***OCC Exhibit* ____________**

BEFORE
THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the 2018 Long-Term Forecast Report on behalf of Ohio Power Company and Related Matters.	)))	Case No. 18-0501-EL-FOR
In the Matter of the Application Seeking Approval of Ohio Power Company's Proposal to Enter into Renewable Energy Purchase Agreements for Inclusion in the Renewable Generation Rider.	)))))	Case No. 18-1392-EL-RDR
In the Matter of the Application of Ohio Power Company to Amend its Tariffs.	))	Case No. 18-1393-EL-ATA

DIRECT TESTIMONY
OF
RAMTEEN SIOSHANSI

On Behalf of
The Office of the Ohio Consumers' Counsel
65 East State Street, 7^{th} Floor
Columbus, Ohio 43215

January 2, 2019

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ATTACHMENTS:

I. INTRODUCTION

Q1. PLEASE STATE YOUR NAME, POSITION, AND BUSINESS ADDRESS.

A1. My name is Ramteen Sioshansi. I am a specialist in operations research, with my research focusing on issues that are related to electricity-industry economics, market design, regulation, operations, planning, and policy. My business address is 60 East Spring Street, Columbus, Ohio 43215.

Q2. PLEASE DESCRIBE YOUR EXPERIENCE AND QUALIFICATIONS.

A2. I have had academic and consulting experience within the electric power industry dating back to 1999. Much of my academic research, which I carry out as a professor in and associate chair of the Department of Integrated Systems Engineering at The Ohio State University, is focused on the design and analysis of restructured wholesale and retail electricity markets and market-power issues in electricity markets in the United States and abroad. My research also examines issues related to energy economics, energy policy, and electric power system regulation. Other areas of my research include techno-economic analyses of the integration of renewable energy sources, electric vehicles, and energy-storage technologies into electric power systems.

Through this and other work, I am very familiar with how short-term operations and long-term planning of electric power systems are conducted and optimized.

Specifically, my consulting work has included the analyses of wholesale electricity market designs for a market participant, including the development of generation offer strategies. I have worked as a research intern for the chief economist to the Federal Energy Regulatory Commission ("FERC"). I am currently serving a third two-year term as a member of the U.S. Department of Energy's Electricity Advisory Committee. I also chair the Energy Storage Subcommittee of the Electricity Advisory Committee.

I hold a B.A. in economics and applied mathematics and an M.S. and Ph.D. in industrial engineering and operations research from the University of California, Berkeley. I also hold an M.Sc. in econometrics and mathematical economics from the London School of Economics and Political Science. My curriculum vitae, summarizing my experience attached hereto (RS-Attachment 1).

Q3. ON WHOSE BEHALF ARE YOU TESTIFYING?

A3. I am providing testimony on behalf of the Office of the Ohio Consumers' Counsel ("OCC"), which represents residential utility consumers.

Q4. HAVE YOU TESTIFIED BEFORE A REGULATORY AGENCY?

A4. Yes. I have submitted testimony to the Public Utilities Commission of Ohio ("PUCO") on behalf of OCC in Case Nos. 14-1297-EL-SSO, 14-1693-EL-RDR, and 14-1694-EL-AAM.

Q5. WHAT IS THE PURPOSE AND SCOPE OF YOUR TESTIMONY?

A5. I am testifying as to whether Ohio Power Company ("AEP Ohio" or the "Utility") has demonstrated that the competitive market is not providing enough energy to meet the electricity needs of customers. I also am testifying with an evaluation of whether AEP Ohio's proposal to have solar-energy projects procured and their full costs guaranteed through customer-subsidized arrangements by a monopoly utility (AEP Ohio) is prudent, reasonable, and economically efficient. The customer-subsidized arrangement I reference is the use of the Renewable Energy Purchase Agreement ("REPA"), with cost-recovery guaranteed by AEP Ohio's captive utility customers via the non-bypassable Renewable Generation Rider ("RGR" or "Renewable Charge"). My testimony also includes a recommendation on how renewable-energy projects could be procured more efficiently for customers through the competitive marketplace compared to the AEP Ohio's proposals. In this proceeding I reviewed filings, supporting testimonies, and workpapers of AEP Ohio, and reviewed discovery.

This proceeding is the consolidation of two filings in three cases. In the first, PUCO Case No. 18-501-EL-FOR, AEP seeks to amend its most recent Long-Term Forecast Report ("LTFR") and asks the PUCO to issue a finding of need for at least 900 MW of renewable-energy projects that are to be located in Ohio. This first filing does not propose specific renewable energy projects. Rather, it provides an analysis of 650 MW of generic renewable resources.[1] The second filing, PUCO Case Nos. 18-1392-EL-RDR and 18-1393-EL-ATA, is an application to advance two specific solar-energy projects totaling approximately 400 MW of nameplate capacity. Under AEP Ohio's proposal in this second filing, the solar-energy projects would be procured and financed through the REPAs and their costs would be collected from captive customers under the non-bypassable Renewable Charge (though the power from the plants will not be dedicated to Ohio customers).[2]

My assignment was to review the Utility's filings, supporting testimonies, workpapers, and discovery in this proceeding. I was asked to determine whether the Utility has demonstrated that the competitive market is not providing enough energy to meet the needs of customers (if such needs indeed exist). I was also asked to evaluate whether the Utility's proposal to have solar-energy projects procured and their full costs guaranteed through customer-subsidized arrangements (*i.e.*, using REPAs, cost-recovery of which is guaranteed by captive customers via the non-bypassable RGR) is prudent, reasonable, and economically efficient. I was finally asked to make a recommendation on how renewable-energy projects could be procured more efficiently (if such needs indeed exist) compared to the Utility's proposals.

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[1] Direct testimony of John F. Torpey on Behalf of the Utility in PUCO Case No. 18-501-EL-FOR, p. 5.

[2] Direct testimony of John F. Torpey on Behalf of the Utility in PUCO Case Nos. 18-1392-EL-RDR and 18-1393-EL-ATA.

Q6. CAN YOU SUMMARIZE YOUR FINDINGS AND RECOMMENDATIONS?

A6. Yes. In a restructured market such as the state of Ohio (where the state legislature introduced competition into the electricity industry in 1999), monopoly megawatts (*i.e.*, capacity that is paid for by captive customers through non-bypassable surcharges) are generally inferior (if not unlawful) compared to market-based megawatts (*i.e.*, capacity that is built based on price signals that come from competitive wholesale and retail markets). This is because Ohio has introduced competition into its electricity industry as well as because the PJM-operated wholesale markets (where AEP Ohio operates) are intended to deliver energy services to customers in the most efficient manner possible, by maximizing social welfare while meeting customers' reliability needs. This is achieved in the long-run by having new (more efficient) generating plants freely enter and old (less efficient) generating plants exit the market based on price signals. These market-design features and capabilities of the PJM-operated wholesale markets (and Ohio's electricity competition) deliver benefits to AEP Ohio's customers (and, indeed, to customers across the state of Ohio and the entire PJM regional footprint).

AEP Ohio's proposal in this proceeding is for captive customers to fund its renewable-energy projects. Customers would fund the projects through AEP Ohio's non-bypassable Renewable Charge (*i.e.*, AEP Ohio would be developing monopoly megawatts) instead of allowing these solar plants to be developed, built and offered for sale through the competitive-market process. As I discuss further in my testimony below, the AEP Ohio's proposal places the full cost and cost risk of its renewable-energy projects on its captive customers, through the non-bypassable Renewable Charge. Moreover, the AEP Ohio's proposal can harm the ability of the PJM-operated wholesale markets to deliver on its design goal of long-run power system efficiency. This is, in part, because the customer-subsidized monopoly megawatts are allowed to compete against unsubsidized market-based megawatts. This creates an uneven playing field, that can hamper the ability of the PJM-operated wholesale markets to deliver reasonable electricity rates to customers. All of these impacts of monopoly AEP Ohio's proposal are to the detriment of its customers (and, indeed, are detrimental to customers across the state of Ohio and the entire PJM footprint all of whom benefit from competitive electric markets). Most significantly, AEP Ohio's proposal runs contrary to state policy, which seeks to deliver the benefits of electricity-market competition to customers in Ohio.

As I discuss further in my testimony below, the competitive wholesale and retail markets in the PJM multi-state footprint, which includes Ohio, are currently efficiently delivering renewable energy to AEP Ohio's customers that wish to procure such resources. As such, the PUCO should allow the competitive market to continue delivering these generation resources to customers in an unfettered manner, without interference from AEP Ohio's proposal for monopoly megawatts. And, most importantly, relying on the free market to respond to customers' electricity needs is consistent with the goal of electric-industry competition of the Ohio General Assembly (as well as of the PUCO's own directives). In a prior case involving the AEP Ohio, the PUCO determined that new generation or capacity projects "will only be authorized when generation needs cannot be met through the competitive market."[3] Indeed, the energy and capacity that is produced by the proposed plants will not even be dedicated to serving the electricity needs of Ohio customers; the plants' output will, instead, be sold in the PJM regional market.

To the point, as I discuss further in my testimony below, AEP Ohio has failed to demonstrate, in regard to its proposed projects, that customers' generation needs cannot be met in the competitive market. Moreover, AEP Ohio has not credibly demonstrated that the proposed renewable-energy projects will deliver cost savings to its customers. In light of these deficiencies of the Utility's proposal, I recommend that it be rejected. Again, a key issue in these cases is whether, under state law, AEP Ohio's customers have a need for the electricity from the proposed solar plants that cannot be met in the competitive market. Electric customers do not have such a need for these projects from their monopoly utility.

[3] In the Matter of the Application of Columbus Southern Power Company and Ohio Power Company for Authority to Establish a Standard Service offer Pursuant to Section 4928.143, Revised Code, in the Form of an Electric Security Plan, Case No. 11-346-EL-SSO, Opinion and Order at 39-40 (Dec. 14, 2011).

II. COMPETITIVE MARKET-BASED INVESTMENT IS MORE EFFICIENT THAN REGULATED INVESTMENT.

Q7. PLEASE EXPLAIN WHAT IS MEANT BY LONG-RUN EFFICIENCY IN AN ELECTRIC POWER SYSTEM.

A7. In the context of an electric power system, the short run normally refers to the period of time when the installed generation, transmission, distribution, and other power-system assets are static, meaning that one is only concerned with how the installed assets are operated. Conversely, the long-run refers to the period of time when assets can be added to or removed from the system.[4]

To achieve long-run efficiency, assets should be added to or removed from the power system to serve customer demands while maximizing social welfare and meeting customers' reliability and resilience needs. By its nature, this long-run planning is forward-looking, and accounts for expected demand growth, changes in operating and capital costs of technologies, and policy and regulatory changes.

[4] S. Stoft, "Power System Economics: Designing Markets for Electricity," Wiley-IEEE, 2002.

Q8. PLEASE EXPLAIN HOW THE PJM-OPERATED WHOLESALE MARKETS AND OHIO'S COMPETITIVE ELECTRICITY MARKETS PROMOTE THE LONG-RUN EFFICIENCY OF THE ELECTRIC POWER SYSTEM FOR THE BENEFIT OF OHIO CUSTOMERS.

A8. The PJM-operated wholesale markets are intended to promote long-run efficiency of the electric power system. This is achieved by allowing generation assets to freely enter and exit the market. These entry and exit decisions are intended to be made on the basis of expected market revenues, which are largely derived from the provision of energy and ancillary services in the real-time and day-ahead markets. These energy and ancillary service revenues are supplemented by the longer-term PJM Reliability Pricing Model ("RPM") capacity market. Generation technologies that are long-run inefficient, in the sense that lower-cost alternatives exist (on the basis of capital and operating costs), are driven out of the market. This is because lower-cost alternatives enter the market, displacing inefficient incumbents from the real-time, day-ahead, and RPM markets. As these inefficient generation technologies are displaced from the market, their market revenues are eroded, driving their exit from the market. Conversely, technologies that are long-run efficient are able to recover their capital and operating costs through market revenues. These competitive pressures provide strong incentives for incumbent generating firms and new entrants to invest in adding efficient generation technologies, because such technologies represent profit opportunities. Such investment in new power plants has occurred in Ohio. The market also provides competitive pressure for incumbent generation owners to reduce capital and operating costs. By doing so, asset owners can increase the profitability of generators that are in the market. These competitive pressures directly benefit customers by having their demands met reliably while maximizing social welfare in the long-run.

Q9. WHAT ROLE DO POWER PURCHASE AGREEMENTS ("PPAS") PLAY IN GENERATION-ASSET INVESTMENT IN RESTRUCTURED WHOLESALE MARKETS?

A9. PPAs can be used to facilitate investment in generation assets. This can be accomplished, for instance, by a generation-asset investor signing a PPA with a counterparty, whereby some combination of energy, ancillary service, or capacity produced by the generation asset are sold to the counterparty. The counterparty normally recovers its PPA costs by selling the generation-asset products in competitive wholesale and/or retail markets. In such market transactions, the counterparty, not captive monopoly customers, is responsible for the loss or profit associated with the PPAs. Contrarily, in this case, AEP Ohio's proposed transaction would inappropriately transfer competitive market risks to its monopoly captive customers for these deregulated services.

Q10. WILL AEP OHIO'S PROPOSAL HAMPER THE ABILITY OF PJM-OPERATED WHOLESALE MARKETS TO ENSURE EFFICIENT INVESTMENT IN GENERATION PROJECTS IN OHIO, THEREBY HARMING CUSTOMERS?

A10. Yes. I believe that AEP Ohio's requests in this proceeding will hamper the ability of the PJM-operated wholesale markets to safeguard and promote efficient investment in renewable-energy (and non-renewable-energy) projects in Ohio. This will harm the Utility's customers, other Ohio customers, and other customers in the PJM region.

AEP Ohio's proposal would provide its renewable-energy projects an unfair competitive advantage relative to other incumbent or potential future renewable-energy projects. This is because the renewable-energy projects that are proposed by the AEP Ohio have a revenue stream that is guaranteed by the Renewable Arrangements (REPAs). The Utility's costs under the REPAs are, in turn, guaranteed by captive (monopoly) customers through the non-bypassable Renewable Charge. This guaranteed recovery of project costs from captive customers can hamper the long-run efficiency of the system in at least two ways.

First, the guaranteed recovery of the projects' costs by captive customers may distort the Utility's incentives to offer the energy, ancillary services, and capacity that are produced by the Utility-procured renewable-energy projects into the PJM-operated wholesale markets. These distorted incentives to offer the Utility-procured renewable-energy projects into the PJM-operated wholesale markets may distort the price signals that are produced by those markets. As discussed in my response to Q8, the PJM-operated wholesale markets are intended to promote the long-run efficiency of the system by having generation assets enter and exit the system based on the market's price signals. Because the Utility's proposal can ultimately result in distorted price signals, it may also result in distorted entry and exit decisions, affecting the long-run efficiency of the power system.

Second, the Utility's proposal may also impact other renewable-energy projects that are either currently in the market or that may consider entering the market. This is because such renewable-energy projects may not have such a revenue stream (*i.e.*, PPA costs that are guaranteed by captive customers through a non-bypassable charge) available to them. As such, the development of future renewable-energy projects may be hampered, as investors will likely prefer having contracting arrangements that provide them with guaranteed customer-funded payments (or subsidies) that the Utility-procured projects would be receiving under the Utility's proposal. In other words, competitors (including renewable-energy developers) who lack the advantage AEP Ohio has for charging its monopoly customers may decide not to build generation in Ohio because the competition is unfair. This interference by monopoly AEP Ohio in the competitive market is bad for consumers who benefit from competition. AEP

Ohio's proposal is inconsistent with the Ohio legislature's introduction of competition into the state's electricity markets.

Furthermore, the AEP Ohio's proposal may set a precedent (be the "foot in the door") for having even more generation assets procured by AEP Ohio or other monopoly utilities, the cost and cost risk of which would be borne by captive customers through non-bypassable charges. If such a precedent is set, future generation investments in Ohio by competitors (*i.e.*, investments in renewable- *and non-renewable*-energy projects) may be hampered for the same reason that is outlined above. Namely, investors may prefer contracting arrangements for future generation projects that provide them with guaranteed payments (or subsidies) by captive (monopoly) customers. This could lead to less generating capacity being built in Ohio through the competitive process that I outlined in my response to Q8 (*i.e.*, the building of power plants based on the market mechanism in the state's 1999 restructuring legislation[5] that promotes long-run efficiency of the power system). Such a precedent could lead to more generating capacity being built through regulatory *fiat*. This would be to the detriment of customers, who rely on the market to provide them with reasonably priced and reliable electricity. Moreover, it would run contrary to state policy, which aims to foster the provision of electricity services through market competition.

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[5] Am. Sub. S.B. 3, 123rd Ohio General Assembly, effective July 6, 1999.

Q11. ***HOW DOES AEP OHIO'S PROPOSAL DIFFER FROM MARKET-BASED GENERATION INVESTMENT THAT IS FOSTERED THROUGH POWER PURCHASE AGREEMENTS?***

A11. A major difference between AEP Ohio's proposal and market-based generation investment is AEP Ohio's approach for its customers to guarantee its recovery of the Renewable Arrangement costs through the non-bypassable Renewable Charge. The costs of PPAs that are used to foster market-based generation investment are normally recovered by competitors selling the energy, ancillary service, and capacity that are produced by the generation asset in competitive wholesale or retail markets. This need to recover PPA costs through the competitive market typically provides strong incentives for the PPA counterparties to build and operate only the most efficient generation projects. AEP Ohio's proposal is anti-competition, because captive customers are forced to guarantee recovery of the cost of the Renewable Arrangements through non-bypassable charges. Thus, AEP Ohio's proposal lacks the strong efficiency incentives that the competitive market normally delivers, to the benefit of Ohio customers.

Q12. HOW DO CUSTOMERS DIRECTLY BENEFIT FROM HAVING RENEWABLE-ENERGY PROJECTS BUILT BY FIRMS THAT DIRECTLY COMPETE IN THE PJM-OPERATED WHOLESALE MARKETS?

A12. As outlined in my response to Q8, the PJM-operated wholesale markets are intended to promote long-run efficiency of the electric power system to the benefit of customers. This is achieved by allowing the free entry and exit of generation assets from the market, on the basis of market-based price signals. If a renewable-energy project enters the market on the basis of this free-entry and -exit principle, that suggests that the renewable-energy project is economically efficient in the long-run. This directly benefits customers, as they are able to receive energy and capacity services from the most efficient renewable-energy projects that are available.

Q13. ARE THERE MARKET-BASED SOLUTIONS THAT CAN MEET THE NEEDS OF THE UTILITY'S CUSTOMERS FOR RENEWABLE ENERGY?

A13. Yes. In analyzing Ohio's market for renewable energy, I relied on several sources. I recently examined the PUCO's Apples to Apples rate comparison chart (on 5 December 2018).[6] That rate comparison shows that there are at least fifty-four retail tariffs that are provided by marketers to shopping customers in the Utility's service territory with some renewable-energy content. Moreover, 35 tariffs that are provided by marketers to shopping customers in the Utility's

[6] http://energychoice.ohio.gov/

service territory provide one-hundred percent of their energy contents from renewable-energy sources.

Furthermore, in my analysis of the Ohio market, I reviewed a report prepared for the Utility by Navigant Consulting (RS-Attachment 2).[7] This report concludes that Ohio has more wind manufacturers than any other state in the country and that Ohio has a thriving renewable-energy market with a variety of different types of wind and solar companies.

This Ohio-specific information supports my conclusion that shopping customers have numerous options available to them in the competitive retail market to serve some or all of their demands from renewable-energy sources, if they so desire. These retail offerings by marketers are supporting a thriving renewable-energy market in Ohio. Moreover, these marketer offerings with renewable-energy sources for Ohio customers do not require the heavy-handedness of government imposing on monopoly customers the obligation to guarantee AEP Ohio's cost-recovery for renewable-energy projects.

[7] Ohio Renewable Energy Manufacturing & Company Establishment Analysis

Q14. WHY IS AN ASSESSMENT OF OHIO'S MARKET IMPORTANT IN THIS CASE?

A14. An assessment of Ohio's market is important because the PUCO has determined, based upon Ohio law, that it will not authorize new generation projects under Ohio law unless, among other requirements, it is demonstrated that the need for the generation cannot be met through the competitive market.[8] As outlined in my response to Q13, the competitive market is able to serve the generation needs as well as the renewable-energy needs of the Utility's customers. As such, the Utility's request fails to meet the regulatory and state policy requirements.

Q15. DOES THE UTILITY'S PROPOSAL ALLEVIATE ANY CONCERNS OR ISSUES WITH THE RELIABILITY OF ELECTRICITY SERVICE TO ITS CUSTOMERS?

A15. No. There is no issue of obtaining reliable wholesale capacity and energy by the Utility to serve its customers. There is also no need demonstrated by the Utility for new generation capacity, renewable or non-renewable, funded by captive customers. To answer this question, I reviewed a report prepared by the North American Electric Reliability Corporation ("NERC"), which provides an assessment of the reliability of the North American bulk power system

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[8] PUCO Case No. 11-346-EL-SSO et al., Opinion and Order adopted December 14, 2011.

(RS-Attachment 3).[9] Pursuant to the Energy Policy Act of 2005,[10] the NERC was certified by the FERC in 2006 as the nation's electric reliability organization, which is responsible for developing and enforcing mandatory electricity reliability standards under the FERC's oversight.[11] The NERC's most recent assessment of the reliability of the PJM power system anticipates PJM to have a 40% reserve margin for the 2018/2019 winter period. That projection is far in excess of PJM's 16.1% target reserve margin. This finding indicates that the PJM-operated wholesale markets are delivering on their design goal of ensuring that sufficient capacity is installed and available to maintain the reliability of the electric power system that serves the customers of the Utility (and customers across the state of Ohio).

Q16. HAS THE UTILITY CREDIBLY DEMONSTRATED COST SAVINGS TO ITS CUSTOMERS FROM THE PROJECTS THAT ARE PROPOSED IN THIS PROCEEDING?

A16. No, I do not believe that it has. In its filings in this proceeding, the Utility submitted an analysis of the economic benefits that would be associated with the addition of 650 MW of generic renewable resources.[12] This analysis estimates that generic renewable resources could result in a $0.07/MWh levelized reduction

[9] 2018/2019 Winter Reliability Assessment.

[10] Public law 109-58.

[11] FERC Docket Nos. RR06-1-000 and RR06-2-000.

[12] Direct testimony of John F. Torpey on Behalf of the Utility in PUCO Case No. 18-501-EL-FOR.

in Locational Marginal Prices ("LMPs"). I do not endorse or support this particular estimation of LMP savings. Moreover, this estimated cost savings is 0.12% of the levelized LMPs (which the Utility estimates to be $54.50/MWh). As such, it is not clear that these estimate cost savings would actually materialize if any of the assumptions or forecasts that underlie the Utility's analysis turn out to be incorrect. Put another way, the Utility's estimated LMP savings is likely sensitive to a number of assumptions and forecasts that underlie the Utility's analysis. If any of these assumptions or forecasts are incorrect, the Utility's estimated LMP savings may become LMP increases. The Utility does not provide any credible assessment of how sensitive its estimated LMP savings are to the assumptions and forecasts that underlie its analysis. Given the difficulty in forecasting market conditions over the twenty-year term of the proposed Renewable Arrangements, I do not characterize these estimated cost savings as being material, if indeed there are any such savings. If AEP Ohio's estimations do not materialize in the future as presented now to the PUCO, it will be Utility customers (not AEP Ohio) who will bear the full risks and costs.

The Utility does provide what it terms a "probabilistic analysis." (This type of analysis is also often referred to as Monte Carlo simulation.) However, my examination of the probabilistic analysis, based upon its description that is given in testimony that is sponsored by the Utility,[13] suggests a number of shortcomings in how the analysis was conducted. Rather than provide an exhaustive critique of all of the shortcomings of the analysis, I will highlight a few notable concerns.

First, the Utility uses the previous ten years of PJM price data to calibrate the standard deviation of future prices. I do not believe this to be a valid means to calibrate the standard deviation of future prices. This is because historical price volatility was, at least in part, driven by (1) decreases in natural gas prices, (2) greater use of natural gas-fired generation, and (3) decreases in the rate of growth of electricity demand. As such, using the historical standard deviation of electricity prices to calibrate the standard deviation of future electricity prices implicitly assumes that these types of changes will continue in the future (*e.g.*, that natural gas prices will continue to decline, as they have over the past ten years). There is no clear evidence that future price volatility will be driven by the same factors or will have the same scale as historical price volatility.

Second, future electricity prices are assumed to follow a normal (also known as a Gaussian) distribution. Empirical analyses of electricity prices suggest that a normal distribution does not provide a good fit to historical data. Practitioners who simulate electricity prices, especially for the purposes of pricing financial

[13] Direct testimony of John F. Torpey on Behalf of the Utility in PUCO Case No. 18-501-EL-FOR, p. 11–12 and Exhibit JFT-1.

contracts and derivatives, tend to use other types of random processes. Examples include mean- or median-reverting processes, Ornstein-Uhlenbeck processes, or Geometric Brownian motions. Another concern regarding the price simulation is that I cannot tell if autocorrelations in the prices are captured (*e.g.*, an hour with a low electricity price tends to be followed by another hour with a low electricity price). These types of autocorrelations can be captured using the types of stochastic processes that I listed before, Autoregressive Integrated Moving Average ("ARIMA") models, or other types of stochastic models. Given these shortcomings in the modeling of the future prices, I do not believe the probabilistic analysis to be a credible analysis of the Utility's proposals.

A third concern is related to the modeling of renewable production. As I understand it, the hourly production of the generic renewable resources is modeled using normal (Gaussian) distributions. Normal distributions do not normally provide good fits to empirical renewable-availability data. For this reason, other distributions (*e.g.*, Weibull distributions) are more commonly used. A further concern regarding the simulation of renewable production is that it is not clear if autocorrelations in these data are captured or not (*e.g.*, a cloudy hour with low solar production is more likely to be followed by another cloudy hour with low solar production) in the Monte Carlo simulation.

A fourth concern is in relation to simulating the ensemble of random variables (*i.e.*, simulating electricity prices, wind availability, and solar availability together). As I understand it, these random variables are all modeled as being statistically independent of one another in the Monte Carlo simulation. If so, this is a poor assumption, as the three variables tend to have some correlation among one another. A Vector ARIMA ("VARIMA") model could be used, as one example, as a means to better capture correlations between these random variables.

Finally, I should note that the analysis of the renewable-energy projects that is presented by the Utility does not fully explain many of the assumptions underlying the analysis. In a number of instances, the analysis is stated as using "professional judgment."[14] Given the numerous shortcomings in the probabilistic analysis, I have concerns regarding the validity of this use of professional judgment.

Based on the estimated levelized LMP reduction being 0.12% of the estimated levelized LMP, it is not clear whether these LMP reductions will actually be realized by the Utility's customers. Moreover, in light of numerous issues with the probabilistic analysis, the Utility has not credibly demonstrated that the cost

[14] Direct testimony of John F. Torpey on Behalf of the Utility in PUCO Case No. 18-501-EL-FOR, Exhibit JFT-1.

savings that it estimates are actually material (*i.e.*, that they would actually be realized by its customers if one or more of the assumptions or forecasts that underlie its analysis turn out to be incorrect). Based on these facts, I conclude that the Utility has not credibly demonstrated that there will be cost savings to its customers from the projects that are proposed in this proceeding. Moreover, even if there are cost savings for customers at some future point (years from now), such savings would not mean that customers have a need for the electricity as required by Ohio law.

Q17. HAS THE UTILITY DEMONSTRATED A NEED FOR THE PROJECTS THAT ARE PROPOSED IN THIS PROCEEDING?

A17. Following on my answers to Q5, Q10, Q11, Q13, and Q16, I do not believe so. The Utility provides two primary rationales for its proposed projects.[15] The first is that the renewable-energy projects will lead to lower costs for the Utility's customers. The second is that there is a strong desire on the part of the Utility's customers for renewable energy.

With respect to the first rationale, as discussed in my response to Q16, the Utility has not credibly demonstrated that there will be cost savings to its customers from the projects that are proposed in this proceeding. Indeed, AEP Ohio

[15] Direct testimony of William A. Allen on Behalf of the Utility in PUCO Case No. 18-501-EL-FOR, p. 7–8.

acknowledges that, at least for years, consumers will not save money but will pay AEP Ohio. As noted in my responses to Q5 and Q11, the cost-recovery mechanism that is proposed by the Utility imposes all of the costs and cost risks of the Renewable Arrangements on captive customers through a non-bypassable charge. This means that if the cost savings that AEP Ohio estimates are not realized, all of those cost increases will be fully borne by its captive customers through a non-bypassable charge. Moreover, as discussed in my responses to Q10 and Q11, the Utility's proposal has the potential to harm the ability of the PJM-operated wholesale markets to ensure the long-run efficiency of the electric power system. Taken together, this means that the Utility-proposed renewable-energy projects may deliver no direct cost savings to its customers. Indeed, the projects may result in cost increases to customers. And the projects may hamper efficient investment in other renewable- and non-renewable-generation projects in Ohio.

With respect to the second rationale, as noted in my response to Q13, the Utility's customers have numerous options, through retail shopping, that allow them to procure one-hundred percent of their energy demand using renewable-energy sources, if they so desire. In other words, assuming that customers desire renewable energy, the competitive retail market is able to fully satisfy such desires.

Q18. HOW DOES AEP OHIO PROPOSE TO RECOVER THE COSTS OF ITS RENEWABLE ARRANGEMENTS THAT WOULD BE USED TO PROCURE ITS PROPOSED RENEWABLE-ENERGY PROJECTS?

A18. As I understand it, the Utility is proposing that the cost of the REPAs be collected from customers through the non-bypassable Renewable Charge. Under AEP Ohio's proposal, the net benefit—or cost—of the Renewable Charge to customers would be determined as follows. The REPA price plus the debt equivalency cost (a $100 million charge to customers) would be netted against any PJM-market revenues (supplemented by RPM credits or assessments) received for the REPAs' output and any revenues that are received from customer participation in a proposed Green Power Tariff.

Q19. COULD THE UTILITY'S COST-RECOVERY PROPOSALS FURTHER HARM CUSTOMERS, BEYOND THEIR IMPACTS ON GENERATION INVESTMENT?

A19. Yes. The Utility's proposal could harm customers, beyond the proposal's impacts on generation investment. This is because of the proposed design of the mechanism to collect these costs from captive customers. As outlined in my responses to Q5, Q11, and Q18, the Utility's proposed cost-collection mechanism means that customers bear the full risk of any difference between the cost of the REPAs and the actual wholesale-market value of the energy and capacity that is provided by the Utility-procured renewable-energy projects. This relates to the fact that AEP Ohio's generation is not dedicated to serving the electricity needs of its customers. The projects' electricity will be sold into PJM's multi-state regional market. Furthermore, the Utility proposes that the cost of the Renewable Arrangements be collected from captive customers through a non-bypassable charge. This means that if the REPAs prove to be an unduly expensive source of energy and capacity, captive monopoly customers have no recourse to obtain lower-cost energy services from a marketer. This clearly harms AEP Ohio's customers (and benefits AEP Ohio and the projects' developers) by placing the full cost risk of the Renewable Arrangements on the Utility's customers.

Q20. ARE THE UTILITY'S PROPOSED RENEWABLE-ENERGY PROJECTS EFFICIENT MECHANISMS TO ALLOW CUSTOMERS TO COVER THEIR ENERGY DEMAND WITH RENEWABLE ENERGY?

A20. No, following on my responses to Q5, Q10, Q11, Q13, Q18, and Q19, I do not believe so. The Utility's customers had (on December 5, 2018) access to at least 54 retail tariffs that are provided by marketers with some renewable-energy content. Moreover, thirty-five tariffs that are provided by marketers to shopping customers in the Utility's service territory provide one-hundred percent of their energy contents from renewable-energy sources. This means that the Utility's customers have access to numerous options through efficient retail competition that provide them with renewable-energy sources.

Moreover, obtaining renewable energy through competitive shopping has the advantage of not threatening to harm the long-run efficiency of generation investment. Nor does shopping for renewable energy from marketers place the full cost and cost risk of the Renewable Arrangements on captive customers as AEP Ohio would do with its non-bypassable Renewable Charge.

III. THERE IS A MORE EFFICIENT WAY FOR CUSTOMERS TO OBTAIN RENEWABLE ENERGY, IN A MANNER THAT IS ALLOWED UNDER OHIO LAW.

Q21. ARE THERE ALTERNATIVES TO THE UTILITY'S PROPOSAL THAT WOULD ALLOW CUSTOMERS TO PROCURE RENEWABLE ENERGY IN A MANNER THAT IS CONSISTENT WITH OHIO LAW?

A21. Yes. As outlined in my response to Q13 and Q20, an examination of the PUCO's Apples to Apples rate comparison charts on December 5, 2018 shows that there are at least 54 retail tariffs that are provided by marketers to shopping customers in the Utility's service territory with some renewable-energy content. Moreover, 35 tariffs that are provided by marketers to shopping customers in the Utility's service territory provide one-hundred percent of their energy contents from renewable-energy sources. This means that customers that wish to procure renewable energy have ample options through efficient retail shopping to do so. Moreover, customers procuring renewable energy through retail shopping does not threaten to harm the long-run efficiency of generation investment nor does it place the full cost and cost risk of the REPAs that are included in the Utility's proposal on captive customers through the non-bypassable RGR.

IV. CONCLUSION

Q22. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A22. Yes, it does. However, I reserve the right to incorporate new information that may subsequently become available through outstanding discovery or otherwise.

CERTIFICATE OF SERVICE

It is hereby certified that a true copy of the Direct Testimony of Ramteen Sioshansi on Behalf of the Office of the Ohio Consumers' Counsel was served upon the persons listed below via electronic transmission this 2nd day of January 2019.

/s/ Maureen R. Willis
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Education

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Ph.D., Industrial Engineering and Operations Research, Spring 2007
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Optimization · renewable energy analysis · power systems economics · energy policy · market and mechanism design · game theory · decision science

Publications

Appeared/Accepted

1. F. Wu and R. Sioshansi. A Stochastic Operational Model for Controlling Electric Vehicle Charging to Provide Frequency Regulation. *Transportation Research Part D: Transport and Environment*, 2019. in press.
2. B. Zhao, A. Zlotnik, A. J. Conejo, R. Sioshansi, and A. M. Rudkevich. Shadow Price-Based Co-ordination of Natural Gas and Electric Power Systems. *IEEE Transactions on Power Systems*, 2019. in press.
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Book Chapters

1. R. Sioshansi, L. F. Cabeza, and J. Yan. Introduction: Energy Storage Technologies. In L. F. Cabeza, R. Sioshansi, and J. Yan, editors, *Handbook of Clean Energy Systems*, volume 5, Energy Storage, chapter 1, pages 2385–2388. John Wiley & Sons Ltd, West Sussex, United Kingdom, June 2015.
2. R. Sioshansi, S. S. Oren, and R. P. O'Neill. The Cost of Anarchy in Self-Commitment Based Electricity Markets. In F. P. Sioshansi, editor, *Competitive Electricity Markets: Design, Implementation & Performance*. Elsevier, 2008.

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1. R. Sioshansi and A. J. Conejo. *Optimization in Engineering: Models and Algorithms*, volume 120 of *Springer Optimization and Its Applications*. Springer Nature, Gewerbestraße 11, 6330 Cham, Switzerland, 2017.
2. L. F. Cabeza, R. Sioshansi, and J. Yan, editors. *Handbook of Clean Energy Systems*, volume 5, Energy Storage. John Wiley & Sons Ltd, West Sussex, United Kingdom, June 2015.

Under Review

1. S. Chen, A. J. Conejo, R. Sioshansi, Z. Wei. Unit Commitment with an Enhanced Natural Gas-Flow Model.
2. S. Mousavian, A. J. Conejo, and R. Sioshansi. Equilibria in Investment and Spot Electricity Markets: A Conjectural-Variations Approach.
3. K. Yagi, R. Sioshansi, and P. Denholm. Can a Concentrating Solar Power Plant Be an Extended-Duration Peaking Resource?
4. L. Boffino, A. J. Conejo, R. Sioshansi, and G. Oggioni. A Two-Stage Stochastic Optimization Planning Framework to Deeply Decarbonize Electric Power Systems.
5. Y. Liu, R. Sioshansi, and A. J. Conejo. How Climate-Related Policy Affects the Economics of Generation-Capacity Investment.
6. J. E. Duggan and R. Sioshansi. Another Step Towards Equilibrium Offers in Unit Commitment Auctions with Nonconvex Costs: Multi-Firm Oligopolies.
7. M. Arbabzadeh, R. Sioshansi, J. X. Johnson, G. A. Keoleian. The role of energy storage in deep decarbonization of electricity production in California.
8. A. Siddiqui, R. Sioshansi, and A. J. Conejo. Merchant Storage Investment in a Restructured Electricity Industry.

Presentations

1. A. J. Conejo and R. Sioshansi, "A Financial Framework for Distribution Systems with Increasing Behind-the-Meter Resources," *2019 IEEE PES General Meeting*. August 4-8, 2019, Atlanta, GA.
2. M. Arbabzadeh, R. Sioshansi, J. X. Johnson, and G. A. Keoleian, "The Role of Energy Storage in Deep Decarbonization of Electricity Production," invited seminar in Wind Energy Fellows Program, University of Massachusetts Amherst. December 6, 2018, Amherst, MA.
3. Y. Liu, R. Sioshansi, and A. J. Conejo, "How Climate-Related Policy Affects the Economics of Generation-Capacity Investment," *FSR Climate Annual Conference*. November 26-27, 2018, Florence, Italy.

4. S. Chen, A. J. Conejo, R. Sioshansi, and Z. Wei, "Unit Commitment Of Integrated Electric And Gas Systems With An Enhanced SOC Gas Flow Model," *INFORMS Annual Meeting.* November 4-7, 2018, Phoenix, AZ.
5. S. Chen, A. J. Conejo, R. Sioshansi, and Z. Wei, "Equilibria In Electricity And Gas Systems Under Limited Information Interchange," *INFORMS Annual Meeting.* November 4-7, 2018, Phoenix, AZ.
6. J. D. Ogland-Hand, J. M. Bielicki, E. S. Nelson, B. M. Adams, T. A. Bushcheck, M. O. Saar, and R. Sioshansi, "Optimizing the Use of CO_2-Bulk Energy Storage for Transmission Deferral," *INFORMS Annual Meeting.* November 4-7, 2018, Phoenix, AZ.
7. R. Sioshansi "Modeling and Decomposing Multi-Stage and Multi-Scale Stochastic Investment Problems," invited seminar to *IEEE Columbus PES Chapter.* October 24, 2018, Columbus, OH.
8. R. Sioshansi, Y. Liu, L. Boffino, A. J. Conejo, G. Oggioni, "What are the Technical Pathways to and Economic Issues with Decarbonizing Electricity Production?" *3rd Japanese-German Workshop on Renewable Energies.* October 17-19, 2018, Tokyo, Japan.
9. R. Sioshansi, "Can We Get Market and Regulatory Designs 'Right' for Energy Storage?" invited seminar in Operations Research and Industrial Engineering Program, University of Texas at Austin. October 5, 2018, Austin, TX.
10. R. Sioshansi, "How Much Does Energy Storage Contribute to Power System Reliability?" invited seminar at Sandia National Laboratories. September 28, 2018, Albuquerque, NM.
11. R. Sioshansi, "Electricity Advisory Committee: Energy Storage Subcommittee," *2018 Department of Energy Office of Electricity Energy Storage Storage Peer Review.* September 24-27, 2018, Santa Fe, NM.
12. L. Boffino, A. J. Conejo, R. Sioshansi, and G. Oggioni, "A Two-Stage Stochastic Optimization Framework for Planning Deeply Decarbonized Electric Power Systems," *42nd Annual Meeting of the Italian Association for Mathematics Applied to Economic and Social Sciences.* September 13-15, 2018, Naples, Italy.
13. A. J. Conejo and R. Sioshansi. "Revisiting Electricity Market Design: What the Past 30 Years Taught Us and What Electricity Systems of the Future Need," *IEEE Power & Energy Society General Meeting 2018.* August 5-9, 2018, Portland, OR.
14. H. Kim, R. Sioshansi, E. Ela, E. Lannoye, and A. J. Conejo. "How Market-Design Choices Affect the Reliability Contribution of Energy Storage" *IEEE Power & Energy Society General Meeting 2018.* August 5-9, 2018, Portland, OR.
15. A. J. Conejo and R. Sioshansi, "Rethinking restructured electricity market design: Lessons learned and future needs," invited brown bag seminar at Deutsches Institut für Wirtschaftsforschung. July 19, 2018, Berlin, Germany.
16. R. Sioshansi, "Energy Storage Subcommittee Update," *Electricity Advisory Committee Meeting.* July 9-10, 2018, Washington, DC.
17. A. J. Conejo and R. Sioshansi, "A Market Design Integrating The View Of Stochastic Producers," invited seminar at Red Eléctrica de España. July 4, 2018, Madrid, Spain.
18. M. Arbabzadeh, R. Sioshansi, J. X. Johnson, and G. A. Keoleian, "Energy storage for time-shifting and greenhouse gas reductions under varying renewable penetrations—A CAISO case study," *2018 International Symposium on Sustainable Systems & Technology.* June 26-28, 2018, Buffalo, NY.
19. S. Chen, A. J. Conejo, R. Sioshansi, and Z. Wei, "Unit Commitment of Integrated Electric and Gas Systems with an Enhanced Second-Order Cone Gas Flow Model," *Technical Conference: Increasing Real-Time and Day-Ahead Market Efficiency and Enhancing Resilience through Improved Software.* June 26-28, 2018, Washington, DC.
20. H. Kim, R. Sioshansi, E. Ela, E. Lannoye, and A. J. Conejo. "Contribution of Energy Storage to Resource Adequacy" *2018 International Conference on Probabilistic Methods Applied to Power Systems.* June 24-28, 2018, Boise, ID.

21. R. Sioshansi. “Can We Get Market Design and Regulation Correct for Energy Storage?” keynote speech at *Workshop on ‘Commodities and Energy Market Organization in the Energy Transition Context’*. June 18-19, 2018, Rueil-Malmaison, France.
22. A. Siddiqui, R. Sioshansi, and A. J. Conejo, “Merchant Storage Investment in a Restructured Electricity Industry,” *41st Annual IAEE International Conference*. June 10-13, 2018, Groningen, The Netherlands.
23. R. Sioshansi, “Using the Flexibility of Energy Storage for Renewable Integration and Power System Operations,” invited seminar at North China Electric Power University. May 10, 2018, Beijing, People’s Republic of China.
24. R. Sioshansi, “Estimating the Capacity Value of Energy-Limited Storage in Wholesale Energy Markets,” *EPRI ISO/RTO Webcast*. March 30, 2018.
25. R. Sioshansi, “EAC Energy Storage Subcommittee: Update,” *Electricity Advisory Committee Meeting*. February 20-21, 2018, Washington, DC.
26. J. D. Ogland-Hand, J. M. Bielicki, E. S. Nelson, B. M. Aadms, T. A. Buscheck, R. Sioshansi, “The Value of Using Sedimentary Basin Geothermal Resources for Bulk Energy Storage in Transmission Constrained Electricity Systems,” *Stanford Geothermal Workshop*. February 12-14, 2018, Palo Alto, CA.
27. R. Sioshansi, “Using Sequential Sampling to Solve a Two-Stage Stochastic Program for Scheduling Electric Vehicle Charging,” *Winter School Workshop 2018 on Stochastic Programming in Energy*. February 11-14, 2018, Geilo, Norway.
28. R. Sioshansi, “Using Distributed Energy Resources for Multiple Applications Via Capacity Rights,” *Distributed Energy Workshop*. January 11-13, 2018, University of Auckland, Auckland, New Zealand.
29. R. Sioshansi, “Using Energy Storage as a Source of Flexibility for Renewable Integration and Power System Operations,” invited panelist at *VII Jornadas de Economía de la Energía*. November 9, 2017, Santiago, Chile.
30. R. Sioshansi, “Regulatory, Rate, and Market Design for Energy Storage,” invited seminar at Groupe d’études et de recherche en analyse des décisions (GERAD), École Polytechnique de Montréal. November 2, 2017, Montréal, Quebec, Canada.
31. A. Siddiqui, R. Sioshansi, and A. J. Conejo, “Merchant Storage Investment In A Deregulated Electricity Industry,” *INFORMS Annual Meeting*. October 22-25, 2017, Houston, TX.
32. A. J. Conejo and R. Sioshansi, “A Market Design Integrating The View Of Stochastic Producers,” *INFORMS Annual Meeting*. October 22-25, 2017, Houston, TX.
33. R. Sioshansi, “Managing the Transition of Electric Power Systems to a Decarbonized Future,” invited seminar at The Ohio State University Environmental Sciences Graduate Program. October 20, 2017, Columbus, OH.
34. H. Bahtiyar and R. Sioshansi, “The Effects of Policy Changes on Households’ Behavior About Electric Vehicles and Energy Related Appliances,” *2nd IAEE Eurasian Conference*. October 12-14, 2017, Zagreb, Croatia.
35. R. Sioshansi, “Energy Storage: An Introduction to Technologies, Real-World Use Cases, and Regulatory Developments,” *Saudi Electricity Forum*. October 10-12, 2017, Riyadh, Saudi Arabia.
36. R. Sioshansi, “Managing Loads and Operation of Electric Power Systems,” *Saudi Electricity Forum*. October 10-12, 2017, Riyadh, Saudi Arabia.
37. R. Sioshansi and A. J. Conejo, “The State of Restructured Electricity Market Design and the Need for Further Reform,” *International Conference on Energy Revolution and Electricity Innovation*. September 21-22, 2017, Beijing, People’s Republic of China.
38. R. Sioshansi, “EAC Energy Storage Subcommittee: Update,” *Electricity Advisory Committee Meeting*. September 13-14, 2017, Washington, DC.

39. R. Sioshansi, "An Overview of the Challenges of Today's Electricity Markets in the United States and European Union," invited joint workshop organized by Directorate-General of the Joint Research Centre and Directorate-General of Energy of the European Union on *Redesigning Restructured Electricity Markets: Accommodating Variable Renewables, Distributed Energy Resources, and System Security*. July 24, 2017, Brussels, Belgium.
40. R. Sioshansi, "Non-technology Barriers to the Deployment of Distributed Energy Storage," *IEEE Power & Energy Society General Meeting 2017*. July 16-20, 2017, Chicago, IL.
41. R. Sioshansi, "Economic, Regulatory, and Modeling Issues with Energy Storage," invited lecturer for tutorial on Energy Storage: An Introduction to Technologies, Applications and Best Practices at *IEEE Power & Energy Society General Meeting 2017*. July 16-20, 2017, Chicago, IL.
42. B. Zhao, A. J. Conejo, and R. Sioshansi, "Coordinated Capacity-Expansion Planning of Natural Gas and Electric Power Systems," invited seminar at Nanyang Technological University School of Electrical and Electronic Engineering. June 22, 2017, Singapore.
43. R. Sioshansi and H. B. Gooi, "Policy Framework for Energy Storage Systems in Singapore," invited seminar at Energy Market Authority. June 21, 2017, Singapore.
44. R. Sioshansi, "Energy Security and Resilience Benefits of Electric Energy Storage," plenary panelist at *40th Annual IAEE International Conference*. June 18-21, 2017, Singapore.
45. R. Sioshansi and A. J. Conejo, "Revisiting Restructured Electricity Market Design: What the Past 30 Years Taught Us and What Electricity Systems of the Future Need," keynote speech at *14th International Conference on the European Energy Market*. June 6-9, 2017, Dresden, Germany.
46. R. Sioshansi, "Using Storage-Capacity Rights to Overcome the Cost-Recovery Hurdle for Energy Storage," *The Economics of Energy and Climate Change*. June 6-7, 2017, Toulouse, France.
47. R. Sioshansi, "'Optimal network tariffs for renewable electricity production,' by Thomas P. Tangerås and Frank Wolak," invited discussant, *The Economics of Energy and Climate Change*. June 6-7, 2017, Toulouse, France.
48. F. Wu, H. Nagarajan, A. Zlotnik, R. Sioshansi, and A. M. Rudkevich, "Adaptive Convex Relaxations for Gas Pipeline Network Optimization," *American Control Conference*. May 24-26, 2017, Seattle, WA.
49. R. Sioshansi, "PowerForward: Economic and Regulatory Innovation to Achieve the Power System of the Future," invited address to the *Public Utilities Commission of Ohio*. April 18-20, 2017, Columbus, OH.
50. R. Sioshansi, "Non-technology Barriers to the Deployment of Distributed Energy Storage," invited seminar in University of Michigan series on *Emerging Topics in Sustainable Electric Power Systems*. February 2, 2017, Ann Arbor, MI.
51. R. Sioshansi, "Analyzing the Effects of Policy Levers on Energy Pricing and Investment with Stochastic Capacity Expansion Models," *Winter School 2017 in Stochastic Programming with Applications in Energy, Logistics, and Finance*. January 15-21, 2017, Passo del Tonale, Italy.
52. R. Sioshansi and A. J. Conejo, "Electricity Grid of the Future," *Presentation to Management of AEP Ohio*. January 12, 2017, Columbus, OH.
53. Y. Liu and R. Sioshansi, "Electricity Capacity Expansion and Cost Recovery With Renewables," *INFORMS Annual Meeting*. November 13-16, 2016, Nashville, TN.
54. A. J. Conejo, B. Zhao, and R. Sioshansi, "Unit Commitment Under Gas-Supply Uncertainty and Gas-Price Variability," *INFORMS Annual Meeting*. November 13-16, 2016, Nashville, TN.
55. R. Sioshansi, "Economic Regulation Issues Regarding VtG in the United States," *Expert Workshop: V2X User Perception, Business Models, and Regulatory Framework*. October 26-28, 2016, Paris, France.
56. C. J. Dent, R. Sioshansi, J. Reinhart, A. L. Wilson, S. Zachary, M. Lynch, C. Bothwell, and C. Steele, "Capacity Value of Solar Power: Report of the IEEE PES Task Force on Capacity Value of Solar Power," *2016 International Conference on Probabilistic Methods Applied to Power Systems*. October 16-20, 2016, Beijing, People's Republic of China.

57. R. Sioshansi, "Using Storage-Capacity Rights to Overcome the Cost-Recovery Hurdle for Energy Storage," invited seminar at Nanyang Technological University School of Electrical and Electronic Engineering. October 13, 2016, Singapore.
58. R. Sioshansi, "Storage Assessment and Five-Year Plan: Update and EAC Approval," *Electricity Advisory Committee Meeting*. September 28-29, 2016, Washington, DC.
59. R. Sioshansi, "Economic, Regulatory, and Modeling Issues with Energy Storage," invited lecturer for tutorial on Energy Storage: An Introduction to Technologies, Applications and Best Practices at *IEEE Power & Energy Society General Meeting 2016*. July 17-21, 2016, Boston, MA.
60. R. Sioshansi, "Using Storage-Capacity Rights to Overcome the Cost-Recovery Hurdle for Energy Storage," invited seminar in Fakultät Wirtschaftswissenschaften, Technische Universität Dresden. July 12, 2016, Dresden, Germany.
61. R. Sioshansi, "Biennial Storage Program Assessment: Update and Work Plan," *Electricity Advisory Committee Meeting*. June 1-2, 2016, Washington, DC.
62. R. Sioshansi, "Energy Storage Subcommittee Activities and Plans," *Electricity Advisory Committee Meeting*. June 1-2, 2016, Washington, DC.
63. A. J. Conejo and R. Sioshansi, "A market design integrating the view of stochastic producers," keynote speech at Third General Consortium Meeting, Centre for IT-Intelligent Energy Systems in Cities, Danmarks Tekniske Universitet. May 25, 2016, Lyngby, Denmark.
64. R. Sioshansi, "Planning, Operational, and Business Models for Public Electric Vehicle Charging Stations," *2016 International Conference on Global Energy Interconnection*. March 30-31, 2016, Beijing, People's Republic of China.
65. R. Sioshansi, "Biennial Storage Program Assessment: Update and Work Plan," *Electricity Advisory Committee Meeting*. March 17-18, 2016, Washington, DC.
66. R. Sioshansi, "Modeling and Decomposing Multi-Stage and Multi-Scale Stochastic Investment Problems," *Winter School 2016 in Stochastic Programming and Energy*. March 13-17, 2016, Oppdal, Norway.
67. R. Sioshansi, "Understanding the Economic and Environmental Impacts of Energy Storage: The Role of Market Structure," invited seminar in Management Science and Engineering Department and Precourt Institute for Energy, Stanford University. February 18, 2016, Palo Alto, CA.
68. R. Sioshansi, "Vehicle-Grid System Integration Policies," *Review of DOE CERC-CVC 1.0 Programs*. January 20, 2016, Columbus, OH.
69. R. Sioshansi, "Modeling and Decomposing Multi-Stage and Multi-Scale Stochastic Optimization Problems," invited tutorial at workshop on Optimization and Equilibrium in Energy Economics, Institute for Pure and Applied Mathematics, University of California, Los Angeles. January 11-15, 2016, Los Angeles, CA.
70. Y. Liu and R. Sioshansi, "A Progressive Hedging Approach to Multistage and Multiscale Stochastic Generation and Transmission Investment," invited seminar at Groupe d'études et de recherche en analyse des décisions (GERAD), École Polytechnique de Montréal. November 26, 2015, Montréal, Quebec, Canada.
71. F. Wu and R. Sioshansi, "Public Electric Vehicle Fast Charging Station Management Strategies," *INFORMS Annual Meeting*. November 1-4, 2015, Philadelphia, PA.
72. Y. Liu and R. Sioshansi, "Stochastic Generation and Transmission Investment Planning Model," *INFORMS Annual Meeting*. November 1-4, 2015, Philadelphia, PA.
73. Y. Liu and R. Sioshansi, "A Progressive Hedging Approach to Multistage Stochastic Generation and Transmission Investment Planning," *9th Annual Trans-Atlantic INFRADAY Conference*. October 30, 2015, Washington, DC.
74. R. Sioshansi and F. Wu, "Vehicle-Grid System Integration Policies: Electric Vehicle Charging Station Placement and Management," *2015 US-China Clean Energy Research Center Annual Meeting*. August 17-18, 2015, Beijing, People's Republic of China.
75. R. Sioshansi, "'Big' Problems in Energy Systems," invited talk at the *JPMorgan Chase & Company Analytics Lunch and Learn Series*. July 13, 2015, Columbus, OH.

76. R. Sioshansi, “Inclusion of solar generation in adequacy studies: a survey by the PES ‘Capacity Value of Solar Power’ Task Force,” *2015 IEEE Power and Energy Society General Meeting*. July 26-30, 2015, Denver, CO.
77. R. Sioshansi, “Needs for Improved Modeling of Storage and Greater Consistency in Methods and Metrics,” *2015 IEEE Power and Energy Society General Meeting*. July 26-30, 2015, Denver, CO.
78. R. Sioshansi, “Non-Technical Barriers to Energy Storage Entering the Market,” *2015 IEEE Power and Energy Society General Meeting*. July 26-30, 2015, Denver, CO.
79. R. Sioshansi, “Stochastic Dynamic Programming Models for Co-Optimizing Storage Operations,” *22nd International Symposium on Mathematical Programming*. July 12-17, 2015, Pittsburgh, PA.
80. R. Sioshansi, ‘A Dynamic Programming Approach to Estimating the Capacity Value of Energy Storage,” invited seminar at Durham University Durham Energy Institute. June 16, 2015, Durham, United Kingdom.
81. R. Sioshansi, “Retail Electricity Tariff and Mechanism Design to Incentivize Distributed Generation,” *The 2nd Meeting of the ERIA Research Working Group 2014–2015 for Studies on “Financing Renewable Energy Development in EAS Countries: A Primer of Effective Policy Instruments”*. May 16-17, 2015, Chiang Mai, Thailand.
82. R. Sioshansi, ‘A Stochastic Dynamic Programming Model for Co-Optimizing Storage Operations,” invited colloquium at University of Texas at Austin Department of Electrical and Computer Engineering. May 6, 2015, Austin, TX.
83. R. Sioshansi, “Stochastic Dynamic Programming and Energy Storage,” *Winter School 2015 in Energy Systems and Markets*. 22-28 March, 2015, Kvitfjell, Norway.
84. R. Sioshansi, “Non-Technical Barriers to Energy Storage Entering the Market,” *University of Michigan Sustainable Systems Forum*, Invited Seminar Speaker. February 20, 2015, Ann Arbor, MI.
85. R. Sioshansi, “Wholesale and Retail Market Design for Incentivizing Renewable Energy Adoption,” *The 1st Meeting of the ERIA Research Working Group 2014–2015 for Studies on “Financing Renewable Energy Development in EAS Countries: A Primer of Effective Policy Instruments”*. January 6, 2015, Jakarta, Indonesia.
86. R. Sioshansi, “Optimizing Offers for Cascaded Hydroelectric Generators in a Market with Centralized Dispatch,” *INFORMS Annual Meeting*. November 9-12, 2014, San Francisco, CA.
87. R. Sioshansi, “Energy Storage and Renewable Integration: Needs, Opportunities, and Challenges,” *University of Iowa Public Policy Center Conference on “Meeting the Renewable Energy Challenge”*, Invited Panelist. October 15-16, 2014, Iowa City, IA.
88. R. Sioshansi, “The Economics of Energy Storage,” *International Summer School ENERstore 2014*. September 22-26, 2014, Technische Universität Dresden, Dresden, Germany.
89. R. Sioshansi and F. Wu, “Vehicle-Grid System Integration Policies: Electric Vehicle (EV) Infrastructure Location Optimization & Charging Load Estimation,” *2014 US-China Clean Energy Research Center Annual Meeting*. August 11-12, 2014, Ann Arbor, MI.
90. R. Sioshansi, “Decision Support Tools for Energy Storage Investment and Operations,” *2014 IEEE Power and Energy Society General Meeting*. July 27-31, 2014, National Harbor, MD.
91. R. Sioshansi, “Energy Storage,” invited tutorial to the *Ohio Consumers’ Counsel*. July 15, 2014, Columbus, OH.
92. R. Sioshansi, “The Role of Vehicle to Grid With Renewable Resources in Electricity Markets,” *Armand Peugeot Chair 1st International Conference on “Electromobility: Challenging Issues”*, Invited Keynote Speaker and Roundtable Participant. December 19-20, 2013, Paris, France.
93. R. Sioshansi, “Welfare Effects of Energy Storage: Market Structure, Ownership, and the Unknown,” invited seminar at Friedrich-Alexander-Universität. December 16, 2013, Nürnberg, Germany.
94. R. Sioshansi, “Economic Impact of Grid Energy Storage,” *Presented at Emerging Technologies’ Impact on U.S. Energy Security*, The MITRE Corporation. December 3-4, 2013, McLean, VA.

95. S. H. Madaeni, R. Sioshansi, and P. Denholm, "Estimating Capacity Value of Energy Storage Using Dynamic Programming," *INFORMS Annual Meeting*. October 6-9, 2013, Minneapolis, MN.
96. X. Xi, R. Sioshansi, and V. Marano, "A Stochastic Dynamic Programming Model for Co-optimization of Distributed Storage," *INFORMS Annual Meeting*. October 6-9, 2013, Minneapolis, MN.
97. R. Sioshansi, "Capacity Cost Allocation and Distributed Renewables," *IET Renewable Power Generation Conference 2013*, Invited Keynote Speaker. September 19-20, 2013, Beijing, People's Republic of China.
98. R. Sioshansi and X. Xi, "Using Price-Based Signals to Control Plug-in Electric Vehicle (PEV) Charging," *2013 US-China Clean Energy Research Center Annual Meeting*. August 19-20, 2013, Beijing, People's Republic of China.
99. S. H. Madaeni and R. Sioshansi, "The Effects of Delayed Price-Responsive Demand in Reducing Wind-Uncertainty Costs," invited seminar at Institutet för Näringslivsforskning. May 31, 2013, Stockholm, Sweden.
100. R. Sioshansi, "Home Energy Management," *The Ohio State University/Battelle Memorial Institute Smart Grid Collaboration Meeting*. January 23, 2013, Columbus, OH.
101. S. H. Madaeni and R. Sioshansi, "Demand Response Can Improve the Emission Benefits of Wind," *The Economics of Energy Markets*. January 17-18, 2013, Toulouse, France.
102. R. Sioshansi and A. Tignor, "Utopia Electric: Do Centrally Committed Electricity Markets Provide Useful Price Signals?" *Electricity Optimization: Optimal Power System Topologies and Generation*. November 8, 2012, Washington, DC.
103. S. H. Madaeni, R. Sioshansi, and P. Denholm, "Capacity Value of Photovoltaic Power," *INFORMS Annual Meeting*. October 14-17, 2012, Phoenix, AZ.
104. R. Sioshansi and A. Tignor, "Do Centrally Committed Markets Provide Useful Price Signals?" *INFORMS Annual Meeting*. October 14-17, 2012, Phoenix, AZ.
105. X. Xi, R. Sioshansi, and V. Marano, "A Nash Equilibrium Method to Control Plug-in Electric Vehicle Charging with Wind Integration," *INFORMS Annual Meeting*. October 14-17, 2012, Phoenix, AZ.
106. X. Xi, R. Sioshansi, and V. Marano, "Optimal Location of Public Electric Vehicle Charging Infrastructure," *INFORMS Annual Meeting*. October 14-17, 2012, Phoenix, AZ.
107. R. Sioshansi, "Electric Vehicle Adoption: Spatial and Demographic Effects," invited panelist at *Great Lakes Symposium on Smart Grid and the New Energy Economy*. September 24-26, 2012, Chicago, IL.
108. M. Roberts, R. Sioshansi, and M. Pham, "Spatial Analysis of PEV Adoption," *2012 US-China Clean Energy Research Center Annual Meeting*. August 27-28, 2012, Ann Arbor, MI.
109. R. Sioshansi, V. Marano, and X. Xi, "Price-based PEV Charging Control," *2012 US-China Clean Energy Research Center Annual Meeting*. August 27-28, 2012, Ann Arbor, MI.
110. R. Sioshansi, V. Marano, and X. Xi, "A Simulation-Optimization Model for Public PEV Charging Stations," *2012 US-China Clean Energy Research Center Annual Meeting*. August 27-28, 2012, Ann Arbor, MI.
111. R. Sioshansi, "Price and Investment Implications of Renewables," invited panelist at *Ohio Clean Energy Transmission Summit*. August 6, 2012, Columbus, OH.
112. S. H. Madaeni, R. Sioshansi, and P. Denholm, "The Capacity Value of Solar Generation in the Western United States," *2012 IEEE Power & Energy Society General Meeting*. July 22-26, 2012, San Diego, CA.
113. M. Muratori, V. Marano, R. Sioshansi, and G. Rizzoni, "Energy consumption of residential HVAC systems: a simple physically-based model," *2012 IEEE Power and Energy Society General Meeting*. July 22-26, 2012, San Diego, CA.
114. U. Helman and R. Sioshansi, "Valuing concentrating solar power with thermal energy storage: A survey of the literature and some extensions," *Advanced Workshop in Regulation and Competition: 25th Annual Western Conference*. June 27-29, 2012, Monterey, CA.

115. R. Sioshansi, "Impact of Renewable on System CO_2 Emission," invited presentation at Cummins Science & Technology Council Meeting. June 27, 2012, Columbus, IN.
116. X. Xi, R. Sioshansi, and V. Marano, "A Simulation-Optimization Model for the Location of Public Electric Vehicle Charging Infrastructure," invited colloquium at Institute for Future Energy Consumer Needs and Behavior and E.ON Energy Research, RWTH Aachen University. June 13, 2012, Aachen, Germany.
117. R. Sioshansi, "Transportation Electrification: What are the Benefits and Challenges?" invited seminar at IFP School. June 11-12, 2012, Rueil-Malmaison, France.
118. R. Sioshansi, "The Economics of Energy Storage: What can be Learned from the U.S. Experience?" invited seminar at IFP School. June 11-12, 2012, Rueil-Malmaison, France.
119. R. Sioshansi, "'Investment Analysis of Power Distribution Networks: The Case of Norway' by Rahmatallah Poudineh and Tooraj Jamasb," invited discussant, *5th International Workshop on "Empirical Methods in Energy Economics"*. June 7-8, 2012, Berlin, Germany.
120. A. Pielow, R. Sioshansi, and M. C. Roberts, "Modeling Short-run Electricity Demand with Long-term Growth Rates and Consumer Prices Elasticity in Commercial and Industrial Sectors," *5th International Workshop on "Empirical Methods in Energy Economics"*. June 7-8, 2012, Berlin, Germany.
121. R. Sioshansi, "Market and Policy Barriers to Energy Storage," *Renewable & Sustainable Energy Technology Workshop*. April 12-13, 2012, Los Angeles, CA.
122. M. Muratori, M. Roberts, R. Sioshansi, V. Marano, G. Rizzoni, "Modeling Residential Power Demand," *6th Annual UCEAO Conference on Securing Ohio's Energy and Economic Future*. April 2-3, 2012, Columbus, OH.
123. R. Sioshansi, and E. Nicholson, "Comparison of Centrally and Self-Committed Electricity Markets," *INFORMS Annual Meeting*. November 13-16, 2011, Charlotte, NC.
124. R. Sioshansi and P. Denholm, "Benefits of Co-Locating Wind and Concentrating Solar Power," *INFORMS Annual Meeting*. November 13-16, 2011, Charlotte, NC.
125. S. H. Madaeni, R. Sioshansi, and P. Denholm, "Estimating the Capacity Value of Concentrating Solar Power Plants," *INFORMS Annual Meeting*. November 13-16, 2011, Charlotte, NC.
126. R. Sioshansi, "EV Charging Infrastructure Siting," *2011 SJTU-UM Workshop on Renewable Energy and New Energy Vehicles*. October 20-21, 2011, Shanghai, People's Republic of China.
127. R. Sioshansi, "EV Charging Infrastructure Siting—Project Overview," *2011 Annual Technology Forum of US-China Clean Vehicles Consortium*. October 17-18, 2011, Beijing, People's Republic of China.
128. R. Sioshansi, "Advanced Energy Technologies: Overview of Research Activities," invited seminar at Battelle Memorial Institute. September 12, 2011, Columbus, OH.
129. M. Muratori, V. Marano, R. Sioshansi, and M. Roberts, "Domestic Power Demand Prediction and Modelling," *The 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems*. July 4-7, 2011, Novi Sad, Serbia.
130. R. Sioshansi, "Market Impacts and Interactions in the Energy/Climate Nexus," NSF Workshop on *Engineering & Social Response to the Energy-Climate Nexus*. June 23-24, 2011, Arlington, VA.
131. R. Sioshansi and P. Denholm, "The Value of Plug-In Hybrid Electric Vehicles as Grid Resources," *34th IAEE International Conference*. June 19-23, 2011, Stockholm, Sweden.
132. R. Sioshansi, "Methods of Modeling the Value of Concentrating Solar Power and Thermal Energy Storage," invited seminar at BrightSource Energy. May 23, 2011, Oakland, CA.
133. R. Sioshansi "Market Interactions Between Wind and Energy Storage: Do Wind and Storage Make Economic Sense?" invited seminar at Tulane Energy Institute, Tulane University. April 8, 2011, New Orleans, LA.
134. R. Sioshansi, "Addressing Computational Issues in Large-Scale Models," *EFRI-RESIN Workshop*. January 13-14, 2011, Tucson, AZ.
135. R. Sioshansi, "Increasing the Value of Wind with Energy Storage." *INFORMS Annual Meeting*. November 7-10, 2010, Austin, TX.

136. S. Madaeni and R. Sioshansi, "Evaluating the Impact of Demand Response and Stochastic Programming on the Cost of Wind," *INFORMS Annual Meeting*. November 7-10, 2010, Austin, TX.
137. R. Sioshansi, "The Impact of Electricity Tariffs on PHEVs," *INFORMS Annual Meeting*. November 7-10, 2010, Austin, TX.
138. S. Madaeni and R. Sioshansi, "Benefits of Demand Response and Stochastic Programming on Reducing Wind Integration Costs," *12th International Conference on Stochastic Programming*. August 16-20, 2010, Halifax, NS, Canada.
139. R. Sioshansi, V. Marano, and R. Fagiani, "Cost and Emissions Impacts of Plug-In Hybrid Vehicles (PHEVs) on the Electric Power Grid," *4th International Conference on Sustainable Energy and Environmental Protection*. June 29-July 2, 2010, Bari, Italy.
140. R. Fagiani, V. Marano, and R. Sioshansi, "Cost and Emissions Impacts of Plug-in Hybrid Electric Vehicles on Ohio Power Grid," *The 2nd International Symposium on Energy Engineering, Economics and Policy: EEEP 2010*. June 29-July 2, 2010, Orlando, FL.
141. R. Sioshansi, "Using Storage to Increase the Market Value of Wind Generation," *Advanced Workshop in Regulation and Competition: 23rd Annual Western Conference*. June 23-25, 2010, Monterey, CA.
142. R. Sioshansi, "Some Policy and Research Questions Related to Energy Storage," *Workshop on Electricity Storage in Paris–Supélec*. May 10, 2010, Gif-sur-Yvette, France.
143. R. Sioshansi, "Using Storage to Increase the Market Value of Wind Generation," *The Economics of Energy Markets*. January 28-29, 2010, Toulouse, France.
144. R. Sioshansi, "Welfare and Incentive Effects of Energy Storage," *INFORMS Annual Meeting*. October 11-14, 2009, San Diego, CA.
145. R. Sioshansi and P. Denholm, "Net Emissions Impacts of Plug-In Hybrid Electric Vehicles," *INFORMS Annual Meeting*. October 11-14, 2009, San Diego, CA.
146. P. Denholm and R. Sioshansi, "The Value of Compressed-Air Energy Storage (CAES) with Transmission-Constrained Wind," *INFORMS Annual Meeting*. October 11-14, 2009, San Diego, CA.
147. S. Oren, R. Sioshansi, and R. O'Neill, "Three part auctions versus self-commitment in day ahead electricity markets," *Workshop: Designing Electricity Auctions*. September 15-16, 2009. Stockholm, Sweden.
148. R. Sioshansi, "Modeling the Impacts of Plug-In Hybrid Electric Vehicles on Electric Power Systems," *20th International Symposium on Mathematical Programming*. August 23-28, 2009, Chicago, IL.
149. P. Denholm and R. Sioshansi, "Estimating the Transmission Value of Combining Wind with Energy Storage," *32nd IAEE International Conference*. June 21-24, 2009, San Francisco, CA.
150. R. Sioshansi and P. Denholm, "Estimating the Value of Energy Storage in Concentrating Solar Thermal Plants," *32nd IAEE International Conference*. June 21-24, 2009, San Francisco, CA.
151. R. Sioshansi, "Evaluating the Impact of Real-Time Pricing on the Cost and Value of Wind Generation," *Second Annual Power Systems Modeling Conference*. March 18-20, 2009, Gainesville, FL.
152. R. Sioshansi, "The Value of Plug-in Hybrid Electric Vehicles as Grid Resources," *Second Annual Power Systems Modeling Conference*. March 18-20, 2009, Gainesville, FL.
153. R. Sioshansi, "Evaluating the Impact of Real-Time Pricing on the Cost and Value of Wind Generation," *Fifth Annual Carnegie Mellon Conference on the Electricity Industry*. March 10-11, 2009, Pittsburgh, PA.
154. R. Sioshansi, "Evaluating the Impact of Real-time Demand Response on the Integration Cost of Wind," *INFORMS Annual Meeting*. October 12-15, 2008, Washington, DC.
155. R. Sioshansi and W. Short, "Evaluating the Impacts of Real-Time Pricing on the Usage of Wind Generation," *The Economics of Energy Markets*. June 20-21, 2008, Toulouse, France.
156. R. Sioshansi, "'Cournot versus Supply Functions: What does the data tell us?' by Bert Willems, Ina Rumiantseva, and Hannes Weigt," invited discussant, *The Economics of Energy Markets*. June 20-21, 2008, Toulouse, France.

157. R. Sioshansi and W. Short, "Demand Response via Real-Time Pricing to Increase Use of Operational Wind Energy Generators," *PSerc Public Teleseminar*. May 6, 2008.
158. R. Sioshansi and E. Nicholson, "Equilibrium Bidding in Unit Commitment Auctions," *INFORMS Annual Meeting*. November 4-7, 2007, Seattle, WA.
159. R. Sioshansi and A. Svoboda, "Optimal Hydro Bidding in a Market with Centralized Dispatch," *Advanced Workshop in Regulation and Competition: 20th Annual Western Conference*. June 27-29, 2007, Monterey, CA.
160. R. Sioshansi, S. Oren, and R. O'Neill, "The Cost of Anarchy in Self-Commitment Based Electricity Markets," *INFORMS Annual Meeting*. November 5-8, 2006, Pittsburgh, PA.
161. R. Sioshansi and S. Oren, "Do Supply Function Equilibrium Models Describe Behavior in Electricity Spot Markets: An Empirical Analysis of the ERCOT Market," *The Economics of Electricity Markets*. June 2-3, 2005, Toulouse, France.
162. R. Sioshansi and S. Oren, "Do Supply Function Equilibrium Models Describe Behavior in Electricity Spot Markets: An Empricial Analysis of the ERCOT Market," *UC Energy Institute Seminar*. March 11, 2005, Berkeley, CA.
163. S. Oren and R. Sioshansi, "Joint Energy and Reserves Auction with Opportunity Cost Payments for Reserves," *Proceedings of the Bulk Power Systems Dynamics and Control IV*. August 22-27, 2004, Cortina d'Ampezzo, Italy.
164. S. Oren and R. Sioshansi, "Joint Energy and Reserves Auction with Opportunity Cost Payment for Reserves," *The Economics of Energy Markets*. January 16-17, 2004, Toulouse, France.

Teaching

Instructor

- Nonlinear and Dynamic Optimization (undergraduate); The Ohio State University; Spring 2013–Autumn 2018
- Restructured Electricity Market Design (graduate-level short course); IFP School; Summer 2012–2018
- Advanced Nonlinear Optimization (graduate); The Ohio State University; Spring 2013, 2014, 2018
- Decision Analysis (graduate); The Ohio State University; Autumn 2012–2013, Autumn 2016–2017
- Decomposition and Relaxation Techniques for Large-Scale Optimization Problems (Ph.D.-level short course); Technische Universität Dresden; Summer 2016
- Market Engineering and Applications (graduate); The Ohio State University; Spring 2010, Winter 2011, and Autumn 2015
- Electric Vehicle Grid Integration (graduate-level short course); CentraleSupélec; Winter 2013
- Optimization Transition (undergraduate); The Ohio State University; Spring 2012
- Seminar in Industrial Engineering (graduate); The Ohio State University; Autumn 2011–Spring 2012
- Nonlinear Programming (graduate); The Ohio State University; Winter 2011–2012
- Introduction to Applied Decision Analysis (graduate); The Ohio State University; Spring 2009 and 2010, Autumn 2011
- Fundamentals of Linear Optimization with Applications (undergraduate); The Ohio State University; Winter 2009, and Autumn 2009–2011
- Advanced Decision Analysis (graduate); The Ohio State University; Autumn 2008
- Market Engineering and Applications (undergraduate); University of California, Berkeley; Fall 2005, 2006

Teaching Assistant

- Nonlinear Programming (graduate); University of California, Berkeley; Spring 2004
- Mathematical Programming (graduate); University of California, Berkeley; Fall 2003
- Decision Analysis (undergraduate); University of California, Berkeley; Spring 2003

Service

Advisory Work

- Peer Review Panelist; 2018 DOE Office of Electricity Energy Storage Program Peer Review, United States Department of Energy (2018)
- Lead Reviewer; 2018 Grid Modernization Initiative Peer Review, United States Department of Energy (2018)
- Technical Review Committee Member; Grid Modernization Laboratory Consortium, United States Department of Energy (2016–Present)
- Member; United States Department of Energy's Electricity Advisory Committee (2014–Present)
  - Chair, Energy Storage Subcommittee (2017–Present)
  - Vice Chair, Energy Storage Subcommittee (2017)
  - Chair, 2018 Biennial Energy Storage Assessment Working Group
  - Chair, Rate, Tariff, and Market-Design for Energy Storage Working Group
  - Chair, 2016 Biennial Energy Storage Assessment Working Group
  - Member, Energy Storage Subcommittee (2014–Present)
  - Member, Smart Grid Subcommittee (2016–2018)
- Invited presenter at 2012 Cummins Science & Technology Council Meeting

Editorial Work

- Co-Editor, *Energy, Sustainability and Society* (2016–Present)
- Editorial Advisory Board Member, *Renewable Energy Focus* (2016–Present).
- Editorial Board Member:
  - *International Journal of Industrial Management* (2016–Present)
  - *Journal of Energy Markets* (2015–Present)
  - *Journal of Modern Power Systems and Clean Energy* (2013–Present)
  - *Foundations and Trends in Energy Markets and Policy* (2013–Present)
  - *IET Renewable Power Generation* (2012–Present)
- Section Editor, Energy Market, *Current Sustainable/Renewable Energy Reports* (2017–Present)
- Subject Editor, Market Design for Renewable Energy Support and Integration, *IET Renewable Power Generation* (2018–Present)
- Associate Editor:
  - *Decision Support Systems* (2008–2015)
  - *IEEE Power Engineering Letters* (2013–Present)
  - *IEEE Transactions on Power Systems* (2013–Present)
  - *Journal of Energy Engineering* (2012–Present)
- Guest Editor, *International Journal of Electrical Power and Energy Systems*, special issue on "Multi-Energy Systems" (2018-2019)
- Guest Editor, *Transportation Research Part D: Transport and Environment* special issue on "Role of Infrastructure to Enable and Support Electric Drive Vehicles" (2018–2019)

Refereeing

- *Decision Support Systems*
- *Energies*
- *Energy*
- *Energy Economics*
- *Energy, Sustainability and Society*
- *Environmental Science and Technology*
- *European Journal of Operational Research*
- *European Transactions on Electrical Power*
- *IEEE Intelligent Systems*
- *IEEE Signal Processing Magazine*
- *IEEE Transactions on Power Systems*

- *IEEE Transactions on Sustainable Energy*
- *IIE Transactions*
- *IISE Transactions*
- *Journal of Modern Power Systems and Clean Energy*
- *Journal of Regulatory Economics*
- *Manufacturing and Service Operations Management*
- *Mathematical Programming A*
- *Naval Research Logistics*
- *Operations Research*
- *Proceedings of the IEEE*
- *Soft Computing*
- *Sustainability*
- *The Energy Journal*
- *Transportation Research Part C: Emerging Technologies*

External Dissertation Examiner

- University of Melbourne; Climate and Energy College; Australia; 2018.
- Nanyang Technical University; School of Electrical & Electronic Engineering; Singapore; 2017.
- University of New South Wales; School of Electrical Engineering and Telecommunications; Australia; 2016.
- University of New South Wales; School of Electrical Engineering and Telecommunications; Australia; 2016.

Proposal Reviewing

- Advanced Systems Integration for Solar Technologies (ASSIST); *United States Department of Energy*; 2018–2019.
- Research Center Proposals; *Khalifa University*; 2018.
- Information and Intelligent Systems Division; *National Science Foundation*; 2018.
- General Research Fund; *Research Grants Council of Hong Kong*; 2017.
- Phase I Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR); *United States Department of Energy*; 2017.
- Fonds de la Recherche Scientifique; (2016–Present)
- Technology Innovation; *Bonneville Power Administration*; 2015.
- Energy, Power, and Adaptive Systems; *National Science Foundation*; 2013.
- Chemical, Bioengineering, Environmental, and Transport Systems; *National Science Foundation*; 2012.

Technical Committees

- Secretary, "Power System Economics Subcommittee," IEEE Power & Energy Society, Power System Operation, Planning, and Economics Committee; 2018–Present
- Chair, "Task Force Decision Support Tools for Energy Storage Investment and Operations," IEEE Power & Energy Society, Power System Operation, Planning, and Economics Committee, Power System Economics Subcommittee; 2014–Present.
- Member, "Working Group on the Economics of Energy Storage," IEEE Power & Energy Society, Power System Operation, Planning, and Economics Committee, Power System Economics Subcommittee; 2017–Present.
- Member, "Task Force on Capacity Value of Solar Power," IEEE Power & Energy Society, Analytic Methods for Power Systems Committee, Reliability, Risk, and Probability Applications Subcommittee; 2012–Present.

Conference Organization

- Chair, Dual Plenary Session "Electromobility," *43rd IAEE International Conference.* June 21-24, 2020, Paris, France.
- Cluster Chair, "Emerging Topics: Sustainable Growth" *INFORMS Annual Meeting.* October 20-23, 2019, Seattle, WA.
- Panel Co-Organizer, "Coupling of Electric Power and Natural Gas Systems," *2019 IEEE PES General Meeting.* August 4-8, 2019, Atlanta, GA.
- Minisymposium Co-Chair, "Decomposition Techniques for Large-Scale Stochastic and Robust Energy System Models," *2019 International Conference on Stochastic Programming.* July 29-August 2, 2019, Trondheim, Norway.
- Scientific Committee Member, *2019 International Conference on Stochastic Programming.* July 29-August 2, 2019, Trondheim, Norway.
- Chair, Dual Plenary Session "Load-Profile Challenges and Energy Storage," *42nd IAEE International Conference.* May 29-June 1, 2019, Montréal, Canada.
- International Programme Committee Member, *42nd IAEE International Conference.* May 29-June 1, 2019, Montréal, Canada.
- Chair, *2018 INFORMS ENRE Section Best Young Researcher Award Committee.* November 4-7, 2018, Phoenix, AZ.
- Panel Co-Organizer, "Prosumage and Future Utilities in a Distributed Resource Electricity System," *2018 IEEE PES General Meeting.* August 5-10, 2018, Portland, OR.
- Panel Co-Organizer, "Revisiting Electricity Markets: Lessons Learned and Future Needs," *2018 IEEE PES General Meeting.* August 5-10, 2018, Portland, OR.
- Session Co-Organizer and Co-Chair, "Decomposition Techniques to Solve Large-Scale Optimization Problems for Electricity and Natural Gas Systems," *23rd Annual International Symposium on Mathematical Programming.* July 1-6, 2018, Bordeaux, France.
- Paper Reviewer, *20th Power Systems Computation Conference.* June 11-15, 2018, Dublin, Ireland.
- Scientific Committee Member, *Workshop on 'Commodities and Energy Market Organization in the Energy Transition Context'.* June 18-19, 2018, Rueil-Malmaison, France.
- Panel Organizer. "Rate, Tariff, and Market Design for Energy Storage," *Electricity Advisory Committee Meeting.* February 20-21, 2018, Arlington, VA.
- Chair, *2017 INFORMS ENRE Section Best Young Researcher Award Committee.* October 22-25, 2017, Houston, TX.
- Session Co-Organizer and Co-Chair, "Redesigning Electricity Markets and Pricing to Account for Uncertainty," *INFORMS Annual Meeting.* October 22-25, 2017, Houston, TX.
- Session Co-Organizer and Co-Chair, "Generation and Transmission Capacity-Expansion Planning," *INFORMS Annual Meeting.* October 22-25, 2017, Houston, TX.
- Session Co-Organizer and Co-Chair, "Operational Modeling for Energy Storage," *INFORMS Annual Meeting.* October 22-25, 2017, Houston, TX.
- Panel Organizer, "Decision Support Tools for Economic Valuation of Energy Storage," *2017 IEEE PES General Meeting.* July 16-20, 2017, Chicago, IL.
- Session Chair, "Energy Markets," *14th International Conference on the European Energy Market.* June 6-9, 2017, Dresden, Germany.
- Session Chair, "Spatial and Temporal Interdependencies in the Power System," *14th International Conference on the European Energy Market.* June 6-9, 2017, Dresden, Germany.
- Session Chair, "Network Pricing," *The Economics of Energy and Climate Change.* June 6-7, 2017. Toulouse, France.
- Technical Program Committee Member, *9th Asia-Pacific Power and Energy Engineering Conference.* April 15-17, 2017. Chengdu, China.
- Session Co-Organizer and Co-Chair, "Power System Operations Under Increasing Uncertainty," *INFORMS Annual Meeting.* November 13-16, 2016, Nashville, TN.
- Session Co-Organizer and Co-Chair, "Capacity-Expansion Planning with Increasing Renewable Levels," *INFORMS Annual Meeting.* November 13-16, 2016, Nashville, TN.
- Scientific Committee Member, *Armand Peugeot Chair 3rd International Conference on Electro-*

mobility. December 15-19, 2015, Singapore.

- Session Organizer and Chair, "Electric Transportation Systems Modelling," *INFORMS Annual Meeting*. November 1-4, 2015, Philadelphia, PA.
- Session Co-Organizer and Co-Chair, "Long-Term Electric Power System Planning Models," *INFORMS Annual Meeting*. November 1-4, 2015, Philadelphia, PA.
- Panel Organizer, "Decision Support Tools for Energy Storage Operations," *2015 IEEE PES General Meeting*. July 26-30, 2015, Denver, CO.
- Paper Reviewer, *Second International Conference on Transformations in Engineering Education*. January 5-8, 2015, Bengaluru, India.
- Judge, *2014 INFORMS ENRE Section Best Student Paper Award*. November 9-12, 2014, San Francisco, CA.
- Session Co-Organizer and Co-Chair, "Robust and Stochastic Modeling in Power System Operations and Planning," *INFORMS Annual Meeting*. November 9-12, 2014, San Francisco, CA.
- Session Co-Organizer and Co-Chair, "Market Issues for Hydro-Dominated Electricity Systems," *INFORMS Annual Meeting*. November 9-12, 2014, San Francisco, CA.
- Technical Programme Committee Member, *3rd IET Renewable Power Generation Conference*. September 24-25, 2014, Naples, Italy.
- Local Organizing Committee Member, *2014 Mixed Integer Programming Workshop*. July 21-24, 2014, Columbus, OH.
- Session Organizer and Chair, "Operations and Planning with Energy Storage," *INFORMS Annual Meeting*. October 6-9, 2013, Minneapolis, MN.
- Head Judge, *2013 INFORMS ENRE Section Best Student Paper Award*. October 6-9, 2013, Minneapolis, MN.
- Technical Programme Committee Member, *2nd IET Renewable Power Generation Conference*. September 9-11, 2013, Beijing, People's Republic of China.
- International Scientific Committee Member, *10th International Conference on the European Energy Market*. May 28-30, 2013, Stockholm, Sweden.
- Session Organizer and Chair, "Research Needs of the Electricity Industry," *INFORMS Annual Meeting*. October 14-17, 2012, Phoenix, AZ.
- Cluster Chair, "ENRE Energy" *INFORMS Annual Meeting*. October 14-17, 2012, Phoenix, AZ.
- International Scientific Committee Member, *9th International Conference on the European Energy Market*. May 10-12, 2012, Florence, Italy.
- Cluster Chair, "ENRE Energy," *INFORMS Annual Meeting*. November 13-16, 2011, Charlotte, NC.
- Session Organizer and Chair, "Capacity Expansion," *INFORMS Annual Meeting*. November 13-16, 2011, Charlotte, NC.
- Cluster Chair, "Energy," *INFORMS Midwest Conference*. August 1-2, 2011, Columbus, OH.
- Panel Organizer and Chair, "Challenges in Vehicle Electrification," *INFORMS Midwest Conference*. August 1-2, 2011, Columbus, OH.
- Session Chair, "Optimal Power Plant Operations," *34th IAEE International Conference*. June 19-23, 2011, Stockholm, Sweden.
- Session Organizer and Chair, "Joint Session Energy/ENRE Energy: Impacts of Supply Uncertainty on Power System Planning and Operations," *INFORMS Annual Meeting*. November 7-10, 2010, Austin, TX.
- Session Organizer and Chair, "Power System Impacts of Electrified Transportation," *INFORMS Annual Meeting*. November 7-10, 2010, Austin, TX.
- Session Organizer and Chair, "Modeling Benefits of Demand Management in Power Systems," *INFORMS Annual Meeting*. November 7-10, 2010, Austin, TX.
- Session Organizer, "Energy Storage Applications in Electricity Markets," *32nd IAEE International Conference*. June 21-24, 2009, San Francisco, CA.

Student-Organization Advising

- INFORMSOSU Student Chapter

- The Ohio State University Alpha Pi Mu Student Chapter

Professional Membership

- Senior Member, Institute of Electrical and Electronics Engineers (IEEE)
- Member, Institute for Operations Research and Management Sciences (INFORMS)
- Member, Institute of Industrial and Systems Engineers (IISE)
- Member, International Association for Energy Economics (IAEE)

GRANTS

- The Ohio State University (PI: J. Y. Lee)
  Project: Developing Capacity for Seasonal Energy Storage Capacity
  Duration: 2018-2019 ($21,450)
- National Science Foundation
  Project: EPCN:Solving Electricity-Expansion Problems Efficiently via Decomposition (SEEPED)
  Duration: 2018-2021 ($299,203)
- The Ohio State University (PI: J. Bielicki)
  Project: Engineering the Subsurface to Seasonally Store Energy While Sequestering CO_2
  Duration: 2018-2019 ($16,000)
- North China Electric Power University
  Project: Solving Electricity-Expansion Problems Efficiently via Decomposition
  Duration: 2018-2019 (50,000 CNY)
- The Ohio State University
  Project: Advancing the Decarbonization of Electric Power Systems with Concentrating Solar Thermal Generation
  Duration: 2018 ($1,000)
- The Ohio State University (PI: J. Y. Lee)
  Project: The Impact of Electric Vehicles on Resilience in Smart Cities
  Duration: 2017-2018 ($49,900)
- Electric Power Research Institute
  Project: Energy Storage Capacity Valuation
  Duration: 2017-2018 ($87,386)
- Greif, Inc. (PI: S. Davanloo Tajbakhsh)
  Project: Rigid Packaging Product Demand Forecasting: Pilot Study
  Duration: 2017 ($16,922)
- National Renewable Energy Laboratory
  Project: Concentrating Solar Power Grid Storage
  Duration: 2017 ($90,663)
- The Ohio State University (PI: G. Bayraksan)
  Project: Energy and Water Infrastructure Planning Under Extreme Events
  Duration: 2016-2017 ($45,000)
- National Science Foundation (PI: A. J. Conejo)
  Project: EAGER: Toward Renewable Dominated Electric Energy Systems (RENDES)
  Duration: 2015-2018 ($292,665)
- The Economic Research Institute for ASEAN and East Asia
  Project: Wholesale and Retail Market Design for Incentivizing Renewable Energy Adoption
  Duration: 2014-2015 ($8,000)
- Energy Foundation
  Project: Electric Vehicle Industry Cluster in Ohio
  Duration: Spring-Fall 2014 ($40,000)
- National Renewable Energy Laboratory
  Project: Photovoltaic Capacity Credit Study
  Duration: 2012-2015 ($139,886)
- National Science Foundation
  Project: GRDS: Decomposition and Precomputation Algorithms for Large-Scale Equilibrium

Computation Models of Energy Systems
Duration: Spring-Autumn 2012 ($41,000)

- United States Department of Energy (PI: G. Rizzoni)
  Project: GATE: Energy Efficient Vehicles for Sustainable Mobility
  Duration: 2011-2016 ($910,000)
- National Renewable Energy Laboratory
  Project: Photovoltaic Capacity Credit Study
  Duration: Spring-Autumn 2011 ($50,000)
- United States Department of Energy (PI: G. Rizzoni)
  Project: U.S.-China Clean Energy Research Center-Clean Vehicles (CERC-CV)
  Duration: 2011-2015 ($3,000,000)
- National Science Foundation
  Project: CDI-Type II: Energy policy and investment analysis driven by large-scale integrated power system simulations
  Duration: 2010-2016 ($1,675,000)
- National Renewable Energy Laboratory
  Project: Analysis of co-located wind and concentrating solar power plants
  Duration: 2010-2011 ($40,000)
- National Renewable Energy Laboratory
  Project: CSP Capacity Credit Study
  Duration: 2010-2011 ($50,000)
- National Renewable Energy Laboratory
  Project: Concentrating Solar Power (CSP)/Thermal Storage Dispatch Study
  Duration: Winter 2008 ($22,000)
- National Science Foundation (PI: S. Oren)
  Project: Development of Course in Market Engineering with Application to Electricity Markets
  Duration: 2004-2006 ($120,000)
- United States Department of Energy
  Project: Testing Strategic Bidding Models of Spot Electricity Markets
  Duration: Summer 2004 ($22,000)

Awards

- Distinguished Faculty Award; 2018. Awarded by graduating undergraduate seniors of Department of Integrated Systems Engineering.
- Distinguished Faculty Award; 2015. Awarded by graduating undergraduate seniors of Department of Integrated Systems Engineering.
- 2015 College of Engineering Lumley Research Award. Awarded for research productivity over the last five years.
- The Campbell Watkins Energy Journal Best Paper; 2010. Awarded for best paper published in *The Energy Journal*, "The Value of Plug-In Hybrid Electric Vehicles as Grid Resources."
- Best Paper Award at the *4th International Conference on Sustainable Energy and Environmental Protection*, for the paper: R. Sioshansi, V. Marano, and R. Fagiani, "Cost and Emissions Impacts of Plug-In Hybrid Vehicles (PHEVs) on the Electric Power Grid."
- Outstanding Graduate Student Instructor Award; 2006. Awarded by faculty of Industrial Engineering and Operations Research department at University of California, Berkeley.
- Best Graduate Student Instructor Award; 2006. Awarded by undergraduate members of the Berkeley chapter of the Institute of Industrial Engineers.

AEP OHIO
An AEP Company
BOUNDLESS ENERGY℠

Legal Department

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December 13, 2017

Asim Z. Haque
Chairman, Public Utilities Commission of Ohio
Public Utilities Commission of Ohio
180 East Broad Street
Columbus Ohio 43215-3793

Steven T. Nourse
Chief Ohio Regulatory Counsel
(614) 716-1608 (P)
(614) 716-2014 (F)
stnourse@aep.com

Re: *In the Matter of Ohio Power Company's Generation Transition Docket,* Case No. 17-882-EL-UNC

Dear Chairman Haque:

On behalf of Ohio Power Company (AEP Ohio), I am submitting the enclosed report entitled "Ohio Renewable Energy Manufacturing & Company Establishment Analysis" conducted by Navigant Consulting, Inc. Submittal of this report fulfills Paragraph III.D.12.e of the Joint Stipulation and Recommendation in Case Nos. 14-1693-EL-RDR and 14-1694-EL-AAM (PPA Rider Stipulation). The report will also be referenced in the Company's 2018 annual update filing, but the Company wanted to submit it now since it is already completed.

Thank you for your attention to this matter.

Respectfully Submitted,

//s/ Steven T. Nourse

cc: Parties of Record

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Ohio Renewable Energy Manufacturing & Company Establishment Analysis

Prepared for:
AEP Ohio

AEP OHIO
An AEP Company

FINAL

Submitted by:
Navigant Consulting, Inc.
1375 Walnut St. #100
Boulder, CO 80302

303.728.2500
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December 13, 2017

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DISCLAIMER

This report was prepared by Navigant Consulting, Inc. (Navigant) for AEP Ohio. The work presented in this report represents Navigant's professional judgment based on the information available at the time this report was prepared. Navigant is not responsible for the reader's use of, or reliance upon, the report, nor any decisions based on the report. NAVIGANT MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

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EXECUTIVE SUMMARY

BACKGROUND

In PPA Stipulation Section III.D.12. e., the Public Utilities Commission of Ohio (PUCO) directed AEP Ohio to "perform an analysis about how to bring or encourage companies to establish renewable energy companies with headquarters and manufacturing plants in Ohio and how to transition the current power plant workforce to such job opportunities."[1] AEP Ohio retained Navigant, an independent third party, to conduct this analysis. Navigant completed six tasks with the goal of providing actionable strategies for achieving the goals outlined in the stipulation.

Table E-1. Task Goals

Project Task	Task Goal
1. Initiate Project	Confirm project goals and define communication plans.
2. Develop Company Motivators	Catalog the reasons why renewable energy companies locate where they do and rank them in order of importance.
3. Define State Strategies	Characterize the different strategies used by states and discuss their relative success.
* 4. Assess in Ohio	Establish a baseline number and type of renewable energy companies already in Ohio.
5. Map Career Transitions	Define pathways for existing conventional power plant workers to move into the renewable energy industry as jobs decline in conventional power plants.
6. Develop Recommendations & Findings	Develop high-impact, feasible options for the state of Ohio to encourage renewable energy companies and manufacturers to set up headquarters in Ohio.

This report details the research and findings of Navigant's analysis and provides a roadmap for encouraging renewable energy companies to establish in or locate to Ohio while also providing pathways for power plant workers to transition into these opportunities.

RENEWABLE ENERGY COMPANY MOTIVATORS

Navigant began this study by determining the factors that drive renewable energy development and services companies and manufacturers to locate headquarters or manufacturing facilities in a certain area. Navigant developed a six-category framework that significantly affect different operational factors and ultimately influence locational decisions, ranking these locational motivators for both renewable companies focused on development and services and manufacturers. These factors serve as levers for states to pull to drive regional renewable energy company growth.

[1]Public Utilities Commission of Ohio, Opinion and Order, Case No. 14-1693-EL-RDR and Case No. 14-1694-EL-AAM, PPA Stipulation Section III.D.12.e.

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Figure E-1. Renewable Energy Company & Manufacturer Locational Motivators

STATE STRATEGIES

Navigant characterized strategies used by states to target companies and manufacturers and discussed each strategies' relative success. This analysis resulted in four overarching themes.

Figure E-2. State Strategies Framework

Based on our analysis, Navigant focused on incentives and policy and created a scoring system to assess wind and solar strategies by state and determine whether there was a correlation between these strategies and the number of solar and wind jobs per state. From this analysis, the team verified that policies, such as RPS, Net Metering, third-party PPAs, and financial incentives, in addition to solar resource availability and high electric rates, play a large role in driving solar jobs at the state level. Meanwhile policies and financial incentives play a less significant role in the growth of wind jobs, due in large part to the types of wind jobs available.

ASSESS OHIO

Navigant assessed the current state of jobs and companies in Ohio, aimed at establishing a baseline for the renewable energy companies in Ohio and helping Navigant target its findings and recommendations to allow for sustained renewable energy company and job growth. Our analysis found that many companies of different sizes and types are currently operating in Ohio.

MAP CAREER TRANSITION

Navigant examined strategies for the state of Ohio to facilitate employee transition to renewable energy opportunities as they arise. Based on the research and resources available, Navigant developed a pathway for transitioning from a conventional power plant career to a renewable energy career. Navigant

NAVIGANT

identified four strategies that key stakeholders can enact. The strategies are intended to work in conjunction, utilizing different levers for helping conventional power plant workers transition.

Figure E-3. Strategies for Facilitating Career Transition

FINDINGS & RECOMMENDATIONS

Navigant developed four guiding principles for implementing strategies to grow a localized renewable energy market, increasing the number of companies and jobs within the state. The guiding principles were: market stability, consistent programs, workforce preparation, and research and development. Using these principles, Navigant developed five actionable recommendations for the state and local governments to implement to drive renewable energy company and job growth. Table E-2 lists the recommendations.

Table E-2. Study Recommendations

Number	Recommendation
1	Publish multi-year state renewable energy procurement plan, led by the state or a state-wide body.
2	Expand JobsOhio to include: • Renewable energy education platform providing career transition resources. • Concierge service to answer renewable energy questions.
3	Remove permitting barriers.
4	Invest in Research & Development.
5	Continue to invest in roads and infrastructure.

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1. INTRODUCTION

1.1 STUDY BACKGROUND

In PPA Stipulation Section III.D.12. e., the PUCO directed AEP Ohio to "perform an analysis about how to bring or encourage companies to establish renewable energy companies with headquarters and manufacturing plants in Ohio and how to transition the current power plant workforce to such job opportunities."[2] AEP Ohio retained Navigant, an independent third party, to conduct this analysis.

This report lays out the findings from the study, providing an in-depth overview of why renewable energy companies establish in specific locations, strategies for attracting these companies, and how different stakeholders can participate in the transitioning of conventional power plant workers to renewable energy opportunities. Ultimately, the analysis serves as a roadmap for encouraging renewable energy companies, particularly in the wind and solar industry, to establish in Ohio and for training and connecting workers to renewable energy opportunities as they arise.

1.2 STUDY GOALS

To provide actionable recommendations, Navigant created a list of questions to guide the analysis. The questions centered on renewable energy company motivators, existing strategies for encouraging regional renewable energy development (and therefore driving regional company location), and pathways for transitioning conventional power plant workers to renewable energy careers. The list below provides these questions.

- What are the factors that drive companies to locate headquarters or manufacturing facilities?
- What strategies do other states use to encourage companies to locate in their state?
- What renewable energy companies currently have headquarters or manufacturing in Ohio?
- And what attracted these companies to locate operations in Ohio or to leave Ohio?
- How can the current power plant workforce transition to work in the renewable energy industry?
- What actions should Ohio take to encourage renewable energy companies to set up headquarters in Ohio?

Based on these questions, Navigant developed a framework of six tasks to explore and answer the questions outlined above, ultimately providing actionable strategies for AEP Ohio and the state of Ohio. Table 1-1 below provides an overview of Navigant's framework.

Table 1-1. Task Goals

Project Task	Task Goal
1. Initiate Project	Confirm project goals and define communication plans.
2. Develop Company Motivators	Catalog the reasons why renewable energy companies locate where they do and rank them in order of importance.

[2] Public Utilities Commission of Ohio, Opinion and Order, Case No. 14-1693-EL-RDR and Case No. 14-1694-EL-AAM, PPA Stipulation Section III.D.12.e.

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3.	Define State Strategies	Characterize the different strategies used by states and discuss their relative success.
4.	Assess Ohio	Establish a baseline number and type of renewable energy companies already in Ohio.
5.	Map Career Transitions	Define pathways for existing conventional power plant workers to move into the renewable energy industry as jobs decline in conventional power plants.
6.	Develop Recommendations & Findings	Develop high-impact, feasible options for the state of Ohio to encourage renewable energy companies and manufacturers to set up headquarters in Ohio.

1.3 REPORT ORGANIZATION

Navigant organized the report to align to the study goals and tasks:

- **Section 2: Company Motivators** – Research and resulting framework for why companies locate where they do.
- **Section 3: State Strategies –** Outline and relative success rank of state strategies for encouraging regional growth or renewable energy companies.
- **Section 4: Assess Ohio –** Definition of solar and wind value chains and map of solar and wind companies located in Ohio.
- **Section 5: Map Career Transitions –** Pathway and strategies to help existing power plant workers transition to the renewable energy industry.
- **Section 6: Findings & Recommendations –** Actionable strategies for the state of Ohio to consider increasing the development of renewable energy companies in the State.

The report includes 2 appendices, which provide additional information:

- Case study key takeaways from renewable energy companies on locational decision-making and stakeholder recommendations.
- Resources for transitioning conventional power plant workers to renewable energy jobs, mentioned in Section 5, Renewable Energy Career Transitioning.

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2. COMPANY MOTIVATORS

Navigant began this study by determining the factors that drive renewable energy development and services companies and manufacturers to locate headquarters or manufacturing facilities in a certain area, ranking these locational motivators. Navigant gained an understanding of locational motivators and how they align to various state strategies for the regional development of renewable energy manufacturers and companies. The findings ultimately resulted in valuable insight into how renewable energy companies may react to proposed strategies. Figure 2-1 illustrates the overarching locational motivators Navigant identified. This section explains the approach and key resources and provides details on the findings.

Figure 2-1. Renewable Energy Company & Manufacturer Locational Motivators

Source: Navigant 2017

2.1 APPROACH

Navigant used a four-step approach to identify, prioritize, and validate the top locational motivators for renewable energy companies and manufacturers. The steps include: conducting general research, brainstorming the initial list of drivers, prioritizing the drivers, and validating the prioritization through additional primary and secondary research. The first step involved examining national and global studies related to regional development as well as measures of "competitiveness" that influence market growth in a specific region. This step yielded a comprehensive catalog of drivers that influence companies and/or manufacturers picking one location over another. Navigant then translated this catalog into overarching categories, leveraging the team's expertise in renewable energy and past Navigant studies. Following the finalization of the locational motivator categories, the team created a qualitative prioritization framework based on renewable energy industry specific studies validating the prioritization through industry interviews and additional market research. The list below details the key sources used throughout the process.

NAVIGANT

- U.S. Government National Network for Manufacturing Innovation Report[3]
- World Economic Forum Studies[4]
- National Renewable Energy Laboratory (NREL) Studies[5,6]
- Deloitte's Global Manufacturing Competitiveness Index[7]
- Company Case Studies[8]
- Recent News Articles[9, 10,11]

2.2 FRAMEWORK

Navigant created a framework of locational motivators for renewable energy companies and manufacturers. The framework consists of six categories that significantly affect different operational factors and ultimately influence locational decisions. These factors serve as levers to pull to drive regional renewable energy company growth. Table 2-1 details the locational motivators framework for renewable energy companies and manufacturers.

> *"Moved locations because we wanted to make this into a real business. To make an impact, we needed to be close to a large population."*
> – Dovetail Wind & Solar

[3] President's Council of Advisors on Science and Technology, Accelerating US Advanced Manufacturing, October 2014, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/amp20_report_final.pdf

[4] World Economic Forum, The Future of Manufacturing: Opportunities Drive Economic Growth, 2012, http://www3.weforum.org/docs/WEF_MOB_FutureManufacturing_Report_2012.pdf

[5] NREL, Manufacturing Conditions in the Global Wind Industry, https://www.nrel.gov/docs/fy14osti/60063.pdf..

[6] NREL, Carbon Fiber Manufacturing Facility Siting, https://www.nrel.gov/docs/fy17osti/66875.pdf .

[7] Deloitte, 2016 Global Manufacturing Competitiveness Index, 2016, https://www2.deloitte.com/global/en/pages/manufacturing/articles/global-manufacturing-competitiveness-index.html.

[8] See Appendix A for details.

[9] The Journal News, "Start-up Business for Water-Power Technology to Open in Hamilton", December 2013, http://www.journal-news.com/news/start-business-for-water-power-technology-open-hamilton/GSCQ3bLbOzaTrRGLDscYHM/

[10] Toledo Blade, "Toledo Area Could Get Another Solar Plant with 600 Jobs", 2010, http://www.toledoblade.com/local/2010/10/15/Toledo-area-could-get-another-solar-plant-with-600-jobs.html

[11] Smart Energy Decisions, "Renewable Energy Access Lures Facebook to Ohio", August 18, 2017, https://www.smartenergydecisions.com/blog/2017/08/18/renewable-energy-access-lures-facebook-to-ohio?contact_id=59160&inf_contact_key=f87cf785d4ce3888273549c39b9591175051586c7ca7f86891a0a3ada8f79751

Table 2-1. Renewable Energy Company & Manufacturer Locational Motivators Framework

Motivators	Description	Examples
Renewable Energy Market	The Renewable Energy Market encompasses the localized climate for building renewables, including policy, permitting, and financial factors. These factors can help reduce long term business and financial risks as well as improve the ease of project development.	• Project economics, including electric rates, renewable energy resource availability, and inexpensive land • Policy, including Renewable Portfolio Standards (RPS), Net Energy Metering (NEM), and Solar Renewable Energy Credits (RECs) • Supportive permitting and financing
Supportive Schemes	Supportive Schemes include incentives for developing a renewable energy product. These schemes can tip the scales in favor of a location if they reduce costs or provide long-term advantages, such as low-cost, innovative R&D opportunities.	• Investment in Research & Development (R&D) • Equipment / manufacturing incentives • Grants
Workforce	Workforce incorporates various labor aspects, including worker preparedness, access to training or educational resources, and cost of labor.	• Education and training program accessibility • Specialized knowledge via universities • Inexpensive labor
Logistics	Logistics encompass ease of access to a stable product or end-user market via transportation corridors or proximity.	• Infrastructure / distribution access • Proximity to stable market
Operating Expenses	Operating expenses include the cost of doing business in a location.	• Inexpensive land • Electric rates • Facility rents • State and local taxes
Supply Chain	Supply chain includes the entire product value chain.	• Supplier market

Source: Navigant 2017

2.3 PRIORITIZATION

Using the framework described, Navigant investigated renewable energy-specific studies, recent company relocations, and firsthand case studies to prioritize each category. Navigant created two separate lists, one for general renewable energy companies and one for manufacturers of wind and

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> *"We knew within a fifteen-mile radius where we wanted to be… which is very close to the I-70/75 highway crossroads."* – Energy Optimizers, USA

solar products, due to differing needs for these businesses. For example, manufacturers need to be located near transportation corridors to move products from different factories for assembly or installation. Meanwhile, renewable energy developers or service firms may prioritize a location near an end-user market to sell their product. The prioritized lists in Table 2-2 represent the most influential drivers in renewable energy company and manufacturer decision-making. This list provides a pathway for determining actionable strategies to entice companies to locate in a certain area.

Table 2-2. Renewable Energy Company and Manufacturer Prioritized Locational Motivators

Rank	Company Locational Motivators	Manufacturer Locational Motivators
1	Renewable Energy Market	Workforce
2	Supportive Schemes	Logistics
3	Workforce	Supply Chain
4	Logistics	Operating Expenses
5	Supply Chain	Supportive Schemes
6	Operating Expenses	Renewable Energy Market

Source: Navigant 2017

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3. STATE STRATEGIES

Navigant characterized strategies used by states to target companies and manufacturers and discussed each strategies' relative success. Task 3 leverages the findings from Task 2 to identify specific and actionable levers for sustained renewable energy company and job growth with the aim of understanding possible high-value strategies. Given that many states and counties have been targeting renewable energy companies and jobs for the last 10 to 15 years, Navigant focused on gaining an understanding of how these strategies have influenced the number of renewable energy jobs and companies to-date.

This analysis resulted in four overarching themes defined in Figure 3-1. The following section provides additional details about the approach for developing this framework and the success of these strategies.

Figure 3-1. State Strategies Framework

Source: Navigant 2017

3.1 APPROACH

Navigant conducted a three-phase approach which involved researching existing literature, identifying strategies, and evaluating each strategies' success. The process began with conducting a literature search incorporating case study details, trade industry information, current initiatives, and information from the Database of State Incentives for Renewables and Efficiency (DSIRE).[12] Like the locational driver analysis, the research yielded a catalog of strategies employed by states to draw renewable energy companies and jobs to their state. Due to the volume of strategies, Navigant grouped these findings by similarity to get an overview of the types of strategies available. Finally, the team evaluated the success of each of the strategies by assigning scores to them at the state level. These scores were then compared against the number of wind and solar jobs in that respective state to test the legitimacy of the scoring. The entire analysis leveraged the sources in the list below.

- NREL Studies[13]
- The Solar Foundation, SolSmart Initiative Funded by the Department of Energy (DOE)[14]
- Database of State Incentives for Renewables & Efficiency (DSIRE)[15]

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[12] NC Clean Energy Technology Center, Database of State Incentives for Renewables and Efficiency (DSIRE), http://www.dsireusa.org/.
[13] NREL, The Role of State Policy in Renewable Energy Development, July 2009, https://www.nrel.gov/docs/fy09osti/45971.pdf .
[14] The Solar Foundation, SolSmart Initiative, https://www.thesolarfoundation.org/policy-research/solsmart/ .
[15] NC Clean Energy Technology Center, Database of State Incentives for Renewables & Efficiency, http://www.dsireusa.org/.

- The Solar Foundation 2016 Solar Job Census[16]
- American Wind Energy Association State Fact Sheets[17]
- Existing Navigant Studies[18]
- Energy Information Administration, Electric Rates[19]

3.2 FRAMEWORK

Navigant's approach resulted in a four-category framework of strategies employed by states to incentivize companies and manufacturers to locate in and ultimately bring jobs to their state. This framework aims to explain strategies currently used, providing an overview of possibilities for the state of Ohio. Table 3-1 outlines the framework created.

Table 3-1. State Strategies Framework

Strategies	Description	Examples
Incentives	Incentive strategies encompass any method of reducing the cost of doing business.	• Tax credits • Rebates • Subsidies • Performance-based incentives • Grants • Loans • Employment Incentives
Policy	Policy strategies include regulations that increase market certainty, reducing the risk and improving the ease of doing business within the state.	• Renewable Portfolio Standards (RPS) • Net Metering (NEM) • Renewable Energy Credits (RECS) • Green tariffs • Community development zones • Preferred or required local sourcing

[16] The Solar Foundation, Solar Job Census 2016, https://www.thesolarfoundation.org/national/.
[17] American Wind Energy Association, US Wind Energy State Facts, https://www.awea.org/resources/statefactsheets.aspx?itemnumber=890&navItemNumber=5067.
[18] Navigant, Washington State Clean Energy Leadership Plan for the Washington Clean Energy Leadership Council, http://www.efsec.wa.gov/Whistling%20Ridge/Adjudication/Intervenor's%20pre-filed%20testimony/Ex%2034-05,%20CELC%20extract.pdf.
[19] Energy Information Administration, Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector, by State, July 2017 and 2016, July 2017, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

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Market Awareness	Market awareness strategies encompass building a market for renewable energy by educating consumers, providing opportunities for projects (e.g. through project aggregation), and any other strategies that encourage end-users to partake in the industry.	• Market awareness education • Choices for customers (market access) • Local organizations/co-ops for project aggregation, policy lobbying, and market education
Company Support	Customer support strategies include methods for supporting prospective renewable energy companies/employers. These strategies include funding as well as general assistance.	• Workforce training • Incentives for industry development • Employee search assistance • Property search assistance • Funding demonstration projects • Focus on building research, technology transfer, and university capabilities

Source: Navigant 2017

3.3 STRATEGY EVALUATION

> *"RPS policies continue to play a central role in supporting RE growth."*
> - NREL

With the framework defined, Navigant focused on evaluating the success of the policy and incentive strategies, stemming from two recent reports from the National Renewable Energy Laboratory (NREL) and the Lawrence Berkeley National Laboratory (LBNL), industry-leading renewable energy research organizations. LBNL recently published its 2017 Annual Status Report of US Renewable Portfolio Standards, which included an analysis of the historical impacts of RPS on renewables development, concluding that "roughly half of all growth in US renewable electricity (RE) generation and capacity since 2000 is associated with state RPS requirements."[20] Likewise a 2014 report from NREL came to a similar conclusion, finding that "niche incentives, only when layered on top of high quality market access policies, can support distributed generation penetration in target markets."[21] In short, the two reports support the idea that policies and incentives are the main drivers for renewable energy market growth, which in turn spurs renewable energy job growth.

Given this information, Navigant created a scoring system to assess wind and solar strategies by state and determine whether there was a correlation between these strategies and the number of solar and wind jobs per state. The solar scoring accounted for RPS, NEM, Solar Renewable Energy Credits (SRECs), third party PPAs, the number of financial incentives available as well as non-policy market factors, such as electric rates and solar resource availability. The wind scoring included RPS, the number of financial incentives, electric rates, and wind resource availability. Table 3-2 shows the scoring framework for all policies and incentives assessed.

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[20] Lawrence Berkeley National Laboratory (LBNL), US Renewables Portfolio Standards: 2017 Annual Status Report Abstract, https://emp.lbl.gov/publications/us-renewables-portfolio-standards-0.

[21] National Renewable Energy Laboratory (NREL), "Are Incentives the Thing?", December 2014, https://www.nrel.gov/docs/fy15osti/63059.pdf.

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Table 3-2. State Strategy Scoring Framework

Categories	Scoring
RPS*	RPS Standards – 4 RPS Goals – 2 No RPS – 0
Net Metering**	Net Metering – 2 Other Rules – 1 No Net Metering – 0
SRECs**	SRECs – 2 SRECs Eligible – 1 No SRECs – 0
Third Party PPAs	Third party PPAs – 1 No Third party PPAs – 0 Status Unclear – 0
Financial Incentives	Many state incentives – 2 Some state incentives – 1 Few state incentives – 0
Electric Rates*	High Rates – 4 Medium Rates – 2 Low Rates – 0
Wind & Solar* Resources	High Resource – 4 Medium Resource – 2 Little Resource – 0

Source: Navigant 2017
**Navigant applied extra weight to these categories given influence on wind or solar developments.*
*** Only used in solar scoring framework*

Navigant chose to add additional weights to RPS, electric rates, and wind and solar resource availability due to their significant influence on renewable energy development. For example, ample sunshine or wind resources reduce business risk while high electric rates improve the financials of developing these resources. Figure 3-2 shows the scoring calculations to assess state strategies for both wind and solar.

Figure 3-2. State Strategy Scoring Calculations

Solar Strategy Score = *RPS + Net Metering + SRECs + Third Party PPAs + Financial Incentives + Electric Rates + Solar Resources*

Wind Strategy Score = *RPS + Financial Incentives + Electric Rates + Wind Resources*

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3.3.1 Solar

The calculations resulted in a ranking of states according to their strategy score. To determine the success of these strategies, Navigant compared the rankings to the number of solar jobs in each state.[22] The table below shows the 10 states with the most jobs per capita and their associated Navigant strategy rank.

Table 3-3. Top 10 Solar Job States vs. Navigant Strategy Rank

Top 10 Solar Job States[23]	State	State Solar Jobs per Capita[24]	Navigant Strategy Framework State Rank[25]
1	California	100,050	1
2	Massachusetts	14,582	5
3	Texas	9,396	15
4	Nevada	8,371	13
5	Florida	8,260	28
6	New York	8,135	15
7	Arizona	7,310	5
8	North Carolina	7,112	5
9	New Jersey	6,056	4
10	Colorado	6,004	3

See footnotes for sources.

As shown above, nine of the top ten solar jobs states land within the top fifteen of Navigant's ranking. The only exception is Florida, which has a particularly strong solar resource and therefore, high number of jobs, despite having fewer policies and financial incentives than its peers. This reinforces the idea that policies and incentives drive market and job growth in the solar industry. In Figure 3-3, Navigant plotted the rankings against the number of jobs per capita per state for the entire country to demonstrate the correlation.

State-level and national policies drive a large portion of business model decisions, particularly related to the location of regional offices and manufacturing. - First Solar

[22] Navigant extracted state jobs data from The Solar Foundation, The 2016 Solar Job Census, https://www.thesolarfoundation.org/national/.
[23] Ibid.
[24] Ibid.
[25] Navigant analysis.

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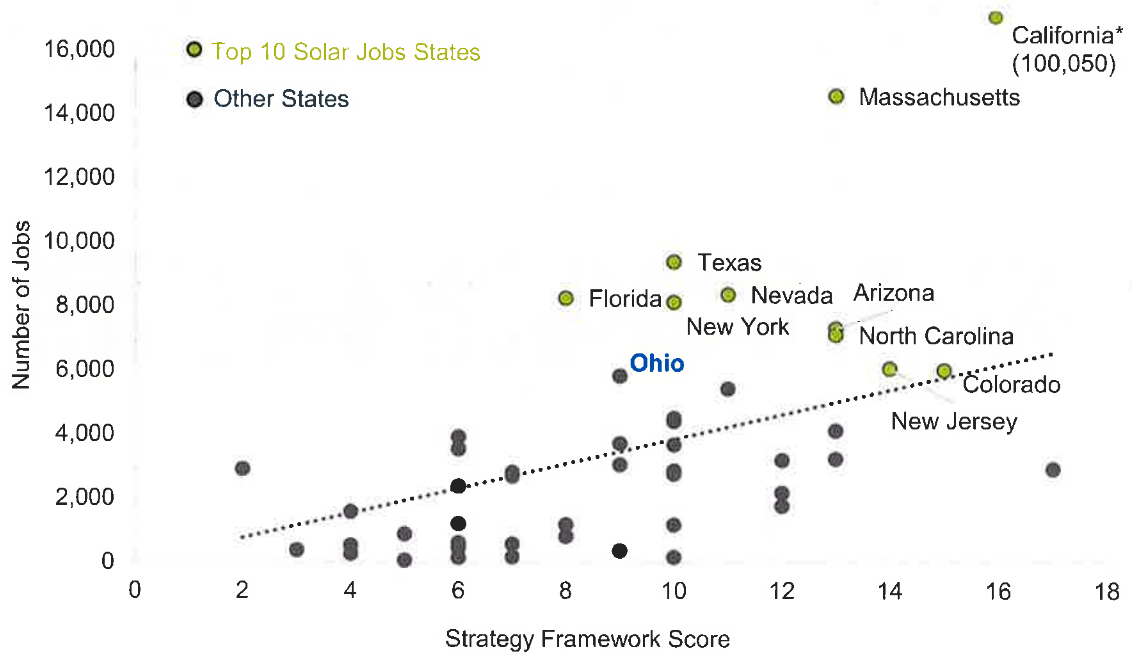
Figure 3-3. Solar Jobs per Capita vs. Solar Strategies



Source: Navigant 2017
**Navigant removed California from the scatter plot and added separately due to the magnitude of jobs in California.*

The plot shows that strong policies and incentives, high electric rates, and a robust solar resource correlates with a high number of solar jobs.

3.3.2 Wind

Similar to the solar analysis, Navigant compared the wind strategy score against the number of wind jobs per state. The table below shows the results of this comparison.

Table 3-4. Top 10 Wind Job States vs. Navigant Strategy Rank

Top 10 Wind Job States[26]	State	State Wind Jobs[27]	Navigant Strategy Framework State Rank[28]
1	Colorado	4,144	15
2	Texas	2,979	15
3	Iowa	1,929	15
4	Ohio	1,626	11
5	Illinois	1,482	15

[26] American Wind Energy Association, Economic Development Impact of Wind Projects prepared by Navigant.
[27] Ibid.
[28] Navigant analysis.

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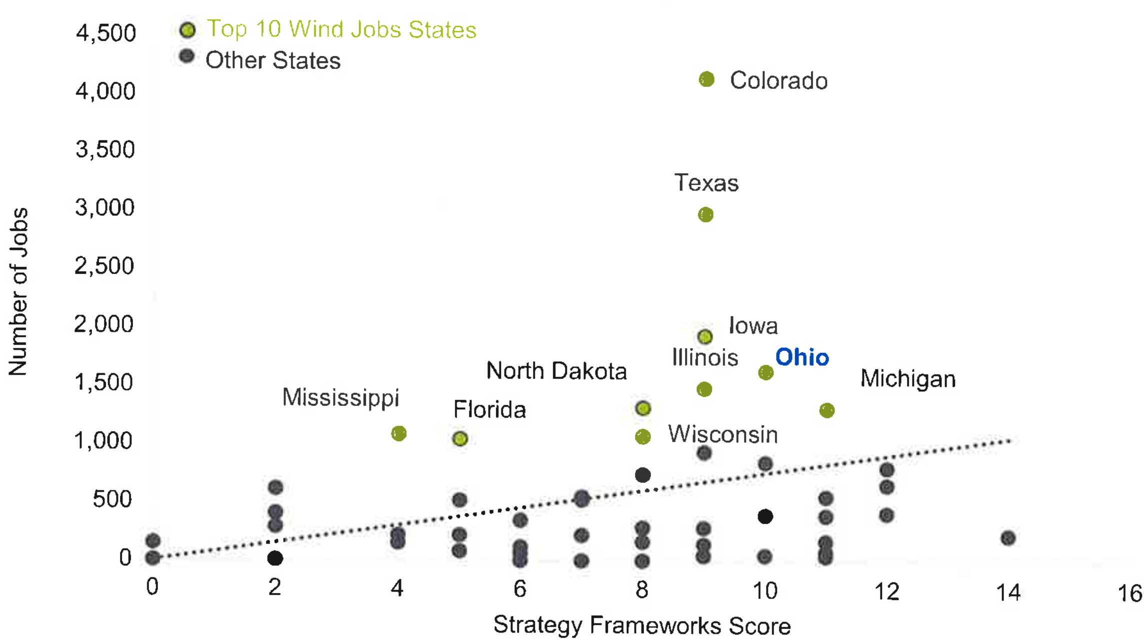
6	North Dakota	1,313	23
7	Michigan	1,308	5
8	Mississippi	1,086	42
9	Wisconsin	1,068	23
10	Florida	1,041	38

See footnotes for sources.

Most of the top wind job states rank within the top fifteen on Navigant's strategy framework scale. The other states including North Dakota, Mississippi, Wisconsin, and Florida fall within the twenty-three to forty-two rank. Other factors, such as proximity to key transportation routes (Mississippi), significant wind resources (North Dakota and Wisconsin), and low state taxes (Florida) contribute to the high number of wind manufacturing jobs in states that do not have strong wind-related policies or incentives. In Figure 3-4, Navigant plotted the rankings against the number of jobs per capita per state to demonstrate the pattern.

Figure 3-4. Wind Jobs per Capita vs. Wind Strategies



Source: Navigant 2017

The plot above shows that only a loose correlation exists between strategies implemented and number of jobs. The correlation is likely not as strong, due to a variety of factors. One of these factors stems from the fact that a large portion of wind jobs are in manufacturing, jobs that are less

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driven by policy and incentives.[29] Instead they are driven by logistics, workforce preparedness, and supply chain, as outlined in Section 2.3 and Table 2-2.

3.4 KEY TAKEAWAYS

By identifying and quantifying the success of state strategies, Navigant further understood the levers and how they may affect the regional market. From this analysis, the team verified that policies, such as RPS, Net Metering, third-party PPAs, and financial incentives, in addition to solar resource availability and high electric rates, play a large role in driving solar jobs at the state level. Meanwhile policies and financial incentives play a less significant role in the growth of wind jobs, due in large part to the types of wind jobs available. This means that crafting strategies and recommendations to target the wind and solar industry will need to account for these differing factors.

When asked how the state could aid the industry, all case study participants noted the need for stable and supportive policies and incentives.

[29] According to AWEA, there were 21,000 jobs in wind manufacturing and 38,000 jobs in operations and development in 2016, meaning 35% of jobs are in manufacturing. Source: AWEA, US Wind Power Jobs Hit Record, Up 20 Percent in 2016, https://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=8736.

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4. OHIO ASSESSMENT

After analyzing factors that may influence renewable energy market and job growth, Navigant assessed the current state of jobs and companies in Ohio, aimed at establishing a baseline for the renewable energy companies in Ohio.

4.1 APPROACH

The approach for the assessment consisted of outlining the value chain for the wind and solar industries, conducting research on companies currently in Ohio, charting companies to the value chain and plotting them on the map of Ohio.

To outline the value chains for wind and solar, the team leveraged Navigant's expertise and assessed the number of companies that fit into each portion of the value chain. This required gathering data on wind and solar companies by state from industry trade associations, including the Solar Energy Industry Association (SEIA)[30] and the American Wind Energy Association (AWEA).[31] Navigant also conducted additional research to find companies that may not have been covered by SEIA or AWEA's databases. Using the information gathered, Navigant compared the value chain to the companies in Ohio to determine if Ohio had any elements missing.

4.2 OHIO RENEWABLE ENERGY COMPANIES & MANUFACTURERS

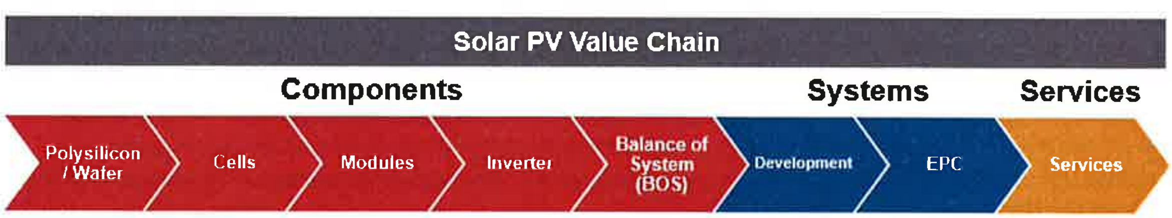
The approach yielded value chains for the solar and wind sectors and a map of the geographic distribution of companies in Ohio. The sections below describe these results.

4.2.1 Solar Companies & Manufacturers

> *"Potential to leverage local glass manufacturing and institutional research provided critical local ecosystems"* – First Solar

The solar value chain consists of manufactured components, system development processes, and downstream services. The manufactured components begin with raw materials, such as water and polysilicon, which companies then transform into cells and modules for the solar panels. The remaining components include the inverters and balance of systems (BOS), which incorporate wiring, switches and racking. Systems is the next element of the value chain, which includes the development of solar site as well as the Engineering, Procurement, and Construction (EPC) of the system. These processes involve acquiring land or a location for the project, obtaining the necessary permits, procuring an end-user or off-taker, and building the system. Once constructed, the system will require additional services including operations and maintenance, financing, etc. Figure 4-1 details the Solar PV Value Chain.

Figure 4-1. Solar PV Value Chain



Source: Navigant 2017

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[30] SEIA, National Solar Database.
[31] AWEA, Wind Farm & Manufacturer Map.

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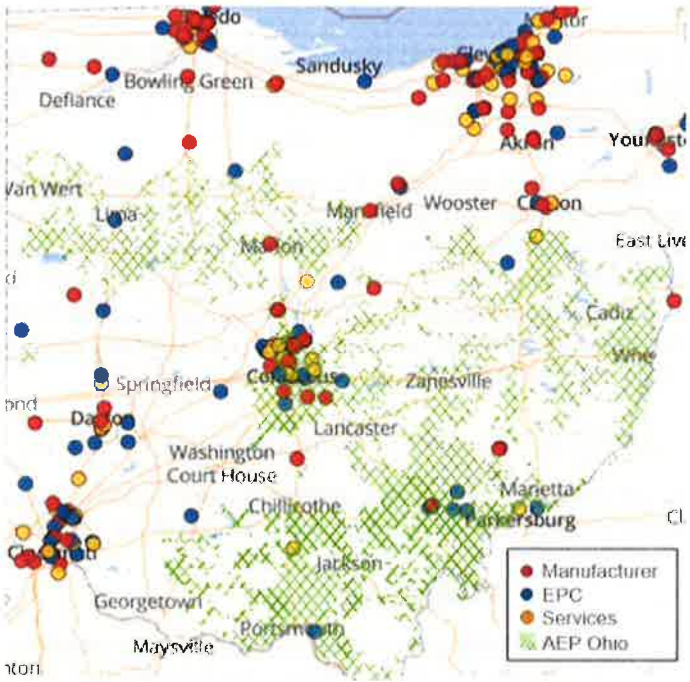
Navigant used SEIA's National Solar database to identify solar companies in Ohio. SEIA's database also consists of a map, showing the geographic distribution of companies by type. Navigant overlaid a layer with AEP Ohio's service territory on top of this map to determine if the companies fell within their service area. Figure 4-2 shows the map.

Figure 4-2. Map of Solar PV Companies in Ohio



Source: SEIA, National Solar Database; Navigant, AEP Ohio Solar Territory Overlay

The map shows that Ohio has a variety of solar-focused companies across the state. These companies tend to be clustered within major cities, such as Toledo, Cleveland, Columbus, and Cincinnati. Clustering within cities is common for most markets. This often occurs due to the solar market potential (a larger population equates to more customers) as well as the ease of access to major transportation routes and skilled labor. Companies spotlighted in the case studies cited these factors as major influencers in the company's locational decisions. Appendix A provides the case study key takeaways.

4.2.2 Wind Companies & Manufacturers

The wind value chain consists of manufacturing components, system development, and downstream services. The manufacturing components include three separate parts: the blades, the tower, and the nacelle, which includes the train, generator, and other electrical components. Next, the system development portion of the value chain involves the system assembly and EPC, including acquiring a system location, designing a system, procuring equipment, finding an off-taker, obtaining the necessary permits, and constructing the wind project. The turbines require routine upkeep and other maintenance activities, which downstream service companies support. Figure 4-3 details the wind value chain.

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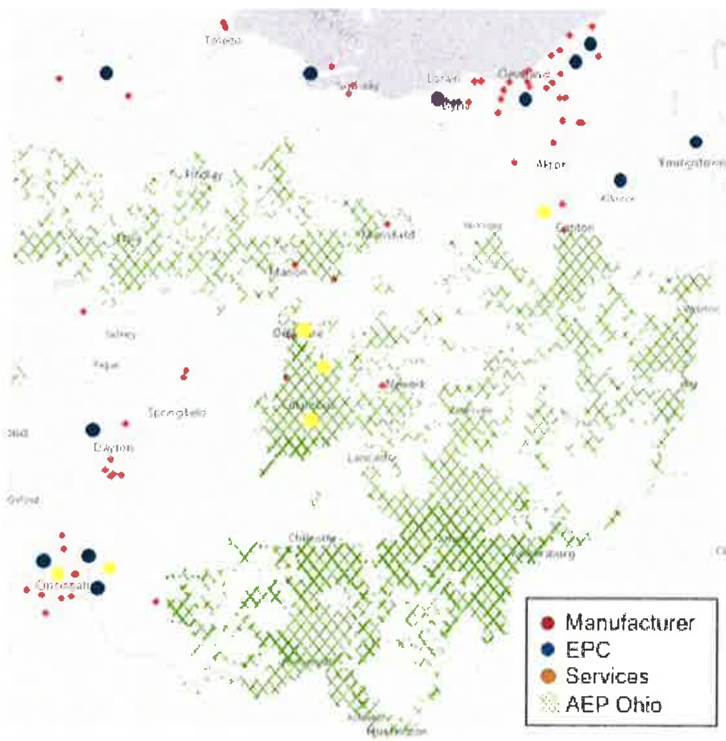
Figure 4-3. Wind Value Chain

*Nacelle includes train, generator, and other electrical components
Source: Navigant 2017

Navigant gathered information regarding the wind companies currently in Ohio, using AWEA's Manufacturing Company database and conducting additional research. Navigant added the non-manufacturing wind companies to the map as well as AEP Ohio's service territory. Figure 4-4 shows the map.

Figure 4-4. Map of Wind Companies in Ohio and AEP Ohio Service Territory



Source: AWEA Wind Farm & Manufacturer Map; Navigant, AEP Ohio Service Territory Overlay; Green Energy Ohio, Renewable Energy Installers in Ohio

The map above illustrates that Ohio has wind manufacturers and developers sprinkled throughout the state. According to AWEA's database of wind manufacturers and wind farms, Ohio has more wind manufacturers than any other state.[32] The companies tend to be clustered in the following major cities: Cleveland, Dayton, and Cincinnati. Companies also exist in smaller numbers near Columbus and Toledo. The clusters around Cleveland, Cincinnati, and Dayton, may be due to existing manufacturing automotive manufacturing near Great Lakes cities, like Cleveland and access to major waterway transport routes. The latter is especially important for wind

[32] AWEA, Wind Farm & Manufacturer Map Database, https://www.awea.org/AWEAWindFarmandFactoryMap.

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manufacturers and developers given the size and weight of the turbines. For example, Cincinnati sits near the Ohio River and at the junction of Interstates-71, 74, and 75, major transportation routes. Likewise, Toledo is located on Lake Erie and near Interstates-75 and 80.

4.3 KEY TAKEAWAYS

Based on this assessment, Navigant concluded that Ohio currently has a thriving renewable energy market with a variety of different types of wind and solar companies. This market has likely resulted from Ohio's proximity to a strong Central and Midwest wind market and a strong solar market driven by policy and incentives in the state of Ohio and the Northeast. As the demand for renewable energy continues to grow, Ohio needs to continue to encourage companies to locate within the state.

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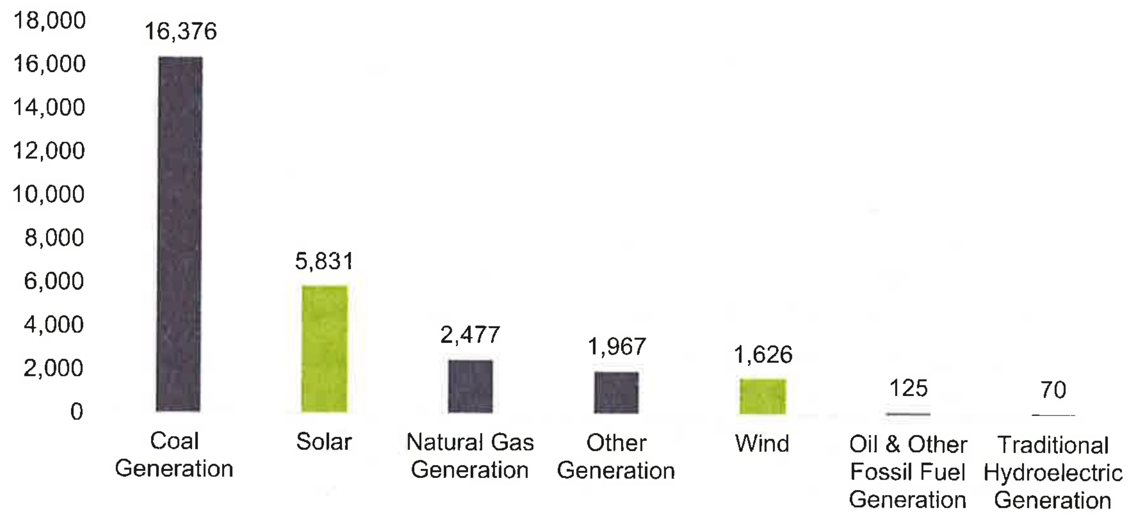
5. CAREER TRANSITION

Navigant examined strategies to facilitate employee transition to renewable energy opportunities as they arise. According to a 2017 report from the US Department of Energy (DOE), traditional fossil fuel generation, specifically coal, makes up the largest electric power job segment in Ohio. Solar generation follows in second place and wind in fifth place, behind natural gas and other generation. Figure 5-1 shows the electric power job segments and their respective number of jobs.

Figure 5-1. Ohio Electric Power Generation Employment by Sub Technology



Source: The Solar Job Census 2016, The Solar Foundation, https://solarstates.org/#state/ohio/counties/solar-jobs/2016; Economic Development Impact of Wind Projects, Navigant report prepared for AWEA; US Energy and Employment Report, January 2017

As Ohio moves away from conventional power plants, existing workers will need to transition into other industries. The graphic above illustrates this point, showing the magnitude of the number of workers that may need assistance in this transition. Given their skillset and knowledge, it naturally makes sense that these workers may transition into other energy industry careers, especially in growing markets, such as wind and solar. This highlights the importance of developing pathways for these workers and assisting in the transition process. The goal of this portion of the study is to outline these pathways, identify resources to aid in the transition, and determine strategies to continue supporting this effort.

5.1 APPROACH

Navigant conducted secondary research on current programs and resources available from trade associations and federal, state, and local initiatives for facilitating transitions to the renewable energy industry. The team developed a pathway of steps for prospective employees to follow, outlining key resources for each step. Next, Navigant identified the roles key stakeholders, including states, utilities, individuals, and solar and wind companies may play throughout the process.

5.2 CAREER PATHWAY TRANSITION

Navigant developed a conventional power plant to renewable energy career transition pathway. Figure 5-2 gives an overview of that pathway, which consists of five steps: assess skillset, map skills to renewables career, analyze gaps, assess strategies for growth, and apply to jobs.

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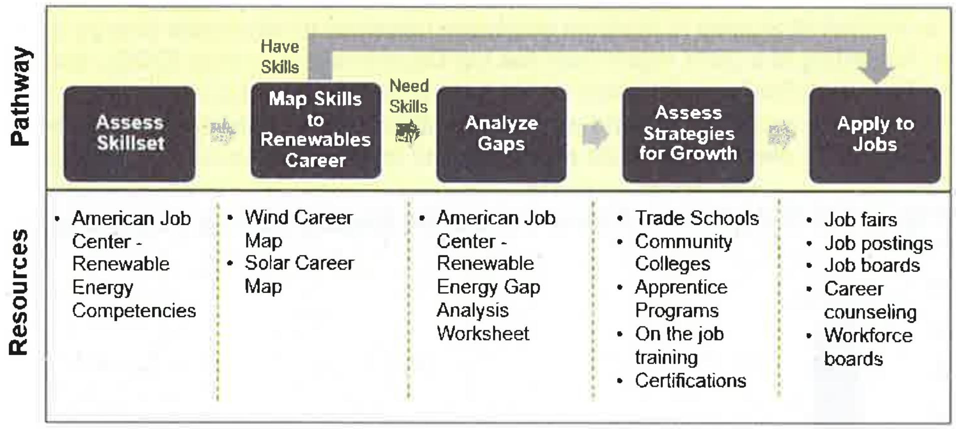
Figure 5-2. Career Transition Pathway



Resource links will be provided throughout the section as well as in Appendix B.
Source: Navigant 2017

- **Assess skillset** – Includes inventorying skills acquired from past jobs. This process will give the transitioning employee an idea of his or her current abilities.
- **Map skills to renewables career** – There are several readily available tools for conducting the mapping, including the Interstate Renewable Energy Council's (IREC) Solar Career Map[33] and the DOE's Wind Career Map.[34] The American Job Center also provides competency models and worksheets related to renewable energy careers.[35] All the tools listed have interactive interfaces for users to explore job details, advancement pathways, lateral pathways, transition success factors, and additional resources.
- **Analyze Gaps** – Once a prospective employee understands his or her skills and the skills necessary for a career in renewables, he or she will need to analyze the gaps between the two. The American Job Center includes a "gap analysis worksheet" and an "identify credential competencies worksheet" to aid in this process.[36]
- **Assess Strategies for Growth** – The pathway user will need to assess opportunities for filling these gaps. Ideas for obtaining skills include attending community college courses, enrolling in an apprentice program, obtaining certifications, and seeking on-the-job training opportunities. The Solar Foundation's Solar Training Network provides an overview of these opportunities by state for those looking for careers in solar.[37]

> *"Only 34% of employer respondents indicated that they provide formal on-the-job training."*
> - The Solar Foundation 2017

- **Apply to Jobs** – Once the prospective employee has the necessary skills and knowledge, he or she can begin applying to jobs by leveraging job fairs, job postings, and job boards.

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[33] Interstate Renewable Energy Council (IREC), Solar Career Map, irecsolarcareermap.org
[34] DOE Office of Energy Efficiency & Renewable Energy, Wind Career Map, https://energy.gov/eere/wind/wind-career-map.
[35] American Job Center Competency Model Clearinghouse, Energy: Renewable Energy Competency Model, https://www.careeronestop.org/competencymodel/competency-models/renewable-energy.aspx.
[36] American Job Center Competency Model Clearinghouse, Energy: Renewable Energy Competency Model – Download Model, https://www.careeronestop.org/competencymodel/competency-models/pyramid-download.aspx?industry=renewable-energy.
[37] The Solar Foundation, Solar Training Network, http://www.solartrainingusa.org/.

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5.3 STRATEGIES FOR FACILITATING PATHWAY

As shown in Figure 5-3, Navigant identified four strategies that stakeholders can enact: conducting targeted marketing, providing educational resources to workers, funding training programs for workers, and incentivizing employers to create or host training programs. The strategies are intended to work in conjunction, helping conventional power plant workers transition.

Figure 5-3. Strategies for Facilitating Career Transition Pathway

- **Targeted marketing** uses strategic advertising channels to increase awareness about training and job opportunities. Often, employees do not know what resources are available and this strategy aims to bridge that gap by helping connect employees to resources. Specific targeted marketing ideas include offering specialized workshops and job fairs, creating user-friendly job boards, and building communication channels to ensure prospective workers can find relevant information.
- **Educational resources** involve developing informational pieces and coordinating educational opportunities. Examples of resources include: pamphlets, fliers, websites, workshops, and other materials. The Solar Training Network lists six solar trainers and workforce boards throughout the state of Ohio. If these trainers and boards are not located near a transitioning employee, it may be difficult to fill skills or knowledge gaps. Providing additional educational resources helps mitigate this issue.
- **Training funding** is important because if a transitioning worker does not have the adequate funding to attend a needed training course, it may be difficult to secure a job within the industry. By providing funding for training programs through scholarships, educational vouchers, grants, or subsidized training, employees stand a better chance of participating. This is especially important as conventional power plant jobs decline.

> *"79% of employers stated that there's a need for solar training."*
> -The Solar Foundation 2017

- **Incentivizing employers** to provide educational resources and training funding to transitioning workers by making industry knowledge and skills more accessible. Navigant's research revealed that employers often understand the need for solar training but do not provide training themselves.[38] The research also mentioned that employers often do not take advantage of incentive opportunities, such as federal funding, due to a lack of knowledge.[39] Therefore, providing more incentives and marketing to employers can aid in changing this culture.

[38] The Solar Foundation, Solar Training and Hiring Insights, 2017, http://www.solartrainingusa.org/wp-content/uploads/2016/10/Solar-Training-and-Hiring-Insights-2017-1.pdf.
[39] Ibid.

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6. FINDINGS AND RECOMMENDATIONS

After completing the analysis, Navigant revisited each individual task to synthesize the findings and provide action-oriented recommendations. This final task involved reviewing key sources, conducting an internal working sessions with key stakeholders, and analyzing programs for renewable energy in Ohio. These activities resulted in high-level guidelines for creating programs and detailed recommendations for Ohio. This section provides the details of these guidelines and recommendations.

6.1 FINDINGS

Upon reviewing the takeaways from each individual analysis, revisiting key sources, and reviewing the case study transcripts, Navigant created four guiding principles for implementing strategies. By applying these principles to their programs, stakeholders can ensure sustainable renewable energy company and job growth. Table 6-1 describes each of the four principles which guide Navigant's recommendations in Section 6.2.

> *"When they put the freeze on it (SB 310), [investors]* said it was too risky to invest in Ohio." – Dovetail Solar & Wind

Table 6-1. Guiding Principles for Implementing Renewable Energy-Related Programs

Guiding Principle	Description
Market Stability 	Renewable energy market growth depends on long-term policies. These policies reduce market risk for stakeholders and ensure a stable long-term market.
Consistent Programs 	Like market stability, companies regularly leverage and rely on state and utility programs (e.g. incentives) to expand operations. Short-term programs will only produce short-term jobs and company expansion; therefore, programs must be consistent in the long-term.
Workforce Preparation 	As the industry grows, market players will need an educated workforce to meet demand. For this reason, workforce preparation should be a focus of renewable energy policies and programs.
Research & Development 	Continuous research and development (R&D) will prepare the renewable energy industry in Ohio for change and enhance its market "competitiveness."

6.2 RECOMMENDATIONS

Based on the analyses and guiding principles, Navigant created five recommendations to drive renewable energy company establishment and job growth. More specifically, the implementation of

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these recommendations will aid in creating a stable market, reducing barriers for prospective market entrants, and providing resources for companies and transitioning workers.

Since policies and programs can drive renewable energy market growth, Navigant identified several recommendations that target these areas. Table 6-2 below lists the recommendations identified.

Table 6-2. Recommendations

No.	Recommendation
1	Publish multi-year state renewable energy procurement plan, led by the state or a state-wide body
2	Expand JobsOhio to include: • Renewable energy education platform providing career transition resources • Concierge service to answer renewable energy related questions
3	Remove permitting barriers
4	Invest in Research & Development
5	Continue to invest in roads and infrastructure

These suggestions align to the broader findings in Section 6.1.

1. **Recommendation: Publish multi-year state renewable energy procurement plan.**

   Importance: A multi-year renewable energy procurement plan helps companies understand the opportunity in Ohio by advertising Ohio's commitment to procuring renewable energy. This commitment helps interested parties understand the long-term market need for renewables, reducing business risk. The publication may spur additional local market entrants, who want to bid into procurement opportunities and signals that Ohio is supportive of renewable energy development.

   Next Steps: The state or a state-wide body should aggregate the plans and publish them in a central location for the public and more importantly, renewable energy companies to view. Trade associations and other communication channels should advertise the plans directly to renewable energy companies. The publication should include details about how companies can participate in the procurement process and where to go for more information.

2. **Recommendation: Expand JobsOhio to include renewable energy as an eligible industry. Include education tools and concierge services for prospective companies and workers.**

   Importance: By expanding JobsOhio to include renewable energy as a targeted industry, the Ohio market can leverage valuable resources and incentives to spur growth. Companies will have access to long-term funding for research and development and operating expense reduction in addition to site selection resources. This centralized website shows the state's commitment to encouraging further renewable energy company and job growth. By expanding the program's services to incorporate concierge services, which provide information regarding the state's renewable energy procurement plans, rate structures, and incentives, will reduce barriers to entering the Ohio renewable energy market. Finally, creating a component of the website that targets workers looking to transition into the renewable energy market can aid in connecting valuable labor resources to prospective companies, while also providing

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educational information to transitioning workers. Once more this improves the ease of doing business in Ohio and prepares the workforce for the growing demand in jobs. These suggestions align closely to the analysis findings in Section 3, which conclude that incentives, in conjunction with policies, contribute to localized renewable energy growth.

Next Steps: The implementation of this recommendation requires expanding the eligibility of the JobsOhio program to include the renewable energy industry. Since the state of Ohio runs the program, the government should set a directive for the incorporation of this industry to spur further growth. Program administrators should also collaborate with utility companies and the PUCO to further expand its concierge services to provide guidance to renewable energy developers, investors, companies and workers looking to transition to the industry.

3. **Recommendation: Remove permitting barriers**

Importance: This recommendation addresses the findings from Section 2, in which Navigant defined and prioritized company motivators. The analysis concluded that the number one driver of industry growth for general renewable energy companies is the Renewable Energy Market, which includes supportive permitting policies. By establishing permitting policies that reduce barriers, the state and local jurisdictions can reduce development costs and time for developers. Key industry stakeholders, including the DOE and NREL, have programs specifically aimed at streamlining permitting processes to encourage renewable energy growth, illustrating the importance of permitting. The DOE's SolSmart program incentivizes local governments to improve permitting processes by awarding special designations to cities that remove permitting obstacles. Cities must create a permit checklist, review current processes, and write a memo describing the existing barriers in zoning and permitting to receive the designation.[40] These actions align to the program goals, which include improving business prospects for solar developers and saving governments time and money.[41] Likewise, a recent study by NREL examined renewable energy permitting in Hawaii and concluded that improved processes for permitting, such as providing checklists and creating permitting application templates, would reduce project delays and improve the feasibility of projects.[42] These initiatives and studies underscore the significance of permitting in renewable energy development.

Next Steps: The state of Ohio as well as local jurisdictions should examine permitting processes to identify barriers, like the NREL report on Hawaii or the SolSmart initiative requirements. The study should focus on understanding how certain requirements affect companies in terms of timing, costs, and overall project feasibility. After identifying barriers, the state should implement targeted actions to improve the process. Actions may include creating a permitting checklist and guidelines, establishing application templates, reducing required paperwork, eliminating stringent permitting requirements, and instating mechanisms for expediting the permitting process.

4. **Recommendation: Invest in Research & Development**

Importance: Investing in research and development will help prepare the state for industry changes and improve its overall competitiveness. This principle and recommendation stems from the findings in Section 2, which included the lists of company locational drivers. Navigant identified research and development as a key supportive scheme that encourages companies

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[40] SolSmart, Program Guide, https://static1.squarespace.com/static/56035ff7e4b01dadee1991a1/t/571feca54d088efedb7f66d6/1461709994244/SolSmart_ProgramGuide_web.pdf

[41] SolSmart, "Why Participate?", http://www.gosparc.org/home-2

[42] NREL, "Renewable Energy Permitting Barriers in Hawaii: Experience from the Field", March 2013, https://www.nrel.gov/docs/fy13osti/55630.pdf.

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to locate in specific destinations and the case studies verified this recommendation. First Solar noted that it decided to locate its manufacturing facilities in Perrysburg, Ohio because R&D facilities and schemes already existed in the area.[43] First Solar also mentioned that this pattern exists in many other states, including California, New York, and Tennessee.[44] Other studies, such as the Deloitte Competitiveness Index, also rank R&D as a significant factor for manufacturing competitiveness. The firsthand accounts along with significant market research emphasize the importance of research and development in encouraging company establishment.

Next Steps: The state should stimulate the growth of renewable energy R&D by providing funding opportunities through loans, grants, and other incentives. The government should also look to leverage resources from local colleges and universities by advertising incentives directly to these entities, establishing targeted research programs dedicated to renewable energy, and helping connect universities and renewable energy firms.[45]

5. **Recommendation: Continue to invest in roads and infrastructure**

Importance: Since renewable energy development requires the transport of large equipment (e.g., turbines and panels), companies and in particular manufacturers locate near major transportation routes, corroborated by the findings of this study. The maps depicting the location of renewable energy companies in Ohio illustrate that companies not only tend to cluster around major cities but also near major transportation routes. A large portion of wind companies are located near Lake Erie, which allows for the transportation of turbines across the Atlantic to the Northeast and to states across the Great Lakes. Additionally, most of the case study participants stated access to transportation as one of their top three locational motivators, providing a firsthand account of its significance.

Next Steps: Ohio should continue funding its roads and transportation infrastructure. The state may also consider expanding transportation routes to cities with the potential for a robust renewable energy industry. This may require an in-depth geographic analysis of potential sites for transportation and infrastructure expansion.

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[43] Interview with First Solar, September 19, 2017.

[44] Ibid.

[45] Stark State College and The Timken Company provide an example of a public-private partnership between a local university and renewable energy company. The two partnered to create the Stark State College and the Timken Company Technology and Test Center, which focuses on creating wind turbine technology. More information can be found on Stark State College's website: https://www.starkstate.edu/news/timken-stark-state-open-technology-test-center/.

APPENDIX A. CASE STUDY KEY TAKEAWAYS

Navigant conducted four case study interviews with renewable energy companies in Ohio. The companies include both wind and solar companies, one manufacturer, and renewable energy developers focused on different end-user segments. The table below provides information about these companies, including business type and renewable energy industry.

Table A-1. Case Study Participants

Company	Solar	Wind	AEP Territory	Ohio Business Type
SunEnergy1	✓		✓	Utility-scale solar developer. Projects in AEP Ohio Territory.
Dovetail Solar & Wind	✓	✓	✓	Residential, commercial, & utility-scale renewable energy developer.
Energy Optimizers USA	✓			Design and installation of solar PV and solar thermal systems for K-12 schools as well as energy efficiency services.
First Solar	✓			Manufacturing for corporate, community, & utility-scale solar developments.

Several key themes regarding locational drivers and recommendations emerged from the case studies. In terms of locational drivers, case study participants felt the following factors were the most influential: a stable and predictable market for renewables; skilled talent; and logistics. As for recommendations, the companies agreed that the state and local utilities should continue to provide renewable energy incentives and enact consistent policies.

The remaining portion of this appendix provides the key takeaways from the case study interviews.

DOVETAIL SOLAR & WIND

Company Background:

Dovetail Solar & Wind primarily focuses on developing commercial and utility scale solar PV. Originally located in Athens, OH, Dovetail moved its headquarters to Cleveland to gain access to more customers and better talent. Today, the company continues to grow its operations and looks towards states and cities with supportive renewable energy policies for additional facilities.

Locational Drivers:

- **Robust market for renewables**: Without a market for its product, a business cannot exist. Dovetail began in Athens and has since moved to urban areas with a larger population and market to build the business.

- **Access to talent:** Building renewables requires a certain skillset. Having access to a larger pool of talent, such as being close to a university, increases access.

- **Access to transportation corridors:** Ease of access and flow of materials makes it easier to conduct business.

Recommendations:

- Help create a climate of stability for investors, businesses, and the overall market through consistent and supportive policy.

- Continue to work with the Public Utilities Commission to create consistent policies as well as ensuring that smaller companies have a role to play in the growing renewables market.

Company Summary

Company Type: Solar & Wind Developer

HQ Location: Cleveland, OH

Other Locations: Columbus, Athens, & Cincinnati, OH; Brighton, MI

No. of Employees: 26

Top 3 Locational Drivers:

1. Utility's Needs
2. Community Interest
3. County Involvement

SUNENERGY1

Company Background:

SunEnergy1 engineers, procures, constructs and operates utility-scale ground and roof- mounted solar projects. To-date, SunEnergy1 has constructed over 500MWs of solar and holds over 2,500 MWs of solar projects in its pipeline. The firm has projects located throughout the eastern United States.

Locational Drivers:

- **Utility's Needs [for renewables]:** SunEnergy1 stated that the utility's needs influenced its project and operational locations in North Carolina.
- **Community Interest:** Similar to the Utility's needs, the company considered project locations based on the community's desire for solar.
- **County Involvement:** Counties may play a similar role to states and communities, providing incentives and driving the market through the permitting process.

Recommendations:

- Incentivize solar further. SunEnergy1 noted that state incentives played a direct role in locating its operations in North Carolina.
- Select proven and well-vetted solar companies when procuring energy for a new project.

Company Summary
Company Type: Development, Engineering, Procurement, Construction, and Operations for Solar **HQ Location:** Mooresville, NC **Other Locations:** Bethel, NC; Projects in OH, WV, VA, SC, and MD. **No. of Employees:** 500, 1-5 in OH
Top 3 Locational Drivers: 1. Utility's Needs 2. Community Interest 3. County Involvement

ENERGY OPTIMIZERS, USA

Company Background:

Energy Optimizers, USA provides comprehensive energy efficiency and renewable energy services. On the renewable energy side, Energy Optimizers designs and installs solar PV and solar thermal systems, primarily for K-12 schools.

Locational Drivers:

- **State Policy:** Energy Optimizers, USA decided to locate in Ohio due to its well-established energy performance contracting legislation for education and governmental institutions. The company also cited the Alternative Energy Portfolio Standard (AEPS) passed in 2009 as a reason for locating in Ohio.
- **Strong Renewables Market**: Due to its specific market, the company sited local schools as a reason for locating in Ohio. Schools provide a strong training network to leverage.
- **Proximity to Transportation:** The firm wanted to be located within a fifteen-mile radius of the I-70 and I-75 highways to serve their customers.

Company Summary

Company Type: Design and Construct Solar PV & Solar Thermal

HQ Location: Tipp City, OH

Other Locations: NA

No. of Employees: 22

Top 3 Locational Drivers:

1. State Policy
2. Strong Market
3. Proximity to Transportation

Recommendations:

- Promote and support renewable energy and energy efficiency programs. Additionally, incentive programs make the state more attractive.
- Provide a positive and supportive perspective of grid-tied renewable energy systems and rebate programs for energy efficiency.

FIRST SOLAR

Company Background:

First Solar engages in solar module manufacturing, research and development, and technology innovation as well as project development, financing, and operations and maintenance for the utility-scale solar projects.

Locational Drivers:

- **Supply Chain Ecosystem:** Surrounding market for R&D and technology innovation as well as high availability of quality materials played a large role in First Solar's decision to locate its manufacturing in Perrysburg.
- **Access to Markets:** Since First Solar is a major international solar PV module manufacturer, the company relies on access to markets through transportation, such as domestic trucking routes.
- **Skilled Labor Force:** A strong manufacturing labor force skilled in working with glass and electronics supported First Solar's decision to locate its manufacturing in Perrysburg.

Company Summary

Company Type: R&D, Manufacturing, Development, Financing, and O&M for Solar PV

HQ Location: Tempe, AZ

Other Locations: Perrysburg, OH; Houston, TX; Bridgewater, NJ; San Francisco, CA; Mexico, Malaysia

No. of Employees: 5,400; 760 in OH

Top 3 Locational Drivers:

4. Utility's Needs
5. Community Interest
6. County Involvement

Recommendations:

- Create certainty through state-level policy. It is important for maintaining a sustainable solar PV manufacturing facility.
- Collaborate with key stakeholders to support existing local infrastructure and manufacturing through sustained renewable energy policies.

APPENDIX B. CAREER TRANSITION RESOURCES

While laying out pathways for existing conventional power plant workers to move into the renewable energy industry, Navigant conducted a thorough review of available resources. Appendix B lists those resources with the goal of providing these resources for prospective renewable energy workers. Section 5 of the report offers more details about the career transition pathway.

Table B-1. Career Transition Resources for Prospective Workers

Resource Name, Author, & Link	Description	Resource Type
American Job Center, Energy: Renewable Energy Competency Model and Worksheets https://www.careeronestop.org/competencymodel/competency-models/renewable-energy.aspx	Model and associated worksheets that describe the skills and competencies necessary to work in renewable energy jobs. Worksheets include a gap analysis and credential competencies identification.	Wind & Solar Worksheets
Interstate Renewable Energy Council (IREC), Solar Career Map http://irecsolarcareermap.org/	Tool that allows users to identify and explore different career paths within the Solar Industry.	Solar Career Exploration
Department of Energy, Office of EERE, Wind Career Map https://energy.gov/eere/wind/wind-career-map	Tool that allows users to identify and explore different career paths within the Wind Industry.	Wind Career Exploration
The Solar Foundation, Solar Training & Hiring Insights 2017, Available Tools and Resources for the Solar Industry, By Category http://www.solartrainingusa.org/research/	Comprehensive survey of trends in solar training and hiring, including resources for prospective workers	Solar Career Tools & Training Resources
Department of Energy, Office of EERE, Wind Career Map Resource List https://energy.gov/eere/wind/wind-career-map-resource-list	List of resources used to develop the Wind Career Map. Resources include a variety of career and training information for prospective employees.	Wind Career Tools & Training Resources

NERC

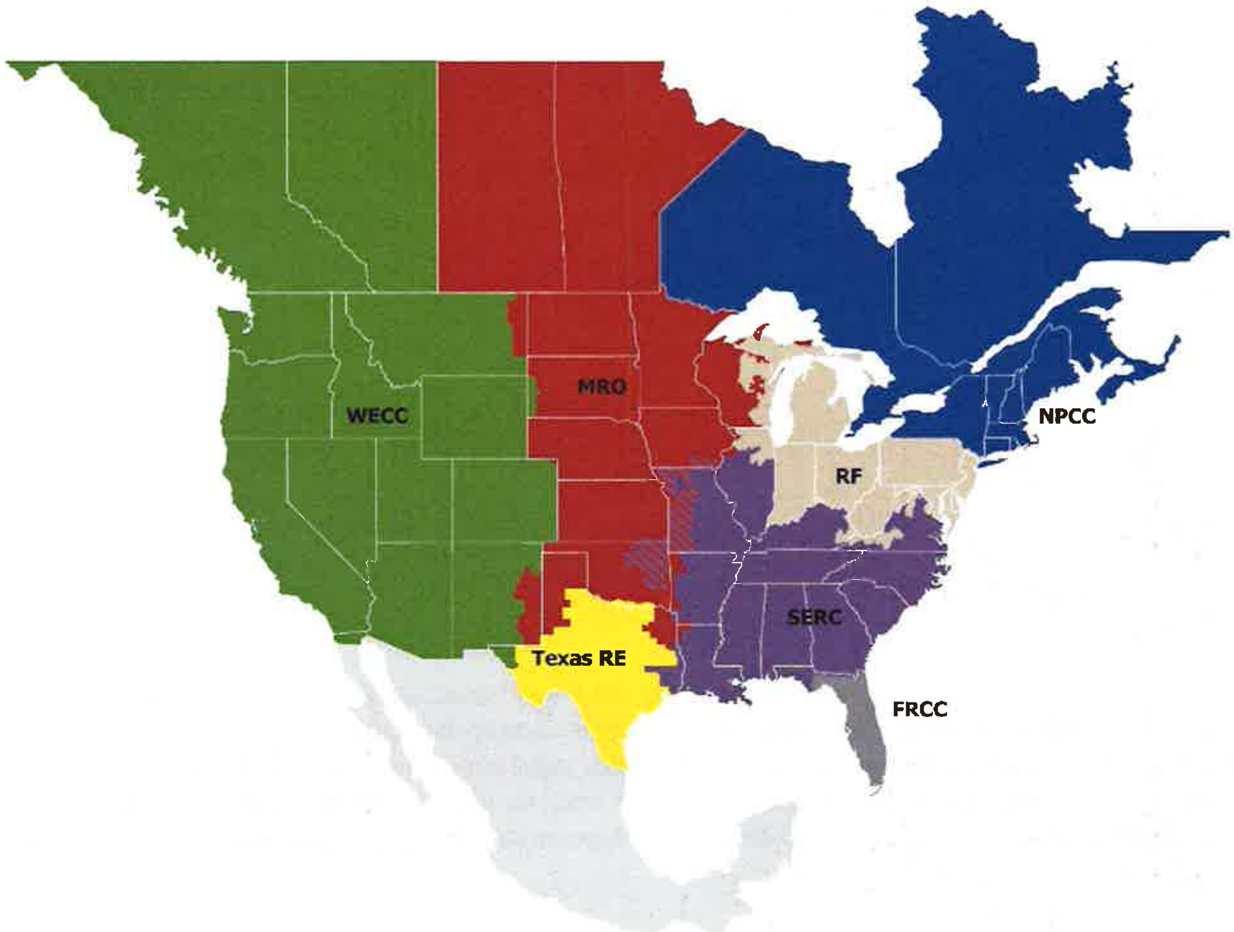
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

2018/2019 Winter Reliability Assessment

Table of Contents

Preface

The vision for the Electric Reliability Organization (ERO) Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the seven Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid. The North American BPS is divided into seven RE boundaries as shown in the map below. The multicolored area denotes overlap as some load-serving entities participate in one Region while associated Transmission Owners/Operators participate in another. Refer to the **Data Concepts and Assumptions** section for more information. A map and list of the assessment areas can be found in the **Regional Assessments Dashboards** section.



About this Report

The objectives for NERC's *Winter Reliability Assessment* (WRA) are to identify, assess, and report details about the reliability of the North American BPS and to make recommendations as necessary. The WRA identifies potential resource deficiencies and operating reliability concerns, determines peak electricity demand and supply changes, and highlights unique regional challenges. The WRA represents the results of collaborative efforts that involve the Reliability Assessment Subcommittee (RAS), the Regions, and NERC staff to develop sound technical bases for understanding these potential concerns, changes, and challenges. The WRA is intended to enable entities to discuss their plans for the upcoming winter period to ensure BPS reliability.

Key Findings

NERC's annual WRA covers the three-month (December–February) 2018/2019 winter period. This assessment provides an evaluation of the generation resource and the transmission system adequacy necessary to meet projected winter peak demands. This assessment also monitors and identifies potential reliability issues of interest and regional areas of concern that pertain to meeting projected customer demands. The following key findings represent NERC's independent evaluation of electric generation capacity and potential operational concerns that may need to be addressed:

- **Adequate Resources for Winter:** Anticipated resources in all assessment areas meet or exceed their respective Reference Margin Levels for the upcoming winter period.[1]
- **Continued Emphasis on Winter Preparedness Programs:** Generator unit winter preparedness programs continue to receive significant attention in assessment areas as a means to mitigate seasonal reliability risks. Cold weather events can trigger generator and transmission facility outages while simultaneously driving electrical demand to seasonal peaks. Across North America, NERC Regional Entities, Reliability Coordinators, and independent system operators/regional transmission organizations conduct various activities aimed at ensuring generator unit reliability under extreme winter weather conditions (see the **Regional Assessments Dashboards** section of this report). Through webinars, workshops, seasonal studies, and operator checklists, entities are encouraged to incorporate best practices and lessons from previous winter operations.
- **Incentives in Market Areas Target Generator Performance:** Market mechanisms are a useful tool for incentivizing generator performance during extreme weather conditions. According to PJM's analysis of generating unit performance data from the last week of 2017 and first week of 2018 (a period referred to as the Cold Snap, when extreme cold temperatures and winter weather across eastern North America led to high electric demand and tight fuel supplies), overall capacity performance (CP) units had fewer forced outages than non-CP units. This program continues in the PJM market area for the upcoming winter season. In ISO New England, a similar program known as pay-for-performance (PFP) is fully implemented for the coming winter and provides strong incentives for all suppliers of generation capacity to maximize unit availability and performance during scarcity conditions on the BPS.
- **Entities Focus on Reducing Risks of Generator Fuel Supply Issues:** Entities are implementing processes and strategies to promote fuel assurance and reduce risks to the BPS from seasonal generator fuel supply issues. During the 2017/2018 Cold Snap, some areas faced generator fuel supply concerns as dual-fueled generators turned to fuel oil over higher-priced natural gas. As fuel oil reserves declined, replenishment was impacted by inclement weather. Below are some noteworthy actions that entities are taking to mitigate generator fuel supply risk for the upcoming winter season:
  - ISO New England is implementing new periodic energy assessments aimed at providing market participants with early indication of potential fuel scarcity conditions that can help inform generator fuel procurement decisions. The new periodic assessments complement existing fossil fuel surveying and monitoring activities and natural-gas-fired generator day-ahead confirmations that are employed to promote fuel assurance in the area.
  - In New York ISO, seasonal generator fuel surveys indicate oil-burning units have sufficient start-of-winter inventories and arrangements for replacement fuel. Emergency protocols are in place for communicating electric reliability concerns to pipelines and natural gas operators during tight electric operating conditions.

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1 The Reference Margin Level is typically based on load, generation, and transmission characteristics for each assessment area. In some cases, the Reference Margin Level is a requirement implemented by the respective state(s), provincial authorities, ISO/RTO, or other regulatory bodies. See **Data Concepts and Assumptions** section of this report.

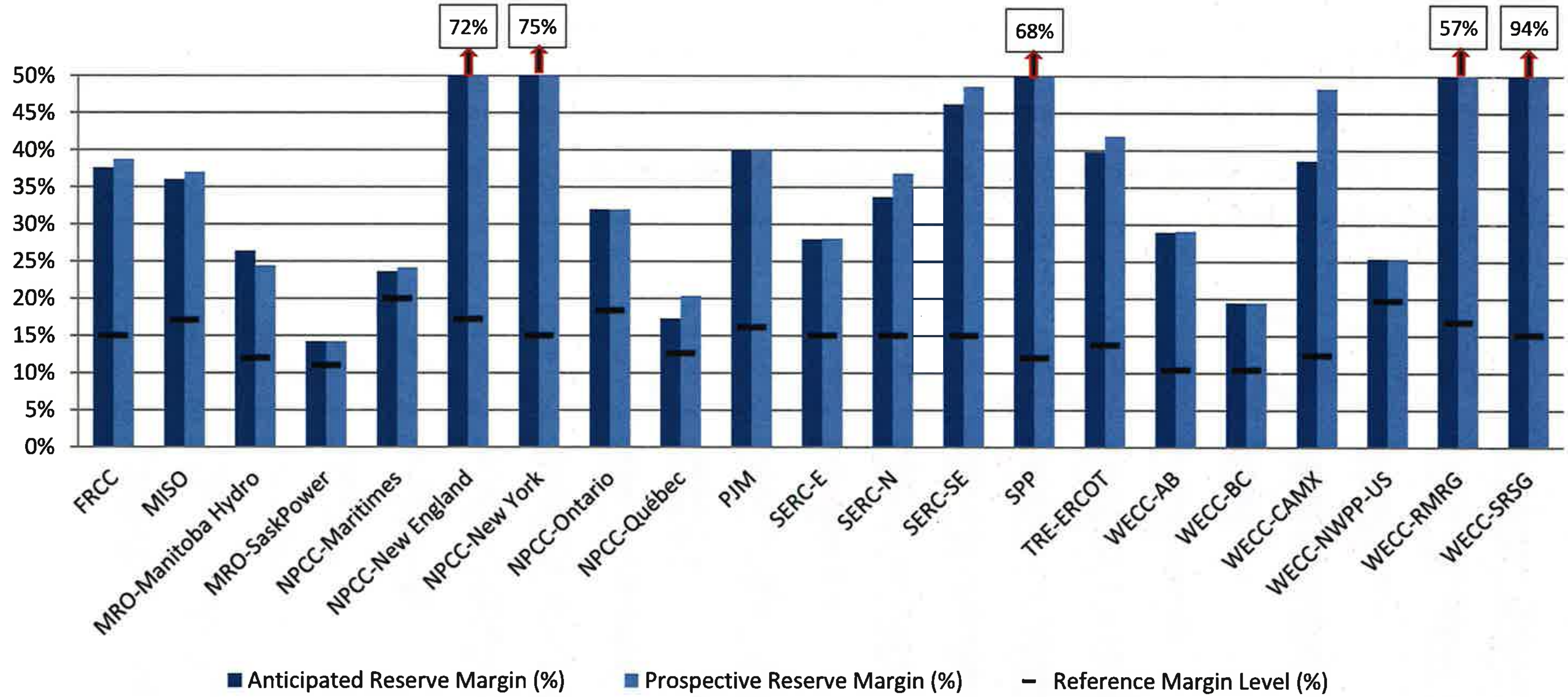
- In PJM, daily natural gas infrastructure analysis is performed to project transmission and generation reserve impacts to the PJM system from natural gas pipeline contingencies.

- **Natural Gas Constraints in Southern California Continue to Have the Potential to Impact Electric Generators in Extreme Conditions:** Natural gas storage and transportation limitations associated with the Aliso Canyon storage facility and natural gas transmission pipelines in the area persist for Winter 2018/2019. The Aliso Canyon technical assessment group found the risk of natural gas service curtailment to be unchanged for the coming winter despite an increase in authorized natural gas inventory at Aliso Canyon. Although natural gas supplies are assessed to be sufficient for anticipated conditions and potential short, single-day demand spikes, there is risk that an extended multi-day period of high demand could reduce storage inventories to a point where natural gas curtailment is needed.[2] As in the two preceding winter seasons, mitigating measures at California Independent System Operator, including demand response, generation redispatching, and increased electricity imports to affected areas, remain in place.

2 See the *Aliso Canyon Risk Assessment Technical Report Winter 2018/19 Supplement,* which is available from the California Public Utilities Commission. The technical assessment group is composed of experts from CPUC, California Energy Commission, the California Independent System Operator, and the Los Angeles Department of Water and Power.

Resource Adequacy

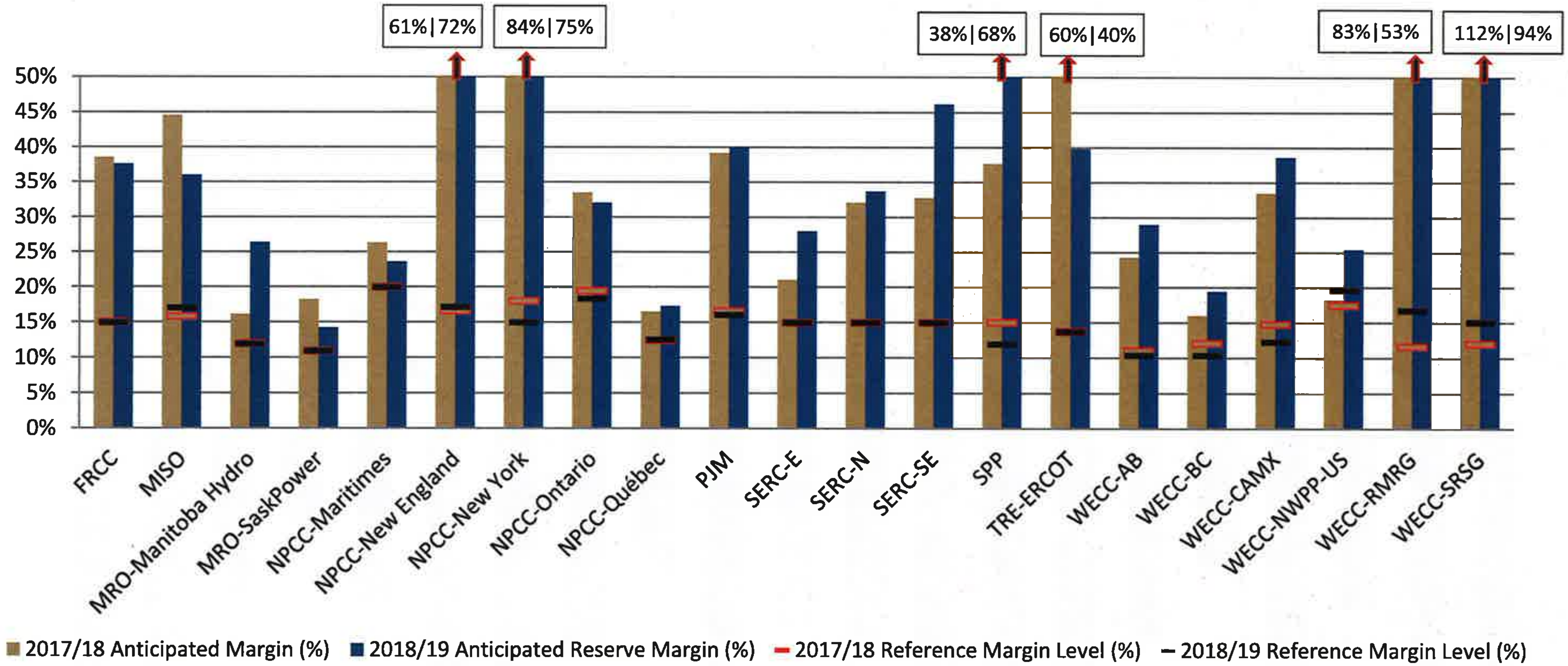
The Anticipated Reserve Margin, based on resource capacity, is a metric used to evaluate resource adequacy by comparing the projected capability of anticipated resources to serve forecasted peak load.[3] Large year-to-year changes in anticipated resources or forecasted peak load (net internal demand) can greatly impact Planning Reserve Margin calculations. All assessment areas have sufficient Anticipated Reserve Margins to meet or exceed their Reference Margin Level for the 2018/2019 winter as shown in the figure below.



Winter 2018/2019 Anticipated/Prospective Reserve Margins Compared to Reference Margin Level

[3] Generally, anticipated resources include generators and firm capacity transfers that are expected to be available to serve load during electrical peak loads for the season. Prospective resources are those that could be available but do not meet criteria to be counted as anticipated resources. Refer to the **Data Concepts and Assumptions** section for additional information on anticipated/prospective reserve margins, anticipated/prospective resources, and Reference Margin Levels.

The figure below provides the relative change in Anticipated Reserve Margin from the 2017/2018 winter period to the 2018/2019 winter period. Significant changes can indicate potential operational issues that emerge between reporting years. Additional details concerning specific areas of interest to NERC are provided in the **Regional Assessments Dashboards** section of this report.

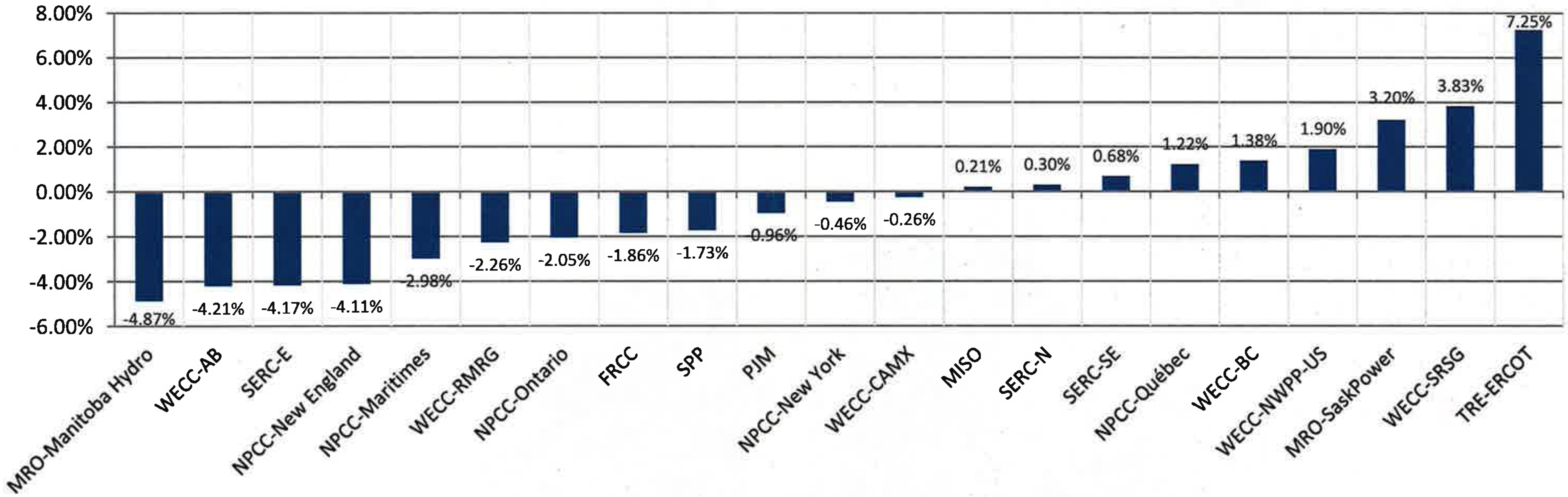


Year-to-Year Change in Anticipated Reserve Margins: Winter 2017/2018 to Winter 2018/2019

While Anticipated Reserve Margins indicate adequate resources for winter throughout the North American BPS, fuel assurance risk remains a reliability concern in some assessment areas. Demand for natural gas is growing both for use as a generator fuel source and for winter heating needs. Winter peak electrical demand can coincide with peak natural gas demand and potentially exceed capacity of natural gas supplies or delivery infrastructure. Generating units that lack alternate fuel sources or firm commitments for natural gas supply may not be able to deliver their full capacity. Operators have implemented steps to mitigate fuel assurance risks, such as generator performance market mechanisms, communications protocols between electric and natural gas operators, and new energy forecasts in ISO New England that provide fuel supply information to wholesale electricity market participants.

Internal Demand

Peak demand forecast for most assessment areas has decreased or remained flat compared to prior assessments. Some assessment areas are forecasting growth in net internal demand of over three percent. The increases in forecasted net internal demand for each assessment area are shown in the figure below.[4]

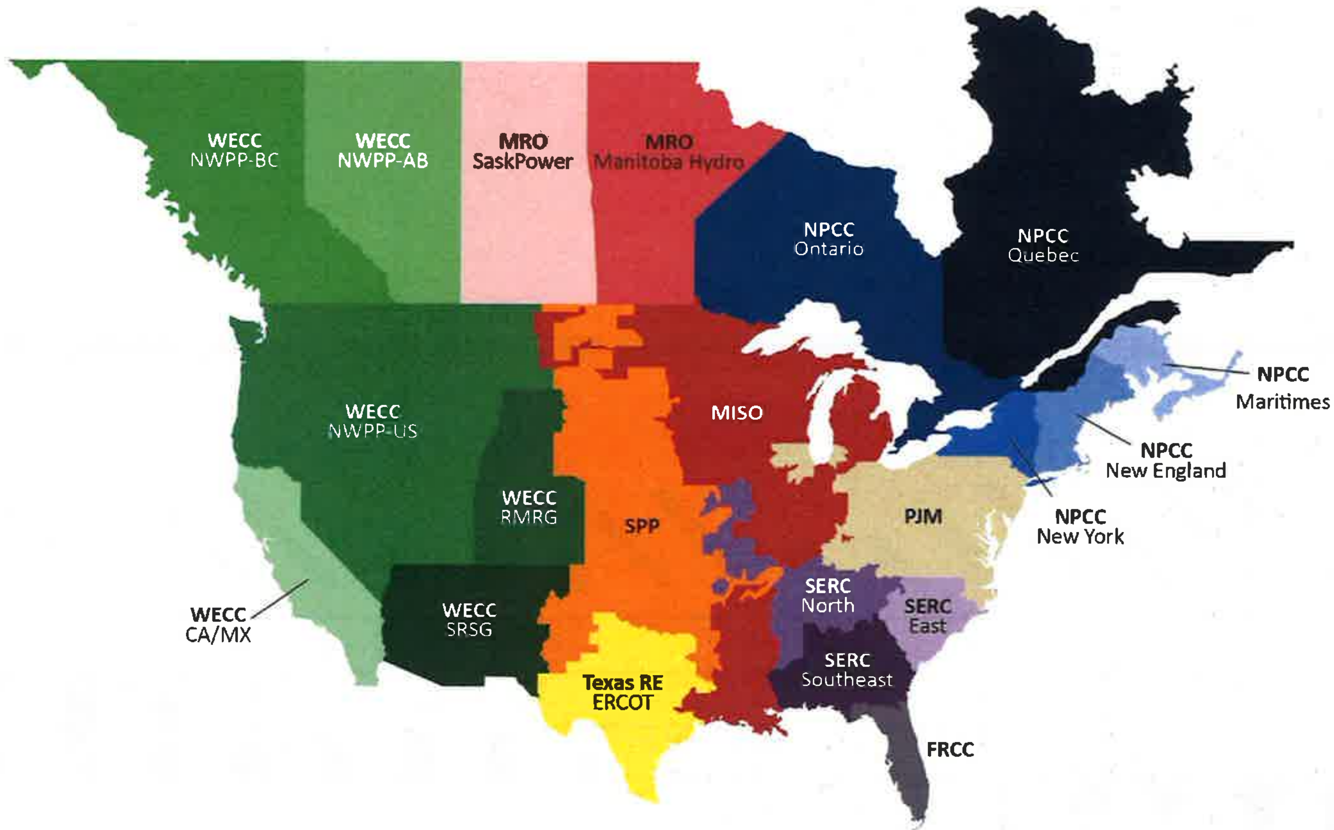


Change in Net Internal Demand: 2018/2019 Winter Forecast Compared To 2017/2018 Winter Forecast

4 Changes in modeling and methods may also contribute to year-to-year changes in forecasted net internal demand projections.

Regional Assessments Dashboards

The following assessment area dashboards and summaries were developed based on data and narrative information collected by NERC from the seven Regional Entities on an assessment area basis.



FRCC – Florida Reliability Coordinating Council
- FRCC

MRO – Midwest Reliability Organization
- MISO
- MRO-Manitoba Hydro
- MRO-SaskPower

NPCC – Northeast Power Coordinating Council
- NPCC-Maritimes
- NPCC-New England
- NPCC-New York
- NPCC-Ontario
- NPCC-Québec

RF – ReliabilityFirst
- PJM

SERC – SERC Reliability Corporation
- SERC-East
- SERC-North
- SERC-Southeast

SPP – Southwest Power Pool
- SPP

Texas RE – Texas Reliability Entity
- Texas RE-ERCOT

WECC – Western Electricity Coordinating Council
- WECC-CA/MX
- WECC-NWPP-AB
- WECC-NWPP-BC
- WECC-NWPP-US
- WECC-RMRG
- WECC-SRSG

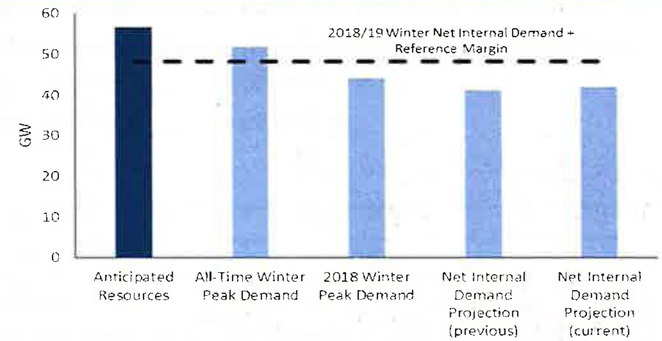
FRCC

The Florida Reliability Coordinating Council's (FRCC) membership includes 32 Regional Entity Division members and 22 Member Services Division members composed of investor-owned utilities (IOUs), cooperatives, municipal utilities, power marketers, and independent power producers. FRCC is divided into 10 Balancing Authorities with 36 registered entities (including both members and non-members) performing the functions identified in the NERC Reliability Functional Model and defined in the NERC Reliability Standards. The Region contains a population of over 16 million people and has a geographic coverage of about 50,000 square miles over Florida.

Existing On-Peak Generation

Generation Type	Percent
Biomass	1%
Coal	13%
Hydro	<1%
Natural Gas	75%
Nuclear	7%
Petroleum	4%

Winter Resource and Demand Summary

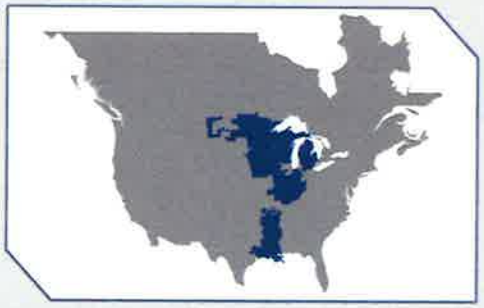


FRCC Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	44,836	44,190	-1.4%
Demand Response: Available	2,842	2,975	4.7%
Net Internal Demand	41,994	41,215	-1.9%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	56,190	53,340	-5.1%
Tier 1 Planned Capacity	715	1,912	-
Net Firm Capacity Transfers	1,253	1,453	16.0%
Anticipated Resources	58,158	56,705	-2.5%
Existing-Other Capacity	535	457	-14.6%
Prospective Resources	58,693	57,162	-2.6%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	38.5%	37.6%	-0.9
Prospective Reserve Margin	39.8%	38.7%	-1.1
Reference Margin Level	15.0%	15.0%	0.0

Highlights

- The FRCC Region does not anticipate reliability issues for the upcoming winter season from resource adequacy.
- The net change in existing capacity for the upcoming winter is a result of retirements in coal-fired and older natural gas units (4,700 MW) and addition of over 1,900 MW in new natural gas and solar resources.
- Generator fuel assurance attributes in the Region include the following:
  - A majority of the natural gas pipeline capacity into Florida is contractually allocated to electric generators.
  - Generator operators maintain liquid backup fuel inventories at multiple locations to mitigate fuel supply risks from potential natural gas supply interruptions and peak demand conditions.
- FRCC continues to promote winter preparedness and performs a detailed winter operational transmission assessment and operational seasonal study to assess the reliability of the BPS during forecasted winter peak load.



MISO

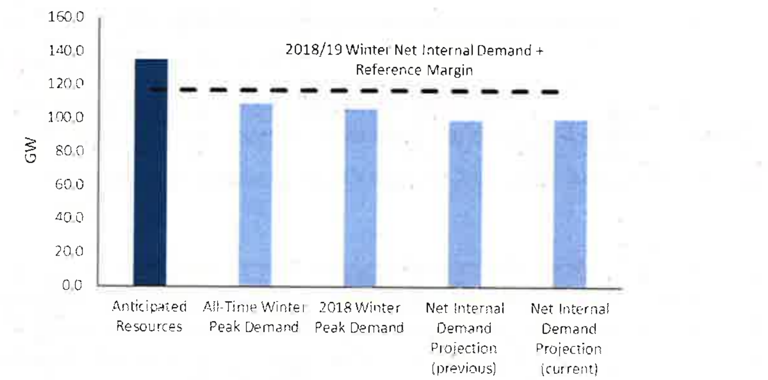
The Midcontinent Independent System Operator, Inc. (MISO) is a not-for-profit, member-based organization administering wholesale electricity markets that provide customers with valued service; reliable, cost-effective systems and operations; dependable and transparent prices; open access to markets; and planning for long-term efficiency. MISO manages energy, reliability, and operating reserve markets that consist of 36 local Balancing Authorities and 394 market participants, serving approximately 42 million customers. Although parts of MISO fall in three NERC Regions, MRO is responsible for coordinating data and information submitted for NERC's reliability assessments.

**For this NERC 2018/2019 WRA, resource projections are based on data provided by MISO from its winter resource assessment. In the previous NERC WRA, resource projections were provided by MISO in its input to the NERC Long-term Reliability Assessment. Some net change from the prior-year NERC WRA is attributed to resource adequacy calculation differences.*

Existing On-Peak Generation

Generation Type	Percent
Biomass	<1%
Coal	42%
Hydro	1%
Natural Gas	42%
Nuclear	9%
Petroleum	2%
Pumped Storage	2%
Solar	<1%
Wind	2%

Winter Resource and Demand Summary

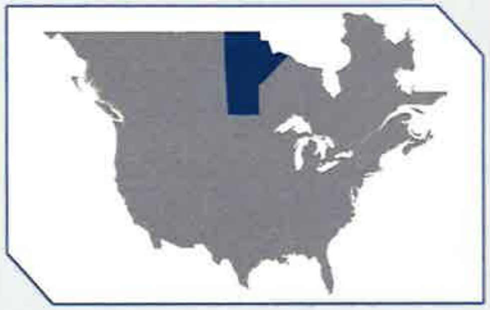


MISO Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	103,731	102,587	-1.1%
Demand Response: Available	4,347	2,715	-37.5%
Net Internal Demand	99,384	99,872	0.5%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	144,108	135,995	-5.6%*
Tier 1 Planned Capacity	1,559	176	-
Net Firm Capacity Transfers	-1,994	-8	-99.6%
Anticipated Resources	143,673	136,163	-5.2%
Existing-Other Capacity	2,194	1,067	-51.4%
Prospective Resources	147,642	137,230	-7.1%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	45.0%	36.3%	-8.7*
Prospective Reserve Margin	48.6%	37.4%	-11.2*
Reference Margin Level	15.8%	17.1%	1.3

Highlights

- MISO anticipates that reliability will be maintained during the upcoming season.
- MISO is working with neighboring Reliability Coordinators (SPP, Southeastern, and TVA) to put in place enhanced communication and operating procedures to address lessons learned from the January 2018 cold weather event.
- MISO hosted its annual a Winter Readiness Workshop on October 29, 2018, to prepare operators for the upcoming season. Topics presented at the workshop include forecasted reserve margin under various scenarios, transmission assessment, and a review of emergency operating procedures. Operating tools and resources for natural gas-electric situational awareness were reviewed as well as preparedness measures and winterization for generator owners. An enhanced winterization review process is being implemented that includes communicating lessons learned.



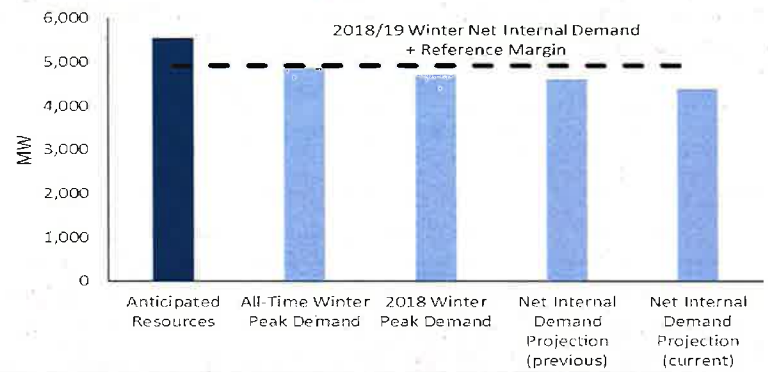
MRO-Manitoba Hydro

Manitoba Hydro is a provincial crown corporation that provides electricity to about 573,000 customers throughout Manitoba and natural gas service to about 279,000 customers in various communities throughout southern Manitoba. The Province of Manitoba has a population of about 1.3 million people in an area of 250,946 square miles. Manitoba Hydro is winter peaking. No change in the footprint area is expected during the assessment period. Manitoba Hydro is its own Planning Coordinator and Balancing Authority. Manitoba Hydro is a coordinating member of MISO. MISO is the Reliability Coordinator for Manitoba Hydro.

Existing On-Peak Generation

Generation Type	Percent
Coal	2%
Hydro	90%
Natural Gas	7%
Wind	1%

Winter Resource and Demand Summary



MRO - Manitoba Hydro Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	4,612	4,388	-4.9%
Demand Response: Available	0	0	0.0%
Net Internal Demand	4,612	4,388	-4.9%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	5,497	5,583	1.6%
Tier 1 Planned Capacity	0	0	-
Net Firm Capacity Transfers	-142	-38	-73.2%
Anticipated Resources	5,355	5,545	3.5%
Existing-Other Capacity	122	5	-95.9%
Prospective Resources	5,477	5,458	-0.3%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	16.0%	26.4%	10.4
Prospective Reserve Margin	18.7%	24.4%	5.7
Reference Margin Level	12.0%	12.0%	0.0

Highlights

- There are no reliability issues for the upcoming season that are unique to this assessment area. Resource adequacy concerns are not anticipated.
- The Bipole III high voltage direct current transmission line was placed in service in 2018, providing increased redundancy in transmission capacity. The line connects generation in northern Manitoba with the majority of Manitoba's load in southern Manitoba.
- There are no changes to the assessment area's winter prepared programs.

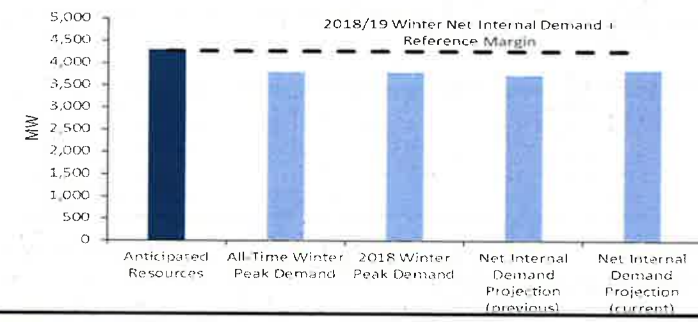
MRO-SaskPower

Saskatchewan is a province of Canada and comprises a geographic area of 651,900 square kilometers (251,700 square miles) with approximately 1.1 million people. Peak demand is experienced in the winter. The Saskatchewan Power Corporation (SaskPower) is the Planning Coordinator and Reliability Coordinator for the province of Saskatchewan and is the principal supplier of electricity in the province. SaskPower is a provincial crown corporation and, under provincial legislation, is responsible for the reliability oversight of the Saskatchewan BPS and its interconnections.

Existing On-Peak Generation

Generation Type	Percent
Biomass	<1%
Coal	36%
Hydro	20%
Natural Gas	43%
Wind	1%

Winter Resource and Demand Summary



MRO - SaskPower Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	3,726	3,843	3.1%
Demand Response: Available	85	85	0.0%
Net Internal Demand	3,641	3,758	3.2%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	4,279	4,266	-0.3%
Tier 1 Planned Capacity	0	0	-
Net Firm Capacity Transfers	25	25	0.0%
Anticipated Resources	4,304	4,291	-0.3%
Existing-Other Capacity	0	0	0.0%
Prospective Resources	4,304	4,291	-0.3%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	18.2%	14.2%	-4.0
Prospective Reserve Margin	18.2%	14.2%	-4.0
Reference Margin Level	11.0%	11.0%	0.0

Highlights

- SaskPower anticipates that it will maintain system reliability during the upcoming season.
- There are no known operational challenges anticipated for the upcoming season.
- There are no emerging reliability issues anticipated that will affect resource adequacy for the upcoming season.
- There are no changes to winter preparedness programs.

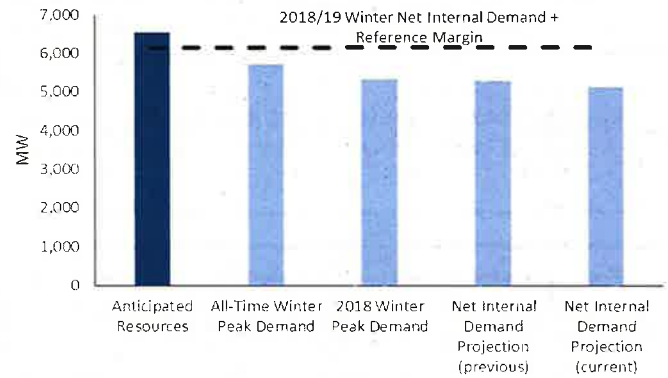
NPCC-Maritimes

The Maritimes assessment area is a winter-peaking NPCC subregion that contains two Balancing Authorities. It is comprised of the Canadian provinces of New Brunswick, Nova Scotia, and Prince Edward Island, and the northern portion of Maine, which is radially connected to the New Brunswick power system. The area covers 58,000 square miles with a total population of 1.9 million people.

Existing On-Peak Generation

Generation Type	Percent
Biomass	3%
Coal	25%
Hydro	19%
Natural Gas	13%
Nuclear	10%
Petroleum	28%
Wind	2%

Winter Resource and Demand Summary



NPCC - Maritimes Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	5,555	5,387	-3.0%
Demand Response: Available	263	253	-3.8%
Net Internal Demand	5,292	5,134	-3.0%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	6,676	6,560	-1.7%
Tier 1 Planned Capacity	8	0	-
Net Firm Capacity Transfers	0	0	0.0%
Anticipated Resources	6,684	6,560	-1.9%
Existing-Other Capacity	20	0	-100.0%
Prospective Resources	6,704	6,560	-2.1%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	26.3%	27.8%	1.5
Prospective Reserve Margin	26.7%	27.8%	1.1
Reference Margin Level	20.0%	20.0%	0.0

Highlights

- The Maritimes area anticipates system reliability will be maintained during the upcoming season.
- Maritimes is a winter-peaking system with few planned transmission or generator outages. Operators are equipped with procedures and mitigations to address unplanned outages and maintain system reliability.

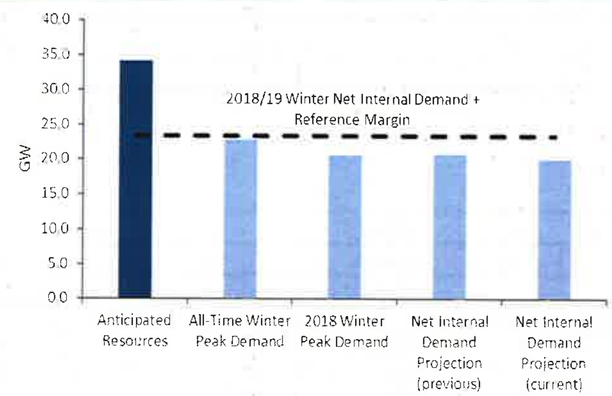
NPCC-New England

ISO New England (ISO-NE) Inc. is a regional transmission organization that serves Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. It is responsible for the reliable day-to-day operation of New England's bulk power generation and transmission system, and it also administers the area's wholesale electricity markets and manages the comprehensive planning of the regional BPS. The New England regional electric power system serves approximately 14.5 million people over 68,000 square miles.

Existing On-Peak Generation

Generation Type	Percent
Biomass	3%
Coal	3%
Hydro	5%
Natural Gas	50%
Nuclear	12%
Petroleum	21%
Pumped Storage	5%
Solar	<1%
Wind	1%

Winter Resource and Demand Summary



NPCC - New England Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	21,197	20,357	-4.0%
Demand Response: Available	388	403	3.9%
Net Internal Demand	20,809	19,954	-4.1%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	31,540	32,939	4.4%
Tier 1 Planned Capacity	780	301	-
Net Firm Capacity Transfers	1,232	986	-20.0%
Anticipated Resources	33,551	34,226	2.0%
Existing-Other Capacity	210	204	-2.8%
Prospective Resources	33,790	34,437	1.9%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	61.2%	71.5%	10.3
Prospective Reserve Margin	62.4%	72.6%	10.2
Reference Margin Level	16.6%	17.2%	0.6

Highlights

- ISO-NE expects to meet its regional resource adequacy requirements this 2018/2019 winter period; however, a growing concern is whether there will be sufficient energy available to satisfy electricity demand during an extended cold spell given the evolving resource mix and fuel delivery infrastructure.
- Since the previous winter, 1,650 MW of natural-gas-fired generation has been added, including an 850 MW dual-fueled unit.
- ISO-NE is implementing a periodic 21-day energy assessment, which will be published to provide market participants with early indication of potential fuel scarcity conditions and help inform fuel procurement decisions. ISO-NE continues to survey fossil fueled generators for fuel inventory data monthly and more frequently when warranted.
- Pay-for-performance market design is implemented for the upcoming winter to provide strong financial incentives for all suppliers of capacity to maximize availability during scarcity conditions.
- Despite having sufficient capacity resources, power system operations could become challenging during periods of cold weather if fuel constraints impact the ability of generators to obtain fuel to produce electricity.

NPCC-New York

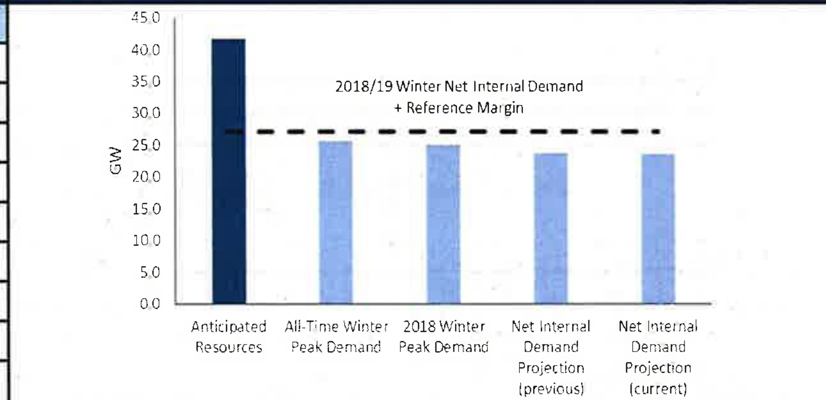
The New York Independent System Operator (NYISO) is the only Balancing Authority (NYBA) within the state of New York. NYISO is a single-state ISO that was formed as the successor to the New York Power Pool—a consortium of the eight IOUs—in 1999. NYISO manages the New York State transmission grid encompassing approximately 11,000 miles of transmission lines, over 47,000 square miles, and serving the electric needs of 19.5 million people. New York experienced its all-time peak load of 33,956 MW in the summer of 2013.

** Wind, solar, and run-of-river hydro resource projected capacity for 2017/2018 WRA was based on nameplate resource capacity. To more accurately project winter resource capacity, variable generation resources have been derated for the 2018/2019 WRA based on NYISO's unforced capacity values. This change in reporting for the 2018/2019 WRA results in a lower capacity value for a similar resource mix.*

***Changed per NERC assessment default level of 15 percent used in the NERC 2017 Long-Term Reliability Assessment*

Existing On-Peak Generation	
Generation Type	**Percent**
Biomass	<1%
Coal	3%
Hydro	10%
Natural Gas	45%
Nuclear	14%
Petroleum	23%
Pumped Storage	4%
Solar	<1%
Wind	1%

Winter Resource and Demand Summary



NPCC - New York Resource Adequacy Data			
Demand, Resource, and Reserve Margins	**2017/2018 WRA**	**2018/2019 WRA**	**2017/2018 vs. 2018/2019 WRA**
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	24,365	24,269	-0.4%
Demand Response: Available	625	637	1.9%
Net Internal Demand	23,740	23,632	-0.5%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	41,257*	39,861*	-3.4%*
Tier 1 Planned Capacity	106	0	-
Net Firm Capacity Transfers	2,311	1,519	-34.3%
Anticipated Resources	43,674	41,380*	-5.3%*
Existing-Other Capacity	0	0	0.0%
Prospective Resources	44,190	41,596*	-5.9%*
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	84.0%	75.1%*	-8.9*
Prospective Reserve Margin	86.1%	76.0%*	-10.1*
Reference Margin Level	18.0%	15.0%	N/A**

Highlights

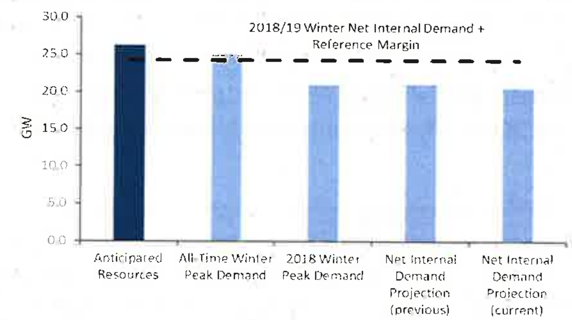
- As New York is a summer-peaking area, it does not anticipate any emerging reliability issues during the 2018/2019 winter assessment period and is projecting adequate surplus capacity margins above its operating reserve requirements.
- Seasonal generator fuel surveys indicate oil-burning units have sufficient start-of-winter inventories and arrangements for replacement fuel. Emergency communication protocol is in place to communicate electric reliability concerns to pipelines and natural gas operators during tight electric operating conditions.
- New York's winter preparedness programs have been effective in ensuring reliable operation of the BPS during cold weather months.

NPCC-Ontario

The Independent Electricity System Operator (IESO) is the Balancing Authority and Reliability Coordinator for the province of Ontario. In addition to administering the area's wholesale electricity markets, the IESO plans for Ontario's future energy needs. Ontario covers more than 415,000 square miles and has a population of over 14 million people. Ontario is interconnected electrically with Québec, MRO-Manitoba, states in MISO (Minnesota and Michigan), and NPCC-New York.

Existing On-Peak Generation	
Generation Type	**Percent**
Biomass	2%
Hydro	25%
Natural Gas/Petroleum	24%
Nuclear	43%
Solar	<1%
Wind	6%

Winter Resource and Demand Summary



NPCC - Ontario Resource Adequacy Data			
Demand, Resource, and Reserve Margins	**2017/2018 WRA**	**2018/2019 WRA**	**2017/2018 vs. 2018/2019 WRA**
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	21,761	21,334	-2.0%
Demand Response: Available	752	795	5.7%
Net Internal Demand	21,009	20,539	-2.2%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	27,068	27,666	2.2%
Tier 1 Planned Capacity	22	40	-
Net Firm Capacity Transfers	-500	-500	0.0%
Anticipated Resources	26,590	27,206	2.3%
Existing-Other Capacity	0	0	0.0%
Prospective Resources	26,590	27,206	2.3%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	33.4%	32.0%	-1.4
Prospective Reserve Margin	33.4%	32.0%	-1.4
Reference Margin Level	19.4%	18.4%	-1.0

Highlights

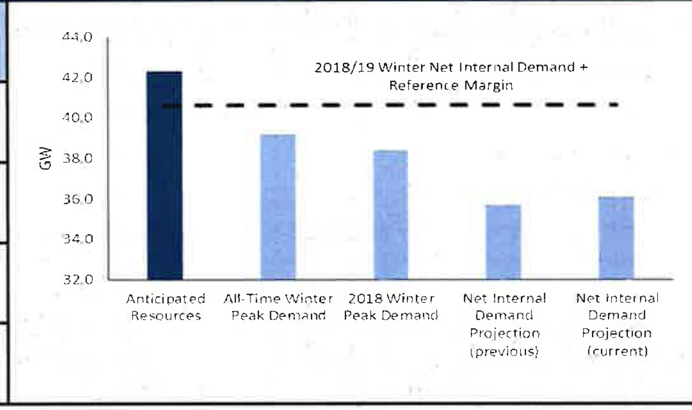
- IESO anticipates that it will maintain reliability on its system during the upcoming season.
- Import and export may be reduced between New York and Ontario due to long-term interconnection equipment outage at the St. Lawrence Transmission Station. Efforts are underway to manage this outage and to consider longer-term solutions. The in-service date for the Napanee Generating Station (985 MW) is delayed to after this winter period.
- The IESO is enhancing its planning reports and processes to give market participants greater transparency and to provide longer-term certainty on outage requests.
- No changes are anticipated to the IESO's Seasonal (Unit) Readiness Program.

NPCC-Québec

The Québec assessment area (Province of Québec) is a winter-peaking NPCC subregion that covers 595,391 square miles with a population of eight million. Québec is one of the four NERC interconnections in North America, with ties to Ontario, New York, New England, and the Maritimes, consisting of either HVDC ties, radial generation, or load to and from neighboring systems.

Existing On-Peak Generation	
Generation Type	**Percent**
Biomass	<1%
Hydro	96%
Petroleum	1.0%
Wind	3%

Winter Resource and Demand Summary



NPCC - Québec Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	37,921	38,461	1.4%
Demand Response: Available	2,248	2,354	4.7%
Net Internal Demand	35,673	36,107	1.2%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	41,340	42,046	1.7%
Tier 1 Planned Capacity	541	0	-
Net Firm Capacity Transfers	-330	299	190.6%
Anticipated Resources	41,551	42,345	1.9%
Existing-Other Capacity	0	0	0.0%
Prospective Resources	42,651	43,445	1.9%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	16.5%	17.3%	0.8
Prospective Reserve Margin	19.6%	20.3%	0.7
Reference Margin Level	12.5%	12.6%	0.1

Highlights

- Québec predicts that it will maintain system resource adequacy this winter.
- The Québec area is a winter-peaking system with predominately hydroelectric generation resources. Adequate capacity margins above its reference reserve requirements are projected for the 2018/2019 winter assessment period.
- No changes have been made to the assessment area's winter preparedness programs.
- Delays to a new 735 kV line planned for 2018 are not expected to impact reliability during the upcoming winter season. A temporary remedial action scheme is implemented to prevent potential voltage issues that could arise during specific events.

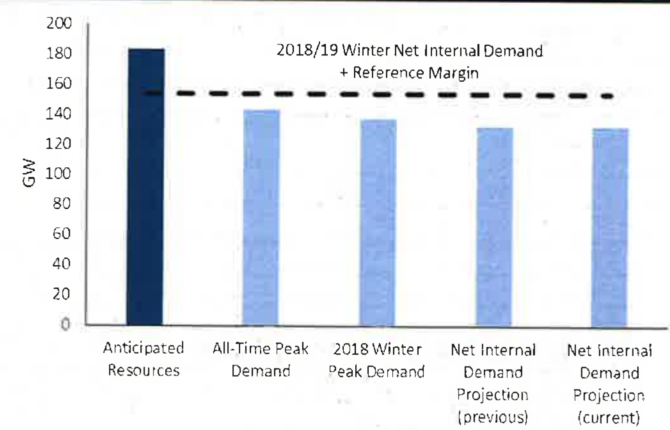
PJM

PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia. PJM serves 61 million people and covers 243,417 square miles. PJM is a Balancing Authority, Planning Coordinator, Transmission Planner, Resource Planner, Interchange Authority, Transmission Operator, Transmission Service Provider, and Reliability Coordinator.

Existing On-Peak Generation

Generation Type	Percent
Biomass	1%
Coal	30%
Hydro	2%
Natural Gas	39%
Nuclear	18%
Petroleum	7%
Pumped Storage	3%
Solar	<1%
Wind	<1%

Winter Resource and Demand Summary



PJM Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	132,652	132,357	-0.2%
Demand Response: Available	355	1,331	274.9%
Net Internal Demand	132,297	131,026	-1.0%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	179,768	181,864	1.2%
Tier 1 Planned Capacity	0	0	-
Net Firm Capacity Transfers	4,304	1,535	-64.3%
Anticipated Resources	184,072	183,399	-0.4%
Existing-Other Capacity	350	0	-100%
Prospective Resources	184,422	183,399	-0.6%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	39.1%	40.0%	0.9
Prospective Reserve Margin	39.4%	40.0%	0.6
Reference Margin Level	16.6%	16.1%	-0.5

Highlights

- PJM anticipates that it will maintain system reliability during the upcoming season.
- PJM has no emerging reliability issues.
- The PJM capacity performance initiative provides resource performance requirements in the PJM energy market with very limited allowances for nonperformance or not producing when called upon. Nonperformance charges during peak-load hours can amount to significant financial penalties to generators. Opportunity for increased capacity market revenues, such as payments for dual-fuel capability and firm fuel service, are also part of the initiative.

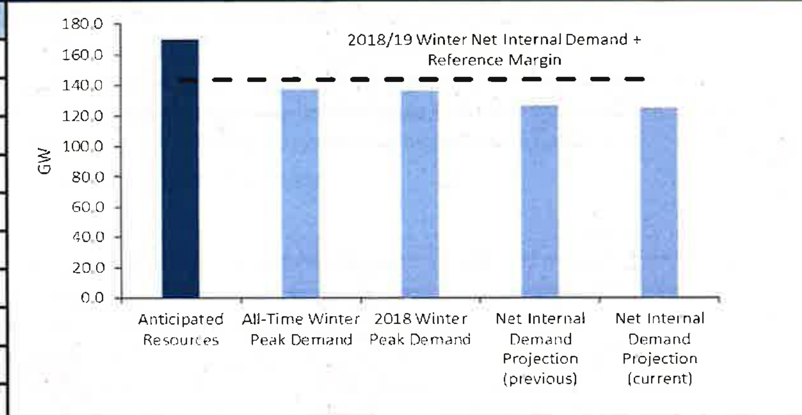
SERC

SERC's assessment areas are traditionally summer-peaking and cover approximately 72,000 circuit miles and serve a population estimated at 23 million. For NERC's assessment, the Region is divided into three assessment areas: SERC- E, SERC-N, and SERC-SE. The assessment areas include 12 Balancing Authorities: Cube Hydro Carolinas LLC, Associated Electric Cooperative, Inc. (AECI), Duke Energy Carolinas (DEC), Duke Energy Progress (DEP), Electric Energy, Inc. (EEI), LG&E and KU Services Company (as agent for Louisville Gas and Electric and Kentucky Utilities (LG&E/KU)), PowerSouth Energy Cooperative (PowerSouth), South Carolina Electric & Gas Company (SCE&G), South Carolina Public Service Authority (SCPSA), Southern Company Services, Inc. (SOCO), Southeastern Power Administration (SPA), and Tennessee Valley Authority (TVA).

Existing On-Peak Generation

Generation Type	Percent
Biomass	<1%
Coal	31%
Hydro	6%
Natural Gas	42%
Nuclear	15%
Other	<1%
Petroleum	2%
Pumped Storage	4%
Solar	<1%
Wind	<1%

Winter Resource and Demand Summary



SERC Resource Adequacy Data

Demand, Resource, and Reserve Margins	SERC-E	SERC-N	SERC-SE	2017/2018 WRA SERC Total	2018/2019 WRA SERC Total	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Megawatts (MW)**	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	43,284	41,274	45,042	131,045	129,600	-1.1%
Demand Response: Available	942	1,663	2,111	4,727	4,716	-0.2%
Net Internal Demand	42,342	39,611	42,931	126,318	124,884	-1.1%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Megawatts (MW)**	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	53,992	54,055	64,162	162,958	172,209	5.7%
Tier 1 Planned Capacity	0	0	40	2,142	40	-
Net Firm Capacity Transfers	184	-1,099	-1,445	-2,898	-2,360	-18.6%
Anticipated Resources	54,176	52,955	62,758	162,203	169,889	4.7%
Existing-Other Capacity	42	1,242	924	1,953	2,208	13.1%
Prospective Resources	54,218	54,197	63,782	164,155	172,197	4.9%
Planning Reserve Margins	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	28.0%	33.7%	46.2%	28.4%	36.0%	7.6
Prospective Reserve Margin	28.1%	36.8%	48.6%	30.0%	37.9%	7.9
Reference Margin Level	15.0%	15.0%	15.0%	15.0%	15.0%	0.0

Highlights

- SERC anticipates that current resources are adequate to meet the peak winter demand for the Region.
- Entities in SERC-E are currently assessing the impact on the BPS from Hurricane Florence and Hurricane Michael. However, impacts are not expected to threaten reliability for the upcoming winter period.
- Parts of SERC experienced stressed transmission system conditions during the peak of the 2017/2018 winter season due to transfers from the mid-west region of MISO to the southern region of MISO. SERC established a task force to analyze the impact and support coordinated actions to address issues in the future.
- SERC is developing a *Cold Weather Preparedness Guideline* to provide pre-season checklists, emergency plans, communications, and protocols.

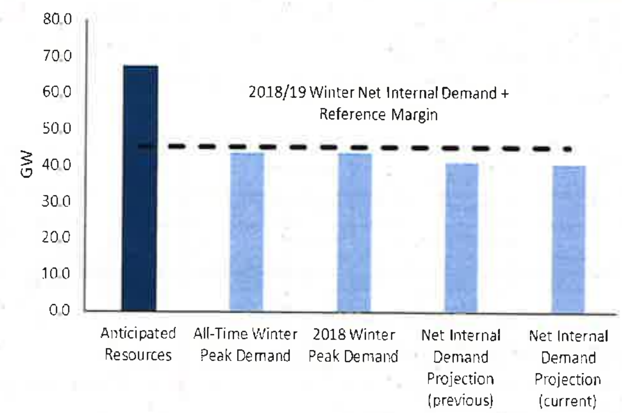
SPP

Southwest Power Pool (SPP) Planning Coordinator footprint covers 575,000 square miles and encompasses all or parts of Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas and Wyoming. The SPP long-term assessment is reported based on the Planning Coordinator footprint, which touches parts of the Midwest Reliability Organization Regional Entity, and Western Electricity Coordinating Council. The SPP assessment area footprint has approximately 61,000 miles of transmission lines, 756 generating plants, and 4,811 transmission-class substations, and it serves a population of 18 million people.

Existing On-Peak Generation

Generation Type	Percent
Biomass	<1%
Coal	35%
Hydro	7%
Natural Gas	49%
Nuclear	3%
Other	<1%
Petroleum	3%
Pumped Storage	<1%
Solar	<1%
Wind	3%

Winter Resource and Demand Summary



SPP Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	41,215	40,510	-1.7%
Demand Response: Available	432	432	0.0%
Net Internal Demand	40,783	40,078	-1.7%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	67,263	67,767	0.7%
Tier 1 Planned Capacity	863	5	-
Net Firm Capacity Transfers	-330	-330	0.0%
Anticipated Resources	67,796	67,442	-0.5%
Existing-Other Capacity	100	100	0.0%
Prospective Resources	68,163	67,542	-0.9%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	66.2%	68.3%	2.1
Prospective Reserve Margin	67.1%	68.5%	1.4
Reference Margin Level	12.0%	12.0%	0.0

Highlights

- SPP anticipates planning reserves are adequate for the upcoming winter season.
- SPP is working with Midcontinent ISO and other neighbors to address potential electric deliverability issues associated with extreme weather events, such as those observed during the January 2018 cold snap when transfers from north to south were in excess of levels agreed upon by entities. Efforts are aimed at enhancing communications and operator preparedness.
- Since last winter season, a response team has been established for addressing load forecasting errors and to support operators with real-time decision making to ensure energy capacity adequacy.
- SPP hosted its winter preparedness workshop on October 2, 2018.

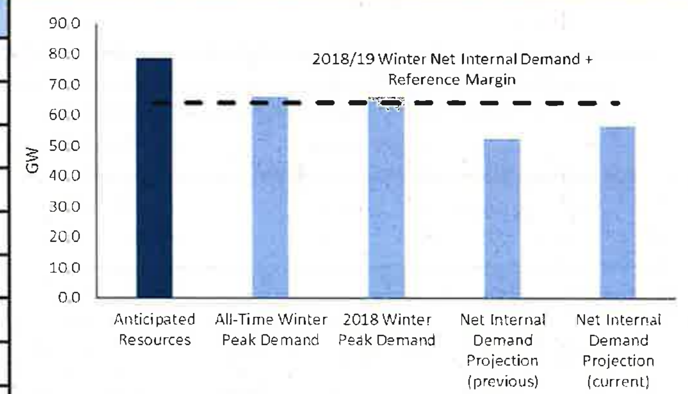
Texas RE-ERCOT

The Electric Reliability Council of Texas (ERCOT) is the ISO for the ERCOT Interconnection and is located entirely in the state of Texas; it operates as a single Balancing Authority. It also performs financial settlement for the competitive wholesale bulk-power market and administers retail switching for 7 million premises in competitive choice areas. ERCOT is governed by a board of directors and subject to oversight by the Public Utility Commission of Texas and the Texas Legislature. ERCOT is a summer-peaking Region that covers approximately 200,000 square miles, connects over 46,500 miles of transmission lines, has over 600 generation units, and serves 24 million customers. The Texas Reliability Entity (Texas RE) is responsible for the regional Reliability Entity (RE) functions described in the Energy Policy Act of 2005 for the ERCOT Region.

Existing On-Peak Generation

Generation Type	Percent
Biomass	<1%
Coal	24%
Hydro	<1%
Natural Gas	62%
Nuclear	6%
Solar	2%
Wind	6%
Biomass	<1%
Coal	24%

Winter Resource and Demand Summary



Texas RE-ERCOT Resource Adequacy Data

Demand, Resource, and Reserve Margins	2017/2018 WRA	2018/2019 WRA	2017/2018 vs. 2018/2019 WRA
Demand Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Total Internal Demand (50/50)	55,003	58,229	5.9%
Demand Response: Available	2,494	1,912	-23.3%
Net Internal Demand	52,509	56,317	7.3%
Resource Projections	**Megawatts (MW)**	**Megawatts (MW)**	**Net Change (%)**
Existing-Certain Capacity	82,139	77,628	-5.5%
Tier 1 Planned Capacity	1,214	762	-
Net Firm Capacity Transfers	804	346	-57.0%
Anticipated Resources	84,157	78,735	-6.4%
Existing-Other Capacity	0	840	-
Prospective Resources	84,269	79,921	-5.2%
Reserve Margins	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	60.2%	39.8%	-20.4
Prospective Reserve Margin	60.5%	41.9%	-18.6
Reference Margin Level	13.8%	13.8%	0.0

Highlights

- ERCOT currently does not expect any emerging reliability issues for the upcoming winter season. Despite a lower Planning Reserve Margin due to coal unit retirements and delays in planned natural-gas-fired combined-cycle projects, there is sufficient resource capacity to meet demand requirements for the winter season.
- Based on its own preliminary seasonal assessment, ERCOT expects to have sufficient operating reserves under expected system conditions as well as a scenario that assumes extreme peak load conditions with associated natural gas curtailment-related unit outages/deratings in North Texas.
- There are no changes to the ERCOT winter preparedness program. The Winter Weatherization Workshop was held September 6, 2018. Spot checks of conventional generation are conducted throughout winter.
- Natural-gas-fired generation was added in 2018, totaling 615 MW (winter rating). Generation retirements announced in late 2017 took affect totaling over 4,000 MW.
- Enhanced forecasting for wind generation mitigates icing risks and improves planning studies.

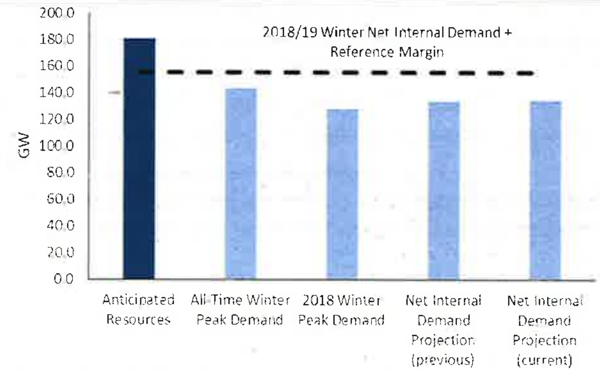
WECC

WECC is responsible for coordinating and promoting BES reliability in the Western Interconnection. WECC's 329 members, which include 38 Balancing Authorities, represent a wide spectrum of organizations with an interest in the BES. Serving an area of nearly 1.8 million square miles and more than 82 million people, WECC is geographically the largest and most diverse of the NERC Regional Entities. WECC's service territory extends from Canada to Mexico. It includes the provinces of Alberta and British Columbia in Canada, the northern portion of Baja California in Mexico, and all or portions of the 14 western states in between. The WECC assessment area is divided into five subregions: Rocky Mountain Reserve Group (RMRG), Southwest Reserve Sharing Group (SRSG), California/Mexico (CA/MX), and the Northwest Power Pool (NWPP), which is further divided into the NW-Canada and NW-US areas. These subregional divisions are used for this study as they are structured around reserve sharing groups that have similar annual demand patterns and similar operating practices.

Existing On-Peak Generation

Generation Type	Percent
Biomass	1%
Coal	17%
Hydro	22%
Natural Gas	47%
Nuclear	4%
Other	3%
Petroleum	<1%
Pumped Storage	2%
Solar	2%
Wind	2%

Winter Resource and Demand Summary



WECC Resource Adequacy Data

Demand, Resource, and Reserve Margins	WECC AB	WECC BC	CA/MX	NWPP US	RMRG	SRSG	2017/2018 WRA WECC Total	2018/2019 WRA WECC Total	2017/2018 vs. 2018/2019 WRA
Demand Projections	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**Net Change (%)**
Total Internal Demand (50/50)	11,737	11,374	39,542	47,644	10,207	15,647	134,387	136,151	1.3%
Demand Response: Available	0	0	815	307	295	144	1,803	1,561	-13.5%
Net Internal Demand	11,737	11,374	38,727	47,337	9,912	15,503	133,498	134,590	1.5%
Resource Projections	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**Net Change (%)**
Existing-Certain Capacity	15,091	13,206	52,121	58,631	15,342	29,020	182,716	183,411	0.4%
Tier 1 Planned Capacity	43	381	1,569	5	232	1,072	887	3,302	-
Net Firm Capacity Transfers	0	0	0	700	0	0	1,486	700	-52.9%
Anticipated Resources	15,134	13,587	53,690	59,337	15,574	30,092	185,089	187,414	1.3%
Existing-Other Capacity	0	0	0	0	0	0	0	0	0.0%
Prospective Resources	15,149	13,587	57,442	59,337	15,574	30,714	185,089	191,803	3.6%
Planning Reserve Margins	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Annual Difference**
Anticipated Reserve Margin	28.9%	19.5%	38.6%	25.4%	57.1%	94.1%	38.6%	43.9%	5.3
Prospective Reserve Margin	29.1%	19.5%	48.3%	25.4%	57.1%	98.1%	38.6%	46.3%	7.7
Reference Margin Level	10.4%	10.4%	12.4%	19.7%	16.8%	15.1%	15.4%	14.1%	-1.3

Highlights

- WECC anticipates that its six assessment areas and all zones within them will exceed their reference reserve margins and maintain resource adequacy through the 2018/2019 winter season.
- Winterization techniques are implemented throughout the freezing zones to mitigate against severe weather conditions or unexpected equipment failure. National Weather Service models predict mild winter conditions throughout the WECC footprint. A potential El Nino pattern could affect precipitation amounts, bringing above average precipitation in the south and below average precipitation in the north.
- The Aliso Canyon natural gas storage facility has higher storage capacity compared to last winter. However, natural gas infrastructure outages and reduced capacity on key natural gas transmission pipelines continue. Mitigation measures from prior winter seasons remain in place at CAISO and SoCalGas (See NERC 2017/18 WRA).

Data Concepts and Assumptions

The table below explains data concepts and important assumptions used throughout this assessment.

General Assumptions

- Reliability of the interconnected BPS is comprised of both adequacy and operating reliability.
  - Adequacy is the ability of the electric system to supply the aggregate electric power and energy requirements of the electricity consumers at all times taking into account scheduled and reasonably expected unscheduled outages of system components.
  - Operating reliability is the ability of the electric system to withstand sudden disturbances such as electric short-circuits or unanticipated loss of system components.
- The reserve margin calculation is an important industry planning metric used to examine future resource adequacy.
- All data in this assessment is based on existing federal, state, and provincial laws and regulations.
- Differences in data collection periods for each assessment area should be considered when comparing demand and capacity data between year-to-year seasonal assessments.
- *2018 Long-Term Reliability Assessment* (LTRA) data has been used for this 2018/2019 winter assessment period.
- A positive net transfer capability would indicate a net importing assessment area; a negative value would indicate a net exporter.

Demand Assumptions

- Electricity demand projection, or load forecasts are provided by each assessment area.
- Load forecasts include peak hourly load,[5] or total internal demand, for the summer and winter of each year.[6]
- Total internal demand projections are based on normal weather (50/50 distribution)[7] and are provided on a coincident[8] basis for most assessment areas.
- Net internal demand, used in all reserve margin calculations, is equal to total internal demand, reduced by the amount of controllable and dispatchable demand response projected to be available during the peak hour.

Resource Assumptions

- Resource planning methods vary throughout the North American BPS. NERC uses the following categories to provide a consistent approach for collecting and presenting resource adequacy:

Anticipated Resources:

- **Existing-Certain Capacity**: Included in this category are commercially operable generating units, or portions of generating units, that meet at least one of the following requirements when examining the period of peak demand for the winter season: unit must have a firm capability and a power purchase agreement (PPA) with firm

[5] *Glossary of Terms* Used in NERC Reliability Standards

[6] The summer season represents June–September and the winter season represents December–February.

[7] Essentially, this means that there is a 50 percent probability that actual demand will be higher and a 50 percent probability that actual demand will be lower than the value provided for a given season/year.

[8] Coincident: The sum of two or more peak loads that occur in the same hour. Noncoincident: The sum of two or more peak loads on individual systems that do not occur in the same time interval. Meaningful only when considering loads within a limited period of time, such as a day, a week, a month, a heating or cooling season, and usually for not more than one year. SERC and FRCC calculate total internal demand on a noncoincidental basis.

transmission that must be in effect for the unit; unit must be classified as a designated network resource; and/or where energy-only markets exist, unit must be a designated market resource eligible to bid into the market.

- **Tier 1 Capacity Additions**: includes capacity that either is under construction or has received approved planning requirements.
- **Net Firm Capacity Transfers (Imports minus Exports)**: transfers with firm contracts.

Prospective Resources: Includes all anticipated resources, plus the following:

- **Existing-Other Capacity**: included in this category are commercially operable generating units, or portions of generating units, that could be available to serve load for the period of peak demand for the summer or winter season but do not meet the requirements of existing-certain.

Reserve Margin Definitions

Reserve Margins: the primary metric used to measure resource adequacy; it is defined as the difference in resources (anticipated or prospective) and net internal demand with the difference divided by net internal demand, shown as a percentile.

$$\textbf{Anticipated Reserve Margin} = \frac{\text{(Anticipated Resources – Net Internal Demand)}}{\text{Net Internal Demand}}$$

$$\textbf{Prospective Reserve Margin} = \frac{\text{(Prospective Resources – Net Internal Demand)}}{\text{Net Internal Demand}}$$

Reference Margin Level: the assumptions of this metric vary by assessment area. The Reference Margin Level is typically based on load, generation, and transmission characteristics for each assessment area and, in some cases, the Reference Margin Level is a requirement implemented by the respective state(s), provincial authorities, ISO/RTO, or other regulatory bodies. If such a requirement exists, the respective assessment area generally adopts this requirement as the Reference Margin Level. In some cases, the Reference Margin Level will fluctuate over the duration of the assessment period, or may be different for the summer and winter seasons. If one is not provided by a given assessment area, NERC applies a 15 percent Reference Margin Level for predominantly thermal systems and 10 percent for predominantly hydro systems.

On-Peak Expected Capacity Generation Mix: generation mix is aggregated from *2018 LTRA* data. Fuel types with nominal quantities were aggregated together as fuel types, renewables, other renewables, or other fuels.

Renewable Nameplate Capacities: these charts include renewable on peak and nameplate (de-rated and expected on peak added together) capacities.