Valuing Flexibility: Looking at the Effect of Renewables on Fossil-Fuel Electricity Generation

BY JULIAN SILK

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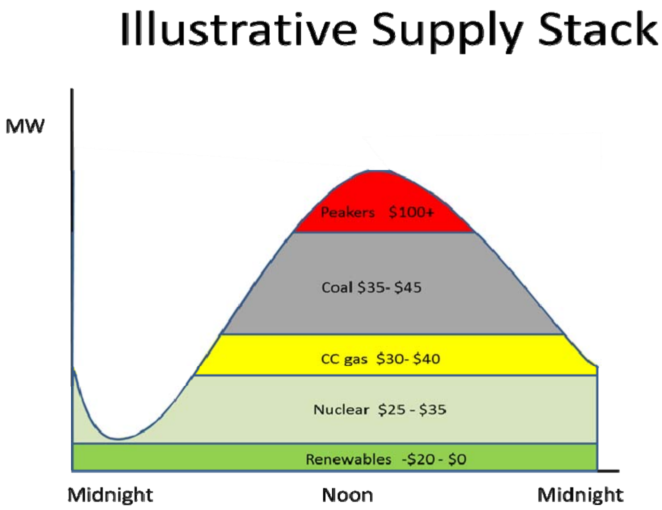
The supercripts refer to references at the end of the text.

Re-Opening the Case

In Jenkins (2018), it is stated that "In short, cheap natural gas may be killing the profitability of nuclear power producers in the PJM Interconnection, but stagnant electricity demand and expectations of future growth in wind generation going forward may be accomplices."[1] There is no mention of the effect of the need to take on current supply of renewable energy in this list of the guilty. This is in stark contrast to the views of Scott Vogt, VP of Energy Acquisition, ComEd, "Integrating Renewable Energy into the ComEd Supply", in the Dual Plenary Session, "Challenges and Opportunities for Renewables", of the United States Association for Energy Economics (USAEE) meeting in Tulsa, Oklahoma in 2016[2]. The following is slide number 8 (of 9) from his presentation. The horizontal



axis should be taken to be hours in the day. The height of the figure in the vertical axis is the number of MW demanded during the hour. Crucially, this is *not* what can be or is *supplied* during the hour, but what is demanded – there is a big difference which is crucial for nuclear power.

When a surge of wind does come on, and the electric system has to take it, and the demand isn't there, the locational marginal price (LMP) at the node reflects the Independent System Operator (ISO) or some other agency *paying someone* else to take the power.

The distinction will be relevant for Maryland in short order. In Maryland, the state legislature, controlled by the Democrats, overrode Republican Governor Lawrence Hogan, who vetoed an attempt to increase the mandated renewable share of electricity produced in the state from 20% by 2022 to 25% by 2020, so their proposal will go into law[3]. This may have a direct effect on the Calvert Cliffs nuclear plant. The Calvert Cliffs nuclear plant has a number of similarities to the recently closed Indian Point nuclear power plant in Westchester County, New York. The Indian Point closure can be traced to a number of factors: political opposition from environmental groups in-state, which has extended to opposition to subsidies for upstate nuclear power as well; the age of the facilities (they would have had to be re-licensed), and the low price of natural gas[4]. But there are a number of similarities between Indian Point and Calvert Cliffs: the relevant facilities were built at almost the same time; the distance between the plant site and a major metropolitan area (or in the case of Calvert Cliffs, two – Baltimore and Washington, DC) is about the same; the same environmental groups oppose both; and both are about the same distance from the seacoast. Both plants are about the same size as well, since a planned third unit for Calvert Cliffs has been abandoned. Both face low natural gas prices. There have been more environmental problems with Indian Point than with Calvert Cliffs, and Maryland has a Republican governor, who supports Calvert Cliffs, while New York's Democratic governor Cuomo has consistently opposed Indian Point. Nevertheless, the similarities are striking, and Governor Cuomo does support nuclear power for upstate New York[5].

If natural gas prices stay low (relatively), and Calvert Cliffs faces financial difficulties, this will be support for the case made by Jenkins. But what if natural gas prices *rise* and are relatively high, and Calvert Cliffs faces financial difficulties? This would be support for the case made by Vogt. Vogt's case is also supported by Bajwa and Cavicchi (2017), which argued that increases in renewable energy use have led to increased frequency of negative electricity prices[6]. Negative electricity prices have also occurred elsewhere, particularly in Germany[7]. Davis (2017) argues the culprit for negative electricity prices is hydroelectricity[8]. But this can hardly be the case for Australia, which has also experienced frequent negative electricity prices[9].

The following is an attempt to outline conditions under which one case or the other can occur. This is probably a foolhardy venture, given the criticism launched by Green (2012)[10]. I am at fault in not making clear that the increase in costs is not an increase in operations and maintenance (O&M) costs per unit of energy for every unit of electricity the fossil producers supply. But the presence of renewable energy, the requirement to use it in the face of variable demand, and its intermittent nature and unpredictability are certainly *suspect* in increasing the difficulty the fossil producers are having. This is clear for natural gas, in that there must be some backup capacity that is used all the time – so the quantity of natural gas used is increased over what it would otherwise be. It is also relevant for both coal and nuclear; coal has to be prepared for some degree of ramping, and the insertion of nuclear into the relevant mix of supply is rendered more difficult. When Professor Green states: "Furthermore, I cannot conceive of a way in which, as in Dr. Silk's world, the presence of a quota of high-cost generators somehow raises the costs of every other generator on the system", this is almost a semantic distinction. The renewable energy doesn't raise the supply costs, but it certainly is a possibility in raising the integration costs. Moreover, the reader may allow me to respond to "This somehow leads him to conclude that the fossil generators would now have a higher marginal cost than the wind farms and would, therefore, require a subsidy if they were to continue to operate" with some care. If the increased difficulties of nuclear power in Illinois that Vogt discusses are not *exclusively* because of low natural gas prices, (or at best the other suspects Jenkins mentions), but also because of the renewable portfolio standards, then the "require a subsidy if they were to continue to operate" is exactly what is happening. Note also that my argument was made years before these subsidies were approved by the state legislatures in question.

The argument here, necessarily awkward as a first attempt, will be an attempt to display flexibility, which seems to me to be the decisive factor, in graphs of the usual supply-demand type. It is my hope that this will illustrate what to look for in the particular cases, in particular, not just prices, but quantities used. It is beyond the scope here to do a statistical analysis to determine which is relevant at the present; it is possible that a panel data analysis using the renewable portfolio standard map provided by DSIRE vs. the financial statistics of the affected fossil fuel generators could provide some insight on this issue[11].

Cases

All the case descriptions that follow will be similar to those of the Hans Auer and Reinhard Haas graph, shown below as Figure 1[12]. My graphs will only describe immediate prices and the merit order that the Independent System Operators (ISOs) are facing in the immediate short run, and will definitely not be as descriptive as the Auer-Hass graph. In these graphs, the simplest possible cases are being described. So, for example, in the first case, there is no pretense that demand is always constant and stable, and certainly no pretense that renewable output is stable for the first two. It is just a matter of focusing on a particular aspect. As with the Auer-Hass graph, all vertical axes are price (though in $/MWH, though this makes no real difference as long as we are consistent), and all horizontal axes are MWh. To simplify life, we look at wind (assumed to have a cost of zero), nuclear and natural gas, and ignore everything else, including hydroelectricity and coal[13]. Quantities are intended to be indicative, not exact.

The Low Natural Gas Price Case –

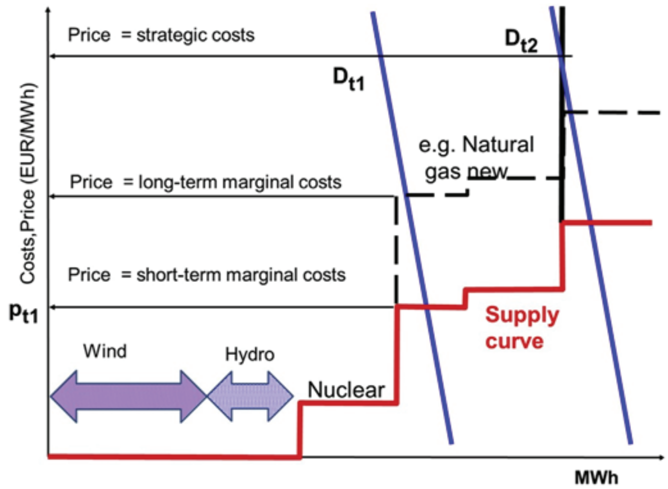
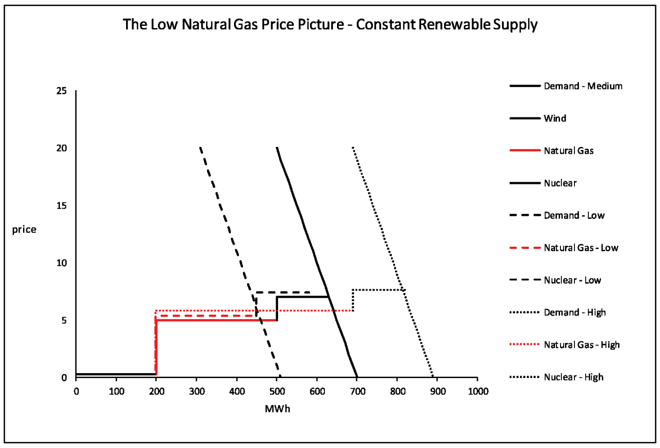


Figure 1 Merit order supply curve with additional wind capacities (incl. run-of-river hydro) at off-peak time with total costs or strategic bidding for conventional capacities. (Source: own illustration).

Constant Renewable Supply

The first case below should be reasonably transparent. When demand is medium, what is expected, the solid lines indicate the merit of order of supply.

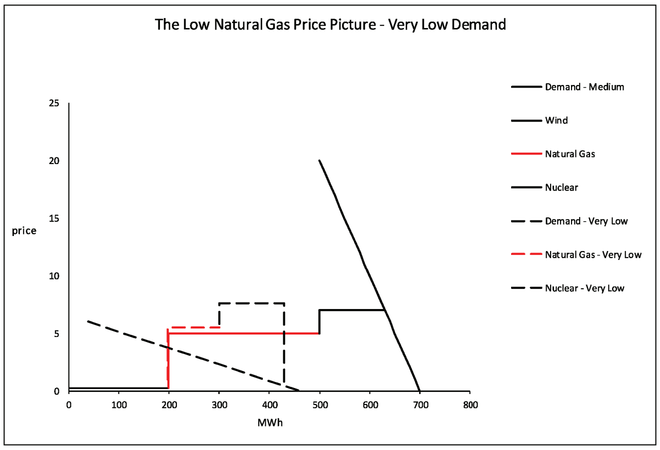


Renewable energy (the solid green line) is basically constant relative to how demand changes, and the ISO can easily cope with the very minor variations that occur. Natural gas supply (the solid red line) makes up the bulk of the supply. Nuclear energy (the grey solid line) always has a higher supply price (or marginal cost) than natural gas, and the difference remains constant. So nuclear energy marginal cost sets the market price, and nuclear energy makes no profits, but suffers no losses, while natural gas and renewable energy both make profits.

For low demand, natural gas output (the red dashed line) contracts significantly, because of its flexibility. Nuclear output (the grey dashed line) cannot contract. In this particular case, market price is in between the constant natural gas supply price and the constant nuclear supply price. This case is worth looking at because here again, both natural gas suppliers and renewable energy suppliers make profits. The nuclear suppliers, who can't contract, make losses, but the losses are not equal to total nuclear output times the difference between nuclear and natural gas supply prices. They are less. As long as market price is greater than zero, it will make sense for the nuclear suppliers to stay in the market in the short run, along the usual argument of price greater than average variable cost.

As long as demand does not fall below the minimum of natural gas supply plus the assumed constant renewable supply (suppose for simplicity this is 300 MWh total, at a price of $5/MWh), natural gas suppliers will not suffer losses. The renewable suppliers never do in this case, as long as price is greater than zero. But the nuclear suppliers do suffer increasing losses as demand declines, unpredictably. It will be easier to see this in the next case, but suppose we can imagine demand falls to 200 MWh at a price of $3/MWh. We can't have the same demand function and have positive or even zero prices, but suppose for simplicity that demand becomes more elastic in this very low price environment. As long as demand at a price of zero is greater than the sum of the all the supplies, the unchanging renewable supply, the minimum natural gas supply and the inflexible nuclear supply, a positive but very low price will prevail in the market. This is shown in the following graph:

Here, both the natural gas suppliers and the nuclear suppliers are suffering losses, but the same argument



keeps them in the market in the immediate short run. Of course, this is a very unlikely case, at least for the present, but it is included for completeness. The much more likely case is that the demand schedule does not change that much, even for very low demand, and prices turn negative.

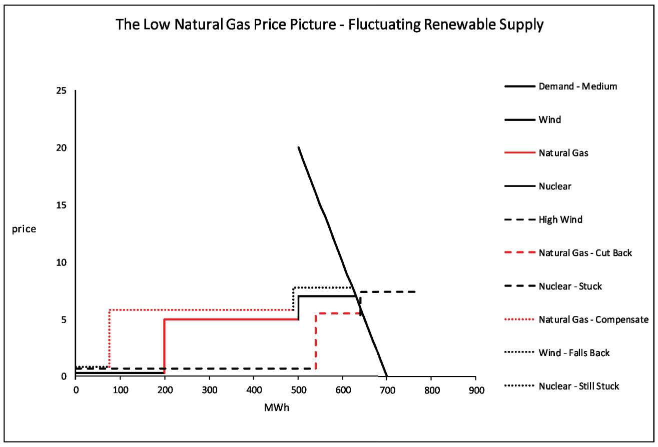
One more case is described in the *Low Natural Gas Price - Constant Renewable Supply* graph shown previously, in the case of high demand. Here natural gas supply expands dramatically and the natural gas facilities make profits once again. Here again, the nuclear suppliers make no profits, but do break even. The renewable suppliers do make profits.

Summing up, if renewable supply is relatively stable compared to demand, the renewable suppliers make profits. Given this situation but varying demand, natural gas suppliers can suffer losses, but the losses are only if market demand is low. The nuclear suppliers are the ones who really suffer dramatic losses if demand is low. The problem for them is that they never make profits to cover for these losses unless market demand, even if high, exceeds the sum of all the renewables can provide, all the natural gas suppliers can provide, and all the nuclear power suppliers can provide, here for the nuclear power supply price of $7/MWh. Such extreme cases would invite purchased power (the equivalent of imports) which would probably be natural gas also. It is possible to imagine excess purchases (of imported or locally produced natural gas) in the case of high local demand also leading to zero or negative prices, but these would seem to be unlikely. Barring this, the relevant point is that nuclear power losses should be highly correlated with low demand for this case of relatively stable renewable supply and low natural gas prices.

The Low Natural Gas Price Case – Fluctuating Renewable Supply

Here, to simplify life, demand will be assumed to stay absolutely constant. The flexibility of natural gas allows it to cope with fluctuating renewable supply. Here again, nuclear power suppliers suffer losses, but not always – only when renewable supply is high. For such cases, there are negative electricity prices.

It is important to note what happens in the high renewable supply case for the natural gas suppliers.



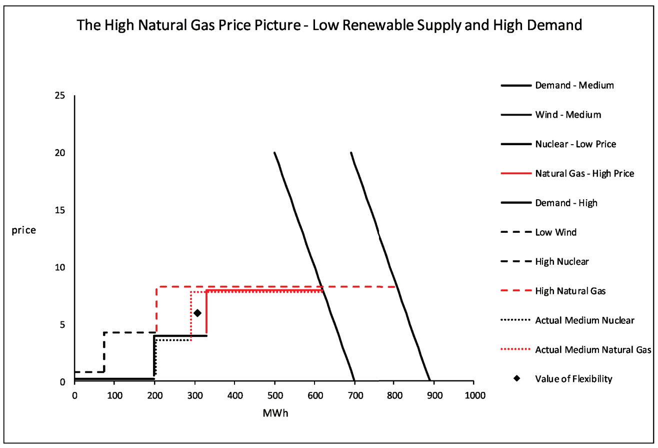
They also suffer the negative prices. But again, in the medium or low renewable supply case, they make profits to compensate for them. In the low renewable supply case, the renewable suppliers and the natural gas suppliers both make profits. But the nuclear power suppliers do not – they break even. So they have losses or they break even; they can't compensate for the losses.

The Value of Flexibility – The High Natural Gas Price Case

This will be the only really new argument. It will be argued here, for the case of high natural gas prices, that the ISOs will still choose natural gas as the compensating source of supply, even though the supply price of natural gas will be greater than that for nuclear generation. Why? Because there is enough uncertainty in *both* supply *and* demand to have a significant value for natural gas because of its flexibility, even though it doesn't show up in the reported (or reportable) costs.

It turns out that the value of flexibility occurs when there is a combination of events, not just one. Suppose we take the case of high market demand and low renewable output, occurring unpredictably after the standard normal case is observed. Then we have the following graph:

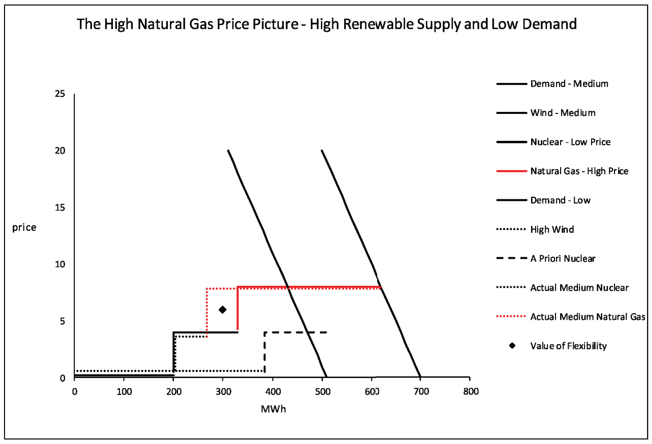
In order to be prepared for the unpredictable jump in market demand, coupled with the fall in renewable



output, more natural gas will be used than would be the case if everything were perfectly predictable far in advance. The (vertical) rectangular area denoted with the diamond is the value of flexibility in this case, the savings at the second for using nuclear power times the quantity of nuclear power foregone, so that if the high demand-low renewable case occurs, there will be enough flexible natural gas to cope with it.

It would seem that with the low demand, high renewable supply case that nuclear power would be used to the full. But this is misleading again; not only can nuclear power (as conventionally used) not go up enough and quickly enough, it can't come down enough and quickly enough, either. The situation is described in the following (similar) graph:

The value of flexibility is shown in the same area marked by a diamond, here a gold one. If nuclear



power were unchanged, then with the combination of circumstances, negative electricity prices would happen, since there is excess supply – this is shown with the "A Priori Nuclear". Even reducing the nuclear supply doesn't guarantee positive prices, if the renewable (wind) surge is big enough. But it reduces the probability.

The cases where natural gas is still used, because of the value of flexibility even with high natural gas prices thus result from a negative product of the difference between expected market demand and actual and the difference between expected renewable supply and actual. With a symmetric probability distribution of outcomes, there is reason to believe such negative product results could occur often, though perhaps not 50% of the time.

In the other two cases, where the product was positive, nuclear power would earn positive profits. Even so, unless nuclear power (and coal generation) could become flexible as well, the total profit earned would not (necessarily) be enough to compensate for all the foregone profits – for all the installed nuclear facilities - as natural gas is substituted for nuclear in the negative product cases[14]. Some of the nuclear would have to be cut back or put out of operation.

It is tempting to think that the cutback in nuclear could be analyzed by a simple expected value calculation. Suppose probability of the negative product cases is p(N), such that p(N) + 1 – p(N) = 1. Suppose the desired cutback in these cases would be r_N. Then it is natural to think that the actual cutback would equal p(N)*(r_N). If the negative cases were assumed to occur with 100% probability, then the cutback would be r_N itself. It is likely that the cutback will be somewhere between these two possibilities, and will depend on the actual probability distribution of the occurrence of the negative product – possibly using some sort of value at risk principles.

Of course, the value of flexibility is not infinite even in these two cases. If natural gas prices were high enough, and nuclear power was inexpensive enough, then nuclear power might be run at all times to power batteries or some other storage mechanism, and natural gas would be foregone. This is not a reasonably cost-effective solution in the immediate future, under any reasonable scenario for natural gas prices.

Conclusion – On Avoiding the Backlash Against Renewable Energy

The argument above is an attempt to isolate exactly what renewable energy is doing to cause financial distress for fossil fuel electric generation and when, and how whatever effect there is can be distinguished from the effect of natural gas. Shale gas has reduced natural gas prices significantly from what they were in 2000-2008, but it is likely that the trough has already been passed, though the rise may stall, or be slow. The one innovation here has been an attempt to argue that high natural gas prices, given the uncertainty of estimation of market demand and renewable energy supply, is by no means sufficient to avoid generating such financial distress.

The financial distress involved affects people's jobs and has already caused backlash. Oklahoma has joined West Virginia in repealing support for renewable energy, and it is possible that Indiana could also join in the near future[15]. It's easy to say that these are just bumps in the road: Dominion Virginia Power is planning to build offshore wind turbines (a first for the state), and Hawaii is looking into have all power supplied by renewable energy, so why worry?[16]

Such attitudes are very dangerous. The Center for the American Experiment, using IMPLAN, found that Minnesota's renewable energy mandate generated about 6,000 jobs, but the increased costs caused a loss of about 8,000 jobs[17]. Of course, this result has been criticized, and it is possible that some counting method that includes public health benefits might result in a net job gain, but to those who lose their jobs, this is very cold comfort[18]. The people who are losing their jobs are in the "red" (Republican) states, and one gets this sense of condescension, that these people really don't matter, and we know what's best for you. This can lead to political backlash, and can cause reduction in renewable sales and loss of momentum, at best, in any effort to reduce global warming with renewable energy.

There are outright hostile critics of renewable energy; the late Glenn Schleede was one[19]. The argument here has nothing to do with that; it is a matter of being honest about renewable energy costs.

This was behind my attempt to write down pricing for renewable energy in what in essence was a real-time pricing form. Suppose, for example, that wind energy (when all the capital costs are included) has a levelized cost of electricity of 18 ¢/KWh, fossil fuels have a cost of 12 ¢/KWh, and on average wind blows 1/3 of the time. We have a renewable mandate to use, say 25% of electricity from wind. Then our expected value of electricity cost is

$$(2/3)*12 + (1/3)*18 = 14 \text{ ¢/KWh}$$

and this is what retailers like Pepco or others will charge consumers. But this is making Pepco and the other retailers much more like insurance firms than they used to be; they are absorbing all the risk of the quantity renewable energy not conforming placidly to its average value. The real-time pricing idea was an attempt to see what would happen if risk were minimized for them.

It is possible that some model can be developed so that their absorption of the risk of renewable energy would increase profitability for them in a static setting. But it is worth considering the possibility that global warming may make the risk associated with any given level of renewable use increase, because the volatility of renewable supply increases, so that the problem becomes worse over time, and not better.

Clearly, there are market fixes for these problems to some extent. The increased use of renewable energy has resulted in a substantial increase in electricity transmission investment; this is one of the best effects it has had[20]. But there are efforts that can be made by targeted government intervention to bring jobs to the people who are being affected by renewables, or the effects of natural gas, once we are clear what they are. It is crucial that the jobs make use of the skills people have developed over their lifetimes, not what they might develop in several years in the future.

One project could be to spend $500 million (or more) to develop West Virginia factories making glass or other reflectors for concentrator photovoltaic (PV) cells. (Concentrator PV is more expensive than regular PV, but also more efficient in converting sunlight (Young, 2015)[21]. It is being developed in Canada with Morgan Solar's "Alberta Solar One" (Hamilton, 2016)[22]) A target for concentrator PV costs might be to $12 per watt power, part of the Department of Energy goal of $1 per watt power for PV of all types (Wesoff, 2017 and Wiesenfarth et. al., 2017) [23]. Mosser Glass could participate, but the project would be open to other entrants as well. The glass manufacture could use the silicates produced by the coal industry, and thus coal and renewable energy could start being seen as complements instead of substitutes.

Another could be looking at sequestration or pumped storage. Increasing natural gas production in shale and coalbed methane reservoirs in Central Appalachia has been discussed (Gilliland et. al., 2015)[24]. A similar project to sequester CO_2, if it could be developed, would enable tapping a lot of coal mines which aren't currently used. Mert Atilhan mentions that coal mines with nanoclay structures might be candidates, and there may be others[25].

Something similar might be done by construction of pumped storage hydroelectric power units in West Virginia like the one in Northfield Mountain in Massachusetts (Gellerman, 2016)[26]. This could be very expensive, but it would be very valuable as a backup for intermittent renewable power. The nature of its development could use the same engineering and laboring personnel (the miners in particular) who have suffered because of coal's troubles.

How exactly is developing concentrator PV or developing pumped storage, or sites for the storage of CO2 from natural gas (or coal) anti-renewable energy? What is the net effect of developing offshore wind if onshore wind is diminished? If the effects of renewable energy can be honestly and openly analyzed, with costs laid right out on the table, and the problems with natural gas or other features of energy supply can be distinguished and dealt with, then a political coalition of all parties involved will accomplish something real.

References

1 Jenkins, Jesse (2018), "What's killing nuclear power in U.S. electricity markets? Drivers of wholesale price declines at nuclear generators in the PJM Interconnection", online at file:///C:/Users/User/Downloads/WhatsKillingNuclearPowerInUSE_preview.pdf.

2 See https://www.usaee.org/usaee2016/program.aspx, for Tuesday October 25, View Presentation for Scott Vogt under the Dual Plenary Session with this title.

3 On this conflict, see http://www.wbal.com/article/211772/21/hogan-announces-2017-environmental-agenda. The optimistic view that this increase will cause no more than a 58 cents per month increase in electricity bills is insisted in http://wypr.org/post/democrats-hogan-fight-over-wind-and-solar-energy. The alternative view that the increase will cause a 77 cents to a few dollars per month increase in electricity bills, calculated by state legislative analysts, is reported in http://www.baltimoresun.com/features/green/blog/bs-md-hogan-energy-policy-20160607-story.html. The override vote is described in http://www.utilitydive.com/news/maryland-senate-overrides-gov-hogans-veto-of-energy-bill-raising-renewab/435424/.

4 On the closure, see http://www.lohud.com/story/news/local/westchester/2017/01/18/local-officials-shocked-surprised-indian-point-news/96723522/. The litigation is described in http://www.lohud.com/story/news/local/indian-point/2017/01/09/entergy-litigation-indian-point-shutdown/96352404/. The suit was reported by the Associated Press, and has been repeated in a number of locations, including http://www.recordonline.com/news/20161201/ny-sued-over-subsidies-for-nuclear-plants. Natural gas is mentioned as a factor in http://www.utilitydive.com/news/ny-gov-cuomo-pushes-closure-of-entergy-indian-point-nuke-in-nrc-filings/409586/.

5 Details on Indian Point are in https://en.wikipedia.org/wiki/Indian_Point_Energy_Center, which is more informative than Entergy's discussion of the plant.

Details for Calvert Cliffs are from https://en.wikipedia.org/wiki/Calvert_Cliffs_Nuclear_Power_Plant. On Governor Cuomo's support for nuclear power in upstate New York, see http://www.politico.com/states/new-york/albany/story/2016/07/cuomo-nuclear-plan-blunts-criticism-by-combining-it-with-renewables-103962.

6 Maheen Bajwa and Joseph Cavicchi, "Growing Evidence of Increased Frequency of Negative Electricity Prices in U.S. Wholesale Electricity Markets", IAEE Energy Forum, Fourth Quarter, (2017), 37-41.

7 See Jeremy Berke, "Germany paid people to use electricity over the holidays because its grid is so clean", December 29, 2017, at https://www.businessinsider.com/renewable-power-germany-negative-electricity-cost-2017-12.

8 Lucas Davis, "Is solar really the reason for negative electricity prices?", August 28, 2017, at http://blogs.berkeley.edu/2017/08/28/is-solar-really-the-reason-for-negative-electricity-prices/.

9 Giles Parkinson, October 27, 2017, "Graph of the Day: Negative prices in windy South Australia", at https://reneweconomy.com.au/graph-day-negative-prices-windy-south-australia-26387/.

10 This controversy was published in the Spring and Summer 2012 issues of the IAEE Forum. My original argument was in Julian Silk, "Welfare Analysis of Offshore Wind", IAEE Forum, 2nd Quarter, 2012, 13-18, at www.iaee.org/en/publications/newsletterdl.aspx?id=165. Professor Green's argument is in Richard Green, ""Welfare Analysis of Offshore Wind by Julian Silk: A Comment", IAEE Forum, 3rd Quarter, 2012, 27-28 at www.iaee.org/en/publications/newsletterdl.aspx?id=177. My response is in "Response to Professor Green's Comment", IAEE Forum, 3rd Quarter, 2012, 29. Professor Green's many publications are listed in https://www.imperial.ac.uk/people/r.green/publications.html. There will be no comment here on what may seem the most pertinent, Green, Richard & Vasilakos, Nicholas, 2011. "The economics of offshore wind," Energy Policy, Elsevier, vol. 39(2), pages 496-502, February.

11 The DSIRE map is at http://www.dsireusa.org/resources/detailed-summary-maps/, but has not been updated since February 2017.

12 See Hans Auer and Reinhard Haas, "On integrating large shares of variable renewables into the electricity System", Energy xxx (2016) 1-10, at http://www.eeg.tuwien.ac.at/eeg.tuwien.ac.at_pages/staff/staff_detail.php?id=12#pu. This graph is from the 2nd page, and is more applicable to Maryland than those following. See also Aaron Praktiknjo and Georg Erdmann, "Renewable Electricity and Backup Capacities: An (Un-) Resolvable Problem?", The Energy Journal, Vol. 37, SI2, 89-106, at https://www.ensys.tu-berlin.de/fileadmin/fg8/2016_energy_journal_praktiknjo_erdmann.pdf.

13 In doing this, we are ignoring any particular differences caused by the continuing use of coal at Brandon Shores, Chalk Point, Morgantown, Charles Crane, Dickerson and Warrior Run. See https://en.wikipedia.org/wiki/List_of_power_stations_in_Maryland.See also Barry Casell, "NRG delays planned deactivations for five Maryland coal units for another year", May 1, 2015, at http://generationhub.com/2015/05/01/nrg-delays-planned-deactivations-for-five-maryland.

14 There is some literature on the possibility of nuclear power and coal generation becoming more flexible. For nuclear, see http://www.utilitydive.com/news/how-market-forces-are-pushing-utilities-to-operate-nuclear-plants-more-flex/427496/. The case of particular interest is the Unterweser facility in Germany, whose ramping profile is available from E.ON Kernkraft. A more skeptical view is from Laurent Pouret and William J. Nuttall, (2015), "Can Nuclear Power Be Flexible?", at http://www.templar.co.uk/downloads/0203_Pouret_Nuttall.pdf. Costs are examined in Thure Traber and Claudia Kemfert, "Gone with the wind? -- Electricity market prices and incentives to invest in thermal power plants under increasing wind energy supply", Energy Economics, 2011, vol. 33, issue 2, 249-256. For coal, see Alexander Buttler, Christian Kunze and Hartmut Spliethoff, "IGCC–EPI: Decentralized concept of a highly load-flexible IGCC power plant for excess power integration", Applied Energy, Volume 104, April 2013, Pages 869–879 and Matthias Meierer, Grosskraftwerk Mannheim AG, 16 December 2016, "Operating a coal fired power plant in a flexible market environment"), are at http://www.eecpowerindia.com/with-vgb-germany-technical-support-eec-and-igef-are-jointly-organising-a-national-seminar.htm.

15 The status of renewable energy mandates as of 2017 is in http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx, which notes West Virginia's repeal. Oklahoma has moved to end subsidies for wind; see https://newsok.com/article/5592693/lawmakers-take-aim-at-wind-energy-subsidy. A bill was introduced in Indiana to eliminate net metering, which would damage solar energy; see https://energynews.us/2017/01/24/midwest/indiana-energy-bill-would-eliminate-net-metering-move-to-buy-all-sell-all-solar-model/.

16 For the Virginia offshore wind project, see https://www.richmond.com/business/updated-dominion-moves-ahead-with-plan-to-build-a-pair/article_58724013-75d9-5934-a266-3fb7096a002a.html. For a (sober) view of Hawaii, see https://www.utilitydive.com/news/hawaii-far-from-100-renewables-but-running-ahead-of-schedule-state-find/527171/.

17 See https://www.americanexperiment.org/green-energy-fails/ and http://info.implan.com/policy-making-webinar.

(References continued on page 21)