

## Our Finite World

*Exploring how oil limits affect the economy*

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## Why We Should Be Concerned About Low Oil Prices

Posted on [May 5, 2017](#) by [Gail Tverberg](#)

Most people assume that oil prices, and for that matter other energy prices, will rise as we reach limits. This isn't really the way the system works; oil prices can be expected to fall too low, as we reach limits. Thus, we should not be surprised if the OPEC/Russia agreement to limit oil extraction falls apart, and oil prices fall further. This is the way the "end" is reached, not through high prices.

I recently tried to explain how the energy-economy system works, including the strange way prices fall, rather than rise, as we reach limits, at a recent workshop in Brussels called "New Narratives of Energy and Sustainability." The talk was part of an "Inspirational Workshop Series" sponsored by the Joint Research Centre of the European Commission.



Figure 1. Empty Schuman room of the Berlaymont European Commission building, shortly after we arrived. Photo shows Mario Giampietro and Vaclav Smil, who were the other speakers at the Inspirational Workshop. Attendees started arriving a few minutes later.

My talk was titled, "Elephants in the Room Regarding Energy and the Economy." ([PDF](#)) In this post, I show my slides and give a bit of commentary.

## Long-term contradiction:

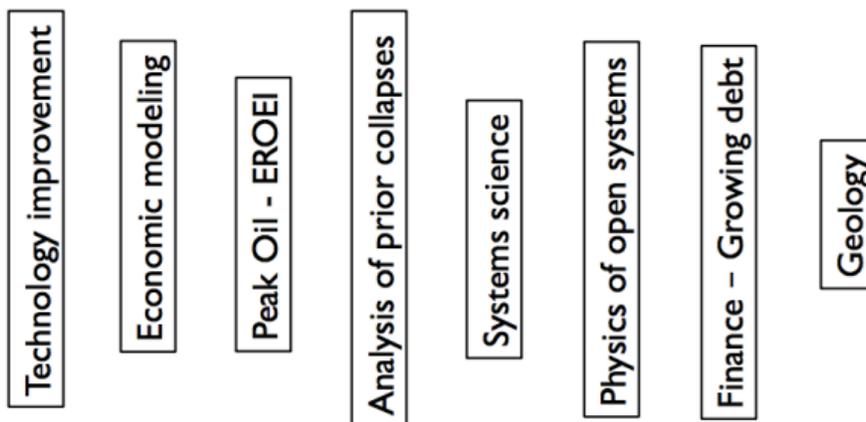
- ▶ [1] Economy needs growth
  - ▶ Economies of scale
  - ▶ Offset diminishing returns
  - ▶ Return “profit”
  
- ▶ [2] Growth cannot continue forever in a finite world



Slide 2

The question, of course, is how this growth comes to an end.

## Many areas looking at the problem - in silos



- ▶ My approach: Try to see real story, based on all sources

Slide 3

I have been aided in my approach by the internet and by the insights of many commenters to my blog posts.

## In a finite world, we find that two types of maps are necessary

### ▶ Local maps



### ▶ Maps that reflect the finite nature of the world

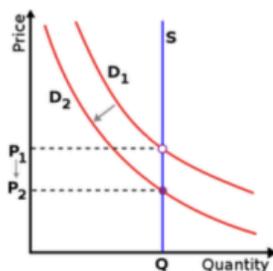


Slide 4

We all recognize that our way of visualizing distances must change, when we are dealing with a finite world.

## Economists haven't discovered need for a second modeling approach near limits

### ▶ Supply and demand, away from limits



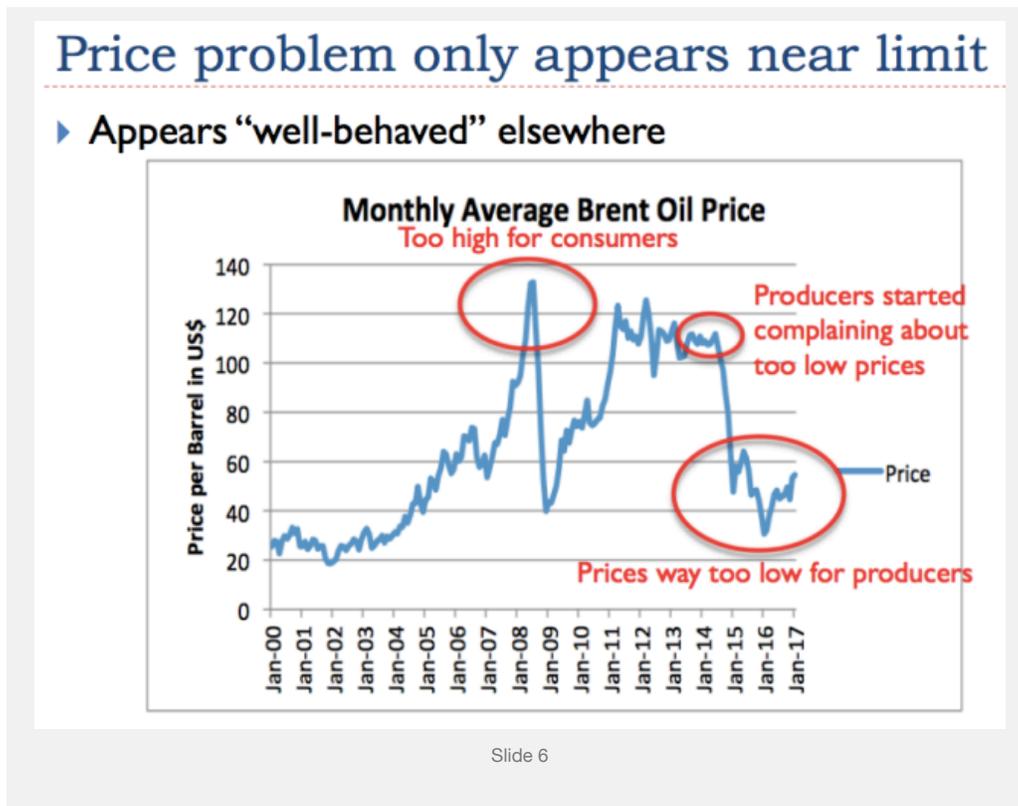
### ▶ Near limits, situation is different

Energy prices too low compared to cost of production

Too few energy suppliers because of low prices

Slide 5

I should note that **not all** economists have missed the fact that the pricing situation changes, as limits are reached. Aude Illig and Ian Schindler have recently [published a paper](#) that concludes, “We find that price feedback cycles which lead to increased production during the growth phase of oil extraction **go into reverse** in the contraction phase of oil extraction, speeding decline.”



The comments shown in red on Slide 6 reflect a variety of discussions over the last several years. Oil prices in the \$50 per barrel range are way too low for producers. They may be high enough to get “oil out of the ground,” but they are not high enough to encourage necessary reinvestment, and they are not high enough to provide the tax revenue that oil exporters depend on.

## Reason why problem is different than expected

- ▶ **Producers** and **consumers** of energy products are both important
- ▶ Energy prices can be **too high for consumers**
- ▶ Energy prices can be **too low for producers**
- ▶ Both consumers and producers are important
  - ▶ World economy cannot operate without both being satisfied
  - ▶ Either **too low** or **too high** a price is a problem
  - ▶ Markets affected because producers need profitability

Slide 7

Most people don't stop to think about the symmetric nature of the problem. They also don't realize that the adverse impacts of low oil prices don't necessarily appear immediately. They can temporarily be hidden by more debt.

## When cost of oil "E&P" suddenly rises, but wages don't, prices behave strangely



Source: IEA, Barclays Research

### E&P Capex per Barrel

Source: Barclays Capital

Figure by Steve Kopits of Westwood Douglas. CAGR is compound annual growth rate.

Slide 8

There would be no problem if wages were to rise as oil prices rise. Or if there were an easily substitutable source of cheap energy. The problem becomes an affordability problem.

## Current oil price level appears to represent lack of *affordability*

- ▶ Result is low prices; glut of oil
- ▶ “Supply – demand” terminology is confusing
  - ▶ Should be “supply – amount affordable”

Slide 9

The economists’ choice of the word “demand” is confusing. A person cannot simply demand to buy a car, or demand to go on a vacation trip. The person needs some way to pay for these things.

## Economic situation is like mirror image problem - more complex than expected



Maroon Bells near Aspen, Colorado - Source: <http://www.worldfortravel.com/2012/09/13/the-maroon-bells-united-states/the-maroon-bells-mirror-landscape/>

Slide 10

If researchers don’t examine the situation closely, they miss the nuances.

# How the Economy Grows and What Goes Wrong

Slide 11

## Tools are clearly one key to economic growth

- ▶ Tools broadly defined
  - ▶ Machines
  - ▶ Roads
  - ▶ Vehicles
  - ▶ Computers
  
- ▶ **Rising quantity of tools** leads to growing productivity
  - ▶ Tools act to leverage human labor
  
- ▶ Growing tool use leads to more energy consumption
  - ▶ Both to make and operate tools

Slide 12

Many people think that the increasing use of tools can save us, because of the possibility of increased productivity.

## Making these tools also requires *debt*

- ▶ Problem with tools: **benefit is all in the future**
- ▶ Need to create tools using human labor, plus energy and mineral resources, **before** the benefit is received
  - ▶ How can the economy pay for these tools?
  - ▶ Debt and debt-like instruments
  - ▶ Selling shares of stock acts like debt as well
- ▶ Using debt, it is possible to **pay workers now, for the future benefit that tools will provide** Important!
- ▶ **Need for debt, besides energy, when tools are added is part of mirror image problem**

Slide 13

Using more tools leads to the need for an increasing amount of debt.

## An economy produces goods and services

Growing quantity of energy products and other resources

+

Growing number of workers

+

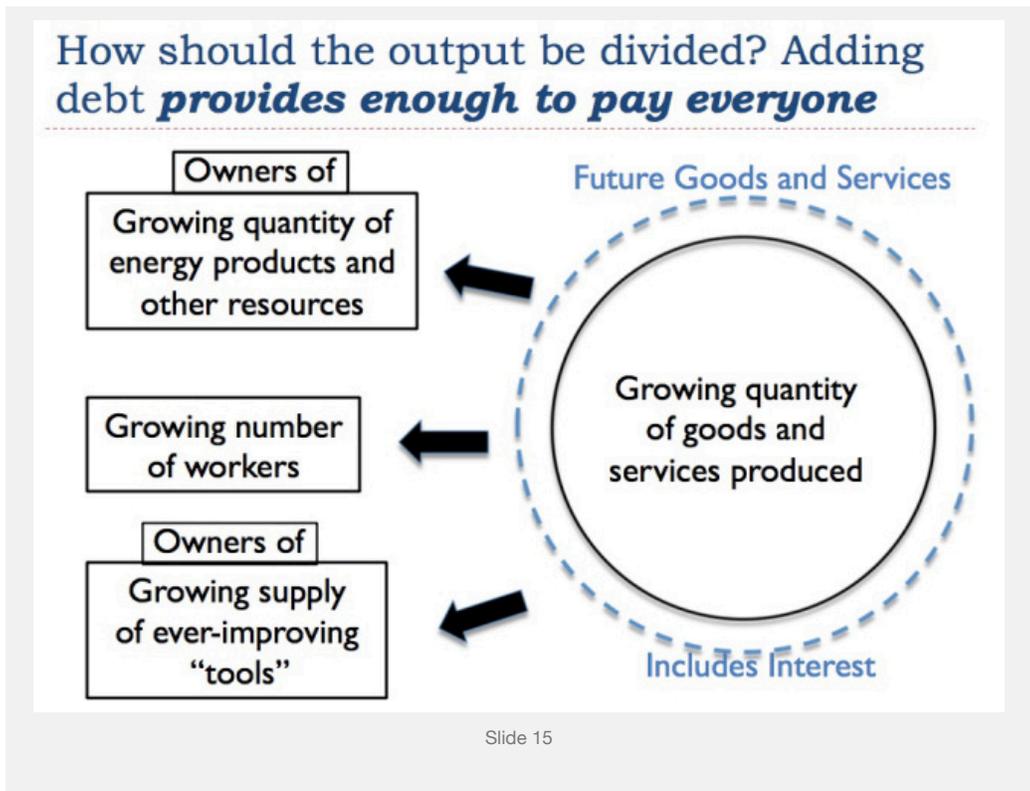
Growing supply of ever-improving "tools"

=

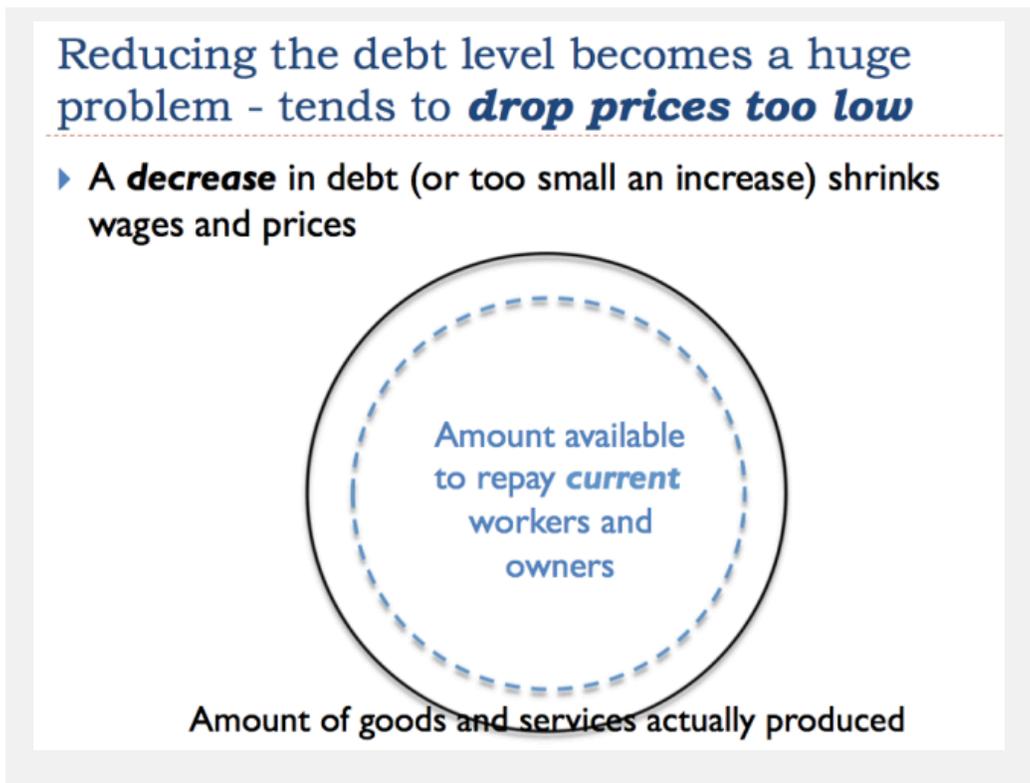
Growing quantity of goods and services produced

Slide 14

Read this chart from left to right. If we combine increasing quantities of resources, workers, and tools, the output is a growing quantity of goods and services.



Read this chart from right to left. How do we divide up the goods and services produced, among those who produced the products? If we can only use previously produced goods to pay workers and other contributors to the system, we will never have enough. But with the benefit of debt, we can promise some participants “future goods and services,” and thus have enough goods and services to pay everyone.



Slide 16

If we decrease the amount of debt, we have a big problem. Instead of the debt **adding to** the amount of goods and services produced, the shrinkage acts to decrease the amount of goods and services available for distribution as pay. This is why moving from deficit spending to a balanced budget, or a budget that reduces debt, is so painful.

## Another source of insight: studies of past collapses

- ▶ See what happened when (resources/population) fell too low
- ▶ Similar to less arable land per person
  - ▶ Able to work around with more technology, such as irrigation
- ▶ Avoid standard false reasoning

In a finite world, we find that two types of maps are necessary

▶ Local maps



▶ Maps that reflect the finite nature of the world



Slide 17

When I say (resources/population), I mean **resources per capita**. Falling resources per capita makes it harder to earn an adequate living. Think of farmers trying to subsist on ever-smaller farms. It would become increasingly difficult for them to earn a living, unless there were to be a big improvement in technology.

Or think of a miner who is extracting ore that is gradually dropping from 5% metal, to 2% metal, to 1% metal content, and so on, because the best quality ore is extracted first. The miner needs to work an increasing number of hours to produce the ore needed for 100 kilograms of the metal. The economy is becoming in some sense “worse off,” because the worker is becoming “inefficient” through no fault of his own. The resources needed to provide benefits simply are less available, due to diminishing returns. This problem is sometimes reported as “falling productivity per worker.”

Falling productivity per worker tends to lower wages. And lower wages put downward pressure on commodity prices, because of affordability problems.

## A few insights from historical collapses

(Turchin and Nefedov; also Joseph Tainter)

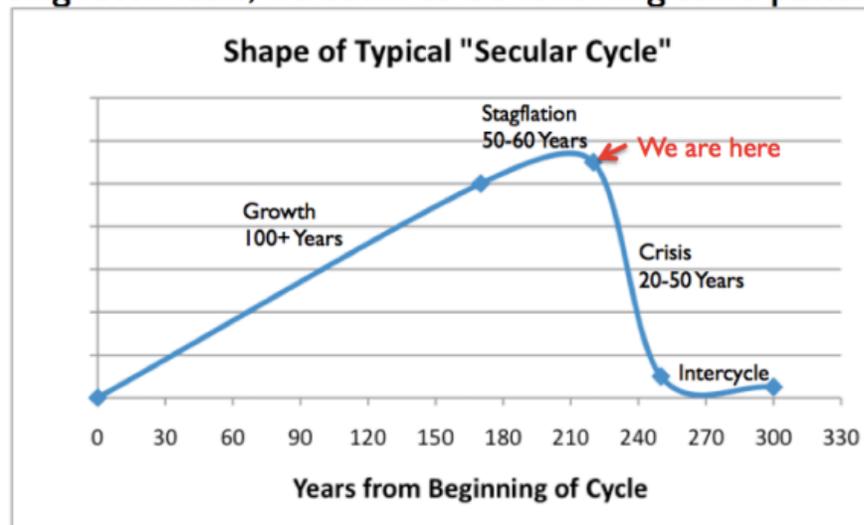
- ▶ Slowing growth and greater use of “complexity” preceded collapses
- ▶ Greater complexity involved specialization; more tools and technology
  - ▶ Problem 1: Rising complexity leads to increasing wage disparity
    - ▶ Some get specialized training; others do not
  - ▶ Problem 2: Complexity reaches diminishing returns (Tainter)
- ▶ Ultimately, collapse comes because **wages of non-elite workers fall too low**
  - ▶ Non-elite workers can't afford output of economy
  - ▶ Governments can't collect enough taxes
  - ▶ Epidemics may become a problem, because of poorer nutrition

Slide 18

The problems that prior civilizations reached before collapse sound in many ways like the problems we are seeing today. We are seeing increased specialization, and falling relative wages of non-elite workers.

## Shape of cycle based on Turchin and Nefedov analysis

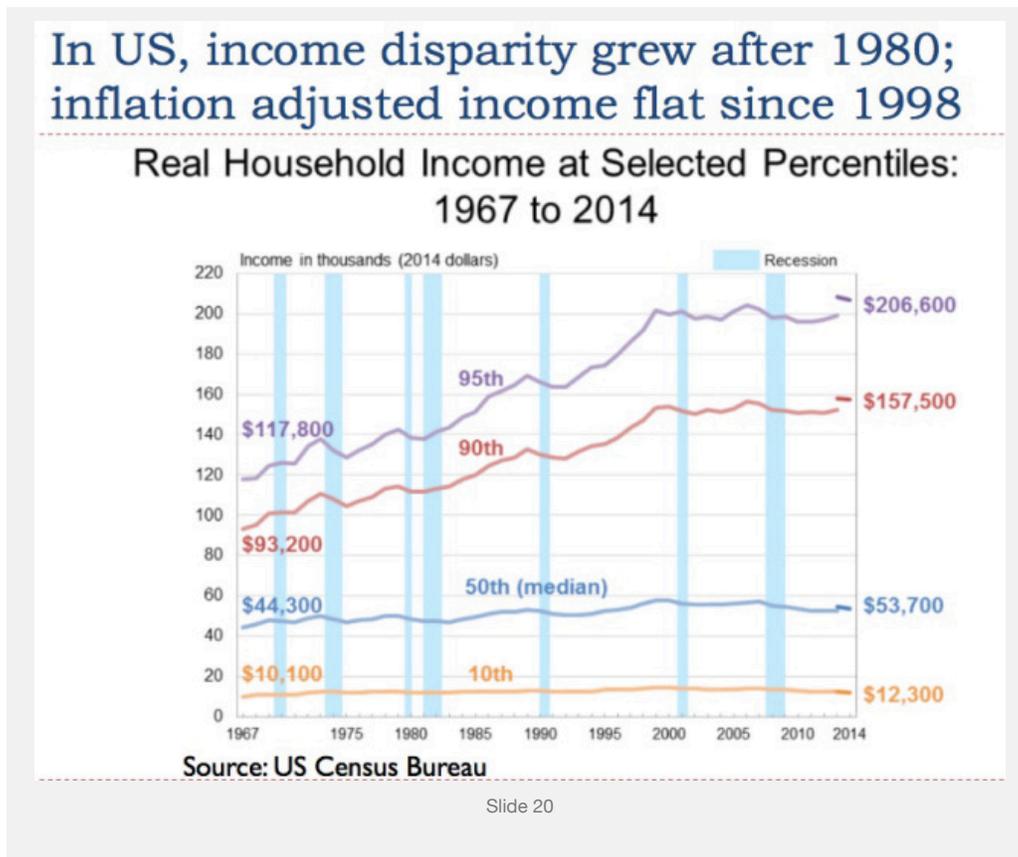
Using fossil fuels, we seem to be following same pattern:



Tverberg image based on Turchin and Nefedov analysis in *Secular Cycles*.

Slide 19

We seem to have already gone through a long period of stagflation since the 1970s. The symptoms we are seeing today look as if we are approaching a steep downslope. If we are approaching a crisis stage, it may be much shorter than the 20 to 50 years observed historically. Earlier civilizations (from which these timeframes were observed), did not have electricity or the extensive international trade system we have today.



The period since 1998 seems especially flat for wages for US wage earners, in inflation-adjusted terms. This is the period since energy prices started rising, and since globalization started playing a greater role.

## How adding tools/technology eventually leads to collapse

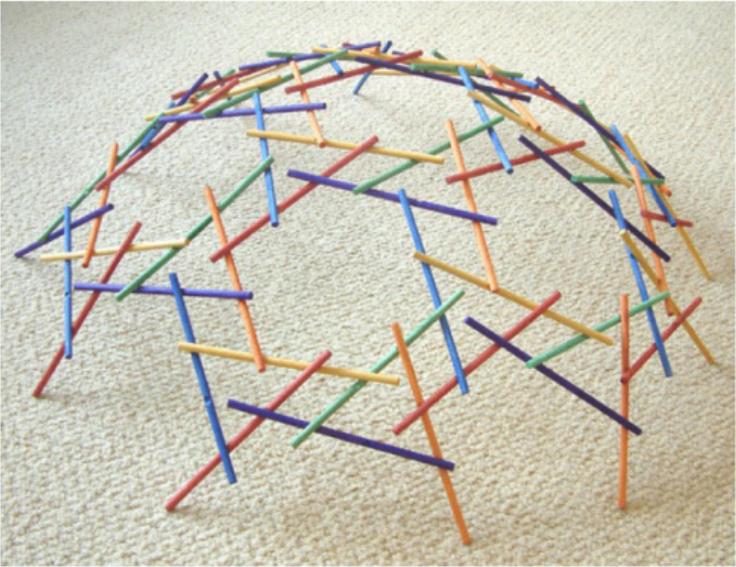
1. Energy extraction reaches diminishing returns, because we extract the cheapest-to-extract first.
2. Benefits of new technology reach diminishing returns.
3. Debt tends to grow rapidly—leads to wealth concentration and interest payments to the wealthy.
4. Specialization leads to wage disparity.
5. Non-elite workers become too poor to afford output of economy.
6. Energy prices fall because of inadequate demand—related to low wages of non-elite workers.
7. Energy producers leave market because prices are too low.
8. Tax collections fall, eventually leading to governmental collapse, or over-run by a stronger economy.

Slide 21

This is a list I made, showing that what looks to be beneficial—adding tools and technology—eventually leads to our downfall. The big problem that occurs is that **non-elite workers become too poor to afford the output of the economy**. Adding robots to replace workers looks efficient, but leaves many unemployed. Unemployment is even worse than low pay.

Economy is a self-organized system that grows in the presence of energy and debt

▶ Energy part of system is reaching **diminishing returns**



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

Slide 22

The image shows a Leonardo Sticks toy, a self-organizing structure made of colorful sticks (red, blue, green, yellow, orange) arranged in a dome-like shape. The sticks are interconnected, forming a complex, interconnected network that resembles a self-organized system. The structure is built on a light-colored, textured surface.

We can think of the economy as being a self-organized network of businesses, consumers, and governments. New products are gradually added, and ones that are no longer needed are eliminated. Government regulations change in response to changing business conditions. Debt is especially important for economic growth, because it makes goods affordable for customers, and it enables the use of “tools.” Prices are created almost magically by this networked system, through the interaction between supply and demand (reflecting affordability, among other things).

## Physics: Our *economy* is a *dissipative structure*

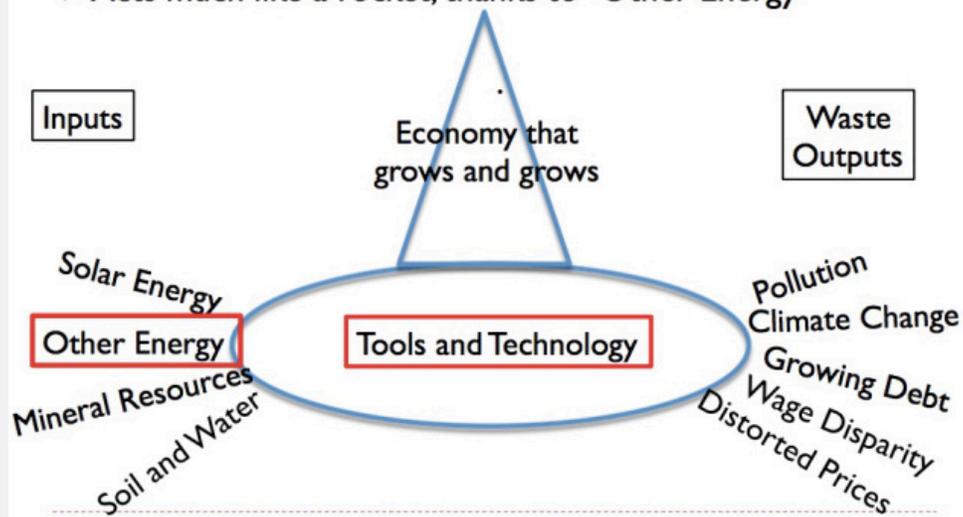
- ▶ Dissipative structures self-organize and “grow” when flows of energy are available. Examples:
  - ▶ Hurricanes
  - ▶ Stars, including the sun
  - ▶ Ecosystems
  - ▶ Plants and animals
  
- ▶ Each type of dissipative structure is a little different
  
- ▶ Energy flows are **essential** to the operation of dissipative structures
  
- ▶ All dissipative systems are temporary
  - ▶ Grow and eventually collapse

Slide 23

It is only in recent years that physicists have become increasingly aware of the fact that many types of structures form in the presence of flows of energy. We have known for a long time that plants and animals can grow when conditions are right. The networked economy illustrated on Slide 22 is one of the types of things that can grow and flourish in the presence of energy flows.

## My view of economy as a dissipative structure

- ▶ Acts much like a rocket, thanks to “Other Energy”



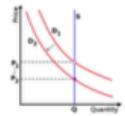
Slide 24

This is my view of how an economy, as a dissipative structure, works. “Tools and technology” are at the center. If a person doesn’t think too much about the issues involved, it is easy to assume that tools and technology will allow the economy to grow forever.

There is a potential for problems, both with respect to inputs and waste outputs. Early modelers missed many of these “issues.” M. King Hubbert created a model in which *the quantity of energy supply* and *technology* are the only issues of importance. He thus missed the impact of the Waste Output problems at the right. The Waste Outputs lead to falling prices as limited supply nears, and thus lead to a much steeper drop in production than Hubbert’s symmetric model would suggest.

**Peak oil story seems to be a mirror image of the correct story**

- ▶ **Peak oil is not a “new and different” problem**
  - ▶ It is a repeat of (resources/population) falling too low
- ▶ **Result is likely falling prices, not high prices**
  - ▶ Wages of non-elite workers fall too low
  - ▶ Cannot afford the goods being produced
- ▶ **Easy to build model using false beliefs of economists**
  - ▶ Economists haven’t discovered need for a second modeling approach near limits
    - ▶ Supply and demand, away from limits



- ▶ Near limits, situation is different
  - ▶ Energy prices too low compared to cost of production
  - ▶ Too few energy suppliers because of low prices

Slide 25

Peak oilers recognized one important point: our use of oil products would at some point have to come to an end. But they did not understand how complex the situation is. Low prices, rather than high, would be the problem. We would see gluts rather than shortages, as we approach limits. Much of the oil that seems to be technologically extractable will really be left in the ground, because of low prices and other problems.

## Elephants in the Room

Slide 26

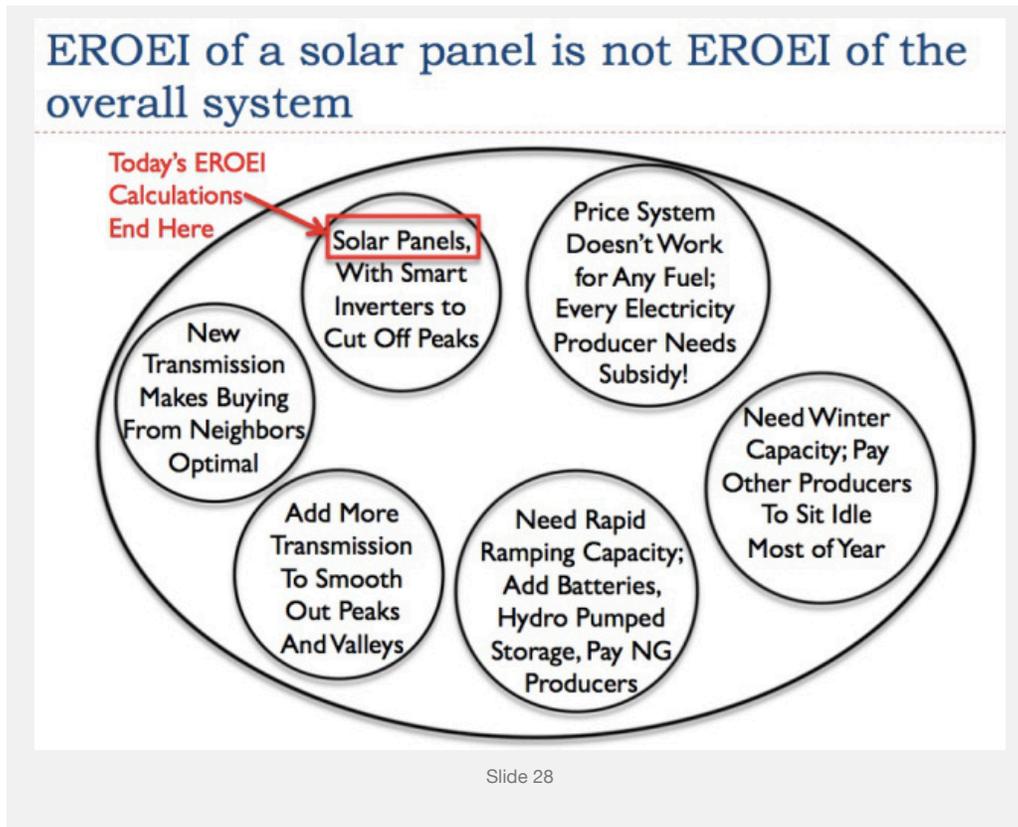
Here, I am getting back to the topic I was originally asked to talk about. What else, besides low energy prices and too much debt, are likely to be problems as we reach limits?

## 1. Wind and solar can't really save us

- ▶ Everyone has modeled the problem in the wrong way
- ▶ Issue is not, "How much electricity can a solar panel or wind turbine produce?"
  - ▶ And, "How much fossil fuel will this displace?"
- ▶ Issue is how wind and solar will affect the overall system
  - ▶ Extent to which they artificially lower wholesale electricity prices
  - ▶ Extent to which they drive electricity producers needed for backup from the marketplace

Slide 27

The easy way of modeling the use of wind turbines and solar turbines is to assume that the electricity produced by these devices is equivalent to electricity produced by fossil fuels, or by hydroelectric. Unfortunately, this is not the case.

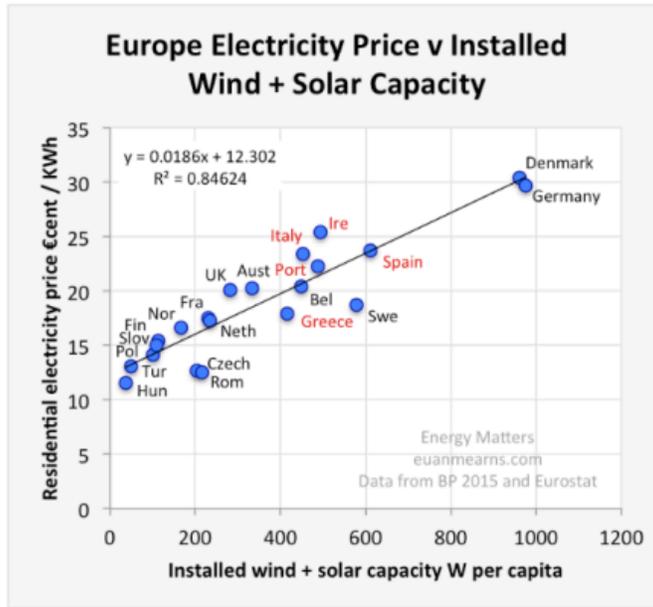


Trying to integrate solar panels into an electric grid adds a whole new level of complexity to the electrical system. I have only illustrated some of the issues that arise in Slide 28.

The fact that the **price system doesn't work for any fuel** is a major impediment to adding more than a very small percentage of intermittent renewables to the electric grid. Intermittent renewables can only be used on the electric grid if they have a 24/7/365 backup supply that can be ramped up and down as needed. Unfortunately, the pricing system does not provide nearly high enough rates for this service. We are now seeing how this works out in practice. South Australia lost its last two coal-fired electricity power plants due to inadequate wholesale electricity prices when it added wind and solar. Now it is [experiencing problems with both high electricity prices and too-frequent outages](#).

Another problem is that **new [long distance] transmission makes buying from neighbors optimal**, over at the left of Slide 28. This is a new version of the [tragedy of the commons](#). Once long distance lines are available, and a neighbor has a fairly inexpensive supply of electricity, the temptation is to simply buy the neighbor's electricity, rather than build local electricity generating capacity. The greater demand, without additional supply, then raises electricity prices for all, including the neighbor who originally had the less expensive electricity generation.

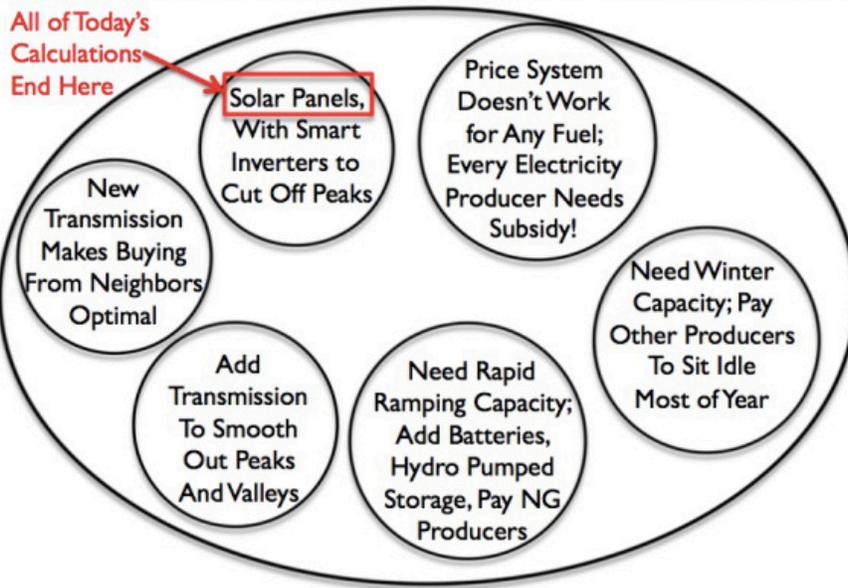
EROEI tells us essentially nothing about cost of wind and solar - but cost seems to be high



Slide 29

It is easy to assume that EROEI (Energy Returned on Energy Invested) or some other popular metric tells us something useful about the cost of integrating intermittent renewables into the electric grid, but this really isn't the case.

No one models how the system really works, because problem is too complex to model!



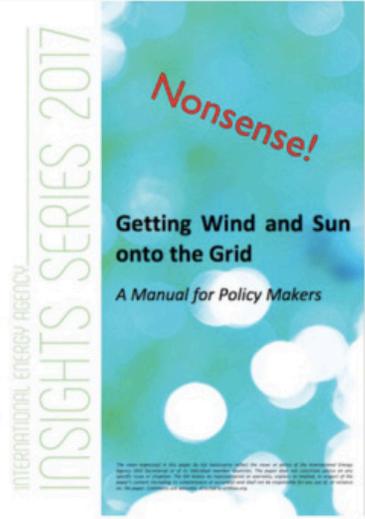
Slide 30

We are now beginning to see what happens in “real life,” as intermittent renewables are added. For example, we can now see the problems South Australia is having with [high electricity prices and too many outages](#) as well as the high electricity prices in Germany and Denmark (Slide 29).

**All analyses equivalently false**

- ▶ EROEI
- ▶ Levelized cost of electricity
- ▶ Low auction prices of wind, solar
- ▶ New IEA report
- ▶ Energy payback period
- ▶ Life cycle analysis

All look at one piece of problem  
But not the important pieces!



The image shows the cover of an International Energy Agency (IEA) report titled "INSIGHTS SERIES 2017: Getting Wind and Sun onto the Grid: A Manual for Policy Makers". The cover features a blue and green abstract design with white circles. A large red stamp with the word "Nonsense!" is overlaid on the top right of the cover. The text on the cover includes "INTERNATIONAL ENERGY AGENCY" and "INSIGHTS SERIES 2017".

Slide 31

Wind and solar are not very helpful as stand-alone devices. Yet this is the way they are modeled. Some researchers have included installation costs, but this still misses the many problems that these devices cause for the electrical system, especially as the share of electricity production by these devices rises.

## 2. Our economy has no option but to grow. If it shrinks, it collapses.

### ▶ Issues are hollow nature of system; role of debt



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

Slide 33

A networked system works differently than a system that is “user controlled.” It builds itself, and it can collapse, if conditions aren’t right. I have shown the economy as hollow, because there is no way of going backward.

## Economy must grow, requiring ever-more energy

### ▶ Problem 1

- ▶ Can’t go backward to less energy-intensive uses
- ▶ Example: Can’t go back to the use of horses instead of cars

### ▶ Problem 2

- ▶ Need to keep adding new debt, and repay existing debt with interest
- ▶ Debt underlies financial system
- ▶ Financial system will collapse if we try to shrink
  - ▶ Will have worse problems than 2008

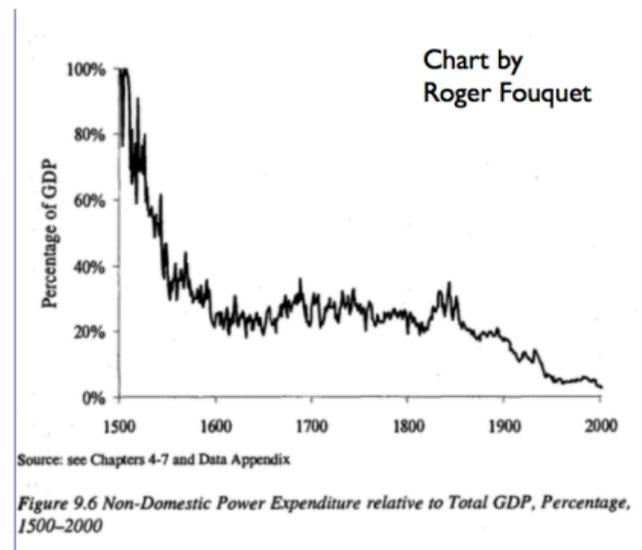
Slide 34

Many people miss the point that the economy must keep growing. In fact, I pointed this out in Slide 2 and gave

an additional reason why it must keep growing on Slide 16. As the economy grows, we tend to need more energy. Growing efficiency can only slightly offset this. Thus, as a practical matter, energy per capita needs to stay at least level for an economy to grow.

### 3. Growth of world economy requires a growing quantity of ever-cheaper energy

#### ▶ Falling energy prices enable growth of rest of economy



Slide 35

If energy prices rise, this will tend to squeeze out discretionary spending on other goods and services. If we cannot obtain energy products sufficiently cheaply, the system of economic growth will stop.

## UN world data also shows falling energy expenditures as GDP% (bottom two layers)

▶ Economy rebalances to the cheapest fuels

▶ Prices can fall below the cost of production

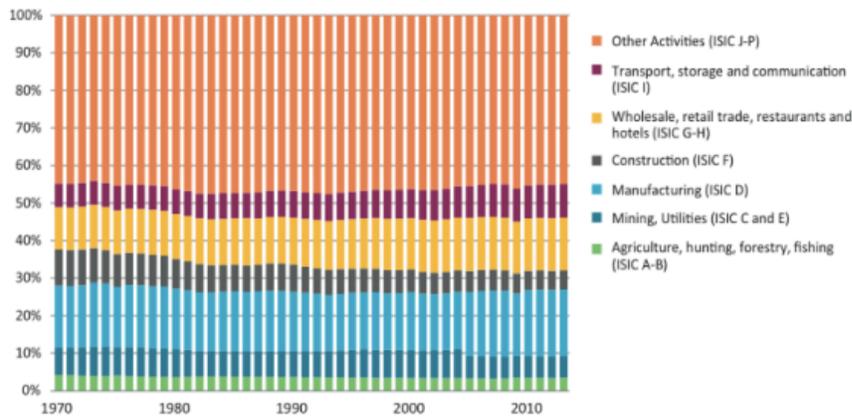


Figure 2. World GDP sector added value shares

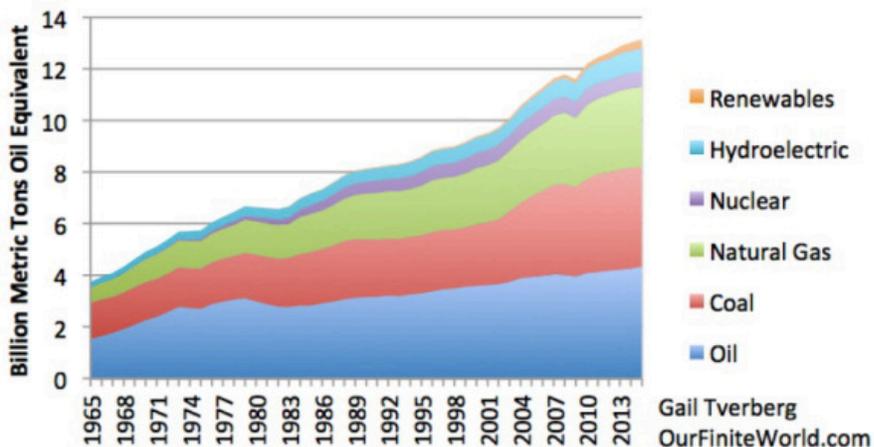
Slide 36

The fact that energy prices can, and do, fall below the cost of production is something that has been missed by many modelers. Prices can go down, even when the cost of production plus taxes needed by governments rises!

## Attempt to shift from cheap coal to high-cost renewables is futile

▶ Can't produce enough renewables, cheaply enough

### World Energy Consumption by Fuel



Gail Tverberg  
OurFiniteWorld.com

Slide 37

Wind and solar are part of the category at the top called “renewables.” This category also includes energy from wood and from geothermal. Many people do not realize how small this category is. Hydroelectric is also considered a renewable, but it is not growing in supply in the United States or Europe.

#### 4. International organizations of governments, such as the EU, are at risk

- ▶ **Expect these signs when an economy has energy surpluses:**
  - ▶ Rapidly growing economies
  - ▶ Rapidly growing tax revenue
  - ▶ Energy products (oil, coal, natural gas, renewables) provide considerable tax revenue
  - ▶ Worker productivity rises
  - ▶ Wages of workers, even non-elite workers, rise
  
- ▶ **Recent problems are signs of too little surplus energy**
  
- ▶ **Most vulnerable organizations are top level organizations**
  - ▶ **Soviet Union collapsed in 1991, when oil prices were low**

Slide 38

It takes energy to have an intergovernmental organization, such as the European Union. In fact, it takes energy to operate any kind of government. When there is not enough surplus energy to go around, citizens decide that the benefits of belonging to such organizations are less than the costs involved. That is the reason for the Brexit vote, and the reason the question is coming up elsewhere.

## 5. Oil exporters can expect to have problems similar to Arab Spring uprisings

- ▶ Issue is continued low oil prices – budgets require \$100+ oil
- ▶ Oil exporters cannot afford to maintain programs for their citizens, without high taxes made possible by high prices
  - ▶ Food subsidies
  - ▶ Fuel subsidies
  - ▶ Programs to provide jobs, schools, hospitals
- ▶ Large unemployed population is likely to be angry
- ▶ Example: Venezuela
  - ▶ Ironical that the country has the world's largest “proven oil reserves”
    - ▶ Problem: Proven reserves are of no value unless oil price is higher
  - ▶ In danger of becoming a “failed state”

Slide 39

The amount of taxes oil-producing countries can collect depends on how high the price of oil is. If the price isn't high enough, oil-exporting countries generally have to cut back their budgets. Even [Saudi Arabia is having difficulty with low oil prices](#). It has needed to borrow in order to maintain its programs.

## 6. Low oil prices may lead to lower oil production and falling productivity

- ▶ Low oil prices lead to inadequate investment in new oil fields
  - ▶ Production too low by 2020, according to IEA
  - ▶ Also, exporters may start failing for financial reasons
- ▶ With less oil, total energy use falls
  - ▶ Less able to build new, more efficient “tools”
  - ▶ May use existing “tools” less
  - ▶ Less leveraging of human labor
  - ▶ Falling productivity more of problem than today
- ▶ Temporary spiking of oil prices doesn't really help
  - ▶ Business will add labor, rather than more “tools”
  - ▶ Addition of more oil requires long-term high prices

Slide 40

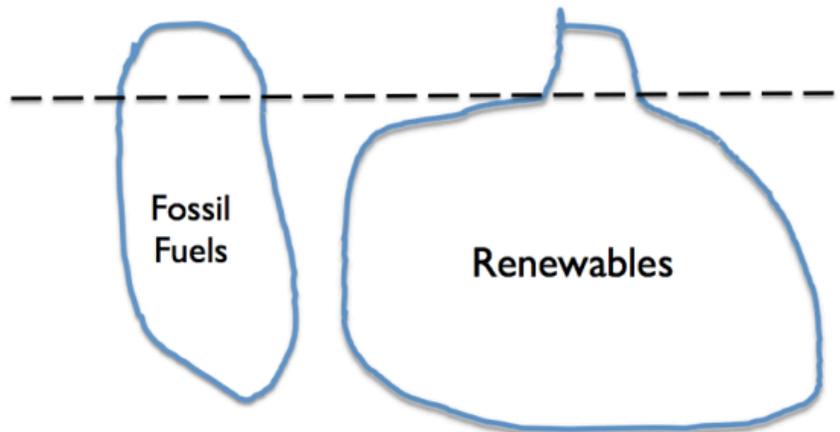
Oil prices have been too low for producers since at least mid-2014. It is possible to hide a problem with low prices with increasing debt for a few years, but not indefinitely. The longer the low-price scenario continues, the more likely a collapse in production is. Also, the tendency of international organizations of government to collapse (Slide 38) takes a few years to manifest itself, as does the tendency for civil unrest within oil exporters (Slide 39).

## How We Arrived Where We Are Today

Slide 41

### 1. We have been expecting too much of models of **pieces of the system**

- ▶ EROEI is specialized tool that measures tips of icebergs
- ▶ Doesn't produce consistent readings for renewables and fossil fuels



Slide 42

It is easy to miss the point that modeling a piece of the system doesn't necessarily tell a person very much about the system as a whole.

## 2. Other issues also contributed

- ▶ Too much wishful thinking
- ▶ Addition of limits adds a whole different dynamic
  - ▶ Virtually everyone missed the **low price** problem
  - ▶ Similar to world as a sphere, instead of a flat plane
- ▶ Research approaches don't get quickly to the right result
  - ▶ Peer-review system perpetuates wrong thinking
  - ▶ Financial grants involve analyses of small pieces of the system
  - ▶ Have to see for ourselves that new approaches don't work!

Slide 43

Once an incorrect understanding of our energy problem becomes firmly entrenched, it becomes very difficult for leaders to understand the real problem.

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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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