because of this slow growth that wages stagnate, debt stops rising quickly, and oil (and other commodity) prices drop too low.

Now let's look at what some early energy researchers have said.

M. King Hubbert

Many believers in Peak Oil theory consider M. King Hubbert to be the originator of their theory. It seems to me, though, that Peak Oilers have inadvertently picked up some of the economists' theories, and mixed them with Hubbert's theories.



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

- Represents how much can be extracted under certain circumstances

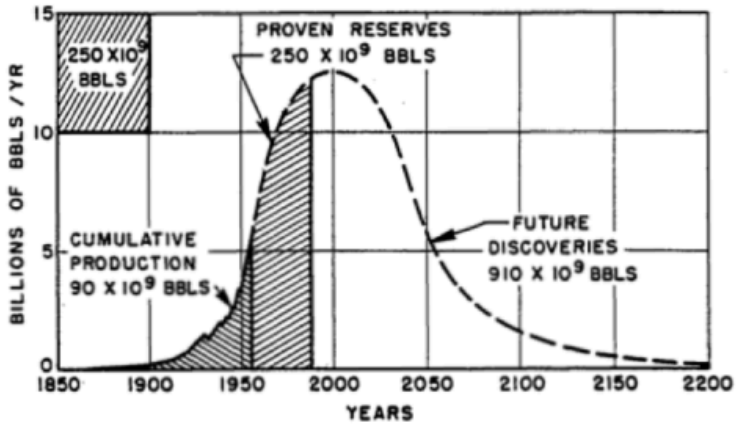


Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

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

10

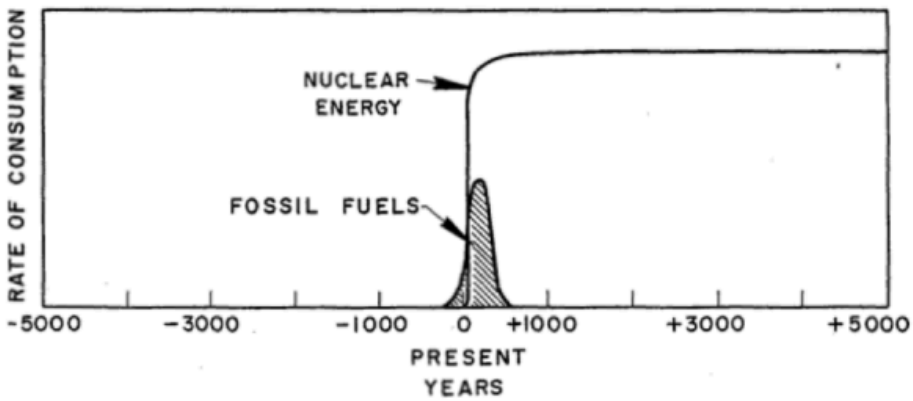
Model applies when there is a "perfect replacement" for the mineral being extracted

- 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

11

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

12

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

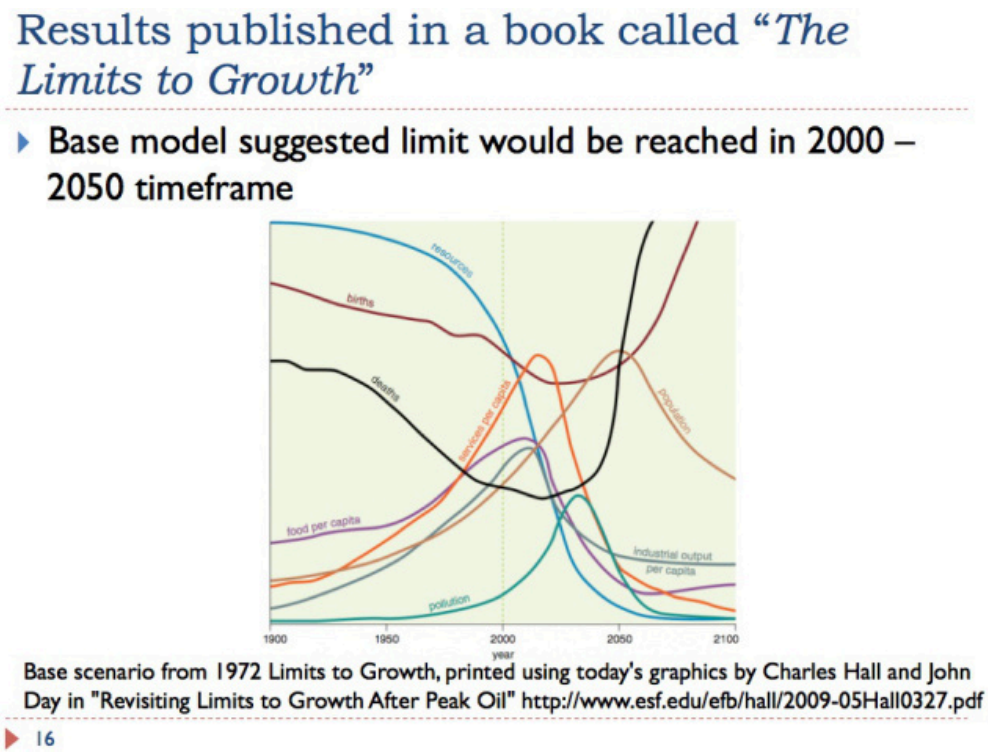
13

It seems to me that the only way a Hubbert Curve might happen is if oil prices stay high, as we approach limits. That way, as much oil as possible can be extracted. If oil prices fall too low, then the decline may be much quicker. If low oil prices are a problem, above ground problems such as governments of oil exporting nations

collapsing, or rising debt defaults leading to bank failures, may be a problem.

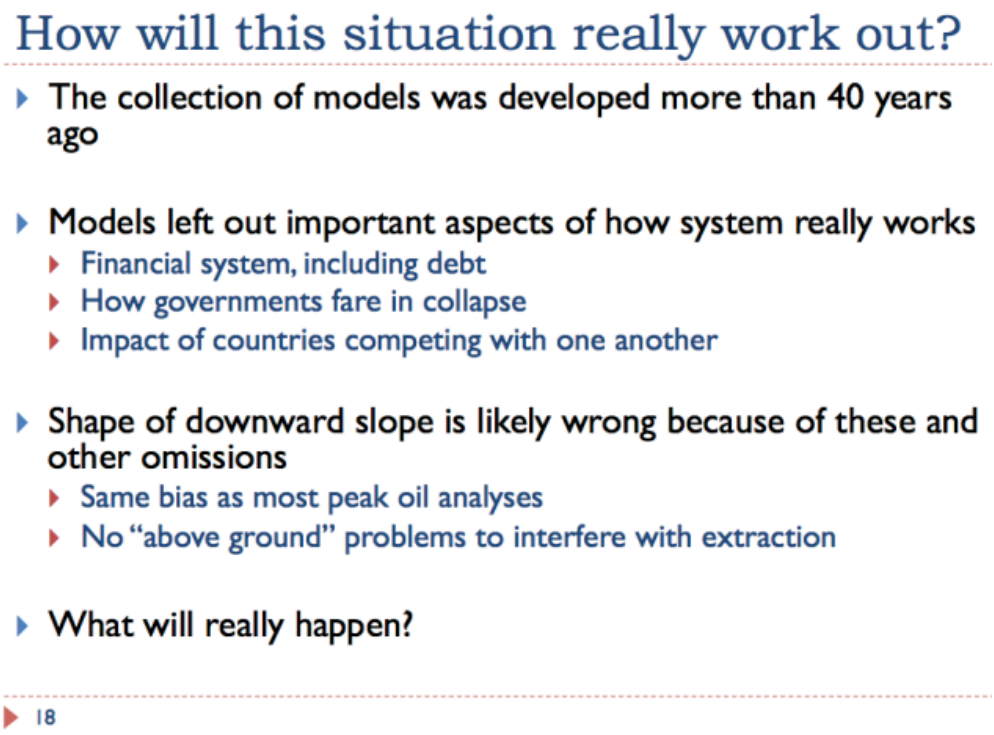
Dennis Meadows and Donella Meadows

Dennis Meadows led early computer modeling efforts at MIT regarding limits of a finite world. His wife, Donella Meadows, led the write-up effort regarding this model in a 1972 book called "Limits to Growth". The model looked at physical quantities of resources, expected amounts of pollution, and expected population trends. The base model suggested that the world would start reaching limits in roughly the current timeframe.



In fact, more recent analyses suggest that the base model is more or less on track.

I don't think that we can count directly on this analysis, however.



Charles Hall

Prof. Charles Hall has been one of the recent thought-leaders with respect to oil limits and how they might play out. He started work in the early 1970s as an ecologist, studying the energy patterns of fish. When he read about the possibility of energy shortages that might occur in the 1972 book *Limits to Growth,* he tried to adapt an approach used for studying energy patterns of fish to the world of energy production. The result was new way of measuring the efficiency of a particular energy product, called Energy Return on Energy Invested (EROEI).

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

20

This idea was an advance when it was first developed, but it has a number of practical difficulties. One of these difficulties is that its usefulness is tied to a particular view of how oil limits will affect us, namely that prices will rise, and this will allow a slow transition to alternative fuels that are less favorable in terms of EROEI. On Slide 21, this is Item (2).

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

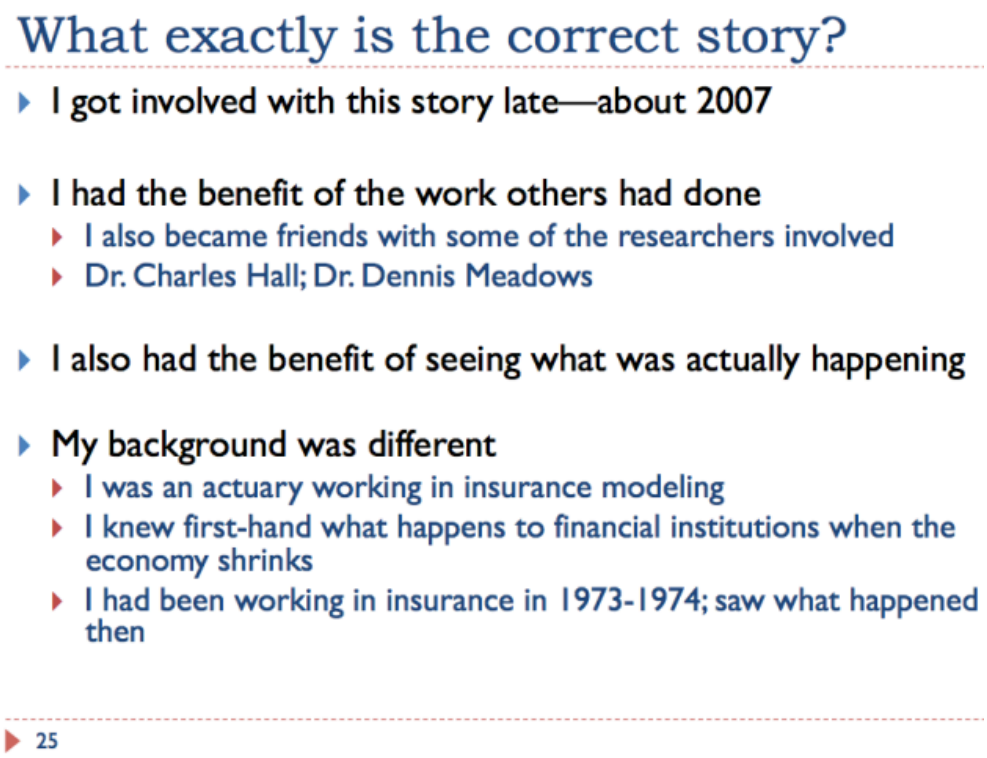
21

At this point, it is my view that the EROEI approach to analyzing energy products can be misleading and needs updating. Energy extraction is much more complicated than the energy use of fish swimming upstream. The EROEI approach, besides being tied to the Peak Oil view of how limits will occur, is difficult to calculate. Different researchers get quite different answers, when analyzing the same energy product.

Furthermore, EROEI looks at a piece of energy costs (those involved with production at the well head), but how this piece relates to the total varies from one type of energy to another. It lumps together cheap energy and expensive energy. There are several other issues as well, with the result being that in practice, low EROEI doesn't necessarily correspond to *expensive to produce*, and high EROEI doesn't necessarily correspond to *low cost to produce*.

I should point out that the same problem exists with a wide range of similar metrics including Life Cycle Analysis, Energy Payback Period, and Net Energy. In practice, what seems to happen is that if an energy type is high-priced, the use of one of these metrics is used to justify its production, anyhow. Low EROEI (for example, of biofuels) does not seem to be a barrier to production, even though it was the hope of Prof. Hall and other EROEI researchers that this would be the case.

My Involvement in Energy Analysis



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

26

I became acquainted with Prof. Lianyong Feng in 2009, when he attended the Biophysical Economics Conference in Syracuse, New York, held by Prof. Charles Hall, and heard me speak.

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

27

How Do Oil Limits Really Affect the Economy?

This is the question I have been working on. I will try to explain some of my findings in the next several sessions.

Early researchers were handicapped because the issue of oil limits crosses many different fields of research. They took approaches from their own areas of study, and worked with them. These approaches offered partial insight into the problem, but didn't completely answer what might happen in the future.

It was not obvious to early researchers which parts of economists' theories were wrong. I have had the benefit of seeing how the system works in practice in several periods: in 1973-1974, in 2008-2009, and now in 2014-2015. I have also been fortunate enough to find a number of recent studies that add new insights as to how the system really works. So I have taken a step back and developed at the least the start of a new theory, which is different from EROEI theory. This is what I will discuss in the next few sessions.

A little explanation behind this series of lectures and my four week stay in China is perhaps in order. When I was in China, Prof. Feng discussed with me some of his intent behind asking me to give this series of lectures. Prof. Hall is now retired, and there is no obvious replacement for him. Prof. Feng would like me to take a more active role is figuring out in which direction energy research should now be headed, both for his own staff, and for others around the world. A better understanding of how the system works could theoretically help researchers everywhere.

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About Gail Tverberg
My name is Gail Tverberg. I am an actuary interested in finite world issues - oil depletion, natural gas depletion, water shortages, and climate change. Oil limits look very different from what most expect, with high prices leading to recession, and low prices leading to inadequate supply.
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