UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Grid Resilience in Regional Transmission Organizations and Independent System Operators	))))	Docket No. AD18-7-000

REPLY COMMENTS OF THE
NEW ENGLAND STATES COMMITTEE ON ELECTRICITY

The New England States Committee on Electricity ("NESCOE") files these reply comments pursuant to the Federal Energy Regulatory Commission's ("FERC" or "Commission") January 8, 2018 order in the above-referenced proceeding ("Resilience Order")[1] and the Commission's March 20, 2018 Order Extending Time for Comments ("March 20 Order").[2] The Resilience Order required each independent system operator ("ISO") and regional transmission organization ("RTO") to file responses with the Commission focusing on how they evaluate and address resilience risks in their respective regions.[3] NESCOE appreciates the opportunity to provide these comments.

I. DESCRIPTION OF COMMENTER

NESCOE is the Regional State Committee for New England. It is governed by a board of managers appointed by the Governors of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont and is funded through a regional tariff that ISO New

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1 *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,012 (2018). The Resilience Order terminated a proceeding that the Secretary of the Department of Energy ("DOE") initiated pursuant to section 403 of the Department of Energy Organization Act. *See Grid Reliability and Resilience Pricing*, 82 Fed. Reg. 46,940 (2017) (the "DOE Proposed Rule").

2 *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,256 (2018).

3 Resilience Order at PP 1, 18. These responses are collectively referred to herein as the "ISO/RTO Responses."

England Inc. ("ISO-NE") administers.[4] NESCOE's mission is to represent the interests of the citizens of the New England region by advancing policies that will provide electricity at the lowest possible price over the long term, consistent with maintaining reliable service and environmental quality. These comments represent the collective view of the six New England states.

II. BACKGROUND

A. The Resilience Order

The Resilience Order established a proceeding "to enable [the Commission] to examine holistically the resilience of the bulk power system."[5] Through the proceeding, the Commission seeks: "(1) to develop a common understanding among the Commission, industry, and others of what resilience of the bulk power system means and requires; (2) to understand how each RTO and ISO assesses resilience in its geographic footprint; and (3) to use this information to evaluate whether additional Commission action regarding resilience is appropriate at this time."[6]

The ISO/RTO Responses must address specific issues and questions regarding resilience that are set forth in the Resilience Order.[7] Interested parties have an opportunity to submit reply comments to the ISO/RTO Responses.[8] The March 20 Order stated that the Commission's consideration of resilience issues "will benefit from a robust record and as much relevant information and thoughtful input as possible" and that, while the Resilience Order "characterized the comments from interested entities as 'reply' comments, we appreciate that interested entities

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4 *ISO New England Inc.*, 121 FERC ¶ 61,105 (2007).

5 Resilience Order at P 1.

6 *Id.* at P 18.

7 *Id.*

8 *Id.* at P 19.

may not only want to respond directly to the express content of the RTOs/ISOs' submissions, but also to provide their own independent perspectives and recommendations with regard to grid resilience."[9]

B. ISO-NE's Response

On March 9, 2018, ISO-NE provided its response to the Resilience Order (the "ISO-NE Response"). ISO-NE identified "fuel security" as the primary challenge to the resilience of New England's power system.[10] ISO-NE described fuel security as "the assurance that power plants will have or be able to obtain the fuel they need to run, particularly in winter" or during periods of stressed conditions.[11]

The ISO-NE Response characterized fuel security as a risk relating to electric power generation and not the transmission system.[12] ISO-NE also discussed how this risk is heightened by the region's significant shift toward natural-gas fired generation, noting that "[s]imilar concerns exist when there is heavy dependence on other resources."[13]

The ISO-NE Response included as an attachment ISO-NE's January 17, 2018 Operational Fuel-Security Analysis (the "Fuel Security Analysis"). ISO-NE sponsored this analysis "to quantify the fuel-security risk, and to frame regional discussions on addressing it."[14] The Fuel Security Analysis examined 23 "hypothetical power system combinations"—scenarios with different resources and fuels on the system and assumed outages of "key energy facilities"—and produced a deterministic analysis to be "viewed as proxies for possible market

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9 March 20 Order at P 3.

10 *See* ISO-NE Response at 1, 4, 6, 50.

11 *Id.* at 1, 4, 50.

12 *Id.* at 50.

13 *Id.* *See id.* at 4-8.

14 *Id.* at 1. *See id.* at 8.

and policy responses in a fuel constrained system."[15] ISO-NE stated that the Fuel Security Analysis results "suggest that New England's limited fuel-delivery infrastructure will eventually cause severe reliability issues if fuel security is not addressed" and that the analysis illustrated "that the impacts of the current industry trends affecting the New England power system are moving in a negative direction, leading to a greater fuel security risk."[16]

What the Fuel Security Analysis is *not* is also important: it is not an investment decisional framework upon which to base consumer investments in certain resources. The underlying model is new and untested. ISO-NE constructed it without input by states or market participants, and ISO-NE did not initially express an intent to use the analysis to establish criteria for, or to base decisions regarding, specific resource retention or to identify cost-effective solutions to future reliability challenges. It should therefore be viewed for what it is—a high-level, directional, and not predictive look at hypothetical futures based on a set of assumptions that ISO-NE identified internally.

The ISO-NE Response recognized that the region's "fuel-security challenges do not lend themselves to easy solutions."[17] ISO-NE discussed how stakeholders are already engaged in discussing the Fuel Security Analysis and the risks ISO-NE has identified, and ISO-NE provided the Commission with an anticipated timetable, beginning this year, for regional discussions of potential long-term solutions.[18] ISO-NE stated that "[s]ome mitigation solutions may be outside the scope of ISO-NE's jurisdiction and may need to be addressed by other appropriate entities."[19]

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[15] *Id.* at 9, 29. ISO-NE stated that "[w]hile the study did not explicitly consider specific market responses, ISO-NE assumed that prices in each scenario would sustain the inputs to that scenario." *Id.* at 9.

[16] *Id.* at 10.

[17] *Id.* at 12.

[18] *Id.* at 2, 12.

[19] *Id.* at 49.

With respect to these solutions, ISO-NE stated that "it will be up to Market Participants and state officials to take actions to secure forward fuel arrangements and bolster supply- or demand-side infrastructure to resolve the fundamental causes of fuel-delivery constraints."[20] More specifically, ISO-NE identified as potential investments "enhancements to natural gas infrastructure or the supply chains for LNG and oil; relaxation of rules to facilitate permitting and operation of dual-fuel resources; investments in even more renewables and the transmission needed to deliver it; or further measures to significantly reduce demand on the power system or the gas system."[21] ISO-NE also assured the Commission that it would take more immediate steps to address fuel security challenges if necessary.[22]

The ISO-NE Response underscored the unique resilience challenges that each region experiences and the need for individual ISOs/RTOs "to determine what, if any, assessments are needed in light of the type of resilience threats faced there."[23] ISO-NE asked that, if the Commission issues further directives on resilience, "that ISO-NE be afforded time to continue working with stakeholders, and be extended flexibility to permit the development of solutions that meet the unique fuel-security challenges facing the region, and are consistent with New England markets."[24]

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[20] *Id.* at 61.

[21] *Id.*

[22] *Id.* at 2, 12. *See also id.* at 49 ("[R]egardless of the probability, system operators need to be able to respond to prevent uncontrolled load shedding and cascading outages.").

[23] *Id.* at 44. *See id.* at 12.

[24] *Id.* at 12.

C. Other ISO/RTO Responses

The ISO/RTO Responses from regions outside New England identified some risks to resilience that appear to be broadly experienced across ISOs/RTOs (e.g., weather)[25] and others that are related to specific conditions and challenges unique to their power systems and markets.[26] PJM noted that the "degree of risk" associated with events and threats to resilience varies among regions.[27]

None of the other ISO/RTO Responses appear to characterize resilience as an acute or imminent risk in their regions at the present time.[28] Like ISO-NE, a number of ISOs/RTOs underscored the need for regional flexibility in developing any solutions to resilience challenges.[29] PJM asked the Commission to initiate a series of additional processes and take

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[25] *See, e.g.,* Comments of Southwest Power Pool, Inc. ("SPP") on Grid Resilience Issues, *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000 (filed Mar. 9, 2018) ("SPP Response"), at 4; Responses of the Midcontinent Independent System Operator, Inc. ("MISO"), *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000 (filed Mar. 9, 2018) ("MISO Response"), at 12; Comments and Responses of PJM Interconnection, L.L.C. ("PJM"), *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000 (filed Mar. 9, 2018) ("PJM Response"), at 13.

[26] *See, e.g.,* Comments of the California Independent System Operator Corp. in Response to the Commission's Request for Comments About System Resiliency and Threats to Resilience, *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000 (filed Mar. 9, 2018) ("CAISO Response"), at 12 (listing as resilience threats "closures of key facilities" specific to California as well as, *inter alia*, the state's evolving resource mix); MISO Response at 14 (identifying as potential resilience risk evolving resource and technological changes and highlighting critical importance of "MISO's continued markets structure, which co-optimizes energy and ancillary services" in addressing this challenge).

[27] PJM Response at 13.

[28] *See, e.g.,* MISO Response at 2, 11-12 (stating that although some events present "credible threats to resilience, MISO does not have any imminent or immediate resilience concerns."); PJM Response at 4 (stating that the PJM power system "is safe and reliable today" though asserting that "improvements can and should be made to make the [Bulk Electric System] more resilient against known and potential vulnerabilities and threats."); SPP Response at 18 ("SPP believes the current [North American Electric Reliability Corporation ("NERC")] construct for continually monitoring and enhancing the NERC reliability standards is sufficient to address current and future needs with regards to enhancing resilience for the [Bulk Power System ("BPS")]."); Joint Comments of the Electric Reliability Council of Texas, Inc. and the Public Utility Commission of Texas, *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000 (filed Mar. 9, 2018) ("ERCOT Response"), at 20 ("ERCOT has robust processes in place to ensure the ERCOT system will be operated in a way that can resist and recover from a variety of foreseeable disturbances. These processes will continue to identify other areas for improvement as the system evolves.").

[29] Response of the New York Independent System Operator, Inc. ("NYISO"), *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, Docket No. AD18-7-000 (filed Mar. 9, 2018),

other actions in connection with resilience issues, with some requests specific to the PJM region and others that implicate all ISO/RTO regions.[30]

The ISO/RTO Responses focused the Commission's attention on the relationship between addressing resilience risks and associated costs. For example, the ERCOT Response stated that "the ultimate goal of policymakers should be to ensure that *all* foreseeable threats to the reliability of the bulk-power system are identified and addressed in the most cost-effective way."[31] The PJM Response noted the objective of meeting needs at the lowest cost: "Assuming that resilience requirements can be clearly articulated, meeting them through market-based solutions that allow resources to compete to meet those requirements is the preferred way to ensure that these objectives are met at the lowest cost to consumers."[32] PJM further stated that "[a]n important consideration to keep in mind when establishing criteria [for mitigating resilience threats] is that it is not economically efficient to protect the [Bulk Electric System] from every conceivable risk."[33] The CAISO Response stated that "nowhere does the proposed definition of resilience contemplate the undertaking of any type of cost-benefit analysis, prudence assessment, or the ability of entities to finance any extensive resilience efforts."[34] It added that "[c]onsidering the potentially substantial costs that could be associated with

at 3 (". . . the NYISO respectfully requests that the Commission allow the NYISO to continue to work with its stakeholders in assessing and developing the enhancements necessary to ensure that the wholesale markets, in serving the evolving needs of the electric system, continue to provide significant benefits to the State and its electricity consumers."); SPP Response at 19 ("SPP agrees with the Commission's premise that a one-size-fits-all approach to resilience is not appropriate given the differences that can exist between the various regions the BPS serves."); CAISO Response at 5-6, 175.

30 *See* PJM Response at 5-7, 11-12, 19-20, 33-34, 66, 69, 73-74, 81.

31 ERCOT Response at 3-4 (emphasis in original). SPP also stated that "[r]esilience has an associated cost, and it is important that state regulators be included in the discussion of how that cost is to be allocated and ultimately paid." SPP Response at 13.

32 PJM Response at 68.

33 *Id.* at 41.

34 CAISO Response at 8.

mitigations to improve resilience, these are necessary considerations in determining how much and what type of resilience is appropriate."[35]

III. COMMENTS

The Resilience Order seeks to facilitate a shared understanding among the Commission, ISOs/RTOs, states, and stakeholders of the potential magnitude of power system risks—and, critically, unique challenges—in each ISO/RTO region. The Resilience Order also reflects a deliberate approach to assessing resilience issues. While requiring ISOs/RTOs to provide detailed information, the Commission does not prejudge the need for more prescriptive action. This approach is key, providing the platform for individual regions to define fully the nature and likelihood of any resilience risks and to explore, as necessary and appropriate, cost-effective solutions tailored to address a region's specific challenges.

NESCOE shares ISO-NE's perspective that fuel security presents the primary challenge to the resilience of New England's power system at this time and emphasizes that New England is already actively considering issues related to understanding and crafting appropriate responses to this challenge. Building on the ISO-NE Response, NESCOE offers below information on the stakeholder discussions underway in New England on fuel security. This information includes a recommendation regarding the need for additional analysis about the range and likelihood of potential risks that ISO-NE has identified and principles to help guide the process for defining risks and considering any proposed solutions that emerge. NESCOE also cautions against prescriptive actions or further processes at this time that could unintentionally impede active regional efforts already underway or state actions that could help to mitigate any fuel security challenges. NESCOE additionally provides its perspective on the Commission's proposed

[35] *Id.*

description of "resilience," underscoring the need to incorporate cost-effectiveness considerations in any proposed actions to address resilience risks.

A. New England's Active Discussions on Fuel Security—and Any Actions Promoting System Resilience—Should Ensure that Risks are Fully Defined and Solutions are Guided by Consumer Interests

1. Active Stakeholder Engagement on Fuel Security Analysis Is Already Underway

ISO-NE initiated work on its Fuel Security Analysis in 2016, well before the DOE Proposed Rule or the Resilience Order.[36] In January 2018, ISO-NE began discussions with states and stakeholders on the results of the Fuel Security Analysis and, working with states and stakeholders, ISO-NE intends "to develop a problem statement and identify a long-term solution to address the [fuel security] risk."[37] While ISO-NE is currently working with stakeholders on defining the risk, it has also initiated a process for developing potential solutions, with that work expected to continue into 2019.[38] NESCOE has been, and will continue to be, an active participant in regional discussions on fuel security.[39]

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[36] *See* ISO-NE Response at 8.

[37] *Id.* at 11.

[38] *Id.* at 2, 12.

[39] New England is currently considering fuel security risks on three parallel tracks: immediate, short-term, and long-term. In addition to potential long-term solutions discussed in the ISO-NE Response and in these comments, ISO-NE more recently informed stakeholders that it has identified pressing fuel security risks arising from the potential retirement of certain generating resources in Massachusetts. *See* Memorandum from Vamsi Chadalavada, ISO New England, Executive Vice President and Chief Operating Officer, to NEPOOL Participants Committee, Discussions of Near-Term Fuel Security Concerns, April 3, 2018. *See also* ISO New England, Fuel-Security Reliability Need for Mystic 8 and 9, New England Power Pool Participants Committee Meeting, April 10, 2018, *available at* https://www.iso-ne.com/static-assets/documents/2018/04/npc_20180406_addl_II.pdf. On May 1, 2018, ISO-NE filed with the Commission a request for a tariff waiver in Docket No. ER18-1509-000 to enable cost-of-service compensation for these units in the periods corresponding with Forward Capacity Auctions ("FCAs") 13 and 14. On April 25, 2018, ISO-NE began discussion with stakeholders on tariff changes related to fuel security to be in place in time for FCA 14. ISO-NE has stated that it intends to continue, as planned, the stakeholder process on longer-term solutions.

2. Additional Analysis to Define Fuel Security Risk

In response to ISO-NE's invitation, in February 2018, states and stakeholders provided feedback on the study assumptions ISO-NE selected for its Fuel Security Analysis and submitted requests for ISO-NE to use its model to conduct additional scenario analysis reflecting other possible future system conditions.[40] Prior to initiating the Fuel Security Analysis, ISO-NE had not solicited state or stakeholder feedback about its model, its assumptions regarding system conditions, or about compliance with state laws or policy outcomes.

NESCOE's feedback focused on ISO-NE's assumption in the Fuel Security Analysis, across the majority of scenarios, that the New England states would *not* meet their statutory renewable and clean energy requirements.[41] While NESCOE appreciates ISO-NE's efforts to examine the region's fuel security risks, NESCOE voiced its concern that "[w]ithout the future energy contributions from the resources state laws require, the [Fuel Security] Analysis likely overstates the region's future fuel-security risk."[42] Accordingly, NESCOE requested that ISO-NE modify the Fuel Security Analysis to align the reference case with the level of renewable and clean energy resources required to meet current laws in the New England states and requested that all scenarios should assume this level of renewable and clean energy resources at a minimum.[43]

ISO-NE met with stakeholders in late March 2018 to discuss the results of additional modeling runs it performed. The results reflected the broad range of requests ISO-NE received,

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40 *See* ISO-NE Response at 11.

41 Memorandum from NESCOE to ISO New England, Preliminary Input – Fuel Security Analysis, Feb. 15, 2018, at 1, *available at* http://nescoe.com/wp-content/uploads/2018/02/FuelSecurityAnalysisComments_15Feb2018.pdf.

42 *Id.*

43 *Id.*

with some scenarios showing a moderated or non-existent risk while others showed a heightened risk compared with the original results.[44] NESCOE's requested scenarios, which included renewable and imported resources at levels commensurate with state law requirements, showed a significantly lower fuel security risk.[45] At this meeting, ISO-NE reiterated that its study was neither a forecast nor a prediction for future conditions or events but, rather, was conducted to provide directional guidance through a "deterministic" analysis.[46] NESCOE appreciates ISO-NE's explicit recognition that the analysis conducted to date is directional and not predictive.

3. Incorporating Probabilistic and Other Analysis

ISO-NE's deterministic analysis has served the objective ISO-NE identified: to commence a regional discussion about fuel security. NESCOE and some stakeholders have cautioned that ISO-NE's deterministic analysis of fuel security is not, however, an accurate indicator of the nature, level, or likelihood of risk in the region.

In general, a deterministic analysis assumes that a set of system conditions will occur without regard to the likelihood of that occurrence. In contrast, a probabilistic analysis "considers the likelihood of various events occurring[.]"[47] The scenarios examined in the deterministic Fuel Security Analysis do not account for the likelihood of events reflected in a scenario or a comparison of risks among scenarios. For example, the analysis does not provide a sense of the respective probabilities of outages of "key energy facilities," which could inform how to weigh certain proposed solutions over others. Similarly, without specific modeling of

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44 *See generally* ISO New England, Operational Fuel Security Analysis: Stakeholder Requests for Additional Scenarios, NEPOOL Reliability Committee, Mar. 28, 2018.

45 *See id.* at Slides 64-66.

46 *Id.* at Slide 6. ISO-NE noted other limitations and constraints of the analysis. Importantly, the study "does not reflect the potential for market response to pricing or other incentives." *Id.* at Slide 6 (emphasis omitted).

47 *ISO New England Inc. and New England Power Pool Participants Committee*, 155 FERC ¶ 61,319 at n. 68 (2016).

market responses and the extent to which such responses might mitigate fuel security risks, potential solutions could be developed in a vacuum—that is, without recognition of the extent to which existing mechanisms and market rules would otherwise address the challenges ISO-NE has identified. While the study informs decision-makers of what might happen if certain assumptions occur, New England does not yet have information about how likely those assumptions are, the extent to which existing market mechanisms could address fuel security risks (including the effects of ISO-NE's Pay for Performance program, which is scheduled to be phased in starting June 1 of this year), and how much remedial action is warranted.

Building on stakeholder discussions, in April 2018, NESCOE provided ISO-NE with information regarding potential approaches to enable better risk-informed judgments about the region's challenges and range of potential solutions (the "NESCOE Letter"). At a high level, these approaches involve the use of probabilistic models to evaluate the likelihood of possible outcomes. The NESCOE Letter, included as an attachment to these comments, also recommended a set of guiding principles for evaluating risks and solutions. These principles, which the Commission could consider adopting as part of this proceeding, are discussed in further detail below.

Viewed in its entirely, the NESCOE Letter is intended to encourage further dialogue with ISO-NE about the type of additional information needed to help ISO-NE, states, and stakeholders make judgments about power system risks and identify solutions with a reasonable relationship to those risks. NESCOE looks forward to further discussion with ISO-NE and stakeholders about the form of additional analysis that would better enable policymakers to thoughtfully respond to the questions ISO-NE has presented about the level of risk the region believes is reasonable to accept. To the extent ISO-NE concludes that it is not in a position to provide additional analysis to this end, NESCOE may seek to otherwise supplement the analytical basis upon which to rest its assessment of fuel-security risk.

4. Principles for Evaluating Risks and Solutions

NESCOE agrees with ISO-NE that the assessment of fuel security risks, and potential development of solutions, is "a complex undertaking."[48] To help guide this complex process, NESCOE provided ISO-NE with a list of proposed principles, set out below. These principles are intended to facilitate a shared understanding of how the region should define the identified risk and evaluate proposed solutions. NESCOE does not intend for this to be an exhaustive list of principles ISO-NE could employ as part of the ongoing process and welcomes discussion with ISO-NE and stakeholders on this list.

Principles for Identifying Risks and Evaluating Solutions

1. The problem is fully and fairly analyzed and precisely defined;
2. A broad range of potential solutions are considered;
3. Consumer interests are the guiding factor in evaluating potential solutions; and
4. All potential solutions are illuminated by a cost-effectiveness analysis to enable assessment of whether the costs of proposed solutions have a reasonable relationship to asserted risks.

The Commission could consider adopting these principles to provide guidance to ISOs/RTOs in their current and future assessments of resilience challenges. The Commission's guidance in this area could help focus regional discussions and serve as an important reference to ISOs/RTOs as they consider numerous and diverse perspectives on resilience issues.

48 ISO-NE Response at 12.

B. The Commission Should Continue to Provide Regions with Flexibility to Develop Appropriate Processes and Solutions to Defined Power System Risks

1. Prescriptive Actions Could Impede Targeted Efforts Already Underway

NESCOE strongly agrees with the majority of ISOs/RTOs that regional flexibility is key to developing solutions to address unique resilience challenges.[49] As NESCOE stated in its comments on the DOE Proposed Rule, individual regions are best positioned to explore whether there are needed attributes not currently valued in their power markets and, as appropriate, to consider market rule changes tailored to the region's specific challenges and market design.[50] The ISO/RTO Responses illustrate that each region has distinct power system conditions, challenges, and market designs.[51] Moreover, as PJM noted, even for common risks like weather events, the "degree of risk" associated with those events "differs by region."[52]

In the Resilience Order, the Commission recognized that "the RTOs/ISOs are well-suited to understand the needs of their respective regions and initially assess how to address resilience given their individual geographic needs."[53] ISO-NE has reinforced the uniqueness of each region's challenges along with the need for individual ISOs/RTOs to determine the nature of any threats to resilience.[54] As discussed, New England has more work to do in this respect. NESCOE respectfully asks the Commission to allow this regional-specific work to continue. New England already has a defined schedule for next steps in its assessment of fuel security risks

[49] *See supra* note 29.

[50] Comments of the New England States Committee on Electricity, *Grid Reliability and Resilience Pricing*, Docket No. RM18-1-000 (filed Oct. 23, 2017), at 4. In its comments, NESCOE discussed New England's proven record of addressing challenges to system reliability, as well as the billions of dollars in investments consumers have made in electric transmission and generation. *Id.* at 3-4, 10-13.

[51] *See supra* notes 23-24, 36-27.

[52] *See* PJM Response at 13.

[53] Resilience Order at P 19.

[54] *See* ISO-NE Response at 12, 44.

and the development of potential solutions addressing both near and longer-term challenges. The Commission should encourage these existing processes.

The Commission should not grant PJM's request for a series of additional Commission actions implicating all of the ISOs/RTOs. NESCOE takes no position on PJM's identified resilience challenges or its request for actions specific to PJM. However, where New England is concerned, a defined process has already been initiated to assess and act on fuel security challenges in the region, and the ISO-NE Response did not identify the need for Commission action on resilience in our region. To the contrary, ISO-NE asked the Commission to allow the region to continue its ongoing process. NESCOE agrees.

Furthermore, the Commission's adoption of PJM's proposed approach or institution of other prescriptive actions could impede the targeted efforts in New England to assess fuel security risks. For example, prior to the DOE Proposed Rule, ISO-NE had planned to release its Fuel Security Analysis in October 2017 and begin stakeholder discussions shortly thereafter.[55] ISO-NE paused those activities in light of the DOE Proposed Rule, stating that it would wait until "FERC has provided direction to the industry on how to interpret the [DOE Proposed Rule] in the context of competitive wholesale markets."[56] The Fuel Security Analysis was released months later, in January 2018, following the clarity the Commission provided in the Resilience Order. New England now has an established process underway, with associated timelines, to consider and evaluate fuel security risks and potential solutions. Granting PJM's request, or imposing other requirements in connection with resilience at this time, could unintentionally

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[55] ISO-NE, *Study on Regional Fuel Security to be Delayed Pending Resolution of DOE Proposal on Grid Resiliency Pricing*, Oct. 13, 2017, at 1, *available at* https://www.iso-ne.com/static-assets/documents/2017/10/20171013_fuel_security_analysis_delay_final.pdf.

[56] *Id.* at 2.

distract ISO-NE and stakeholders from the ongoing work tailored to New England's unique circumstances. For these reasons, NESCOE respectfully asks the Commission to treat PJM's request as relating solely to the PJM region and to withhold other prescriptive action.

2. Regional Flexibility Promotes Cooperative Paths Forward Between the Commission and States

Empowering regions to assess their specific resilience challenges and fashion appropriate solutions, as necessary, helps to foster constructive partnerships between the Commission and states. Both the Commission and the states have a shared interest in power system reliability, with respective authorities to address risks to reliable service in different ways. As the ISO-NE Response noted, some strategies for mitigating fuel security challenges are state jurisdictional.[57] Questions about power system "resilience" implicate state authorities over, *inter alia*, integrated resource planning, resource adequacy, and utility procurement.[58] In addition, as the Commission noted, "the concept of resilience necessarily involves issues, topics, and questions that extend beyond the Commission's jurisdiction, such as distribution system reliability and modernization."[59]

A regional approach to resilience helps to ensure that any proposed solution, whether market design changes or solutions outside of ISO-NE's jurisdiction, respects the authorities of both the Commission and the states. This flexibility also allows states to interact with the Commission and its ISO/RTO at an early stage to avoid unnecessary jurisdictional conflicts. Indeed, any proposed solution to a resilience challenge should strive to be cognizant of the

57 *See supra* at 4-5.

58 *See, e.g., Hughes v. Talen Energy Mktg., LLC,* 136 S. Ct. 1288, 1292 (2016); *New York v. FERC*, 535 U.S. 1, 24 (2002); *Allco Finance Ltd. v. Klee,* 861 F.3d 82, 101 (2nd Cir. 2017); *Conn. Dep't of Pub. Util. Control v. FERC*, 569 F.3d 477, 481 (D.C. Cir. 2009).

59 Resilience Order at n. 31.

requirements of New England states' laws and, of course, implemented in such a way as not to shift the costs of individual state laws to other states. In appropriate circumstances, given respective state and federal authorities concerning resilience, the Commission and state entities could also convene a joint technical conference to explore specific regional challenges to resilience, as the Commission and states have done on other issues.[60] The flexibility to define the problem in a way that accurately reflects a region's facts and circumstances, and to develop regional responses to emerging challenges to system reliability, promotes cooperation between the Commission and states on an issue of shared interest and responsibility.

C. Additional Information Is Needed Before Formalizing Any Definition of Resilience, Which Should Incorporate Cost-Effectiveness

NESCOE disagrees with PJM that the Commission should finalize a definition of resilience as part of this proceeding.[61] The Resilience Order is not clear how a "finalized" definition would be applied, or even that the Commission intended to formally define resilience in this or another proceeding.[62] Instead, like other sections of the Resilience Order, the Commission's chief interest appears to be in collecting information. NESCOE believes that New England is today squarely in a place of requiring more detailed information about the region's specific system risks in order to discuss potential solutions in an informed way and appreciates the Commission's efforts in this respect. Without a more developed record and guidance, there could be confusion regarding the effect of the Commission's formal adoption of resilience as a defined, nationally-applied term. Some could, for example, liberally interpret such adoption as

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[60] *See, e.g., Joint Technical Conference on New York Markets & Infrastructure*, Docket No. AD14-18-000 (2014).

[61] PJM Response at 5.

[62] *See* Resilience Order at P 21 ("In order to appropriately study the resilience of the bulk power system in the RTO/ISO regions, we think it is appropriate to first achieve a common understanding of what resilience is in the context of the bulk power system.") and P 23 (providing the Commission's understanding of resilience "[t]o help guide consideration of issues related to resilience of the bulk power system . . . .").

requiring the development of new mandatory reliability standards to address resilience issues, a directive that would raise critical legal, implementation, and consumer cost questions that warrant a full discussion and hearing *before* those rules are put in place. NESCOE appreciates the Commission's efforts to facilitate a dialogue about resilience and hopes that, before any formal action is taken, there will be additional opportunities to consider the meaning and proposed use of resilience as a defined term. If the Commission does decide to adopt a definition of resilience, NESCOE suggests that any definition be accompanied by quantifiable metrics in order to provide clarity regarding performance and compliance.

The ISO/RTO Responses illustrated a diversity of perspectives on the meaning of resilience. Building on responses regarding the relationship between resilience and costs,[63] the Commission should consider revising its proposed description to incorporate explicitly the principle of cost-effectiveness. The Federal Power Act's "primary aim . . . is the protection of consumers from excessive rates and charges." *Xcel Energy Servs. Inc. v. FERC*, 815 F.3d 947, 952 (D.C. Cir. 2016) (citation omitted); *see also FERC v. Elec. Power Supply Ass'n*, 136 S. Ct. 760, 781 (2016) (stating that the Federal Power Act "aims to protect against excessive prices") (citation omitted). Given the Commission's statutory duty to protect consumers from unnecessary costs, cost-effectiveness should be an integral component of resilience and, more specifically, the description of potential responses to resilience risks. Options for addressing resilience risks should be accompanied by a consideration of both increased consumer costs and measurable consumer benefits.

A number of ISO/RTO Responses addressed the need to consider costs in responding to resilience challenges. For example, as discussed above, the PJM Response noted that "[a]n

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63 *See supra* at 7-8.

important consideration to keep in mind when establishing criteria [for mitigating resilience threats] is that it is not economically efficient to protect the [bulk electric system] from every conceivable risk."[64] PJM also stated that to the extent "resilience requirements can be clearly articulated, meeting them through market-based solutions that allow resources to compete to meet those requirements is the preferred way to ensure that these objectives are met at the lowest cost to consumers."[65] Similarly, the ERCOT Response stated that "the ultimate goal of policymakers should be to ensure that *all* foreseeable threats to the reliability of the bulk-power system are identified and addressed in the most cost-effective way."[66] The SPP Response noted that "[r]esilience has an associated cost, and it is important that state regulators be included in the discussion of how that cost is to be allocated and ultimately paid."[67] Thus, there appears to be a common understanding among many ISOs/RTOs that actions to address resilience challenges must include a consideration of cost implications and must strive to mitigate risks cost-effectively.

The Resilience Order stated that: "At the most basic level, ensuring resilience requires that we both (1) determine which risks to the grid we are going to protect against, and (2) identify the steps, if any, needed to ensure those risks are addressed."[68] NESCOE respectfully suggests that, at a similar foundational level, the identification of steps to address resilience risks should be guided by cost-effectiveness to ensure that proposed solutions and their costs have a reasonable relationship to asserted risks.

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64 PJM Response at 41.

65 *Id.* at 68.

66 ERCOT Response at 3-4 (emphasis in original).

67 SPP Response at 13.

68 Resilience Order at P 24.

IV. CONCLUSION

NESCOE appreciates the time and opportunity to further analyze risks to the New England power system, their likelihood, and potential cost-effective solutions tailored to them and looks forward to continued collaboration with the Commission on these critically important challenges. For the reasons stated herein, NESCOE respectfully requests that the Commission consider its comments in this proceeding.

Respectfully submitted,

/s/ Jason Marshall

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Date: May 9, 2018

ATTACHMENT A

NESCOE'S APRIL 13, 2018 LETTER TO ISO NEW ENGLAND

NESCOE
New England States Committee on Electricity

To: ISO New England
From: NESCOE
Date: April 13, 2018
Subject: Analysis to Enable Risk-Informed Judgments

ISO New England has made clear that fuel-security risks - which ISO New England has defined as the possibility that power plants will not have or be able to get the fuel they need to run, particularly in winter) - are the foremost challenge to a reliable power grid in New England. NESCOE appreciates ISO New England's initial efforts to study this issue and continues to evaluate the results of ISO New England's deterministic Operational Fuel Security Analysis (OFSA) as well as the results of subsequent analysis that ISO New England conducted at NESCOE's and stakeholders' request.

In Congressional testimony in January 2018, ISO New England explained an objective of the OFSA this way: "…to stimulate discussion with regional stakeholders and policymakers as to the degree of operational risk the region is willing to accept, and whether additional changes to the market design may be necessary to address the fuel security risks identified in the study." (p. 3) The OFSA appears to have achieved the purpose of illustrating a range of potential winter seasonal risks that could threaten New England's power system if fuel and, in turn, energy is constrained. The additional analysis ISO New England conducted in response to NESCOE's and stakeholders' requests shows markedly different outcomes based on changed assumptions, such as assuming states satisfy their clean energy laws.

While NESCOE recognizes ISO New England's preference to begin discussing solutions, these discussions must be informed by greater specificity about the problem to be solved. For example, does ISO New England assess the risk to power system reliability to be centered on the likelihood of losing an LNG terminal, having less dual-fuel units participating in the markets, losing a nuclear or other resource to retirement, or a combination of those or something else?

Further, ISO New England has identified a key question to be addressed: what level of fuel-security risk is New England willing to accept? States - and we believe all stakeholders - need more rigorous analysis of uncertainties and their likelihood to understand fully the risk reflected in the scenarios in order to develop cost-effective mitigation strategies and to prioritize potential approaches. An informed judgment requires information about the relationship between the asserted risks and proposed solutions and their associated costs, and an assessment of the benefits and trade-offs between various potential solution options.

To facilitate our thinking about the kind of analysis that would enable responsiveness to the question ISO New England has posed to New England states and stakeholders - what level of risk is the region willing to accept? - we sought independent guidance about analysis approaches well-suited to facilitate our thinking given the current New England circumstance. That third-party information is attached for your reference. To be clear, this guidance does not suggest that precise predictions are achievable. Nor does it indicate, and we do not suggest, that only one kind of analysis could enable better risk-informed judgements about the type or level of investment that makes operational and economic sense.

With this information as a reference point, we look forward to dialogue with ISO New England about the need, ability to conduct and the benefits of additional analysis ISO New England may be able to provide to help states and stakeholders make risk-informed judgments about the line between unacceptable and unacceptable risks. Following that, we look forward to discussing the range of means to mitigate unacceptable risks in a way that makes economic sense. If, on the other hand, ISO New England believes the OFSA or other information it possesses suffices to make cost-effective investment level decisions on behalf of consumers it would be helpful to better understand why that is.

Finally, we attach some suggested principles to help guide the discussion of risks and evaluation of potential solutions. These principles are intended to facilitate a shared understanding of how ISO New England will define identified risks and evaluate proposed solutions. NESCOE does not intend for this to be an exhaustive list of principles ISO New England could employ as part of the ongoing process and would welcome discussion with ISO New England and stakeholders on this list.

ATTACHMENT

Principles for Identifying Risks and Evaluating Solutions

1. The problem is fully and fairly analyzed and precisely defined;

2. A broad range of potential solutions are considered;

3. Consumer interests are the guiding factor in evaluating potential solutions; and

4. All potential solutions are illuminated by a cost-effectiveness analysis to enable assessment of whether the costs of proposed solutions have a reasonable relationship to asserted risks.

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Your ref: N/A
Our ref: LTR-RAM-18-46, Rev. 0

Date: April 12, 2018

Subject: Risk Assessment for Fuel-Security in Support of ISO-New England

Mr. Bentz,

Westinghouse is pleased to provide a proposal for scope of work that we can performed to support ISO-New England in your desire to better understand and address the potential fuel-security risks as the region transitions away from base load generation units and dual use power production facilities to a new mix of power sources with varying output and availability constraints. The attached proposal provides a structure framework for evaluating these issues, enabling decision makers at ISO-New England to have a risk-informed viewed of risks and benefits of alternative fuel-security management strategies with the intent to control unfavorable outcomes to an acceptable level.

Thank you for considering Westinghouse in helping your organization respond to such a timely and important issue.

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Proposed Scope Description for the Application of a Risk-Informed Assessment of ISO-New England Fuel-Security Scenarios for Use in the Development of Mitigation Strategies

The ISO-New England Fuel-Security study uses deterministic evaluations of potentially credible fuel availability scenarios to assess the region's ability to provide reliable power supply during the winter months. The study specifically considers the consequence of the scenarios involved without regard to the likelihood of the events postulated. The study concludes that most of the future power system scenarios would not result in adequate levels of fuel for the entire winter. Furthermore, most scenarios resulted in forced "brown-outs" and mandated load shedding. It was noted in closing that a key question that remains to be addressed is the "level of fuel-security risk" that the region's "policymakers and regulators are willing to tolerate".

Given that risks cannot always be reduced to zero, it is important that risk-significant alternatives be evaluated in a methodological manner. Many methods are available to establish a risk-informed approach to evaluating fuel-security. "Assessing Energy Security: An Overview of Commonly Used Methodologies," (Reference 1), provides a high-level introduction to the availability of various strategies including application of portfolio theory and traditional engineering reliability assessment. Risk-Informed decision making (RIDM) is routinely utilized in the United States nuclear industry to optimize plant resources and guarantee that nuclear plants in the United States are operated with an acceptable level of risk, where risk is measured by specific metrics and evaluated against acceptably low changes in those metrics (see for example, Reference 2). Typically, these metrics reflect frequency (or probability) of occurrence of an unfavorable outcome.

To fully understand the risk posed by the fuel-security scenarios and to establish mitigation strategies in a risk-informed approach, Westinghouse recommends that ISO-New England consider an expanded study using state-of the-art Event Tree and/or Bayesian Belief Network (BBN) (See Attachment A for brief description) approaches supported by a statistical assessment of potential winter challenges, key fuel availability parameters (e.g., plant retirements, implementation of alternate resources), resource make-up limitations (e.g., pipeline restraints) and knowledge of changing of resources. These approaches are similar to the engineering approaches identified in Reference 1 and may be applied within a limited scope or comprehensive framework. A limited scope approach would focus on placing the developed scenarios and consequences in perspective by quantifying and risk-ranking the bounding scenarios developed by ISO-New England.

Limited scope treatments discussed above provide partial detail of the "tails" or low probability fuel-security outcomes. While this process can quantify specific defined scenario risk, the limited scope approach does not systematically identify the spectrum of higher likelihood scenarios with significant, but potentially less severe, outcomes. To provide a more robust fuel-security risk assessment, a probabilistic model of resource availability should be developed based on anticipated weather hazards, and known resource changes, allocations, and limitations. Specific outcomes of this model would include:

1. Probability distribution of expected duration of "brown-outs".
2. Probability distribution of expected duration and extent and duration of load shedding.

This information can provide a direct assessment of fuel-security risk for various scenarios and would enable stakeholders to make a risk-informed judgement regarding securing delivery contracts and the need and extent of further operational or market design measures.

References

1. "Assessing Energy Security: An Overview of Commonly used Methodologies," Månsson, A., Johansson, B., Nilsson, L, Energy, Volume 73, 2014.
2. Regulatory Guide 1.174, "An Approach For Using Probabilistic Risk Assessment In Risk-Informed Decisions On Plant Specific Changes To The Licensing Basis" USNRC, May 11, 2011.

Attachment A

Event Tree

Event Tree Analysis (ETA) is a forward, bottom up, logical modeling technique for both success and failure that explores responses through a single initiating event and lays a path for assessing probabilities of the outcomes and overall system analysis. This analysis technique is used to analyze the effects of functioning or failed systems given that an event has occurred. ETA is a powerful tool that will identify all consequences of a system that have a probability of occurring after an initiating event that can be applied to a wide range of events. This Technique may be applied to a system early in the design process to identify potential issues that may arise rather than correcting the issues after they occur. With this forward logic process use of ETA as a tool in risk assessment can help to prevent negative outcomes from occurring by providing a risk assessor with the probability of occurrence. ETA uses a type of modeling technique called event tree which branches events from one single event using Boolean logic.

The overall goal of ETA is to determine the probability of possible negative outcomes that can cause harm and result from the chosen initiating event. It is necessary to use detailed information about a system to understand intermediate events, accident scenarios, and initiating events to construct the event tree diagram. The event tree begins with the initiating event where consequences of this event follow in a binary (success/failure) manner. Each event creates a path in which a series of successes or failures will occur where the overall probability of occurrence for that path can be calculated. The probabilities of failures for intermediate events can be calculated using fault tree analysis and the probability of success can be calculated from 1 = probability of success (ps) + probability of failure (pf). For example, in the equation 1 = (ps) + (pf) if we know that pf=.1 from fault tree analysis then through simple algebra we can solve for ps where ps = (1) - (pf) then we would have ps = (1) - (.1) and ps = .9.

The event tree diagram models all possible pathways from the initiating event. The initiating event starts at the left side as a horizontal line that branch vertically. The vertical branch is representative of the success/failure of the initiating event. At the end of the vertical branch a horizontal line is drawn on each, the top and the bottom representing the success or failure of the first event where a description (usually success or failure) is written with a tag that represents the path such as 1s where s is a success and 1 is the event number similarly with 1f where 1 is the event number and f denotes a failure. This process continues until the end state is reached. When the event tree diagram has reached the end state for all pathways the outcome probability equation is written.

Bayesian Belief Network (BBN)

A Bayesian network, Bayes network, belief network, Bayes(ian) model or probabilistic directed acyclic graphical model is a probabilistic graphical model (a type of statistical model) that represents a set of variables and their conditional dependencies via a directed acyclic graph (DAG). For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases.

Formally, Bayesian networks are DAGs whose nodes represent variables in the Bayesian sense: they may be observable quantities, latent variables, unknown parameters or hypotheses. Edges represent conditional dependencies; nodes that are not connected (there is no path from one of the variables to the other in the Bayesian network) represent variables that are conditionally independent of each other. Each node is associated with a probability function that takes, as input, a particular set of values for the node's parent variables, and gives (as output) the probability (or probability distribution, if applicable) of the variable represented by the node.

Efficient algorithms exist that perform inference and learning in Bayesian networks. Bayesian networks that model sequences of variables (e.g., speech signals or protein sequences) are called dynamic Bayesian networks. Generalizations of Bayesian networks that can represent and solve decision problems under uncertainty are called influence diagrams.

Introduction

Computer-based models are widely used in the energy sector to provide forecasts of the future to help inform decision-making, particularly to better appreciate the risk of future actions or inaction. A variety of approaches have been developed within the industry to do so, described below. It is helpful to remember, however, that while most approaches offer insight into possible outcomes based on certain initial assumptions, none will accurately predict the future. This fact does not diminish the usefulness of widely-used models and forecasts, but the reader should keep firmly in mind the impossibility of knowing the future with a degree of certainty, even when using the most sophisticated of modeling techniques available.

One recent example of an energy system forecast is ISO New England's (ISO-NE) *Operational Fuel Security Analysis* (OFSA), which "evaluated the level of operational risk posed to the power system by a wide range of potential fuel-mix scenarios. The study quantified the risk by calculating whether enough fuel would be available for the system to satisfy consumer electricity demand and to maintain power system reliability throughout an entire winter."[1] The OFSA analyzed 23 scenarios to test stress on the system, and concluded that "New England could be headed for significant levels of emergency actions, particularly during major fuel or resource outages."[2]

Reishus Consulting LLC has prepared, at the request of NESCOE, this brief memo that offers background and context on approaches to power system forecasting, including a high-level discussion of probabilistic versus deterministic modeling, and links to relevant literature for further reading.

Types of models used to forecast the future of energy systems

The following types of analyses, which vary somewhat by purpose and methodology, are typically used by utilities, grid operators, regulators, consultants and other stakeholders to predict energy-related outcomes.[3] These predictions are most frequently focused on the amount and type of capacity investments needed to serve future electricity demand or to estimate the future price of power, given certain initial assumptions such as the expected cost of new generation and availability of specific resources:

- Scenario analysis. Various forms of scenario planning have been widely used in the energy sector for many decades, as well as across other capital-intensive industries.[4]

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[1] ISO-NE, *Operational Fuel Security Analysis*, January 2018, p. 6. https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf.

[2] *Ibid.* p. 9.

[3] Excluded from this discussion are the highly technical, in-depth studies performed to monitor short-term power system reliability, such as circuit fault analyses and load (power) flow studies between specific points on a transmission grid, that RTOs and other transmission balancing authorities routinely conduct as part of their grid reliability responsibilities.

[4] McKinsey, *The use and abuse of scenarios,* November 2009. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-use-and-abuse-of-scenarios.

Pioneered by Shell Oil in the early 1970s as a means of exploring different potential outcomes related to the global production and consumption of fossil energy, scenarios today are used to help answer many "what if" questions within the US power and natural gas sectors, such as "what would the power system look like in two decades if renewable generation targets were doubled?" Along with insights gained from testing the sensitivity of inputs within a scenario, many practitioners would argue that the major benefit of running scenarios is not to predict which future outcome is most likely but rather to consider the implications of how decisions made in the near-term may play out, for better or worse long-term, across strikingly different views of the future.[5] Scenarios are often used when companies or industries are facing disruptive challenges, to help identify signposts or early trends that may lead to radically different future outcomes.[6]

- Integrated Resource Plans (IRPs), capacity expansion modeling and cost estimates. Vertically-integrated utilities have created IRPs as far back as the 1970s, to forecast supply, demand, and price within the utility's footprint, with a specific focus on predicting what new generation and/or transmission investments might be needed over the next 10-25 years to ensure resource adequacy. These planning exercises are typically conducted even in periods when a supply shortfall is not expected in the near-term, and some plans are updated periodically to incorporate speculative elements such as potential changes to supply technology cost, commodity fuel prices, and regulatory policy over the forecast period. Prior to the wave of state restructuring in early 2000s, most New England utilities routinely produced and updated IRPs within their footprint, often in conjunction with estimates of long-term avoided costs, for review and/or approval by their respective state regulatory commissions. Since the development of the wholesale power market in the 1990s, generation and transmission (G&T) modeling in restructured states has shifted in large part to regional transmission organizations (RTOs). Many utilities and agencies in

> Definition of Capacity Expansion: "Capacity expansion models simulate generation and transmission capacity investment, given assumptions about future electricity demand, fuel prices, technology cost and performance, and policy and regulation."
>
> Definition of Production Cost: "Production cost models simulate operation of a specified power system over a relatively short period compared to Capacity Expansion Model (1-week to 1-year), but at higher temporal resolution (hours to 5-minutes) [to answer the question of] what is the least cost dispatch of a complex system of interconnected generators to reliably meet load in every hour of the day at every location?"
>
> Source: US DOE, *Power Sector Modeling 101*

[5] Although there exists no universal definition, a significant difference between scenarios and sensitivities relates to the number of parameters that are adjusted in a given model run, with sensitivities typically used to test the impact of changes to a single variable, such as a high, low and base case around the expected price of natural gas price. Sensitivities are thus used as a means of bounding the uncertainty around a given input, but there are many examples in the literature in which sensitivities failed to adequately capture the wider range of actual outcomes. See for example, forecasted versus actual German energy prices noted in McKinsey, *From Scenario Planning to Stress Testing: The Next Step for Energy Companies,* February 2017. https://www.mckinsey.com/business-functions/risk/our-insights/from-scenario-planning-to-stress-testing-the-next-step-for-energy-companies.

[6] McKinsey, *Overcoming obstacles to effective scenario planning*, June 2015. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/overcoming-obstacles-to-effective-scenario-planning.

restructured regions however still engage in planning and resource adequacy reviews, such as state efforts made to advance clean energy goals.[7] More recently, energy stakeholders and regulators are exploring a related approach called Integrated Distribution Planning, which examines alternative investments within the distribution-side system.[8]

- Regional System Plans (RSP). Like utility IRPs, RSPs routinely assess the long-term reliability and resource adequacy of the grid through capacity expansion modeling, albeit across an RTO's multi-state region. In New England, the region's grid modeling efforts have thus mostly shifted to ISO-NE, except for Vermont's utilities, which continue to produce their own IRPs. This state of play is similar in other restructured areas, where RTOs, such as PJM and the Midcontinent-ISO, provide the overall transmission planning for their regions, although within those RTOs there also remain some non-restructured utilities that produce independent resource plans.[9] As an example, here is a summary of ISO-NE's annual RSP process:

> The Regional System Plan (RSP) accounts for the addition of generating units and demand-response resources (i.e., resources made available when customers reduce their electricity consumption in response to reliability and price), potential resource retirements, and load growth, with due consideration of the system's economic performance and impact on system-wide air emissions. As is evident in the RSP, electrical problems and solutions can—and in many cases do—cross state and operating-company boundaries. As the Regional Transmission Organization, ISO New England leads the annual planning effort through an open stakeholder process. With input from the Planning Advisory Committee (PAC) and other stakeholders, and technical assistance from the transmission owners, the ISO analyzes and plans for the reliability and adequacy of the New England bulk power system as an integrated whole. This ensures that system modifications made to one part of the system, including newly interconnected generating units, will not have an adverse impact on another part of the system.[10]

- Network reliability reviews, risk and contingency planning, including single point of failure (SPOF) or of disruption (SPOD) analyses. The NERC, RTOs, utilities and others often produce risk assessments that focus on the potential impact of a single factor or contingency, such as the failure of the largest operating plant in the region, or the loss of a major gas storage facility, to assess how such one-off events may adversely affect the reliability of a power system. These reviews are typically modeled over shorter time periods than that considered by capacity expansion plans.

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[7] For example, the Massachusetts Department of Energy Resources is responsible for "ensuring the adequacy, security, diversity, and cost-effectiveness of the Commonwealth's energy supply to create a clean, affordable, and resilient energy future[…]" https://www.mass.gov/orgs/massachusetts-department-of-energy-resources

[8] ABB, *The new era of integrated resource planning in California and beyond,* 2017. https://library.e.abb.com/public/271d8b844b20410995c73e234d230413/New%20era%20of%20IRP_WP_Mar17.pdf

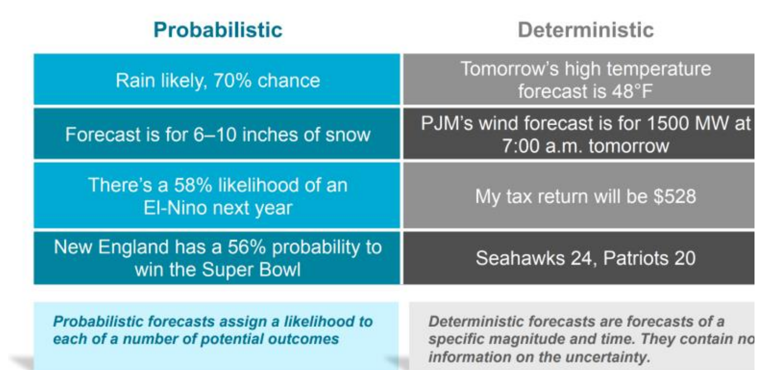
[9] For a more complete discussion, see the report by US DOE Lawrence Berkeley National Lab (LBNL), *The Future of Electricity Resource Planning,* September 2016, p 65- 70. https://emp.lbl.gov/sites/all/files/lbnl-1006269.pdf

[10] The ISO/RTO Council, *ISO/RTO Electric System Planning: Current Practices, Expansion Plans and Planning Issues*, 2006, see p. 50-52 for a fuller description of the RSP process. http://www.ercot.com/content/news/presentations/2006/IRC_PC_Planning_Report_Final_02_06_06.pdf

Deterministic versus Probabilistic Approach

A review of energy sector literature suggests that an important discussion has been underway in the power industry regarding how forecasts can be improved to better to capture risk, uncertainty and complexity in planning models, particularly for those used in forecasting capacity expansions. One facet of this discussion focuses on the difference between deterministic and probabilistic modeling. In many industries, both types of models are used in forecasting the future, although deterministic appears to more pervasive in energy modeling, based on this brief review of the literature.[11]

Deterministic models use specific assumptions, i.e. inputs, that are determined in advance, and then are run through computer models to estimate what effect those assumptions may have in the future, with the outcome typically expressed as a single point solution. For example, if one knew both the initial balance in a savings account and could predict with accuracy what the interest rate would be over a decade into the future, then one could also accurately predict what the balance of that account will be in ten years. Because deterministic models will result in solutions that depend on the specific assumptions provided as inputs, they often fail to adequately capture what degree of uncertainty is associated with the resulting forecast.



Source: *Probabilistic Forecasting in Renewable Energy*, 2015

Probabilistic models typically run many simulations using inputs that are assigned a specific level of probability. Using the same example, above, one could assign a higher probability to what the forecaster expects to be the most likely interest rate in the future with less likely interest rates assigned lower probabilities; doing so will lead to a forecast that can typically express a range of possible outcomes for the account balance in year ten. Probabilistic modeling (also known as stochastic analysis) has not been historically used as often as the deterministic approach within the energy sector for medium- and long-term planning, as it has tended to both require more sophisticated and expensive data-intensive models, as well as necessitates making assumptions about the likelihood of various inputs that can be at best difficult to estimate or are highly

[11] Probabilistic modeling is more commonly used for very short-term reliability purposes, i.e. such as daily analyses related to calculating operating reserves. See discussion, e.g., in US DOE Quadrennial Energy Review, 2nd Installment, 2017. *Transforming the Nation's Electricity System.* https://www.energy.gov/policy/initiatives/quadrennial-energy-review-qer/quadrennial-energy-review-second-installment

speculative.[12] Thus, probabilistic models are not inherently more "accurate," but may provide insight that better captures the uncertainty of forecasting the future in a way that deterministic scenarios and sensitivities may not.

Examples of specific approaches to forecasting by energy sector participants

This section highlights the planning efforts of different organizations responsible for aspects of energy forecasting, and briefly describes their approach to further illuminate the discussion above.

ISO-NE, which is largely responsible for resource adequacy in the New England region, has produced many forecasts for use by stakeholders since its inception, including the annual ten-year outlook of the Capacity, Energy, Loads, and Transmission (CELT) forecast, the Regional System Plan (RSP), and various ad hoc studies, such as the recently released Operational Fuel Security Analysis. As noted in a recent review by the consultancy ICF, ISO-NE's primary models used in its planning forecasts include the Siemens PSS/E (power flow analysis), PowerGEM TARA (security assessment), and ABB/Ventyx GridView (production costing). These are all commercially-available forecasting models that are widely used in the power sector.

Notably, all seven RTOs, including ISO-NE, use deterministic models for their contingency analyses, although PJM uses an additional probabilistic layer for limited purposes.[13] Researchers at the US DOE's national labs, particularly NREL, as well as various consultancies such as ICF, the Analysis Group, and Brattle, have pushed the research on improvements in modeling and methodologies, especially as traditional aspects of the power system change, reflecting the growing additions of intermittent resources and behind-the-meter generation.

For example, efforts have been made in recent years to model the entire eastern and western US electric systems (interconnections), to assist stakeholders in analyzing and forecasting changes to power that are beyond the scope of individual RTOs and utilities. Cited in the bibliography below are the full reports of two such studies conducted by NREL: the 2016 Eastern Renewable Generation Integration Study (ERGIS) and the 2017 Western Wind and Solar Integration Study, Phase 2 (WWSIS-2). In each, the forecasters used models[14] that simulate operations of the power grid over small enough increments of time to capture the impact of adding significant wind and solar resources to the power system. Each relied on a scenario approach to answer a specific set of questions, such as what would be the impact on the operation of gas-fired plants when renewable resources were increased by different magnitudes in alternative scenarios. Unlike the ISO's recent OFSA, these large-scale modeling efforts were not designed solely to test fuel security risk.

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[12] Although not technically the same approach, some forecasters have used a deterministic planning model to run hundreds or in some cases thousands of sensitivities, and by combining them into a value-at-risk analysis, they strive to account for the risk and uncertainty of multiple factors and decisions into the future in the same way that probabilistic modeling achieves more directly.

[13] The ISO/RTO Council, *Ibid*.

[14] The WWSIS-2 and ERGIS used the commercially-available PLEXOS software, while also making use of an NREL-developed tool called Regional Energy Deployment System (ReEDS).

North America's reliability organization, NERC, has produced many examples of large scale contingency analyses, consistent with its mission of monitoring and ensuring reliability of the power systems operating in the US & Canada. These studies are focused mainly on shorter-term network reliability rather than longer term expansions, often making use of tools such as power flow studies. NERC has also produced risk assessments that identify when additional studies may be necessary. For example, a recent report from NERC[15] on the potential reliability impact of natural gas disruptions was widely cited in the trade and popular press this past winter. It surveyed utilities in forty regions in the US where natural gas dependency could contribute to power reliability risks. The report itself offered several recommendations to power system operators and planners regarding possible additional actions to mitigate risk and reduce reliability concerns associated with gas disruptions, including adding natural gas system contingencies to power system planning frameworks.

Many vertically-integrated utilities continue to routinely conduct IRPs or scenario analyses, often in conjunction with the periodic review of their plans by the respective state commission. The LBNL report *The Future of Electricity Resource Planning* in 2016 profiled the approach of ten utilities, including two power planning systems in the US that used probabilistic (stochastic) analysis to estimate uncertainty in their planning forecasts, TVA and Pacificorp.[16] The researchers urged regulators to encourage wider adoption of risk analyses by planners using the best-available modeling techniques, while acknowledging the challenge of simulating the disruptive changes ongoing in the power system. Many other utilities continue to use deterministic approaches to assess their future options. A survey of generation-owning utilities in the 2000s showed that at least a handful of utilities incorporated risk into their IRP planning efforts by running a massive number of sensitivities, as a proxy for probabilistic modeling.[17]

Notably, between 2011-2015, the United Kingdom's energy regulator, Ofgem, examined the risk of a winter capacity shortfall three years in the future by annually running a forecast model that mixed probabilistic and deterministic methodologies to test scenarios and related sensitivities that could result in blackouts. After proposing this methodology at the start of the process, Ofgem requested comments from stakeholders,[18] who generally agreed with the proposed approach,[19] and it remained in use for the next several annual risk assessments. The forecasts included both probabilistic variables for certain short-run inputs such as wind speed and forced outages, and deterministic measures for other longer-term inputs such as plant retirements. Ofgem affirmatively noted that the scenario approach, which incorporate both types of variables,

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[15] NERC, *Potential Bulk Power System Impacts Due to Severe Disruptions on the Natural Gas System*, November 2017. https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SPOD_11142017_Final.pdf

[16] LBNL, *Ibid*., p. 57.

[17] *Survey of Utility Resource Planning and Procurement Practices for Application to Long-Term Procurement Planning in California*, 2008. www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10960

[18] The United Kingdom Office of Gas and Electricity Markets (Ofgem), *Electricity Capacity Assessment: Measuring and modelling the risk of supply shortfalls*, 2011 https://www.ofgem.gov.uk/ofgem-publications/40421/capacityassessmentconsultationdocument.pdf

[19] Of the eleven respondents to Ofgem's initial request for comment on its methodology, nine supported the mixed approach, one preferred a fully probabilistic model, and one preferred that no probabilistic elements be used. See Ofgem February 2013 report, *Electricity Capacity Assessment 2013: decision on methodology.* https://www.ofgem.gov.uk/publications-and-updates/electricity-capacity-assessment-2013-decision-methodology

plus the application of a wide range of sensitivities, would together provide a reasonable basis for assessing the risk of energy demand exceeding supply in the nation's power system. The forecasting effort shifted from Ofgem to the UK's system operator, National Grid, once the capacity market was in place in 2016. The electricity capacity and related forecasts produced annually by National Grid since then appears to continue to use a mix of variables (probabilistic and deterministic) along with a large set of scenarios and sensitivities to test stress on the system in the winter three years out.[20]

Links to these studies as well as additional analyses and reports are included in the bibliography below for further reading.

For Further Reading

General resources on power system models and forecasting:

- A good starting point for the lay reader is a slide deck from the US Department of Energy that briefly describes different power system models and offers some commentary on their appropriate use. US DOE, *Power Sector Modeling 101* (presentation), 2016. https://www.energy.gov/sites/prod/files/2016/02/f30/EPSA_Power_Sector_Modeling_FINAL_021816_0.pdf
- For a slightly more technical but still high-level discussion of how resource planning works, see *Production Cost Model Fundamentals,* undated Midwest ISO presentation. http://home.eng.iastate.edu/~jdm/ee590-Old/ProductionCostModleFundamentals_EE590.pdf
- Also helpful is Synapse Energy's 2016 presentation on energy modeling tools, albeit in the context of the now defunct Clean Power Plan. http://www.synapse-energy.com/sites/default/files/Guide-to-Modeling-Tools-Clean-Power-Plan-Other-Analyses.pdf
- For a broader discussion of the underlying principles of future forecasting, see this Harvard Business Review article, *Living in the Futures*, May 2013 https://hbr.org/2013/05/living-in-the-futures
- For a general discussion of planning approaches for both short- and long-term periods, see US DOE Quadrennial Energy Review, 2nd Installment, 2017. *Transforming the Nation's Electricity System.* https://www.energy.gov/policy/initiatives/quadrennial-energy-review-qer/quadrennial-energy-review-second-installment
- From the US DOE Pacific Northwest National Lab, a thorough list of energy forecasting models with brief descriptions of key features, identification of major studies making use of specific models, and links to model documentation sites, *North American Modeling Compendium and Analysis*, 2016. https://www.energy.gov/sites/prod/files/2017/01/f34/North%20America%20Modeling%20Compendium%20and%20Analysis.pdf

[20] National Grid EMR Electricity Capacity Report, 2015. https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Electricity%20Capacity%20Report%202015.pdf

For a discussion of scenario planning in general, see:

- Description by Shell of its scenario forecasting approach, on its website: https://www.shell.com/energy-and-innovation/the-energy-future/scenarios.html
- McKinsey, *The use and abuse of scenarios,* November 2009 https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-use-and-abuse-of-scenarios
- McKinsey, *Overcoming obstacles to effective scenario planning*, June 2015. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/overcoming-obstacles-to-effective-scenario-planning

For sources that focus on power system modeling specifically, including its evolution in recent years to better incorporate a broader set of variables that better reflect the growing complexity of G&T planning, see:

- Analysis Group, *Electricity Markets, Reliability and the Evolving U.S. Power System*, June 2017. http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/ag_markets_reliability_final_june_2017.pdf
- Brattle Group, *Reviving Integrated Resource Planning for Electric Utilities: New Challenges and Innovative Approaches*, 2008. http://files.brattle.com/files/6665_energy_newsletter_2008_no_1_-_irp.pdf
- McKinsey, *From Scenario Planning to Stress Testing: The Next Step for Energy Companies,* February 2017 describes the evolution of more risk-based planning in the energy industry. https://www.mckinsey.com/business-functions/risk/our-insights/from-scenario-planning-to-stress-testing-the-next-step-for-energy-companies
- ABB, *The new era of integrated resource planning in California and beyond,* 2017. https://library.e.abb.com/public/271d8b844b20410995c73e234d230413/New%20era%20of%20IRP_WP_Mar17.pdf
- For some historical perspective, see an early discussion of utility planning by Sandia Labs, circa 1997. https://www.osti.gov/servlets/purl/522766

Sources that specifically address approaches to risk and uncertainty, including probabilistic versus deterministic forecasting:

- Eric Grimit, *Probabilistic Forecasting in Renewable Energy,* 2015, (presentation) https://www.ametsoc.org/cwwce/index.cfm/committees/renewable-energy-committee/meeting-minutes/september-24-2015/probabilistic-forecasting-in-renewable-energy/
- Excerpt from AIMMS Modeling guidebook, 2014, describing the methodology used to model power system expansion, including a brief description of stochastic modeling. https://download.aimms.com/aimms/download/manuals/*AIMMS3OM*_PowerSystemExpansion.pdf

For examples of specific energy forecasts, see:

- ISO-NE*, Fuel Security Analysis*, January 2018, https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf
- For a helpful look at the recent state of resource planning based on a review of ten representative utilities across the US, see the DOE Lawrence Berkeley National Lab

report, *The Future of Electricity Resource Planning,* September 2016. https://emp.lbl.gov/sites/all/files/lbnl-1006269.pdf

- Aspen Environmental Group (AEG) and Energy and Environmental Economics (E3), *Survey of Utility Resource Planning and Procurement Practices for Application to Long-Term Procurement Planning in California*, (prepared in 2008 for the California Public Utilities Commission) provides a somewhat dated but still helpful survey of utility planning efforts broadly across the US. www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10960
- The ISO/RTO Council, *ISO/RTO Electric System Planning: Current Practices, Expansion Plans and Planning Issues,* 2006, is an extensive report cataloging approaches to modeling power systems by RTOs, including the ISO-NE. http://www.ercot.com/content/news/presentations/2006/IRC_PC_Planning_Report_Final_02_06_06.pdf
- ICF, *Comparison of Transmission Reliability Planning Studies of ISOs/RTOs in the US*, 2016, (commissioned by NESCOE). While not focused specifically on generation resource planning, it nonetheless provides some helpful detail on RTO studies. http://nescoe.com/resource-center/t-planning-comparison-feb2016/#_Toc441425491
- ISO-NE, 2017 Regional System Plan. https://www.iso-ne.com/system-planning/system-plans-studies/rsp
- NREL, 2017 *Western Wind and Solar Integration Study Phase 2* https://www.nrel.gov/grid/wwsis.html and NREL, 2016 *Eastern Renewable Generation Integration Study* https://www.nrel.gov/grid/ergis.html
    - See also the NREL technical paper *Time Domain Partitioning of Electricity Production Cost Simulations*, January 2014, which describes the advanced production cost model modifications used to support the ERGIS analysis. https://www.nrel.gov/docs/fy14osti/60969.pdf
- NERC's special review in the aftermath of the unexpected loss of the Aliso Canyon gas storage in California, *Potential Bulk Power System Impacts Due to Severe Disruptions on the Natural Gas System*, November 2017. https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SPOD_11142017_Final.pdf
- International Renewable Energy Agency (IRENA), *Planning for the Renewable Future,* 2017, a report on long term planning in the energy sector from a European perspective that suggests probabilistic approaches will be helpful to better capture the impact of renewable sources. http://www.irena.org/publications/2017/Jan/Planning-for-the-renewable-future-Longterm-modelling-and-tools-to-expand-variable-renewable-power-in
- Vermont's Green Mountain Power IRP, 2014 https://www.greenmountainpower.com/wp-content/uploads/2017/01/IRP-The-Supply-of-Electricity.pdf
- For a discussion of the scenario-based methodology that the Australian Electricity Market Operator uses in its supply and demand forecasting, see http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2017/2017-NEM-ESOO-Methodology.pdf and http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database
- United Kingdom Office of Gas and Electricity Markets (Ofgem), *Electricity Capacity Assessment: Measuring and modelling the risk of supply shortfalls*, 2011

https://www.ofgem.gov.uk/ofgem-publications/40421/capacityassessmentconsultationdocument.pdf

- Ofgem decision document, re the choice of model used to capture the risk of capacity shortfalls in the medium term, 2013. Ofgem February 2013 report, *Electricity Capacity Assessment 2013: decision on methodology*. https://www.ofgem.gov.uk/publications-and-updates/electricity-capacity-assessment-2013-decision-methodology and https://www.ofgem.gov.uk/publications-and-updates/decision-document-electricity-capacity-assessment-measuring-and-modelling-risk-supply-shortfalls.pdf
- See also UK's system operator, National Grid, portal website to its capacity assessments https://www.nationalgrid.com/uk/electricity/capacity-emr-and-cmn
    - For example, National Grid EMR Electricity Capacity Report, 2015. https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Electricity%20Capacity%20Report%202015.pdf