Can't We Just Replace Coal With Renewables? (Hint: No)

December 6, 2019

It has become popular to claim that renewable power can replace electricity generation from coal-fueled power plants while lowering costs to consumers. Studies that make this claim tend to use dubious economic assumptions about the cost of generation while ignoring real and important differences in the way each resource provides power. Coal generation can be scheduled to run when needed and can increase output as customer demand increases. Wind generation arrives when the wind blows, and is typically highest in the overnight hours when power demand is at its minimum and lowest when power demand peaks in the late afternoon. When we examine what replacing large amounts of coal with large amounts of renewables would actually mean to the hour-by-hour operation of the power grid, it is clear these cost savings could not materialize. It is also clear that the grid would strain to meet customer demand for electricity.

One recent report claiming renewable generation could replace coal generation at a lower cost was submitted by Applied Economics Clinic ("AEC") to the Indiana legislature's 21st Century Energy Policy Development Task Force.[1] The AEC report concludes that replacing the coal generation in Indiana with renewable resources would lead to lower costs for Indiana electricity customers. To reach this conclusion, the authors identify the amount of electricity generated from coal (77 million MWh in Indiana in 2018), propose a cost per-MWh for that coal generation, and assume it is replaced on a MWh-by-MWh basis by renewable generation at a different (and lower) presumed cost. This naïve approach assumes that Indiana's annual power demand is akin to a bucket that can be filled however and whenever we choose, but that is not the case. Electricity demand varies day-by-day, hour-by-hour, and minute-by-minute, and power must be generated at the precise moment it is needed.

What would it look like if we actually replaced Indiana's coal generation with renewable generation in 2018? Indiana is primarily in the Midcontinent Independent System Operator (MISO) region, and both the state and the wider MISO region are dominated by coal, natural gas, and wind generating capacity (see the table below). Although hourly load and generation data are not available for Indiana individually, they are available for the MISO market[2] and we can use

[1] B. Woods and E.A. Stanton, *A Future for Indiana Coal: Emissions and Costs of Alternative Electric Generation*, Applied Economics Clinic on behalf of Indiana Citizen's Action Coalition, October 17, 2019.
[2] Hourly data used here is available at MISO's web site, https://www.misoenergy.org.

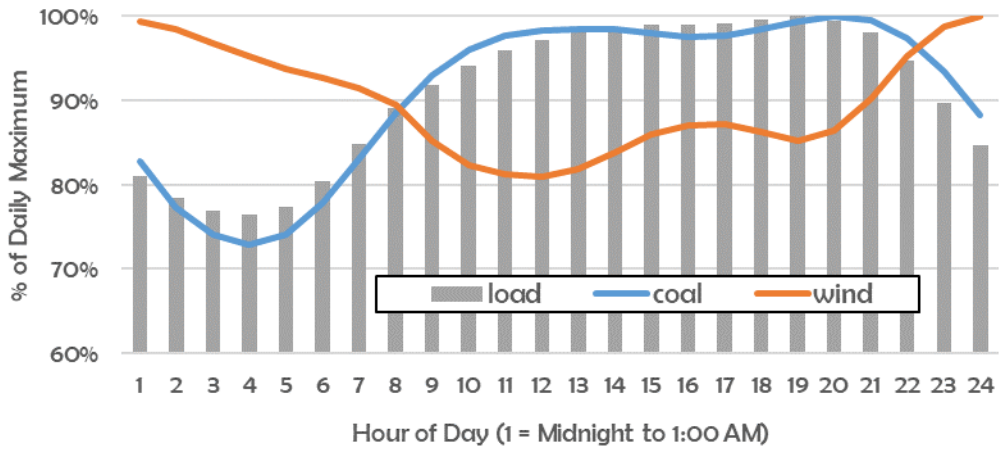
these data to see what would have happened in 2018 if renewable generation replaced coal.[3] What we learn from MISO would apply even more to Indiana as it is more coal-dependent.

2018 Generating Capacity (Summer Rating)[4]

	INDIANA	MISO
COAL	57%	33%
NATURAL GAS	30%	38%
NUCLEAR	0%	7%
HYDRO	0%	6%
WIND	9%	11%
SOLAR	1%	1%
OTHER	3%	4%

In order to replace MISO's 2018 coal generation of 296.9 million MWh with wind generation, we would have to scale the region's 50.2 million MWh of wind output in 2018 up to 347.1 million MWh. Yet we cannot change the timing of this generation to match the timing of the coal generation it replaces. The wind blows when the wind blows, and we know when the wind blew in 2018. As the following chart shows, wind generation was highest when MISO load was at its lowest, while coal generation follows load closely.[5] Replacing coal with wind will disproportionately add more generation in off-peak hours and less in peak hours.

Average of Daily Generation and Load by Hour, MISO 2018



[3] We assume the added renewable generation will be wind power as there is very little utility-scale solar power in the Midwest due to the region's relative abundance of wind, and we assume here that this trend will continue.
[4] Indiana data is taken from 2018 EIA-Form 860 information; MISO generating capacity is taken from S&P Global Market Intelligence database.
[5] Statistically, coal generation was 87% correlated with load while wind generation had a negative 20% correlation, meaning wind output tends to decrease as MISO load increases.

When we substitute an equal amount of wind generation for coal generation, as the AEC report suggests, we find not only a 2018 version of MISO that would need to incur additional costs that AEC doesn't address, but we find a comic version of the MISO system that no grid operator would accept. In particular, we find that:

1. **At times when it least needs it, more wind power would be generated by the system than MISO can possibly use.**
    - Wind generation is greater than total MISO load 11.5% of the time. This means that not only would wind replace coal, it would have to replace nuclear, hydro, natural gas, and all other generators as well during those hours—and there would still be too much generation. This is obviously a nonsensical result, as many of these other generators cannot simply cycle on and off in response to wind generation, and the excess wind generation would have to be disconnected in order to preserve grid stability.
    - The amount by which wind generation exceeds load is not small, and is more than 10% of system demand during nearly 8% of hours. At its greatest, wind generation alone exceeds total system load by an astounding 60%.
    - If natural gas generation is assumed to ramp down to offset the glut of wind power (but nuclear, hydro, and other generation are not), then MISO has an unusable surplus of generation 22.6% of the time.

2. **During periods of high demand, there is not enough new wind power to make up for lost coal output, forcing other sources of generation to increase their output.**
    - Other existing generators (likely natural gas) would need to increase their output in 55% of the hours of 2018 in order to make up the shortfall.
    - The amount of generation shortfall that must be met when additional natural gas generation is needed is not small, averaging 21% of system load (with a high of 52%).
    - This would amount to an increase of natural gas generation by an average of 82% (with a high of 336% in one hour).
    - In fact, during 2% of the hours of 2018, the nearly 70 GW of installed natural gas generating capacity in MISO is not enough to fill the shortfall left by replacing coal generation with wind.

3. **Replacing the output of MISO's 60 GW of coal generators would require at least an additional 92 GW of wind turbines.**
    - In 2018, there were 19 GW of wind capacity in MISO, and 96 GW in the entire country.
    - This generously assumes that wind generators are 100% available during high wind periods.

In summary, replacing each MWh of MISO coal generation with wind generation would result in a system that has vast amounts of worthless and unusable wind generation during much of the year, but a desperate need for replacement power during other times of the year. In fact, replacing the 296 GWh of 2018 coal generation in MISO with wind would then require an extra 84 GWh of generation from natural gas generators. This extra generation would cost at least $2 billion per year, if it was even available.[6] For Indiana, the situation would be worse than MISO, as it has proportionately more coal to be replaced with wind generation that is mismatched to load.

The AEC study is a textbook example of how oversimplifying the operation of the power system can lead to meaningless conclusions based on impossible results. It also serves as an example of a study that uses unrealistic generating cost assumptions to reach its desired results. This is best illustrated in the report's handling of ongoing capital costs for existing coal units. AEC admits that *retaining the existing Indiana coal fleet is actually $5 billion cheaper* than replacing it with new renewables if "we adopt the unrealistic assumption that existing coal-fired power plants will not need any capital investment over the next 30 years." Instead, the value they use for the cost of ongoing capital expenses at existing coal plants is actually the cost of building a brand new coal unit, and is nearly four times the cost they assume for building new wind generation ($5,700 per kW for coal and $1,457 per kW for wind).[7] Certainly, it is unrealistic to assume that an existing power plant will not require some capital expenses to maintain it over time, but it is much more unrealistic to assume that the cost of maintaining an existing plant is equal to the cost of building a brand new one.

[6] This presumes a natural gas generating cost of $22.3/MWh, based on $3.0/MMBtu natural gas prices and (unrealistically efficient) heat rate and fixed variable operating cost assumptions from the AEC study.

[7] AEC adopts both of these costs from the widely-cited *Lazard's Levelized Cost of Energy Analysis (Version 12)*, in which the costs are clearly presented as costs for new unit construction.