US Electricity Supply Vulnerabilities

Posted by Gail the Actuary on December 6, 2007 - 11:05am
Topic: Miscellaneous
Tags: coal, electricity, natural gas, nuclear energy, uranium [list all tags]

We on The Oil Drum spend so much time worrying about oil supply that we tend to think that electrical supply is relatively safe in comparison. If we stop to think about the issues, I think that we will find that the electrical situation is not much better than the oil situation. The likelihood of widespread electrical outages in next five to ten years is uncomfortably high.

We may already be starting to see some beginning examples of electrical shortages, such as this recent story regarding Maine. Residents were being asked to conserve electricity because of a natural gas shortage related to supply disruption and cold weather. Maine has a relatively tight electrical supply and heavy dependence on natural gas, so it is at high risk for this type of disruption. I expect to see more outages like this in the coming months and years, especially in high-risk areas.

In this post, we will look at some areas of vulnerability for the US electrical supply. While this analysis is restricted to the United States, some of the issues discussed may also be relevant to other countries.

(More beneath the fold)

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1. Inadequate natural gas supplies

We don't have as good projections regarding future natural gas supplies as oil supplies, but it is pretty clear that the US is headed for a decline in available natural gas. Our current production is flat, and we are dependent on imports and liquefied natural gas (LNG) to meet our needs:

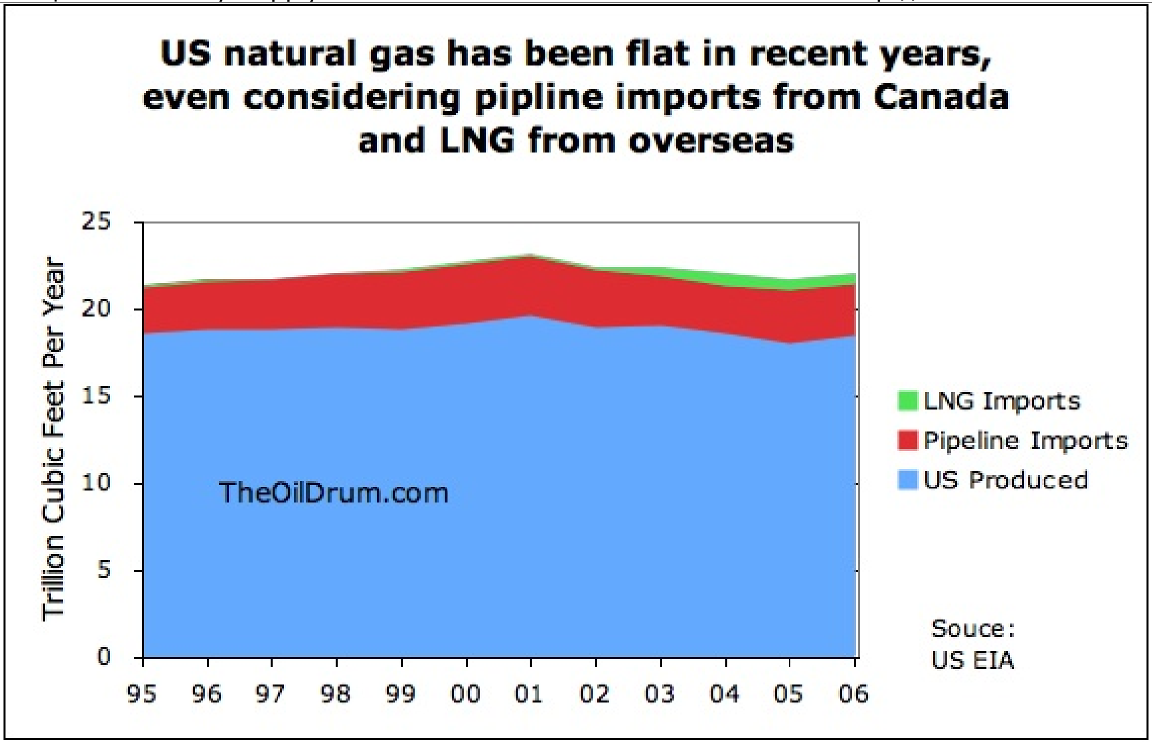

Figure 1

We keep having to drill more and more, to keep our current production flat:

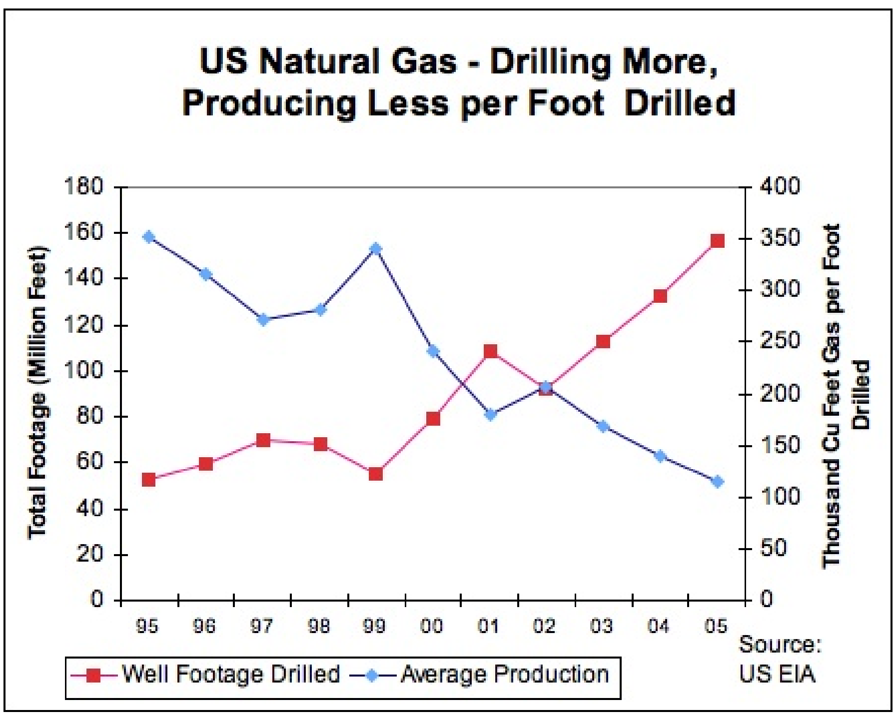

Figure 2

The question becomes one of how much drilling we can do for natural gas, before costs exceed the value of the natural gas produced. Heading Out wrote [a post](#) recently pointing out that gas production from the Barnett Shale does not seem to be economic at today's prices. Is there some analysis we at TOD can do, perhaps using the natural gas per foot drilled figures from Figure 2, to put a limit on how much drilling it makes sense for natural gas? The real question comes down to energy return -- at what point are we spending too much energy to make the effort worthwhile.

Imports do not seem to be a solution either. Canada recently announced that its natural gas exports are expected to decline because of reduced drilling and decline issues.

Some people hope that LNG imports will be a solution. This seems unlikely. LNG production is not expanding rapidly enough to provide the quantity we would require. In addition, a huge amount of new infrastructure would be required, which has not been built.

The states most vulnerable to natural gas shortages are heavy users of natural gas, especially those at the end of supply lines. Some states meeting this description are Arkansas, California, Massachusetts, Maine, Nevada, and Rhode Island. (See Figure 7 at the end of the post for state natural gas percentages.)

2. Temporary disruption of fuel supplies, particularly natural gas supply.

This is closely related to inadequate supply. The tighter the supply, the more important a small outage in natural gas supplies becomes. Short unplanned maintenance in a field, or a pipeline problem, can be enough of a disruption to cause a problem, if supplies are very tight. On the coal side, closure of a major railroad can disrupt coal supplies to a number of power plants simultaneously.

3. Inadequate nuclear fuel.

The majority of uranium used to run U. S. nuclear reactors is imported:

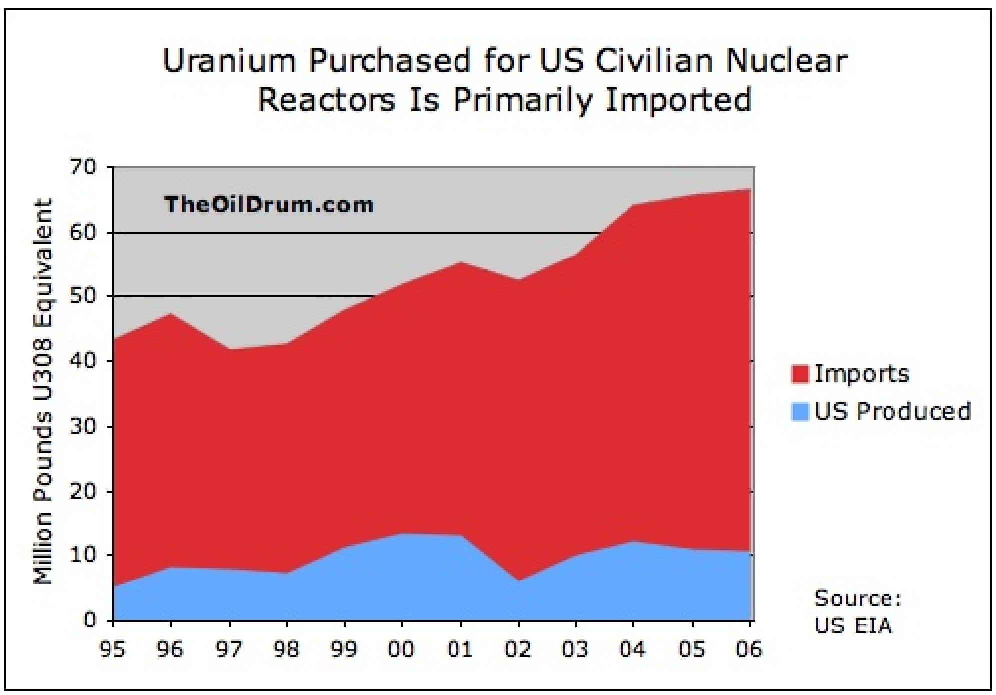

Figure 3

There is a considerable amount of controversy regarding whether there will be a gap in the available fuel for nuclear reactors in the next few years.

According to Sanders Research Associates, a major source of imports is fuel created from dismantled Russian nuclear weapons. EIA data shows that in 2006, about 23% of US total nuclear fuel needs was from Russia. According to Sanders, our agreement for importing this material will end in 2013, and it is unlikely to be renewed. Other countries are also using dismantled Russian nuclear weapons as a source of fuel, so there could be an impact on competition for imports as will as a direct impact on supply.

According to the World Nuclear Organization (WNO), uranium production in recent years has been relatively flat, while world demand is much higher. WNO indicates current uranium production amounts to only 61% of world demand.

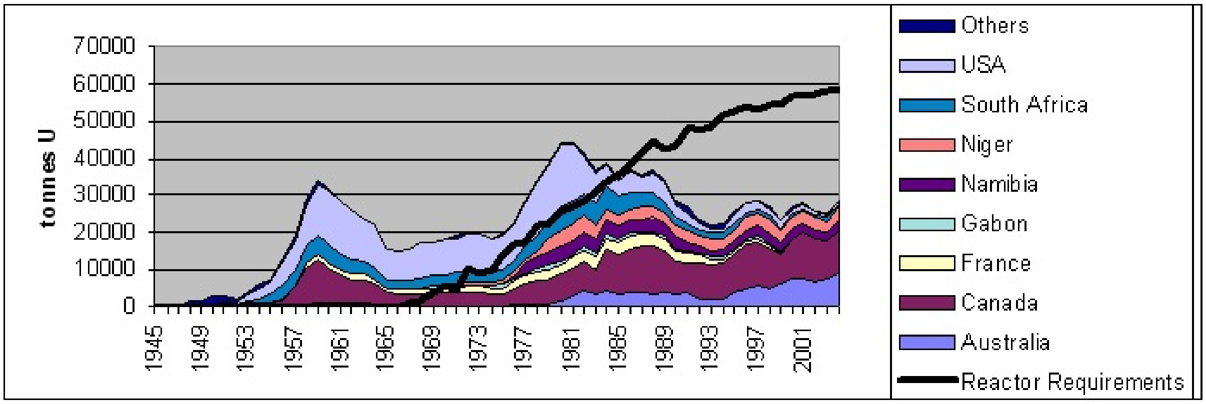

Figure 4

Demand for uranium is likely to continue to grow in the future, because there are many plants planned or under construction in Asia (18 reactors under construction, and 112 planned or proposed, according to the WNO).

Most people believe that there are ways of working around the likely shortfall in supply. Some options include recycling US nuclear weapons; recycling used nuclear fuel; building new mines in places where there is lower-grade ore; and adapting nuclear power plants to use another input, such as thorium. The question as I see it is whether enough will be done in a short enough time frame to avoid having to close reactors for lack of fuel. A solution that will work in 2020 will not be of much help in 2010 or 2015.

The EIA Uranium Marketing Annual Report shows the following schedule of contracts for future supply for the United States:

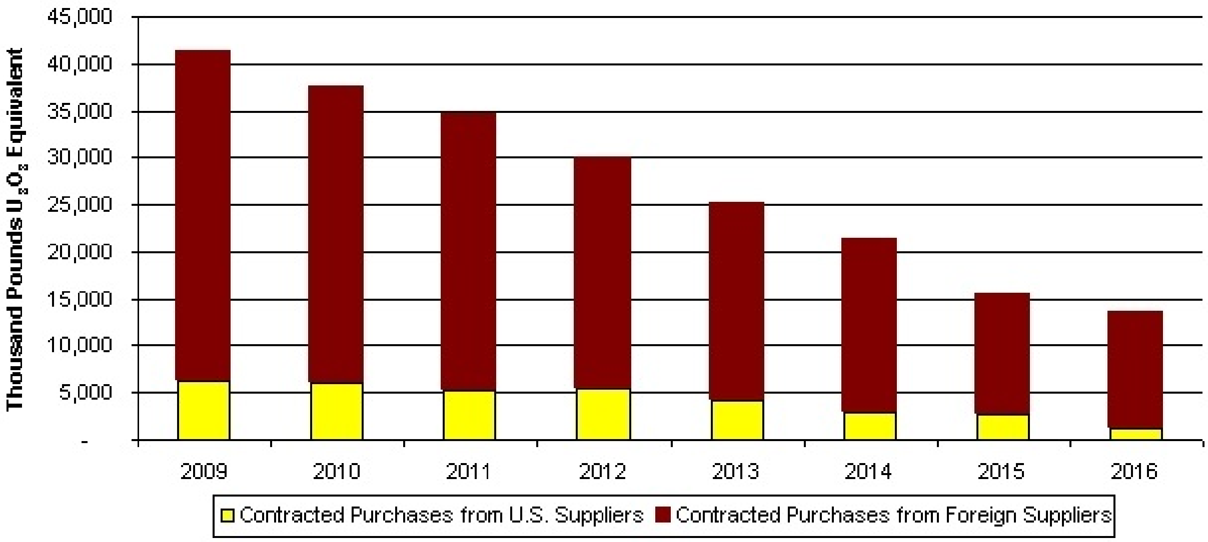

Figure 5

Since uranium use in 2006 totaled 66.5 million pounds of U3O8 equivalent, and future contracted amounts are much lower than this, there is a gap that will need to be filled, in some way. If not, some plants may have to be taken off line.

The states with the highest percentages of electricity from nuclear power are Vermont, New Jersey, South Carolina, Illinois, and Connecticut. (See Figure 7 at the end of this post for the distribution of fuels used in each state). Other states using nuclear power might also be subject to electricity shortages, if their nuclear reactors are not able to obtain fuel.

4. Power plants temporarily off line, or decommissioned, for reasons other than fuel shortages

Of the various types of power plants that can be taken off-line, the ones that are biggest and likeliest to have the most impact are nuclear plants. Nuclear plants generate so much power that having one of them off line, even for a short time, is likely to be a problem. There are any number of reasons for nuclear plant outages, including

- Maintenance, planned or unplanned
- Earthquake
- Water supply problem - not enough, or output too hot for river
- Terrorist attack
- Permanent decommissioning

With our nuclear plants now quite old, the number of maintenance issues is likely to be higher, and thus the number of unplanned outages greater.

With respect to non-nuclear plants, one threat I see is that water shortages may take a group of plants (of various types) off-line simultaneously. This kind of risk has the highest probability where there are water shortages, such as the Southwest and more recently, Atlanta. Hydroelectric plants (generally located more in the North) are particularly susceptible to problems in times of drought.

5. Deregulation of Electric Utilities

Deregulation is often cited as a reason for increased power outages. In states with deregulation, the newly regulated industry has little incentive to build new power plants, to prevent the occasional black-out. Matt Simmons has been quoted as saying that deregulation has made Maine more vulnerable to blackouts than it would otherwise be "because the private sector will not finance a plant to supply peak energy for the 'rare' cold snap".

What tends to happen in deregulated states is that as the need for power grows, inadequate new capacity is added, leaving the state with less power than it really needs when demand is high. The states which have been de-regulated are mostly in the North-East. This is a link to an EIA map showing states' current status.

6. Inadequate base production capacity.

Traditionally, coal and nuclear power have been used to provide "base power"-- that is, a constant level of power that is sufficient for normal demand levels, but that needs to be supplemented with "peaking power" (usually natural gas or hydroelectric) at times when electrical needs are higher. Since the Clean Air Act was passed in 1990, there has been considerable opposition to building new coal fired power plants. As a result, few new coal plants have been built, even in regulated states. There has also been opposition to nuclear plants, so none have been added.

With virtually no coal or nuclear capacity being added, base production capacity has drifted downward relative to demand, making utilities more dependent on peaking capacity. The "solution" has been to add many natural gas plants since 1990. Natural gas power plants are attractive to utilities, because

- They are less polluting than coal, both with respect to CO_2 and other pollutants
- The plants are relatively cheap and quick to build
- The EIA still forecasts relatively plentiful supplies

Going forward, it is not entirely clear what will happen to fix the current deficiency in base capacity and to compensate for old plants which will need to be retired. The EIA forecasts that many coal plants will be built in the future. The National Coal Council (NCC) (similar to the National Petroleum Council, but for coal) recommends that the country build a large number of coal plants, and try to sequester the CO_2 (even though it is not clear that this can be done on any significant scale).

I suspect that despite these projections/recommendations, there is a significant chance that very little in the way of base electrical power plants will be built in the next few years. People will continue to object to coal and nuclear. It will become clear that natural gas is not really an option, either, because of supply issues. Electric utilities will try to add renewables such as wood chip burning plants and geothermal as base production, but will be difficult to scale these up to the needed level. (Solar and wind are not suitable as base capacity.) According to EIA data, renewables other than hydroelectric generated only 2% of total electric supply in 2006, so the starting base is very low.

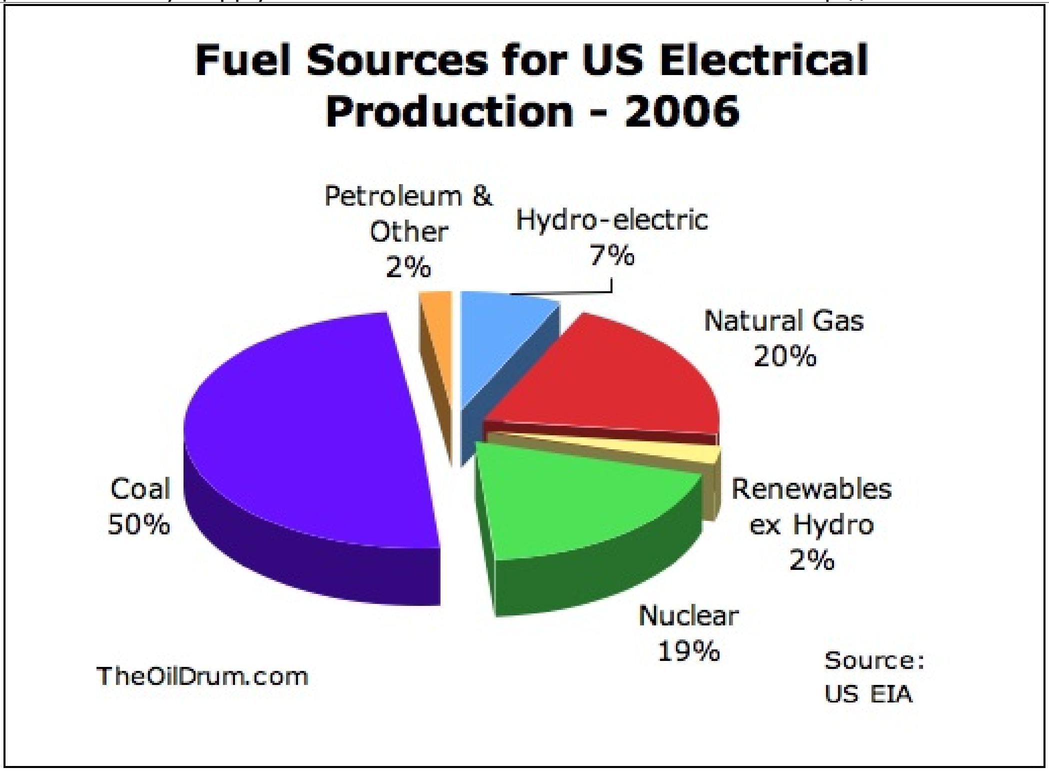

Figure 6

Because of these issues, it seems likely to me that base capacity is likely to continue to erode, making utilities more and more vulnerable to power outages.

7. Workforce close to retirement age.

A recent article in EnergyBizOnlline says:

> Workforce levels in the electric utility industry have dropped more than 20 percent since 1990, while power generation has increased by more than 30 percent. A little less than half of the industry's roughly 400,000 workers are eligible for retirement in the next five to 10 years, without nearly enough recruits to take their place.

It sounds like the workforce problems we have seen in the oil and gas industry also apply to the electric industry.

8. Inadequate maintenance of the grid.

The grid is now in serious need of maintenance and upgrading, made worse by deregulation. Attendees at a recent "Grid" conference were asked to judge the likelihood of a major power outage in the next five years, using a scale of 1 to 10, with 10 being "most likely." The average of the responses was an 8.

The same article quoted in Point 7 above had this to say about the grid:

> The average age of power transformers in service is 40 years, which also happens to be

> the average lifespan of this equipment. Combine the crying need for maintenance with a shrinking workforce, and we may find that the 2005 blackout that affected parts of Canada and the northeastern United States might have been a dress rehearsal for what's to come. Deregulation and restructuring of the industry created downward pressure on recruitment, training and maintenance, and the bill is now coming due.

There is discussion of moving from an analog to a digital grid with new transformers and new meters capable of two-way communication. All of this will be very expensive, and require a lot of manpower. With all of the pressures on the electricity industry, I am skeptical that the resources will be found to make this needed upgrade.

9. Spillover impact of oil shortages.

Suppose oil shortages affect the world first. How long will it be before the electric utilities are affected? I suspect not very long, due to Liebig's Law of the Minimum. If any necessary item needed for production is missing, production will stop.

If there are shortages of gasoline, workers may not be able to get to work. If there are shortages of diesel, needed parts may not be delivered, and needed maintenance of the grid may not be performed.

If there are financial impacts from oil shortages, these will affect utilities, just like everyone else. They will find it harder to raise rates to fiance all of the new infrastructure that is needed. They may even find it difficult to pay their workers.

In a few places like Hawaii, there may be direct impacts on electrical production from a drop in oil production. Figure 7 below indicates that 78% of Hawaii's fuel for electricity in 2006 was petroleum.

When we put the strain of peak oil on electric utilities together with the other strains on electric utilities, I expect our electrical system will degrade significantly. I expect that we will begin to see fairly frequent and widespread electrical power outages, if these have not already begun because of issues such as natural gas or uranium shortages. I expect that the electrical supply that continues will be less reliable, and less able to handle peak demands. In some parts of the country, electric service may only be available for a few hours a day. With this limited electrical supply, I question whether grid-tied solutions to our oil problems, such as plug-in electric vehicles, will be feasible for very long.

SUPPLEMENTARY MATERIAL

I put together a table of electrical production by fuel source by state using EIA data:

2006 Net Power Generation by Type as Percentage of State Total

State	Coal	Natural Gas	Nuclear	Hydro Conventional	Non-Hydro Renewable	Petroleum	Other
AK	9%	61%	0%	18%	0%	12%	0%
AL	55%	14%	23%	5%	3%	0%	0%
AR	46%	18%	29%	3%	3%	0%	0%
AZ	39%	31%	23%	7%	0%	0%	0%
CA	1%	49%	15%	22%	11%	1%	1%
CO	72%	23%	0%	4%	2%	0%	0%
CT	12%	30%	48%	2%	2%	4%	2%
DC	0%	0%	0%	0%	0%	100%	0%
DE	69%	16%	0%	0%	0%	2%	13%
FL	29%	43%	14%	0%	2%	10%	1%
GA	63%	9%	23%	2%	2%	1%	0%
HI	13%	0%	0%	1%	5%	78%	2%
IA	76%	5%	11%	2%	5%	0%	0%
ID	1%	10%	0%	84%	5%	0%	1%
IL	48%	3%	49%	0%	0%	0%	0%
IN	95%	2%	0%	0%	0%	0%	3%
KS	73%	4%	21%	0%	2%	0%	0%
KY	92%	1%	0%	3%	0%	3%	0%
LA	27%	45%	18%	1%	3%	2%	4%
MA	24%	51%	13%	3%	3%	5%	0%
MD	60%	4%	28%	4%	1%	1%	1%
ME	2%	43%	0%	25%	24%	3%	2%
MI	60%	10%	26%	1%	2%	0%	0%
MN	62%	5%	25%	1%	6%	1%	1%
MO	84%	4%	11%	0%	0%	0%	0%
MS	39%	34%	23%	0%	3%	1%	0%
MT	60%	0%	0%	36%	2%	1%	0%
NC	60%	3%	32%	3%	1%	0%	0%
ND	94%	0%	0%	5%	1%	0%	0%
NE	65%	2%	28%	3%	1%	0%	0%
NH	18%	27%	43%	7%	3%	2%	0%
NJ	18%	26%	54%	0%	2%	0%	1%
NM	80%	16%	0%	1%	3%	0%	0%
NV	23%	66%	0%	6%	4%	0%	0%
NY	15%	30%	30%	19%	2%	5%	0%
OH	86%	2%	11%	0%	0%	1%	0%
OK	50%	47%	0%	1%	3%	0%	0%
OR	4%	21%	0%	71%	4%	0%	0%
PA	56%	6%	34%	1%	1%	1%	0%
RI	0%	97%	0%	0%	2%	1%	0%
SC	40%	6%	51%	2%	2%	0%	-1%
SD	46%	4%	0%	48%	2%	0%	0%
TN	65%	1%	26%	8%	1%	0%	-1%
TX	37%	49%	10%	0%	2%	0%	2%
UT	89%	8%	0%	2%	0%	0%	0%
VA	47%	10%	38%	2%	3%	1%	-1%
VT	0%	0%	72%	21%	6%	0%	0%
WA	6%	7%	9%	76%	2%	0%	0%
WI	65%	9%	20%	3%	2%	1%	0%
WV	98%	0%	0%	2%	0%	0%	0%
WY	94%	1%	0%	2%	2%	0%	1%
US Total	49%	20%	19%	7%	2%	2%	1%

Prepared from "State Historical Tables for 2006" "Net Generation by State by Type" from EIA (10/26/2007)

Figure 7

Figure 7 data can be downloaded from this page An Excel version of the exhibit and summary data can be found here.

The non-hydro renewables includes a wide range of renewables, including waste wood used as fuel for electrical power plants and geothermal. I believe the non-hydro renewables for Maine are high as a percentage of the total because of waste wood; California non-hydro renewables are high because of geothermal. Negatives in the "Other" column are OK - they reflect geo-thermal pumped storage, which is a negative reflecting the energy lost in the process.

Additional Supplementary Material

1 . Analysis of California's 2000-2001 electrical problems by the World Nuclear Organization.

2. Coal: America's Energy Future published by the National Coal Council in 2006. The report talks about declines in oil and natural gas, and the need to use coal for many purposes: electric generation; coal-to-liquid; and coal-to-gas.

3. EnergyBiz Magazine. Many interesting articles about electric industry. Online version seems to be free.

4. Carnegie Mellon Industry Center Research papers on electricity issues.