Energy Reliability Assessment Task Force (ERATF) Industry Workshop Q&A

ERATF Leadership and NERC Staff

1: Our coal-NG dual fuel units are obliged by a settlement with the Sierra Club to soon cease all use of coal, regardless of grid reliability impact. Will NERC add resiliency studies to TPL-1 Planning Assessments? This could help in dealing with the overwhelming anti-resiliency initiatives we face.

This question is outside the scope of this workshop.

2: Will the ERATF reconsider the DOE resiliency proposal rejected by FERC in 2018? ERCOT consequently lost over 6 GW of coal capacity, which greatly exacerbated that harm wrought by winter storm Uri.

As reflected in NERC's comments in the Commission's 2018 proceeding in Docket No. AD18-7-000, NERC is committed towards a resilient and reliable BPS. Resilience is an essential aspect of reliability and thus a feature of all NERC's activities.

3: FERC's report on winter storm Uri shows that at the height of the crisis (Feb. 17) Texas wind plants generated at only 1.6% of nameplate capacity. Will the ERATF recommend using a wind dependability factor no higher than 0.016% in TPL-1 Planning Assessments?

This question is outside the scope of this workshop.

4: Are these considerations already being required (or will be required) in market & state jurisdictions with regard to Integrated Resource Plans filed by utilities? How does a NERC Reliability Standard propose to enforce what is effectively a Resource Plan?

The specific elements that should be included in a study are determined by the organization that is conducting the study. IRPs should be considered when conducting a study.

5: How would a standard requiring analysis help or not? It sounds like the panelists are looking at new tools and assumptions already.

A standard would be helpful since it would ensure consistency and comparability, hence it would be an improvement since organizations would end up following similar philosophies.

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Panel #1 – Operations and Operational Planning

1: What are the data requirements to perform and improve energy assessments?
Data requirements used for real time operations energy assessments would consist of real time SCADA, forecasted load, forecasted renewable generation, forecasted intertie capacity and forecasted weather conditions (J. Bucholtz, AESO)

The data requirements will vary based on the specifics of the study being performed. Knowledge of the interconnected systems will drive the data needed to fully understand the fuel supply constraints on a system and the data that is required will come from that research. (M. Knowland, NE-ISO)

I agree with the AESO, and would add that we need to have a transmission topology that includes planned and forced transmission outages to identify if there is capacity behind transmission facilities that is stranded by outages. (N. Millar, CAISO)

2: Any comments about Minnesota/MISO report in 2020 that found massive overbuilding of renewables with curtailment was far, far cheaper in that region than investing in massive storage with just adequate capacity?
Please see: Using Overbuilding + Curtailment to Achieve 100% Clean Electricity (12.15.20)[1]. We have not reviewed the Minnesota/MSO report in detail. For the California ISO footprint, the integrated resource planning activities led by the California Public Utilities Commission has found that storage will play a major role in addressing reliability needs and bulk grid-connected storage is being added to the network accordingly.
(N. Millar, CAISO)

3: Please speak to the volume of inverter base resources operating with respect to the Odessa Outage report.
This information is available in the NERC report[2], (N. Millar, CAISO)

4: Can you please expand more on the seasonal outage limits?
No comments from the panel.

5: How do you account for BESS in the operations planning time frame? Specifically, if/when you have significant storage, what assumptions do you make about your ability to recharge your storage resources and what energy assessment do you perform to provide assurance?
Storage is a point where I believe that we can improve our analysis capabilities. We currently use a fixed dispatch of storage in the overnight hours to pump and on-peak to generate. We do factor in the efficiency

[1] https://vimeo.com/491390330
[2] https://www.nerc.com/pa/rrm/ea/Documents/Odessa_Disturbance_Report.pdf

of storage, in that more energy is required to be utilized to operate storage than not (approximately 70 to 75% efficient). Studying the impact of better optimized storage is on our radar for future consideration, depending on the performance of intermittent resources. (M. Knowland, NE-ISO)
Production cost modelling studies are performed in the long term planning and seasonal assessment studies to address overall energy sufficiency including charging requirements. In the day ahead (Operations Planning Analysis time frame), the CAISO optimizes the need for resources across all 24 hour intervals to account for the need of charging and discharging. (N. Millar, CAISO)

6: We appreciate that all of the panelists are doing comprehensive analysis. What improvements do each of them think are needed?
Depending on the BA's generation profile, forecasted renewable generation patterns are most important when trying to understand the impacts in real time. When looking further out our assessments assume renewable generation at zero to understand what the real energy assessment risk is. During cold winter days or hot summer days, we often have minimal wind generation, so it is assumed to be zero. Seasonal assessments for winter would look at lack of wind, solar and potential risk of lack of natural gas. Improvements for us would be to have generators provide accurate capability due to potential natural gas curtailments and always working to improve renewable forecasts. (J. Bucholtz, AESO)

For us in New England, the improvements that I am looking for currently are in improving the forecasting of various conditions (i.e. weather and load). In order to better understand the risks that we are facing, a wider variety of possible conditions could be studied with more available input data. (M. Knowland, NE-ISO)

In California, we expect to continue to refine our study approaches as the generation fleet evolves and as new information becomes available about operating characteristics and needs. (N. Millar, CAISO)

7: Each regional operator view is showing they are performing comprehensive assessments and analysis. Our regional operator is working extensively. What is the gap perceived by other RTO ISO beyond ISO NE? I'm not hearing one. Do the other regional operators view a standard is needed? For what?
Standards and or rules around firm natural gas contracts could be investigated to see how this information can be made available to real time operations. (J. Bucholtz, AESO)

Studies of this nature come from necessity. ISO New England is in the position now of having a fairly well developed energy analysis process because the energy needs are more immediate than they may be in other areas. (M. Knowland, NE-ISO)

The California ISO has not identified a need for standards on the issue of analysis. To the extent that standards are imposed, they will need to provide the flexibility to address local demand-side characteristics and needs, varying resource mixes, and resource planning and procurement responsibilities. (N. Millar, CAISO)

8: Would the panel speak to the timeliness of communications with generators and their status in the operational timeframe (moment-to-moment, next hour, etc.) as a contrast between vertically integrated vs. markets.
Moment to moment dispatches in real time for an energy market are clear and go out as needed based on system changes. Typically, an electronic dispatch to move to a new level. If for some reason they can't meet their dispatch, communication takes place in the form of a phone call. Offers are in the market 2 hours out and they can change their price offers further out. An example of a challenge in future energy offers is understanding when natural gas offers might change based on how much natural gas has been used for their daily amount in their contract when curtailments occur. Forcing generators through standards or rules to offer based on their projection of natural gas usage could benefit assessments. (J. Bucholtz, AESO)

9: For your energy or reliability studies which software platform do you utilize? Which metrics do you output, i.e., LOLP, LOLE? Which software do you utilize?
In real time, assessments are done in our EMS and Internal built Dispatching tools. We run future power flow analysis for current day and next day on an automated basis, with forecasted interties, load, generation offered, and renewable forecasts. (J. Bucholtz, AESO)

Metrics for the performance of energy analyses will be a key focal point of the work that is being done at NERC right now. Capacity metrics have been in place for a very long time and are very well understood by the industry. Energy metrics can be challenging to convey while the industry adapts to a new paradigm of system operation and planning. To help bridge that gap, ISO New England conveys the results of our energy analyses in terms of capacity and reserve shortages. Forecasted EEA levels are one example of how we convey our results. EEA levels are used in reference to capacity at any given time, but Forecasted EEA levels can be a longer duration span of time, where EEA conditions could exist at any point in the study. (M. Knowland, NE-ISO)

10: Which method do you utilize for your energy reliability assessments, is it based on a Cumulative Outage Probability Table (COPT), or do you run a Monte Carlo production cost model to calculate these metrics?
No comments from the panel.

11: All of them are doing analysis. What does the group think needs to change or agree needs to change?
The premise for the analyses needs to be clearly defined for consistency. Even if energy analyses are being performed across the board, without consistent performance requirements and standardized metrics, the results cannot be easily shared and compared. Energy issues, as seen by the expansive natural gas pipeline networks in North America, are not limited to a single NERC region at a time. Circumstances in one location can have an impact on any other region that shares the same fuel supply source or other consumable resource. (M. Knowland, NE-ISO)

12: Is it a really a good idea to try and separate energy and capacity moving forward to assess our systems?
The specifics of how to quantify our risks is still to be determined. The power system has a capacity requirement and an energy requirement. Capacity analysis still has a place in the future, but compounding

that with an energy analysis will tell the operator or planner if the capacity that they're counting on being there will actually be there when it's needed. (M. Knowland, NE-ISO)

13: Does coordination occur between ISOs in the assessments? If so what does that look like?
Seasonal assessments are discussed between ISO through planned meetings. Discuss weather or fire concerns that could be impacting the energy assessment. Daily discussions take place between RC operators in WECC where concerns around weather, fire, or energy shortages can be discussed. (J. Bucholtz, AESO)

Right now, I'd say that coordination is limited. We are aware of studies in neighboring areas but there are opportunities for coordinating on the assumptions and results. (M. Knowland, NE-ISO)

14: Have we, as an industry, reached the point where the time delays to build infrastructure and the associated impacts on rates has made controlled load shedding a de facto necessity? And do we need to do a better job at managing end user expectations?
Load will continue to be used as a resource to balance supply and demand when supply can no longer meet demand. (J. Bucholtz, AESO)

We have seen instances of load shed that were a result of constrained or unavailable energy. Managing end user expectations can be a powerful tool for navigating through a potential energy shortage, but needs to be done before the shortage is imminent. Messaging from government officials, utilities, ISOs, etc. all have to be unified, consistent, and planned in advance in order to maximize effectiveness. (M. Knowland, NE-ISO)

Demand side management through effective market participation and other programs can play a vital role in meeting reliability needs. However, the need for reliable service and corresponding service expectations are growing, not declining, and load shedding is even less tolerable now than in the past. (N. Millar, CAISO)

15*:* Do you feel your communications and interactions with Natural Gas suppliers are adequate to meet your near-term planning and assessments? Do you have direct communications with Gas or rely on the GOP to keep you informed of problems? How often are updates provided?
I feel our communications have recently improved to provide a heightened awareness around natural gas capacity issue. We have created a heat map to initiate communications when there may be an electricity supply concern or when the natural gas providers for see capacity curtailments. Updates are provided based on issues occurring on the system or if our energy assessments detect cold weather conditions that may warrant a discussion to find out the current status of the natural gas system or any supply concerns. (J. Bucholtz, AESO)

For the operations planning and operations work that I'm doing in New England, the communication is certainly adequate. We get updates from both gas control and from generators very quickly. Considerable time has been spent building strong relationships between the ISO and pipeline operators which results in streamlined communication where most of the detail work has already been done, and then it becomes a situation report rather than an educational endeavor. That is a two-way street. (M. Knowland, NE-ISO)

Communications on a seasonal, monthly, and weekly basis, as well as daily update reporting, are meeting our needs today, and we expect increased coordination in the future. (N. Millar, CAISO)

16: Question for Neil Millar. At a high level how computationally challenging is your stochastic planning process? Is it reasonable to expect that a wide range of planner at all scales might be able to adopt stochastic methods to try to plan for high impact, low probability events? (N. Millar)
We have been able to maintain access to sufficient computation resources to provide reasonable turnaround in stochastic planning studies to meet our needs, and coordinate the use of those resources across several departments inside the CAISO. The requirements are substantial, however, and studies need to be scoped carefully accordingly. (N. Millar)

17: Question for Rodney O'Bryant. Can you explain in more detail how you do your temperature analysis for your seasonal assessments?
Answer: We leverage 10-year/20-year averages along with the Seasonal Temperature outlook to establish a baseline expectation for the season in question. From this point we perform sensitivity analysis for additional temperature ranges for our area. In normal winter evaluations a 25 Degree baseline with sensitivities at (20, 17, 15, 13, 10) degrees. In the summer evaluations we leverage a baseline of 93 with sensitivities at (94, 95, 98, 101,102) and this is for the Southern Balancing Area footprint. (R. O'Bryant)

18: Question for Rodney O'Bryant. How is seasonal outage limits determined and implemented? It is for planned outage only, right?
Answer: This seasonal outage limit is only for planned outages. We have identified months of increased risk (June, July, and August) and (December, January, February). In these months we minimize planned outages and set additional limits for the shoulder months not listed based on load patterns. This allows us to schedule and coordinate generation resources to maintain generation levels considering expected forced outage rates for various times of the year. (R. O'Bryant)

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Panel #2 – Mid to Long Term Planning

1: It seems like in the planning horizon, many load serving entities rely on "market imports" in certain hours and time-frames. How can load serving entities assess the risk that there may not be any energy to be bought at any price in those hours?
This is why regional planning is important so that the region can look across multiple LSEs to assess energy adequacy. In addition, if individual LSEs do a probabilistic resource adequacy study, they would typically model their neighbors as well – factoring in their energy availability as well as import constraints (transmission). (K, Messamore, Evergy)

2: The Feb 2021 cold weather event would probably have been considered a low-probability event, but had a very high impact/cost. If using probabilistic methods, do you only try to mitigate high-probability events, or also low-probability/high-impact events. How?
Probabilistic assessment usually studies a range of weather conditions. Tail events should be included as well. NERC Probabilistic Assessment Working Group is developing a white paper about probabilistic planning for tail risks. This white paper should be able to shed some light on how to model tail events. (J. Jin, ERCOT)

Probabilistic methods are certainly capable of providing information on low-probability, high impact events. The challenge is justifying actions to mitigate these events when the probability is known or unknown because it's an event that has never occurred before. (A. Lafoyiannis, IESO)

At the IESO, we conduct periodic operability assessments. Part of this effort includes a stage where staff across the organization come together to identify potential high impact events and assess them. In 2019, we looked at a risk that a significant portion of our existing DER fleet trips and could become our most severe single contingency. (A. Lafoyiannis, IESO)

3: What tools/applications do you use, home grown or something else? Are they adequate or need additional development? What metrics do you use to compare each assessment?
ERCOT use commercial software for this type of analysis. They have all the capabilities we need but we don't have data to model some uncertainties like stochastic wind and solar profiles, gas supply uncertainty etc. We usually compare loss of load hours, loss of load expectation and expected unserved energy. (J. Jin, ERCOT)

4: Does the current 1 day in 10 requirement need to be revised? Is that risk threshold applicable for a modern power system?
The 1 day in 10 years requirement has been subject to a lot of scrutiny recently. As far as a requirement based on frequency goes, it has served this industry well for decades and the metric has not yet shown itself

insufficient for assessing frequency. That said, as more and more critical infrastructure depends on our grid, we should monitor whether consumer expectations on reliability change. (A. Lafoyiannis, IESO)

Where I think we *should* revise our thinking is on whether a frequency metric is enough. We need to think about duration of events and magnitude, as well as root causes to be able to plan our system to be reliable. (A. Lafoyiannis, IESO)

The main problem of the LOLE metric is that it doesn't provide the duration or magnitude information of the loss of load events, so loss of load hours (LOLH) and expected unserved energy (EUE) need to be calculated as well. (J. Jin, ERCOT)

5: Communications between operators and planers has improved over the years. What are your companies doing to avoid silos and ensure that new scenarios and solutions include both O&P perspectives?

ERCOT operations and planning work on many projects and various reports together. ERCOT has developed tools like Seven-day Grid Outlook and Trend Analysis Tool which includes operators log and all real-time and historical information for the whole system. ERCOT operations and planning teams also have frequent day-to-day communication. (J. Jin, ERCOT)

Don't need to add this, but just in case it's helpful - We are new to resource adequacy studies, but we are involving our operations team in reviewing all assumptions & results as we go along to ensure we are appropriately capturing their view of risk. (K. Messamore, Evergy)

At the IESO, we created a new department last year to focus attention on exactly this challenge. The team is comprised of a diverse set of staffs – with experience from operations, procurements, planning and stakeholder relations roles. The team monitors the control room experiences, and works with staff in operations to understand risks on the system today to ensure that they are factored into planning. Similarly, the team translates planning studies into actions – sometimes that is requirements for future acquisitions, but in the future, it could include areas to improve operational procedures or processes. This team works closely with planning to scope their studies. (A. Lafoyiannis, IESO)

6: Question for Kayla Messamore. How do you manage planning for an energy reliable system while performing an optimal capacity expansion plan? Do your systems co-optimize energy and capacity or how are both considered when solving the energy and capacity problem?

The capacity expansion model does co-optimize energy and capacity *value* (cost to customers) while trying to meet a required reserve margin, but it does not necessarily look at energy reliability in a probabilistic way. We tend to use things like energy balance (i.e., dependence on market purchases), fuel diversity, reserve margin and resource accreditation assumptions (looking at both summer & winter) to inform our assessment of the reliability of a given plan. We are also evaluating additional reliability-focused (probabilistic) modeling which we hope to use to supplement our capacity planning in the future, in addition to informing our work on resource adequacy topics with our ISO. (K, Messamore, Evergy)

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Panel #3 – Research and Development

1: What level of detail is needed to model energy reliability assessments in terms of gas pipelines, variable generators, or energy storage at operational and long-term planning horizons?

The effect of gas pipelines can be assessed by first studying scenarios with the expected effect on generators to get a sense of the effect of those outages. Depending on the outcome of those scenarios, the modelers should decide whether building a more detailed analysis would be worth it. It is not uncommon to rely on models external to the main resource adequacy software for further estimate how those impacts should be incorporated.

For variable generation it is common practice to model generation at an hourly level. Those profiles are usually based on historical generation data or reproduced with historical weather data and the modeling should include as many years as possible to better capture variability between years.

For low levels of energy storage, particularly short-term storage, it is usually sufficient to pre-dispatch the storage to charge during low net load periods and generated in lo net load periods (net load being load minus hourly-based resources, such as wind and solar PV). This approximation can generally be used until the hours of risk start to shift and don't align as well with times of discharge. One can also use specific storage models for resource adequacy software. (E. Ibanez, GE Energy Consulting)

EPRI has identified this topic - the level of detail required for energy assessments – as a key research area. Part of EPRI's ongoing "Resource Adequacy for a Decarbonized Future[1]" effort is looking at the level of modeling granularity needed for ensuring you properly capture the risk in operations or in planning. One of the things we have been looking at is developing risk profiles based on the impact that a given issue (say, modeling of gas network) will have on the overall outcome for a given system. Every region will be different based on their resource mix, the weather, and other factors that impact on energy availability. Some of this risk can be calculated quantitatively based on historical data (with adjustment for future conditions such as climate projections), while other risk may have to be dealt with on a categorical basis (i.e. it is a risk worth examining or not). For example, a region with a strong likelihood of gas network limitations (such as one at the end of a gas pipeline) may need to perform a more thorough examination of the likelihood of pipeline failures with a more complete model of the gas system than one that has a stronger gas network or less reliance on gas, where sensitivity analysis may be suitable[2]. From a research perspective, we are testing the assumptions as part of the above project and looking to develop guidelines for assessment practices. As an example of how that may work, EPRI recently examined different potential modeling options for hybrid renewables plus storage plants and showed that certain aspects, such as the specific technologies being

[1] https://www.epri.com/resource-adequacy

[2] https://www.epri.com/research/products/000000003002019300

coupled, whether they were ac or dc coupled and whether they provided reserves were more important than factors such as their specific charging mode in determining their contribution to adequacy[3].

In an operational time horizon, it will be more important to capture some of the detailed interactions, but at the same time the number of different outcomes that might arise in the coming weeks will be significantly lower than when looking at a long term planning time frame – as such more detailed modeling would be appropriate. EPRI has been developing methods to simulate operational conditions under high renewable penetration and shown that it is important to be able to consider risk of shortfalls when setting things like reserve targets. By modeling operating decisions in detail from day ahead to real time, and with uncertainty included through probabilistic methods, one can get a better picture of the reliability implications (see Operational Probabilistic Tools for Solar Uncertainty (OPTSUN)[4] for more details). (A. Tuohy, EPRI)

All of these factors are important to consider. The level of details in modelling depends on how important these factors are for a given system. If the system is gas generation based, it is important to consider dependencies of power supply on gas supply and ambient weather conditions. For systems that are high on variable generation it's important to consider continues one 8760 hours of operation across many future scenarios (e.g. high economic growth scenario; high gas price scenario etc.) and across many weather years to capture impact of various weather conditions. ESIG's report Redefining Resource Adequacy for Modern Power Systems[5] talks about the factors that matter for the assessment but decision of level of detail depends on each system characteristics as well as computational time limitations. (J. Matevosyan, ESIG)

2: What are the data requirements to perform and improve energy assessments? Are these datasets available for both the development and application of the methods and tools?

The data requirements vary from region to regions and largely depend on the energy mix, weather patterns and expected evolution of the system. These are some of the most common data needs for energy assessments:

- Load understanding load profiles is critical and this is usually accomplished by collecting historical data. It is important to try to understand the effects of behind-the-meter resources and other changes in the composition of the load, as shifting load patterns are expected to evolve over time
- Load forecast uncertainty: Load forecasts is still one of the biggest drivers of resource adequacy models and it is very helpful to rely on a distribution-based approach to forecasting, rather than a single 50/50 forecast
- Variable generation: As with load it is important to understand the patterns for wind, solar and other variable generation sources. This is usually achieved with multiple years of historical generation data, either actual or simulated (through numerical weather models)
- Hydrological conditions: the ability of hydro power to be dispatched and balance the grid could have a tremendous impact on the ability of a system to procure energy.

[3] https://www.ferc.gov/sites/default/files/2020-07/Panel-4-Ela-AD20-9-000.pdf
[4] www.epri.com/optsun
[5] https://www.esig.energy/resource-adequacy-for-modern-power-systems/

- Transmission outages: Similar to generators, transmission assets suffer outages, which affect system reliability. Historical data to characterize the most common outages is crucial.
- Emergency assistance: The ability of a system to rely on neighboring areas for imports of firm capacity, but that assistance should consider stress factors that could be reducing its use during times of need
- Common-mode of failure data: understanding that not all failures in the system are independent

Most of these datasets are typically available of can be developed at regional levels by system operators. However, they are not always as accessible or available for researchers that don't have direct access to system operators. (E. Ibanez, GE Energy Consulting)

Data is an important factor for energy assessments. Ongoing work EPRI has with ISO-NE is focused on developing datasets that start with long time series datasets for weather, including decades of historical data (40+ years), together with climate projections (for different climate pathways) to come up with a distribution of data for relevant variables such as temperature, wind speed, irradiance/cloud cover, precipitation, and so on. This data can then be sampled and used with power system information (e.g. load data, wind/solar locations, capacities and technologies, gas network information, generator information, etc.) to develop inputs for energy adequacy tools. It is important that such datasets come from a common underlying data source to capture relevant correlations, that they have the appropriate level of temporal and spatial granularity, and that they sufficiently cover extreme events. In the future, such extreme events may not just be extreme temperatures, but also include periods of prolonged low wind speed or other related aspects that would result in energy deficiencies. As part of the EPRI resource adequacy effort, we will be making a tool available for developing scenarios such as these that can be used in assessments. We are also carrying out case studies to prove the concepts, with results expected later in 2022 and early 2023. (A. Tuohy, EPRI)

As mentioned in the answer to question #3 ideally, gas supply information is needed (if a system is highly dependent on gas-fired generation), many years of weather data with at least hourly resolution and corresponding load profiles, wind, solar (rooftop and utility scale) production profiles; weather dependent generation outage information is preferable (but rarely available today). ESIG's report Redefining Resource Adequacy for Modern Power Systems[6] also talks about some of the data requirements for comprehensive energy reliability assessment. ESIG is currently working on the report to highlight the importance of consistent weather data set in energy reliability assessments, identify need for and specification for comprehensive North American weather data set. Relatively good solar data set is available from NREL NSRDB[7], however the wind data base includes only seven years of data[8] , which is insufficient to capture weather distribution. (J. Matevosyan, ESIG)

[6] https://www.esig.energy/resource-adequacy-for-modern-power-systems/
[7] https://nsrdb.nrel.gov/
[8] https://www.nrel.gov/grid/wind-toolkit.html

3: More than one panelist mentioned economics. What is the appropriate balance between reliability and cost?

The balance of economics and reliability should be a consensus to be achieved by the appropriate regional and national stakeholders. (E. Ibanez, GE Energy Consulting)

Economics should be considered in a number of ways. As energy deficiencies can be driven by how a given set of resources is operated (e.g. with storage, whether there is energy available when needed), the economics are an important factor to consider when understanding those resources contribution to reliability. This can help design incentives for new or existing resources, e.g. through pay-for-performance in a capacity market or through demand curves for ancillary services products. Economics should also be considered when determining the suitable metrics to use and in setting the criteria for whether a system has sufficient energy. (A. Tuohy, EPRI)

To be able to answer that question reliability needs to be valued in dollar terms first, until then any balance struck is based on pre-defined reliability metric which not necessarily is very meaningful such as 1 event in 10 years. What does this metric mean in reality, how much energy is lost in that one event and for how long? (J. Matevosyan, ESIG)

4: With the advances in new nuclear generation options, how do you see nuclear generation fitting into the energy mix in the future?

Nuclear can play an important role in the future, depending on its relative costs and performance versus other resources. EPRI's Advanced Nuclear Technology program[9] is researching such new technologies. (A. Tuohy, EPRI)

As with any technology, it's all based on economics new nuclear generation options are cost effective and considered safe option to provide energy and essential reliability services (including energy/capacity adequacy) in a given market these will be built. (J. Matevosyan, ESIG)

5: Question for Josh Novacheck. Could you share more about the collaboration with NERC on studying weather related outages as was done for PJM? What is the expected timeline?

The PJM outage information was conducted by Sinnott Murphy while a PhD student at Carnegie Mellon University. You can find a couple of journal articles he published here[10]: The articles also link to where results of the data analysis could be accessed. Sinnott now works at NREL and is actively collaborating with NERC to extend the analysis beyond PJM. Initial results from the analysis are being used in the beta version of the NAERM Cold Wave Report and we hope to have a publication ready for peer review in September. We'll continue to work with NERC on making the results available to industry stakeholders. (J. Novacheck, NREL)

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[9] www.epri.com/portfolio/programs/065093

[10] https://doi.org/10.1016/j.apenergy.2019.113513 and https://doi.org/10.1016/j.apenergy.2019.114424