Meeting Notes

U.S. Department of Energy
Quadrennial Energy Review
Technical Workshop on
Resilience Metrics for Energy Transmission and Distribution Infrastructure

Offices of Electricity Delivery and Energy Reliability (OE) and
Energy Policy and Systems Analysis (EPSA)
Tuesday, June, 10th, 2014
Brookhaven National Lab

These notes are intended to be an accurate representation of the presentations and discussions occurring during this workshop.

Purpose

The purpose of this workshop was to seek feedback from stakeholders on proposed resilience metrics for energy infrastructures that transport, transmit, and deliver electric power, natural gas, and oil in the United States. The information shared at this technical workshop will feed into the analysis conducted by the U.S. Department of Energy (DOE) and other federal agencies for the purpose of preparing the Year One Quadrennial Energy Review (QER) Report. This workshop served as a follow-up to the Energy Resilience Metrics workshop held on April 29, in Washington, D.C.

Workshop Timeline and Meeting Notes

9:00 – 9:15 Introductions and Purpose, EPSA

Kate Marks (EPSA) welcomed and thanked the attendees. She welcomed an introduction from Doon Gibbs, Director of Brookhaven National Laboratory (BNL).

Doon Gibbs (BNL) welcomed the attendees to Brookhaven and offered some background of the laboratory. He highlighted Brookhaven's science-oriented mission, as well as his personal interest in renewable energy integration and energy storage.

Kate Marks (EPSA) then recapped the results from the April 29th workshop that was held in Washington, D.C., summarizing the following key points:

- Leaders of the various sectors of the energy industry are committed to improving resilience of our energy infrastructure.

- The industry is currently addressing specific aspects of resilience, while it was agreed that a comprehensive approach could help to drive policy and planning decisions (meaning, investment priorities) on a larger scale.
- Industry representatives cautioned that the incorporation of resilience metrics into a regulatory framework should have minimal impact on reporting requirements.
- The framework presented was well-received. The audience expressed eagerness to put it to use, while stressing significant research and development (R&D) needs.

Ms. Marks next presented the purpose of this June 10th workshop – namely feedback and recommendations on the information to be presented by Sandia National Laboratories (SNL) – and gave an outline of the upcoming presentations. In closing Ms. Marks reminded attendees that they were invited because of their specialized knowledge and expertise on resilience metrics. She went on to say that attendees were chosen to provide a range of experiences on the topic and were encouraged to share their independent personal views based on their expertise and experience relevant to the resilience metrics. Ms. Marks explained that it was not the intent nor were attendees being solicited by the Department to reach a consensus on any matter or was it the desire of the Department to receive formal or informal group recommendations; rather, the purpose of the event was to seek as many recommendations as possible from all individuals at this meeting. Ms. Marks added that to most effectively use the limited time, attendees were asked to refrain from passing judgment on another attendee's recommendations or advice and instead concentrate on their own individual experiences.

9:15 – 10:15 Energy Resilience Metrics Framework, SNL

Charles Hanley (SNL) thanked EPSA and others for the opportunity to present the metrics framework and gave the audience a chance to introduce themselves. He stated the goals of this meeting to be: demonstrating a resilience metric framework, providing examples, soliciting input, and building a team for further research and implementation. Mr. Hanley presented the motivation of this work as developing input for the Quadrennial Energy Review with regard to measuring the resilience of energy infrastructure systems. The definition of resilience that SNL is using comes from Presidential Policy Directive 21, with rationale from the National Academy of Sciences report *Disaster Resilience: A National Imperative.* After discussing this rationale, he entered into the proposed process for developing, using, and benefiting from resilience metrics in the energy sector. The steps to this process are: define goals, define the system and metrics, characterize threats, determine the level of disruption, define and apply system models (to estimate system performance), calculate consequence, and evaluate resilience improvements. He stressed that the framework for the resilience metrics fits within this process as the metrics are created, populated, and finally applied to a decision.

An attendee asked if the slides presented would be available, and Ms. Marks claimed they would be made available on the workshop website. In addition a report will be made available to DOE by the end of June that will incorporate feedback from both workshops.

The same commenter asked to keep alive the question of how models dealing with resilience will be validated. Another attendee claimed that the question of how hardening fits into the resilience metric process has not been addressed, and a third commented that self-healing must fit into the framework as well. Mr. Hanley answered that these are components or concepts of resilience and they all are reflected by the metrics. Ross Guttromson (SNL) added that SNL will present the metrics framework, but what populates the metrics is up for discussion and potentially worthy of research and development.

Bobby Jeffers (SNL) took the podium to introduce the resilience metric framework and how it would be used in a hypothetical planning instance. He showed that the framework is designed to be useful for multiple decision makers, multiple types of decisions – including planning, operations, and policy decisions – and multiple types of threat. In his hypothetical example he showed how a public utility might use the proposed resilience metrics to make a planning decision about how to prepare for hurricanes. He then showed that a direct link could be made between the resilience goals of the decision maker, the measures of performance for these goals, and the final measures of consequence that ultimately describe how systems perform under disruption in terms of things the decision maker cares about. In this case, Dr. Jeffers linked the goals of delivering energy at reasonable cost for a productive public to measurements/simulations of energy not delivered, increased cost of system operation, and decreased labor hours.

A discussion between the attendees and Dr. Jeffers questioned the use of energy not delivered as a viable indicator of performance under threat, since demand and supply may be heavily interdependent in these cases. Dr. Jeffers acknowledged the difficulty of analyzing supply and demand separately, and agreed that “load available” may be an acceptable measure of demand during an extreme event, which could then be compared to an estimate of available capacity to serve load. He highlighted that creating a baseline measurement for comparison is important to developing useful metrics, and that “energy not delivered” was useful for presentation of the framework in this respect.

Another attendee stressed that after recent extreme events it is clear that utilities need to understand how their communities work and be able to provide some level of support to basic functions (e.g., safety, security, etc.) that increase consequences. He posed a question for the upcoming discussions: how much information should utilities include and how do they coordinate with the multiple stakeholders that control this overall consequence?

Dr. Jeffers continued with the presentation, showing that the proposed resilience metric is a probability distribution of consequence of the considered system to the considered threat(s). The stated reason for the probability distribution instead of a single number is the large amount of uncertainty in the performance of these systems under threat. He stressed that a single decision maker could use as many resilience metrics with as many units of consequence as needed. He then contrasted these metrics that describe system performance with characteristic-based metrics that count assets or fill checklists, claiming that the two approaches are complimentary but ultimately a performance-based metric will better inform decisions because the goal is often to improve performance. He presented the process that a utility may go through, of calculating performance during a hurricane in comparison to a baseline, integrating this performance over time and converting to units of consequence. He then presented how this measurement should take uncertainty into account, stating that this step is usually done by using one or more models and varying their parameters over multiple runs. He showed that the culmination of multiple measures of consequence and their associated probabilities can be described by the consequence distribution function, which is the proposed resilience metric. He posited that once the appropriate range of uncertainty is accounted for, this distribution describes the utility's resilience to hurricanes, instead of a single hurricane. Finally, Dr. Jeffers presented how a decision maker could compare two distributions to make decisions on courses of action such as investment or policy. These distributions represented alternative improvement decisions, and one distribution exhibited lower average consequence, as well as less area in the upper high-consequence tail, indicating a more resilient system. He concluded by leaving the audience with two questions related to the potential use of these resilience metrics: what new tools, models, techniques are needed to populate these metrics, and who are the decision makers, what are their goals, how can the metrics fit into their current process?

A discussion was initiated by a representative of an electric utility regarding the designation in the presentation of public utilities versus Investor Owned Utilities (private utilities). Dr. Jeffers referred to a public utility as that which is commonly managed and owned by a municipality or other level of government. The utility representative offered that many of what Dr. Jeffers refers to as IOUs (private utilities) have an obligation to the public interest, often through regulation by the state Public Utilities Commission or a similar agency.

One attendee found the presented shape of the SNL illustrative consequence distribution (the illustrative resilience metric) as odd, claiming to expect an exponential distribution with the highest probability of consequence at zero. Dr. Jeffers agreed that this may be the case for normal operations, but claimed that the resilience metric as presented considers only threats of potentially high consequence (e.g. hurricanes, earthquakes), and ignores many low-level threats that would already be considered under metrics for reliability. Therefore very few threats would be expected to have zero consequence, driving the distribution's peak to the right.

A commenter raised that long term planning can be based on this type of probability distribution, but that short-term planning should be based on a well-understood list of pre-defined events with risk measured by the probability of surviving these events. Therefore, to incorporate resilience in operations, the current accepted definition of risk must be broadened to account for multiple high-risk events. He recommended that this philosophy be applied to many other infrastructures.

Another attendee commented that they did not explicitly see restoration and recovery within the metric. Dr. Jeffers pointed out that since the process as presented specifically includes performance over time; faster recovery would lead to an improved resilience metric, all else being equal.

9:15 – 10:15am Presentation of Electricity Resilience Metrics in a Use-Case Context, SNL

Jean-Paul Watson (SNL) addressed the audience to present the use of the proposed resilience metric framework to analyze the resilience of an electric grid. He began by stating that resilience metrics can first provide a solid baseline for comparison of alternatives. Beyond this however, he offered that resilience metrics can be used for a more consequence-focused operations and planning. Using the IEEE 118 bus test case against a simulated hurricane event, Dr. Watson presented how the resilience metrics help assess the baseline resilience, evaluate the improvement in resilience due to alternative investment decisions, and how one might optimize the investment alternatives themselves to decrease expected consequence. His example metric of consequence was the economic loss compared to the system without a hurricane event. He expressed how the choice and prioritization of which threats to address could be formulated using a scenario tree, with multiple levels of detail depending on the questions being addressed.

To calculate the expected consequence given multiple realizations of a hurricane, Dr. Watson used a base model of how the IEEE 118-bus power system serves expected load, augmented with a translation between unserved loads at multiple busses to economic consequence. He uses an optimization model as a mixed-integer program, but stresses that the choice of model is not dictated. He uses normal distributions to assess the uncertainty of the impact of a certain threat. In response to earlier discussion, Dr. Watson commented that the effect of loads not being available to accept power could be captured using individual models of those loads, with a similar translation to consequence. He then presented the results from the analysis of hurricanes on the IEEE 118 system as a histogram of consequence, and stated that it depends on one’s risk stance as to how to compare these distributions.

Dr. Watson presented research he has been leading on consequence-driven dispatch, in which the algorithms that control dispatch on the grid are changed to minimize consequence instead of minimizing operation cost. This research incited comments as to who gets to explain that an algorithm turned off lights in someone’s house to save a factory. Another commenter noted that in a sense the regulations would help drive this. Dr. Watson added that these types of constraints are simple to add to the algorithms, and the key is in exposing these types of decisions so that the public can debate how they want the system to perform under threat. An attendee claimed that this type of prioritization is something the public and private sectors are already discussing.

Dr. Watson highlighted that models of recovery and restoration are currently lacking for the power grid, and so he used a simple relationship between a fixed budget and recovery. A discussion then picked up with the audience over how to account for new concepts related to recovery that the system operator has no experience with, and there appeared to be agreement that these types of models will need to be improved through R&D.

Another discussion focused on the use of more than one measure of consequence and how to convey a decision when there are three or more resilience metrics as described here. Dr. Watson mentioned that this is possible with the framework, but the critical work is in addressing a multiple-metric situation with statistical rigor as well as effectively communicating the trade-offs to multiple stakeholders inherent in this type of decision.

The presentation continued with an analysis of alternative long-term investment portfolios on the same hypothetical IEEE 118 system. Not only did Dr. Watson ask which portfolio was better, but he also mentioned that research must go into how resilience improvement affects nominal (e.g. reliability and efficiency) operations. He contrasted two distributions that represented the improvement alternatives and showed how both improved versus the baseline, but one had lower expected consequence, as well as lower probability of extremely high consequence (the upper tail in this case). He also showed how his algorithm can optimize the investment decision using a combination of the alternative portfolios.

Comments from the audience centered on the interface between transmission and distribution as being non-optimal, pointing to a greater need for global simulation and optimization over the coupled transmission-distribution network. Attendees pointed toward the need for more concentration on the distribution network than has been presented to date. Furthermore, real-time automation to improve recovery and response was highlighted as a key R&D need. A caveat was mentioned that other models in addition to optimization will likely be needed as the details of the resilience-improvement process are discussed.

A participant complemented Dr. Watsons approach, adding that it’s important to identify and categorize vulnerabilities through cause and effect analysis of infrastructure, which would supplement the presented approach by decreasing uncertainty in the effects of disruption on the physical and human systems.

An attendee asked what metrics other than economic consequence are being considered, and Dr. Watson answered that the general categories are financial, safety, security, and environment.

A discussion was held over the amount of information and data needed to be shared, and how uncertainty surrounding low probability events could lead to misunderstanding of the potential consequences. An attendee mentioned that there may be pushback when the metrics go against common perception or historic knowledge, but also that institutional knowledge is important and must be captured. Dr. Watson added that this approach allows for small steps to be made at first, and that some model and data – when used correctly – are better than no model and data.

1:00 – 2:00pm Presentation of Oil Resilience Metrics in a Use-Case Context, SNL

Tom Corbett (SNL) presented the use of the resilience metric framework for assessing the resilience of the U.S. oil infrastructure to a New Madrid earthquake. He began by giving background on the threat and potential vulnerability to a New Madrid earthquake. Some of the largest earthquakes to hit the continental United States have been in this area. He overlaid a map of the earthquake threat level, measured in shaking intensity, with a map of the U.S. oil infrastructure. Dr. Corbett claimed that the US system is heavily interconnected and interdependent, so modeling the entire system is important. He showed that 4 oil transmission pipelines could be damaged by a New Madrid earthquake. His source of uncertainty for this example was the time to repair the damaged pipelines. He described his simulation model, which is able to include changes to attributes of the system and translate this to performance over time. The results of his modeling show a consumption shortfall, with a price that's heavily related to supply, and a demand closely related to price. Dr. Corbett highlighted that there may be other drivers to demand during this event that he has not modeled. His model also calculates how long it takes to replenish inventories after the conclusion of the event. The sum of consumption shortfall over multiple areas that are impacted are his indicator of performance.

Dr. Corbett then showed the connection of uncertainty quantification for probability of repair times to the creation of a histogram of his performance indicator. Even though the outage times assumed were skewed toward shorter durations, the histogram of total shortfall skewed toward higher impacts, something that Dr. Corbett claims highlights the usefulness of a descriptive model. This performance metric was transformed to consequence using a price versus consumption curve for an overall distribution of cost which is his resilience metric.

Dr. Corbett then presented the use of the resilience metric for investment decisions, describing two options for enhancement through seismic hardening of the pipelines. By running through the process again he showed that one option reduces the likelihood of cost being over $2.2 billion from 1 in 3 to 1 in 10.

An attendee mentioned that the overall cost of oil might be actually lower if there were rationing and/or people decided to telecommute. Dr. Corbett replied that he has seen cases where this type of cost is lower during the disruption, but that this is dependent on one's point of view and how they define the market. For example, there may be an unaccounted cost of people working from home.

An attendee from the natural gas industry commented that the model is a good representation of the system and that price structure is an important arbiter of shortages. Added complications arise when the interdependencies with loads and other systems, as well as the shifting of loads, comes into play. Also, many disruptions don't show their affects until long after the initiating event, such as hurricanes in summer affecting prices in winter.

A national laboratory representative asked how established this type of modeling was, and Dr. Corbett replied that the industry does not yet use system-wide dynamic models such as this with the caveat that today's discussion was not focused on individual models. The attendee asked whether import and export were having an effect, to which Dr. Corbett replied that the time to recover inventories is typically longer than the time of disruption, which may impact performance if multiple events occurred closely in sequence.

Observations from the oil industry were that: 1) someone is paying, regardless of consumer or supplier; 2) Dr. Corbett expects to see a tremendous pickup of regional trucking on the consumer side; and 3) the assumption of fuel as being one large bucket is a good way to simplify the problem. He claimed that it would be interesting to see if the supply closely follows dynamic demand now that the industry has gone "off shore." Dr. Corbett responded that updating the model rapidly is one of his near term goals.

A participant asked whether refineries could be a point of disruption, in contrast to the transmission infrastructure presented here, to which Dr. Corbett responded that the refinery capacity does impact performance and is included in this model, but does not have the wide-reaching consequence that a transmission outage would have.

2:00 – 3:00pm Presentation of Gas Resilience Metrics in a Use-Case Context, SNL

Jim Ellison (SNL) presented an example evaluation of resilience of the Southern California (SoCal) natural gas system to a large San Andreas Fault earthquake. He compared the resilience of this system with historical storage withdrawals to one with increased available storage withdrawals. He defined the system as the SoCal portion, including the Mexico gas network, but modeled the entire North American network for completeness. Mr. Ellison chose the units of his resilience metric to be the economic impact caused by delivery shortfalls and accounted for the uncertainty in restoration time for the damaged components. For the natural gas system, production is more or less constant while demand is seasonal with storage bridging the difference. The Alysso Canyon storage facility is one of the largest in the United States and is located within the SoCal area. The threat is defined as the "shakeout scenario" by the United States Geological Survey, and Mr. Ellison assumed this occurred in December, a time when storage is drawing down and demand is high. He showed that disruption to two transmission corridors is likely, with a third possible, and that only these three lines supply the Los Angeles basin. His model is called the gas pipeline competition model (GPCM), which is a network model that performs competitive partial equilibrium. He showed, using this model, that the natural gas system is somewhat resilient because of rerouting and storage capability, as well as the supply-demand-price relationships.

Solving the model for three cases – the base case with no earthquake, the restricted storage withdrawal, and the unrestricted withdrawal – Mr. Ellison showed that with unrestricted, the expected supply shortfall was 25%, while with the restricted case it was 50%. Translating this to consequence, Mr. Ellison assumed repair time uncertainty was normally distributed and showed similarly normally distributed estimates of overall economic impact. However, with the unrestricted case, the mean consequence was not only lower but the distribution was tighter (thinner).

An attendee from the natural gas industry commented that complications arise because economic impacts are distributed differently, in that some distribution companies have higher consequence, and therefore higher incentive to build storage than others, even though the overall economic impact may be the same. He highlighted the need for clear price signals related to resilience.

A participant mentioned that Mr. Ellison did not account for how the distribution system in Los Angeles may do in such a quake, to which Mr. Ellison responded that the demand side is a needed area of research. However, the transmission's ability to supply a nominal demand is still a useful metric. An overall comment from many attendees in this regard was that supply resilience and demand resilience should not be calculated in a vacuum, but should be considered concurrently using coupled simulations and cooperation between stakeholders. An improvement in supply resilience without an improvement in demand resilience may not actually lower overall consequence.

Several attendees agreed that a suite of models would be needed for different decisions. For example, being able to prepare quickly before an expected event would require a different set of tools than most investment decisions. This was followed by a comment that the group should decide who will be using resilience metrics and who will benefit most from them. Additional comments centered on the need for further consideration of holistic consequence given the interdependencies between energy systems, and with communication, financial, and humans systems.

3:15 – 5:00pm Framing of a Resilience Roadmap: Implications and Consequences of Introducing New Energy Resilience Metrics, SNL and Breakout Groups

Ross Guttromson (SNL) took the podium to open a discussion about the path forward, stating that the presentation of a resilience metric framework is only the beginning of improving resilience for energy systems.

Comments were fielded about the lack of an emphasis on rapid recovery and the risk that organizations are willing to accept given this high level of uncertainty. A participant commented that his research has found that the ability to recover directly equates to the performance during extreme events, and that hardening only goes so far. Mr. Guttromson agreed, saying that recovery and adaptation are co-integrated and do fit into the framework presented.

An attendee from the DOE observed that the presentation lacked a process for evaluating the resilience metrics (e.g. what makes a good resilience metric, and how does that metric capture the most important aspects of resilience such as recovery and adaptation). Mr. Guttromson claimed that the framework does capture these aspects and that this evaluation will be performed in the future. The DOE representative suggested that meta-models be developed that guide future population of the metric.

Other attendees commented that the operators, engineers, and users of the systems should be involved at an early point so that the metrics have validity. Expert elicitation should be a central component going forward.

Mr. Guttromson also highlighted that the system owners and operators, e.g. the utilities, are not the only stakeholder of interest, and that the metric should better define the benefit or consequence to the overall society. This will help guide top-down recovery or investment decisions and help figure out who pays for improved resilience. While the resilience metrics are a critical piece of this process, feedback is needed on the best eventual overall process for using these metrics.

Charles Rath (SNL) next organized five breakout sessions based on topics generated by the audience. These breakout sessions were led by attendees, not SNL or DOE representatives. The goal of these breakouts was to elicit challenges and opportunities for using and implementing these resilience metrics going forward. Attendees were encouraged to roam from issue to issue. The issues were:

- Defining end user needs for resilience metrics
- Establishing R&D priorities
- Facilitating industry adoption
- Promoting standard methods
- Defining the role of government and utilities in enhancing resilience

A brief summary of the feedback from these breakout sessions is included:

End User Needs

Challenges

1. Who is the end user? Spans different costs and benefits (fundamentally cost-benefit analysis), therefore different values of resilience for different users. How do you reconcile different approaches (i.e., e in some sense the PUC should be stepping above what gas/electric utilities want, and should reconcile with public benefit)?
2. Application of techniques is complicated when measurement and characterization of uncertainty is difficult.
3. How do you communicate to end users the value of science-based rigor to risk assessment and cost-benefit analysis?
4. Complicated to define scope given interdependencies among different types of infrastructures.

Opportunities

1. Begin by applying approaches retrospectively to big events.
2. Stakeholder engagement and outreach – show the users the benefits of resilience. Demonstrate value and get everyone discussing whose risks are traded and whose costs/benefits are assessed.
3. Empowering customers – what do they get for what they pay, and what are they expected to do on their own?
4. Potential for new business models: selling resilience.
5. Leverage current reliability risk management process and build resilience metrics into existing models that end users already have in place (e.g., state energy assurance plans)
6. Drive the cost of resilience down, e.g. resilience choices up drives demand

Proposals

1. Retrospective application
2. Engage and outreach to users
3. Define and discuss new business models (e.g. utilities owning microgrids)
4. Recognize side-benefits of investing in resilience, or resilience benefits of investing for other reasons

Establishing R&D priorities

Challenges

1. Accurate and comprehensive definition of resilience – not just examples
2. Data collection and analysis – real data
3. Baseline or benchmark for resilience metrics. If town is wiped out again, what level of service do we want to achieve?
4. Interdependencies between infrastructures
5. Computational challenges – really hard optimization problems, no technology to solve in real time right now.
6. Cascading events – not very good definitions or theory to handle this.
7. System integrity metrics – at what point to you lose integrity of whole infrastructure?
8. Big data – models that don't exist – how to populate for rare events?
9. Competitive barriers and information hiding among stakeholders. Need to expose and cooperate enough to allow resilience
10. Don't penalize those who have already improved their resilience
11. Development of human resilience metrics – what are basic human needs and how are they incorporated?
12. Develop a suite of metrics – cannot have one to rule them all, but need to cover the full space
13. Operational, planning, recovery models don't play well together – integrate what we have

Opportunities (first three are high priority)

1. Consolidate data and model building, including data analytics fusion and inference, including interdependency analysis
2. Design, planning, operation, recovery – take a new look at all infrastructure, are they optimal when resilience is considered? What would make them more resilient? Vulnerability analysis. A number or curve is not enough – must know the causal links.
3. Computation capabilities to achieve automation where it's necessary. E.g. operations, self-healing.
4. Actionable info from resilience metrics
5. Models designed to be valid for extreme events
6. Micro/mini grid and islanding
7. Placement of intermittent gen for improved resilience
8. Crowdsourcing for recovery

Facilitating industry adoption

Challenges

1. Industry are those responsible for infrastructure, and suppliers that supply them
2. The final metrics must be tangible, actionable, and reproducible.

3. Cannot simply fall back on hardware, hardening, etc. Recovery is important. It's not about plans, it's about planning, training, and exercises. How well prepared you are needs to go into the metric.
4. Industry does not want to find themselves in unpleasant financial position, so who is accountable for financially fixing a goof caused by an inappropriate implementation of resilience metrics?

Actions

1. Convening and buy-in of regulators. Almost every state has a utility that operates in another state, so they need to work together.
2. Utilities need to believe that resulting metrics are tangible, actionable, and translatable into appropriate business architecture. Dialogue between regulators and industry, then suppliers turned loose on this set of problems.
3. Must include the human dimension. Humans are not noise. People are not created to demand electricity. Path to recovery is important. People will be fixing, people will be hardening.

Promoting standard methods

Challenges

1. Presenting this so that different people can analyze the same problem and come up with results that are sufficiently consistent for dialogue. Not the same numbers to three decimals, but close enough for meaningful conversation.

Principles

1. Framework fits into multiple models – estimate of threat, damage, so on… but should be one or more standard models in each piece of process. Relentless in defining abstraction between the models, so new and better models won't break entire stack.
2. Abstraction – host and implement models from a shared environment (e.g. the cloud).
3. Hard data says execution of models takes 5% of time, data collection 80%. Define models to use data that models are already collecting, and formats that they are already using.
4. For things that are hard/impossible to estimate, get best people together to produce best estimates, publish and get everyone to use them.
5. Standardize outputs – all tools and products produce similar tables for everyone as default, allow comparison of your data with anonymized aggregate of comparable organizations. Get people to compare themselves to the best.
6. Common data store – accessible to SAS, MATLAB etc.
7. Social framework – get people talking about the models and data they're using. Exchange ideas. Create a nexus for driving resilience.
8. Fractal approach to scale. Approach consistently across scale so they can talk with each other.
9. Ask everyone their hypothesis before they analyze. Why do models sometime disagree with hypotheses? Don't want people to adopt the model output, but to THINK about them.
10. There are disasters all the time. If you look at the whole energy system, there will be floods, ice storms, winds, tornadoes; there is enough data there to validate many new models.

Defining the role of gov't and utilities in enhancing resilience,

The primary comment from this breakout was that there is a great deal of consistency and overlap between groups.

Actions

1. Demonstrate resilient and robust designs with projects, on the order of 100 demonstrations
2. Build on existing energy assurance plans. Identify infrastructure and needs, consistent definition of critical infrastructure, common interdependencies, and vulnerabilities.
3. Identify and disseminate best practices and lessons learned

Closing

Kate Marks thanked the attendees for their input and feedback on resilience metrics and said the information will be used in the QER. She also mentioned the 17 stakeholder meetings across the country related to this and other aspects of the QER, and reminded participants that DOE is accepting written comments at <www.energy.gov/QER>. Discussion around the challenges and opportunities will continue through communication, added Ms. Marks, and feedback on specific metrics should be addressed to Dan Ton (DOE-OE).