Synapse Energy Economics, Inc.

Memorandum

TO: JOE LOVETT, APPALACHIAN MOUNTAIN ADVOCATES

FROM: RACHEL WILSON, SYNAPSE ENERGY ECONOMICS

DATE: NOVEMBER 17, 2015

RE: ANALYSIS OF RENEWABLE ENERGY AS AN ALTERNATIVE TO NATURAL GAS IN VIRGINIA AND THE SURROUNDING REGION

Synapse Energy Economics, Inc. (Synapse) is engaged in an ongoing project on behalf of Appalachian Mountain Advocates (AMA) and the Southern Environmental Law Center (SELC) to analyze natural gas demand and proposed pipeline expansion in Virginia and the surrounding region. Related to this, AMA has commissioned Synapse to assess the cost and potential for renewables in the Virginia area.

Synapse has assessed renewable energy options in Virginia, including both renewable energy sources built in state and renewable energy produced in the surrounding region and purchased by Virginia. Specifically, we examined three issues related to renewable energy in the near term:

- Technical potential: What types and amounts of renewable energy sources are physically feasible?
- Economic feasibility: What types and amounts of renewable energy sources are realistic given the current economic landscape?
- Integration issues: What are the concerns about integrating larger amounts of renewable energy into Virginia and surrounding states, and what are the implications of those concerns?

This memo details the results of our assessment.

Renewable Energy: Economic and Technical Potential

The greatest potential for renewable resources in Virginia and the surrounding areas comes from wind and solar energy; thus, those technologies are the focus of this memo.

Wind Energy

Technical potential

There have been a number of advances in wind technology over the last 15 years: turbines have gotten larger, with the average nameplate capacity increasing 172 percent over 1998 levels; hub heights have increased to an average of 82.7 meters, a 48 percent increase over 1998 levels; and rotor diameters now average 99.4 meters, up 108 percent from 1998.[1] These technological improvements have increased the technical potential of electric generation from wind, as they have allowed developers to tap into greater wind speeds and generate more power from a single turbine. Table 1 demonstrates the impact of this trend on the land-based wind capacity potential in Virginia and each of the nearby states.

Table 1. Land-based wind capacity potential

State	Past: Potential installed capacity (MW) >=35% capacity factor at an 80m hub height, circa 2008 turbine technology (MW)	Present: Potential installed capacity (MW) >=35% capacity factor at an 110m hub height, current 2014 turbine technology (MW)	Future: Potential installed capacity (MW) >=35% capacity factor at an 140m hub height, near future turbine technology (MW)
NC	2,201	7,174	102,730
SC	557	10,299	98,638
VA	2,273	9,539	72,112
WV	806	6,950	39,357
Total	**5,837**	**33,962**	**312,837**

Source: U.S. Department of Energy. "Wind Resource Maps." Last accessed November 2015. Available at: http://apps2.eere.energy.gov/wind/windexchange/wind_resource_maps.asp?stateab=va.

In North Carolina, Iberdrola Renewables recently broke ground on the Amazon Wind Farm U.S. East, the first utility-scale wind farm in the state and one of the first in the Southeast.[2] Iberdrola Renewables is developing the project in conjunction with Amazon.com in order to power the online retailer's cloud-computer division.[3] The first phase of the project will consist of 104 turbines with a capacity of 208 MW and will start generating electricity in late 2016. If fully built out, the project would consist of 150 turbines with a 300 MW capacity. Iberdrola spokesman Paul Copleman stated that "(f)ive or 10 years ago, North Carolina was not registering on these maps or barely registering at all. This project is able to take advantage of continuing improvements in technology."[4]

Technological improvements apply to offshore wind technologies as well, though experience with these projects in the United States is much more limited than with land-based wind farms. Earlier this year, Virginia became the first state in the country to secure a wind energy research lease to build and

[1] Wiser, R. and M. Bolinger. *2014 Wind Technologies Market Report*. Lawrence Berkeley National Laboratory. August 2015. Page vi.

[2] Iberdrola Renewables. *Groundbreaking at North Carolina's First Wind Farm*. July 14, 2015. Available at: http://iberdrolarenewables.us/rel_15.07.14.html.

[3] Murawski, J. "Amazon backs NC's 1st large-scale wind farm." *The News Observer*. July 13, 2015. Available at: http://www.newsobserver.com/news/business/article27125410.html.

[4] Ibid.

operate wind turbines in federal waters.[5] Dominion Resources, Inc. had planned to build two test wind turbines off the coast of Virginia Beach, but halted the project in April, citing cost concerns.[6] Dominion now plans to solicit another round of bids.[7]

Economic feasibility

On-shore wind is currently cheaper than ever before. Average wind turbine prices have dropped significantly since 2008, declining from $1,500/kW to $850-$1,250/kW.[8] The combination of technology improvements and declining prices has led to downward pressure on both project costs and wind power prices in recent years—currently the average capacity-weighted installed project cost average is $1,710/kW, which is $580/kW lower than the peak in average reported costs in 2009 and 2010.[9]

Wind power purchase agreement (PPA) prices have also fallen to new lows. After peaking at almost $70/MWh in 2009, the national average levelized price for wind PPAs signed in 2014 was approximately $23.50/MWh nationwide. Note that this sample is largely from the interior region of the United States where wind prices are the lowest.[10] Withfalling PPA prices wind generation has become more competitive economically with other generating technologies. PPAs for wind that were executed in 2013 or 2014 have average price streams that begin below the range of reference case natural gas fuel cost projections, and remain below even the low-end of Energy Information Administration gas price forecasts through 2040,[11] as shown in Figure 1.

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[5] Dietrich, T. "Virginia gets country's first wind energy research lease in federal waters." *Daily Press*. March 25, 2015. Available at: http://www.dailypress.com/news/science/dp-nws-wind-turbines-governor-20150325-story.html.

[6] Applegate, A. "Dominion: Offshore wind turbines too expensive." *The Virginian-Pilot*. April 24, 2015. Available at: http://www.pilotonline.com/news/local/environment/dominion-offshore-wind-turbines-too-expensive/article_974dac9a-8105-51af-9248-29e348994cc0.html.

[7] Eckhouse, B. "Dominion to seek offshore wind bids after nixing costly proposal." *Bloomberg News*. September 18, 2015. Available at: http://www.pilotonline.com/news/local/environment/dominion-offshore-wind-turbines-too-expensive/article_974dac9a-8105-51af-9248-29e348994cc0.html.

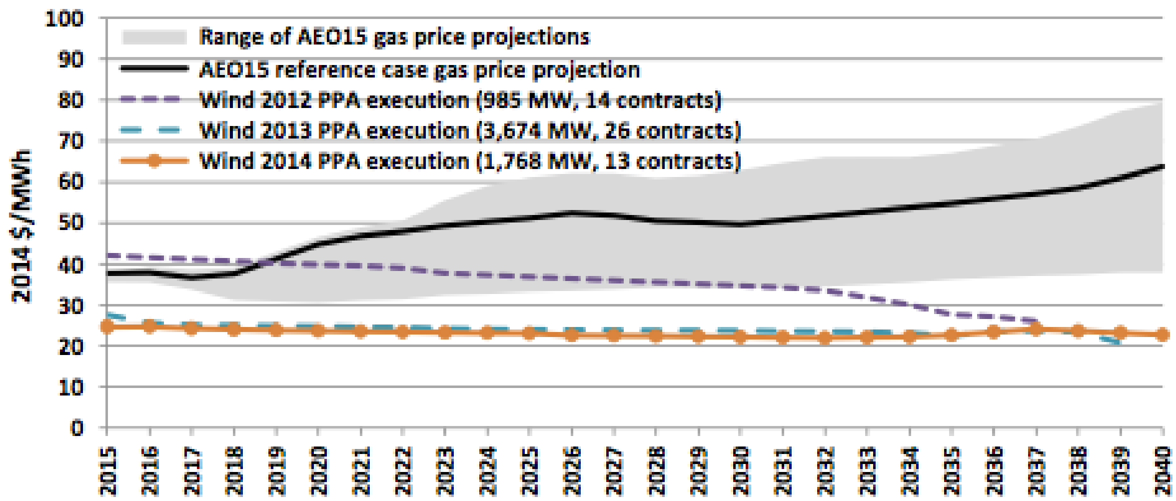
[8] Wiser, R. and M. Bolinger. *2014 Wind Technologies Market Report*. Lawrence Berkeley National Laboratory. August 2015. Page viii.

[9] Ibid.

[10] Ibid.

[11] Ibid. Page 59.

Figure 1. Average long-term wind PPA prices (by vintage) and natural gas fuel cost projections over time



Source: Lawrence Berkeley National Laboratory. Image available at: Wiser, R. and M. Bolinger. 2014 Wind Technologies Market Report. Lawrence Berkeley National Laboratory. August 2015. Page 59.

This means that wind generation is becoming increasingly more competitive with natural gas-fired generation. The Southeastern region does not have any wind farms that are a part of this data set; however, while we might expect to see regional differences in installed project costs and costs for wind PPAs, we would also expect to see that the general trends hold from region to region.

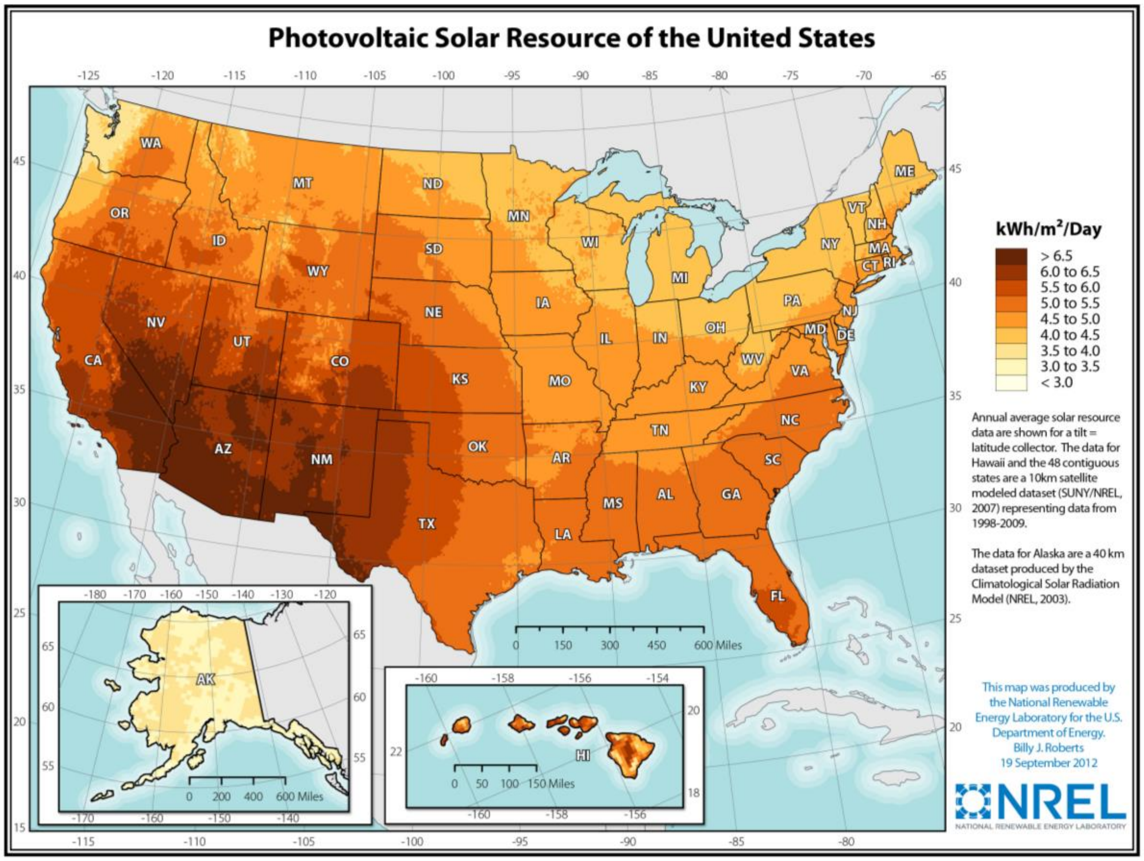
Solar Energy

Technical potential

According to the U.S. Department of Energy's (DOE) 2014 *SunShot Vision Study*, "every region of the contiguous United States has a good solar resource."[12] Photovoltaic (PV) technologies are more prevalent than concentrating solar power (CSP) and are the focus of this memo. Figure 2 shows the PV potential across the United States. In our study region, South Carolina has the highest potential at 5-5.5 kWh/m^2/day. The PV potential declines slightly as one moves farther north; nonetheless, the PV potential in Virginia still ranges from 4.5-5.5 kWh/m^2/day.

[12] U.S. Department of Energy. *SunShot Vision Study.* February 2012. Available at: http://energy.gov/sites/prod/files/2014/01/f7/47927_chapter2.pdf

Figure 2. Photovoltaic solar resource of the United States



Source: U.S. National Renewable Energy Laboratory. Image available at: http://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg.

The DOE's assessment examines the potential for solar technologies to meet a significant share of U.S. electricity demand over the next several decades as the cost of these technologies decline. In determining assumptions, DOE set price targets so that PV- and CSP- generated electricity would become competitive with conventionally generated electricity without subsidies by 2020, with prices for utility-scale PV declining along a linear trajectory to reach $0.06/kWh by 2020.[13] Table 2 shows the cumulative installed PV capacity that is installed in each state in our study region under the DOE's cost assumptions. In Virginia alone, 8,700 MW of PV are installed by 2030, and 21,200 MW are installed by 2050.

[13] U.S. Department of Energy. *SunShot Vision Study.* February 2012. Available at: http://energy.gov/sites/prod/files/2014/01/f7/47927_chapter3_0.pdf.

Table 2. Cumulative installed PV capacity in the SunShot scenario (MW)

State	2030 PV	2050 PV
NC	8,200	21,700
SC	14,500	18,800
VA	8,700	21,200
WV	200	1,500
Total	**31,600**	**63,200**

Source: U.S. Department of Energy. Available at: http://energy.gov/sites/prod/files/2014/01/f7/47927_appendices.pdf.

Virginia had only 15 MW of solar energy installed as of 2014.[14] North Carolina, by contrast, has made greater strides toward installing solar capacity. In 2014, the state installed 397 MW of solar electric capacity, bringing its total to 1,088 MW of installed solar capacity. With this total, North Carolina ranks fourth in the country and has a higher solar capacity than all other Southeast states combined.[15] South Carolina had 12 MW of installed solar as of 2014,[16] while West Virginia had 3 MW.[17]

Economic feasibility

Much like wind technologies, advances in solar technologies have led to improved performance along with declining installed costs. Since 2010, the installed costs for utility-scale solar PV projects have fallen by more than half as shown in Figure 3.

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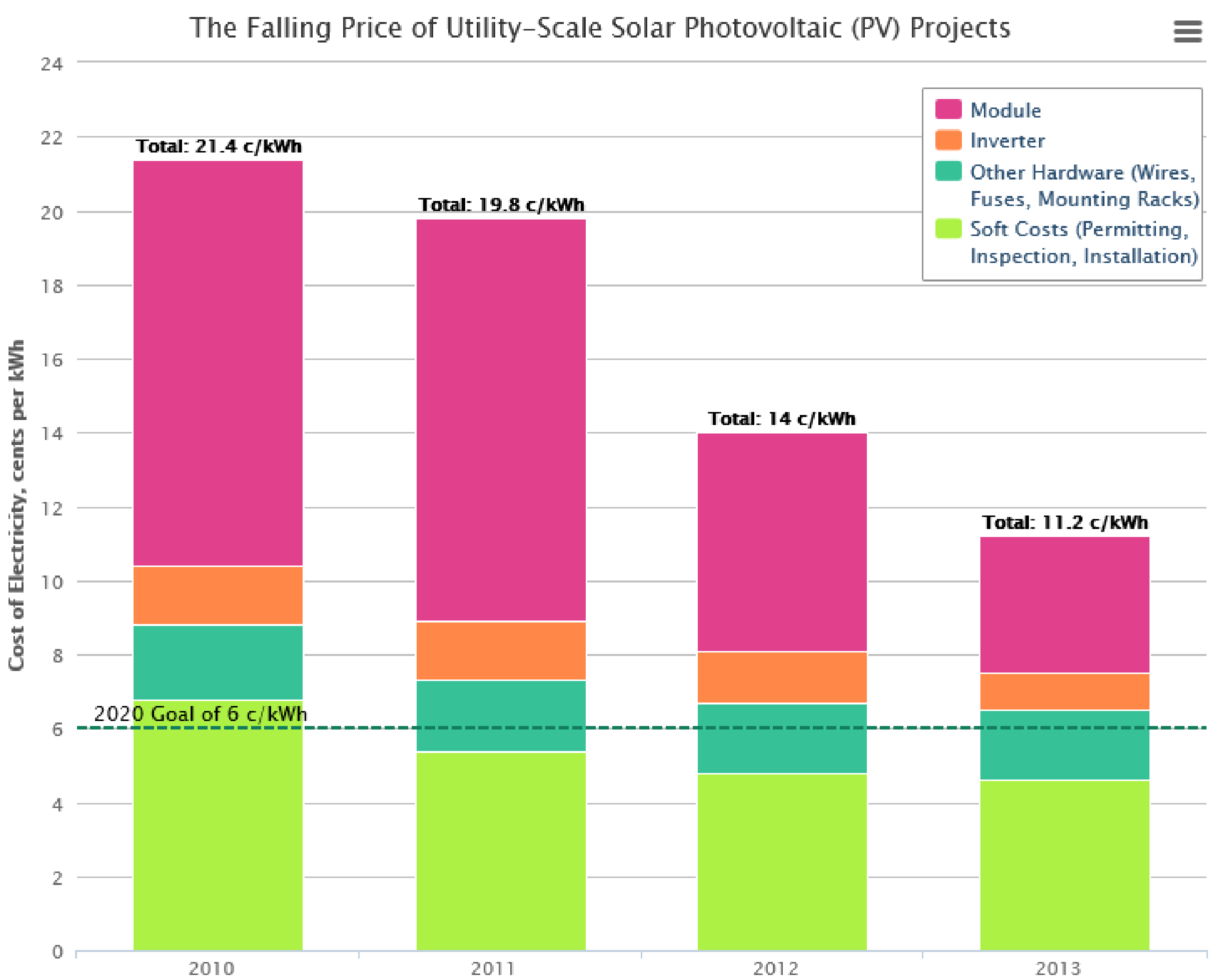
[14] Solar Energy Industries Association. *State Solar Policy: Virginia*. Accessed November 16, 2015. Available at: http://www.seia.org/state-solar-policy/virginia-solar.

[15] Solar Energy Industries Association. *State Solar Policy: North Carolina*. Accessed November 16, 2015. Available at: http://www.seia.org/state-solar-policy/north-carolina.

[16] Solar Energy Industries Association. *State Solar Policy: South Carolina*. Accessed November 16, 2015. Available at: http://www.seia.org/state-solar-policy/south-carolina.

[17] Solar Energy Industries Association. *State Solar Policy: West Virginia*. Accessed November 16, 2015. Available at: http://www.seia.org/state-solar-policy/west-virginia.

Figure 3. Prices for utility-scale solar photovoltaic projects



Source: Data courtesy of the National Renewable Energy Laboratory. Chart by Daniel Wood of the U.S. Department of Energy. Image available at: http://energy.gov/articles/progress-report-advancing-solar-energy-across-america.

PPAs for utility-scale PV have fallen even more dramatically than those for wind. A recent report from the Lawrence Berkeley National Laboratory (LBNL) states that on a levelized basis, PPAs for solar PV have fallen from 2006 to 2015.[18] Currently, average solar PV PPA prices are approximately $42.1/MWh compared to $48.1/MWh for the reference case natural gas fuel price projection. According to LBNL, this suggests "that PV may be able to compete with even just the fuel costs of *existing* gas-fired generators (i.e., not even accounting for the recovery of fixed capital costs incurred by *new* gas-fired generators)."[19]

As costs for renewable resources decline, a shift from fossil-fired generating sources to wind and solar technologies can result in cost savings to customers. Natural gas is currently a key determinant of electricity, heating, and cooling costs in the United States. This is because natural gas generation plants are usually the last power source to be activated to meet a given load and thus often set the wholesale

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[18] Bolinger, Mark and Joachim Seel. *Utility-Scale Solar 2014*. Lawrence Berkeley National Laboratory. September 2015. Page ii.

[19] Bolinger, Mark and Joachim Seel. *Utility-Scale Solar 2014*. Lawrence Berkeley National Laboratory. September 2015. Page 35.

market price for electricity. Solar generation corresponds well with times of peak electricity demand in summer, and solar electricity frequently offsets more expensive peaking generation resources, such as natural gas generators.[20] By substituting the fixed cost for solar PV in place of a potentially volatile natural gas fuel cost, solar energy technologies provide potential price-hedging benefits to individual consumers. They can also benefit the broader public, by displacing demand for natural gas.[21] Table 3 shows the potential impact on retail electricity rates from increases in solar capacity. Note that these projected rates are an average for the United States and include both PV and CSP technologies, where applicable.

Table 3. Average U.S. retail electricity rates in the Reference and SunShot scenarios (2010 cents/kWh)

Year	Reference	SunShot	% Change
2010	10.1	10.1	0.0%
2012	10.4	10.4	0.0%
2014	10.5	10.5	0.0%
2016	10.6	10.6	0.0%
2018	10.7	10.7	0.0%
2020	10.9	10.8	-0.9%
2022	11.1	10.9	-1.8%
2024	11.2	10.9	-2.7%
2026	11.4	10.9	-4.4%
2028	11.6	11.1	-4.3%
2030	12.0	11.4	-5.0%
2032	12.3	11.6	-5.7%
2034	12.7	11.9	-6.3%
2036	12.9	12.1	-6.2%
2038	13.2	12.3	-6.8%
2040	13.3	12.4	-6.8%
2042	13.4	12.5	-6.7%
2044	13.5	12.6	-6.7%
2046	13.6	12.7	-6.6%
2048	13.8	12.8	-7.2%
2050	13.9	13.0	-6.5%

Source: U.S. Department of Energy. Available at: http://energy.gov/sites/prod/files/2014/01/f7/47927_appendices.pdf.

Electric rates decline beginning in 2020 between the Reference and SunShot scenarios as solar installations increase above reference levels in the SunShot scenarios. Rates in the SunShot scenario are 5 percent lower than reference levels in 2030, and 6.5 percent lower in 2050.

[20] U.S. Department of Energy. *SunShot Vision Study.* February 2012. Available at: http://energy.gov/sites/prod/files/2014/01/f7/47927_chapter3_0.pdf.

[21] U.S. Department of Energy. *SunShot Vision Study*. February 2012. Available at:http://energy.gov/sites/prod/files/2014/01/f7/47927_chapter2.pdf.

Integration Issues

The wind and solar technologies described in the previous sections rely on supplies of wind and solar energy to generate electricity, and these renewable fuel sources may not be available during particular times of day. Exaggerated concerns about integrating intermittent renewable technologies with the rest of the electric system may be a hindrance to renewable energy development in certain regions. According to a recent report by the American Wind Energy Association, the intermittency of wind is easily smoothed out over the electric system as a whole as demand rises and falls, and as output from other energy sources fluctuates. As more wind power is added to the electric grid, the less variable wind energy becomes as a whole, as the wind in different locations blows differently. The gradual and predictable aggregate changes in wind power are much easier for electric system operators to address than the large-scale outages that can occur at conventional power plants, as when the entire capacity of a baseload power plant is taken offline due to an unplanned outage.[22]

The DOE's SunShot Vision Study[23] cautions that there are challenges with PV generation due in particular to its limited dispatchability,[24] and that new transmission facilities may be needed to access high quality solar resources. However, the DOE report also states that electric markets like PJM—which includes Virginia—that are larger, more diverse, and more flexible will allow for the integration of solar generation at a lower cost. It should be recalled that the integration of solar offers benefits to the grid as well, as the time when PV installations are most effective—midday through late afternoon—coincides with summer peak demand. Distributed solar offers similar falling costs to utility-scale technologies and adds geographic diversity to a utility's system—it may be cloudy in one area but sunny in another. This distributed generation presents an opportunity to avoid the expensive investments in transmission and distribution infrastructure often required for maintaining and expanding centralized systems.

As part of the PJM electric market, renewables in Virginia and the surrounding states will be integrated within this Regional Transmission Organization (RTO). PJM commissioned a Renewable Integration Study[25] in 2014 to assess impacts to grid operations if state renewable energy goals are achieved or exceeded in the next 15 years. The study examines a business-as-usual scenario (2 percent renewable integration is maintained over the study period), as well as nine other scenarios with up to 30 percent of wind and solar penetration. The study found that:

- No insurmountable operating issues were found over the simulated scenarios;

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[22] American Wind Energy Association. *Wind energy helps build a more reliable and balanced electricity portfolio*. February 2015. Available at: http://midwestenergynews.com/2015/02/13/blowing-away-myths-study-says-wind-energy-could-be-even-more-reliable-than-baseload-power/.

[23] U.S. Department of Energy. *SunShot Vision Study.* February 2012. Available at: http://energy.gov/sites/prod/files/2014/01/f7/47927_chapter6.pdf.

[24] Dispatchability means that power plants may be turned on or off, or can adjust their power output on demand.

[25] GE Energy Consulting. *PJM Renewable Integration Study Executive Summary Report*. March 2014. Available at: http://www.pjm.com/~/media/committees-groups/subcommittees/irs/postings/pris-executive-summary.ashx.

- With adequate transmission expansion and additional regulation reserves, the PJM system would not have any significant reliability issues operating with up to 30 percent of its energy (not capacity) coming from wind and solar generation;
- Additional transmission will be required to support increased renewable penetration, at a cost of $8 billion, which is far less than the $15.6 billion in energy savings;
- PJM's large geographic footprint provides a significant advantage for integrating renewable generation because it greatly decreases the magnitude of variability-related challenges;
- Every scenario with increased renewables resulted in decreased fuel and variable O&M costs over the PJM market, lower average locational marginal prices and zonal prices, and lower system-wide production costs;
- Additional regulation was needed to compensate for the increased variability introduced by the renewable generation; and
- Renewable generation increased the amount of cycling on the existing fleet of generators. While this implies increased variable O&M costs on these units, the increase in cost was small relative to the value of the fuel displacement. These costs did not significantly affect the overall economic impact of the renewable generation.

As capabilities to forecast wind and solar patterns improve, the intermittency of renewable generation becomes less of a concern in utility service territories and in regional markets. The PJM integration study recommends using a four- to five-hour-ahead timeframe for wind and solar forecasts to increase the accuracy of forecasting day-ahead commitment prices and improve dispatch. This would minimize the suboptimal commitment of generation resources in real-time operations. We can conclude from this information that while integration issues may exist, a variety of techniques—from forecasting methodologies to dispersal of resources on the grid—will allow them to be overcome.