Replacing nuclear with wind power: Could it be done?

Posted on May 10, 2012 | 9 Comments

by Ulrich Decher

Many people would like it to be theoretically possible to replace nuclear power with wind power, since the wind is a free resource. The way that I would like to approach the topic is to not discuss the *source* of power, but to discuss this question from the perspective of "intermittency." Stating the question another way: Can an intermittent source replace a baseload power source for producing electricity? This question has nothing to do with *how* the electricity is generated, but everything to do with *when* the electricity is generated.

The production of electricity involves understanding concepts such as *capacity*, *capacity factor*, and *generation*. These three concepts are often misunderstood and misused when comparing the generation of intermittent electricity with baseload generated electricity. It is sometimes useful to use a familiar analogy when explaining complicated topics. I will, therefore, use the automobile for this analogy, since many of us own a car and everyone is familiar with them.

Capacity

Here is the analogy: Suppose there is a car on the market that is very environmentally friendly. Its mileage is phenomenal! I call it a "super-green" car.

This super-green car has the same horsepower as a conventional car. It will handle steep hills as well as a conventional car. It has the same 0 to 60 mph performance. The only difference is that when you try to start it in the morning, it will only start 25 percent of the time, and you can never predict on which day it will start. It runs, randomly, 25 percent of the time.

Would you replace your conventional car with a super-green car to get you to work every day? To keep the analogy simple, let us assume that *if* the car starts on a particular day, it will also take you home at the end of the workday. If it doesn't start on a particular day, however, it won't start that day no matter how often you turn the starter key.

To most people, the answer is obvious. Most of us would not hold on to a job very long if we randomly showed up at work only 25 percent of the time. So the answer is no, the super-green car cannot replace the conventional car. Horsepower is the equivalent of capacity in this analogy. An *intermittent* electrical power source with a capacity (or power capability when it is working) to generate 1000MW cannot replace a conventional power plant with a capacity of 1000MW. Even though the capacities are the same, the power plants are not equivalent. Yet capacity comparisons are made all the time, as if this somehow makes the power plants equivalent. They are not equivalent.

Capacity factor

Others would say that since the *capacity factor* is 25 percent (the car works 25 percent of the time), you would just need four cars to reliably get you to work every day. This is also not true, however. There is a chance that *none* of the cars will work on a particular day. As a matter of fact, this probability can be computed, if the probability of each car not working is independent of the other cars not working. It is 0.75 x 0.75 x 0.75 x 0.75 or (0.75)^4, which is equal to 32 percent. So if you owned four super-green cars, the probability of *none* of them working on a particular day is 32 percent. So, with four super-green cars, you get to work 68 percent of the time, which is better than 25 percent of the time, but it is still a long way from 100 percent of the time.

Another problem with using capacity factor as an equalizing parameter is that there are times when *more* than one car will start. The extra cars, however, are of no value to you as far as getting to work is concerned. The extra working cars do not average out with the demand to get to work on time each day. They are working at the wrong time.

Note that in the case of a wind farm, the probability of each turbine not working is not independent. If the wind doesn't blow in a particular area, it will affect all wind turbines. The probabilities are not randomly independent. Therefore, wind farms must be in separate weather patterns, in order to significantly reduce the unavailable time.

Generation

A better equalizing parameter is *generation*. When the super-green car works, it generates highly economical miles. That parameter has its problems as well, however. The generation of economical miles can be increased simply by taking the long route to work. Those extra economical miles are of no value as far as getting to work is concerned. In the same way, generated electricity has no value unless there is a demand for it at the time that it is generated. This is because electricity has zero shelf-life. It must be consumed when it is generated.

So, when generation cost comparisons are made between intermittent and baseload power sources, this presumes that the resulting electricity value is the same. This is actually not the case, because electricity generated when the demand for it is not certain does not have the same value as electricity that is generated when there is demand for it.

There is no perfect equalization parameter when making comparisons between intermittent and baseload generated electricity. Capacity is by far the worst, next comes capacity factor, and the best is generation, but it is not perfect.

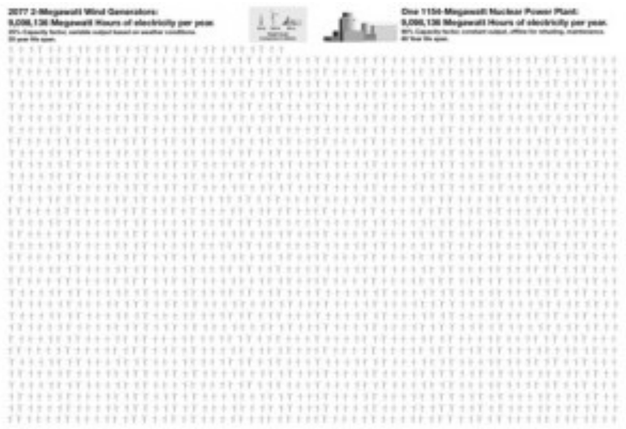
Conclusion

So, the conclusion is that intermittently generated electricity cannot replace baseload generation. Just like there is a chance that none of the super-green cars are working on a particular day, there is also a chance that no electricity is generated by an intermittent source. Hence, all the conventional power sources are still needed.

Intermittent power sources can be of value, however, because they do save fuel in conventional power plants. But the economics are usually not very good at today's fuel prices. In the car analogy, I compute that my 20-mile round-trip commute to work would save me about two gallons of gas a month if the super-green car gets double the mileage of my conventional car. At $4 per gallon, that is $8 per month saving. It is obvious that, from an economic point of view, this saving is nowhere near the hundreds of dollars required per month to own an extra car. Similarly, I wrote an article explaining that wind farms cannot be justified on an economic basis, except in Hawaii, where expensive oil is used to generate electricity.

But perhaps using intermittent power plants can be justified environmentally. Perhaps not burning fossil fuels is worth the environmental benefit of not releasing as much greenhouse gases. Also, the fossil resource can be saved for other uses such as plastics. That argument breaks down, however, when the baseload generator is nuclear. Nuclear power does not generate greenhouse gases during operation. Saving the uranium for other uses is not applicable, because uranium has no other commercial uses. What exactly would we be saving it for?

So, to answer the general question, can wind power replace nuclear? The answer is clearly no. No technology is perfect, and there is always some impact in everything we do. Nuclear has the capability to meet the electrical needs for humanity for a millennia. That is a very compelling reason to use it, versus using a technology that only works intermittently and requires keeping all the conventional generators that we already have.



Click to go to wind to nuclear info-graphic article by Jason Correia

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9 RESPONSES TO REPLACING NUCLEAR WITH WIND POWER: COULD IT BE DONE?

Steven B. Krivit | May 10, 2012 at 11:56 | Reply

Brilliantly clear. This is the type of communication this industry needs.

Anna Garden | May 10, 2012 at 15:13 | Reply

Thanks!

Jim Bowlby | May 10, 2012 at 20:54 | Reply

A great way to explain the difference between intermittent and base load generation. Back to the super-green cars and to carry the analogy a little further, the obvious answer to a car that only starts 25% of the time is to have a back-up gasoline powered car. It may not be economical but it is reliable.

David Walters | May 11, 2012 at 15:13 | Reply

I think this is an excellent introduction to the concept of baseload and intermittentcy and capacity/capacity-factor.

To throw another electrical industry term out there, more a grid operations term, "capacity" is not quite that relevant. The Independent System Operators/Grid Operator and various "Power Control" depts of utilities are far more concerned with "availability". This is the term we use when actually planning production for the day, week, year. Availability. As in "on demand, I want this instant, give it to us". As in "Plant Number 1, ARE you available for full today?".

Capacity and capacity factors are for planners, long term planners dealing with load growth (or shrinkage). And of course, the term 'capacity' being almost totally irrelevant when applied to unreliables while completely relevant to baseload plants like gas, coal, hydro and nuclear.

There is a generalized anti-science attack on the concept of "base load" itself, some arguing 'we don't need it', just lots of renewables.

It’s actually possible, depending on how one defines baseload, that most MWhrs are actually NOT baseload. If baseload is the *minimum* 24/7 load on the system then everything above that minimum is not baseload. In the city of San Francisco, our night time base load is less than 100MWs. Quite often it is down to 40MWs. But our average intermediate load is around 400MWs. Peaks average higher, around 600MWs. If you look at the mouse curve of the load in SF, you will see that baseload is a minority of the total load of the day. So what?

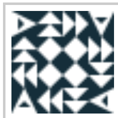
Well, it means that the real question isn’t baseload vs intermittent, but ‘on demand’, can power be generated when it’s needed. That is what this whole discussion is really about, “availability” again, to use ISO-speak.

At the end of the day, if you overbuild with wind and *some solar* (the latter being a nice boutique affectation of the rich and famous) you can replace *a lot* of baseload, that is, on demand units. But can you rely on this scheme? I don’t believe so. There will always be some need for some on demand power, from fossil, nuclear or some sort of storage.

I used ‘rich and famous’ because it’s clear to me that some rich and famous countries don’t mind paying say, 45 cents for a kwhr to subsidize this belief system. They don’t mind over building their land and sea based wind, massive quantities of roof-based PV. So they can ‘effect’ baseload by throwing money at it, but they can’t replace the on-demand characteristics of it.

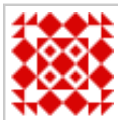
David Walters

Bill Eaton | May 12, 2012 at 09:07 | Reply



Good topic, and great explanation.
Unfortunately, the people most likely to read past the first technical term are those of us who already know the answers. And, the young and curious. The key audience venue is the classroom.
As a side bar comment, I was driving home from a plant visit yesterday on I-44 and passed by a renewable energy demonstration project set up in front of a state police headquarters facility. I drove past the small scale site at dusk, and the wind turbine was not rotating. I wish we could scrub renewable out of our lexicon and replace the term with occasional or lucky.

Nathan Wilson | May 12, 2012 at 22:10 | Reply



Good explanation of renewables vs. baseload. But it is also important to understand the role of load following plants.

The total demand on a typical electrical grid varies by a factor of about two from minimum (spring nights) to maximum (summer evenings). So only about 60 or 70% of the total average power can come from baseload plants (those like light water reactors and geothermal, which become un-economical at part load). The rest comes from load-following plants (i.e. peaking and intermediate load), typically natural gas or hydro powered.

With cost-effective load following, studies by the DOE National Renewable Energy lab (NREL) have shown that variable renewables can contribute 20% or a more of the total electrical demand. In such scenarios, the dispatchable power plants are forced operate at lower average capacity factor, which is to say, there is no more baseload. The result is that no new nuclear power plants would be built, and we would be locked into 60+% fossil-fuel mix thereafter.

Today, wind and solar contribute about 3% of US electric supply, and are growing rapidly. This poses a serious threat to the light water reactor's future in the US.

Several of the Gen IV reactors are more suitable for use in a renewable-rich environment. Fast reactors such as the IFR as well as liquid fuel reactors like LFTR allow rapid load-following because xenon transients are not as severe as with LWRs. The IFR, LFTR, and PBMR operate at high enough temperatures to use solar salt for thermal energy storage, which would make operation at low capacity factor more economical (solar salt is an order of magnitude cheaper than batteries).

Load following and thermal storage will increase the cost of electricity from nuclear power plants. But with enough renewables on the grid, these features may become mandatory for any new nuclear plant.

Ed Knuckles | May 13, 2012 at 11:08 | Reply

The statement that "generated electricity has no value unless there is a demand for it at the time that it is generated … It must be consumed when it is generated " ignores the possibility of energy storage. While I also don't believe that wind can replace nuclear today and that energy storage is not economical with today's technology and existing fuel prices, ignoring energy storage and the interconnected electrical grid shouldn't be left out of the debate because such possibilities are within the realm of your articles subtitle "can it be done."

Ulrich Decher | May 13, 2012 at 16:52 | Reply

All are good comments. My article is really about intermittent vs dispatchable generation of electricity. I probably should have used "dispatchable" rather than "baseload". Baseload is just one type of dispatchable power. Dispatchable generation can turn on when needed. Intermittent generation may not be able to turn on when needed.

As for storage, it is also a good point. The problem with storage is that amount of storage necessary for signficant impact is huge. The only technology that I know about that can have a significant impact is pumped hydro storage. It is a technology that is being used today. Unfortunately, there are few sites available for pumped storage development.

Arcs_n_Sparks | May 13, 2012 at 20:42 | Reply

Great article. I note: "…since the wind is a free resource" is mentioned. This is also usually done in the solar context. I would point out that all energy resources are "free" in the sense that our Creator has provided them. The cost of these resources is extraction and utilization. Fossil fuels, nuclear power, hydro, wind, and solar each have extraction and utilization costs. Nothing is "free." Merely pointing out that the wind is blowing or the sun is shining does not put electrons at my wall outlet.
