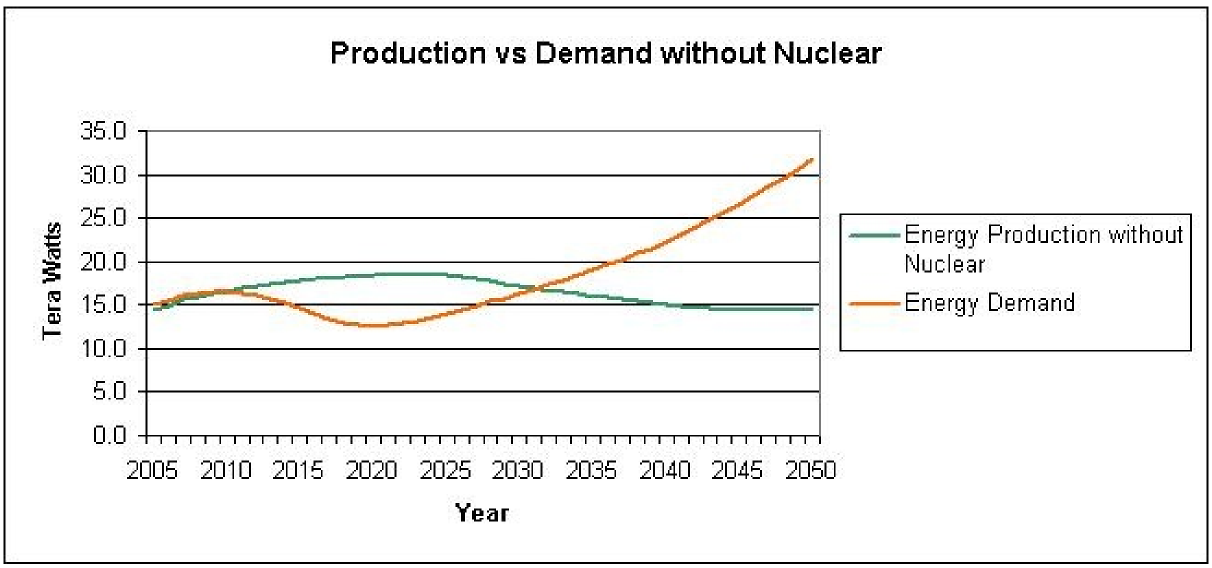
Energy Vision 2050 - part I

Posted by Luis de Sousa on September 10, 2008 - 10:10am in The Oil Drum: Europe
Topic: Alternative energy
Tags: 2050, alternative energy, economic growth, nuclear, renewable energy [list all tags]

This is a guest post by Sterling Smith (TOD user Sterling). This first installment of the series outlines the evolution of the energy panorama from now to 2050. A second installment will deal with technical and political aspects of the path put forward.



Sterling is a software architect who works in Silicon Valley and lives in Woodside, California. He was born in the suburbs of New York City and graduated from Dartmouth College, where he majored in physics. He has worked in the software business for 35 years, still writes code, and has been part of eleven start-ups as well as several major corporations. Sterling's wife, Deborah Metzger, PhD, MD, is a very prominent gynecologist with whom he is raising four kids.

Overview

While many people who are just beginning to learn about peak oil do not yet grasp how serious it will be for society, many of those who do understand the threat are perhaps overly pessimistic of the world's chances for shifting to a new energy base and even of maintaining civilization. Much of this debate revolves around the desirability of trying to preserve modern civilization and its apparent reliance on physical growth, but many also doubt that there are any energy alternatives to oil and the other fossil fuels that could possibly ramp up to address the looming need. I think we need to decouple these two issues and debate them separately. This article does not attempt to answer the question of whether civilization is worth saving. I think we need to answer that question "**can** we preserve modern civilization" before we try to take on the question of "**should** we do so"? The objective of this and a future piece is to derive and present a vision of a world that preserves modern civilization after it can no longer rely on fossil fuels as its primary sources of energy, with the assumption, supported in the second piece, that energy sources exist to support this outcome.

The world may follow any of several paths but the single one presented here seems to me the most likely. The first step will be to project the overall economic path that the world is likely to take as it struggles through the coming peaks of fossil fuels and replaces them with an alternative infrastructure. In step two, I will attempt to derive the total energy that would be required to support this projected economic activity. The third step will be to determine the energy mix that could support this energy demand. A future article will attempt to describe how we get there from here and what the new energy system would look like.

My reading of the evidence convinces me that the world possesses adequate energy resource to power a civilization like ours into the indefinite future. However, for this to happen, we will have to transition to a radically different energy infrastructure in the years to 2050. Can the world survive this transition? My faith in the ingenuity, persistence and will to survive of mankind says yes but I am not prepared to defend that at this time.

The Size of the World Economy in 2050

Assumptions:

- Energy resources exist that could power a civilization like ours forty years from now.
- The long term growth rate will approximate the current rate after a new energy infrastructure is built.
- The world will not be able to avoid a severe downturn, due to peaking, lasting about 20 years.
- Concerted societal action will mitigate the downturn.
- Total world population growth will end by 2050.
- The world economic activity mix will shift toward less energy intensive activities.
- Growth in traditional economic activities will slow.

My starting assumption is that the rate of economic growth in the next forty years, if unconstrained by declining energy, would likely be about what it has been for the last fifty years, which is 3.9% (World Economic Growth - Earth Policy Institute). However, since the current population growth rate is about 1% (1.167% - 2007 est.) and population growth is expected to go to zero by 2050, I reduce the expected growth rate without an energy shock to 3% in 2050. The rapidly developing countries such as China and India have had more than twice this growth rate in recent years but many critical resource are becoming constrained. These physical resource limitations are likely to slow physical economic activity but the economic mix is trending towards more creation of intellectual capital (entertainment, knowledge, communications, software, etc.) through activities that are placing much lower demands on physical resources. It should be possible to maintain this 3% level of aggregate economic activity growth while dramatically reducing physical resource consumption. I think it is fair to conclude that this level of economic growth in 2050 would maintain the current level of economic vitality.

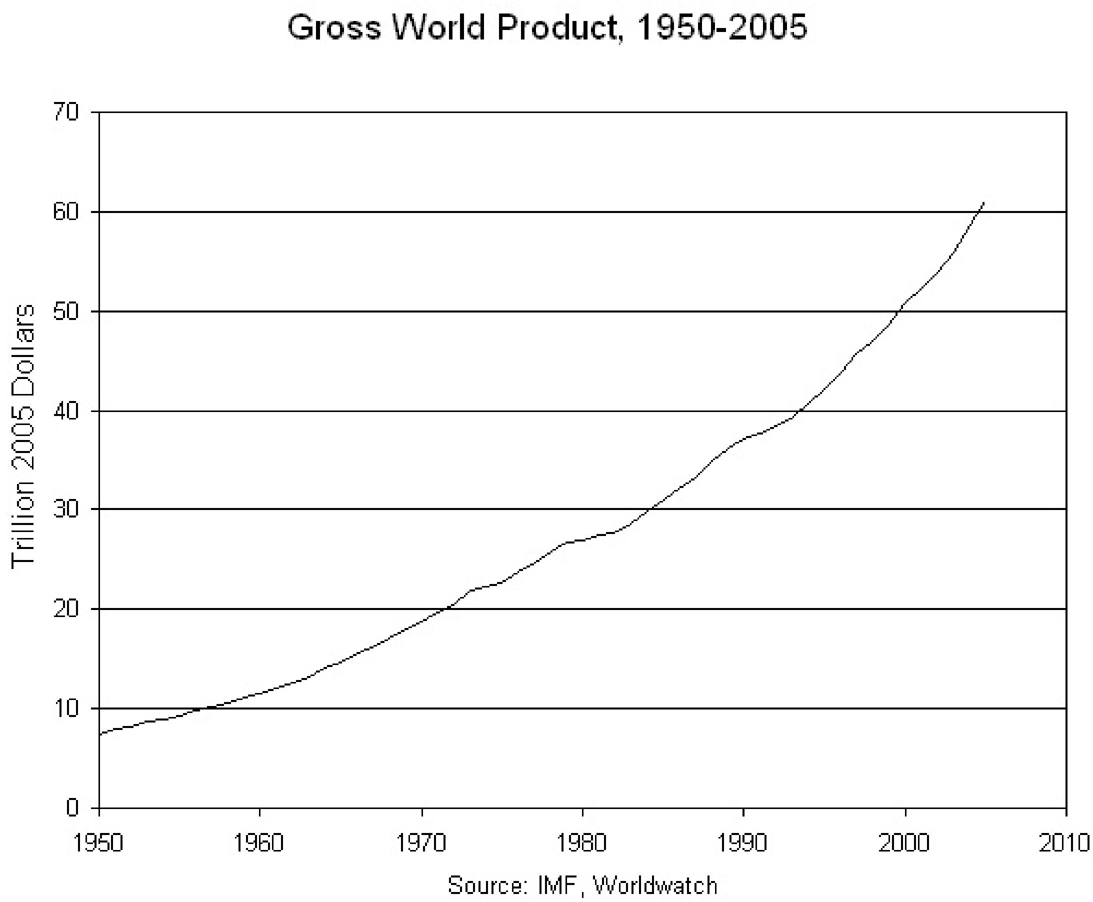


Figure 1. Gross World Product, 1950-2005

The next task is to estimate the impact of fossil fuels peaking on economic activity. Three potential scenarios come to my mind as possible with a fourth thrown in since it seems to be popular.

Collapse – In this scenario, once the crisis of peaking hits, it is never successfully mitigated. Economic activity turns down and continues down to a low level. Since there are potential mitigations, this might happen is if the shock causes the economic system to break down so that a coordinated response is not possible. This scenario would undoubtedly be accompanied by wars, tremendous environmental destruction and a huge die-off.

No Growth – For some reason that I cannot fathom, zero economic growth seems to have great appeal to some. This scenario seems completely implausible to me. We will either make the transition to a new energy base or we will not.

Profound Oil Shock – In this scenario, economic growth slows down as shortage of oil, principally, puts people out of work. Eventually, substitutions emerge and economic growth resumes. The net effect is the time at with the economy reaches a certain level is delayed for some years.

World War Mobilization – This scenario would occur if the world mobilized to take concerted action to mitigate the problem as quickly as possible by focusing world resources narrowly. It seems more likely to happen after a more rapid deterioration. Growth could be significantly above trend for the entire world for up to ten years. A third World War might not include as much wholesale killing as the first two. It might just be an intense economic competition with dramatic winners and losers. The rapid wealth transfers now occurring are setting the conditions for this kind of event.

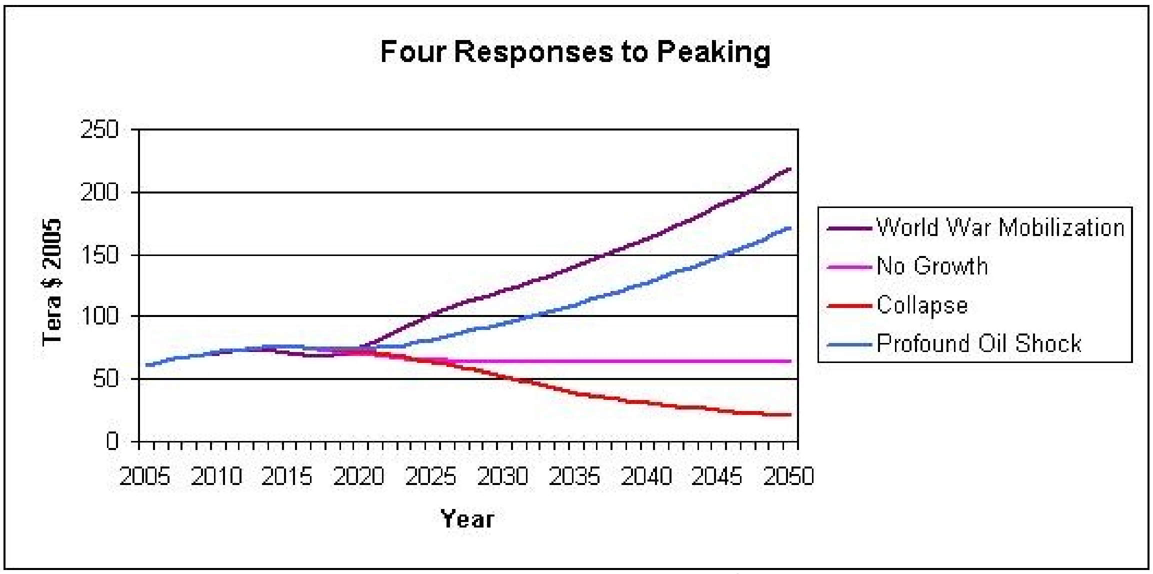


Figure 2. Four Responses to Peaking

While the world war level mobilization seems to me almost as likely as a profound oil shock, I am going to arbitrarily choose the oil shock perturbation as the basis for my model. The question is, what is a plausible depth and duration for the downturn? The [Hirsh Report](#) predicts that it will take twenty years to fully mitigate the effects of oil peaking. It also notes that economic upheaval is not inevitable ("given enough lead-time, the problems are soluble with existing technologies.") During the Great Depression in the US, the economy lost 25% of its value in 1930-1933, but was back to its previous high by the beginning of 1937. My guess for the coming downturn is that it will be similar in magnitude to the 1930s depression but that it will be shallower and last longer. With this in mind, my model estimates that the world will lose about 70% the economic growth that it would have otherwise had during the twenty year mitigation process starting in 2010 (23 vs 78 T$). This is a very severe downturn but I am simply making guess here how severe it will be.

The only somewhat similar historical precedent for such a downturn happened after the 1979 oil shock, prompted by the Iranian revolution and the subsequent Iran – Iraq War, when the price of oil rose two and a half fold and stayed at about twice the previous level for about six years before collapsing in 1986. This event involved a temporary reduction on consumption of about 15% which created a noticeable blip in world economic growth (see figure 1) but no overall downturn. This was a much smaller event than the 2010-2030 downturn assumed here. It is interesting to note that this event was mitigated not only by the rapid increase in oil supply in many countries but also by the world's first nuclear power buildup.

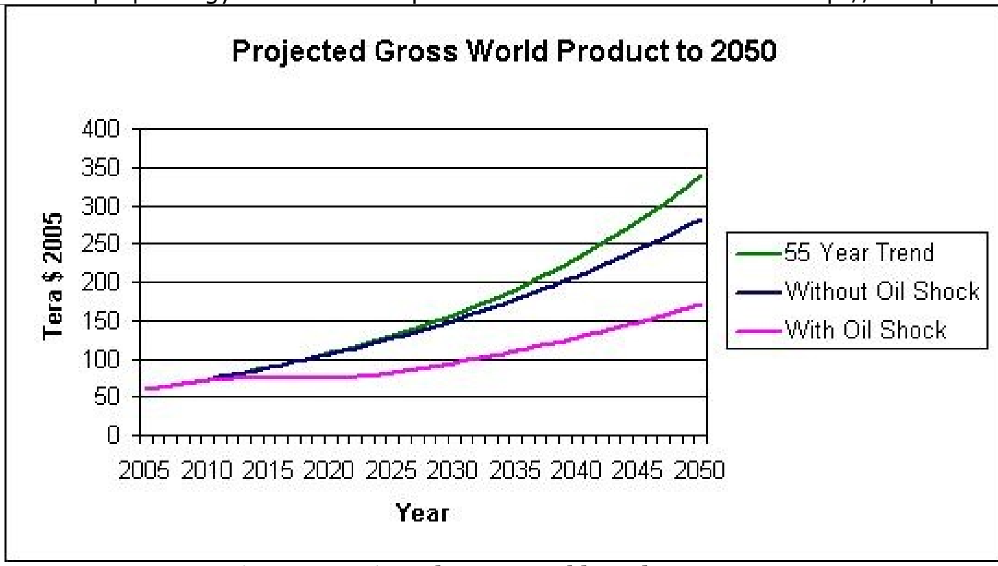


Figure 3. Projected Gross World Product to 2050

Energy Demand

Assumptions:

- Economic activity and energy consumption are directly related.
- Energy supply constraints produce greater energy efficiency.
- Greater energy supply leads to lesser energy efficiency.
- Emerging knowledge intensive activities will use proportionally lower energy.

It is widely believed that there is a direct relationship between a level of economic activity and the amount of energy that must be consumed to produce it (see works by Robert Ayres and Charles Hall). However, I expect three major trends which will slow the growth of energy demand. The first is the already stated expectation that world population growth will go to zero by 2050 which will lower long term economic demand growth to 3%. The second is that energy efficiency will improve for the current mix of economic activity, which will itself decline by one third due to resource constraints. However, these efficiency improvements will be largely given up once the supply of new energy resources increases. In my model, the current mix of economic activity improves to 70% of the current energy consumption per unit of GPD in 2020 (i.e. these activities are 30% more efficient), but then reverts to 90% by 2050 once the supply of energy has rebounded. I believe the world will add an additional approximately 1% of growth per year (of 3% total growth) of low physical resource activities which characterize the information society. These are modeled at half as energy intensive as the current mix and grow to 33% of the total mix by 2050. Together these would provide 3% economic growth with 75% of the current energy demand per unit of economic activity in 2050. The current world energy demand is about 15 TW per year (World energy resources and consumption).

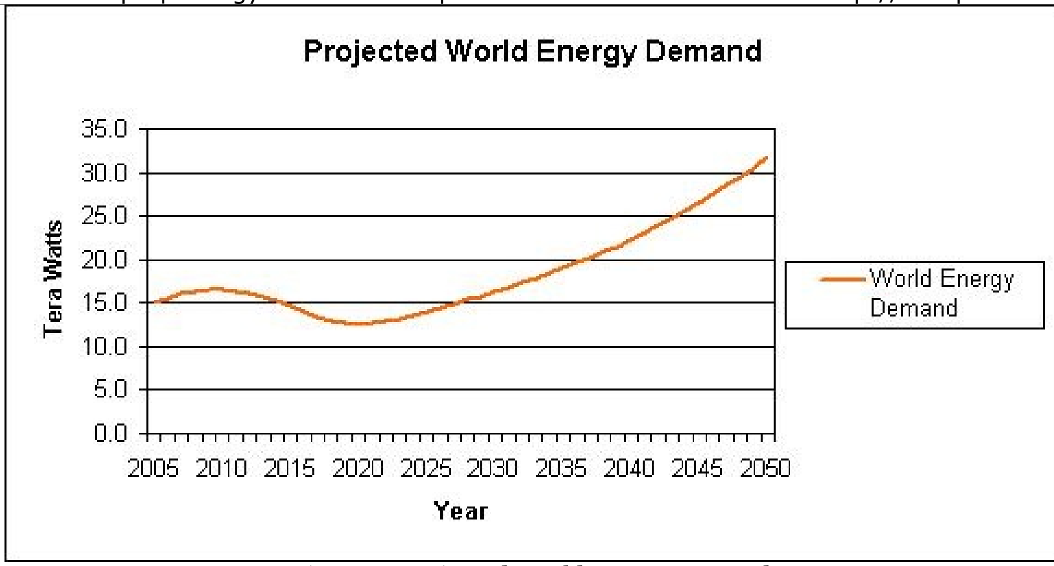


Figure 4. Projected World Energy Demand

The question has been raised if it is plausible that energy efficiency could improve 30% by 2020? For the purposes of my model, I am mainly concerned with deriving the demand in 2050 so the efficiency in 2020 does not matter except for the light it might shed on the plausibility on the depth of the downturn. To me a 30% improvement in 12 years does seem plausible in a severe crisis.

Energy Mix

Assumptions:

- Oil will peak by 2012 , coal by 2024 and natural gas by 2029.
- The amount of electricity that can be generated by nuclear, wind and solar is not effectively limited by the amount of available fuel.
- No new energy source will be significant between now and 2050.
- Production volumes of fuels from low grade hydrocarbons will never rival today's production of traditional fossil fuels.
- It will be important to leave a significant amount of coal in the ground to lessen global warming.
- It will be necessary to slow the consumption of remaining oil and gas below the projected natural decline to save some for future generations.
- A future electricity grid will be designed around the principal of power on demand

Transportation will shift to an electricity base from an oil base.

The next question is how to provide for the energy demand with the resources that are likely to be available. Fossil fuels are all projected to peak in this period. It is probably not possible, in the short to mid term, to ask people to reduce their use of oil and gas more than they will have to due to peaking, since there are not good immediate substitutions. However, if possible, it would be better to slow the consumption of these so that we do not exhaust the last supplies of these as soon as projections now suggest we will. Coal is another matter. It is the dirtiest of fossil fuels and it can be displaced directly for electricity generation by sources that I do not expect to be in short supply. Due to the seriousness of global warming, my model phases coal out for electricity generation by 2050. It will presumably still be used in 2050 for transportation fuel, especially for aviation and for such uses as steel production.

Dave Rutledge of CalTech, who has done some of the best work on the peaking of coal supplies, has estimated that even if all fossil fuels are consumed as quickly as they can be produced, that carbon dioxide levels will peak at only 460 ppm, a level that most climate scientist recognize as at just the threshold of doing serious damage to the climate. Does this mean that fossil fuel depletion will solve the global warming problem and that we do not need to do anything about it? I do not think so. James Hansen, NASA's top climate expert, thinks that this threshold needs to be 385 ppm, below the current level, and we are already seeing serious negative effects. Even once emissions decline significantly due to peaking production, it will take several hundreds of years for the carbon dioxide levels to come down to acceptable levels.

My model will use these data compiled by Luis de Sousa for his Olduvai revisited 2008 article (thank you Luis) which has oil peaking in 2012, coal in 2024 and gas in 2029 (1 TW = .086 Mtoe):

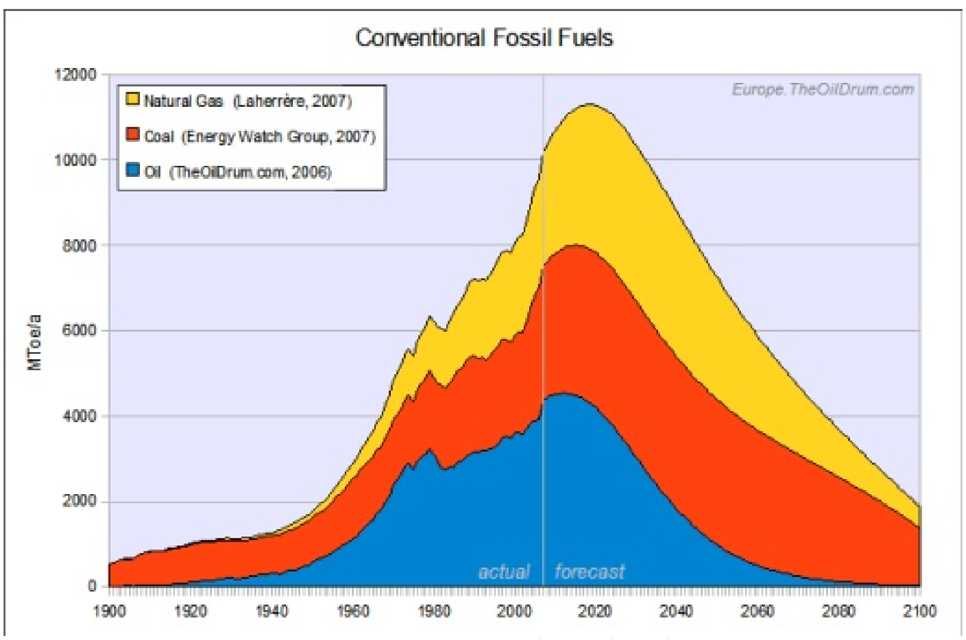


Figure 5. Conventional Fossil Fuels

In the following three graphs I show how each of the three fossil fuels is expected to decline due to peaking and also provided recommended levels of consumption, shown as dashed lines below the solid lines of the same color. I assume that coal will be phased out in the model by 2050, except for expected non electricity generation purposes, due to its severe impact on global warming. For oil and natural gas, I cut back the consumption of each on the assumption that these will become too value for us to consume them as fast as we can. I am convinced that this will only be possible once we have alternative sources rapidly coming on line. All data are converted to tera watts.

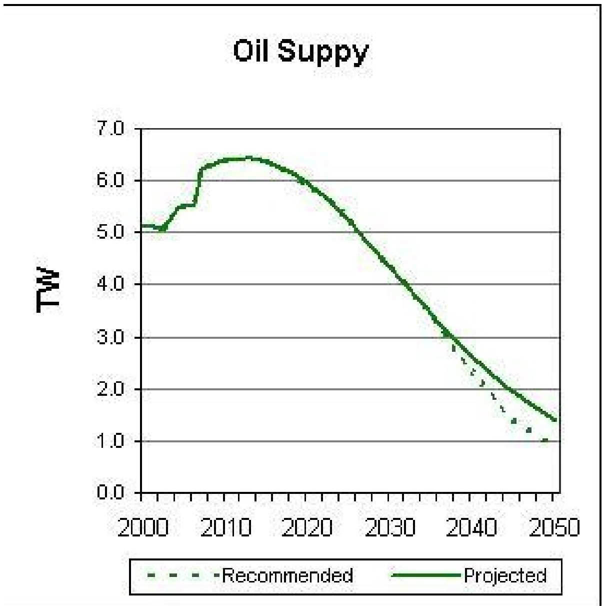


Figure 6. Projected and Recommended Oil Supply

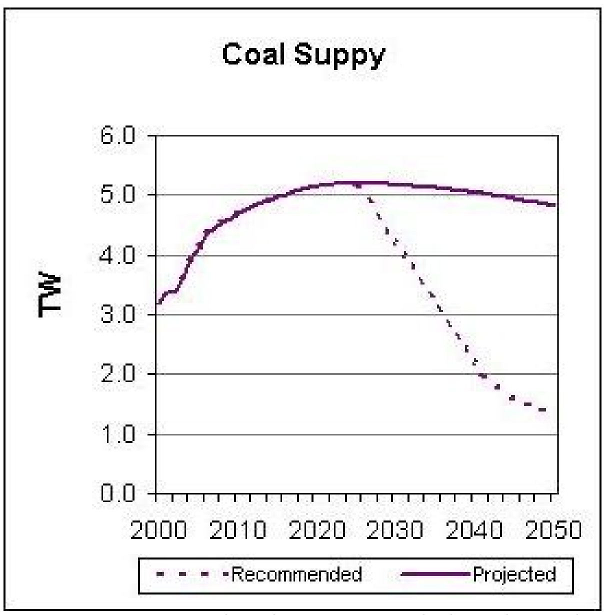


Figure 7 . Projected and Recommended Coal Supply

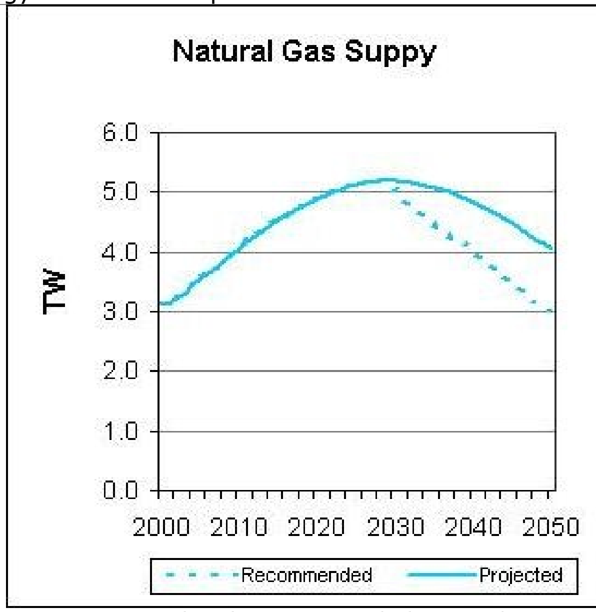


Figure 8. Projected and Recommended Natural Gas Supply

As you can see, I am projecting that by 2050 we will be able to rely on fossil fuels for only 5.5 TW of my expected world demand of 31.7 TW or 17.3%. I believe this total includes essentially all likely production from alternative fossil fuel source such as oil sands, oil shale and bio fuels which are essentially repackaged fossil fuels. None of these sources seem to be capable of producing much net energy and/or to be producible at high rates. I expect that Biomass, hydro and all other sources (excepting nuclear, wind and solar) will provide about 1 TW combined, as they do today bringing the conventional total to just over 20% of my predicted demand. (I do anticipate the there might be a very large increase in hydro to deal with the wind and solar intermittency issue.) Here is a view of the current world energy mix ([World energy resources and consumption](http://)):

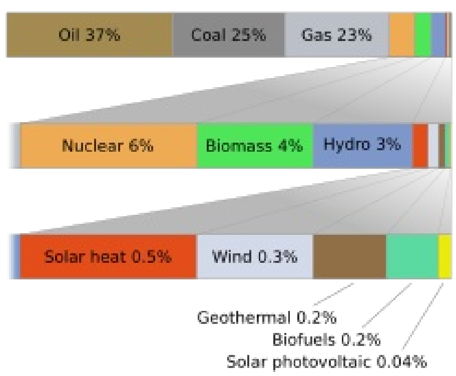


Figure 9. Current World Energy Mix (Click to enlarge)

Wind and Solar will play vital roles in the future. However, they will have to operate within a power on demand grid. People will not stand for not being able to get on the Internet at night or use air conditioning during the day because the sun is not shining or the wind is not blowing. Today, all wind and solar has to be redundantly backed by dispatchable sources such as gas or hydro to cover for their intermittency. A max of 20% for these sources is widely accepted as the upper bound of their usefulness without a method of large scale power storage or other way to cover for their intermittency. This situation will be made worse in 2050 by gas becoming too precious for power generation. The only large scale storage method of power storage that has emerged to date is pumped water storage. Stuart Staniford and others have proposed a world wide super grid as a way allow solar to be used where the sun is not shining. Al Gore has also recently described a large scale electrical grid as a way to allow wind power to provide a very high percentage of electrical power. To give these vital sources the benefit of the doubt, my model will allow 30% wind and solar with one third of it assumed to be backed by some storage method or grid yet to be determined. I do not think that the proponents of these approaches have demonstrated that they could reach the high levels of renewables they advocate, preserving the power on demand nature of the system and competing on cost with alternatives likely to be available at the time. Note that my model does not adequately provide for the dispatchable power sources that would be necessary to provide the redundancy for the level of wind and solar projected.

My model assumes that 80% of the energy that the world will require in 2050 will have to come from nuclear, wind and solar, or 25.4 TW of electricity. At least the current amount of gas used for electricity generation and all the hydro totaling another roughly 1.5 TW will also be part of the total for an electricity total of 26.9 TW. Of this 30% could come from wind and solar together adding up to 8.07 TW which is 158 time the current .051 TW from these sources. Note that the level of wind and solar projected would only be possible in a mix with nuclear baseload or if the power on demand characteristic of the current system were abandoned. In the latter case, the grid would be completely dominated by the intermittent characteristics of wind and solar.

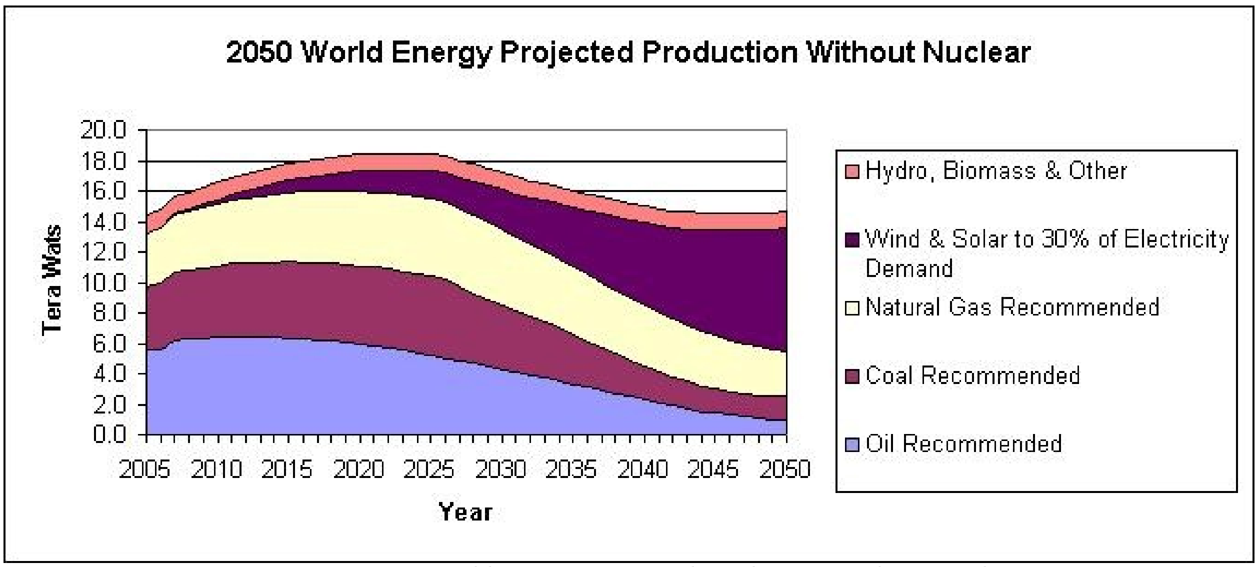


Figure 10. 2050 World Energy Projected Production Without Nuclear

The next chart shows the dilemma of what would be possible without nuclear power or some other energy source not here considered. Again, remember that this scenario would also feature an electric grid that would only provide power on intermittent supply.

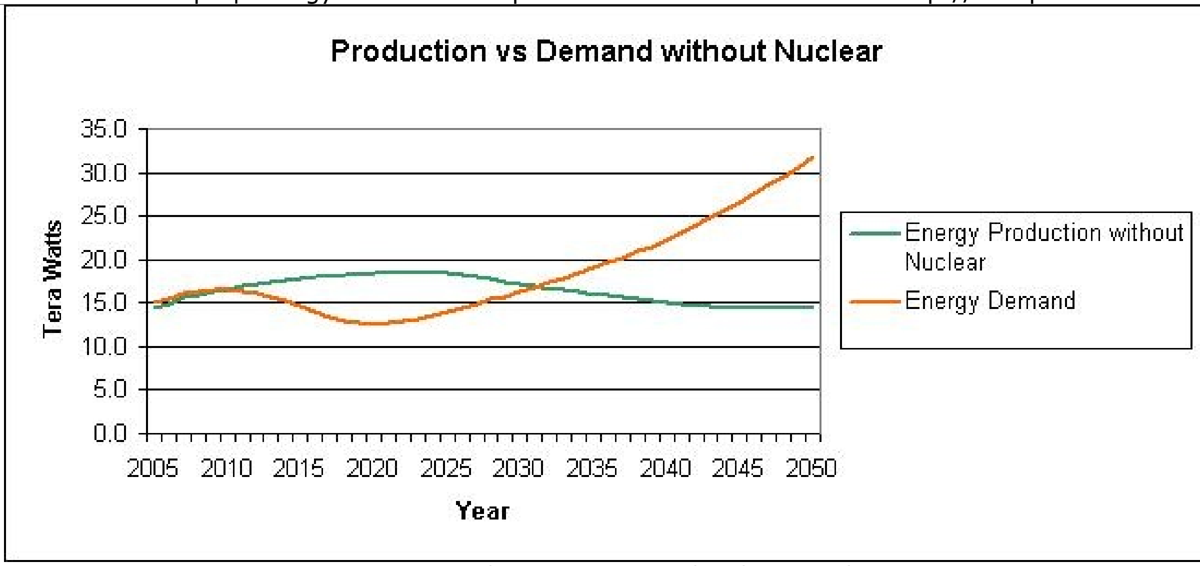


Figure 11. Production vs Demand without Nuclear

I am not sure how to explain the gap in 2010-2030 between the energy projected to be available and the demand projection of the model. One interpretation is that the crisis will be primarily a shortage of oil and that coal and gas cannot immediately substitute. Demand goes down because the oil shortage depresses economic activity and enforces conservation. This article does not pretend to understand what happens during that period, how we would muddle or suffer through it. The important point here is to look at the end state: what is the size of the world economy in 2050? Perhaps the downturn does not have to be a severe as I am forecasting it to be. Tom Whipple, former CIA analyst and top peak oil reporter, has a recent article the comments on the coming crisis. He concludes:

> It is getting very complicated out there, and none of us really know what is going to happen.

The Solution

This article assumes that the world has sources of energy in nuclear, wind and solar that are not supply limited and it has the will and the means to transition to a new energy base after fossil fuels are no longer available. In my view, the only credible way to do this is with a large nuclear, wind and solar buildup. In my model nuclear increases 19 fold and wind and solar increase 158 fold.

Energy Mix in 2050 (Tera Watts)		
Oil	1.0	3%
Coal	1.5	5%
Natural Gas	3.0	9%
Wind & Solar	8.1	25%
Nuclear	17.0	54%
Other	1.1	3%
Total	31.7	

My goal is to write a future article which describes what this world would look like and how we would get there. My hope would be to write that article with the collaboration of several Oil Drum posters who know more about the details of this issue than I do. It is obviously controversial to put forth a vision that assumes that the world can resume the kind of growth it has seen in the last 50 years after fossil fuels are largely depleted and especially to base the vision heavily on nuclear power. Regarding nuclear, I cannot think of a topic where so many contradictory views are debated so often without a consensus emerging. For example, many people still think that nuclear has a low energy return and that supply of fuels are nearly running out, views that I think are strongly at odds with the evidence.

Is this vision hopelessly naïve and cornucopian? Only if you assume that there no way to go but down for mankind.

Spreadsheet with calculations and graphs.