Jesse Jenkins

Can Nuclear Power and Renewable Energy Learn to Get Along?

Posted April 15, 2014

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Nuclear power and variable renewable energy sources like wind and solar power "don't play well together."

That's a commonly accepted nugget of wisdom these days. I heard the argument most recently during an interesting colloquy on Twitter this week with Fresh Energy CEO Michael Noble, reporter Matthias Krause, and author and editor of Renewables International Craig Morris.

If true, the idea that renewables and nuclear don't mix has important implications. It would mean that if we want to build an ultra-low carbon electricity system to confront climate change, we may face two *mutually exclusive* paths: one path dominated by nuclear energy (call it the French paradigm) and the other dominated by variable renewables (call it the German paradigm).

(In fact, supporters of the German *Energiewende* use this argument that large penetrations of renewables are incompatible with nuclear as one of the justifications for the nuclear phase-out underway there now).

The more I think about this, however, the more I'm convinced that the accepted wisdom that renewables and nuclear mix like oil and water is true only up to a point.

In fact, if we want to build an ultra-low carbon system powered by variable renewables, we're going to have to solve precisely the same technical challenges that will make a hybrid renewables and nuclear power system possible as well.

My thinking is as follows, and I present this as a hypothesis for discussion and with plans to analyze this in more detail in the future (i.e. using power systems modeling)…

I begin with this basic point: In rough terms, once a variable source of renewable energy, such as wind or solar power, reaches an energy penetration level (measured as the share of total energy supply) equal to that source's average capacity factor, aggregate output from that variable renewable energy source will routinely fluctuate between 0 and 100 percent of total electricity demand.

For example, if the average capacity factor of solar photovoltaics is 10 percent (about what it is in Germany), once solar PV reaches about 10 percent of the system-wide energy mix, solar output will vary from 100 percent of demand when producing at full capacity on a bright mid-summers day and 0 percent when night falls. Wind turbines in the breezy American Midwest have a capacity factor closer to 35-45 percent, so wind would reach a ceiling at about 40 percent of energy share in that region.

There are two important implications of reaching this point where a renewable energy source's share equals its capacity factor.

First, without energy storage, high penetrations of renewables don't leave much room in the power system for nuclear power plants (or any other "baseload" power plant).

While nuclear reactors *can* technically "ramp" or vary output up and down to follow loads (albeit less flexibly than gas turbines), "cycling" or shutting down entirely and start up again later is too challenging for a nuclear plant to do routinely. Yet at high penetrations of variable renewables, every other plant on the system would have to be capable of routinely cycling on and off.

- **Summary: it's true then that *absent energy storage and flexibility*, high penetrations of variable renewable energy sources doesn't play well with nuclear.**

Second, increasing the penetration of renewables beyond the point where energy share equals capacity factor would mean the renewable source would begin to regularly produce more electricity than demanded. Without storage or energy sinks willing to buy up excess power, renewable generators would then have to curtail a growing share of their output and waste any associated revenues.

In practice, this ceiling could actually be reached before renewable energy penetration equals capacity factor, as production would begin to regularly exceed demand on high output/low demand days long before this point.

In addition, if renewables are exposed to wholesale prices (and not subsidized outside the wholesale market, i.e. with feed-in tariffs), the market prices earned by renewables would be negatively correlated with their output. Wholesale prices are lowest precisely when renewable generators are all cranking out power (again, this assumes no energy storage/sinks.) At some point, adding more renewables just wouldn't be profitable any more. If renewables have to pay for the system balancing services and flexibility needs they contribute to, this economic limit is reached even earlier.

This point where *energy share = capacity factor* is probably a generous ceiling for renewable energy penetration absent storage then.

If solar capacity factors typically range from 10-20 percent and wind from 25-45 percent, that makes it awfully hard to reach an ultra low carbon energy system powered principally by renewables. Once these sources reach a combined share of maybe 30-40 percent of the energy mix, technical and economic constraints will make it very hard to increase their share further.

- **Summary: *absent energy storage and sinks* that can make profitable use of excess energy *and massive system flexibility* to handle variations in renewable output from 0 to 100 percent of load, penetration of variable renewables is effectively constrained below the point where their energy share equals their capacity factor.**

If we want to increase renewable penetration beyond these levels and drive truly deep decarbonization of the power system, we therefore need massive amounts of new system flexibility to match demand with varying renewable energy output.

We'd need electric batteries and thermal energy storage to shift output to when its needed, dynamic load shifting and demand response to align demand with output, and 'energy sinks' to make productive use of excess output.

But here's the kicker: if we have the massive amounts of storage and flexibility needed to achieve an ultra-low carbon electricity system dominated by variable renewables, we *also* have the storage and flexibility needed to make a hybrid nuclear-renewable power system feasible as well.

With that kind of system flexibility, we could store energy and shift loads to avoid having to cycle off and on nuclear plants and limit their ramping only to when it's the most economical way to provide system flexibility.

- **Here's my contention then: If you want an ultra-low carbon renewable energy system, you *need* storage and flexibility. And if you *have* storage and flexibility, then renewables play just fine with nuclear.**

Maybe renewables and nuclear can learn to get along after all. Maybe they won't offer competing visions for a low-carbon power system in the end.

Let's discuss…

(A note for comments thread: this post isn't asking whether you want *a nuclear-renewable hybrid power system. It's asking whether a renewable-hybrid system is technically and economically feasible if we* did *want one. This is a post about what options we have, not which ones we want to chose. So let's save those discussions on which you'd choose for another day. Thanks! -Jesse)*

Recommended resources

- Joint Institute for Strategic Energy Analysis workshop reports: "Nuclear and Renewable Energy: Potential Synergies"
- Ruth et al. "Nuclear-Renewable Hybrid Energy Systems: Opportunities, Interconnections, and Needs" *Energy Conversion and Management* 78 (2014): 684–694
- MIT Energy Initiative symposium report: "Managing Large-scale Penetration of Intermittent Renewables"
- Data on daily operations of French nuclear reactors (by reactor and in aggregate) showing load-following and flexible operation.
- Electricite de France (EDF) technical presentation on flexible operation of nuclear reactors.
- OECD/Nuclear Energy Agency white paper: "Nuclear Energy and Renewables: System Interaction Effects in Low-carbon Energy Systems"
- Denholm et al. "Decarbonizing the electric sector: Combining renewable and nuclear energy using thermal storage," *Energy Policy* 44 (2012): 301-311
- California Science and Technology Council report: "California's Energy Future: Portraits of Energy Systems for Meeting Greenhouse Gas Reduction Requirements"
- National Renewable Energy Laboratory: "Renewable Energy Futures Study"
- Fosberg, "Hybrid systems to address seasonal mismatches between electricity production and demand in nuclear renewable electrical grids," *Energy Policy* 62 (2013): 333–341.
- Mills & Wiser: "Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California," LBNL (2012).
- International Electrotechnical Commission, "Grid-integration of large capacity Renewable Energy sources and use of large-capacity Electrical Energy Storage," IEC (2012).

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Authored by: *Connect:*

Jesse Jenkins

Jesse is a researcher, consultant, and writer with ten years of experience in the energy sector and expertise in electric power systems, electricity regulation, energy and climate change policy, and innovation policy.

Jesse authors the *Full Spectrum* column at *TheEnergyCollective.com* and is a recognized thought leader with over 10,000 followers on social media. He has delivered invited ...

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June 1, 2014

Ron Davison says:

Like it? 65

For storage the optimum % of total power mix is a function of two distinct energy catagoryies:

1) Tend to be NEW energy types, renewable or ***Variable output energy sources.***

Optimum storage for these variable output type sources is between 33% and 66% of the variability capacity we as society wish to nullify:

2) Old baseload types, typically heat engine based.

Optimum Storage % is about 50% of Wastage you wish to eliminate.–> lower pollution AND lower cost of a kWatt produced. Arguably the same 33 to 66% range applies to wastage as well.

If we have 20% wastage in production due to DUMB Grid (Delay tactics used by Utilities to Monitize Billable wastage).

Then 10% Storage at thermal plants is about optimum to eliminate wastage in real time from the future smart grid.

So if we have 10% Solar in 5 years, and 10% wind, and 10% storage installed at thermal palnts.

The Thermal storage owner(s) get to monitize:

The shared profits from:

1) More efficient heat engine operation.

2) Smoothed Solar powerdded value monitization.

3) Wind smoothing added value monitization.

Excess storage not used by 1) and 3) can be used to

store Solar peak relative to demand peak. 2 to 6 hours is the sweat spot in terms of demand need.

ROI brings this down once storage multiplier drops toward the enevitable value of 1 ie. bulk storage.

Back to the 10% per renewable scenario. assume 50% for simplisity for each technology including base load wastage elimination.

10+10+10=30% d50% of 30% is 15%

15% TES is about optimum

If the variable sources of power, correlate (100% positive variance) then 15% is the optimum #

If they do not correlate then they each get higher utilizability of the storage from their variability perspective.

So this is an effective storage multiplier.

Lets keep the math simple and just say that avaialbility of the storage is 66% for each variable source.

And that they each pay for and use the same % of storage costs in some means form partial ownership, to rent or a % of $'s power resold later...

So if they each bought 1/3 of the storage, power plant owner(s-co-op), Solar Co-op, Wind Co-op.

But they would each get 1.5 times the access to the storage because one or both of their partners did not need to use the storage in real time. Perhaps they both would share the extra monitization in some fashion or time swapping arraingment.

That is a free 50% income that is essentially free for couperating.

As the power % of fossil fuel deminishes over the next 4 score and 7 years we will need to adjust the amount od storage away from TES and toward Electrical storage.

This is because TES storage only works for storing a thermal heat source in a three way araingment between renewable source getting first rights to demand and a thermal source that can be modulated off or to storage to allow PV or wind 1st refusal of end customer.

The exception to this rule will be % of CSP+TES on the grid in the comming decades.

This three way colaboration is what society needs NOW.

it allows an instant 20% reduction of greenhouse gas emmission reduction as soon as 10% of TES storage is on line.

Why would we not want to do this?

Why will it probably not happen?

Because the utility industry will drag their feet as long as possible, dealling out mis-information to not get on the train to save the future.

The monitization of TES will allow for half to 3/4 of the wastage billage reduction possible.

if we cut wastage profits to be 1/2 to 1/10 of the demand amount,

AND

incentify TES by low interst rates and renewable financing options just like wind and solar.

Grants for 1st adopters to pay for risk of learning curve of industry.

As they improve design and efficiencyies, remove the grants and direct subsidies but leave the cleaqn energy financing pathways.

Optimum storage of All power types on the grid with.

10% Solar

10% Wind

10% thermal storage (of all heat engine based sources.)

This being 80% after wastage elimination, (= instant 20% (40% total ! Wastage +Solar Wind %) decrease in green house gas reduction gift to Gaia.)

Vs 100% heat engine based % without wastage elimination via TES, thermal storage.

OK lets do the math so no one gets offtrack...we have all already forgot about wastage, we have accepted it.

But we don't have to, if we don't want to. Just stop and understand it....

20% renewable + 80% thermal based + 20% wastage (Also thermally based)

that = 120% of demand.

Total Production = 100% demand +20% (forgotten wastage, your utility is counting on it.)

10% TES eliminates up to 20% wastage!

And if the thermal plant is not using the thermal storage it is available to store renewable power via curtailling thermal to electricity production and storing the thermal energy.

Thats the key and the challenge. Each entity must act in the best interest of society.

And that will not happen unless the storage value is priced correctly for ANYONE benifiting form it existance, jst pay your fair share to access its value. (along with carbon output for that matter, it will add to ROI of storage.)

We all HAVE TO support a collabortion to facilitate this common society goal of lowering fossil fuel pollution and greenhouse gas emmissions.

Why HAVE TO?

Because

utilities cannot justify the cost of storage alone, even removing the lost revenue from biilable waste from the logic of utility owners, TES alone is marginal ROI on its own with only the heat source optimization monitsing the TES.

But add in Solar and Wind revenue for power smoothing and it has a 1 to 3 year payback.

This is roughly true for the first 5% of TES added.

The next 5 to 10% TES has 3 to 6year payback period.

The next 10 to 1% TES has a 5 to 8 year payback.

This will drop significantly iff:

Storage technolgy becomes cheaper as its volume ramps up. (pretty good bet)

When PV Solar and wind climb above 10% each then this supports a higher % of storage.

If 80% of the E power comes from thermal sources then 20% comes form Solar and Wind.

for the portion of sources that do not have good negative correlation with ech other. that is they both want the resource at the same time then that % of lost storage oportunity will pay for additional storage that is needed.

My 15% total TES now become 18 or 20% with this coumpounding of needs.

Working against this is the lower utilization of each % of TES added that lower ROI.

When these two delt costs are =, then optimum % TES has been reached.Wastage elimination requires a certain% storage reserve you never use unless the grid is under commanded on a gross scale, it cannot be monitized directly.

it must be monitzed by the wastage elimination cost reductions of higher efficiency of thermal sources.

But t can be tapped and violate reserve capacity margins available (not the same as sourced power in real time). For additional reasons like afternoon pollution. as an additional thermal plant is ramped up for production mid afternoon, the storage can be tapped while supply dipps below 100% because just as storage output starts to drop power palnt(s) will be up and running withexcess capacity to refill storage hit beyond normal limits..

As an example pollution can be prevented just by load shifting and storage usage to opituum operation.

Just as thermal storage is running out from delayed fossil fuel burning, the inversion layer breaks down as plant is fired up in a JIT fashion. Most of this time displaced pollution does not reach ground level improving the air pollution imensly.

So not just price signals but qulity of life signal should be all integrated together in a holistic way.

The need for bulk Solar storage in real time, watt for watt, in absolute terms is ***not until*** 35 to 60% of Peak demand is filled by Solar. This is 3 to 6 decades away perhaps, unless oil spikes and stays above historical trends. This dovetails with the death of coal as a heat source. another few decades until renewables and storage eliminate oil, another decade after that natural gas.

By then we will have enough peakers and mothballed natural gas plants to ride through abig 1000 year volcanic event for a few years.

Its important to keep these as back up and should be incentified.

Eliminate inventory and capitol taxes on these stranded assets. Pay for upkeep because there will be no bussiness case to support.

it may not ever be cost effective to store PV solar for nigjht time use only for BULK storage.

So this favors a % CSP+TES instead of just 100 PV.

How about train based TES platforms that can be rolled in and out of thermal storage wherehouses by high temp robots?

When the thermal palnts start shutting down because Solar CSP and PV are coming on line recucing fossil fuel need toward small %'s, we could just roll them out to the newly build CSP+TES plants and instanly increase their working storage capacity.

Now CSP+TES ultimate PV and wind modulator.

Fourway co-operation, 2 electrical sources, (1 renewable, 1 thermal to electrical converter) 1 thermal source (feeding the thermal to electrical converter) and 1 composite load.

By storing heat from CSP instead of producing electricity, PV and wind get 1st refusal to load or demand because they are al ready electrical ready to be consumed. The CSP energy that is also renewable is now stored as thermal heat.

Once wind and solar do not support demand heat to electrical converter at CSP+TES starts generating electricity instead of storage.

ultra fast responce to grid signals can be accomidated because you can modulate the heat source in real time away from electrciity or to electrical generation as needed.

Again two way modulation is the added attributre of any storage.

Double the usage of 2x source AND sink.

multiple user availability multiplier from 1.0 to N.0

N=3 in this example

N = 4 add wave energy

N = 5 Add Geothermal

Good rule of thumb would be sqrt of N for multiplier value as 1st order aproximation.

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May 17, 2014

Bas Gresnigt says:

Like it?

76

It is remarkable that the post neglects the free whole sale market with renewable and it effects on nuclear, as that free market is the situation in many countries & states now. So lets take an example.

Germany
In the first quarter of this year renewable delivered 27% of Germany's electricity. During a day in May renewable delivered 75% (wholesale price was negative). Solar+Wind capacity in Germany is now ~75GW which is more than German peak demand (~70GW).
Taken the German implementation rate of Solar+Wind of ~10GW/a, we will see days in which renewable deliver >100% of all electricity Germany needs before ~2018. Then the number of those days will grow.

What will(is) happen(ing)?
As the variable costs of wind and solar are ~ zero, they will continue to produce until the price is zero. That implies that during an increasing number of days the whole sale electricity price will become <$1/MWh.

As NPP's costs are substantial higher, they will make increasing losses with the increasing share of renewable. It implies that the high 'fixed' costs of NPP's (interest, depreciation, maintenance, employees, etc) have to be earned during less hours in the year.
Which implies that the needed price during those hours will become higher the less of those hours are available in the year. And those hours will become less and less due to increasing renewable.

As other more flexible methods of electricity generation do not have those high fixed costs (e.g. a remote controlled gas turbine), those will compete NPP's out of the market even if the gas price is rather high.

With the present German priority system for renewable this will happen even much faster as part of renewable production will enter the market even if the price is negative. Leipzig saw already electricity prices of minus $100/MWh.
Considering present NPP's cannot regulate down below ~70%, it implies loosing money fast. As Germany's new coal plants can regulate down towards ~10%, even those will compete nuclear out of the market.

Other effects
Those low whole sale electricity prices make electricity-to-(car)fuel/gas conversion plants economical. So you see much pilot plants in Germany springing up (e.g. the Audi 6MW plant).

About 35 pumped storage plants are installed in Germany, but those make losses as whole sale price nowadays nearly never rise above $50/MWh. One may expect those may start to makee a profit in the 2025-2030 period when the share of renewable becomes >50%.

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June 2, 2014

Robert Bernal says:

Nuclear and solar will HAVE to get along, or the biosphere will die. We need to power up to FIVE times what the world powers now (can't forget all the other billions who want to "live"). Efficiency will reduce that by a factor of about 2. Therefore we still need to replace at least 2.5 total global power supplies with nothing but CO2 free energy. Guess where ALL THAT will come from? Nuclear, wind, solar (proper mineral) sequestration of fossil fuels and a tad fro hydro, geothermal and even less than that from wave and tidal. Biofuels needs to be limited for obvious reasons. So we better get our act together and learn how to properly MANAGE ALL of these CO2 free sources... or the biosphere will die. First, it's the loss of shellfish and icecaps, then subsequent loss of biodiversity and poor ocean circulation causes ocean anoxia, then comes the killer, microbes that "instantly" replicate in anoxic oceans which exhale hydrogen sulfide... nuff said.

Like it? 63

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April 27, 2014

Pieter Siegers says:

Like it? 65

Hi Jesse, to be honest it is difficult to say whether xRE + yN should be the energy mix formula. I could agree with it if at this moment all fossil fuel plants would be shut off, and nuclear plants could provide for the basepower we currently depend on. That would lower carbon emissions significantly.

I just read the following article, which puts nuclear in the midst of some clean and some dirty energy sources: http://www.nature.com/climate/2008/0810/full/climate.2008.99.html

Whilst nuclear looks a great option to include in the energy mix at short term, on the longer term we will need to leave nuclear behind, the reasons for that are already being discussed in the same article so here I won't mention them again.

So basically what the main argument is for nuclear is that it provides baseload power continuesly. In other words, nuclear would provide for an adequate energy backup when RE do not provide enough energy. On the short term, for existing nucelar plants I would be willing to accept that.

I think there are other arguments that come into play when talking about combating climate change, or better said, avoiding it by reducing carbon emissions to levels where it was when the industrial revolution began. We're talking long term business here.

First one is energy efficiency. There is much energy to save when talking transportation and industrial processes. I have read that this argument is very real and big business.

Second one is a bit far fetched and related to energy grids that could be integrated, passing along any energy that is generated extra to the ones that are in need. With RE, that means that grids that receive lots of sun and / or wind could transport energy to the ones that are without sun or wind. This requires some very intelligent power regulating components and lots of interconnection, but is doable.

Third argument is lowering the carbon footprint at the residential level, by using concepts like passiv house, excelent insulation, solar boilers on the roof for showering washing and cooking, heat pumps, and using LED lighting, just to name a few. Some of them apply very well or even better on industrial level as well.

The argument in your article Jesse that you suppose the energy use per capita should be based on what the Americans use today, I think that Americans should first lower their energy use per capita to be fair. What happens instead is that even when the US saw an increase in the use of RE, there was also an increase in carbon emissions last year...! So something is still very wrong, and I doubt it very much should we take the US strategy as an example. We all know that the fossil industry is a very powerful wall and is insisting on using up all fossil fuel there is to find, driving up the prices as is needed... This is clearly what our planet does not need at all, and we should refuse any attempt they make to continue this madness. The answer is simple. What we need to do is lower fossil fuel demand. How? Use RE and efficiency, develop sustainable energy storage. Lower fossil fuel demand.

As an example of the fossil fuel industry being like a tsunami that apparently can't be stopped, is that while the whole world saw the Arctic 30 protest, being put in prison for a long time, then sent home by Christmas, and what do we see? The first tanker with Arctic oil has arrived. Where? In Rotterdam, the Netherlands... being Dutch, it is hard to understand why they, being very active with recycling, bicycles, and solar and wind, let this happen... it makes me ashamed, but on the other hand it makes it very clear that commercial power from fossils is so strong, it almost makes you feel like you cannot do nothing. But then, we are all part of the same demand, so lowering it seems to me the only viable option we have to break their power, to finally really see some substantial reduction in carbon emission. As long as the fossil fuel industry is in power, or, in other words, we are providing them with demand, no real changes will be seen on our planet indicating the ship is moving in opposite direction.

So, tell me, knowing this, what will you do?

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April 27, 2014

B W says:

Like it? 63

Peter, not to discourage your commenting but a lot of people commenting here are very well educated on the global energy problem including Jesse.

energy efficiency is a very cost effective means of carbon abatement, though due to the large rapid growth of energy usage in the developing world, the importance of energy efficiency to mitigating the climate change problem is limited.

the idea of vast interconnected networks of renewables does not work without a storage component, because equatorial sunshine is still only during a part of the day, and wind varies in a less predictable manner. Creating enough output from wind and solar to meet the needs of billions of people throughout the day and night without substantial storage capacity would mean overbuilding peak demand capacity by several factors with intermittent generation sources, and even that may not cover all peaks. It would also necessitate throwing large amounts of energy away. Any scenario with out large capacities of stored energy is essentially an impossibility. Nuclear power seems to have a significant edge on other forms of stored energy in terms of cost and scalability.

Peter, why can we not use nuclear energy long into the future? Work done at Argonne labs in the 80s provided a lot of progress in terms of reducing the waste and proliferation threat of the fuel cycle, and the energy content in spent fuel alone is enough to power a country such as the US for centuries.

We have to understand fully the developments in all technologies, unfortunately far too many people are completely in the dark about the research advances made in regards to proliferation resistance, waste minimization, and safety of nuclear fuel cycles and reactor designs.

since nuclear doea well as base load and to load follow, and solar can provide a lot of peak output (though the duck curve is still a problem) it seems apparent that nuclear and solar will work well together. I can't say the same about wind, which at large penetrations would undermine the economics of every other generator on the grid due to ita high variability.

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April 23, 2014

Csaba Urbaniczky says:

Like it? 70

Hi all,

With risk to sound arrogant, I think the discussion here is ytterly strange (or academic in a ivory tower in the worst sense)

The point is not what combination of xRE +yN goes together as a simple linear combination, or maybe it is: The point is if nuclear (N) is expensive AND unsafe AND with uncertain future waste handling AND unclear cost of decommissioning than why not set y to zero. These are the German arguments. The French argument about going the nuclear way has ended with the Flamanville Nuclear Power Plant and Olkiluoto Nuclear Power Plant.

100% RE as wind and solar power without pumped hydro and other complementary systems might not possible - but other solutions exist, time to leave the ivory tower.

But nuclear is not the answer, it should be zero in the future. And for all the other “once upon a time” stories about new wonderful nuclear technology that will give limitless low-cost energy; I don’t believe in them, I have heard them for 50 years now, and it is always 20 years away. You can't cry Wolf all the time.

So you have xRE +yH+zX instead to consider.

Sorry…..

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April 23, 2014

Jesse Jenkins says:

Like it? 69

We all know those arguments well here. There have been hundreds of posts at this site hashing out those issues. So please, if you don't want to have this particular conversation, then don't. No one is forcing you to.

As I've told other commenters, please stay on topic for this discussion thread, or refrain from commenting. The question here is not do *you* specifically *want* nuclear or renewables? Your answer is clear. Others disagree. That's not what were discussing in this specific post. The question is, if a nation decided it wanted both nuclear and renewables, could they work together?

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April 24, 2014

Csaba Urbaniczky says:

Like it? 61

Sorry, again a arrogant answer: Yes, since it is a political decion; for that you don't need any advanced simulation program in an Ivory Tower. (This is my last entry for the discussion).

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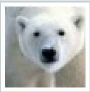

April 22, 2014

Lou Vellucci says:

Like it? 70

Yes Sir, Jesse, we indeed need them both; nuclear for the short term as this is time -sensitive (see NYT editorial April 20) and will decades to bring enough renewables on-line. Would like to see us be a little more protective of birds when using renewables however...and I do not like the damage to fish caused by unrestricted hydro....

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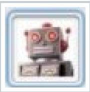

April 19, 2014

Capt D says:

Like it? 64

RE: C. Forsberg, "Hybrid Systems to Address Seasonal Mismatches Between Electricity Production and Demand in a Nuclear Renewable Electricity Grid," Energy Policy, 62, 333-341, November 2013). That is because about 70% of the electricity demand is baseload." (spelling corrected in last use of electricity)

Sir, in your article you make the assumption that nuclear must be used along with other forms of generation, why is that since many example exist where nuclear is not being used at all?

The same question applies to the concept of "baseload" which again has also been debunked, since the nuclear industry feels that it should be given a special priority in the energy mix being used.

Being used together in the short term is not an indication that both nuclear and other forms of generation will be used in the future.

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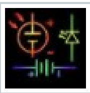

April 20, 2014

Robert Bernal says:

Like it? 59

I consider it the other way. After realizing that it takes an overbuild of renewables to supply a baseload (which is not debunked) I find that the math is more favorable towards some advanced reactor design which uses molten salts as the storage medium (and possibly even molten salt for fuel mix in the reactor itself to prevent any possibility of meltdown as with the MSR or LFTR). Consider the we must transition over to an all electric fleet, except for industrial processes, in order to actually *really* solve the excess CO2 problem. The industrial processes shall be fueled by liquid fuels made by some kind of high process heat (again, MSR or similar), thereby further transitioning from some 80% to 99.9% non fossil fuels. Or, battery tech will enable heavy equipment as well.

Solar panels for rooftops will be made by nuclear derived electricity, thereby causing them to be 100% carbon free as well (reducing fission products a few percent as well).

Let's do some math! Assume 10 billion people will want clean water and food, transportation and entertainment (including all the "unseen" industrial processes required for all such infrastructure support). Currently, the world consumes about 500 quads in all primary energy. The USA consumes about 1/4th of that yet is about 1/20th the population, thus, to be fair, the world should be consuming 5x more, or 2,500 quads. Most of that energy is wasted due to thermal losses in the traditional way: 66% in steam generation from nuclear and coal, and 75% from transportation. NG looses about 60%. We will not account for line losses (at this point in the equation). Therefore, we can say that the world would need about 800 quads (equivalent) from renewable sources (in order to power 10 billion happy humans without harm). That is still more than what the world uses now, so we will count on conservation and efficiency to cut this number in half (besides, it wouldn't hurt the USA to cut some of the waste)! Now, a solar panel will generate about 150

Now, a solar panel will generate about 150 watts for about 6 hours from a single sq m (in perfect sunlight). That's about 900 Wh x 365 or 328 kWh/sq m/year (without clouds).

Half of my projected fully electrified global requirements will need 60,000,000,000,000 kWh / 328 or 182,000,000,000 sq meters. At $2/watt installed (x 150 watts per sq m), that's about $50 trillion... and 182,000 sq km (or about 70,000 sq mi) of land.

Much of this electricity will have to be stored. Let's say that about half (not 3/4ths) of the energy will need to be used in the 3/4ths of the 24 hour cycle that the sun isn't shining (I believe this is "about" the right amount since most industriual and commercial processes are concentrated around business hours while the sun is shining). We will assume that battery technology will kick ass and cost just $100/kWh of storage, and that they last the lifetime of the solar setup (there are already reports of utility scale zinc air batteries coming down to just $200/kWh that last for 10,000 cycles!). We will need to store up to two day's worth of that, or about 165,000,000,000 kWh to make up for any serious weather related issues assuming regional distribution will even out any further such issues (so batteries should cost $16 trillion, globally). Thus cheap solar and batteries should cost about $70 trillion to power half of the projected global population at half of the American standard (efficiency improvements from electric cars, led lighting and better insulation/passive solar siting should enable that).

We can say that the other half will require even more money! Wind has longer and less predictable lulls and costs slightly more per watt to install (than the $2/watt figure I used for solar).

Thus, I come up with about $150 trillion for the complete wind and solar scenario for 10 billion people. This does not account for the 25% loss due to ineffeciency of storage. neither does it count for extra powerlines and extra labor/equipment needed to periodically clean *70,000 square miles* of solar panel.

Now, for the mass deployment of high temp nuclear scenario. Since it will be baseload, we can try to calculate how much needed for storage. But first, let's say that it is most economical to crank out a bunch of 100MW units instead of 1GW units (and safer, too).120 trillion kWh = 120,000 trillion watts / 100,000,000 (for each unit) / (about) 8,000 hours in the year = 150,000 such units, globally for 10 billion happy humans. At $10/watt, which is the cost of *today's one of a kind, more complicated light water reactors*, a whopping $150 trillion.

If mass produced, these units will come down to about $2-5/watt. For comparison, a **brand new coal plant** costs about $2/watt and with (some) CCS, about $5/watt.

However, much of this electricity will also, need to be stored. Unlike the renewable option, the nuclear is still running during grid variabilty. Thus, we need to divert its power for charging whenever demand is low to be added to demand when high. Again, let's say that we need to store half of the generated electricity, but for only up to a whole 24 hour cycle (instead of for 48 hours, as with the renewables, it should be less than that, since no full on nuclear power outages should occure for that long at the regional level). That's about $8 trillion for batteries.

We should throw in another 8 trillion (over 50 years) for the proper disposal of fission products. But we should also assume that they will not cost anymore than $4/watt to make, ship and install because they *must* be made in the factory just *as* solar and gas turbines are today.

Thus, the nuclear option is not only more predictable, it is half the costs!

Other considerations are:

- That solar peaks in the middle of the day, which could reduce the amount of nuke plants and battery storage for nuke plants.
- That liquid fuels will need to be made (and possibly from thermal which is 3x the energy equivalent of electricity) from nuclear, thus offsetting some storage.
- That molten salts should instead be used for storage if cheaper than battery.
- That machine automation required for the solar should also be used for vastly reducing the costs of electric car (and utility scale) batteries.

Clearly, **less battery storage** is needed with an (almost) all nuclear scenario than with an (almost) all renewable scenario.

April 21, 2014

Capt D says:

Like it? 71

Robert - In order to save space, I'd like to mention that others are using different cost than you mentioned above and since I am not current with many of the costs you mentioned, I would urge you and all others that are interested, to read this article and its comments which speaks to future Utility energy costs:

Bernstein: Utilities Have 4 Choices In Solar Revolution (None Are Easy To Swallow) http://po.st/kTDCZz

Share this comment:

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April 21, 2014

Capt D says:

Like it? 63

Robert - RE: "After realizing that it takes an overbuild of renewables to supply a baseload (which is not debunked) I find that the math is more favorable towards some advanced reactor design which uses molten salts as the storage medium (and possibly even molten salt for fuel mix in the reactor itself to prevent any possibility of meltdown as with the MSR or LFTR). "

I see a problem with your vision of the future, which is that SMR's and similar forms of ***new nuclear generation*** are nowhere near either being developed and/or ready to be commercially deployed in the real world. In fact R&D is now being reduced as US Energy companies and others World-wide realize that there are better ways to invest their resources that have none of the drawbacks to using nuclear.

Babcock & Wilcox scaling back work on small modular nuke program | SNL http://shar.es/TA8JM

+

China has given its scientist until 2024 to prove Thorium will be economically viable!

Chinese scientists urged to develop new thorium nuclear reactors by 2024: http://shar.es/TA81e

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April 22, 2014

Robert Bernal says:

Like it? 50

These companies and governments that withdraw development do not really care about 99% fossil free. If they did, there would be a "war like effort" towards developing the best option. I'm not sure if the highly radioactive MSR is it, but know that it will take a lot more resources to do it with wind and solar than to build reactors and shielding.

In the above figures, I *forgot* to consider shadow (and access) **spacing**. NREL has come up with a figure of 7.9 acres per MW and I assume just over 20% capacity for a total of 30 acres per MW at "100% CF", or 3,000 acres (12 sq km or 4.6 sq miles) per 100MW. Since the nuclear would have about a 90% CF, it still takes about 4 sq miles of solar PV and spacing to equal the output of just one 1/10th GW hardened reactor. In actual resources demands (without spacing) that is still about 1 square miles of solar infrastructure to one such reactor plus the extra amount of storage and powerlines needed.

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April 22, 2014

Capt D says:

Like it? 58

Robert - First Happy Earth Day and also thank you for your comments.

I agree that most Governments and/or Companies do not care and that is the crux of the problem mankind faces!

Those in charge of making decisions are now narrowly focused on near term profits for themselves and their supporters instead of the long term success of mankind.

When it comes to providing Energy, there is no free lunch.

While I agree that Nuclear generation has many orders of higher energy output than Renewable generation, that high output comes at a very high price, which includes potential accidents (I noticed your use of *hardened reactor*), decommissioning cost and the handling the all varieties of radioactive waste created to mention just a few.

I for one would love to see a "war like effort" focused on shifting to renewables because I truly believe that is one War the USA could not only win, but do so with massive public support.

As far a spacing goes, I think that if every rooftop had PV, then our energy requirements would be far less than they are now especially since that once you install a PV system you never look at energy or consume it the same way again. Similar to how the average amount of miles driven per year has fallen since gasoline and diesel fuel prices have skyrocketed, as ever more people add their own Solar systems they will use less Utility generated energy, which will make it easier not harder to use renewables. I wonder if the NREL has calculated what the size of available rooftops are in teh USA, I'd be interested in how that figure would decrease the amount of Utility scale acreage required, my gut feeling is that it would be much less, especially if conservation was included. I know for a fact that in CA, since San Onofre NPP was shutdown, there has been no brownouts and demand has actually been reduced because of ratepayer conservation.

Share this comment:

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April 22, 2014

Robert Bernal says:

Like it? 64

Thanks, I believe that rooftop PV is the best way to supplement electrical needs, that we all should reduce, especially the corporations. When I go to the store and buy anything, chances are it is over packaged with mostly air. If they don't do it that way, then they lose to the competition. So we need laws. I think this is my "Earth day awareness" talking but what we really need to do is transition to a resource based economy, where things are not designed to break down and where money doesn't get in the way of our efforts (where machines make and manage "everything" and people somehow get compensated for not being able to work). The technology is headed there anyways!

We still need nuclear to make solar PV, musical instruments, computers, electric cars, fuel for heavy machinery and such but I agree, there is A LOT that the Americans could cut! I am simply born into the "suburban, spend lots of energy on trivial stuff and drive everywhere" type mentality... and can have a hard time figuring out our way out (I can tell you to not buy into all the holiday stuff and to not travel but you could say for me to not buy musical instruments, computers and such). We need to be able to have what we want most. Problem is, if I was rich, I don't think the solar panels (that I would buy) would make up for all the musical instruments, larger house, electric cars and the extra running around... even though most of it would be to bring attention to climate change solutions *awareness*. So, in effect, I would be adding more CO_2 to the equation even though money buys efficiency. Once in a totally electric powered world, then it doesn't matter. Then, we all could concentrate on the less serious things such as over packaging.

Earlier, I read about how many people went to movies and meetings about climate change and just made me sick! I commented about how much *extra* they are causing to the problem by driving there (and I said) "unless the meetings were actually about how to get to 99% clean and abundant electricity". They were mostly *just* about picking up trash, reducing plastics, drinking less soda and such (but, at least some of it was about planting trees).

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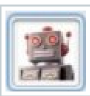

April 23, 2014

Capt D says:

Like it? 61

Robert - I agree, doing more with less is the beginning of saving the planet! Those will more things have a harder time saving Energy becaue they have a larger Energy ***Footprint*** to deal with...

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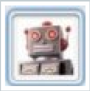

April 17, 2014

Capt D says:

Like it? 58

Lets not let our nuclear shortsightedness keep US from looking to other solutions that do not require the use of nuclear or generating additional nuclear waste which mankind will have to deal with for generations.

Wind is good, but when ocean water current and/or tidal generation come online then it will be a game changer since it will provide 24/7 TRULY GREEN energy in very large quantities.

Very Soon:
The Tide Is High · Lockheed Martin: http://www.lockheedmartin.com/...

and in the near future perhaps even this:

Global Sustainable Electricity, Fresh Water, and Deep-Ocean Mining from Marshall Hydrothermal http://shar.es/T5Dai

If we enable engineers to examine all solutions with equal funding, then 10 to 20 years from now their will be no need for aging nuclear reactors unless there is a fundamental breakthrough in physics...

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April 19, 2014

Nathan Wilson says:

Like it? 61

In the spirit of pulling this discussion back on topic, the two energy technologies that Capt D mentioned nearly exactly fit the mold of the other renewables and nuclear compatibility problem.

Tidal power has a varying output, with both a 12 hour cycle (which maybe could be smoothed with advanced batteries) and a 2 week cycle which could only be smoothed with fuel synthesis. Basically this is another technology which is a difficult fit for any grid that is not fossil fuel or hydro dominated.

The deep-sea hydro thermal plan is the "nuclear energy" of renewables. (Anyone who thinks small is beautiful will hate this: Marshall Systems wants to hook a pipe into a 50 GWatt hydro thermal vent in 7500 feet of water, hundreds of miles off-shore. All they need now is a few billion$ for a small prototype.) Like land-based geothermal, this baseload technology can be combined in any ratio with nuclear and baseload solar thermal, but will need a lot of hydro, storage, or dispatchable fuel synthesis to go beyond around 80% non-fossil.

So basically, neither of these technologies can flourish in a grid that is 40% solar+wind, unless and until we develop and deploy the exact same technologies which are needed to add new nuclear to such a grid. These technologies also have the additional impediment that they are new and have unproven economics.

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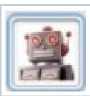

April 21, 2014

Capt D says:

Like it? 68

Nathan - Your points are all well taken but I would also suggest that by deploying a number of renewable generation methodologies they will tend to overlap each other and therefore back each other up as needed.

Until other forms of storage (not just battery) come online I expect to see NG peaker plants which are already less expensive to build, maintain and far less risky than nuclear be used to replace traditional coal generation, especially in the USA since we are blessed with large NG deposits.

I hope soon, there will be no such thing as an idle wind turbine, PV panel or any other form of Solar generation since any excess power could be used to desalinate ocean water, and/or many other things that would later be used by mankind.

Share this comment:

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April 17, 2014

Jesse Jenkins says:

Like it?
65

As I've told a couple other commenters: please keep the discussion focused on the question at hand. This isn't the right forum to air your views on nuclear or renewables. The question is *can* they work together. Not do you *want* them to work together.

To keep things off topic, I'm going to prune this part of the thread of off-topic comments. I mean no disrespect to those posting their strong beliefs about nuclear power (one way or the other), but I don't want this comment thread to devolve into another battle over nuclear. I hope everyone understands. Thanks,

Jesse

Share this comment:

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April 17, 2014

martin burkle says:

Like it?
79

Two thoughts:

1. A really good cheap energy storage system works better for a nuclear system than wind/solar because less storage is needed for the nuclear only system. So, if nuclear and storage are available, why have wind and solar at all?

2. Let's assume a molten salt reactor is developed. What does the reactor do when there is less demand than production? "Produce less heat" is one answer but that is a waste of capital. "Make liquid fuel" is another answer. But a billion dollar MSR might need a billion dollar liquid fuel generator. Eithor the electric generator is under used or the liquid fuel generator is under used. "Store heat for later use" is the most likely economic answer using a secondary molten salt repository.

I vote with the guy that says, "Right now we need more R&D".

Share this comment:

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April 19, 2014

Nathan Wilson says:

Like it?
61

Should we over-build electrical generation and add fuel synthesis? It depends a lot on whether we need the liquid fuel for other purposes. There will always be some nations that can't grow enough bio-fuel for their transportation system (maybe most nations). For these nations to get off fossil fuel, their syn-fuel industries will be roughly 1-2 times the size of their electricity industry.

Such a nation would need very little energy storage, since the syn-fuel plants would constitute enough dispatchable load. To put down some ball-park numbers, say the baseload power plant costs $6/Watt (plus fuel for nuclear at around 2¢/kWh) and the hydrogen plant costs an extra $1/Watt, including several days of storage. Then baseload electricity is around 8¢/kWh, and dispatch load at the syn-fuel plants adds 1¢/kWh to the cost of baseload for the idled equipment; this is really cheap peaking power (it does assume that as with today's costs, per-Watt the chem plant is much cheaper than the nuke, and of course a cheap chem plant is crucial for applicability to low capacity factor off-peak wind and solar).

Thermal energy storage at nuclear plants or advanced batteries (for a few hours) might also fall to the $1/Watt point, but we would still have to pay depreciation for the storage, even on days we didn't need it. When we don't need the syn-fuel plant to load-shed, it makes product for its fuel customer, so it does not burden the electricity economics (in reality there would likely be a small payment).

I mentioned several days of hydrogen storage, but note that if liquid fuels (e.g. ammonia or DME) are produced, or if the local geology is suited to underground hydrogen storage, then seasonal energy storage is feasible.

Providing syn-fuel for the entire transportation market using plants configured for dispatchable load is such a powerful tool, that nuclear and renewables can almost be mixed freely on such a grid.

Note that the energy prices given (8¢/kWh for baseload electricity, $1/Watt for hydrogen plant) and 70% conversion efficiency suggest a hydrogen cost of $4.60 per gallon of gasoline equivalent. Conversion to ammonia fuel would add another 5-25%, depending on the technology (this improves storability/transportability and allows simpler ICE cars rather than expensive fuel cell vehicles).

This cost would not be attractive in the US unless the hydrogen/ammonia car got much better mileage than gasoline cars (20-50% better is likely). However, it is possible that the very high temperature nuclear plants in development coupled with thermo-chemical hydrogen production could reduce the cost substantially. Also in China and India nuclear power is only one third of what it costs in the US, so the retail price of ammonia syn-fuel would easily beat imported fuel.

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February 18, 2015

Steve Darden says:

Like it? 24

Providing syn-fuel for the entire transportation market using plants configured for dispatchable load is such a powerful tool, that nuclear and renewables can almost be mixed freely on such a grid.

Nathan, for me, that should be the debate-winning argument. Question: powering the syn-fuel plants by nuclear works economically, and radically reduces the amount of multi-week level storage required for the ultra-low carbon pathway. How could we accomplish the same design based mainly on VRE?

I want to see Lion Hirth and Schalk Cloete tackle the modeling to find the optimal nuclear-VRE contributions in a system that exploits syn-fuel load-shedding to substitute for most of the storage. My guess it will turn out to depend heavily on System LCOE and location particulars.

Share this comment:

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August 15, 2015

Nathan Wilson says:

Like it? 5

Steve, of course variable renewables can be used to produce syn-fuel. But you'll also have the challenge of explaining to the public certain bad news (especially compared to the nuclear alternative).

When dispatchable load is added to the grid, it provides a valuable service which deserves compensation: the synfuel plant will buy power at a discount (this discount must grow as the capacity factor drops). This discount is funded by **raising the price** that everyone else pays for renewable electricity.

Also, fuel is easy to transport from place to place, which tends to make market prices converge. People in many locations will find that synfuel for them is an **import**, since their local renewable resources won't be able to compete with the low cost regions. This will be unpopular in fossil fuel producing regions which face loss of energy jobs (long distance electricity transmission does the same thing).

Finally, with variable renewables, thermal generation will likely still be needed as **backup**, likely with subsidy support (unless you want to occasionally declare "load shedding grid emergencies" aka TOU price spikes, which people in developing nations are used to but hate). Plus you'll have the difficult choice of burning clean but expensive synfuel at transportation fuel prices in the backup plants, or cheap and dirty fuel (such as dirty but politically powerful German lignite coal).

Share this comment:

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August 17, 2015

Grace Adams says:

Like it? 6

Often resources that lots of persons want badly but are unwilling to pay for are often paid for through government in general revenue taxes. In this case, most need energy storage, whether thermal energy storage, or electric storage or pumped hydro storage, whatevrr will get the job done, and it makes sense to have utilities control storage, hopefully with computers doing the job automatically, rather with humans getting bored and dozing off. It might make sense for federal government to buy energy storage of assorted types, have utilities maintain and operate them, have both firms producing extra energy and wanting to store surplus for later, pay half the cost of the storage, and have customers of electric or of heat from distric heating or whatever, pay for the energy and the other half of the cost of storage as they buy energy, of whatever form.

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August 16, 2015

Jesper Antonsson says:

Like it? 4

Very good points. However, it's unclear to me why thermal generation would need subsidy support. I'd think that in developed nations, consumers would be able and willing to pay the very high spot prices necessary to support thermal backup plants and generation.

What does need support, though, is the renewable generation itself, since income from synfuel plants likely won't pay for the marginal wind turbine and solar cell (which will produce mostly excess power that would be of no value if the synfuel plant doesn't take it). Of course, this is just restating what you said about discount and "raising the price that everyone else pays".

I think it is kindof premature to talk of thermal backup, btw. It's ok in sci-fi such as this, I guess, but for the foreseeable future, thermal is the power source and intermittent power extends its fuel somewhat. And it seems the primary purpose to extend thermal fuel, for now, is to get rid of nuclear.

Share this comment:

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April 17, 2014

Jesse Jenkins says:

Like it? 63

It sounds like you'd like the paper Charles Fosberg references below...

Share this comment:

Login or register to post comments

April 17, 2014

Charles Forsberg says:

Like it? 70

The conclusion that storage and hybrid systems are required for a zero carbon nuclear or renewable grid is correct; that is, same technical solutions required for nuclear and renewable systems. It implies many ways to couple nuclear and renewables. However the storage challenges are somewhat greater for renewables than nuclear. The quantity of electricity that must be stored is substantially higher for solar or wind versus nuclear (C. Forsberg, "Hybrid Systems to Address Seasonal Mismatches Between Electricity Production and Demand in a Nuclear Renewable Electricity Grid," Energy Policy, 62, 333-341, November 2013). That is because about 70% of the electrcity demand is baseload.

There is a second factor. Thermal storage systems for peak power will be more economical for nuclear than solar because of the economics of scale of thermal storage systems. That suggests that large-scale nuclear with thermal storage may be the enabling technology for large-scale economic use of solar and wind.

Last, the cost of wind and solar are strongly dependent upon lattitude and climate. The cost will be lowest in places like northern Chile with the world's dryest desert, high elevations, and the sun directly overhead in the summer. As one moves to higher latitutes, performance degrades. Any zero-carbon economic solution likely implies wide variations with location in the relative amounts of nuclear versus renewables based on solar and wind conditions.

Share this comment:

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April 19, 2014

Nathan Wilson says:

Like it? 63

Here is a summary on MIT News of Dr. Forsberg's 2013 paper discussing hybrid energy systems, and here is a video in which he discusses an advanced nuclear technology which would be well suited to the renewable-rich grid of the future.

Share this comment:

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April 17, 2014

Jesse Jenkins says:

Like it? 68

Thanks for the comment Charles. I'll add that paper to the resources link above and take a look myself as soon as I get a chance. Cheers,

Jesse

Share this comment:

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April 16, 2014

Joe Schiewe says:

Like it? 64

Am I missing something here? It seems to me that no amount of being rationale and playing nice between current nuclear and wind/solar with or without storage will solve the problem of "Climate change is a pressing global imperative" unless we can get their high upfront capital costs/kwh and environmental intrusion down substantially. I just don't see the poorer high growth nations making the necessary upfront investment sacrifices if they can get the heat for their homes & meals, fuel for their transportation and electricity from fossil fuels, wood and dung for less cost. If they don't come along - we are sunk on this global imperative. At the risk of being considered an anti-nuke (not the case at all) - again I recommend that we get fully behind the R&D for future nuclear & wind/solar low energy cost innovations that can allow these key nations to come along. I recommend that we get behind this even if we don't feel that climate change is an issue but just to help these 1 billion impoverished people out.

Share this comment:

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June 2, 2015

Grace Adams says:

Like it? 9

Yes, we need lots of R&D, especially at the engineering level, getting technology already proven technically feasible down in price enough to be not only economically feasible but cost competitive with fossil fuels, dung, and wood in less developed nations. Maybe governments and large private philanthropic organizations in already industrialized nations (mostly US and most of EU) could rent land in less developed nations (mostly near equator) for pilot plants for both advanced nuclear power and renewable energy, and for technology that still looks good after a pilot plant several more similar plants for beta testing, then donate the pilot and beta testing plants and some licenses for more plants of the same design, reserving the right to also use the technology in middle income and industrialized nations. Already industrialized nations will have to subsidized both advanced nuclear power plants and renewable energy until they do become cost-competitive with fossil fuels, dung, and wood in less developed nations. And probably also bail out politically powerful fossil fuel firms by buying much of their otherwise stranded inventory of fossil fuel reserves at generous prices to prevent them from engaging in a price war against advanced nuclear power and renewable energy.

Share this comment:

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April 18, 2014

Nathan Wilson says:

Like it? 67

All too often, the claim that we need more R&D is used as an excuse for postponing deployment of new technology. One thing that is a clear lessons from the recent declines in the cost of solar power is that R&D alone is not enough to bring costs down; it takes dozens of GWatts of deployment (which has not really been done for the post-TMI enhanced safety nuclear plants of today).

Another factor that helped solar a lot was the societal commitment, and streamlining of red-tape and permitting processes. We know that nuclear has great potential for cost reductions (the fuel only contributes 0.5¢/kWh, and the steel and concrete inputs are only a tenth of that used for wind energy). Safety by design can be cheaper than safety through regulations.

Another message from the clean energy movement that is applicable to developing nations is that with the right technology from the start, there will be no need to make a difficult transition to clean energy. This is most often part of a promotion for renewable energy, but it is also applicable to the question of nuclear versus coal, and striking the right balance between nuclear and solar.

If developing nations could get loans or vendor financing to develop nuclear plants, the up-front cost would be less of a problem, since they would be built with mostly local labor, steel, and concrete which allow them to produce energy for a cost which is easily competitive with imported fossil fuel (or fuel that would otherwise be exported at world prices).

The whole issue of nuclear and solar playing well together is a non-issue if nuclear and baseload solar (i.e. desert solar with storage) provide all baseload, and other solar is limited to peaking and does the much of the load following via curtailment. If wind power is introduced, then developing nations must also develop the domestic fossil fuel industry to go with it, and they must develop robust long-distance power transmission to smooth out the power flows.

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June 2, 2015

Grace Adams says:

Like it? 7

Most developing nations are close enough to the equator to make solar a much better option for renewable energy than wind. So I doubt that they will really want wind. Wind is good mostly more than 30 degrees away from the equator. They will want energy storage of some sort.

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April 17, 2014

Jesse Jenkins says:

Like it? 56

You're preaching to the choir with me Joe!

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Login or register to post comments

April 16, 2014

Bill Hannahan says:

Like it? 79

It makes no sense to spend 5 to 20 cents for an un reliable un dispatchable kwh in order to save 1/2 cent worth of uranium.

The simplest non breeder MSR can reduce uranium consumption per kwh by a factor of 5 due to improved neutron economics and higher thermodynamic efficiency at high temperature. Extracting uranium from seawater is estimated to cost about three times that of land based mines.

Factory mass production of simple non breeding land and floating MSR's can get the capitol cost down such that the plants could be profitable even at fairly low capacity factors without land based uranium mining.

Share this comment:

Login or register to post comments

April 16, 2014

Jarmo Mikkonen says:

Like it? 56

I think there has been very little thought on how to integrate wind and solar with base load. In Europe, the emphasis has simply been on how to increase renewable generation, and, in case of Germany, getting rid of nuclear.

The only country that has attempted a systematic approach is Denmark. They have not been interested to have two intermittent electricity sources on the grid (just one, wind). Solar applications have been about heating:

In Braedstrup, the community's solar district heating system stores heat in a borehole STES (BTES) facility that uses 19,000 cubic metres of underground strata as a heat battery. It can hold 500 mwh of heat at a temperature of 65 oC. Two water tanks provide additional heat storage. When extracting heat, a 1.5 MW heat pump boosts the temperature to 80 oC, for circulation in the district heating loop. The present system is the first expansion of an original smaller system, and now provides 20% of the community's heat on an annual basis, from a solar collector area of 10,600 square metres. A second expansion is planned, to provide 50% of the heat demand from a total solar collector area of 50,000 square metres and using an enlarged BTES store. The remainder of the demand is provided by electric and gas-fired boilers.

http://en.wikipedia.org/wiki/Solar_power_in_Denmark

This is the way to go without cheap storage. Use intermittent energy as locally as possibly, for applications that can use it when generated.

Recent German EEG reform attempts aims pointed to this direction. I think the *Energiewende* will show us by 2022 the feasibility of current approach (give subsidized renewables priority and dump them on the grid no matter what the demand is).

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April 16, 2014

Nathan Wilson says:

Like it? 76

Solar thermal heating has for years been the most economical form of solar energy, and solar swimming pool heaters have been popular in some locations. However, sunlight is weakest in winter when heat is needed most.

The district heating concept can be applied to nuclear power as well when the reactors are small and safe enough to be located near energy users, so new SMRs could be enablers of this application.

Conventional (LWR) nuclear plants can produce heat for about one third of the per kWh cost of electricity, and high temperature plants can deliver usable waste-heat while making almost their full electrical output. This means the nuclear solution for combined heating & power for district heating can displace more fossil fuel when substituted in a solar-dominated system than solar alone.

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April 16, 2014

Jarmo Mikkonen says:

Like it? 63

Nathan,

3 years ago Fortum Plc in Finland proposed that they would build a new reactor in Loviisa to eventually replace two current reactors. Furthermore, they proposed to build a district heating loop from the turbine to city of Helsinki to provide heat for the whole city. Currently disctrict heat in Helsinki is supplied by CHP plants using coal and natural gas. Biofuel was the other option.

Engineering firm Pöyry made a study which showed that nuclear option was very economical and would save at least two billion euros compared to biofuel (read: wood pellets) option in its lifetime and cut more emissions. The study is in Finnish:

http://www.jukkajonninen.fi/wp-content/uploads/2012/10/228-Fortum_Ydinkaukolampo_Poyryn_esitys.pdf

The Greens are the second largest political group in Helsinki City Council so you can make a bold guess which option was chosen....

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April 16, 2014

Robert Bernal says:

Like it? 64

The remainder of the demand can not be supplied by fossil fuels... in the end.

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April 17, 2014

Nathan Wilson says:

Like it? 71

"... if you *have* storage and flexibility, then renewables play just fine with nuclear. "

Yes, if we had a hypothetical 100% renewable grid (primarily solar and wind), with LCOE costs matching the current average for US wind power (about 25% less than nuclear according to the EIA, as it is weighted toward the central plains), and assuming use of battery storage which cost about one third of today's costs (so that it reached about $0.10/kWh), then it is likely that overall costs would be reduced by replacing a big chunk of the renewables with nuclear (especially in areas with poor solar & wnd resources), since storage and curtailment would also be reduced, and less transmission would likely be needed.

Likewise, for a 100% nuclear grid, it is likely that overall costs would come down if some of the nuclear in the south was replaced with solar (to boost summertime output), and possibly some wind in the north (to boost wintertime output, but this would entail large springtime curtailment).

But to get there from here is a problem that the renewable lobby does not like to discuss. They admit that a renewable-friendly grid must have **flexibility**, but flexibility in general is expensive. Flexibility comes for free with big hydro, but the only other energy source which can truly say this are those with high fuel costs (e.g. Hawaii's oil-fired grid). Even natural gas and biomass produce cheaper power in baseload mode than when load-following. Of course the demand variation will require some flexibility anyway. But substitute storage for the fossil fuel, and all of a sudden the cost of the *extra* flexibility needed by supply variation will become very apparent.

This cost of flexibility also applies on the demand side and shows up in the net-metering debate. Electricity users buy energy and flexibility. Home solar system owners who use the grid for backup or time-shifting need just as much flexibility as other users, but buy less energy. An electric car that is charged during the evening peak requires more flexibility from the grid, but one charged at night needs no added flexibility. So a billing system that gives away the flexibility for free to anyone regardless of how much electricity they buy will strike many as unfair.

With low penetration wind and solar, the external cost of flexibility caused by use of wind and solar is mostly born by fossil fuel fired merchant power producers, who receive no sympathy from the public. When public utilities complain of the added cost, they are accused of greedily clinging to an obsolete business model (generally by those who demand flexibility for free).

The result is that no large-scale energy storage solution or dispatchable load solution (thus no 100% renewable or renewable+nuclear grids) can be implemented unless and until **the cost of the missing flexibility is internalized into the cost of variable renewables**.

—

Great topic/kick-off Jesse.

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June 2, 2015

Grace Adams says:

Like it? 9

Can the cost of flexibility be internalized into the cost of variable renewables by measuring net metering in $ rather than kWh with time of day pricing? You don't want to drive suburbanites with rooftop solar off the grid into lower cost batteries completely, but you also don't want to end up trying to balance utilities' books on the backs of the poor. Utilities have a hard enough time trying to collect utility bills from the poor already.

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April 15, 2014

Like it?

Robert Bernal says:

73

Great, a call to join forces!

Full on closed cycle nuclear, full on rooftop PV and full on wind (and lots of powerlines). Since these create a lot of variables, and since we can't really throttle the nuclear baselod to match perfectly, the nuclear must make synthetic fuel as the storage buffer. The high temp nuclear could be coupled to gas turbines (of a higher max rating) designed to burn the synthetic fuel already hot, more efficiently and "instantly" variable. Theoretically, we wouldn't need the RE, but this would vastly minimize fission products and allow for the continued expansion of wind and solar. Now, the tricky part: figuring if there is enough "room" for smaller reactors, larger turbines and all that synthetic fuel storage in such a wildly fluctuating environment!

Edit: These are probably not options we already have but I'm sure that we have the tech to make it happen.

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June 2, 2015

Grace Adams says:

Like it? 7

Yes, synthetic fuel would be nice useful flexible load to follow variable renewables and variable but beyond power of utilities to control other loads. I would hope some of the synthetic fuel could be sustainable liquid fuels for transportation, especially diesel, since rechargeable battery electric vehicles could largely substitute for ICE engine powered vehicles for light duty vehicles.

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April 15, 2014

James Hopf says:

Like it? 72

It's a little bit too simplistic to lump all renewables in the same category, with respect to this question. Geothermal and hydro have no issues with respect to combining with nuclear (hydro would be great for use as peaking capacity). Solar generates its power roughly at the times of peak demand, so unless the penetration level is very significant (too high) it will act to flatten out the demand profile, making the remaining profile MORE able to be covered by baseload nuclear. It is only wind that has a significant problem combining with nuclear, in the absence of large scale energy storage.

Also, it seems that the discussion is considering one extreme scenario or the other, with respect to electricity storage cost. In the limit of extremely expensive storage, yes there are issues with mixing nuclear and renewables. At infinite, zero cost storage, either nuclear or renewables could provide all electricity, and mixing them together will also not be an issue at all. The answer will probably lie somewhere in between, where storage can make things practically possible, but will cost enough so that the amount of storage capacity will be an important factor, where minimizing the needed amount of storage will significantly reduce overall cost. It seems clear to me that a mixture of nuclear and renewables would require a significantly lower amount of storage capacity than any renewables only scenario.

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April 15, 2014

Jesse Jenkins says:

Like it? 68

Hi James,

Thanks for the comment. I think you're probably right about the spectrum of storage costs and nuclear/renewable hybrids. That's something I hope to explore in future modeling work with a colleague here at MIT.

Just to be clear: as I noted in the intro sentance, this post is focused on nuclear in combination with *variable* renewables like wind and solar, not more reliable sources like hydro, geothermal, or biomass.

Also, while solar better aligns with electricity demand than wind, that doesn't solve the integration issues with nuclear. If it reaches a penetration level where at mid-day, solar is producing close to 100% of load, nuclear will have to cycle off. Solar also is closer to peak, but not really on-peak. In nearly all regions, peak demand is experienced in late afternoon or early evening, not midday when solar systems are at 100%. So what we're seeing in some of the modeling around here (MIT) of high-penetration of solar is that the remainder of your system (i.e. excluding solar) becomes a "double peaking" system: you get a peak in late morning, then a big trough as solar ramps up around midday, then another sharper peak in the afternoon/evening as solar falls off and peak demand picks up. That actually *increases* rather than decreases the need for fast-ramping system capabilities. California regulators have dubbed this the "Duck Curve," while Jeff St. John calls the even more pronounced situation in Hawaii the "Nessy Curve" (both for their shapes).

Cheers,

Jesse

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April 16, 2014

B W says:

Like it? 68

the trough created by the duck curve could best be solved by an energy sink rather than storage because an energy sink would have greater efficiency. If we can sink the nuclear output in industrial heat applications, desalination, fuel synthesis, or possibly even CO2 sequestration from the open air (as Berkeley research suggests we may be able to) we could maintain a healthy utilization of our nuclear plants in combination with larger capacities of solar.

The question then becomes: would the variable use as nuclear capacity for energy sink purposes be economically viable (the nuclear plant output would go to the sink according to the PV output, and therefore become variable). I am not sure of the answer to this question, most industrial processes run according to tight schedules and thermal capacities are sizes specifically according to need. Inputting a variable contributor to the energy sink may undermine the economics, but perhaps in cases of desalination such variability wouldn't be such an issue.

I think the best solution would be to construct large elevated reservoirs that would double as energy sinks for desalinated water and act at the same time as a form of stored hydro energy capacity.

i have little doubt that principally nuclear and solar can approach the cost of fossil fuels, if we can overcome the fossil lobbyists and excessive litigation.

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June 2, 2015

Grace Adams says:

Like it? 6

Yeah! California and its neighbors to the east can certainly use the desalinated seawater. And some pumped storage hydro should also be welcome. Maybe the most politically feasible, if not really cost-competitive, way to cope with fossil fuel lobbyists would be a program to buy fossil fuel reserves especially coal as mineral rights at fairly generous prices to support income of too big to fail (politically powerful) fossil fuel firms (limit to keeping their incomes up to a fair amount). Also sell much of the synthetic fuel through too big to fail oil firms, splitting the income between the nuclear power plant operator and the too big to fail oil firms.

Share this comment:

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April 17, 2014

Marcus Pun says:

Like it? 65

I have never thought that it was an either or for nuclear and renewables. A solid base load is critical to maintaining economical electric power.

Ultimately this all comes down to storage. In other posts I have brought up the rather clever use of 3MWH of storage over at Gil Onions in Southern California - storing 5-7 cent/kwh power at night and using it to replace power from the grid that costs up to 30 cents/kwh. Flow battery technology storage is practical, ready to go, but the infrastructure for marketing, production, installation is not there. That means the prices are high per installation. Solar had this problem until a few years ago but anyone who has driven by a Solar City yard or that of any other installer undoubtably has noticed that they are now rather crowded with vehicles at the end of the day where a few were parked only a few years ago. Perhaps the next government sponsored push should be for local storage in areas where the power, due to storms and other natural disasters, is less than reliable, and to also build out in areas where there is a lot of wind power.

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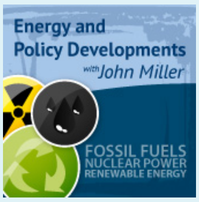

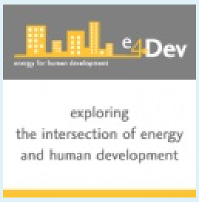

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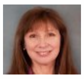
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