What does Sustainability Mean for Energy?

Posted by Gail the Actuary on March 12, 2009 - 9:14am
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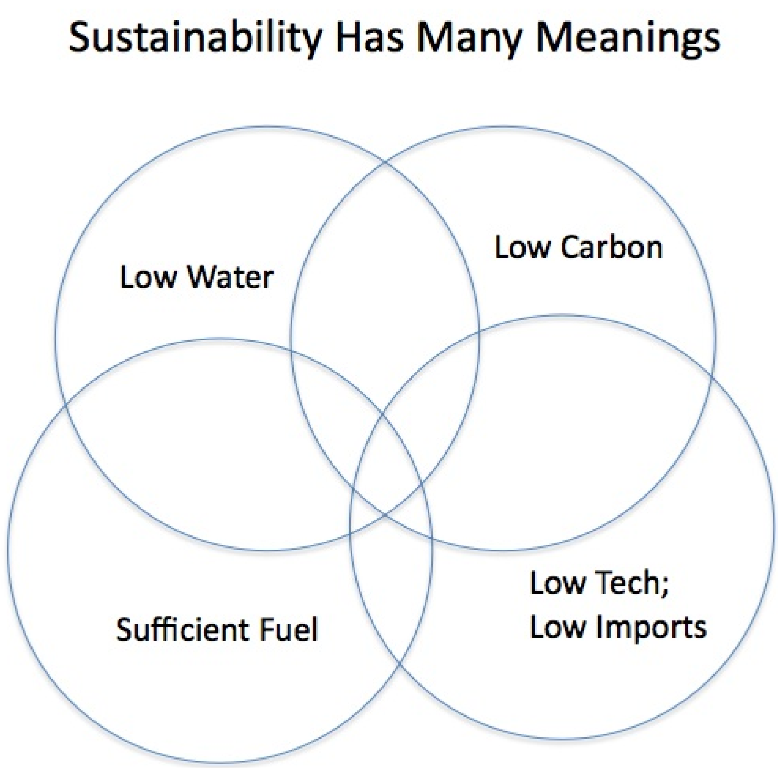
What makes energy sustainable? I think each of us has our own idea, and the various ideas are not entirely the same.

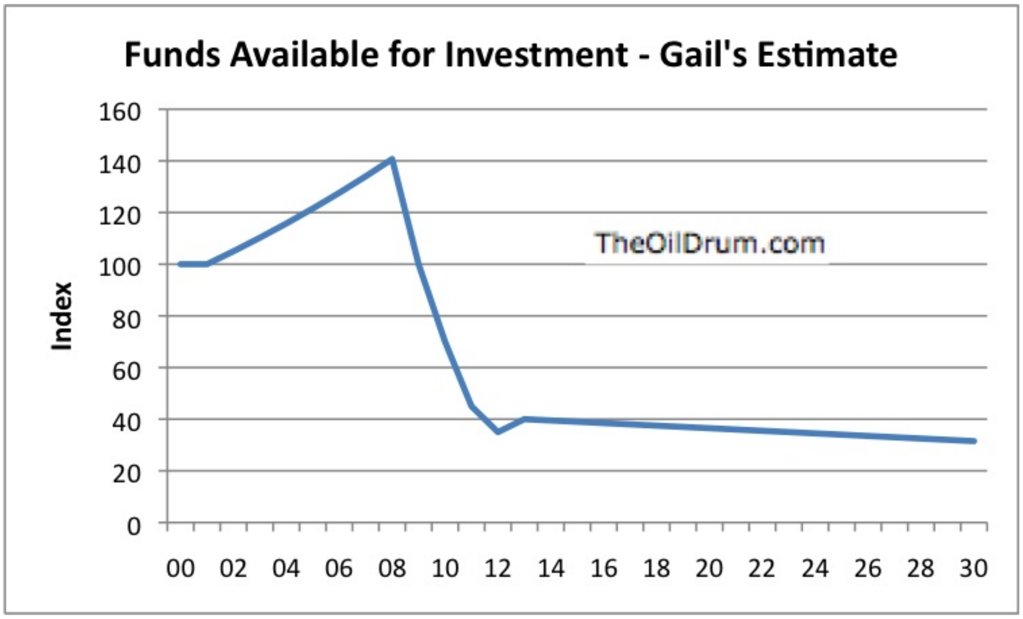


To be sustainable, clearly the fuel supply must be adequate--not run out shortly. If we are concerned about climate change, a sustainable source of energy production should not add much carbon to the atmosphere, either. We are running short on fresh water, so a sustainable fuel must not put a burden on the water supply. Furthermore, it is becoming more and more clear that the system of international trade that underlies our high-tech system will not hold together indefinitely. Because of this, an energy source that depends heavily on imported raw materials or parts, or is dependent on our whole high-tech way of life, is not likely to continue very long.

Ideally, any energy source we want to emphasize in the future will meet all of these criteria, and additionally, will be inexpensive to produce. The problem is that it is very difficult to find fuels that meet all these criteria.

Future Investment

This last criterion, being inexpensive to produce, is becoming more and more important. With the credit unwind, the amount of money available for investment has already dropped. The credit unwind is not yet over, so I expect that the amount of money available for investment will continue to drop in the future, perhaps something like this:



With a smaller amount of funds (and energy) available for investment, all types of new investment will suffer. New energy infrastructure spending will need to be kept low, if we want to have funds for other things, such as building factories and maintaining roads.

Sustainability Grid

What happens when we evaluate various fuel sources on the now five sustainability criteria (assuming we add "new capacity inexpensive" to the four above)?. I tried to make a rough stab at answering this question, putting together a "Sustainability Grid".

In the Sustainability Grid, I used a very simple scale going from 0 to 3 for each criterion, with 3 being the best, and 0 being the worst. My evaluations are not very scientific--they are mostly based on impressions, rather than close comparisons of data, but they give a general idea of where the different fuels stand on the various criteria.

Sustainability Grid	Oil	Natural Gas	Coal	Wind	Solar PV	Hydroelectric	Nuclear	Corn Ethanol	Wood
Low Carbon	1	2	0	3	3	2	2	1	3
Low Water	2	1	1	3	3	2	1	0	2
Sufficient Fuel	0	1	2	3	3	1	1	1	0
Low Tech; Low Imports	1	0	3	0	0	2	0	1	3
New Capacity Inexpensive	0	2	3	0	0	0	0	0	3
Unweighted Total	4	6	9	9	9	7	4	3	11

Besides the individual values for the various cells, another question is how a person combines the indications. I have just shown an unweighted sum. Theoretically, if one of the issues listed is vastly more important than others, (for example, low carbon, because of climate change concerns), one could weight the results, so that attribute is given much more weight in any consideration. Another approach would be to require that any possible substitute for our current energy sources meet all of the criteria. If that were the case, we might be left only with "energy efficiency", or perhaps "doing without" as an option.

I should also point out that these aren't the only criteria one might consider. One might consider whether a new fuel type fits with the existing infrastructure. If it doesn't, then the infrastructure conversion cost might be considered along with the new capacity cost.

There may also be specific issues for specific fuels. Nuclear comes to mind, with the question of how one handles toxic waste 100 years from now, if we are very short on energy supplies at that time.

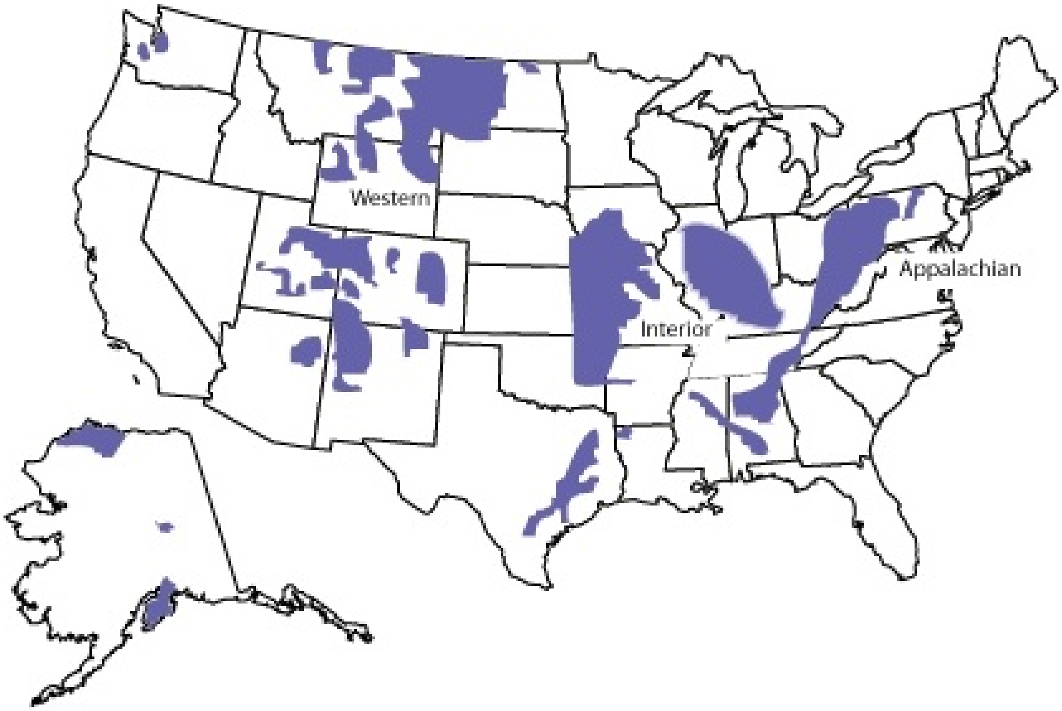
Sustainability Grid: Looking at Various Fuels

The fuel that in some sense is best on my sustainability chart is wood. It is low carbon. In the areas where it grows, it doesn't need extra water. Planting and harvesting can be done in a low tech way, and new capacity seems to be inexpensive--all one needs to do is plant another tree in an area where trees grow.

The catch is that there are way too many people for the number of trees. Much of the US' (and world's) land is not suitable for growing trees, because of inadequate water or incorrect temperature. If people come to see wood as a "good" solution, it won't be long before we have serious deforestation issues. So wood is not really sustainable as a solution, if more than a small percentage of the population tries to adopt it as a solution.

If a person looks at the other energy sources on my sustainability grid above, most of them require a fairly high level of technology to sustain them. This could be a problem, if the financial situation continues to deteriorate, and we find ourselves with many fewer foreign imports. Without imports of spare parts and raw materials, it seems likely that much of our advanced technology could disappear within five or ten years.

The one exception to requiring a high level of technology is coal. Certainly, the current method of mining coal uses advanced technology. But coal production can also be done with very low technology--a few pick axes and a bucket in a makeshift mine. This approach is unsafe and certainly not recommended, but if other possibilities disappear, many people will consider this a fall-back option. Coal deposits are very widespread in the US, and many have never been mined. I suspect that if technology really fails, this will be an option considered by many who live near coal deposits. By that time, we may be using so little in fossil fuels in total that the carbon issue may be less of a concern.



Coal can also be burned in a very low-tech way. We did this for years before modern regulations. I wouldn't recommend it, but when people are desperate, I don't think they will be thinking of those details.

The question then becomes: What are our best options, as long as imports and technology hang together? Should be making wind turbines or solar PV panels, corn ethanol, or something else?

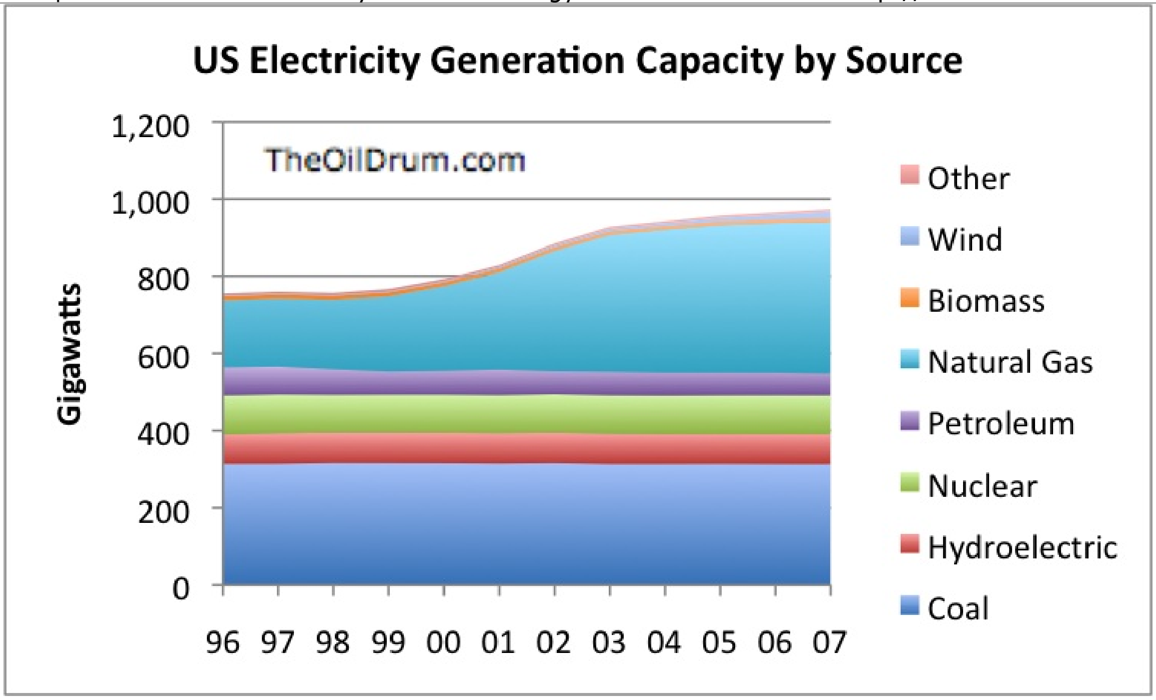
I am not certain I really have the answer to this question, because the answer depends on how one weights the various items in the sustainability grid, and whether the values I picked are even half-way right. It also depends on how long we think technology in its current form can be maintained. If we can only maintain our import-driven, high tech society for five or ten more years, then one could argue that we really don't need to be spending anything on new capacity, since, as I show in the next section, we already have quite a bit more electrical generating capacity than we are using.

If technology can be expected to hold together for 20 years, even then we cannot expect investments to behave as in the past. Instead, we must amortize the cost over a much shorter period, and investment costs become much more expensive than they have been in the past. It is only if our current high tech lifestyle can be maintained for 50 years or more that the type of investments we have made in the past make sense, because of the long planning cycle involved, and the long life (and high cost) of new generating capacity.

What Is the Structure of Our Current Electricity Generating Capacity?

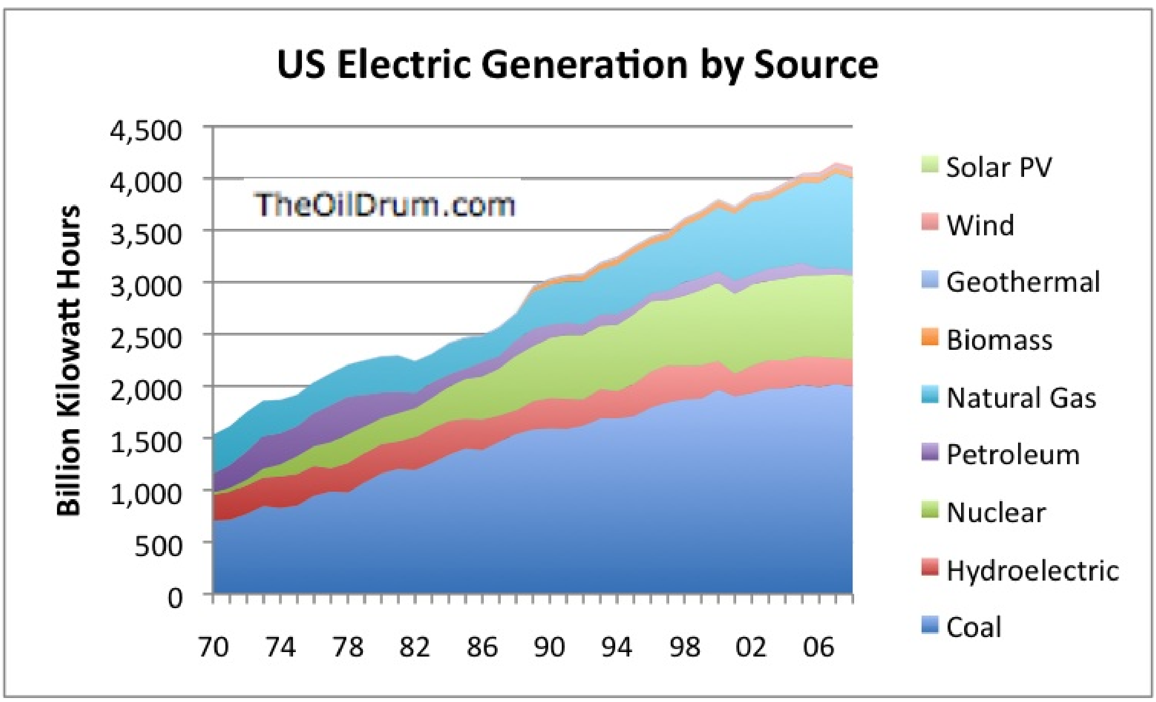
I find it interesting to look at where we are today, in terms of electric generating capacity, electric production, utilization, and cost of new infrastructure (assuming we really can amortize costs over the conventional time frame).

If we look at EIA data, US electric generating capacity has grown as follows since 1996:



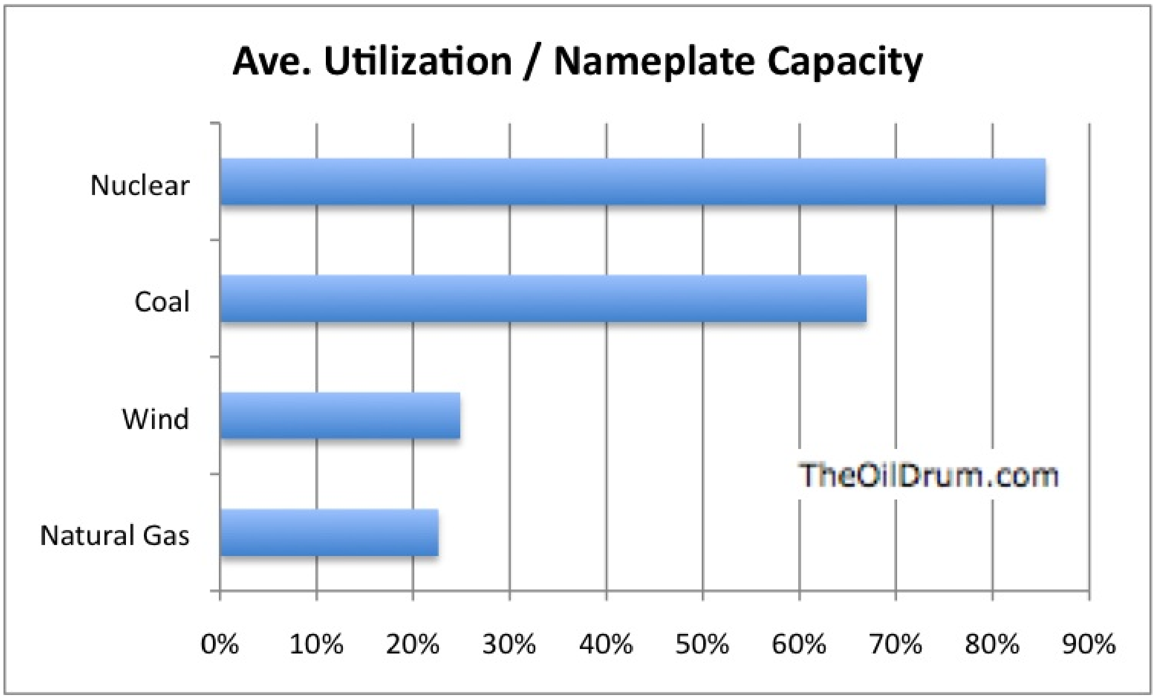
From this graph, one can see that coal, hydroelectric, petroleum, and nuclear generating capacity have remained almost constant since 1996. Natural gas generating capacity is now huge, exceeding even that of coal.

The electricity that is actually produced in the US has grown much differently, as shown in this graph of EIA data:



What has happened is that coal and nuclear generated electric power have increased in recent years, because these plants are now being operated longer hours. Natural gas production has also increased, but not in proportion to the additional capacity added. Wind capacity has been added, but production remains tiny--only 1% of total US electricity produced.

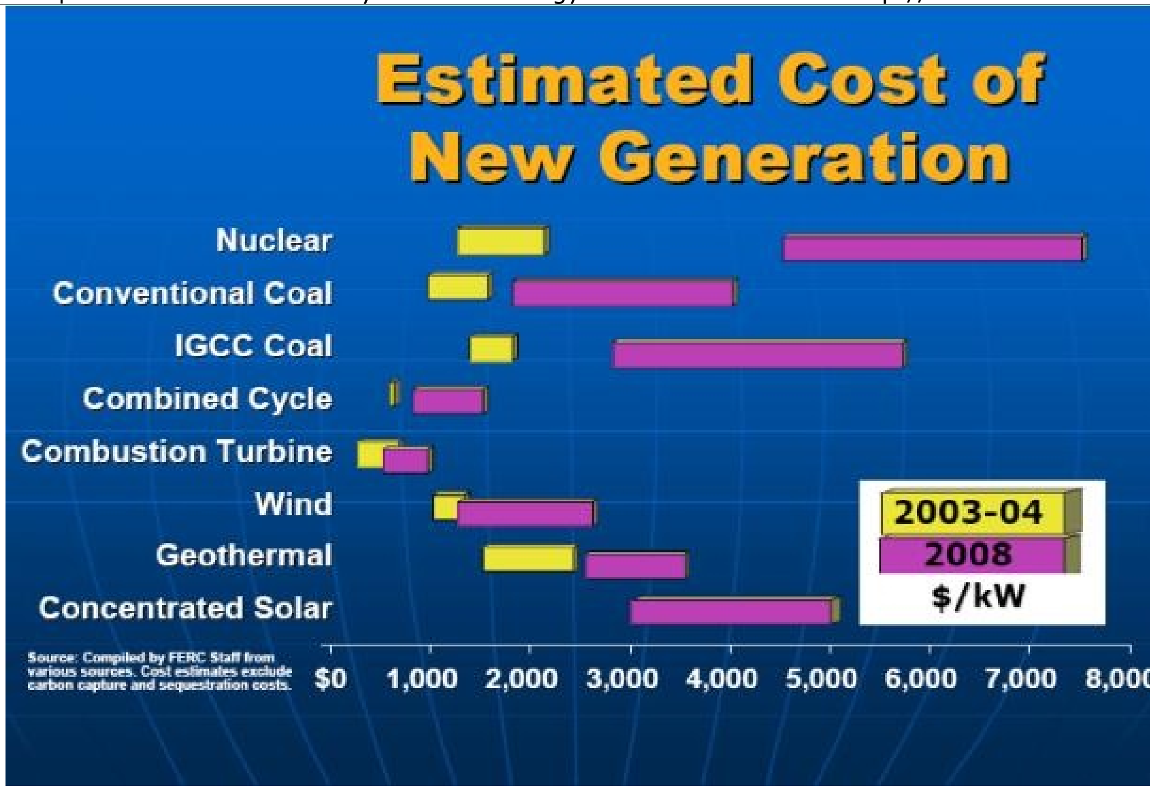
If we compute what percentage of nameplate capacity the various types of generation are operating at, using EIA data, this is what we get:



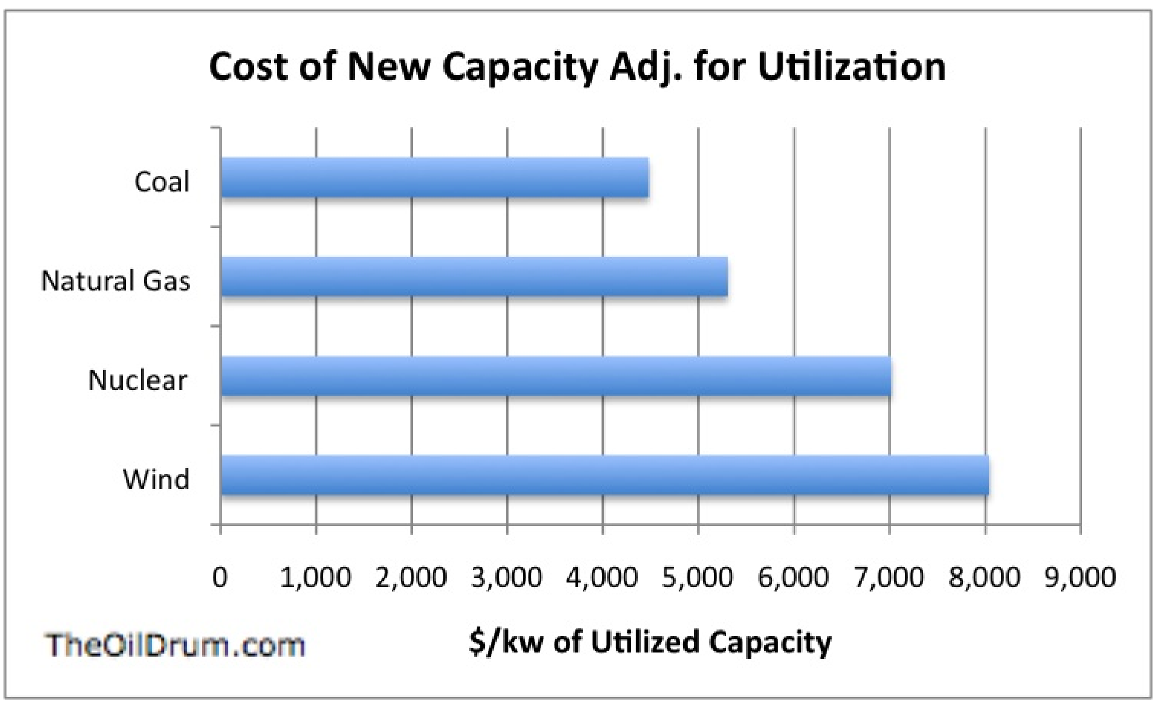
Nuclear operates nearly constantly, except down-time for maintenance. Coal plants operate in the upper 60% range, because many of them ramp down to a lower level at night, when demand is lower, and then back up again during the day time. On average, they are at very close to full capacity, considering down-time for maintenance and the fact that less power is needed at night.

Wind and natural gas operate at much lower percentages, about 25% for wind, and 23% for natural gas. Natural gas operating percentages vary greatly from power plant to power plant, with some operating many hours ("intermediate" or "base load"), and some operating only for occasional "peaking". I am sure many were originally planned to operate more hours than they in fact are operating. Natural gas costs were cheap when most of these plants were planned, but once the cost natural gas rose, the desire to use the plants dropped considerably. Recently, the cost of natural gas has fallen again.

Federal Energy Regulatory Commission (FERC) has published this table of energy costs, for the various types of fuels. This table is for nameplate capacities, rather than actual production.



I made a stab at converting FERC 2008 costs based on nameplate capacity to costs based on actual electricity produced. In doing this, I assumed natural gas used "combined cycle" technology, since it is my understanding that this is what is currently popular. I assumed that coal used conventional coal, since IGCC is quite a bit more expensive, and carbon capture and storage (CCS) (which is the prime selling point of IGCC) and storage to go with IGCC is nowhere near ready. To fully amortize the cost of IGCC plus CCS, it seems like one would need a planning horizon of at least 70 years, because of the time to design and build the CCS.



When one looks at construction costs in terms of actual electricity produced, wind is highest at about $8,000 per kilowatt of capacity (adjusted for utiliztion). Nuclear is second, at $7,000 per kilowatt of capacity (adjusted for utilization). Natural gas is next, and coal is lowest.

The costs I show per kilowatt hour of capacity on the graph above are the costs assuming "normal" amortization. I would think we would need at least a 50 year timing horizon for this--ten years or more for planning and building, plus 30 or 40 years for the operation of the new capacity. Costs will be higher per kilowatt hour if the real time they can be used is shorter.

Combining cost of capacity with existing infrastructure

When I look at these graphs, I scratch my head. We have a huge amount of unused capacity for producing electricity from natural gas. Most of these natural gas plants need to be manned around the clock, whether or not they are actually producing electricity. We currently have natural gas selling for record low prices (at least in recent years). If we need extra electrical production, why not just burn a little natural gas? The capacity is already built, so its additional cost is $0, and even the additional manpower needed is low. If we support our unconventional natural gas producers, natural gas production could probably continue for quite a few more years. At this point, natural gas is out of favor, after being ramped up only a few years ago. We have the infrastructure, but we aren't really using it.

Longer term, it seems like we need to be doing better planning than we did for natural gas. We should be considering questions such as: What is the new mix going to look like, considering our views of sustainability? What other infrastructure (grid upgrades, electrical storage) is needed? How long do we really expect to be able to use it? What is the cost likely to be? Can we really afford it? Are there better uses for our capital, considering where society is likely to be 100 years from now?