Many people have the impression that recessions come from financial missteps, such as the US subprime loan fiasco. If energy is involved at all, the problem comes from high oil prices as supply becomes inadequate to meet demand.

The real situation is different. We already seem to be on the road toward a new crisis; this crisis is likely to be much worse than the Great Recession of 2008-2009. This time, a major problem is likely to be energy prices that are too low for producers. Last time, a major problem was oil prices that were too high for consumers. The problem is different, but it is in some ways symmetric.

Last time, the United States seemed to be the epicenter; this time, my analysis indicates China is likely to be the epicenter. Last time, the world economy was coming off a high growth period; this time, the world economy is already somewhat depressed, even before hitting headwinds. These differences, plus the strange physics-based way that the world economy is organized, explain why the outcome seems likely to be worse this time than in 2008-2009.

I recently explained what I see as happening in a presentation for actuaries: Recession Likely: Expect a Bend in Trend Lines. This post is based on this presentation, omitting the strictly insurance-related portions.

The big thing that the vast majority of people do not understand is how important energy is to the economy. Because of this issue, I started my presentation with this slide:

After an opportunity for discussion, I offered the explanation that the role of food for humans is very much parallel to the need for energy of various types for the world economy. Food provides people with the energy required if they are to have the ability to think, move and speak. Energy products of many kinds enable the activities that we associate with GDP. For example, energy consumption enables machinery to operate and goods to be transported.
Using data from Smil, as well as more recent BP data, we can estimate how fast energy consumption has been growing over a very long period—nearly 200 years. We can see that the highest energy consumption growth occurred in the 1961 to 1970 period; the second highest growth occurred in the 1951 to 1960 period. These are periods we associate with rapid GDP growth and prosperity.

On the next slide, I show the same data displayed in a different way.

On this slide, I make two changes in the way the data are displayed:

1. The increases in energy consumption are split into two components: (a) energy used to support population growth and (b) all other, which I describe as energy used to support improvement in “living standards.”
2. A different graphing approach is used.

Note that when population growth corresponds to the full amount of energy consumption growth (in other words, at times when there is no red area above the blue area), energy consumption per capita is flat. High growth in energy consumption per capita seems to correspond to rising living standards, as occurred in the 1950s and 1960s.

While I label the “all other” category as if it is simply changes in living standards, there are other components, as well. One breakdown might be the following:
1. True improvement in living standards.
2. Additional energy investments required to offset diminishing returns.
3. Increasing use of energy for overhead items that don’t get back to individuals, such as energy used to fight pollution or to allow globalization.
4. Efficiency improvements allowing available energy to be more productive.

Efficiency improvements (Item 4) will allow more energy to be available for improvement in living standards, while Items 2 and 3 in the above list act in the opposite direction. We do not know to what extent these items really offset each other. Thus, “All other” = “Improvement in Living Standards” is only a rough approximation.

We can see from Slide 6 that whenever there is no red area above the blue area (flat living standards or flat energy per capita), adverse events seem to happen.

For example, the US Civil War (1861-1865) came at a time of low energy consumption growth. The Great Depression of the 1930s came during another period of low energy consumption per capita growth. World War I came at the beginning of this period, and World War II came at the end. The collapse of the central government of the Soviet Union in 1991 ushered in a decade of low world energy consumption growth, in part because of the loss of the central currency of the Soviet Union.

The “China Coal” note at the end pertains to the way that China and its coal supply has helped pull the world economy forward since 2001. This benefit seems to be already declining.

Slide 7 shows China’s energy production by fuel. Coal production (in red) soared after China was added to the
World Trade Organization in December 2001. Beginning about 2012, China’s coal production began to plateau. Depleting mines and low prices for coal have kept production flat. Imports can be used as substitutes, to some extent, but it is difficult to keep costs low enough and provide adequate total supply.

With the loss of growth in China’s coal production, its economy has had to cut back. Each year, we read about coal mine closures and miners needing to find new jobs. We know that China discontinued its paper and plastic recycling business as of January 1, 2018. China has also been cutting back on solar subsidies, leading to fewer jobs installing solar panels. All of these types of changes reduce the number of people who can afford to buy high-priced goods, such as new homes, vehicles and smart phones.

It is becoming increasingly clear that China is being forced to cut back on heavy industrialization because of its coal difficulties. Slide 8 shows automobile purchases for six large economies. China is by far the largest of these economies in terms of auto sales. China’s auto sales began to slide in 2018 and are sliding further in 2019 (about -11%).

If we look back at the time of the 2008-2009 recession, we see that auto sales of the US dropped precipitously. The United States was the country that led the world into recession. The inability of US citizens to buy cars was a sign that something was seriously wrong. Now we are seeing a similar pattern in China.

China has reported that its GDP growth rate has been slightly lower during 2019, but we really don’t know how much lower. The amounts it publishes are too “smooth” to be believed. The actual GDP growth rate is believed to be lower than the recently reported 6.0%, but no one knows by precisely how much.
Figure 8b gives a little more information about recent car sales by country. We can see from this chart that based on data through October 2019, world automobile sales are expected to fall by about the same percentage (3%) in 2019 as during the recession year of 2008. I find this disturbing.

We can also see the huge impact that China has had on keeping world private passenger auto sales rising. The world economy looked like it was headed into recession in January, 2016, when world oil prices were very low, but a spike in China’s automobile sales at that time helped keep total world automobile sales rising and allowed world oil prices to rise from their low point.

In the next sections, I provide some background regarding this story.

Slide 10 shows the way that I visualize the world economy self-organizing and growing. The economy grows by adding new “layers” of businesses, products, consumers and laws. Unneeded products, such as buggy whips, are dropped from the bottom. Unprofitable businesses close. In some sense, the economy is hollow because of these deletions. It cannot easily go backward because, for example, the support services for widespread use of transport using horses are lacking.

Energy is used to operate all aspects of the system. One part of the system is a self-organizing financial system that helps decide, through wage levels, who gets the benefit of the goods and services that are made. This financial system includes self-organizing interest rates and self-organizing commodity prices.

The most important connection within the economy is the one I show at the center as “Consumers = Employees.” Consumers are very dependent on their wages as employees. If the economy is to continue to operate, **workers must receive high enough wages to purchase the goods and services the economy produces.** Even the lower-paid workers need to be able to afford food, housing and transportation, or the economy will tend to collapse.
When we look back through the history on Slides 4, 5 and 6, we see that the growth of energy consumption is very important in how economies operate. The theories of Ilya Prigogine explain why this is the case; when adequate flows of energy are available, self-organizing systems are able to grow.

Few economists today include energy consumption in their models, however. Economic theory has grown over time in its own “ivory tower.” Like other academic subjects, it depends on early theories and the process of peer review. The views expressed must also be pleasing to those in power, who would like everyone to believe that politicians, rather than the laws of physics, are in charge.

There are many types of self-organizing systems that grow. They all, directly or indirectly, require energy. Plants and animals of all types are self-organizing systems that grow. Hurricanes grow using the energy that they get from warm water.

Governments grow from the tax revenue that they are able to collect; they use the revenue to buy energy products such as electricity to operate governmental offices, oil to build roads and operate police cars, and natural gas to heat buildings.

The Internet grows through the revenue collected to provide its services. The Internet uses revenue to buy computers (made with energy products) and electricity to operate those computers.
Nearly all of the energy we use is hidden. For example, modern food production is very much dependent on energy consumption. Agricultural machines are made using energy products. Soil amendments, including organic soil amendments, are transported using fossil fuel energy. Refrigeration is possible through the use of energy. Hybrid seeds are only possible through energy consumption. Planting seeds by digging with a stick would only use human energy, but such a process would be terribly inefficient.

Most of us can easily recognize today’s goods and services, such as those listed.
Promises of future goods and services act like promises of future energy supplies. This happens because creating goods and services that people can actually use requires energy supplies of the appropriate type.

When people get cash or a check, they expect to use it to buy goods and services. Creating these goods and services requires energy consumption. If there is no energy of the right type available, the goods and services won’t be available to fulfill the promises.

Promises of future goods and services tend to grow faster than actual goods and services because it is these promises that, in some sense, “pull the economy along.” For example, if a young person gets a loan, (s)he can often buy a new car. The fact that a new car is being purchased leads to more jobs in the supply line leading up to new car production. Or, if a business takes out a loan or sells shares of stock, it can use the proceeds to hire employees. It is these growing wages that keep the system operating.

As long as the economy is growing rapidly, the mismatch between growing debt and actual output doesn’t become apparent. As the economy slows, some workers find themselves working fewer hours. Some businesses become less profitable and lay off workers to try to restore profitability. The catch is, with fewer workers, the economy slows even more. It usually takes more debt, at lower interest rates, to get out of such an economic slowdown.

There is a lot of confusion about prices. “Demand” is what people, through their wages and debt, can afford. As
economists tell us, price depends on supply and demand.

In the short term, prices tend to bounce around a lot. The short term buyers of oil are oil refineries. They need to keep their employees busy. If they see a shortage of oil, they may bid up the price of oil to allow their workers to continue to be employed.

Over the longer term, prices of all energy products tend to depend on consumers’ ability to afford finished products, like cars, homes and cell phones. Producing these objects and shipping them takes energy. They also use energy as they operate.

The various energy prices shown here are simply a few of the many, many energy prices that we see around the world. Strangely enough, prices of all energy products tend to fluctuate together, over the longer term. Prices depend on affordability of end products, such as cars, homes, computers, food and clothing. Our problem since about 2012 has been lack of affordability of end products.

The primary way of raising affordability is by increasing productivity. Increased productivity is made possible by increasingly leveraging human labor with devices that are built with energy and are operated using energy. For example, a worker with a ditch digging machine is much more productive than a ditch digger with only a shovel. An analyst is more productive with a computer and Internet access than with only pencil and paper.

With higher productivity, more goods are produced in total. As long as not too much of this productive output is skimmed off the top (by governments, or by business hierarchy, or to pay for the devices and their fuel), it is possible for each worker to afford more goods and services, raising total demand.

An alternative way of raising affordability is by adding more debt at ever-lower interest rates. This approach tends to make goods such as cars, homes, and factories appear more affordable because their monthly payments are lower. This added-debt approach only works as long as the economy is growing quickly enough. If the economy slows too much, the added debt leads to financial crashes of many types.

\textbf{# 4 QUANTITY AND PRICE ARE DETERMINED BY PHYSICS}
Many people think that they know the amount of oil that can be extracted based on the current technology and the assumption that prices will eventually rise high enough to extract all of the fossil fuels that seem to be available. For example, the International Energy Agency has prepared reports in which it shows expected oil availability if oil prices rise to $300 per barrel.

The catch is that even if oil prices can bounce high, it is not clear that they can stay very high. The current price of oil is only in the $55 to $65 per barrel range. A price of $300 per barrel will allow oil extraction using very advanced technology. We don’t have any evidence that oil prices can stay this high because demand comes primarily from wages. Prices cannot stay high without adequate support from wage levels.

Of course, the issue is not just oil prices staying sufficiently high. Natural gas, coal, uranium and electricity prices all have difficulty rising high enough and staying high enough. Commodity prices such as copper and steel have the same issue.

There are many people who say, “Of course, oil prices will rise. Oil is a necessity.” They forget that it is really a two way tug of war between producers getting a high enough price to be profitable and consumers getting a low enough price to be affordable. There will be a winner and a loser.

People also forget that most commodity use is hidden. We see the fuel we buy for our personal vehicles, but there are a huge quantity of oil products required for shipping goods, paving roads, growing food, and for many other uses that we are not aware of. While we might be able to pay a little more to fill our gasoline tank, most of us would not be able to simultaneously pay more for food, transported goods of all kinds and road maintenance.
Economists often assume that if energy prices rise, wages will rise, as well. If we look at the data historically, however, it doesn’t work that way at all. What happens is the opposite: average wages tend to rise as long as oil prices stay low. Once oil prices spike, average wages tend to flatten out.

The amounts shown on Slide 24 are average wages, computed by taking the total inflation-adjusted wages for the population in total and dividing by population. When oil prices spike, recession soon sets in. The reason why average wages fall is partly because more people become unemployed. Other workers find it necessary to accept lower-paying jobs.

Many people focus on the run-up in oil prices to July 2008. An equally important point is the fact that the world economy has not been able to maintain these high prices since July 2008. The general price trend has been downward. The cuts by OPEC have not had a material impact.

Low prices are a huge problem

- Lead energy producers to cut back on production
  - China coal
  - OPEC oil
  - US natural gas and oil from shale

- Makes reserves “disappear”
Citizens of the United States, Europe, and Japan are used to thinking of *high energy prices* as being a problem because they are from countries that require substantial imported energy to maintain their GDP. For example, Greece will sell fewer trips on its tour boats, if oil prices are high. This will have an adverse impact on employment and the ability to repay debt with interest.

If a country is an oil exporting country, *low oil prices* are an even worse problem. This happens because oil exporting countries tend to earn a large share of their revenue from taxes on the sale of oil. These taxes can be much higher if oil is selling for, say, $120 per barrel than if it is selling for $60 per barrel. These tax dollars are used to provide subsidies to offset the high cost of imported food. They are also used to build industry and infrastructure to provide employment to the population.

If oil prices are too low, oil exporting countries will tend to cut back on oil production. In fact, this has been happening for OPEC for the entire year of 2019.

Similar problems occur if commodity prices of any kind (coal, natural gas, uranium, steel, copper, etc.) stay too low for an extended period. Producers go bankrupt, or they stop production, or they pay their employees so poorly that the employees go on strike. Sometimes, they may even start rioting. Many of the riots around the world today are related to low commodity prices.

The world experienced spiking oil prices in the period leading up to mid-2008. These high prices caused a recession and much lower prices followed. The chart on Slide 28 gives a somewhat exaggerated view of what goes wrong with high oil prices.

If the price of oil suddenly spikes to two or three times its previous price, both the price of food and gasoline are likely to increase. This change tends to lead to a big shift in a family’s budget. Debt payments, such as for a home and car, are pretty much fixed, so the big increase in food and gasoline prices must be taken out of the budget earmarked for everything else. This leads to cutbacks in discretionary spending such as vacations,
restaurant meals, and charitable contributions.

In a short time, there are layoffs in discretionary sectors. Those who are laid off are more prone to defaults on loan payments. The problem soon escalates to a recession, with high unemployment and low oil prices.

Strangely enough, central banks push back against high oil prices as well. They know that high oil prices lead to high food prices. Citizens of energy-importing countries will be unhappy with elected officials if oil and food prices rise. Thus, central banks tend to *raise* short-term interest rates, as soon as they become concerned about high oil and food prices.

The recession that follows will quickly bring food and energy prices back down. If food and energy prices fall, the low prices will be the problem of the energy producers. Oil exporters will find their tax revenue too low, but the high-price problem of oil importers will be gone.

You will recall that the rapid energy consumption growth periods were 1961 to 1970 and 1951 to 1960. During these periods, the economy was growing almost too quickly. The Federal Reserve was able to keep raising interest rates, as a way of holding down economic growth. It was not until 1981 that the pattern changed from raising interest rates to falling interest rates.

Since 1981, the US Federal Reserve and other central banks have been reducing interest rates. Lowering interest rates and rising debt levels, as mentioned previously, makes goods appear more affordable because of lower monthly payments. The concern now is that interest rates are about as low as they can go. Central banks no longer have room to offset recessionary tendencies (because of slow growth in energy consumption) by lowering short-term interest rates.
Most people never consider the possibility of low energy prices leading to collapse. It looks to me like this is the danger facing us today. Let’s start by looking back at what happened in 1991.

When the central government of the Soviet Union collapsed in 1991, the individual republics making up the Soviet Union were left on their own to find new currencies and new trading partners. Satellite countries of the Soviet Union were affected as well. Slide 31 shows that the consumption of many types of resources dropped for many years for the whole area. The low point was not reached until 1998.

If we look back to see what had happened previously, the Soviet Union was an oil producer and exporter. When oil prices were high in the 1973 to 1980 period, the Soviet Union prospered. But then low prices came along, at least partly because the US Federal Reserve raised interest rates to almost 20% in the 1980-1981 period. (See Figure 29b.)

The long-term low oil prices, in some sense, indicated that the world economy was producing too much oil; some inefficient area(s) of production needed to leave. The Soviet Union may have been singled out by the self-organizing economy because it used energy products in a less efficient manner than other economies. Its adverse outcome may also have reflected the fact that its cost of production was higher, leaving less of the sale
price for reinvestment and taxes.

The Soviet Union is an example of what can happen if oil prices stay too low for several years. The central government of such an economy can collapse.

World has experienced low oil prices since 2014
- World can expect some collapses again
- Governments of oil exporters at risk
  - Venezuela
  - Nigeria, Congo, South Sudan
  - Saudi Arabia and other Middle Eastern exporters
- US shale oil companies at risk

When commodity prices are too low, the economies of countries exporting those commodities are stressed. This is why we see so many uprisings in commodity-producing countries right now. Iraq with its oil has been having protests. Chile, with its copper and lithium exports, has been seeing protests. South Africa with its exports of coal, precious metals and gems has been having riots. With some escalation, any of these low-price situations could lead to an overturned government.

#7 ECONOMY “MAKES A SMALLER BATCH,” IF ENERGY IS TOO LOW

Commodity producers extract less in response to low prices
- Economy responds by “making a smaller batch”
  - Like making a cake
  - Can substitute almond if vanilla is missing
  - But if flour is in short supply, need to make a smaller batch
In Slide 36, I give an example of two different kinds of ingredients in a cake:

1. Ones that are substitutable: the flavoring, which can be vanilla, almond, or something else
2. Ones that are not substitutable: the flour, which is the energy product

With too small a quantity of flour, all we can do is make a smaller cake. Perhaps we can substitute a different energy product, but electricity most certainly will not do! Some bacteria eat electricity, but humans do not. Substitutability is limited, even within energy products/carriers.

Economists make models focusing on the special case when a material is not essential for the economy. This gives a misleading impression. If they had looked back at what happened when energy supplies were low relative to population growth, as we saw on Slide 6, they could make much better models.

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We seem to be sitting on the edge of some form of collapse for at least parts of the world economy, right now.

Without enough energy consumption growth, top-level organizations, such as the European Union, the United Nations and the World Trade Organization, are especially at risk of collapse.

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One of our big problems today is excessive wage disparity. High-wage workers rarely have trouble being able to
afford homes, cars, vacations, and air conditioning. It is non-elite workers, the ones who have not been able to find high-paying jobs, who have an affordability problem.

The wage disparity problem is an outgrowth of how the physics of the economy works. If there are not enough goods and services to go around, the physics of the economy effectively “freezes out” some of the workers. Under this arrangement, there will be some survivors even if there is not quite enough for everyone. In some sense, the “best adapted” are able to survive. If the inadequate supply of finished goods and services were spread around evenly, there might be no survivors at all.

The thing that is key is that workers need to be able to afford finished goods and services produced by the economy. If too large a share of wages goes to high paid workers, or to owners of robots, there is not enough left over for the “regular” employees.

Many workers have seen their jobs disappear as their employers moved production to another country where wages were lower. Or, jobs can remain, but the wages will fall from the low-wage competition.

Income disparity back at level of the Depression of 1930s
US income disparity seems to be as great as it was in about 1930, at the time of the Great Depression.

If we look at historical world energy consumption by fuel, we observe that it has been rising the vast majority of the time. The little dip that we see about 2008-2009 occurred at the time of the Great Recession. It doesn’t take much of a cutback in energy consumption to cause a major problem.

Back at Slide 20, I remarked,

*The primary way of raising affordability is by increasing productivity. Increased productivity is made possible by increasingly leveraging human labor with devices that are built with energy and are operated using energy.*

The world economy requires growing energy supply, of suitable kinds, to operate. If the quantity of energy available is reduced, productivity is likely to nosedive. This is true even if the reduction is intentional and seems to be for a good cause, such as reducing CO2 emissions.

We seem to be heading for a contraction in energy supplies now because of continued low energy prices. Fossil fuels are, in some sense, leaving us, whether we like it or not. World coal production has been flat to falling since 2012. IPCC scenarios assume a very different pattern: Fossil fuel use, especially coal, will grow indefinitely, presumably because of high prices and improved technology.

Many people are hoping that wind, solar, and hydroelectric will someday replace fossil fuels. I consider this highly unlikely because all three are made using fossil fuels. Furthermore, these “renewables” in total represented only 10% of world energy supply in 2018. The 10% is divided as follows: wind, 2%; solar, 1% and hydroelectric 7%.
There clearly is a correlation between GDP growth and energy consumption growth. China with its growing coal use was pulling the world economy along, especially in the 2002 to 2012 period. Recently, it has lost much of this ability.

In my opinion, Trump’s tariffs are not the cause of our current trade problems. Tariffs seem to be enacted whenever growth in energy consumption per capita is very low. Tariffs were enacted both immediately before the US Civil War and at the time of the Great Depression. The problem is that jobs that pay well indirectly require significant energy consumption. When growth in energy consumption per capita is low, it becomes impossible to find enough jobs that pay well for everyone. Tariffs are used in an attempt to keep jobs that pay well at home.

We may be hitting another very low energy growth period
- Or even a period of energy contraction
- Situation is unprecedented in modern times
  - Closest analogy is Depression of 1930s
- Major financial problems likely
  - Banks; pension plans; 2008 on steroids
- Already seeing reduced cooperation amongst nations
  - Also tariffs; radical politics

We don’t know quite what will happen. The closest analogy is the Great Depression of the 1930s. More financial problems seem likely. In fact, they could escalate quite quickly. More strikes, such as those currently going on in France, seem likely. The situation is likely to play out a little differently in various countries.

The physics of the situation seems to try to keep some parts of the system operating, if at all possible. But, as mentioned at Slide 10, the self-organizing system deletes parts of the economy that are no longer needed. We no longer have an economy that can operate with horse and buggy, for example. We can’t just “go backwards” to an economy of an earlier era.
We are already seeing changes in this direction. Hong Kong’s protests are in the news practically daily. Germany is experiencing job layoffs. We know that in an interconnected world, a recession that starts in one large country is likely to eventually affect much of the rest of the world.

Now we are in a waiting period, waiting to see what happens next. Major changes seem likely over the next five years, but they could happen much sooner.