Our Energy Predicament in Charts

Posted by Gail the Actuary on March 27, 2013 - 11:48am

A friend asked me to put together a presentation on our energy predicament. I am not certain all of the charts in this post will go into it, but I thought others might be interested in a not-so-difficult version of the story of the energy predicament we are reaching.

My friend also asked what characteristics a new fuel would need to have to solve our energy predicament. Because of this, I have included a section at the end on this subject, rather than the traditional, "How do we respond?" section. Given the timing involved, and the combination of limits we are reaching, it is not clear that a fuel suitable for mitigation is really feasible, however.

ENERGY BASICS

Energy makes the world go around

Figure 1. Source: Jewish World Review

Energy literally makes the world turn on its axis and rotate around the sun.

Energy is what allows us to transform a set of raw materials into a finished

product.

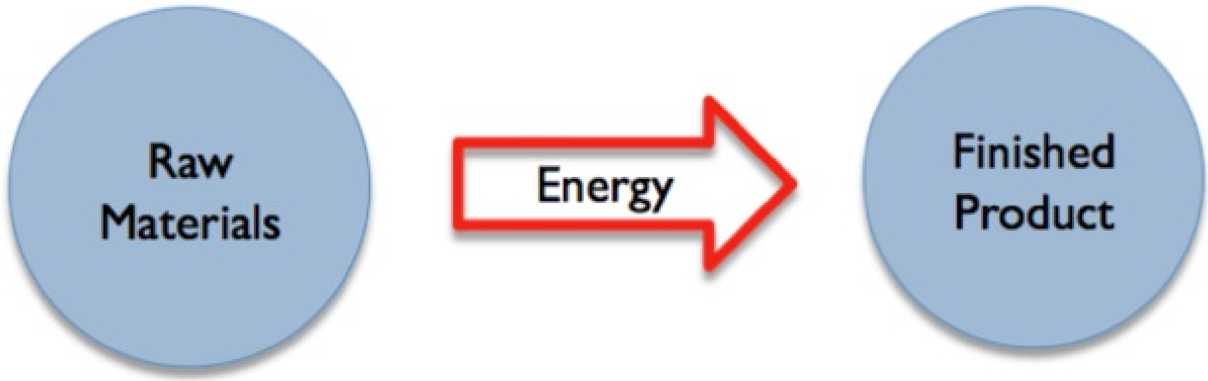

Figure 2. Energy is what allows us to transform raw materials into finished products. (Figure by author.)

Energy is also what allows an us to transport goods (or ourselves) from one location to another. Services of any type require energy–for example, energy to light an office building, energy to create a computer, and human energy to make the computer operate. Without energy of many types, we wouldn't have an economy.

Increased energy use is associated with increasing prosperity.

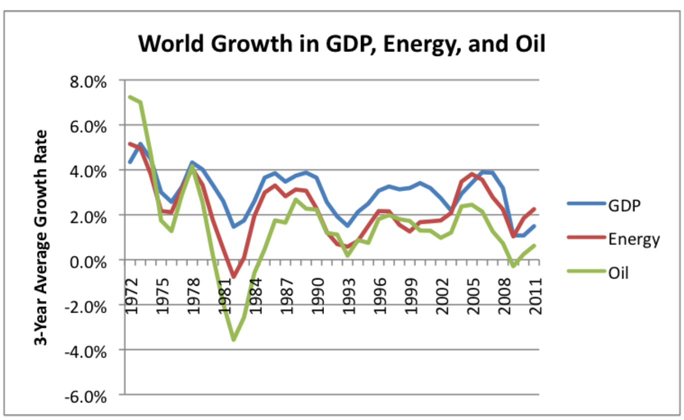

Figure 3. World growth in energy use, oil use, and GDP (three-year averages). Oil and energy use based on BP's 2012 Statistical Review of World Energy. GDP growth based on USDA Economic Research data.

Energy use and oil use have risen more or less in tandem with GDP increases. Oil is expensive and in short supply, so its increases have tended to be somewhat smaller than total energy increases. This happens because businesses are constantly seeking ways to substitute away from oil use.

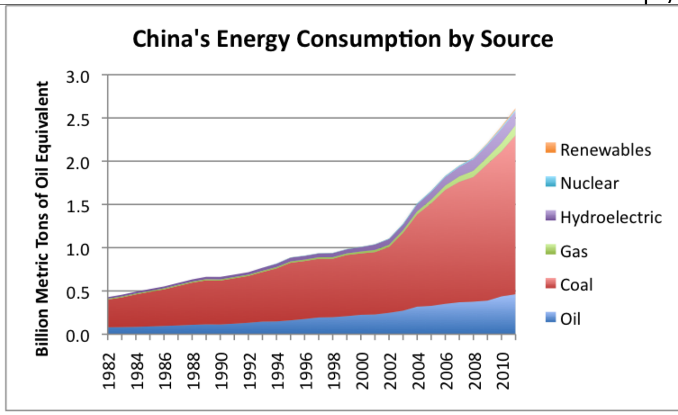

Figure 4. China's energy consumption by source, based on BP's Statistical Review of World Energy data.

China is an example of a country with very high growth in energy use. China's energy use started growing rapidly immediately after it joined the [World Trade Organization in December 2001](). China's energy use is mostly coal.

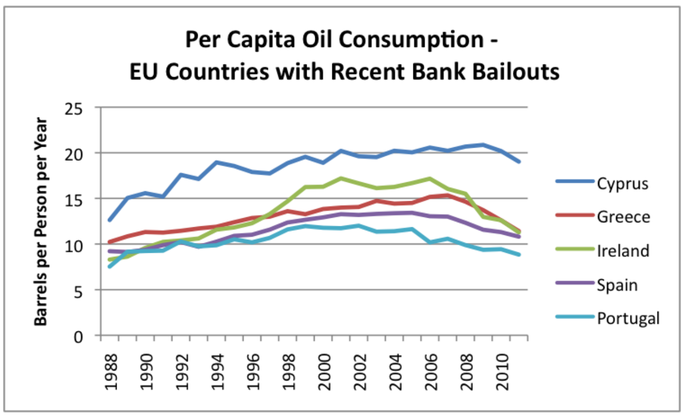

Figure 5. Per capita oil consumption in countries with recent bank bailouts, based on data of the US Energy Information Administration.

European countries with bank bailouts show declining oil consumption.

Increased fuel use is also associated with rising population growth.

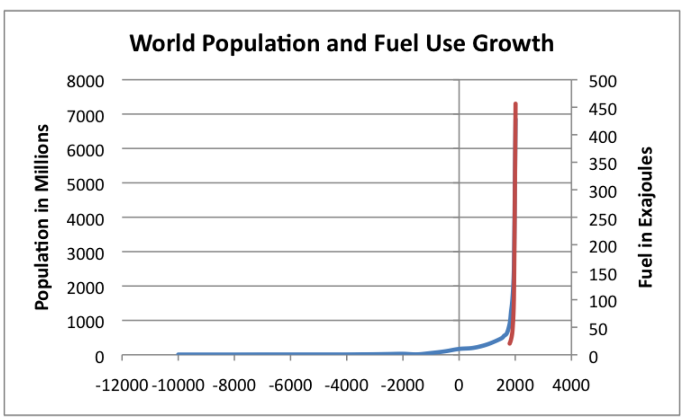

Figure 6. World population from US Census Bureau, overlaid with fossil fuel use (red) by Vaclav Smil from Energy Transitions: History, Requirements, Prospects.

On Figure 6 above, the fuel use and population growth rise very rapidly, after fossil fuels were added about 1800. In fact, the lines overlay each other, so it is not possible to see both. Adding fossil fuels allowed much better food supply, sanitation, and medical care, all leading to huge population growth.

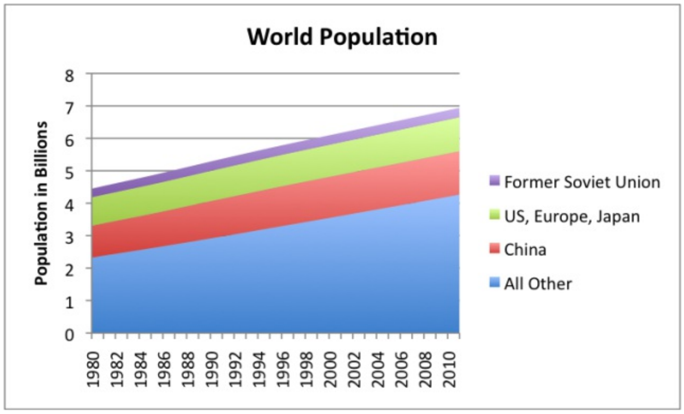

Figure 7. World Population 1980 to 2011, based on EIA data.

World population is still growing rapidly, especially outside of the developed countries. The countries with the most population growth (blue) are only now beginning to obtain goods and services that the developed world takes for granted, like better medical services, cars, and electricity for every home. Their fuel use is growing rapidly.

There are many sources of usable energy.

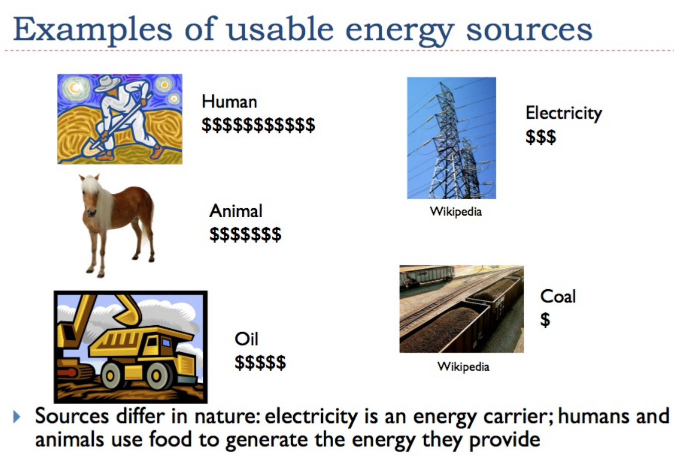

Figure 8. Examples of usable energy sources. Images from Wikipedia and Power Point clip art.

Figure 8 illustrates a few sources of usable energy. Clearly, there are great differences among them, both in terms of how the energy they provide is created, and in terms of the types of energy services they can most easily provide. Businesses will substitute a cheaper source of energy whenever they can. Businesses especially seek ways to substitute away from human energy, since it is the most expensive type. One approach is automation. This substitutes machines (running on electricity or oil) for human labor. Another approach is outsourcing the manufacturing of goods to countries that have lower-cost labor.

One factor that limits fuel switching from oil to electricity is the amount of machinery currently using oil. Robert Hirsch says

Worldwide machinery operating on oil is valued at $50 to $100 trillion (Automobiles, airplanes, tractors, trucks, ships, buses, etc.)

There is also a huge investment in roads, bridges, refineries, and pipelines. Past transitions have taken more than 30 years, because it usually makes economic sense to wait for current machinery to reach the end of its economic life before replacing it.

LIMITS WE ARE REACHING

Unfortunately, we live in a finite world. At some point we start reaching limits.

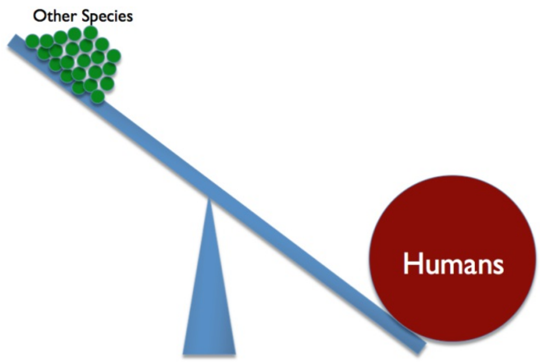

Figure 9. Humans at this point are winning the competition with other species for resources.

One limit we are reaching is **how many people the world will support, without unduly affecting other species**. There are now over 7 billion humans on earth, compared to fewer than 200,000 gorillas and chimpanzees, which are also primates.

The natural order is set up so that each species–including humans–reproduces in far greater numbers than is needed to replace itself. Natural selection chooses which of the many organisms will survive. With the benefit of fossil fuel energy, humans (as well as their cows, pigs, goats, chickens, dogs and cats) have been able to survive in far greater numbers than other species. In fact, paleobiologists tell us that the Sixth Mass Extinction has begun, thanks to humans. At some point, interdependencies are disturbed, and we can expect more population collapses.

Figure 10. Air pollution in Taiwan, from Wikipedia.

Another limit is pollution of many types. This image is of air pollution, but there is also water pollution and CO_2 pollution. Even what we think of as renewable energy often poses pollution challenges. For example, battery recycling/disposal can pose pollution challenges. Mining of rare earth minerals, used in electric cars, wind turbines, and many high tech devices is often cited as being very polluting in China.

Another limit is declining soil quality. In the natural order, soil is not disturbed by plowing, and the nutrients animals use are recycled back into the soil, after they use them.

As we disturb this natural order, we find erosion reduces top-soil depth. The amount of organic matter in the soil is reduced, making crops less drought-resistant. Nutrients such as phosphorous and potassium are often depleted, and need to be added as soil amendments, requiring fossil fuel transport. Soils often suffer from salinity related to irrigation. Nitrogen levels also become depleted.

It is possible to mitigate these problems using fossil fuels. However, we discover that our ability to feed 7 billion people becomes increasingly dependent on continued fossil fuel use. If we increase biofuel production, this tends to make the situation worse. Techniques such as regrading of hills to improve rainwater absorption can help the situation, but this too requires energy.

Another limit is imposed by the Second Law of Thermodynamics. Entropy happens. Things fall apart. All of the "stuff" humans have produced (including roads, bridges, pipelines, electricity transmission equipment, cars, and computers) keeps degrading, and eventually needs to be replaced. If we intend to continue to have roads, we need to keep repairing them and building new ones. Using current technology, this requires an increasing amount of fossil fuel energy.

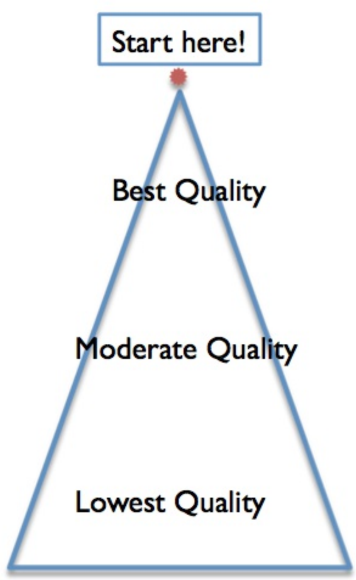

Figure 11. Declining resource quality image by author.

Another limit arises because we extract the cheapest, easiest to extract resources first. (Figure 11) As a result, at some point, the cost of extraction rises, because the cheap resources have already been depleted. Outside observers don't necessarily notice a difference as the quality of resources drops over time; it always looks as if there is an increasing quantity of reserves available as we move down the resource triangle.

Unfortunately, the apparently increased resources are not really comparable to what was already extracted. The resources lower down in the resource triangle, such as oil and gas that requires "fracking" to extract, require the use of increased energy resources. The speed of extraction is often remarkably slower–light oil flows like milk, while heavy oil can be the consistency of peanut butter. Extracting oil using fracking has been compared to getting oil from the pores of a concrete driveway.

Another example is fresh water. Initially we take it from a local stream, or from a shallow well, where little energy (and cost) is required to obtain it. As this resource depletes, we seek other sources–deeper wells, or water piped from afar, or desalination. All of these approaches use much more energy. If the world's total energy supply is not growing rapidly, using more energy for water supply is likely to mean less energy is available for other uses. I discuss this issue in [Our Investment Sinkhole Problem](#).

OIL LIMITS

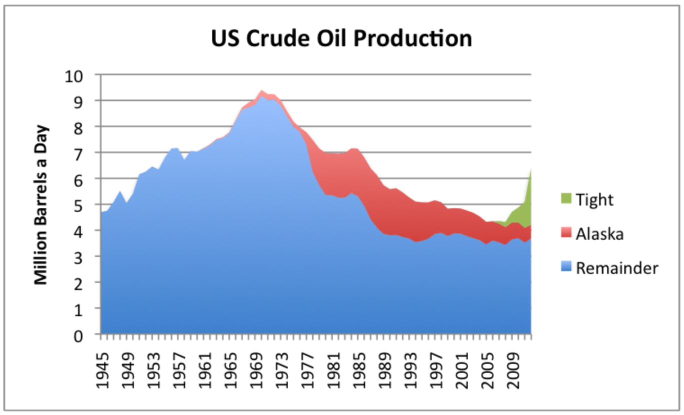

Figure 12. US crude oil production, based on EIA data. 2012 data estimated based on partial year data. Tight oil split is author's estimate based on state distribution of oil supply increases.

An example of how resource depletion can work is illustrated with US oil supply. US oil production (blue) suddenly began to decline in 1970, despite the oil industry's best efforts to extract more. By scrambling around quickly, it was possible to add more oil production from Alaska (red), but this soon declined as well.

It wasn't until oil prices rose in the late 2000s that it made economic sense to use technology which had been developed much earlier to extract tight oil. Tight oil is expensive oil to extract. How much production will rise from current levels depends to a significant extent on how much oil prices are able to increase in the future. The higher that oil prices rise, the greater the recessionary impact that can be expected, but the more oil that can be produced.

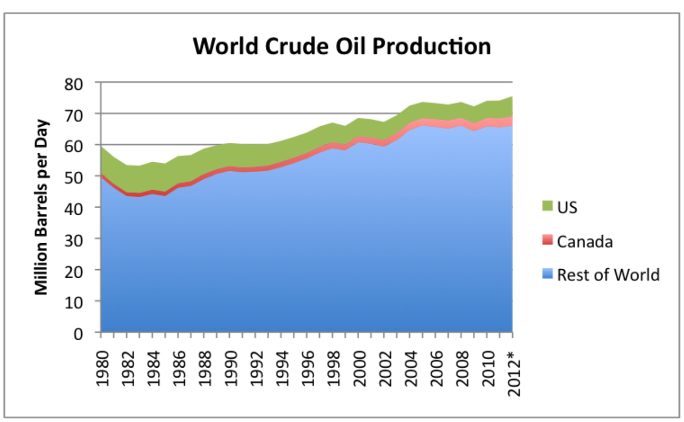

*Figure 13. World crude oil production based on EIA data. *2012 estimated based on data through October.*

World oil supply is now about level, except for the small increase added by US and Canadian oil supply. (Figure 13) One concern with world oil supply as flat as it is, is that at some point, world oil supply will suddenly take a nosedive, just as US oil production did.

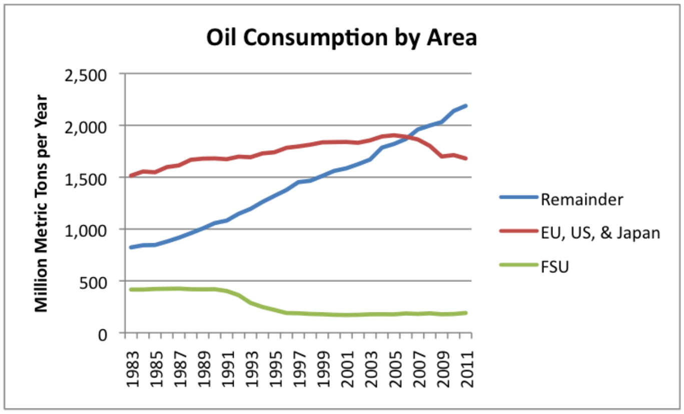

Figure 14. Oil consumption by area, based on BP's 2012 Statistical Report. FSU is Former Soviet Union.

Another concern is that the developing world will get the majority of the world oil supply, leaving little for historically large users (Figure 14). US, Europe, and Japan experienced severe recession in the 2007-2009 period, and still are seeing economic headwinds, at the same time that countries that were able to obtain the oil continued to experience economic growth.

I think of our current situation as being like that of a host who gives a party for 10 people. There is enough food to go around, but just barely. The host decides to invite another 50 people to the party. Surprise! Suddenly there is a shortfall. Globalization has its downside!

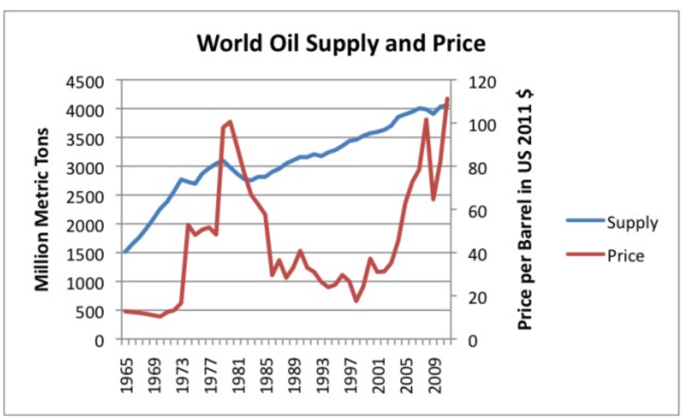

Figure 15. World oil supply and price, both based on BP's 2012 Statistical Review of World Energy data. Updates to 2012$ added based on EIA price and supply data and BLS CPI urban.

A third concern is that oil prices will disrupt economies of oil importing nations. Oil prices rose sharply after US oil production dropped in the 1970s. They began rising rapidly again about 2003, as the world became more globalized. In addition, oil resources became increasingly expensive to extract. There is little possibility now that oil prices can decline for long without a drop in oil production.

Oil price spikes lead to recession. Economist James Hamilton has shown that ten out of the most recent 11 US recession were associated with oil price spikes. When oil prices rise, food prices tend to rise at the same time. Consumers cut back on discretionary spending, because fuel for commuting and the price of food are necessities. This cutback in spending leads to layoffs in the discretionary sector and recession.

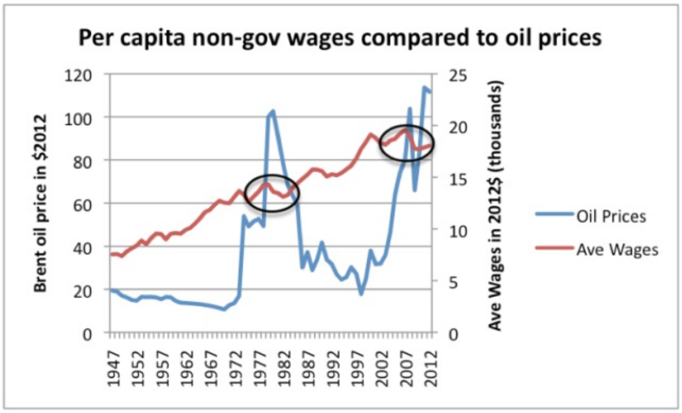

Figure 16. High oil prices are associated with depressed wages. Oil price through 2011 from BP's 2012 Statistical Review of World Energy, updated to 2012 using EIA data and CPI-Urban from BLS. Average wages calculated by dividing Private Industry wages from US BEA Table 2.1 by US population, and bringing to 2012 cost level using CPI-Urban.

High oil prices also seem to lead to depressed wages. (Figure 16. Here, I am dividing total wages for all non-government employees or by the total US population, and then taking this average wage, and adjusting if for inflation.) This is the effect we would expect, if the major substitution caused by high oil prices is a *loss of human employment*. This shift tends to occur because human energy is very expensive, and because wages tend to be a big share of a company's costs.

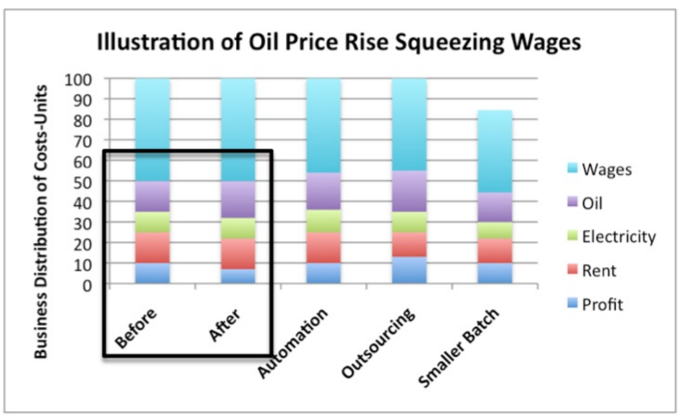

Figure 17. Illustration by author of ways oil price rise could squeeze wages. Amounts illustrative, not based on averages.

Figure 17 shows an illustration of the effect that happens. If oil prices rise, the cost of making goods and transporting them to their destination rises. If the sales prices of goods doesn't rise, a business' profits will shrink. (Before and after the oil price rise shown in black box). The company will consider low profits unacceptable.

The company has several ways of fixing its lower profit. Wages tend to be one of the company's largest costs, so these are a likely target. One approach is automation. This may slightly raise electricity costs, but it will lower wage costs, and raise profits. Another approach is outsourcing production to a low-cost country like China. This will lower wage costs and probably other costs, leading to higher profit for the company.

A third approach is what I call "making a smaller batch." It involves closing unprofitable offices, or flying fewer jets, so that the quantity produced matches the new lower demand for the product, given the higher required sales' price, now that the oil price is higher. Any of these approaches reduces the amount of wages paid to US employees.

HOW DOES THIS CONCLUDE?

A person could argue that any of the limits could eventually bring the system down. The pressure on wages is particularly a problem, since a further rise in oil prices would seem likely to lead to more job loss, and further pressure on wages of those who keep their jobs. The large amount of debt outstanding is another issue of concern.

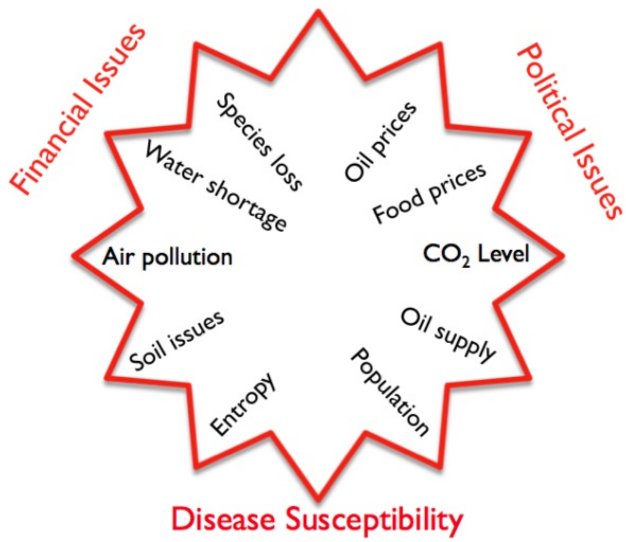

Figure 18. Author's view of how various limits might work together to produce different symptoms.

My personal view is that the most likely scenario is that the various limits will work together to produce secondary effects, and it is the secondary effects that are likely to bring society down. These secondary effects are Financial (wealth disparity, debt defaults, inability to collect enough taxes), Political (not enough taxes, uprising by the lower classes, government collapse) and Disease Susceptibility (inadequate food, medicine, and sanitation due to inadequate wages and government cutbacks).

These effects are similar to ones experienced in the past when economies started reaching resource limits, based on the research of Peter Turchin and Sergey Nefedov reported in the book [Secular Cycles](). In the past, societies seemed to go through about 300 year cycles. The first was Growth, lasting over 100 years. The second was Stagflation, lasting perhaps 50 or 60 years. This third was Crisis, with population decline, lasting up to 50 years (but perhaps a much shorter time). The fourth was Depression/ Intercycle.

If we estimate that today's complete cycle started in 1800 with the use of coal, and the Stagflation period started about 1970 with the decline in US oil production, then we now seem to be nearing the Crisis stage. Of course, each situation is different. This is the first time we are reaching resource limits on a world-wide basis.

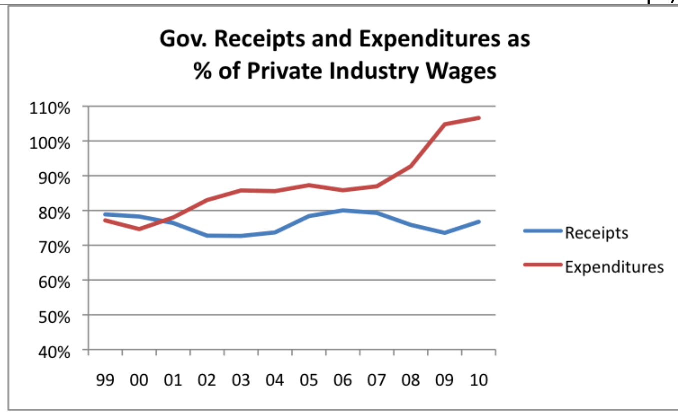

Figure 19. Government receipts divided by private industry wages, and government expenditures divided by private industry wage, based on BEA data.

There is considerable evidence that we are already reaching the situation where governments are encountering financial distress of the type shown in Figure 18. With wages being depressing in recent years (Figure 16), it is difficult to collect as much taxes as required. At the same time, expenses are elevated to handle the many issues that arise (such as payments to the unemployed, subsidies for alternative energy, and the higher costs of road repairs due to higher asphalt costs). The big gap between revenue and expense makes it hard to fix our current financial predicament, and increases the likelihood of political problems.

REQUIREMENTS FOR A FUEL TO FIX OUR CURRENT PREDICAMENT

Is it possible to fix our current situation? To really fix the situation, we would need to reproduce the situation we had in the post-World War II period–when energy was cheap, and growing very rapidly. Economists have observed that historically, the cost of energy was very low. Given the importance of energy, its low price was an important *feature*, not a *bug*. It is what allowed society to have plenty of energy for growth, at minimal cost.

In order for a new alternative fuel to truly fix our current predicament, it would need the following characteristics:

1. Abundant – Available in huge quantities, to meet society's ever-growing needs.
2. Direct match for current oil or electricity – Needed to avoid the huge cost of building new infrastructure. Electricity needs to be non-intermittent, to avoid the cost of mitigating intermittency. We also need an oil substitute. This oil substitute theoretically might be generated using electricity to combine carbon dioxide and water to create a liquid fuel. Such substitution would require time and investment, however.
3. Non-polluting – No carbon dioxide or air and water pollution.
4. Inexpensive – Ideally no more than \$20 or \$30 barrel for oil equivalent; 4 cents/kWh electricity. Figure 15 shows wage growth has historically occurred primarily below when oil was below \$30 barrel.
5. Big energy gain in the process, since it is additional *energy* that society really needs – This generally goes with low price.
6. Uses resources very sparingly, since these are depleting.
7. Available now or very soon
8. Self-financing – Ideally through boot-strapping–that is, generating its own cash flow for future investment because of very favorable economics.

It is interesting that when [M. King Hubbert originally made his forecast of the decline of fossil] fuels, he made his forecast as if an alternative fuel would become available in huge quantity, by the time of the decline. His original idea (in 1956) was that the new fuel would be nuclear. By 1976, his view was that the new fuel needed to be some version of solar energy.

What kind of solar energy might this be? Solar panels PV located on the ground are heavy users of resources, because they have a low capacity factor (percentage of the time they are actually collecting sunlight), and because they need to be fairly sturdy, to withstand wind, rain, and hail. Space solar theoretically would be much better, because it is much more sparing in its use of resources–it would have over a 99% capacity factor, and the PV film could be much thinner. Timing for space solar would be a big issue, however, assuming financial issues can be worked out.

Also, even if space solar or some other fuel should provide the fuel characteristics we need, we still need to address the population issue. As long as world population keeps rising, humans are an increasing strain on earth's resources.

This post originally appeared on Our Finite World.