Energy-Economy Update/Perspective
We Are Entering a New, More Fragile World

Gail Tverberg, Dec. 12, 2018, SSP IEEE WiSEE 2018

We are entering a new, more fragile world - outline

1. The Energy-Economy story that we have been told
2. A few things that are going wrong with the current story
3. What the real Energy-Economy story seems to be
4. Conventional models are wrong
5. Conclusion: A major downturn may be ahead
   - The future seems less welcoming for any new technology

The Energy-Economy Story that We Have Been Told

The Energy-Economy story that we have been told:

- The world is filled with resources of many types
- We will be able to access these resources thanks to
  - Improved technology
  - Higher energy prices
  - Continued globalization
- Our biggest problem is climate change
  - Can fight this with carbon taxes; subsidies for intermittent wind and solar
  - Electric system is expected to continue
  - Fossil fuel system will shrink back greatly

US Energy Information Administration shows estimates of levelized costs of electricity per kWh in 2022 (in 2017$)

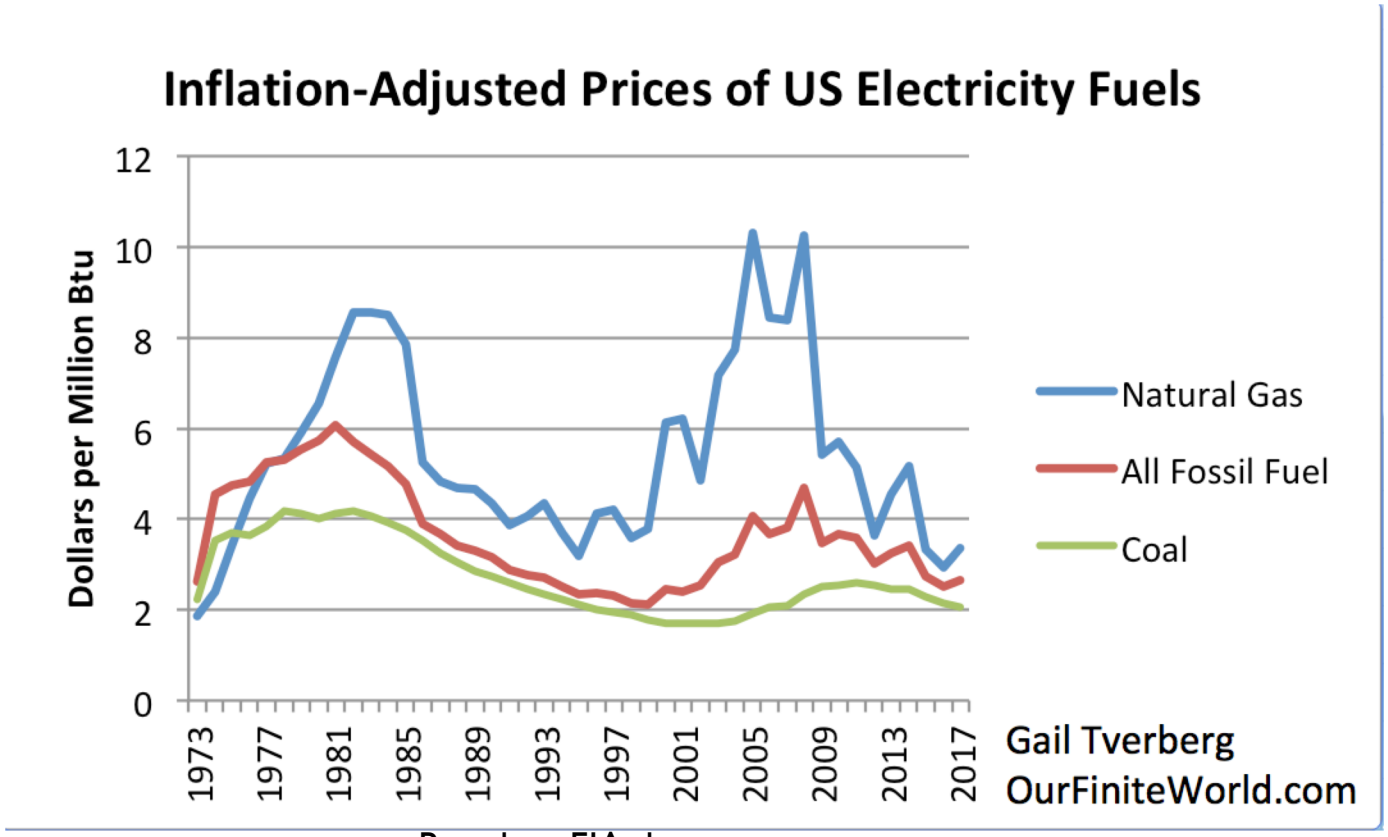
- Coal with 30% CCS: 11.7 – 19.1 cents
- Combined Cycle Natural Gas w/o CCS: 4.5 – 7.9 cents
- Combined Cycle Natural Gas with CCS: 6.7 – 8.5 cents
- Natural Gas Peaking Plants: 7.5 – 14.5 cents
- Advanced Nuclear: 9.0 – 9.8 cents
- Biomass: 7.0 – 11.1 cents

- Non-dispatchable technologies
  - Onshore wind: 4.1 – 7.7 cents
  - Offshore wind: 12.2 – 16.8 cents
  - Solar PV: 4.2 – 11.4 cents (regional variation)

These 2022 expected costs are very high compared to recent costs

- Nuclear: Forecast 9.0 – 9.8 cents
  - 2017 average cost of operational plants, 3.4 cents (Nuclear Energy Institute)
  - Close to triple cost of older plants, now in operation
- Wind: Forecast 4.1 – 7.8 cents; current selling price of wind in PPAs, less than 3 cents
  - At least double what variable wind power sells for today
- Coal with 30% CCS: Outrageously expensive at 11.7 – 19.1 cents
  - No new coal permitted without CCS
- Natural Gas Combined Cycle without CCS shown as 4.5 – 7.9 cents
  - Only price that is vaguely close to today's costs
  - Assumes some upward variability of natural gas prices; could be much worse

Natural gas prices have historically been quite variable. Also much higher than delivered coal prices.



Based on EIA data.

Forecasts basically assume

- Rising cost of electricity production will be no problem
- Variability in energy costs (natural gas) will be no problem
  - Variability in supply (intermittent wind and solar) will be no problem
- Resource depletion will be no problem
  - With rising prices, new technology will be possible; more can be extracted
- Economy can either
  - Get along with much less energy per capita
  - Or can scale up intermittent renewables to replace most fossil fuels, very quickly

Forecasts basically assume (continued)

- Politicians are in charge
  - Can make whatever changes to energy-economy they choose
  - No pesky interference from the laws of physics!
- It is appropriate to assume continuation of BAU in climate models
  - Globalization will continue indefinitely to allow BAU to continue
- Citizens will have no problem with higher carbon taxes
- Energy-Economy system will adapt to the changes political leaders choose

A Few Things Going Wrong with the Current Story

Item 1. France is rioting in response to higher carbon taxes on diesel

- Riots in Paris and across the country
- Morphed into protests against the high general cost of living
- France's big plan to tackle climate change is in question
- Many want to get rid of the current president
  - Impose tax on the very rich

Item 2. UK's high industrial electricity price concerns the steel industry; price may be even higher this winter

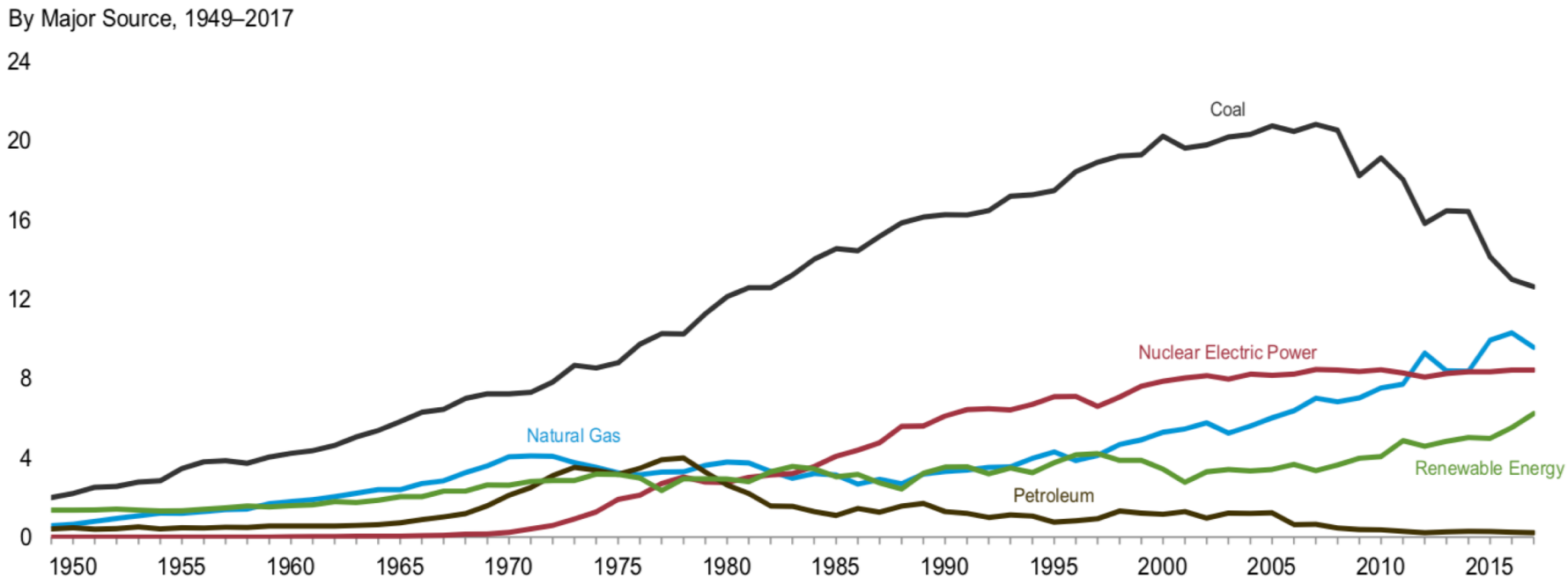
- UK electricity price for steel is now the equivalent of 8.3 cents per kWh, compared to 3.9 cents in France, and 5.5 cents in Germany
  - Some US prices: Washington State, 4.6 cents; Illinois, 6.5 cents; Tennessee, 5.8 cents; California, 12.7 cents
  - UK at 8.3 cents cannot compete
- Potential for much higher UK electricity prices this winter
  - UK natural gas in storage is a third of that three years ago
  - Planning to use more LNG this winter
- Variability of wind supply a contributor to price problem;
  - Also rising carbon prices

Item 3. Higher energy prices because of diminishing returns is very much like rewarding inefficiency

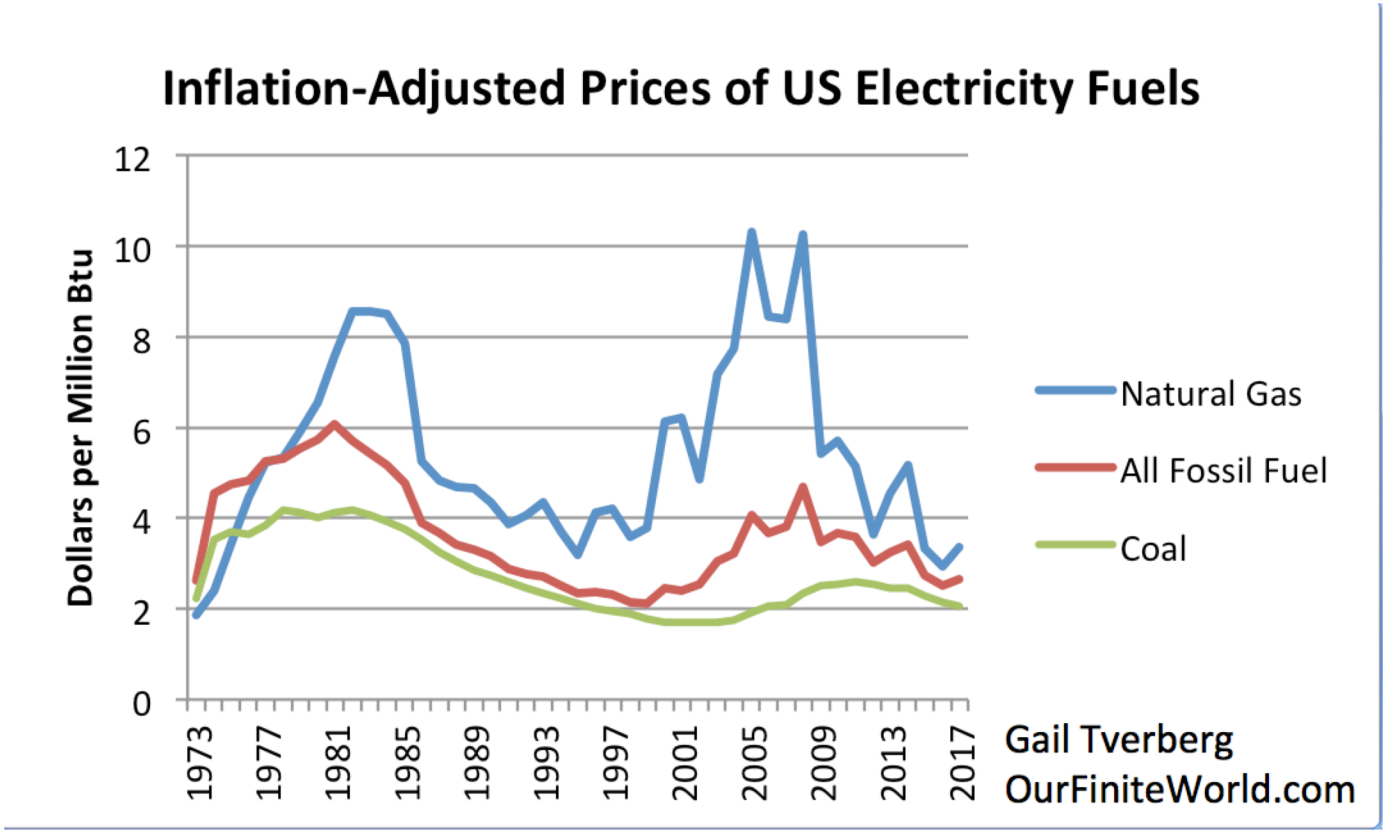
- Energy costs have been increasing because of diminishing returns
  - We extracted the cheapest-to-extract resources first, for example
  - Diminishing returns affect the system very much in the same way as growing inefficiency
- If a widget maker makes fewer widgets per hour
  - Number of widgets he makes falls
  - Price of a widget doesn't rise
- Why should the price of a barrel of oil rise, as the producer's costs rise?
  - Or the price of a Btu of electricity?
- Who gets penalized for growing inefficiency?
  - The seller or the buyer?

Item 4. US electricity looks as if subsidized renewables are killing off nearly all other production, but renewables are not enough

Figure 2.6 Electric Power Sector Energy Consumption
(Quadrillion Btu)



Item 4a. Coal-produced electricity is dropping rapidly; had been electricity source with lowest, most stable fuel price



Item 4b. Natural gas sector cannot be depended upon because it needs much higher prices than today

- Companies producing natural gas as their primary business generally have "junk ratings" for their bonds
  - Poor ratings are evidence that today's prices are too low
  - Chesapeake Energy; Southwest Energy; Anadarko; Devon Energy
- If natural gas for electricity production is ramped up, higher prices are especially needed
- Electricity sector cannot depend upon a natural gas sector that is struggling financially
  - Especially if customers cannot really afford higher electricity prices

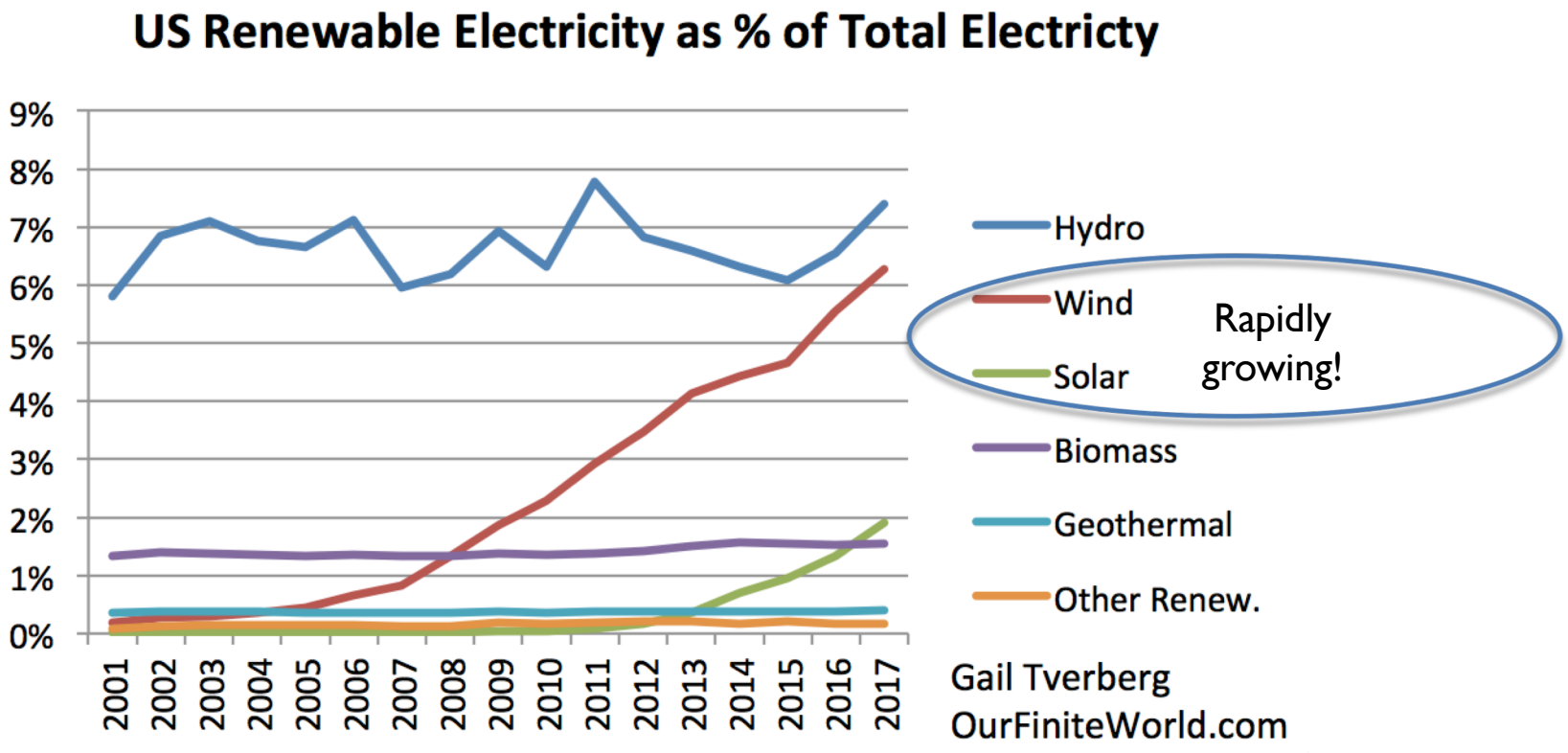
Item 4c. Nuclear power sector also struggling

- Prices for purchasing wholesale electricity fall artificially low part of the time, if intermittent wind and solar are given first priority on the grid
  - Electricity generation with high capital costs cannot compete
  - Low prices affect nuclear especially; also coal and natural gas baseload plants

- Some places use "capacity auctions" to try to fix this problem
  - Doesn't really fix the problem – need to fix the entire supply chain, not one part
  - UK courts have ruled that these auctions are illegal
  - Citizens don't understand the problem; all they want is low prices

- Hard to see how nuclear power can continue at current level
  - Many aging reactors; escalating costs of new reactors after Fukushima; supplier bankruptcies

Item 4d. Excessive faith is being placed in subsidized wind and solar



Intermittent wind and ground solar cannot carry the load, for many reasons

- "Going first," whether electricity is needed or not, is a huge subsidy
  - Cost of wind-solar combination without storage is about 5 cents per kWh (Roger Andrews analysis at Energy Matters)
  - With battery backup for one year, cost rises to 70 cents to $1.10 per kWh
  - Cost depends on how well generation matches up with seasonal needs

- China slashed incentives for solar panels in mid-2018
  - Previously installed close to half of world's solar panels
  - This is reason for today's oversupply of solar panels; low prices

- Wind cannot be scaled up as much as most studies assume
  - Wind shadow increases spacing above assumptions in most models
  - Theoretical: Adams and Keith, 2013; Observational: Miller and Keith, 2018

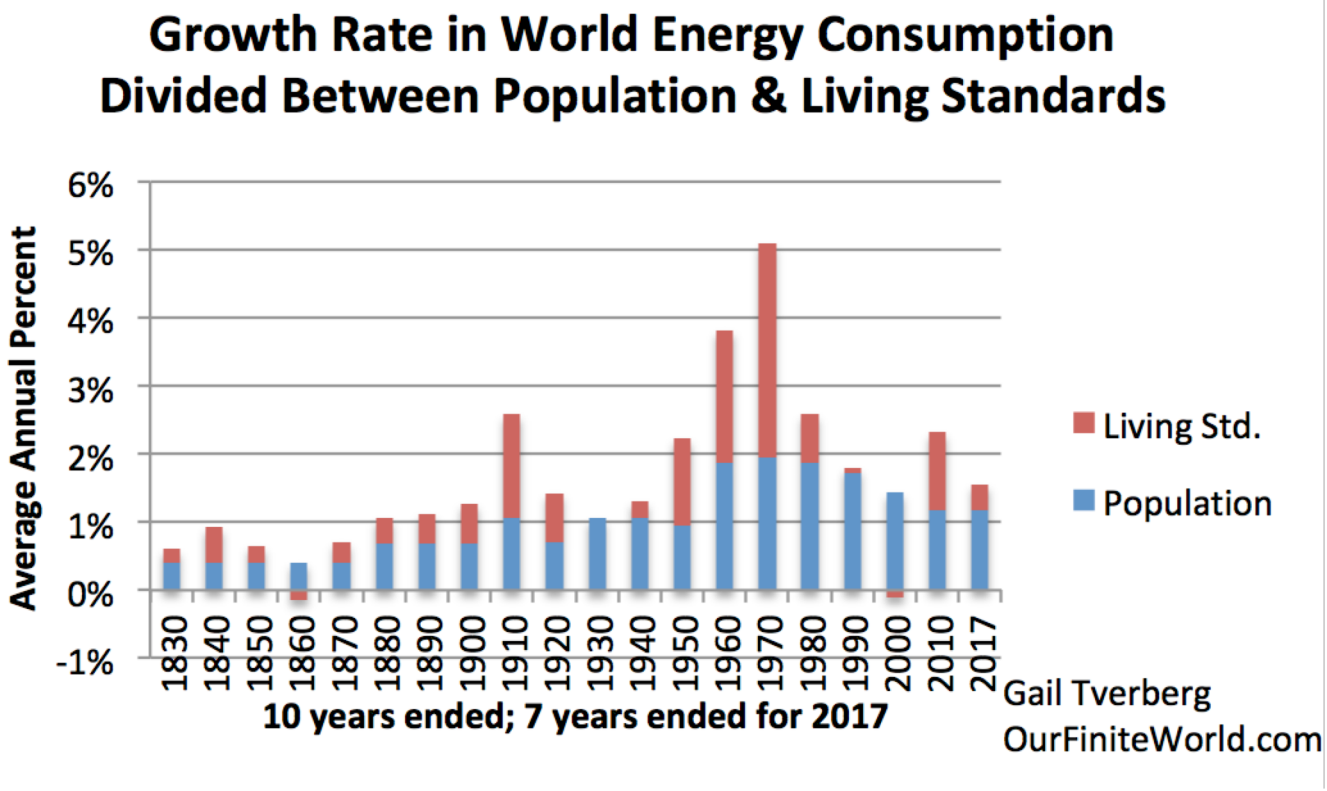
What the Real Energy-Economy Story Seems to Be

Item 1. Growth in per capita energy consumption is associated with many "good things"

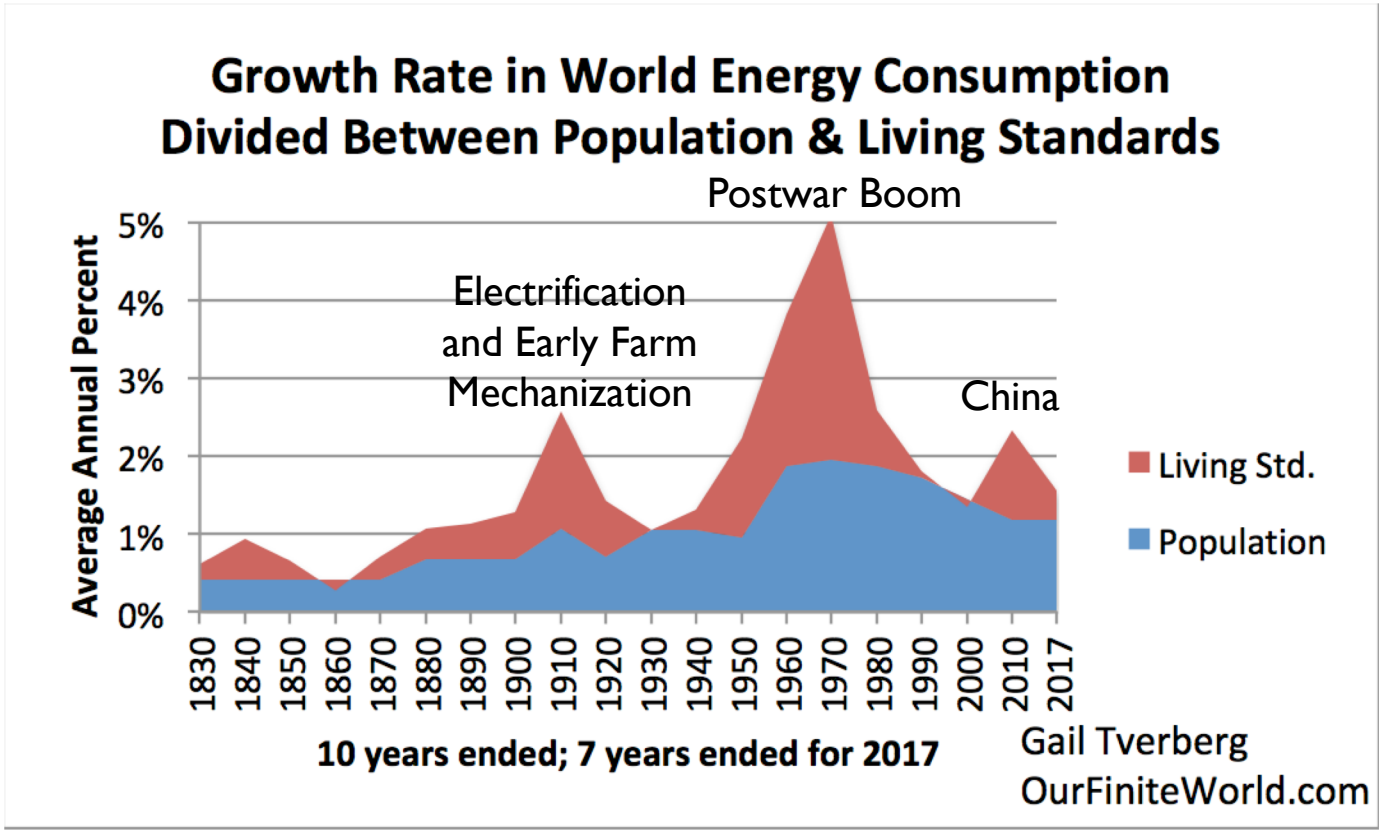
- Rising standard of living
- More technology
- More education, better medicine
- Longer life expectancies
- Higher returns on investment
- Higher interest rates on debt
- Representative democracies, instead of dictatorships

- Also
  - Birth rates higher than needed for replacement

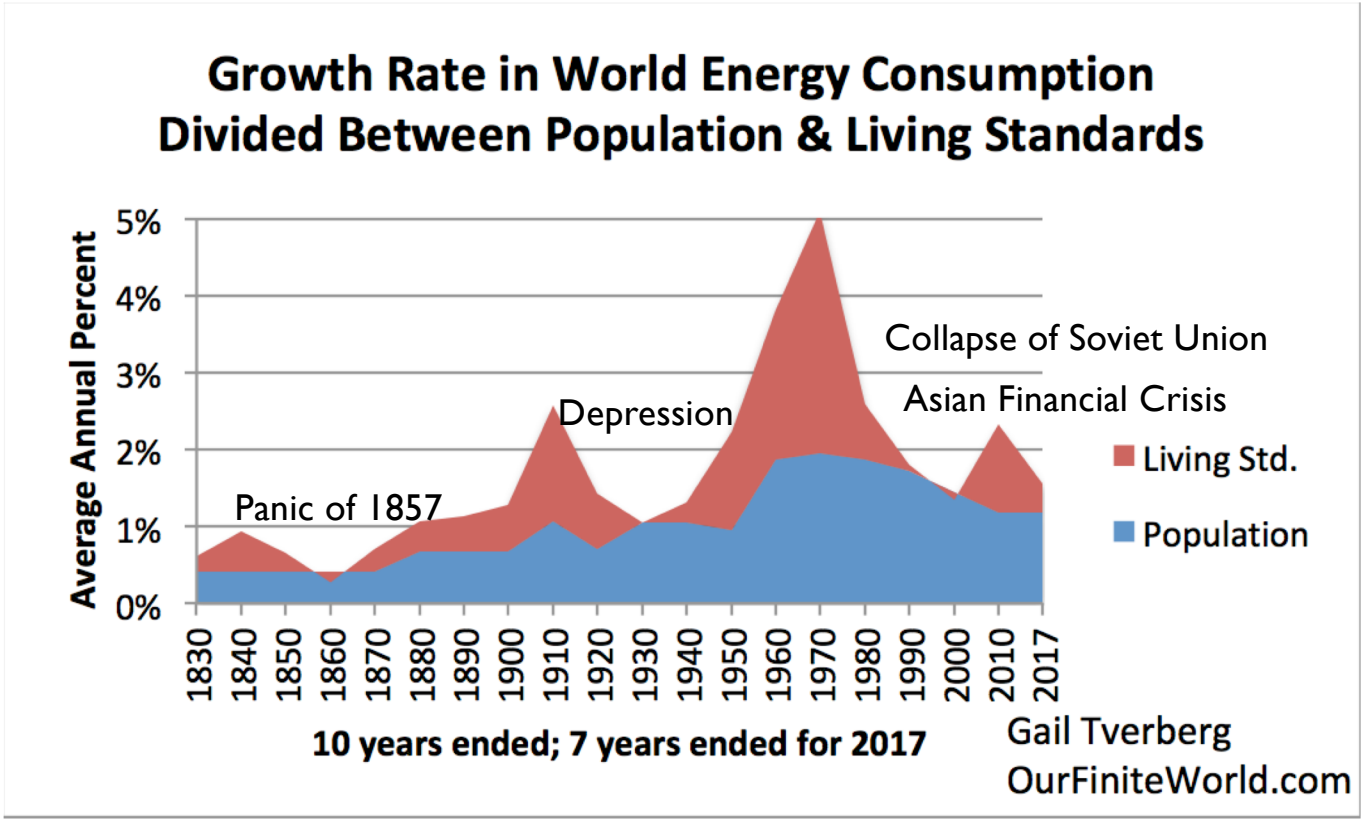
Item 2. We can look back and see how growing energy consumption has played out, for nearly 200 years



Area graph makes it easier to see the overall pattern in growth; red portion represents per-capita growth in energy



Troughs are equivalent to low growth in per capita energy consumption. They correspond to collapses and low oil prices.



Peaks are associated with

- High oil and other energy prices
  - 1974-1980; 2008 and 2011
- Push toward international cooperation
  - More interest in democracy
  - Growing international trade
  - Growth of international organizations, such as EU, IMF, WTO
- Favorable outcomes disbursed to all
  - Interest rates high
  - Return on investment high
  - Wages of non-elite workers relatively high

Troughs are associated with collapses of many kinds

Ten years ended:

- 1860 – Panic of 1857 – Asset and commodity price collapse that preceded US Civil War
- 1930 - 1940 – Agricultural price collapse and stock market crash; Great Depression, eventually resolved by World War II
- 1990-2000 – Multiple smaller collapses
  - US Savings and Loan Crisis 1986 -1995
  - Soviet Union - Collapse of central government 1991
  - Japan asset price collapse 1992
  - Asian financial crisis 1997

Before collapses occur, there tend to be many signs of problems

- Energy prices that are **too low for producers**
- Rising debt levels
- Low interest rates
- Increased friction between nations
  - Call for more tariffs
- More radical leaders; political divisiveness

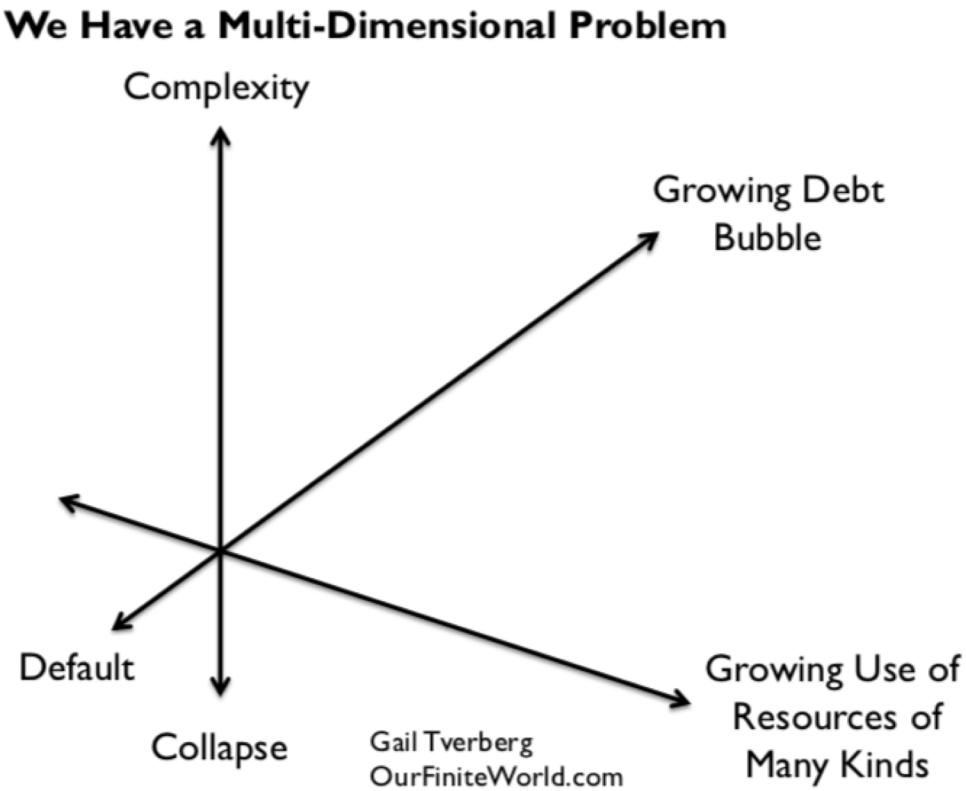
Item 3. Energy-economy seems to depend on growth of three different vectors, two of which are energy-related

1. Energy consumption vector
   1. Contains oil, natural gas, coal, hydro-electric, intermittent wind, etc.
   2. Contains human labor sold as labor (not as management skills; asset ownership)

2. Complexity vector
   1. Includes growth of technology and increased specialization
   2. Growing sizes of businesses and levels of government services
   3. Increased globalization
   4. Increased education for part of the workforce

3. Debt vector (Claims on future goods and services, made with **energy**)
   1. Besides debt, includes many debt-like items: prices of shares of stock, Social Security
   2. Even asset prices represent claim on future goods and services, made with energy

How system energy/economy system seems to work



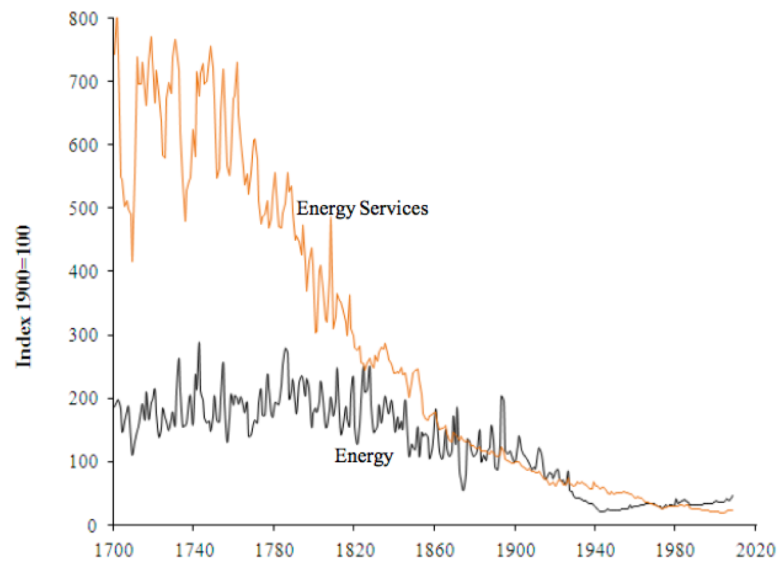
All three of these vectors are self-limiting. Complexity limit seems to come first.

- Complexity leads to growing wage disparity
  - Some workers receive education, others do not
  - More management workers
- Non-elite workers cannot afford to buy the output of the economy
  - "Affordability" of finished goods is a limit
  - Tax rate becomes too high
  - Education and health care costs become unbearable for non-elite workers
  - Cost of assets, such as farmland and homes, too high for non-elite

Energy prices are caught in a squeeze

- Normal trend of inflation-adjusted, efficiency-adjusted energy **prices** is downward
- Diminishing returns eventually sends **costs** higher
  - Need to shift to higher cost energy resources
  - Need to use resources requiring more complexity
- Low **wages** of non-elite workers tend to pull energy prices below those needed by energy producers
- UK inflation-adjusted and efficiency-adjusted energy prices since 1700

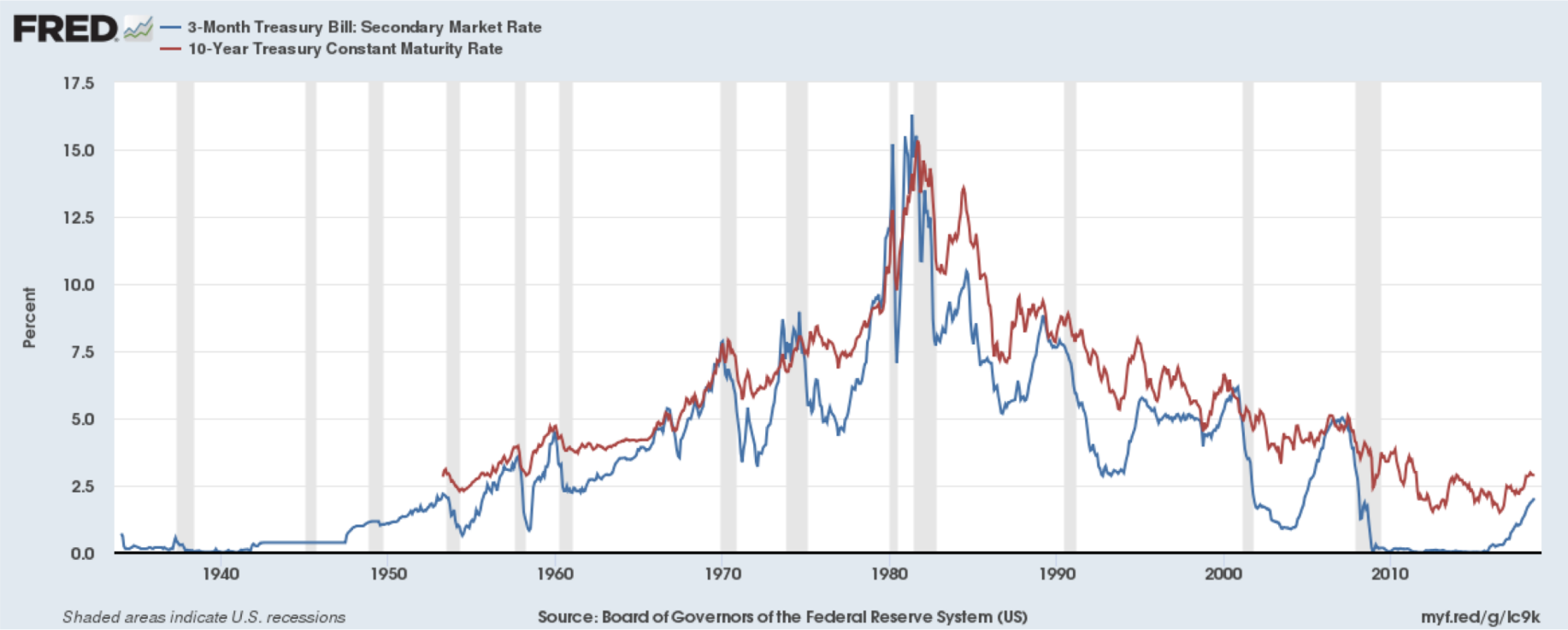
Figure 8. Average Prices of Energy and Energy Services in the United Kingdom (1700-2008)



Source: Fouquet (2008), Allen (2007)

Source: Roger Fouquet, Divergences in Long Run Trends in the Prices of Energy and Energy Services, http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/06/LREnergyPricesREEP2011.pdf

Debt-vector reaches a limit because interest rates cannot fall much below zero

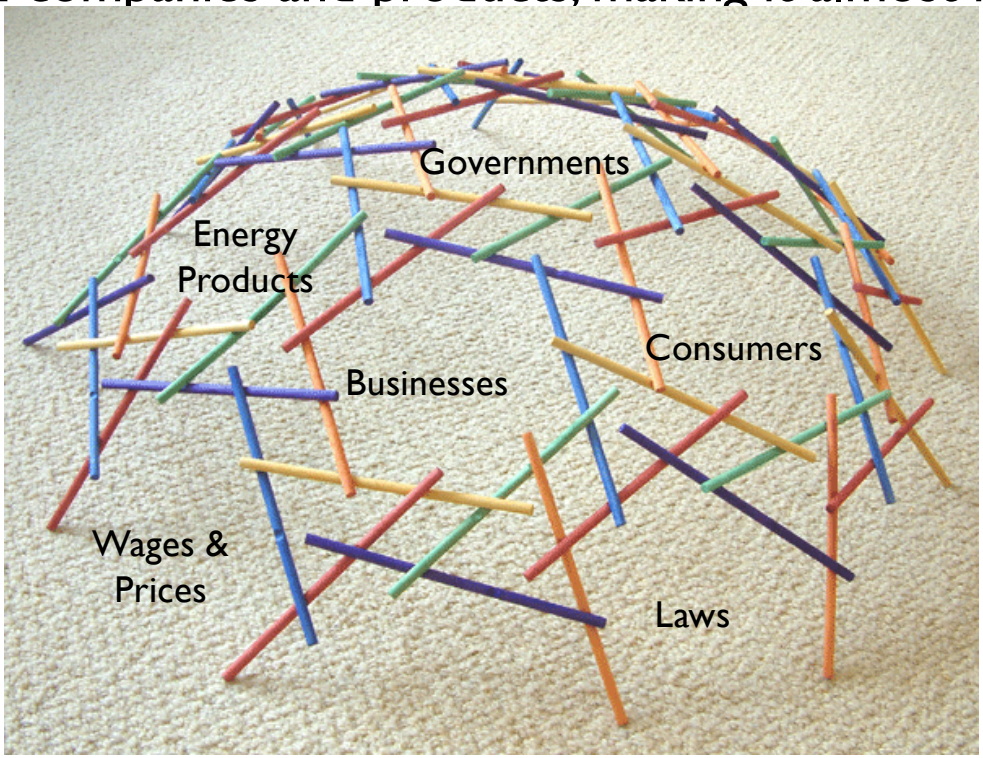


Conventional Models Are Wrong

Other researchers have missed fact that the economy is a complex self-organizing structure that builds up over time

- It deletes unneeded companies and products, making it almost impossible to "go backward"

Not being able to go backward makes the system ***fragile***



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

The energy-economy is controlled by the laws of physics

- Energy-economy can only grow in the presence of energy flows
  - In physics terms, the economy is a dissipative structure
  - Not unlike stars, hurricanes, ecosystems, plants and animals
  - Collapse in absence of sufficient energy supply

- Self-organizing systems grow in thermodynamically open systems
  - May take on more complex structure, as they grow
  - Growth is temporary; eventually dissipative structures collapse
  - François Roddier – Thermodynamique de l'évolution (2012) - economy in this context

- Researchers missed because knowledge is new – in fact, still developing

Items most energy researchers missed:

Item 1. Economic growth is a one-way process

- It is not possible to de-grow
  - Great Recession of 2008-2009 represented a slight contraction
  - This tends to be the direction that the economy goes as resource limits are hit
- Even a steady state economy is not possible because of diminishing returns
- Arrow of time problem; like taking out lower rungs of ladder, as we climb up

Item 2. Even efficiency growth takes adequate energy supply

- Growing complexity is only possible because of energy consumption
- Need to be able to replace old inefficient devices with new more efficient devices
- Adding complexity adds overhead to the system
  - Bigger government; more hierarchical businesses; more education; more capital devices financed by debt; more interest to fund the debt

Items most energy researchers missed (continued):

Item 3. It is a mistake to overly focus on oil

- It is the "package" of energy and other resource costs
- How does that package of higher costs translate to higher prices of finished good and services?
  - Will the new, higher prices be affordable to non-elite workers?

Item 4. Countries whose overall energy costs are low have a competitive advantage

- Warm countries have an advantage over countries that require winter heating
- Countries with heavy use of coal have an advantage
- Already-built nuclear tends to be quite inexpensive, if it still works
- Countries with low wages for non-elite workers have a cost advantage

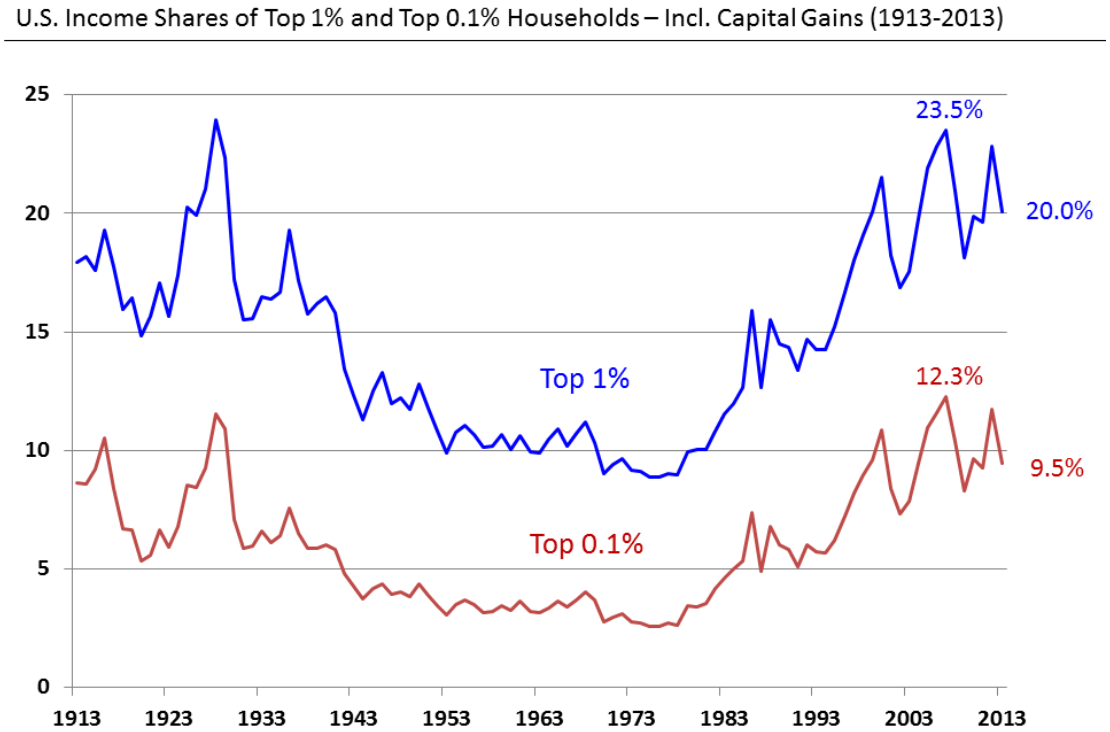
Item 5. Raising carbon taxes tends to push jobs to countries without such taxes

- Ultimately may raise total carbon usage, if countries without taxes use coal

Items most energy researchers missed (continued):

- Item 7. It is **lack of affordability of finished goods and services by non-elite workers** that tends to bring economies down.
  - Products that become unaffordable include homes, vehicles, meat, restaurant food, health care costs, and education costs
  - Use of "Supply and Demand" terminology confuses the situation
    - Can't people simply **demand** what they want?
    - Most energy isn't used directly; it is well hidden in goods and services
  - Young people especially affected
    - Live with parents longer; don't start families of their own
  - Affordability can be somewhat alleviated by
    - Lower interest rates on debt
    - More debt, for a longer term

Item 7 (continued). Wage disparity is at a level near that of the 1930s today.

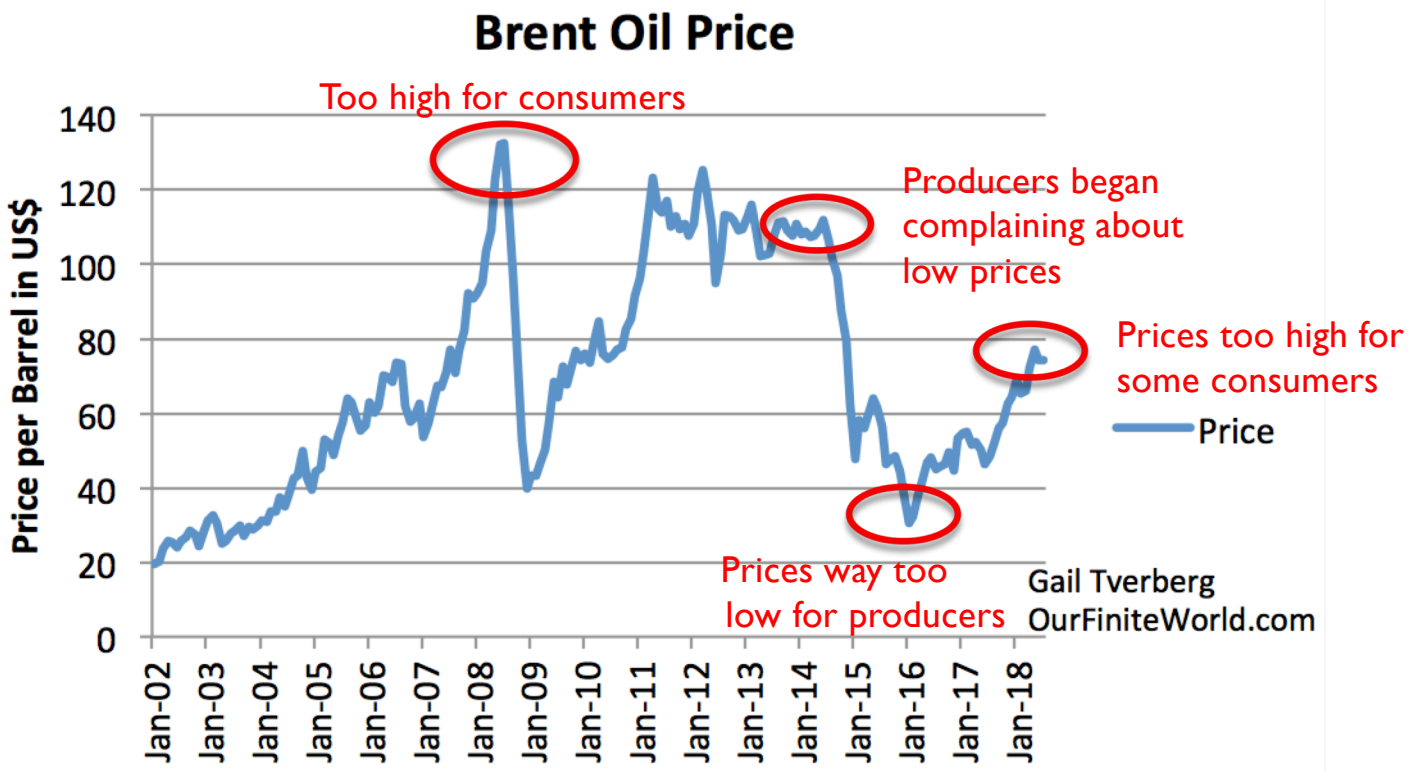


https://en.wikipedia.org/wiki/Income_inequality_in_the_United_States Farcaster at English Wikipedia [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Items most energy researchers missed (continued):

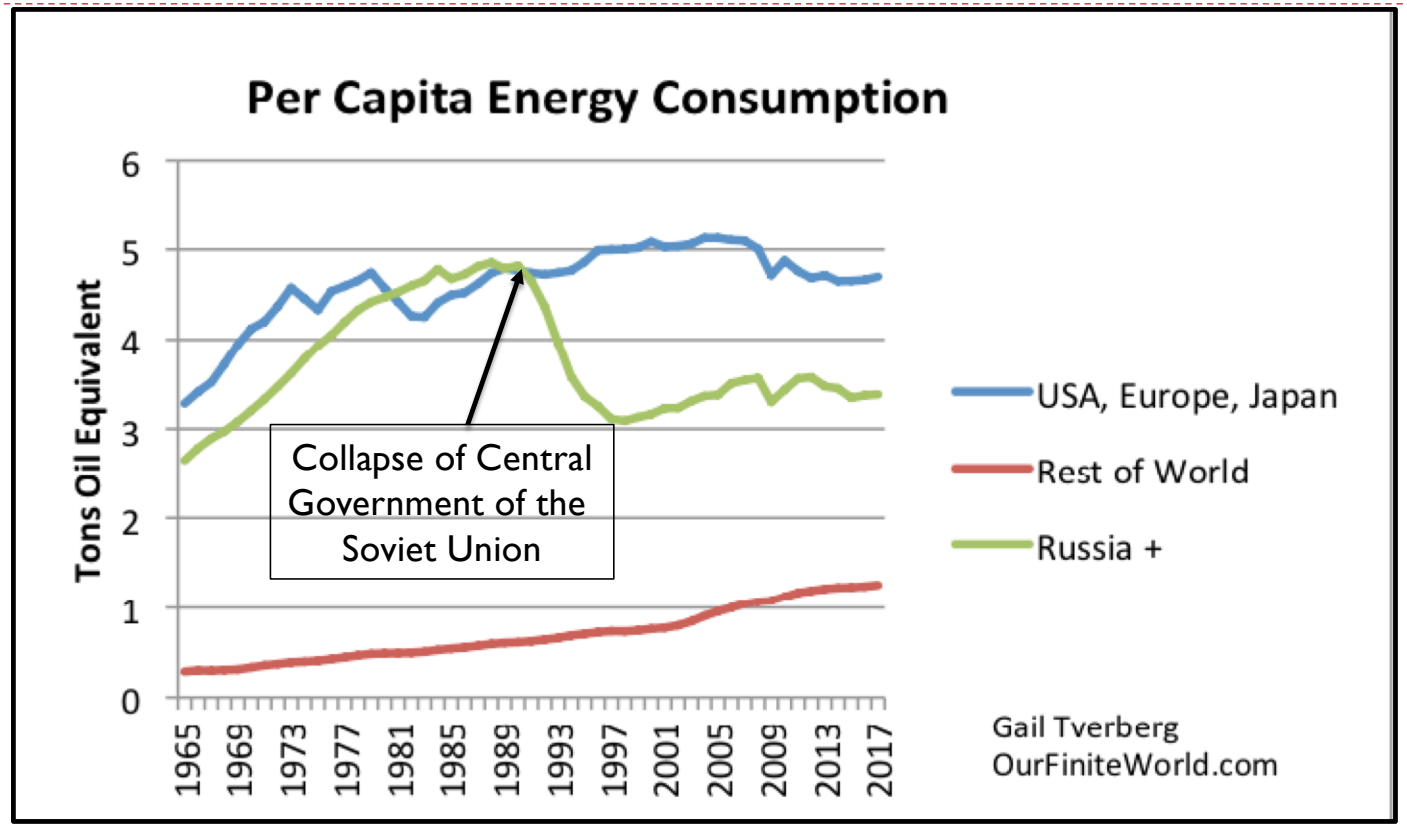
- Item 8. When energy supply falls, **energy prices don't generally rise**
  - It is **the total energy supply per capita** that is important
    - If energy consumption is growing rapidly enough, oil and other energy prices can rise
    - Otherwise, energy prices tend to fall
  - A person needs to look at historical data to see this pattern
    - Growing energy supply per capita leads to jobs that pay well
    - More, better jobs lead to more people being able to start homes of their own; raise children
    - When energy supply falls, end up with mostly low-paying service jobs
      - Workers cannot afford homes of their own; own vehicles
  - Leads to energy prices that are too low for energy producers of all kinds
    - Takes a few years for these low prices to bring down the whole system
    - We are living in the period between the start of low prices, and the system coming down
  - Energy production is likely to fall dramatically because prices fall too low for producers
    - Low prices are the real cause of peak oil, peak coal, and peak natural gas!

Item 8 (continued). We are living in a period when oil is too low-priced for oil producers



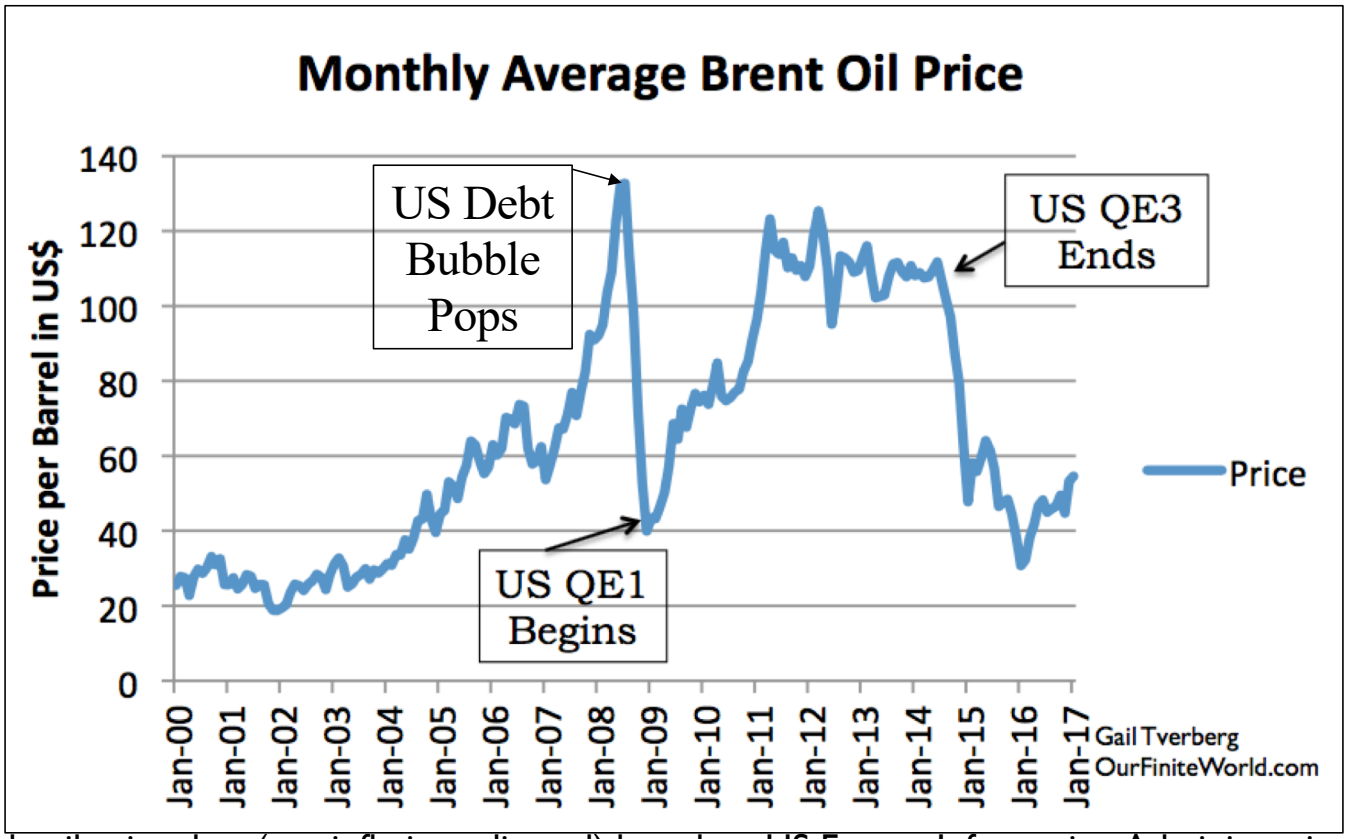
Oil prices are monthly averages, without inflation adjustment, based on US Energy Information Administration data.

Collapse of central government of Soviet Union had a dramatic impact on its long-term energy consumption



Based on 2018 BP Statistical Review of World Energy data.

Interest rates and size of debt bubble determines how high oil prices rise. Pricking the bubble causes prices to drop dramatically.



Monthly oil price data (not inflation adjusted) based on US Energy Information Administration data

Models that are wrong include

- Standard economic models
  - Supply-demand model misses how affordability really works; not enough dimensions
- Peak oil model
  - Assumes oil is all important; assumes prices will rise in response to shortages
- Climate change models
  - Scenarios modeled are impossible under the laws of physics
  - Miss likely near-term collapse

Even Energy Returned on Energy Invested (EROEI) models are wrong

- Miss the fact that energy consumption per capita needs to rise
  - Adding a product that is not sufficiently scalable is a problem
  - Especially if other energy (coal, nuclear, baseload natural gas) is disappearing
- Miss the fact that energy is not the only limit
  - Too much complexity is equally a limit
  - Substituting high-tech intermittent electricity will likely bring down the system
- Miss the fact that EROEI on newly added energy products needs to be high
  - Needs to offset adverse impact of falling EROEI elsewhere in system
  - It is really overall average EROEI that matters
- Miss the fact that pricing matters greatly
  - Subsidies for intermittent electricity drive out other, higher EROEI electricity supplies

Conclusion:
A Major Downturn May Be Ahead

The Future Seems Less Welcoming for Any New Technology

Many symptoms point to the possibility of some kind of collapse(s) ahead

- General downward trend in **growth** in energy consumption per capita, since 2010
  - China is having problems with peak coal
- Follow-on impacts from high wage disparity
  - Growing popular unrest
  - Call for tariffs, to try to raise local wages
  - More **divisive leaders** elected
- Persistently low commodity prices, including oil
- High level of debt
  - Federal reserve is raising short-term interest rates and selling QE securities
  - Actions may pop the debt bubble; affects **affordability of goods and services**

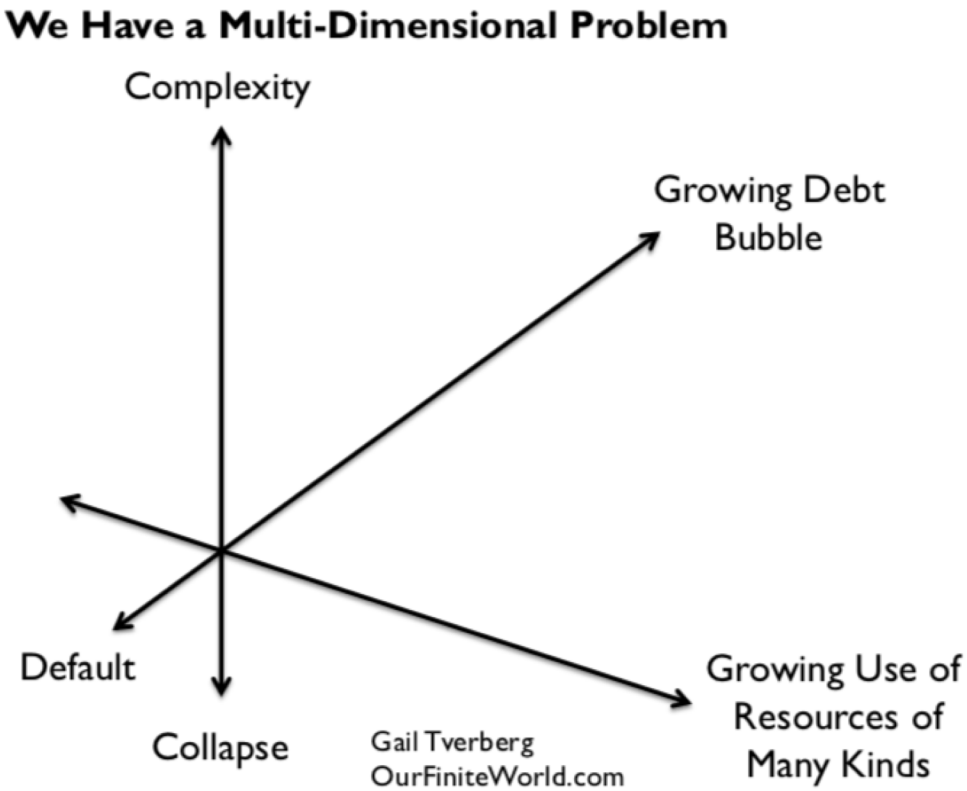
At this point, "game" seems to be to push the affordable resource problem (and thus, the collapse problem) elsewhere

- Higher interest rates intended to give the US an advantage over other countries
- Most collapses in the past have affected only part of the world
- Perhaps collapse can be kept away from US, for a time
  - US needs international trade, however

Situation makes world unwelcoming for new technologies

- Oil price level is already low
  - Seems likely to be heading lower
- Wholesale electricity prices are distorted by allowing intermittent wind and solar to go first, plus other subsidies
  - New technologies need to compete with the **subsidized price** of wind and solar
  - Makes price hurdle almost impossible for **any technology**, new or old
- Carbon prices likely to go nowhere, after experience in France
- Globalization likely to shrink back
  - Growing globalization requires increasing energy for transport
- Banking system may be adversely affected if a major debt collapse occurs

If a major debt bubble collapses occurs, there is a chance of a very substantial complexity crash



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