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Performance Metrics to Evaluate Utility Resilience Investments

Designing Resilient Communities: A Consequence-Based Approach for Grid Investment Report Series

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ABSTRACT

In 2019, Sandia National Laboratories (Sandia) contracted Synapse Energy Economics (Synapse) to research the integration of community and electric grid resilience investment planning. Synapse produced a series of reports to explore the challenges and opportunities in several key areas, including benefit-cost analysis, performance metrics, microgrids, and regulatory mechanisms. This report focuses on performance metrics. Performance metrics define the information that utilities, regulators, and other stakeholders can use to monitor and improve grid performance of resiliency investments.

Electric grid resilience can be improved through investments, such as transmission and distribution systems, generation, and automation and controls. However, the data to track and report the performance of these grid resilience efforts are still in development. To date, there is no industry consensus on the data to evaluate the performance of investments intended to create a more resilient electric system. The purpose of this report is to guide jurisdictions to take the important step of defining and establishing performance metrics for resilience that are tailored to their needs and situation. First, we explain the performance mechanism development process. Next, we describe seven principles for developing well-designed performance metrics. Lastly, we provide a menu of performance metrics for grid resilience and discuss their applicability.

Using these materials, jurisdictions can determine where they are in the process of defining and setting performance metrics, define next steps, and take action to improve their understanding of current resilience performance and capture opportunities to improve. The menu of performance metrics for grid resilience described in this report is also provided as an accompanying Excel-based tool which takes the form of a performance metric reporting template. We encourage utilities to take the lead on collecting, organizing, and reporting this data to their regulators and stakeholders in public proceedings, with support from community and institutional partners.

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EXECUTIVE SUMMARY

In 2019, Sandia National Laboratories (Sandia) contracted Synapse Energy Economics (Synapse) to research the integration of community and electric utility resilience investment planning.[1] The research was funded by the U.S. Department of Energy (DOE) and conducted as part of the Grid Modernization Laboratory Consortium (GMLC), under the project named Designing Resilient Communities: A Consequence-Based Approach for Grid Investment (DRC).

The primary objective of the DRC project is to understand and provide guidance on the challenges and opportunities facing communities and electric utilities seeking to coordinate energy-related resilience efforts.[2] The project seeks to demonstrate an actionable path toward designing resilient communities through consequence-based approaches to grid planning and investment, and through field validation of technologies with partners that enable distributed and clean resources to improve community resilience. As part of the DRC project, Sandia is partnering with a variety of government, industry, and university partners to develop and test a framework for community resilience planning focused on modernization of the electric grid.

In support of DRC, Synapse produced a series of reports to explore challenges and opportunities in several key areas, including benefit-cost analysis, performance metrics, microgrids, and regulatory mechanisms. This report focuses on performance metrics. Performance metrics define the information that utilities, regulators, and other stakeholders can use to monitor grid performance of resiliency investments. The purpose of this report is to guide jurisdictions to take the important step of defining and establishing performance metrics for resilience. We do this by providing:

- A roadmap of the performance mechanism development process, which identifies and names the steps in the process, discusses the sequence of the steps, defines key terminology associated with each step, and categorizes the steps as necessary or optional;
- A list and discussion of seven principles for developing well-designed performance metrics;
- A menu of performance metrics for grid resilience and associated discussion, for consideration by utilities and their regulators; and
- An Excel based tool visualizing these performance metrics in the form of reporting templates for utilities to use to track their performance and provide ongoing updates to regulators and other stakeholders.

In the benefit-cost analysis report, titled *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*,[3] we describe how regulators can direct utilities to take the lead on collecting and organizing resilience data by establishing resilience performance metrics. In that report, some of these metrics are proposed to evaluate different resilience solutions as part of benefit-cost analysis. We suggest that utilities act as a central repository for the data and lead the reporting of the metrics. We acknowledge that utilities will not have access to all the data and will need to partner with other stakeholders to obtain key pieces of data. We identify communities as a

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[1] In this research, municipal governments are considered communities due to their broad lens into local, public efforts and investments as well as their decision-making authority. Municipal governments include communities that are both urban and rural and both large and small.

[2] Department of Energy. *New GMLC Lab Call Awards for Resilient Distribution Systems*. September 4, 2017. Available at: https://www.energy.gov/articles/new-gmlc-lab-call-awards-resilient-distribution-systems.

[3] Sandia National Laboratories. *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*. Executive Summary. Figure 1.

key data source and propose that communities provide existing data to utilities directly. We also identify the need for utilities, communities, and other stakeholders such as research institutions to conduct research and analysis to address additional data and capability gaps.

There is no established set of standard performance metrics for resilience, and many of the metrics that have been proposed in the literature require extensive data, modeling, and analysis. The menu of metrics contained in this report, and included in the attached Excel-based tool, is intended to provide a starting point for utilities, regulators, and stakeholders to develop metrics that are tailored to the needs and data available in a given jurisdiction, and which can be quantified with reasonable effort. Because these metrics are achievable, they may serve as a bridge between today's state-of-the-art for resilience quantification and a more optimal ideal proposed by the literature. These metrics focus on annual event-level, customer-level, and system-level performance, while also breaking out performance into important customer and geographic subsegments.

Once roles and responsibilities for developing resilience performance metrics are established, the utilities responsible for leading the effort can propose resilience performance metrics to their regulators.

1. Regulators and utilities can start by holding a technical session to review the suggestions in the Excel-based tool and identify resilience performance metrics of interest.
2. Once a regulator approves the utilities' proposed resilience performance metric reporting template, utilities can populate the metrics using actual data and review the calculations and outputs with regulators and other stakeholders at a second technical session.
3. Utilities can formally file baseline performance metrics in the proceeding of their regulators' choosing and with a frequency that makes sense for that jurisdiction.
4. Once the baseline data is established, the utility, regulator and other stakeholders can work together to identify performance metrics that need improvement and discuss the level of improvement desired.
5. Utilities can explore many investment options to achieve the goals. Utilities can offer programs to promote customer implementation of measures that achieve the desired improvement. Utilities can also implement measures directly to achieve the desired levels of improvement. Utility investment proposals should identify the resilience performance metrics of interest and the impacts of the potential investments on the resilience performance metrics.
6. After utilities select investments to pursue and implement the measures, resilience performance metrics can demonstrate the impact of the investments.

Ongoing review and update of the performance metrics can document progress, allow for adjustments, and identify new opportunities over time. The extent of beneficial impacts can take time – potentially many decades – and therefore this process may require longer time frames than typical for other investments.

ACRONYMS AND DEFINITIONS

Acronym or Term	Definition
IEEE	Institute of Electrical and Electronics Engineers
All days	Includes major and resilience event days
Baseline period	The time period over which data such as the utility's past performance, the performance of peer utilities, or other indicators of desirable performance levels is collected and used for context and comparison with data from the reporting period.
BTM	Behind-the-meter. On the customer-owned portion of the grid.
CAIDI	Customer Average Interruption Duration Index. A measure of the duration and frequency of electric grid outages calculated by dividing the total duration of customer interruptions by the total number of customers interrupted.
CAIFI	Customer Average Interruption Frequency Index. A measure used in electrical reliability analysis. It is designed to show trends in customers interrupted and helps to show the number of customers affected out of the whole customer base.
Critical customers	Customers who are prioritized for restoration.
Critical community services	Customers that provide a critical, or life-sustaining, good or service that is accessible to others.
Critical individual services	Critical customers that do not provide a community service, such as vulnerable residential customers who require additional individual attention due to higher health risks or lower mobility.
Exogenous factors	Outcomes over which the utility has little to no control.
High consequence geographies	Contiguous and non-contiguous geographies, such as communities or portions of communities across states and larger utility service territories, with a high level of expected consequence from threats or events.
Medium consequence geographies	Contiguous and non-contiguous geographies, such as communities or portions of communities across states and larger utility service territories, with a medium level of expected consequence.
FOM	Front-of-meter. On the utility-owned portion of the grid.
Functioning islandable resources	Islandable resources that offer any relief during an event.
Islandable resources	The ability to disconnect a resource from the local utility grid and use the resource to power local load.
Major event days	As defined by IEEE Major Event Standard 1366, a day in which the daily SAIDI exceeds a threshold value, TMED which is calculated as 2.5 standard deviations higher than the statistical mean SAIDI for days with any interruptions in the past five years.
Maximum affected	The highest number affected at any point during an event.
Normal event days	Days in which the electric utility grid does not experience disruptions from threats.
Performance areas	Goals that can be addressed through utility investments in electric grid improvements.

Acronym or Term	Definition
Performance incentives/penalties	Financial motivators that might be needed in specific instances, such as to correct an especially strong utility financial disincentive to achieve some performance targets.
Performance metrics	Metrics define the information that utilities, regulators, and other stakeholders can use to monitor grid performance.
Performance standards	Minimum performance requirements that set baselines for acceptable performance.
Performance targets	Desired levels of performance outcomes that exceed minimum performance standards.
Post resilience event days	A multiyear period after event, similar in duration to the pre resilience event days period. For this report we assumed 5 years.
Pre resilience event days	A relatively recent, multiyear period prior to the event. For this report we assumed 5 years.
Resilience	The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions[4]
Resilience event	A subset of events defined by Institute of Electrical and Electronics Engineers (IEEE's) Major Event Standard 1366 that have a lower probability of occurring, but are longer-lasting, higher-consequence and more spatially widespread when they occur.
Resilience event days	The period over which outages are occurring and caused by the same underlying threat or event.
Reporting Period	The time period over which utility performance data is collected and compared with data from the baseline period.
SAIDI	System Average Interruption Duration Index. A measure of the duration of electric grid outages calculated by dividing the total duration of customer interruptions by the total number of customers served.
SAIFI	System Average Interruption Frequency Index. A measure of the frequency of electric grid outages calculated by dividing the total number of customer interruptions by the total number of customers served.

[4] U.S. Office of the Press Secretary. *Presidential Policy Directive/PPD-21 -- Critical Infrastructure Security and Resilience*. February 12, 2013. Available at: https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

1. INTRODUCTION

1.1. Purpose

The increase in the frequency and severity of natural disasters and the increased risk of cybersecurity breaches is driving broad interest in energy investments with resilience benefits. Electric grid resilience can be improved by investments in the transmission and distribution systems, generation, automation and controls, and cross-cutting measures such as planning, training, microgrids, and performance measurement and evaluation. Resilience events can be caused by physical, climatological, and man-made hazards. However, the data to track and report the performance of these grid resilience efforts are still in development. To date, there is no industry consensus on the data to evaluate the performance of investments intended to create a more resilient electric system.

The purpose of this report is to guide jurisdictions to take the important step of defining and establishing performance metrics for resilience. The report provides several essential pieces of content:

1. a visualization and explanation of a performance mechanism development process;
2. a list and details of seven principles for developing well-designed performance metrics;
3. a menu of performance metrics for grid resilience; and
4. an Excel-based tool to organize the calculation and reporting process.

The accompanying Excel-based tool takes the form of a performance metric reporting template. We intend for utilities to complete this reporting template and provide it to their regulators and stakeholders in public proceedings. The tool contains three sections. The first section (Annual Performance Metrics) provides a suite of resilience performance metrics for annual review. The second section (Resilience Event Performance Metrics) provides a suite of performance metrics for review of each resilience event in the year when it occurs, and in the years directly following each event. A resilience event is a subset of events defined by Institute of Electrical and Electronics Engineers (IEEE's) Major Event Standard 1366, that have a lower probability of occurring, but are longer-lasting, higher-consequence and more spatially widespread when they occur.[5] We also provide a Data Definitions section to explain the terminology that appears in the template.

We suggest many metrics that can be produced immediately, and some more challenging ones for

Completing this template and reporting its contents is intended to be an exercise, not an endpoint.

utilities and communities to work towards over the years to come. Some of the more detailed customer, temporal, and geographical segmentation we propose will need to be defined, and the definitions documented, before calculations can begin. A few of these metrics may require data about customer-sited equipment that is not tracked by utilities today. Though this data may not have been provided previously, we believe it is worthwhile for utilities, regulators, and stakeholders to work together to produce it. Completing this template and reporting its contents is intended to be an exercise, not an endpoint.

[5] IEEE Guide for Electric Power Distribution Reliability Indices," in *IEEE Std 1366-2012 (Revision of IEEE Std 1366-2003)* , vol., no., pp.1-43, 31 May 2012, doi: 10.1109/IEEESTD.2012.6209381.

1.2. Report Organization

The remainder of this report is organized as follows:

- Section 2 lays out a performance mechanism development process;
- Section 3 describes seven principles for well-designed performance metrics;
- Section 4 proposes a menu of grid resilience performance metrics and discusses how they meet the principles described in Section 3; and,
- Section 5 discusses next steps.

An Excel-based tool with the proposed performance metric reporting templates accompanies this report.

2. PERFORMANCE MECHANISM DEVELOPMENT PROCESS

Performance metrics are one step in a performance mechanism development process to monitor and improve performance in areas of interest. Understanding the steps in this process is critical to understanding progress to date, next steps, and future opportunities. The figure below provides an illustration of the process described in more detail in the section that follows.

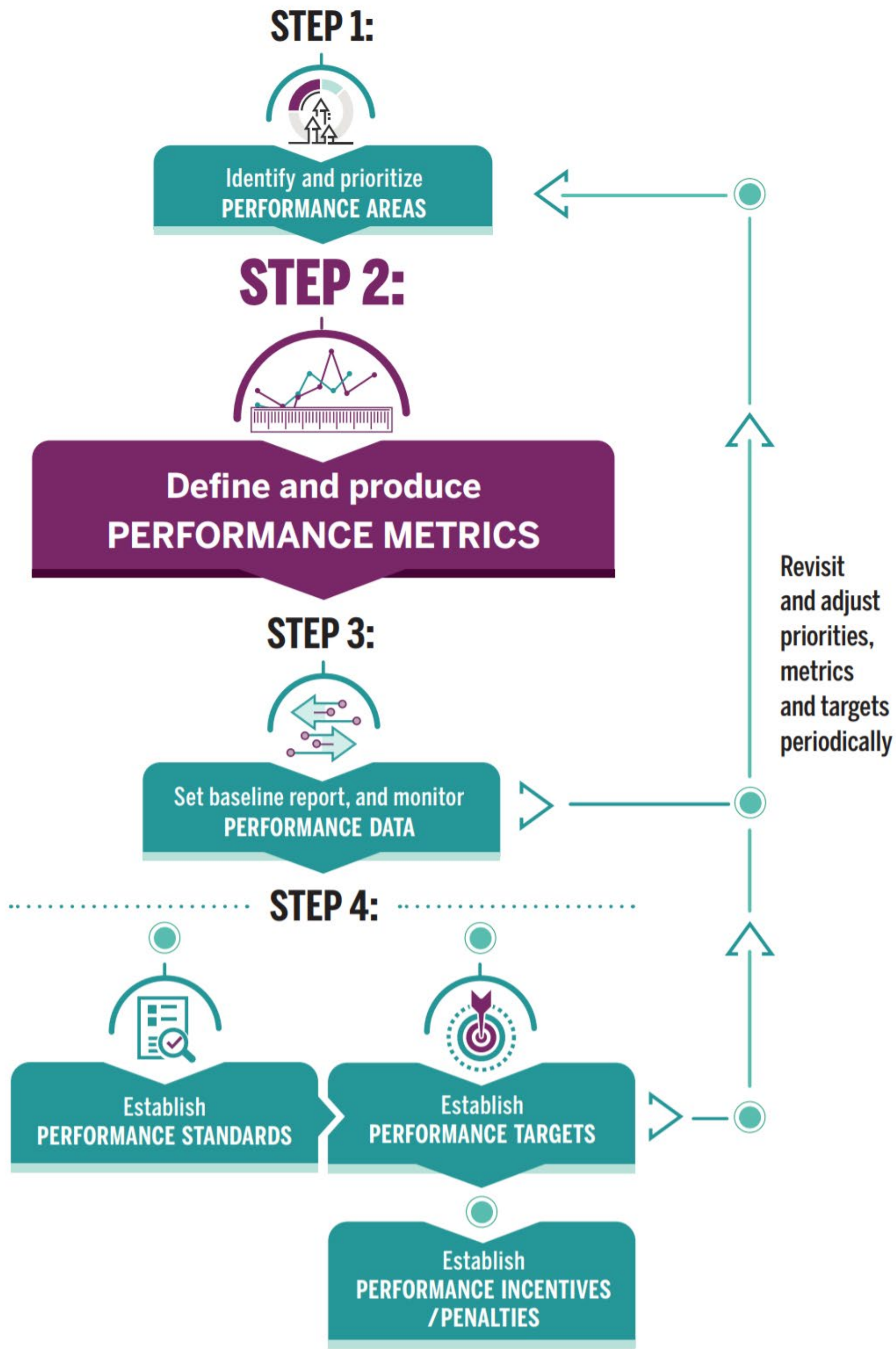

Figure 1. Performance Mechanism Development Process

There are four steps in the performance mechanism development process. The steps are intended to be followed in sequence and the process is iterative to ensure continued relevance and applicability. The first step is identifying and prioritizing **performance areas**. Performance areas can be addressed through utility investments in electric grid improvements.

For this report, we focus on resilience performance areas such as:

- avoiding or reducing consequences to key electric infrastructure;
- avoiding or reducing consequences to priority customers;
- avoiding or reducing consequences in key geographic areas.

Improvements to each performance area can reduce economic, social, and/or national security consequences. For example, eliminating or lessening utility electric infrastructure damages can reduce the resilience event recovery costs for ratepayers. Targeting resilience investments to certain customers or geographies with a greater need for these services can decrease the consequence of outages from economic, social and national security perspectives.

Performance areas should be clearly documented in Step 1 and referenced in discussions in Step 2.

After performance areas are identified and prioritized, **performance metrics** should be developed in the second step to address the performance areas. Metrics define the information that utilities, regulators, and other stakeholders can use to monitor grid performance.

Metrics define the information that utilities, regulators, and other stakeholders can use to monitor grid performance.

Monitoring performance can be simple. For example, it can be simple to publicly report existing data that is already collected and used internally. Also, it may not be too difficult to aggregate or disaggregate existing data and develop new calculations based on this data. However, in some cases, the utility may need to track new data and new data sets can take more time and effort to build. If the data are new, it should be noted, but should not impede the identification of this data. Also, at this point in the process, there may be uncertainty as to whether the data will be useful. This should also not impede the identification of this data as Step 3 provides the opportunity to remove, change, or add metrics as utilities, regulators, and other stakeholders increase their knowledge and experience.

During Step 3, **performance data** is collected, and metrics populated and reviewed. Stakeholders also tackle the important task of setting baselines. Baselines are data used on a going-forward basis for context and comparison. They can be based on the utility's past performance[6], the performance of peer utilities, or other indicators of desirable performance levels. Baselines are useful for understanding and evaluating fluctuations in the data over time. Stakeholders can use this data to determine if the observed fluctuations are acceptable, or if changes are desired or necessary. The act of illustrating and discussing the metrics and baselines among stakeholders can drive improvements through coordination and collaboration. In many cases this is enough to improve performance.

[6] It may also be worthwhile for utilities to provide resilience event reporting for resilience events that happened in the recent past.

The act of illustrating and discussing the metrics and baselines can drive improvements through coordination and collaboration. In many cases this is enough to improve performance.

In some cases, the level of desired improvement cannot be reached without additional regulatory guidance. Step 4, an optional step, offers several additional mechanisms to encourage improved utility performance.

- First, **performance standards** can be established to set baselines for acceptable performance. Performance standards are minimum performance requirements. Today, NERC requirements exist that provide for transmission system resilience, so we recommend this process focus on setting requirements for distribution system resilience as the scope is very different. However, it is important to keep the transmission system resilience standards in mind as distribution system resilience standards are developed so the standards are well coordinated and reinforce one another. The process can stop after standards are set, or the process can continue to the next step.
- Next, **performance targets** can be established in specific instances, such as to encourage utilities to attain higher performance levels in priority areas. Performance targets are desired levels of performance outcomes that exceed minimum performance standards. The process can stop after targets are set, or the process can continue to the next step.
- Lastly, **performance incentives and/or penalties** can be established in specific instances, such as to correct an especially strong utility financial disincentive to achieve a target. Performance incentives and/or penalties are financial motivators that might be needed to achieve some performance targets. Any incentive or penalty should be constructed carefully to avoid unintended consequences, such as lower performance in other performance areas.

After completing Step 3 or Step 4, the process repeats. Regardless of whether any mechanisms in Step 4 are pursued, reporting practices should be established to require periodic review and updates. This is typically done on an annual basis and should include: (a) establishing the information to be reported, often with reporting templates; (b) providing information on all metrics in place; and (c) comparing the performance metrics with any baselines, standards, or targets in place. A key goal of this process is to ensure continued relevance and applicability. At this time, the utility should also examine its resilience performance metrics with an eye towards the broader context, including organizational policies and practices, Public Utility Commission (PUC) rulings or guidance, state or local legislation, and local or regional priorities or interests. Over time, it may become apparent that some data are no longer useful and other needed data are missing. As a result, baselines, performance areas, metrics, standards, targets, and incentives/penalties may be removed, changed, and added.

3. PRINCIPLES FOR WELL-DESIGNED PERFORMANCE METRICS

With so much readily available data, it can be difficult to select a subset of the data that will provide the most useful information. Though there is flexibility to make changes, it is in all the stakeholder's best interest to get off to a good start. When applied, the seven principles in the table below can ensure that performance metrics are well designed. We used these principles to develop the proposed resilience performance metrics and we demonstrate how we applied these principles in Section 4.

Table 1. Principles for Well-Designed Performance Metrics [7,8]

Principles	Description
1. Tied to Performance Areas	Performance metrics should enable utilities to convey whether progress in performance areas is achieved.
2. Clearly Defined	There should be a description of and methodology for quantifying the performance metrics, including data definitions and formulas. Also, responsibility for measuring, calculating, reporting, and verifying the metrics and how often these tasks will be performed should be established.
3. Comparable	Performance metrics should have applicable baselines. Baselines are used on a going-forward basis for context; illuminate the level to which data fluctuates over time; and inform the extent to which the observed fluctuations are acceptable, or if changes are desired or necessary.
4. Readily Available	Performance metrics should be available, obtainable, and updatable without substantial difficulty. Readily available information includes data that is currently reported for compliance with existing industry standards. It also includes data that can be gathered without imposing new and/or excessive costs, technologies or methodologies, and administrative burdens on both utilities and regulators.
5. Objective	Performance metrics should address outcomes over which the utility has some degree of control.[9] Exogenous factors often have an impact on the measurement of resilience. While controlling for all these factors may not be an option, stakeholders should make their best attempt to control for as many factors as possible and reasonable. This is especially important if the utility's performance will be attached to financial rewards or penalties. Otherwise, the extent to which the utility's actions brought about the result will not be clear, and proceedings to set incentives may be contentious.
6. Easily Interpreted	Performance metrics should be easy for stakeholders to understand and communicate to others. Naming conventions should be intuitive, calculations should be transparent, and definitions should be memorable.
7. Verifiable	Performance metrics should lend themselves to evaluation and verification wherever possible. Metrics that require costly, multi-year studies or complex calculations or models to validate and update may not have value.

[7] Whited, Melissa, T. Woolf and A. Napoleon, 2015. Utility Performance Incentive Mechanisms: A Handbook for Regulators. Available at: https://www.synapse-energy.com/about-us/blog/synapse-handbook-provides-guidance-designing-implementing-utility-performance

[8] Littell, D, C. Kadoch, P. Baker, R. Bharvirkar, M. Dupuy, B. Hausauer, C. Linvill, J. Migden-Ostrander, J. Rosenow, W. Xuan, O. Zinaman and J. Logan, 2017. Next-Generation Performance-Based Regulation: Emphasizing Utility Performance to Unleash Power Sector Innovation. Available at https://www.nrel.gov/docs/fy17osti/68512.pdf.

[9] Littell, D, C. Kadoch, P. Baker, R. Bharvirkar, M. Dupuy, B. Hausauer, C. Linvill, J. Migden-Ostrander, J. Rosenow, W. Xuan, O. Zinaman and J. Logan, 2018. Next-Generation Performance-Based Regulation. Available at https://www.nrel.gov/docs/fy18osti/70822.pdf.

4. PROPOSED RESILIENCE PERFORMANCE METRICS

Performance metrics define the information that utilities, regulators, and other stakeholders can use to monitor grid performance. This section identifies data that adhere to the principles described in Section 3 and are useful for electric utilities to provide to regulators and stakeholders responsible for monitoring utility performance related to resilience. We anticipate these initial suggestions will provide a starting point for data collection and reporting that will result in meaningful discussion and further iteration over time. Implementation will reveal the extent to which these data can be easily and consistently produced across many jurisdictions. To the extent adjustment of these metrics is needed, it will be important for jurisdictions to refine and adjust these metrics in partnership and coordination with other utilities and communities.

In this section we present six figures to illustrate the metrics provided in the accompanying Excel-based tool. The first three figures summarize the material in the Annual Performance Metrics section and the second three figures show the material in the Resilience Event Performance Metrics section.

- The Annual Performance Metrics reporting template provides more general, ongoing, annual reporting of utility resilience performance.
- The Resilience Event Performance Metrics reporting template captures information specific to each resilience event that the utility faced.

A major event is defined by the Institute of Electrical and Electronics Engineers (IEEE) Major Event Standard 1366 as, a day in which the daily System Average Interruption Duration Index (SAIDI) exceeds the major event day identification threshold value (T_{MED}). T_{MED} is calculated as 2.5 standard deviations higher than the statistical mean SAIDI for days with any interruptions in the past five years.[10]

We support the idea of a new standard for resilience events, in order to highlight the disparity between a "typical" major event and the types of events commonly addressed with resilience analysis. We are not aware of an IEEE Standard for a resilience event. We define a resilience event as a subset of IEEE's major events that have a lower probability of occurring but are higher consequence when they occur. In the future, the threshold for a resilient event may be determined by the jurisdiction and/or by a standard. For example, we consider the devastation of Puerto Rico by Hurricane Maria in 2017 to be a resilience event. Resilience events can be caused by physical threats such as a terrorist attack, electromagnetic pulse event, or geomagnetic disturbance; climatological threats, such as hurricanes, earthquakes, or major storms; and security-related threats such as cyberattacks. Several types of threats that occur at the same time can be considered a single resilience event.

We suggest developing a way to differentiate resilience events from major events for two reasons. First, with resilience events included, major event day SAIDI and all day SAIDI (major event days and normal days) can vary significantly. Second, averages of major and resilience event day SAIDI can be misleading. Major events and resilience events are fundamentally different. Resilience events are more likely to have exponentially increased consequence as compared to major events, due to the many nonlinear effects present with extremely long-duration or widespread outages. Since major

[10] IEEE Guide for Electric Power Distribution Reliability Indices," in *IEEE Std 1366-2012 (Revision of IEEE Std 1366-2003)* , vol., no., pp.1-43, 31 May 2012, doi: 10.1109/IEEESTD.2012.6209381.

and resilience events are so different, an average of the two is a poor representation of either one. We suggest data be provided on these two types of events separately.

Within each of the two reporting templates, there are three tables to capture the event level details, the customer level and the system level. The first table set to be described is the event-level tables and they provide information on:

- event characteristics (such as threat type, location, timing, frequency, duration, and probability of occurrence);
- utility staff impacts;
- utility infrastructure impacts;
- non-utility staff and population impacts; and
- non-utility goods, infrastructure, and economic development impacts.

4.1. Menu of Grid Resilience Performance Metrics

The first step of the Resilient Community Design Framework[11], referred to as Resilience Drivers Determination,[12] involves defining the system, threats, performance areas or goals, and performance metrics. We encourage utilities applying this framework to leverage this report and accompanying resilience performance metric tool to accomplish this step. In this section, we provide and discuss a menu of resilience performance metrics that utilities should consider producing and reporting. The next steps section provides further detail on the steps utilities should take to produce and report these metrics.

The figures below start with the Annual Performance Metrics tabs shown in the Excel based Tool shown in Appendix A. The figure below shows the information in the event-level reporting table of

[11] The Resilient Community Design Framework was developed by Sandia National Laboratories under the Department of Energy GMLC "Designing Resilient Communities" project.
[12] Energy.gov. Designing Resilient Communities Stakeholder Advisory Group 2020 Meeting. Available at: https://www.energy.gov/sites/prod/files/2020/03/f73/DRC%20SAG%20Meeting%20-%20SNL_Jeffers.pdf

the Annual Performance Metrics tab. The table examines the frequency and duration of major events and resilience events on an annual basis.

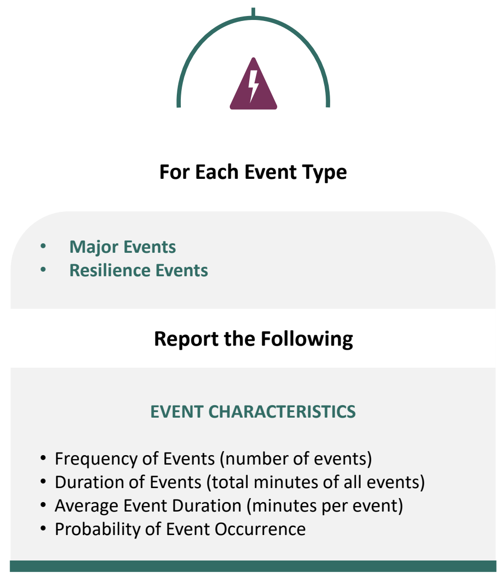

Figure 2. Annual Performance Metrics, Event-Level Reporting

The figure below shows the information in the customer-level reporting table of the Annual Performance Metrics section. The table examines annual performance from a customer perspective, including segments of customers. It can be helpful to have segments, or tiers, within the group commonly and more generally classified as critical customers, since different types of critical customers lead to different types of consequences when not served with power.

For Each Customer Category

- **Tier I: Critical Community Services**
- **Tier II: Critical Individual Services**
- **Tier III: Non-Critical**

Report the Following

CUSTOMERS AND LOAD

- Number of Customers
- Percent of Customers
- Total Load (kWh)
- Percent of Load
- Average Customer Size

- Critical Customers
- Percent of Critical Customers
- Critical Load (kWh)
- Percent of Critical Load

ISLANDABLE RESOURCES

Number of customers with any islandable resources:

- Total
- FOM Supply source provided by the utility
- BTM solar PV + storage generator
- BTM battery storage system (no solar PV)
- BTM natural gas generation
- BTM diesel generation
- BTM propane generation

Percent of customers with any islandable resources:

- Total
- FOM Supply source provided by the utility
- BTM solar PV + storage generator
- BTM battery storage system (no solar PV)
- BTM natural gas generation
- BTM diesel generation
- BTM propane generation

CUSTOMER RESILIENCE

	CAIDI		CAIFI	
	Reporting Period	**Baseline Period**	**Reporting Period**	**Baseline Period**
Normal Days				
Major Event Days				
Resilience Event Days				
All Days				

Figure 3. Annual Performance Metrics, Customer-Level Reporting

One way to segment critical customers is whether they provide a critical community service. For this discussion, we categorize this group as Tier I. Customers that provide a critical community service are ones that provide a critical, or life-sustaining, good or service that is accessible to others. For example, hospitals, urgent care facilities, community cooling centers, water and sewer treatment and pumping facilities, vehicle fueling stations, and grocery stores provide critical community services. State and local emergency management agencies are excellent resources for utilities seeking to develop a taxonomy and datasets describing these critical assets. Critical customers are not defined by how much utility revenue they paid but rather by the critical community service they provide.

As shown in the Annual Performance Metrics section of the accompanying Excel workbook, we can further categorize these critical community services by customer by the subcategories. We anticipate that these will be designed to align with the Commercial and Industrial customer classes already reported by utilities. As we illustrate, each customer subcategory should be defined, and definitions documented, in the Data Definitions tab of the Excel workbook. Rate classes can be used to help define each one. Utilities should work with communities to provide breakouts for municipally owned and operated facilities as a separate subcategory if this is not being done already.

Critical customers that do not provide a community service may be vulnerable residential customers who require additional individual attention due to higher health risks or lower mobility. We refer to service for a single critical household as an individual service and categorize it as Tier II.

Tier I Critical Community Services includes assets delivering life-sustaining services to a significant portion of the population; such as hospitals, urgent care facilities, community cooling centers, water and sewer treatment and pumping facilities, vehicle fueling stations, and grocery stores.

Tier II Critical Individual Services may include vulnerable residential customers who require additional individual attention due to higher health risks or lower mobility.

Utilities should work with regulators and stakeholders in each jurisdiction to determine the definitions of these tiers and any subsegments within each tier. For example, utilities can use subsegments to break out municipally owned and operated facilities from those owned and operated by private commercial and industrial customers.

We categorize all other non-critical customers as Tier III. Tier III may include customers with a high economic consequence of outage but that do not provide critical services, such as a casino that employs many people in the community. Similar to Tier I, we recommend breaking out these non-critical customers by customer subcategory. Utilities should work with regulators and stakeholders in each jurisdiction to determine the definitions of these tiers and any subsegments within each tier. For example, utilities can use subsegments to break out municipally owned and operated facilities from those owned and operated by private commercial and industrial customers. We recommend keeping this segmentation consistent between the Metrics reporting templates.

The figure below shows the information in the system-level reporting table of the Annual Performance Metrics section.

For Each System Category

- Tier I: High Consequence Geographies
- Tier II: Medium Consequence Geographies
- Tier III: Low Consequence Geographies

Report the Following

EQUIPMENT

- Total Substations
- Customers Served by Substations
- Average Number of Customers Served per Substation
- Critical Substations
- Customers Served by Critical Substations
- Average Number of Customers Served per Critical Substation

- Total Feeders
- Customers Served by Feeders
- Average Number of Customers Served per Feeder
- Critical Feeders
- Customers Served by Critical Feeders
- Average Number of Customers Served per Critical Feeder

SYSTEM RESILIENCE

	SAIDI		SAIFI	
	Reporting Period	**Baseline Period**	**Reporting Period**	**Baseline Period**
Normal Days				
Major Event Days				
Resilience Event Days				
All Days				

Figure 4. Annual Performance Metrics, System-Level Reporting

It is also helpful to have spatial segmentation, especially for larger utility territories. To start, we recommend categorizing existing geographic segments as having a high (Tier I), medium (Tier II), or low (Tier III) level of expected consequence. These geographies can be non-contiguous, such as communities or portions of communities across states and larger utility service territories. Tier I can include geographies with the highest level of likely consequence when the event occurs. Tier II can be used to distinguish performance in medium consequence geographies that are still affected and worthy of additional protections. Tier III can be used for all other non-priority areas. Utilities should work with regulators and stakeholders in each jurisdiction to determine the definitions of these tiers and any subsegments within each tier. For example, utilities can use subsegments to break out performance by state or subsidiary to align with the purview of their PUCs. Also, guidance for defining and calculating consequence needs to be developed. We recommend the categorization be based on readily available utility and community data and frameworks.

As shown in the Annual Performance Metrics section of the accompanying Excel workbook, we can further categorize each system by subcategories. Sub segments could be components of utility service territories that merged or were acquired or regions, states, or distribution system-related geographical boundaries (such as the areas served by a district office or line crew dispatch garage).

Tier 1 High Consequence Geographies can include geographies, such as non-contiguous communities or portions of communities across states and larger utility service territories, with a high level of likely consequence when the event occurs.

Tier II Medium Consequence Geographies can be used to distinguish performance in geographies that do not experience the highest consequences but are still affected and worthy of additional protections.

Tier III Low Consequence Geographies can be used for all other non-priority areas.

Utilities should work with regulators and stakeholders in each jurisdiction to determine the definitions of these tiers and any subsegments within each tier. For example, utilities can use subsegments to break out performance by state or subsidiary to align with the purview of their PUCs.

Each utility and its associated regulator have flexibility to structure these subsegments as appropriate for their territory, regulators, and stakeholders. The structure should consider how the data is tracked, stored, and reported. Over time, it may be helpful for these geographies to be broken out further or redefined to better align with geographic areas in need of distinctly different levels of resilience, through coordination with communities.

The figures below start with the Resilience Event Performance Metrics section shown in the Excel based Tool shown in Appendix A. The figure below shows the information in the event-level reporting table of the Resilience Event Performance Metrics section. This table provides a more detailed look at each resilience event that occurred in the past year. If multiple resilience events occurred in that timeframe, this table should be provided for each event.

Report the Following

EVENT CHARACTERISTICS

- Threat Type(s)
- Location(s)
- Starting Date
- Ending Date
- Duration (days)
- Probability of Event Occurrence

UTILITY STAFF IMPACTS

- Affected Staff
- Total Staff
- Affected Staff as a Percent of Total Staff
- Staff Injuries
- Staff Deaths
- Staff Injuries as a Percent of Total Staff
- Staff Deaths as a Percent of Total Staff

UTILITY INFRASTRUCTURE IMPACTS

- Infrastructure Damages ($)

NON-UTILITY STAFF AND POPULATION IMPACTS

- Affected Municipal Staff
- Total Municipal Staff
- Affected Municipal Staff as a Percent of Total Municipal Staff
- Injuries
- Deaths
- Injuries as a Percent of Total Customers
- Deaths as a Percent of Total Customers

NON-UTILITY GOODS, INFRASTRUCTURE, AND ECONOMIC DEVELOPMENT IMPACTS

- Critical Goods and Infrastructure Damages ($)
- Total Goods and Infrastructure Damages ($)
- Critical Goods and Infrastructure Damages as a Percent of Total Damages
- Critical Goods Not Produced/Sold ($)
- Total Goods Not Produced/Sold ($)
- Critical Goods Not Produced/Sold as a Percent of Total Goods Not Produced/Sold
- Forgone Future Economic Development Opportunities ($)

Figure 5. Resilience Event Performance Metrics, Event-Level Reporting

The figure below shows the information in the customer-level reporting table of the Resilience Event Performance Metrics section. This table contains data specific to each resilience event that occurred in the past year. If multiple resilience events occurred in that timeframe, this table should be provided for each event. While the customer categories are the same as those in the Annual Performance Metrics section, the metrics differ. Also, the customers included in this data should be located within the clearly defined geographical boundary of the resilience event which will likely differ from the utility service territory boundary.

For Each Customer Category

- **Tier I: Critical Community Services**
- **Tier II: Critical Individual Services**
- **Tier III: Non-Critical**

Report the Following

CUSTOMERS AND LOAD

- Maximum Affected Critical Customers
- Maximum Affected Critical Customers as a Percent of Critical Customers
- Departed Customers

- Maximum Affected Critical Load
- Maximum Affected Critical Load as a Percent of Critical Load
- Departed Load

ISLANDABLE RESOURCES

Number of customers with any islandable resources that functioned during the event:

- Total
- FOM Supply source provided by the utility
- BTM solar PV + storage generator
- BTM battery storage system (no solar PV)
- BTM natural gas generation
- BTM diesel generation
- BTM propane generation

Percent of islandable resources that functioned during the event:

- Total
- FOM Supply source provided by the utility
- BTM solar PV + storage generator
- BTM battery storage system (no solar PV)
- BTM natural gas generation
- BTM diesel generation
- BTM propane generation

CUSTOMER RESILIENCE

	CAIDI		CAIFI	
	Without Islandable Resources	**With Islandable Resources**	**Without Islandable Resources**	**With Islandable Resources**
Pre-Resilience Event Days				
Resilience Event Days				
Post Resilience Event Days				

Figure 6. Resilience Event Performance Metrics, Customer-Level Reporting

The figure below shows the information in the system-level reporting table of the Resilience Event Performance Metrics section. Like the previous two tables, this table contains data specific to each resilience event that occurred in the past year. If multiple resilience events occurred in that timeframe, this table should also be provided for each event. While the system categories are the same as those in the Annual Performance Metrics section, the metrics differ. Also, the definition of the system segments presented in this data should be located within the clearly defined geographical boundary of the resilience event.

For Each System Category

- Tier I: High Consequence Geographies
- Tier II: Medium Consequence Geographies
- Tier III: Low Consequence Geographies

Report the Following

EQUIPMENT

- Maximum Affected Critical Substations
- Customers Served by Affected Critical Substations
- Affected Critical Substations as a Percent of Critical Substations
- Average Number of Customers Served per Affected Critical Substation

- Maximum Affected Critical Feeders
- Customers Served by Affected Critical Feeders
- Affected Critical Feeders as a Percent of Critical Feeders
- Average Number of Customers Served per Affected Critical Feeder

SYSTEM RESILIENCE

	SAIDI		SAIFI	
	Without Islandable Resources	With Islandable Resources	Without Islandable Resources	With Islandable Resources
Pre-Resilience Event Days				
Resilience Event Days				
Post Resilience Event Days				

Figure 7. Resilience Event Performance Metrics, System-Level Reporting

While these figures provide general guidance for breaking out customer and system types, utilities will need to work with regulators and other stakeholders to identify segmentation that makes sense for their jurisdiction. While existing segmentation may not be ideal or perfect, we recommend working with readily available segments to start (e.g. existing geographic sub-divisions such as the areas served by crews from a particular regional office) and developing additional segmentation that better aligns with resilience related risks and goals over time. In developing additional segmentation, the value of improved precision should be weighed against the cost of obtaining it. Whatever segmentation is adopted, we recommend keeping these segments consistent in the tables in the Annual and Resilience Event reporting templates, as indicated by the structure and format of the columns in these tables.

4.2. Connection to the Principles

These metrics are designed to meet the seven principles discussed in Section 3. Below, we describe how each of these principles is met.

Tied to Performance Areas

The performance metrics were designed to tie to the key performance areas for resilience. Each of these metrics are calculated separately for resilience events and major events, so that they may be compared. For example:

- **Avoiding or limiting damage to key infrastructure** is assessed through counts of maximum affected critical substations and feeders and the costs to repair damaged utility property.
- **Avoiding or reducing impacts to priority customers** is evaluated through counts of maximum affected critical customers and load, CAIDI and CAIFI by customer categories, the proportion of sites served by islandable resources.
- **Avoiding or reducing impacts to key geographies** is related to SAIDI and SAIFI by system categories.

Clearly Defined

Utilities and regulators using this reporting structure will want to tailor the tools. While standardization and cross-comparability have real value, we understand that customization is necessary and inevitable. We request that users maintain the metrics and formulas as shown in the templates and focus customization on the data definitions, customer and system categories, and types of behind-the-meter (BTM) and front-of-meter (FOM) islandable generation to include in the reporting. <u>We do recommend that a naming convention be established for resilience events and a definition be established by IEEE for resilience event days.</u>

Data definitions will vary by jurisdiction, so we provide a place for utilities to insert definitions of key data on the Data Definitions tab of the template. This table includes the following:

- Event types (major and resilience events);
- Interruption measures (CAIDI, CAIFI, SAIDI, and SAIFI);
- Periods (all, normal, major event, resilience event, pre resilience event, post resilience event, reporting, and baseline);
- Maximum affected critical customers, load, substations and feeders;
- Islandable resources and functioning islandable resources;
- Customer categories and subcategories (such as Critical Customers, Tier I: Critical Community Services, Tier II: Critical Individual Services, Tier III: Non-Critical Services); and,

- System categories and subcategories (such as Tier I: High Consequence Geographies, Tier II: Medium Consequence Geographies, Tier III: Low Consequence Geographies).

We establish the timing and frequency of data reporting through the structure of the tables. We intend for the metrics on the Annual Performance Metrics section to be updated and provided each year. The timing should align with distribution system planning or other relevant planning dockets or efforts. The metrics on the Resilience Event Performance Metrics section are intended to be provided together with the annual metrics, for years in which resilience events occur and the five years after. These events could occur once in a decade or for several consecutive years in a given decade, depending on the jurisdiction. However, it is likely that the metrics on the Resilience Event Performance Metrics section will be provided less frequently than the metrics on the Annual Performance Metrics section for many jurisdictions and may rarely, if ever, be provided for some jurisdictions.

If there were no resilience events in the past five years, a utility should only provide the Annual Performance Metrics section to its regulators.

If there were one or more resilience events in any of the past five years, a utility should provide the Annual Performance Metrics section and a Resilience Event Performance Metrics section for each resilience event experienced.

The Resilience Event Performance Metrics section includes several new reporting time periods that will require definition and will drive reporting timing and frequency. “Pre resilience event” data should be reported for a relatively recent, multiyear period prior to the event to establish a baseline that is not fluctuating substantially with changes in weather, global security, economic booms or recessions, or other potential drivers. We suggest a period of five years. “Resilience event” data should be reported for the period in which outages are occurring and caused by the same underlying threat or event. This period can range from days to a year or more, depending on the severity of the event. “Post resilience event” data should be reported annually for a similar amount of time (e.g., five years) starting from the last day of the resilience event.

The table below illustrates the proposed performance metric reporting timing and frequency for Hurricane Katrina which struck New Orleans, Louisiana in 2005. We show a snapshot of what the recommended reporting timing and frequency would have looked like for the years before and after this one event. Annual performance metrics are reported for all years, from 2000 to 2011. Resilience event performance metrics are reported starting the year the event occurs and annually, for the five years that follow.

Table 2. Proposed Reporting Timing and Frequency, New Orleans Example

Metric Reports	Pre-Resilience Event Years					Resilience Event Years	Post-Resilience Event Years					
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Annual Performance Metrics	X	X	X	X	X	X	X	X	X	X	X	X
Resilience Event Performance Metrics						X	X	X	X	X	X	

Comparable

We establish context and baselines primarily through the metrics in the Annual Performance Metrics section. The primary purpose of the annual reporting metrics is to provide baseline information that is generally not widely or consistently reported today. This baseline information can be used to evaluate probabilities, understand performance, set goals for improvement, and motivate utilities to achieve resilience goals. Important baseline information includes:

- the average frequency and duration of major and resilience events;
- the definition of critical customers;
- the number and proportion of customers considered critical;
- the amount and proportion of load considered critical;
- the number and percent of islandable resources; and,
- the types of islandable resources.

Lastly, the Annual Performance Metrics section includes a historical period of comparison, to contextualize performance in the past year. We recommend comparing to the previous five years.

The Resilience Event Performance Metrics section builds upon the contextual data in the annual reporting in a few ways. First, it provides context regarding the type, severity, and recurrence probability of the event. For example, the Event Level table logs the threat types, locations, timing and duration of the event, damages (in dollars), injuries, and deaths. It is important to note that this data is not intended to be used to attribute responsibility for damages, injuries, and deaths to the utility or any other entity. This information provides helpful context for understanding degree of consequence of the event for the jurisdictions involved and monitors the extent to which targeted investments can avoid some of these consequences. Additionally, we suggest utilizing a national data source for the calculation and reporting of damages, injuries, and deaths for consistency and comparability. For example, the Federal Emergency Management Agency provided a summary of key data in its 2017 Hurricane Season After-Action Report that can be referenced by utilities.[13] We also suggest that the utility add a row to report utility-related damages. We are not aware of common reporting or consistent calculation of this metric. A nationally consistent approach should be defined for calculating this metric.

Second, the Resilience Event Performance Metrics section provides information on how critical customers fared during an event. For example, it shows how many and what proportion of critical customers were affected by the event. The template also collects information on whether different types of islandable resources offered any relief during the event. It is important to note that we do not find that the data is developed enough at this time to evaluate the extent to which these islandable systems performed. As a result, we recommend starting by simply evaluating if they performed at all. We also note that this data includes both FOM and BTM systems, many of which are not owned or operated by utilities. We acknowledge that this type of data is not available in many utility datasets today. However, we feel it is important to begin to discuss how to collect and report this data. We hope that including a placeholder for this data in reporting will spur discussion of how to best accomplish this goal and enable future action.

Third, the Resilience Event Performance Metrics section provides information on how equipment and systems fared during an event. For example, it shows counts of substations and feeders affected during an event.

Readily Available

We consider much of the data requested to be readily available. We base these metrics on common regional and national reliability reporting practices (e.g., CAIDI, CAIFI, SAIDI, SAIFI) and international reliability standards (e.g., IEEE) to facilitate comparisons with entities in other jurisdictions that follow the same standards.

Some customer-level data may not be readily available today (such as data regarding the existence and performance of BTM generation or storage). However, we believe that such data is readily available to utilities by simply asking customers about it through customer satisfaction surveys. It could be reasonable, for example, to collect site-specific information about the BTM resources available at the largest and/or most critical customers, and then use surveys and sampling to collect information about the BTM resources on residential customers' premises.

Objective

Objectivity is one of the most important and challenging principles to address in developing resilience performance metrics. The probability of resilience event recurrence, which appears on the Resilience Event Performance Metrics section can be highly uncertain as well as outside of a utility's control. We refer to factors that are outside of an organization's control as exogenous factors.

The existence of exogenous factors does not obviate the need for utilities to conduct good planning and preparation for resilience events. However, utilities should not be penalized for the impacts of exogenous factors. To the extent exogenous factors can be controlled for in the development of performance metrics, they should be.

To start, we recommend reporting an event recurrence probability using the best available information, including historic recurrence as well as future projected recurrence where available.

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[13] Federal Emergency Management Agency. *2017 Hurricane Season After-Action Report.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema_hurricane-season-after-action-report_2017.pdf

While we do not propose normalization by the likelihood of occurrence in this report, we recommend this data be used to normalize some of the metrics. See the report *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*,[14] for discussion of expected values. Once reporting of event probability of occurrence is established, a methodology for this normalization could be incorporated into a future iteration of the reporting templates.

Even with this normalization, jurisdictions will still experience impacts from exogenous factors. Utilities will need to work with regulators and communities to identify the most pressing exogenous factors to control for and develop quantitative or qualitative approaches to attempt to control for these factors. All parties will need to gain experience with the uncertainties associated with resilience planning and develop good communication, planning processes, and trust to move forward.

Easily Interpreted

Through this exercise, we identify two important dimensions where more detail is needed: customer and system level. These align well with existing reliability metrics which we feel provide a good starting point for metric development. For example, greater data granularity for customer-level metrics is accomplished by reporting CAIDI and CAIFI for different groups of customers. Greater data granularity for system-level metrics is accomplished by reporting SAIDI and SAIFI for sub-systems within the larger system. By leveraging common regional and national reliability reporting practices (e.g., CAIDI, CAIFI, SAIDI, SAIFI) and international reliability standards (e.g., IEEE), we avoid the hurdle of developing and learning brand new metrics. Further, many metrics are simple counts (of customers) and distributions (in the form of percentages) that are easy to understand for a broad group of participants.

Verifiable

Relying on simple counts and calculations to get started avoids the need to run complex models or calculations to produce and report this data, which can be time and resource intensive. While studies can be performed for further evaluation, validation, and verification purposes, it is not necessary that studies be performed for stakeholders to derive value from these metrics right away.

[14] Sandia National Laboratories. 2021. *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*. Executive Summary. Figure 1.

5. NEXT STEPS

Regulators, utilities, communities, and other stakeholders can work together to advance performance metrics for grid resilience investments. In the benefit-cost analysis report, titled *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*,[15] we suggested several roles and responsibilities for different parties in developing performance metrics, including:

- For regulators: directing utilities to take the lead on collecting and organizing resilience performance metrics;
- For utilities: acting as a central repository for the data and leading the reporting of resilience performance metrics;
- For community leaders and local governments: working with utilities directly to fill gaps in resilience performance metrics with existing data, working with regulators to define critical customer groups and tiered consequence geographies; and
- For other stakeholders, including research institutions: working with utilities to conduct new research and analysis for cases where data for resilience performance metrics are nonexistent.

Once roles and responsibilities for developing resilience performance metrics are established, the utilities responsible for leading the effort can propose resilience performance metrics to their regulators.

Regulators and utilities can start by holding a technical session to review the suggestions in the Excel-based tool and identify resilience performance metrics of interest. Communities and other stakeholders should be invited to participate in this technical session and all parties should work together to prioritize metrics and identify data sources for each metric. All parties to the proceeding should also be allowed to provide written comments on the metrics proposed by the utility to the regulator after the technical session. Utilities can make further adjustments to their proposal based on the comments received and provide regulators with a performance metric reporting template for review and feedback.

Once a regulator approves the utilities' proposed resilience performance metric reporting template, utilities can populate the metrics using actual data and review the calculations and outputs with regulators and other stakeholders. A second technical session can be scheduled for this purpose. During the session, regulators and other stakeholders can discuss how to interpret each metric and provide feedback on the usefulness of the metrics as produced. All parties can identify any data gaps and discuss how to best address missing data in both the nearer- and longer-term.

Utilities can formally file their resilience performance metrics report in the proceeding of their regulators' choosing and with a frequency that makes sense for that jurisdiction. In the Sandia National Laboratories report titled *Regulatory Mechanisms to Align Utility Investments with Resilience*,[16] we identify various types of proceedings where grid resilience investments may be contemplated. For jurisdictions conducting integrated planning,[17] utilities can include resilience performance metrics in

[15] Sandia National Laboratories. 2021. *Application of a Standard Approach to Benefit-Cost Analysis for Electric Grid Resilience Investments*. Executive Summary. Figure 1.
[16] Sandia National Laboratories. 2021. *Regulatory Mechanisms to Align Utility Investments with Resilience.*
[17] Integrated planning can include integrated resource planning, integrated distribution planning, and integrated grid planning.

an integrated planning proceeding. For jurisdictions not conducting integrated planning, other utility regulatory proceedings such as performance-based regulation, grid modernization, and cost recovery proceedings can provide opportunities for utilities to include resilience performance metrics. These resilience performance metric filings will provide baseline data on an ongoing basis.

Once the baseline data is established, the utility, regulator and other stakeholders can work together to identify performance metrics that need improvement and discuss the level of improvement desired. Thoughtful, responsive iteration will be key to success. Utilities can explore many investment options to achieve the goals. Utilities can offer programs to promote customer implementation of measures that achieve the desired improvement. Utilities can also implement measures to achieve the desired levels of improvement. Utility investment proposals can identify the resilience performance metrics of interest and the impacts of the potential investments on the resilience performance metrics.

After utilities select investments to pursue and implement the measures, resilience performance metrics can demonstrate the impact of the investments. Ongoing review and update of the performance metrics can document progress, allow for adjustments, and identify new opportunities over time for more efficient and cost-effective resilience investments.

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APPENDIX A. ENERGY INVESTMENTS WITH RESILIENCE BENEFITS: PERFORMANCE METRICS REPORTING TOOL

A.1. Annual Performance Metrics, Event Level Reporting

Event Level Reporting			
Metrics	**Calculations**	**Major Events**	**Resilience Events**
Event Characteristics			
Frequency of Events (number of events)	a		
Duration of Events (total minutes of all events)	b		
Average Event Duration (minutes per event)	b / a		
Probability of Event Occurrence			

A.2. Annual Performance Metrics, Customer Level Reporting

Customer Level Reporting												
Metrics	Calculations	TOTAL CUSTOMERS	Tier I: Critical Community Services				Tier II: Critical Individual Services	Tier III: Non-Critical				
			Customer Sub-Category 1	Customer Sub-Category 2	Customer Sub-Category 3	Customer Sub-Category 4	Customer Sub-Category 5	Customer Sub-Category 1	Customer Sub-Category 2	Customer Sub-Category 3	Customer Sub-Category 4	Customer Sub-Category 5
Customers and Load												
Total Customers	c											
Percent of Customers by Customer Subcategory												
Total Load (kWh)	d											
Percent of Load by Customer Subcategory												
Average Customer Size	d / c											
Critical Customers	e											
Percent of Critical Customers by Customer Subcategory												
Critical Customers as a Percent of Total Customers	e / c											
Critical Load (kWh)	f											
Percent of Critical Load by Customer Subcategory												
Critical Load as a Percent of Total Load	f / d											
Islandable Resources												
Number of customers with any islandable resources:												
Total	g											
FOM Supply source provided by the utility	h											
BTM solar PV + storage generator	i											
BTM battery storage system (no solar PV)	j											
BTM natural gas generation	k											
BTM diesel generation	l											
BTM propane generation	m											
Percent of customers with any islandable resources:												
Total	g / c											
FOM Supply source provided by the utility	h / c											
BTM solar PV + storage generator	i / c											
BTM battery storage system (no solar PV)	j / c											
BTM natural gas generation	k / c											
BTM diesel generation	l / c											
BTM propane generation	m / c											
Customer Resilience												
Normal Days - CAIDI (reporting period)												
Major Event Days - CAIDI (reporting period)												
Resilience Event Days - CAIDI (reporting period)												
All Days - CAIDI (reporting period)												
Normal Days - CAIDI (baseline period)												
Major Event Days - CAIDI (baseline period)												
Resilience Event Days - CAIDI (baseline period)												
All Days - CAIDI (baseline period)												
Normal Days - CAIFI (reporting period)												
Major Event Days - CAIFI (reporting period)												
Resilience Event Days - CAIFI (reporting period)												
All Days - CAIFI (reporting period)												
Normal Days - CAIFI (baseline period)												
Major Event Days - CAIFI (baseline period)												
Resilience Event Days - CAIFI (baseline period)												
All Days - CAIFI (baseline period)												

A.3. Annual Performance Metrics, System Level Reporting

System Level Reporting									
Metrics	Calculations	TOTAL SYSTEM	Tier I: High Consequence Geographies		Tier II: Medium Consequence Geographies		Tier III: Low Consequence Geographies		
			System Sub-Category 1	System Sub-Category 2	System Sub-Category 3	System Sub-Category 4	System Sub-Category 5	System Sub-Category 6
Equipment									
Total Substations	n								
Customers Served by Substations	o								
Average Number of Customers Served per Substation	o / n								
Critical Substations	p								
Customers Served by Critical Substations	q								
Percent of Customers Served by Critical Substations	q / c								
Average Number of Customers Served per Critical Substation	q / p								
Total Feeders	r								
Customers Served by Feeders	s								
Average Number of Customers Served per Feeder	s / r								
Critical Feeders	t								
Customers Served by Critical Feeders	u								
Percent of Customers Served by Critical Feeders	u / c								
Average Number of Customers Served per Critical Feeder	u / t								
System Resilience									
Normal Days - SAIDI (reporting period)									
Major Event Days - SAIDI (reporting period)									
Resilience Event Days - SAIDI (reporting period)									
All Days - SAIDI (reporting period)									
Normal Days - SAIDI (baseline period)									
Major Event Days - SAIDI (baseline period)									
Resilience Event Days - SAIDI (baseline period)									
All Days - SAIDI (baseline period)									
Normal Days - SAIFI (reporting period)									
Major Event Days - SAIFI (reporting period)									
Resilience Event Days - SAIFI (reporting period)									
All Days - SAIFI (reporting period)									
Normal Days - SAIFI (baseline period)									
Major Event Days - SAIFI (baseline period)									
Resilience Event Days - SAIFI (baseline period)									
All Days - SAIFI (baseline period)									

A.4. Resilience Events Metrics, Event Level Reporting

Event Level Reporting			
Metrics	Calculations	Data	Sources
Event Characteristics			
Threat Type(s)			
Location(s)			
Starting Date			
Ending Date			
Duration (days)			
Probability of Event Occurrence			
Utility Staff Impacts			
Affected Utility Staff	a		
Total Utility Staff	b		
Affected Utility Staff as a Percent of Total Utility Staff	a / b		
Staff Injuries	c		
Staff Deaths	d		
Staff Injuries as a Percent of Total Staff	c / b		
Staff Deaths as a Percent of Total Staff	d / b		
Utility Infrastructure Impacts			
Infrastructure Damages ($)			
Non-Utility Staff and Population Impacts			
Affected Municipal Staff	e		
Total Municipal Staff	f		
Affected Municipal Staff as a Percent of Total Municipal Staff	e / f		
Injuries	g		
Deaths	h		
Injuries as a Percent of Total Customers	g / m		
Deaths as a Percent of Total Customers	h / m		
Non-Utility Goods, Infrastructure and Economic Development Impacts			
Critical Goods and Infrastructure Damages ($)	i		
Total Goods and Infrastructure Damages ($)	j		
Critical Goods and Infrastructure Damages as a Percent of Total Damages	i / j		
Critical Goods Not Produced/Sold ($)	l		
Total Goods Not Produced/Sold ($)	m		
Critical Goods Not Produced/Sold as a Percent of Total Goods Not Produced/Sold	l / m		
Forgone Future Economic Development Opportunities ($)			

A.5. Resilience Events Metrics, Customer Level Reporting

Customer Level Reporting												
Metrics	Calculations	TOTAL CUSTOMERS	Tier I: Critical Community Services				Tier II: Critical Individual Services	Tier III: Non-Critical Services				
			Customer Sub-Category 1	Customer Sub-Category 2	Customer Sub-Category 3	Customer Sub-Category 4	Customer Sub-Category 5	Customer Sub-Category 1	Customer Sub-Category 2	Customer Sub-Category 3	Customer Sub-Category 4	Customer Sub-Category 5
Customers and Load												
Total Customers *(from Annual Metrics)*	m											
Maximum Affected Customers	n											
Maximum Affected Customers as a Percent of Total Customers	n / m											
Departed Customers												
Total Load (kWh) *(from Annual Metrics)*	o											
Maximum Affected Load (kWh)	p											
Maximum Affected Load as a Percent of Total Load	p / o											
Departed Load (kWh)												
Islandable Resources												
Number of customers with any islandable resources: *(from Annual Metrics)*												
Total	q											
FOM Supply source provided by the utility	r											
BTM solar PV + storage generator	s											
BTM battery storage system (no solar PV)	t											
BTM natural gas generation	u											
BTM diesel generation	v											
BTM propane generation	w											
Number of customers with any islandable resources that functioned during the event:												
Total	x											
FOM Supply source provided by the utility	y											
BTM solar PV + storage generator	z											
BTM battery storage system (no solar PV)	aa											
BTM natural gas generation	ab											
BTM diesel generation	ac											
BTM propane generation	ad											
Percent of islandable resources that functioned during the event:												
Total	x / q											
FOM Supply source provided by the utility	y / r											
BTM solar PV + storage generator	z / s											
BTM battery storage system (no solar PV)	aa / t											
BTM natural gas generation	ab / u											
BTM diesel generation	ac / v											
BTM propane generation	ad / w											
Customer Resilience												
Pre Resilience Event Days - CAIDI												
Resilience Event Days - CAIDI (reporting period) *(from Annual Metrics)*												
Post Resilience Event Days - CAIDI												
Pre Resilience Event Days - CAIDI w/ islandable resources												
Resilience Event Days - CAIDI w/ islandable resources												
Post Resilience Event Days - CAIDI w/ islandable resources												
Pre Resilience Event Days - CAIFI												
Resilience Event Days - CAIFI (reporting period) *(from Annual Metrics)*												
Post Resilience Event Days - CAIFI												
Pre Resilience Event Days - CAIFI w/ islandable resources												
Resilience Event Days - CAIFI w/ islandable resources												
Post Resilience Event Days - CAIFI w/ islandable resources												

A.6. Resilience Events Metrics, System Level Reporting

System Level Reporting									
Metrics	Calculations	TOTAL SYSTEM	Tier I: High Consequence Geographies		Tier II: Medium Consequence Geographies		Tier III: Low Consequence Geographies	
			System Sub-Category 1	System Sub-Category 2	System Sub-Category 3	System Sub-Category 4	System Sub-Category 5	System Sub-Category 6
Equipment									
Critical Substations *(from Annual Metrics)*	ae								
Maximum Affected Critical Substations	af								
Customers Served by Affected Critical Substations	ag								
Affected Critical Substations as a Percent of Critical Substations	af / ae								
Average Number of Customers Served per Affected Critical Substation	ag / af								
Critical Feeders *(from Annual Metrics)*	ah								
Maximum Affected Critical Feeders	ai								
Customers Served By Affected Critical Feeders	aj								
Affected Critical Feeders as a Percent of Critical Feeders	ai / ah								
Average Number of Customers Served per Affected Critical Feeder	aj / ai								
System Resilience									
Pre Resilience Event Days - SAIDI									
Resilience Event Days - SAIDI (reporting period) *(from Annual Metrics)*									
Post Resilience Event Days - SAIDI									
Pre Resilience Event Days - SAIDI w/ islandable resources									
Resilience Event Days - SAIDI w/ islandable resources									
Post Resilience Event Days - SAIDI w/ islandable resources									
Pre Resilience Event Days - SAIFI									
Resilience Event Days - SAIFI (reporting period) *(from Annual Metrics)*									
Post Resilience Event Days - SAIFI									
Pre Resilience Event Days - SAIFI w/ islandable resources									
Resilience Event Days - SAIFI w/ islandable resources									
Post Resilience Event Days - SAIFI w/ islandable resources									

A.7. Data Definitions

Data	Definition
Major event	
Resilience event	
CAIFI	
CAIDI	
SAIFI	
SAIDI	
Normal days	
Major event days	
Resilience event days	
All days	
Maximum affected customers	
Maximum affected load	
Maximum affected substations	
Maximum affected feeders	
Maximum affected circuits	
Islandable resources	
Islandable, functioning resources	
Critical customer	
Tier I: Critical community services	
Tier II: Critical individual services	
Tier III: Non-critical services	
Tier I: High consequence geographies	
Tier II: Medium consequence geographies	
Tier III: Low consequence geographies	
Pre resilience event days	
Post resilience event days	
Reporting period	
Baseline period	

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