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Energy and Water Resilience Indicator Library

December 2021

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Executive Summary

The Technical Resilience Navigator (TRN), a web-based tool developed by the U.S. Department of Energy's Federal Energy Management Program (FEMP), helps organizations manage the risk to critical missions from disruptions in energy and water services. In support of the TRN, FEMP has outlined an approach for evaluating a broad range of energy and water resilience indicators. These indicators can help an organization assess the current energy and water resilience posture of their sites relative to higher-level organizational goals and provide a mechanism for tracking progress over time. They also provide a mechanism for identifying opportunity areas across sites so that an organization can prioritize funding of measures that would benefit multiple sites. Some of the indicators go beyond the criteria included in the core TRN risk-informed process and, therefore, can be leveraged to yield a more holistic resilience planning process.

The first part of this document describes a process for developing energy and water indicators, which at a high-level includes (1) selecting indicators that measure progress in meeting resilience goals; (2) selecting a method to measure the indicators; and (3) tracking site performance over time. For every indicator, an organization can select a method for measuring the site's ability to meet the indicator objective, referred to in the library as a 'metric.' Metrics are presented in the library on two scalable levels: high-level resilience metrics, which can be used to screen sites across their portfolio and compare resilience levels; and in-depth resilience metrics, which can be used to measure indicators at a more granular level, including at the building or critical load level.

Once an organization identifies the metrics under each indicator, the next step is to select a way to track sites' resilience performance, including how it will rate the performance. For each indicator, the library includes two options for rating performance: binary rating and multi-component rating. The binary approach uses a yes or no response to characterize whether a site has achieved the indicator's objective. The multi-component rating more precisely assesses the indicator using a range of responses (e.g., high, medium high, medium low, low). The binary approach requires a lower level of effort while the multi-component provides more detailed insight on the site's achieved level of resilience. These rating categories provide flexibility to allow organizations to define, either qualitatively or quantitatively, the thresholds for the ratings.

The main part of this document comprises the library of energy and water resilience indicators. Each indicator contains associated metrics, a recommended approach for tracking the metric's performance, binary and multi-component rating options, and how the indicator is connected to the TRN.

The library's indicators are organized around four main attributes of energy and water resilience. These attributes, or "4 R's," are as follows: resourcefulness, redundancy, robustness, and recovery. Below is a summary that goes over what these attributes mean and the indicators that reflect these attributes contained in the library.

> ***Resourcefulness*** encompasses several indicators and refers to the ability to prepare for and manage an energy or water disruption. These indicators provide the ability to track a site's progress in meeting reduction goals through efficiency and conservation efforts. This attribute is further broken down into two categories. The first category is *optimization* which includes indicators that energy and water systems are designed and operated to minimize energy and water use, thus facilitating sites to support critical functions more efficiently. In

addition to indicators on *energy and water use*, other optimization indicators include *performance monitoring* which describe a site that proactively monitors building energy and water performance using advanced meters. These are indicators that consider whether personnel are actively managing systems to respond to operational issues, thereby achieving more resilient operations. The second category of resourcefulness indicators is *preparedness* which refers to the adequacy of a site's planning, training, and system testing. The three indicators under preparedness (preparedness planning, staffing and training, and redundant system training) points to how well a site is positioned to respond to and mitigate the impacts of energy and water outages.

Redundancy refers to redundant generation systems that support primary energy and water systems in case they fail. The library details two indicators under redundancy. The first, *redundant system sizing*, reflects the adequacy of the sizing of a site's redundant systems by addressing whether the site's energy and water systems' capacities are large enough to continue critical missions' operations during a disruption. The second indicator, "primary utility supply feed redundancy," determines whether there is adequate redundancy of the energy and water supply lines feeding a site from the primary supplier.

Robustness describes the ability to maintain critical operations and functions during a disruptive event. Indicators associated with the robustness attribute determine the reliability of the primary supplier, redundant systems, and distribution systems. These indicators include *primary utility supply reliability,* which considers the reliability of the primary supplier to provide energy and water; *onsite distribution system reliability and condition* to determine the reliability of sites' onsite energy and water distribution systems; and *redundant system reliability*, an indicator that examines the reliability of sites' redundant systems through operations and maintenance (O&M) practices.

Recovery represents a site's ability to return to or reconstitute normal operating conditions as quickly and efficiently as possible following a disruption. It may include carefully drafted contingency plans, competent emergency operations, and having the right people and resources in the right place at the right time. There are three indicators associated with recovery. The first, *component inventory*, looks at the ability of site personnel to access required components during an outage. The second, *restoration planning* examines how well sites have planned for quickly and efficiently restoring energy and water after an outage, including priority restoration with primary suppliers and energy and water curtailment plans. The third, *mission duplication*, indicates the ability of a site to move critical functions to another location and is an important strategy to implement to quickly restore the mission.

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Acronyms and Abbreviations

COOP	continuity of operation plan
EUI	energy use intensity
FEMP	Federal Energy Management Program
O&M	operations and maintenance
PV	photovoltaic
SAIFI	System Average Interruption Frequency Index
TRN	Technical Resilience Navigator
UPS	uninterrupted power supply
WUI	water use intensity

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1.0 Introduction

There is a growing focus on the resilience of national infrastructure and individual sites with legislation, Executive Orders, and organizational policies driving investment in measures to enhance the resilience of federal and private organizations. To help organizations with energy and water resilience planning, the U.S. Department of Energy's Federal Energy Management Program (FEMP) has developed a web-based tool called the Technical Resilience Navigator (TRN). The TRN offers operators of individual sites a risk-informed assessment and planning process for critical mission continuity. To complement the TRN, FEMP has partnered with PNNL to outline an approach for evaluating a broad range of energy and water resilience indicators. The indicators presented in this document are "hazard and threat neutral". In other words, the indicators are not tied to specific threats or hazards that may impact a site, such as earthquakes, extreme weather events, or cybersecurity breaches. These indicators evaluate resilience broadly, examining a site's technological and institutional practices that reveal generally how well a site is prepared to meet critical missions.

Energy and water resilience indicators provide a way to assess a site's current energy and water resilience status relative to higher-level organizational goals. Using a consistent approach for evaluating the resilience posture of a portfolio of sites provides a mechanism for an organization to track progress over time. It also provides a mechanism for identifying opportunity areas across sites so that organizations can prioritize funding of measures that would benefit multiple sites.

What is resilience?
The TRN broadly defines resilience as the ability to anticipate, prepare for, and adapt to changing conditions and to withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions.

The information presented in this document provides an approach to defining energy and water resilience indicators that align with organizational goals, and a reference library of indicators that can help organizations create their own process of tracking the resilience performance of their sites over time. With respect to energy, the energy resilience indicators defined in this library are primarily focused on electricity. However, organizations can also develop commensurate indicators for other energy sources such as natural gas.

1.1 How to Use the Library

The library is organized as follows:

- Section 2.0 provides background information on the resilience indicator library. Use this section to learn how the indicators are structured, how they are tied to resilience attributes, and how they are connected to FEMP's TRN.

- Sections 3.0 through 7.0 are the heart of the library, listing individual energy and water indicators categorized under resilience attributes. This organizational structure provides specific indicators that help track a site's progress in achieving the resilience attribute. More information on this is discussed in the next section.

2.0 Resilience Indicator Library Structure

This section outlines the general steps to establish resilience indicators that create a meaningful way to measure and track resilience performance. Energy and water resilience indicators presented in the library establish a method for tracking progress in meeting these goals over time (Figure 1).

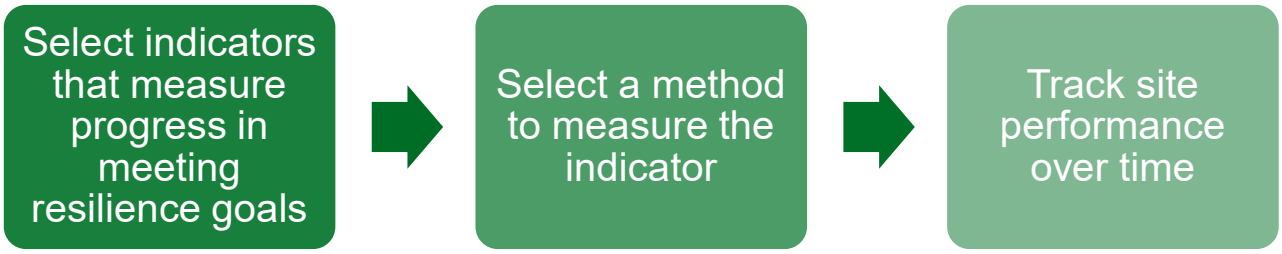

Figure 1. Resilience Indicator Process

2.1 Resilience Attributes

A process for developing energy and water indicators starts with defining the attributes of resilience that align with the organization's broader mission and goals. These attributes are the key characteristics of resilience that help an agency define what it means to be resilient. FEMP's TRN references[1] the "4Rs" as high-level attributes for site-level energy and water resilience—resourcefulness, redundancy, robustness, and recovery.

- **Resourcefulness** refers to the ability to prepare for and manage an energy or water disruption. Being resourceful implies that physical system performance is optimized and that human systems are prepared to manage a disruption.
- **Redundancy** refers to having backup systems to support primary systems in case of failure. Example redundant systems include islandable onsite generation systems, backup generators serving critical power loads, water storage tanks servicing critical water loads, as well as redundant systems that enable the continuity of operations during a primary disruption of energy or water.
- **Robustness** refers to the ability to maintain critical operations and functions during a disruptive event. This includes the reliability of the energy and water supplies and distribution systems.
- **Recovery** refers to the ability to return to normal operating conditions as quickly and efficiently as possible after a disruption. This includes restoration plans, emergency operations, and having the right people and resources in the right place at the right time.

For the resilience indicator library, the *resourcefulness* attribute is broken into two categories: optimization and preparedness. The library includes two separate sections for each of these subcategories to capture the different intents of the associated indicators:

[1] American Institute of Architects. 2016. Chapter 3, "Building Resiliency," page 108. In Architectural Graphic Standards, 12th Edition, John Wiley & Sons, 2016.

- **Optimization** refers to ensuring that energy and water systems are designed and operated to minimize energy and water use, thereby enabling sites to support critical functions more efficiently.
- **Preparedness** refers to the adequacy of a site's level of planning, training, and testing to manage an energy or water disruption.

TRN Risk Indicators

Metrics in the library with the TRN logo denote that the indicator is directly incorporated in the site-level TRN Risk Assessment module. Only abbreviated information is provided in this report and the user is directed to find more information in the TRN. This approach helps users focus on selecting indicators in areas that complement the TRN analysis instead of recreating indicators that could potentially duplicate efforts.

2.2 Resilience Indicators

Once resilience attributes and related goals are established at the organizational level, energy and water resilience indicators are developed to measure their sites' ability to meet the resilience goals across the organization. Resilience indicators measure performance at different levels in an organization and can help identify the organization's overall energy and water resilience posture and prioritize sites or assets for resilience improvements. This library offers key indicators for each resilience attribute that are viable options for organizations to track their sites' resilience.

2.3 Measuring Resilience Indicators

For each selected indicator, an organization selects a method for measuring the site's ability to meet the indicator objective, referred to in the library as a *metric*. Metrics are presented in the library on two scalable levels:

- **High-level Resilience Metrics:** Shown in the library using **green font section headings,** these are high-level metrics to measure site resilience. They can be used by an organization to screen sites across their portfolio and compare resilience levels. This screening approach can help prioritize sites for further evaluation and investments needs.
- **In-depth Resilience Metrics:** Shown in the library using **blue font section headings,** these are in-depth metrics to measure indicators at a more granular level, including at the building or critical load level, which helps a specific site assess the resilience of their critical functions closer to the points of failure.

2.4 Performance Tracking

Once the metrics are developed for each indicator, the next step is to develop a way to track sites' resilience performance. Performance tracking gives organizations a way to compare the relative level of resilience across multiple sites. As part of this performance tracking process, the organization establishes how it will rate the performance. The rating provides a "score" for the indicator to indicate how well the site is meeting the resilience objective. Two methods offered in the library are binary or multi-component rating methods:

Binary rating: A binary rating provides a yes or no response that simply states whether a site has achieved the indicator's objective. A binary response is typically straightforward and can be useful for a high-level screening to quickly discern a site's progress in meeting a specific resilience goal. However, a yes or no measurement may not provide much insight into the level of resilience that has been achieved for the specific indicator.

Multi-component rating: A multi-component rating provides a range of achieved resilience (e.g., high, medium high, medium low, low). A multi-component rating may provide more meaningful results that judge the level of resilience and can assist an organization in understanding relative resilience across its sites. The multi-component rating offered in the library has a four-tiered system of high, medium high, medium low, and low. These rating categories provide flexibility to allow organizations to define, either qualitatively or quantitatively, the thresholds for the ratings. Generally, the library defines the four-tier ratings as follows:

- High: This rating denotes the site has achieved specific requirements of the indicator that fully support the energy/water resilience objective.
- Medium High: This rating denotes the site has partially achieved the indicator's requirements, but additional progress is needed to fully support the resilience objective.
- Medium Low: This rating denotes the site made marginal progress toward the requirement but has not achieved an acceptable level to meet the resilience objective.
- Low: This rating denotes the site has made little to no progress in achieving the requirement.

Choosing a binary or multi-component rating option depends on the organization's overall objectives as well as available resources to complete the analysis. Greater effort is needed for users to research and respond to more detailed indicator response options.

Track energy and water separately!
For most of the indicators, the library tracks energy and water performance separately. Energy and water systems are fundamentally different; therefore, it is important to track energy and water resilience metrics separately.

Qualitative versus quantitative rating options: The rating options provided in the library may be qualitative or quantitative. Qualitative metrics judge the overall quality of the site's ability to meet the indicator. For example, planning indicators generally gauge whether the plan includes all of the essential elements that produce a sound and high-quality plan. Quantitative metrics provide a direct numeric measurement of the indicator. For example, the number of unplanned outages is a quantitative metric to gauge system reliability. For these quantitative metrics, the library does not prescribe the specific target that should be met. The library simply provides example targets denoted as "X", "Y", and "Z". Organizations must define these targets, which should be tailored specifically to the organization's or site's desired objective. Therefore, organizations and sites should carefully consider these values, which will to help establish an appropriate tracking mechanism.

2.5 TRN Connection

The TRN's resilience planning process involves planning at the portfolio level[2] and site level, developing baseline information, and conducting a risk screening assessment to guide the development and prioritization of resilience solutions. The TRN references indicators throughout these steps to guide the user in collecting and tracking useful information. For organizations that are using the TRN, this library links the indicators to specific steps in the TRN process where such data are collected and analyzed. This allows users to see how data collected for a resilience indicator can also be leveraged in other parts of the TRN process. It should be noted that some of the resilience indicators included in the library are broader than what is included in the TRN. The library is meant to expand the criteria by which an organization can measure

[2] At the time of this publication, the module outlining the TRN's approach to portfolio planning is not yet public.

resilience and evaluate potential resilience solutions. The box below demonstrates how the library's energy and water resilience indicators fit into some of the TRN modules.

Linkages between the library's indicators and TRN modules

Site-Level Planning: Establishes the resilience planning process for a site, including setting up the resilience planning team, engaging leadership and stakeholders, and collecting relevant planning information. The information collected helps inform the planning-focused indicators found in the library.

Baseline Development: Guides the collection and review of data that focus on identifying and quantifying energy and water loads required for critical functions at a site as well as supporting redundant systems. Some of the data collected in Baseline Development inform several of the library's indicators, such as energy and water use, performance monitoring, and redundant system operation.

Risk Assessment: Incorporates the following elements: (1) information about hazards and threats, which are potential events that may damage or affect the operation of energy and water systems (e.g., flood events, hurricanes, cyber breaches); (2) vulnerability of those systems determined by characterizing the site's redundant systems, which provide reliable energy and water to meet critical functions of the site; and (3) consequences of a failure of those systems, quantified as the outage duration (hours of disruption that are likely to occur if hazards/threats are realized). The risk analysis itself can be leveraged to monitor progress over time in a way similar to the indicators described here. This formal risk assessment approach parallels several of the resilience indicators presented here and, in those cases, the indicator can be evaluated through the TRN's Risk Assessment module.

Solution Development and Solution Prioritization: The TRN's Solution Development and Solution Prioritization modules guide users through the process of identifying solutions that enhance resilience at their site and then prioritizing solutions based on the ability to reduce risk. In addition, the TRN allows users to include additional criteria that can be used to prioritize resilience solutions. These criteria represent site priorities that must be considered when determining which potential solutions to prioritize. The library's multi-component rating system is designed to easily map onto the scoring of resilience solutions in the TRN.

One example of how the indicators can support the TRN is the multi-component rating approach. This rating system can be used to evaluate how well potential resilience solutions meet specific prioritization criteria in the TRN's Solution Prioritization module (see Table 1).

Table 1. Mapping of Library Multi-component Ratings to the TRN's Solution Prioritization Rating Scale

Resilience Indicator Multi-Component Rating Scale		TRN's Solution Prioritization Criteria Rating Scale	
High	This rating denotes the site has achieved specific requirements of the indicator that fully support the energy/water resilience objective.	**Very Well**	Solution fully addresses the criterion
Medium High	This rating denotes the site has partially achieved the indicator's requirements, but additional progress is needed to fully support the resilience objective.	**Well**	Solution provides significant progress in meeting the criterion, but does not fully address it
Medium Low	This rating denotes the site made marginal progress toward the requirement but has not achieved an acceptable level to meet the resilience objective.	**Moderately Well**	Solution only partially addresses the criterion
Low	This rating denotes the site has made little to no progress in achieving the requirement.	**Not Well**	Solution does not address the criterion

Energy and Water Resilience Library

The remaining sections of the document provide the library of energy and water resilience indicators categorized under each associated resilience attribute.

3.0 Resourcefulness – Optimization

Resourcefulness is the attribute that refers to the ability to prepare for and manage an energy or water disruption. Optimization refers to ensuring that energy and water systems are designed and operate to minimize energy and water use, thereby enabling sites to support critical functions more efficiently. For example, a site that implements efficiency measures on a critical load can reduce the capacity or storage size of the required redundant energy and water systems. The indicators listed in this section provide a method for organizations to track efficiency and performance monitoring.

3.1 Energy and Water Use

A site's energy and water use are important indicators of whether energy and water system design and operations are optimized. These indicators provide the ability to track a site's progress in meeting reduction goals through efficiency and conservation efforts.

Site Energy Use Intensity and Water Use Intensity

Description: Site energy use intensity (EUI) is a normalized measurement of the site's total energy use, typically measured in annual British thermal units per building area square footage (Btu/ft^2/yr) or in kilowatt-hour per square feet per year (kWh/ ft^2/yr). Similarly, site water use intensity (WUI) is a normalized measurement of the site's total water use, typically measured in annual gallons per building area square footage (gal/ ft^2/yr). Data can be gathered from utility billing, production data, and real property to calculate these values.

Performance Tracking: An effective approach to tracking site EUI and WUI performance is the percent reduction compared to a baseline year. Per Energy Independence and Security Act of 2007 requirements, federal agencies' energy baseline year is fiscal year 2003.[3] The current water baseline year for federal agencies is fiscal year 2007. Other baseline years may also be appropriate for organizations depending on the resilience goals and objectives set by the organization.

Rating Options: The rating options are quantitative and tracked against an organization's specified targets.

[3] Find more information about Federal statutory requirements at https://www4.eere.energy.gov/femp/requirements/requirements_filtering/buildings_energy_use

Table 2. Metrics: Site Energy Use Intensity and Water Use Intensity

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has met a specified percent annual EUI reduction target relative to an established baseline	**High:** The site has reduced EUI by more than X% of the organization-established baseline.
No: The site has not met a specified percent annual EUR reduction target relative to an established baseline	**Medium High:** The site has reduced EUI between Y% and X% of the organization-established baseline.
	Medium Low: The site has reduced EUI between Z% and Y% of the organization-established baseline.
	Low: The site has reduced EUI <Z% of the organization-established baseline.
WATER	
Yes: The site has met a specified percent annual WUI reduction target relative to an established baseline.	**High:** The site has reduced WUI by more than X% of the organization-established baseline.
No: The site has not met a specified percent annual WUI reduction target relative to an established baseline.	**Medium High:** The site has reduced WUI between Y% and X% of the organization-established baseline.
	Low: The site has reduced WUI between Z% and Y% of the organization-established baseline.
	Low: The site has reduced WUI <Z% of the organization-established baseline.

TRN Module Connection: Baseline Development Module, Action 1 Worksheet – monthly energy and water consumption and real property data are listed in this worksheet as data to collect in the baselining process. These data are needed to determine site EUI and WUI values.

Building EUI and WUI

Description: Building EUI and WUI are normalized measurements of an individual building's energy and water use. EUI is typically measured in Btu/ ft^2/yr or kWh/ ft^2/yr. WUI is typically measured in gal/ ft^2/yr.

Performance Tracking: An effective approach to tracking building EUI and WUI performance is comparing the building to an established benchmark of the same building type. ENERGY STAR Portfolio Manager can be used to develop energy benchmarking: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/get-started-benchmarking

For water, ENERGY STAR Portfolio Manager has released water use trends by specific building types, which can be used for water benchmarking: https://www.energystar.gov/sites/default/files/buildings/tools/DataTrends_Water_20121002.pdf

Rating Method Options: The rating options are quantitative and tracked against an organization's specified target EUI and WUI benchmark.

Table 3. Metrics: Building EUI and WUI

Binary Rating	Multi-component Rating
ENERGY	
Yes: The building has met a specified building type EUI benchmark.	**High:** The building's EUI meets or is better than the EUI benchmark for the associated building type.
No: The building has not met a specified building type EUI benchmark.	**Medium High:** The building's EUI is >X% of meeting the building type's EUI benchmark.
	Medium Low: The building's EUI is Y%–X% of meeting the building type benchmark.
	Low: >Y% of the building type's EUI benchmark.
WATER	
Yes: The building has met a specified building type WUI benchmark.	**High:** The building's WUI meets or is better than the building type benchmark.
No: The building has not met a specified building type WUI benchmark.	**Medium High:** The building's EUI is >X% of meeting the building type's WUI benchmark.
	Medium Low: The building's WUI is Y%–X% of meeting the building type benchmark.
	Low: >Y% of the building type's WUI benchmark.

TRN Module Connection: Baseline Development Module, Action 1 Worksheet – monthly energy and water consumption and real property data are listed in this worksheet as data to collect in the baselining process, which can inform the development of building-level EUI and WUI.

3.2 Performance Monitoring

A site that proactively monitors building energy and water performance using advanced meters[4] enables personnel to actively manage systems to respond to operational issues, thereby achieving more resilient operations. The following metrics are approaches to tracking how well a site is actively monitoring systems by metering.

Advanced Energy and Water Metering Program

Description: The existence of a metering program is a high-level indicator of a site's ability to properly monitor their building performance.

Performance Tracking: Track the performance of an energy and water metering program by determining whether the metering program is complete and up to date and includes essential elements such as:

- A prioritized approach to installing advanced energy and water meters
- A procurement plan for purchasing the appropriate equipment
- A method for collecting and analyzing the data to make operational changes
- A cybersecurity plan to ensure that meters are connected safely to the site's networks
- An ongoing maintenance program to ensure the meters are calibrated and operated correctly.

[4] Advanced meters are defined as meters that record energy or water consumption data hourly or more frequently and provide for daily or more frequent transmittal of measurements over a communication network to a central data collection point.

Rating Method Options: The rating options are qualitative and track energy and water together because typically metering plans include both energy and water meters.

Table 4. Metrics: Advanced Energy and Water Metering Program

Binary Rating	Multi-component Rating
ENERGY AND WATER	
Yes: An advanced metering program that includes both energy and water is in place.	**High:** An advanced metering program is in place, which includes both energy and water and all essential elements.
No: An advanced metering program does not include both energy and water or is not in place.	**Medium High:** An advanced metering program is in place, which includes both energy and water but does not include all essential elements.
	Medium Low: An advanced metering program has been initiated but is not complete or does not include both energy and water.
	Low: No advanced metering program is in place.

TRN Module Connection: Baseline Development Module, Action 1 Worksheet – building interval meter and submeter energy and water consumption data are listed in this worksheet as data to collect during the baselining process.

Building-Level Advanced Energy and Water Meters

Description: Assessing advanced meters at the building level provides a more in-depth way to determine a site's ability to monitor energy and water use and actively manage and respond to issues using metered data.

Performance Tracking: Advanced meter implementation can be tracked by the percent of advanced meters installed at buildings housing critical energy and water loads.[5] An important element of the performance is to ensure that meters are equipped with data analytics capabilities. It is important to track energy and water meters separately for this building-level measurement. The rating methods below track energy and water separately.

Rating Method Option: The rating options are quantitative; they track the percent of buildings that have energy and water metered separately.

[5] Find information about critical energy and water loads in the TRN Baseline Development Module: https://trn.pnnl.gov/module/baseline-development.

Table 5. Metrics: Building-Level Advanced Energy and Water Meters

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has met a specified percent of advanced meters installed at buildings housing critical energy loads.	**High:** All buildings housing critical energy loads have advanced energy meters with operational data analytics capabilities.
No: The site has not met a specified percent of advanced meters installed at buildings housing critical energy loads.	**Medium High:** Between X% and 100% of buildings housing critical energy loads have advanced energy meters with operational data analytics capabilities.
	Medium Low: Between Y% and X% of buildings housing critical loads have advanced energy meters with operational data analytics capabilities.
	Low: <Y% of building housing critical energy loads have advanced energy meters.
WATER	
Yes: The site has met a specified percent of buildings with advanced water meters.	**High:** All buildings housing critical water loads have advanced water meters with operational data analytics capabilities.
No: The site has not met a specified percent of buildings with advanced water meters.	**Medium High:** Between X% and 100% of buildings housing critical water loads have advanced water meters with operational data analytics capabilities.
	Medium Low: Between Y% and X% of buildings housing critical water loads have advanced water meters with operational data analytics capabilities.
	Low: <Y% of building housing critical water loads have advanced water meters.

TRN Module Connection: Baseline Development Module, Action 1 Worksheet – building interval meter and submeter energy and water consumption data are listed in this worksheet as data to collect in the baselining process.

4.0 Resourcefulness – Preparedness

The second element of the resourcefulness attribute relates to the preparedness of human systems to manage a disruption. Preparedness specifically refers to the adequacy of a site's planning, training, and system testing. For example, a site that has emergency preparedness plans is better positioned to respond to and mitigate the impacts of energy and water outages.

4.1 Preparedness Planning

This indicator provides the ability to track whether a site has plans in place for identifying resilience planning priorities and addressing gaps in site-wide preparedness for emergencies and continuity of operations for energy and water disruption scenarios. This indicator includes plans for responding to short-term emergencies and as well as mitigating and adapting to longer-term climate changes.

Site Emergency Planning

Description: Emergency planning helps a site prepare for continuous operation of energy and water systems during prolonged unplanned disruptions. This requires careful identification of a site emergency team that will coordinate the development of an emergency plan and ensure that the plan is dynamic and contingent upon ongoing processes. It also requires close alignment with organizational, utility, and government policies. Documentation of emergency

planning may be captured in emergency preparedness plans, response plans, site master plans, and continuity of operations (COOP) plans, among others.

Performance Tracking: Emergency planning documents serve to document the processes a site follows to respond to emergency disruption. An effective approach to tracking this indicator is by gauging the completeness of the planning documents and ensuring the plans include procedures for redundant energy and water systems. Essential elements of proper planning that can be used to track the quality of plans should include the following[6]:

- Identification of essential functions
- Assessment of hazards and threats
- Assessment of risks
- Essential staff and delegation of authority
- Succession planning
- Interoperable communications
- Vital records and databases
- Training and exercise program
- Testing program
- Implementation plan and process for revising/updating the emergency plan
- Plans for devolution and reconstitution

Rating Options: The rating options are qualitative and track energy and water together because planning documents should typically describe processes for both energy and water.

Table 6. Metrics: Site Emergency Planning

Binary Rating	Multi-component Rating
ENERGY AND WATER	
Yes: The site has documentation of a current emergency plan, which includes the operation of redundant energy and water systems and contains the established essential elements.	**High:** An emergency plan is in place that addresses redundant energy and water systems and has the established essential elements.
No: The site does not have documentation of a current emergency plan, or it does have a plan, but it is incomplete.	**Medium High:** An emergency plan for redundant energy and water systems is in place and includes most, but not all, essential elements.
	Medium Low: An emergency plan for redundant energy and water systems has been initiated but not completed or the plan has significant gaps.
	Low: No emergency plan is in place.

TRN Module Connection: Site-Level Planning Module, Action 2 Worksheet – Emergency or All-Hazards Plans are listed in this worksheet as relevant information to collect to inform the resilience planning process.

Site Climate Adaptation Planning

Description: A site climate adaptation plan provides a description of the likely impacts the site faces due to climate change and outlines the actions that are needed to prepare and adapt to these changes. The plan helps to identify specific buildings and systems at risk and identifies

[6] As an example, FEMA has established the important elements of COOP planning, which can be obtained here: https://www.fema.gov/pdf/about/org/ncp/coop_brochure.pdf

actions to mitigate the impacts of climate change on the site's ability to provide energy and water resources when and where they are most needed.

Federal agencies have been charged with ensuring they are prepared to meet challenges brought about by climate change impacts. For example, Executive Order 14008: *Tackling the Climate Crisis at Home and Abroad*[7] (27 January 2021) places the climate crisis at the forefront of national security planning and "sets out to move quickly to build resilience both at home and abroad, against the impacts of climate change." Federal agencies are required to develop Climate Action Plans as part of this Executive Order. These action plans may be able to help inform the site's climate adaptation plans.[8]

Performance Tracking: Whether a site has a climate adaptation plan in place and how comprehensive it is can make a difference in how well the site can manage climate impacts and the degree of the impact on critical functions. Ideally, the plan should include the following essential elements:

- An assessment of the impact of climate on energy and water resource availability and the potential impacts on critical functions;
- An assessment of potential impacts based on historical event data and an assessment of future climate scenarios; and
- Climate actions are identified and an implementation plan is developed to address any gaps and help eliminate or reduce the severity of impacts from climate-related energy and water disruptions.

Rating Options: The rating options are qualitative; they track energy and water together because climate change adaptation documents typically describe processes for both energy and water.

Table 7. Metrics: Site Climate Adaptation Planning

Binary Rating	Multi-component Rating
ENERGY AND WATER	
Yes: The site has a climate adaptation plan in place that includes all essential elements.	**High:** A climate adaptation plan is in place that includes all essential elements.
No: The site does not have a climate adaptation plan in place or the plan does not include all the essential elements.	**Medium High:** A climate adaptation plan is in place that includes most, but not all, essential elements.
	Medium Low: A climate adaptation plan has been initiated but is not complete or the plan has significant gaps.
	Low: No climate adaptation plan is in place.

TRN Module Connection: Not currently in the TRN.

4.2 Staffing and Training

Energy and water resilience begins with trained site leadership and staff. This indicator tracks whether the site has staff in place to prepare for and respond to energy and water disruptions

[7] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

[8] Federal agency climate adaptation plans (also called climate adaptation and resilience plans or climate action plans) can be accessed here: https://www.sustainability.gov/adaptation/

and whether it provides those staff with the necessary training. Sites with staff trained in relevant topics and with documented testing procedures are less likely to have catastrophic failures and are better equipped to request and receive temporary assets quicker when needed.

Site Operations Personnel

Description: A resilient site has dedicated staff to direct efforts, coordinate stakeholders, and track progress consistently and efficiently relative to the complex task of resilience planning. Identifying operations personnel across different relevant sectors (energy and water) with relevant training/certifications helps ensure that planning efforts align with other site initiatives. Establishing a dedicated team is also essential for securing funding and implementing solutions.

Performance Tracking: The performance of this indicator can be tracked by establishing the minimum number of personnel that are required for each site with the required training and/or certifications related to energy and water systems.

Rating Options: The rating options are qualitative; they track whether site personnel have the proper training/responsibilities for operating and maintaining energy and water systems separately.

Table 8. Metrics: Site Operations Personnel

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has a dedicated energy manager and other relevant personnel (e.g., energy facility operators) who have training/certification related to operating and maintaining the site's energy infrastructure, including redundant energy systems that provide continuity during a utility disruption.	**High:** The site has a dedicated energy manager and other relevant personnel (e.g., energy facility operators) who have training/certification related to operating and maintaining site energy infrastructure when there is a sustained utility disruption.
No: The site does not have dedicated personnel with training/certification related to operating and maintaining the site's energy infrastructure when there is a sustained utility disruption.	**Medium High:** The site has a dedicated energy manager and personnel who are responsible for energy management at each site, but they do not have training/certification related to operating and maintaining site energy infrastructure when there is a sustained utility disruption.
	Medium Low: The site does not have personnel that are dedicated to energy management or resilience, but there is a vacant position that has yet to be filled.
	Low: The site does not have personnel that are dedicated to energy management or resilience.
WATER	
Yes: The site has a dedicated water manager and other relevant personnel (e.g., water facility operators) who have training/certification related to operating and maintaining site water infrastructure including redundant water systems that provide continuity during a water disruption.	**High:** The site has a dedicated water manager and other relevant personnel (e.g., water facility operators) who have training/certification related to operating and maintaining site water infrastructure including redundant water systems when there is a water disruption.
No: The site does not have dedicated personnel with training/certification related operating and maintaining site water and wastewater infrastructure when there is a water disruption.	**Medium High:** The site has a dedicated water manager and personnel who are responsible for water management at each site, but they do not have training/certification related to operating and maintaining site water infrastructure when there is a water disruption.
	Medium Low: The site does not have personnel that are dedicated to water management or resilience, but there is a vacant position that has yet to be filled.
	Low: The site does not have personnel that are dedicated to water management or resilience.

TRN Module Connection: Site-Level Planning, Action 1 Worksheet – This action in the TRN focuses on identifying staff and stakeholders who have expertise relevant to the energy and water resilience planning process. Staff identified for this metric will likely be key stakeholders in the resilience planning process and may be good candidates to be part of the resilience planning team.

Emergency Response Training

Description: As part of the resilience planning process, it is vital that site staff are adequately prepared to ensure that energy and water systems can continue operations during an energy/water disruption. This metric helps to determine whether site staff are trained to respond, withstand, and recover from energy and water disruptions.

Performance Tracking: The performance of this indicator can be tracked by determining whether a site conducts emergency and response training focused on preparing for energy and water disruptions, as well as tracking the frequency of those trainings. It is important that these trainings are reoccurring because the risks to a site will continually change.

Rating Options: The rating options are quantitative; they track the number of emergency response training sessions provided annually and track energy and water separately to ensure personnel are trained on both energy and water redundant systems.

Table 9. Metrics: Emergency Response Training

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site conducts emergency and response trainings regularly (e.g., annually) that include energy disruption scenarios	**High:** The site conducts >X emergency and response training sessions annually to prepare for energy emergency scenarios.
No: The site does not conduct emergency and response trainings regularly for energy disruption scenarios.	**Medium High:** The site conducts between Y and X emergency and response training sessions annually to prepare for energy emergency scenarios.
	Medium Low: The site conducts <Y emergency and response training sessions to prepare for energy emergency scenarios.
	Low: The site does not conduct energy emergency and response training.
WATER	
Yes: The site conducts emergency and response trainings regularly (e.g., annually) that include water disruption scenarios.	**High:** The site conducts >X emergency and response training sessions annually to prepare for water emergency scenarios.
No: The site does not conduct emergency and response trainings regularly for water disruption scenarios.	**Medium High:** The site conducts between Y and X emergency and response training sessions annually to prepare for water emergency scenarios.
	Medium Low: The site conducts <Y emergency and response training sessions to prepare for water emergency scenarios.
	Low: The site does not conduct water emergency and response training.

TRN Module Connection: Baseline Development Module, Action 3 Worksheet – Information about whether personnel are trained on manual operation of redundant systems is collected in Baseline Development to inform the vulnerability assessment in the TRN risk screening.

4.3 Redundant System Testing

Regular testing of redundant energy and water systems is an important element of resilience preparedness to ensure that these systems are operating at their designed capacity in the event of an energy or water outage. This indicator includes two metrics—one to assess at the site level whether sites have an adequate plan in place for system testing and one to assess at the asset level to determine whether individual redundant systems are adequately tested.

Site System Testing Protocol/Plan

Description: An energy and water system testing plan outlines the requirements for routine and full-scale testing of the site's redundant energy and water systems that support site critical functions. Routine testing is often completed as part of regular operations and maintenance (see Section 7.3).

Performance Tracking: The completeness of the system testing plan and the specificity provided in the plan can be the appropriate measures for determining how well the site is meeting this indicator.

Essential elements of a good system testing plan include the following:

- Staff with assigned roles and responsibilities;
- Defined testing procedures for both the system and its components that are part of the critical functions (e.g., water treatment is a component of a redundant water system);
- Testing frequency; and
- Administration, including resource allocation, documentation, and reporting of outcomes.

Rating Options: The rating options are qualitative, identifying whether the plans are complete and include essential elements, and tracking energy and water separately to ensure testing plans are in place for both systems.

Table 10. Metrics: Site System Testing Protocol/Plan

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has a current system testing plan in place for energy systems and components that support critical site operations.	**High:** The site has a system testing plan in place for energy systems and components that support critical site operations, which includes the essential elements.
No: The site does not have a current system testing plan in place for energy systems that support critical site operations.	**Medium High:** The site has a system testing plan in place for energy systems and components that support critical site operations, but it does not include all essential elements.
	Medium Low: The site has initiated a system testing plan for energy systems, but it is not complete.
	Low: The site does not have a testing plan for critical energy systems and components.
WATER	
Yes: The site has a current system testing plan in place for water systems and components that support critical site operations.	**High:** The site has a system testing plan in place for water systems and components that support critical site operations, which includes the essential elements.
No: The site does not have a current system testing plan in place for water systems that support critical site operations.	**Medium High:** The site has a system testing plan in place for water systems and components that support critical site operations, but it does not include all essential elements.
	Medium Low: The site has initiated a system testing plan for water systems, but it is not complete.
	Low: The site does not have a testing plan in place for critical water systems and components.

TRN Module Connection: See next metric.

Redundant Systems Testing

Description: Testing of redundant systems is a key input to the TRN risk screening assessment. The TRN specifically includes criteria to ensure redundant systems are tested, individual components are systematically reviewed, and outcomes and follow-up actions are documented.

TRN Module Connection: Baseline Development Module, Action 3 Worksheet – Information about whether redundant systems are tested is a key input for the vulnerability assessment in the TRN risk screening.

5.0 Redundancy

Redundancy refers to redundant generation systems that support primary energy and water systems in case they fail. A redundant system refers to an onsite system able to supply energy or water to a critical load in the event of an energy or water utility disruption. A backup generator, uninterruptible power supply (UPS), building-integrated photovoltaic (PV) system, or microgrid with PV and battery storage are all examples of redundant energy systems to a utility supply. To be considered redundant, an onsite energy system should not be reliant on grid power to function and supply the critical load. Redundant water systems may include onsite water cisterns connected to a critical load, portable water tanks, and treatment and purification systems.

5.1 Redundant System Sizing

This indicator examines the adequacy of the sizing of a site's redundant systems by answering the question – are the site's energy and water systems' capacities large enough to continue critical missions' operations during a disruption? This indicator has two metrics—one at the high-level that generally assesses the capacity of a site's energy and water generation and storage, and an in-depth asset-level metric that assesses individual redundant systems, which is covered specifically in the TRN's Risk Assessment module.

Site Electricity and Water Generation and Storage Capacity

Description: A site's generation and storage capacity refers to the level of capacity at which a site can meet critical energy and water requirements in the event of an unplanned utility interruption. This metric examines both the capacity to generate and store energy and supply and store water onsite.

Performance Tracking: This indicator is measured in terms of the number of days a site's critical energy and water needs can be met as calculated by comparing the total onsite generation plus storage capacity divided by the site's total critical energy and water loads as described below. Outage duration minimums and goals are typically established at the organizational level.

Here are example calculations that can be used for determining the system capacity of electric power systems and water systems:

- Electricity includes the total generation capacity of all available generating and storage systems including the following with capacities determined in kWh/day available: standby generator capacities (assuming the site has adequate fuel supply for continuous operation); site-connected renewables (PV and wind); other onsite generation technologies such as microgrids and fuel cells; and electricity storage technologies such as batteries, flywheels, and uninterrupted power supplies[9]. Electric capacity during an outage can be calculated as

$$D_{CEL} = \frac{G + S}{L_{PE}}$$

[9]When determining electricity generation and loads, it is important to consider seasonal fluctuations in the generation capacity and the loads. For example, renewable energy generation is impacted by the time of day and season. Peak loads may change throughout the year. Consider these changes when estimating the generation capacity and peak loads to accurately calculate this metric.

where D_{CEL} is the number of days the critical electric load is met, G is the total daily onsite electricity generation, S is the total daily onsite electricity storage, and L_{PE} is the peak daily critical electric load.

- Water includes the total generation capacity of backup water treatment processes and water storage capacity. Use this metric for potable and non-potable systems separately. Water capacity during an outage can be calculated as

$$D_{CWL} = \frac{V}{L_{PW}}$$

where D_{CWL} is the number of days the critical water load (gallons) is met, V is the total onsite volume of backup water, and L_{PW} is the peak daily critical water load.

Rating Options: The rating options are quantitative; they track energy and water capacity separately relative to established levels set by the organization.

Table 11. Metrics: Site Electricity and Water Generation and Storage Capacity

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site can provide 100% of peak critical electricity loads for X days with standby/off-grid generation plus storage capacity.	**High:** The site can provide 100% of peak critical electricity loads for X days with standby/off-grid generation plus storage capacity.
No: The site is not able to provide 100% of peak critical electricity loads for X days with standby/off-grid generation plus storage capacity.	**Medium High:** The site can provide 100% of peak critical electricity loads between Y and X days with standby/off-grid generation plus storage capacity.
	Medium Low: The site can provide 100% of peak critical electricity loads for <Y days with standby/off-grid generation plus storage capacity.
	Low: The site has minimal or no standby/off-grid generation capacity to meet peak critical electricity loads.
WATER	
Yes: The site can provide 100% of peak critical water loads for X days with onsite water generation plus storage capacity.	**High:** The site can provide 100% of peak critical water loads for X days with onsite water generation plus storage capacity.
No: The site is not able to provide 100% of peak critical water loads for X days with onsite water generation plus storage capacity.	**Medium High:** The site can provide 100% of peak critical water loads for Y and X days with onsite water generation plus storage capacity.
	Medium Low: The site can provide 100% of peak critical water loads for <Y% days with onsite water generation and storage capacity.
	Low: The site has minimal or no onsite water generation and storage capacity.

TRN Module Connection: Baseline Development Module, Action 3 Worksheet – Information about the operating capacity of redundant systems can inform the vulnerability assessment in the TRN risk screening.

Redundant Systems Operating Capacity

Description: The TRN's Baseline Development and Risk Assessment modules use redundant system operating capacity as an input to determine the duration over which the redundant system can enable continuous operations. This is key because it determines how much of the outage can be mitigated and, therefore, this input is integral to the risk results obtained from completing the TRN's risk screening assessment.

TRN Module Connection: Baseline Development Module, Action 3 Worksheet – Information about the operating capacity of redundant systems is a key input for the vulnerability assessment in the TRN risk screening. To help users determine the expected runtime for their redundant systems, the TRN provides a runtime calculator for diesel generators.

5.2 Primary Utility Supply Feed Redundancy

This indicator determines whether there is adequate redundancy of the energy and water supply lines feeding a site from the primary supplier. If the main supply feed is out of service and there is no redundant line to serve the site, this poses a distinct vulnerability to the site.

Energy and Water Supply Feeds

Description: This indicator can be measured by determining the number of non-collocated and collocated redundant supply feeds that are available at a site and by determining whether the feeds can meet the needed capacity of the site. Non-collocated supply feeds are preferred because having them lowers the vulnerability of two collocated lines going down because of an external threat, such as an earthquake. For electric power feeds, redundant lines may originate from different substations or even from different power generation sources. For water feeds, redundant lines may originate from different water sources.

Performance Tracking: Track the performance of this indicator by locating and identifying the number of supply feeds and verifying the capacities of each of the supply feeds.

Rating Options: The rating options are quantitative; they track the number of non-collocated and collocated supply feeds separately for energy and water.

Table 12. Metrics: Energy and Water Supply Feeds

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has two or more electric power supply feeds (non-collocated or collocated) each capable of providing full site peak electric power requirements.	**High:** There are two or more non-collocated electric power supply feeds, each capable of providing full site peak electric power requirements.
No: The site does not have two or more non-collocated electric power supply feeds, each capable of providing full site peak electric power requirements.	**Medium High:** There are two or more collocated electric power supply feeds, each capable of providing full site peak electric power requirements.
	Medium Low: There are two or more collocated electric power supply feeds and only one feed is capable of providing full site peak electric power requirements.
	Low: There is no electric power supply redundancy.
WATER	
Yes: The site has two or more non-collocated or non-collocated water supply feeds, each capable of providing full site peak water requirements.	**High:** There are two or more non-collocated water supply feeds, each capable of providing full site peak water requirements.
No: The site does not have two or more non-collocated water supply feeds, each capable of providing full site peak water requirements.	**Medium High:** There are two or more collocated water supply feeds, each capable of providing full site peak water requirements.
	Medium Low: There are two or more collocated water supply feeds and only one feed capable of providing full site peak water requirements.
	Low: There is no water supply feed redundancy.

TRN Module Connection: Baseline Development Module, Action 2; Solution Prioritization Module, Action 3 and 4 Worksheets – Data related to supply feeds are collected as part of

mission owner interviews in Baseline Development Module, Action 2. However, because the TRN's Risk Assessment module is focused on critical load level analysis, it does not explicitly incorporate the impact of having multiple feeds at a site. Nevertheless, this can be an important component of a resilience plan and a site may wish to evaluate resilience solutions based on their ability to improve the redundancy of the resource supply to the site. In such cases, consider including a prioritization criterion related to improving energy or water supply to the site. The multi-component rating approach described above can easily be modified to evaluate how well a solution would achieve that priority on a *"not well–moderately well–well–very well"* scale.

6.0 Robustness

Robustness refers to the ability to maintain critical operations and functions during a disruptive event. This includes the reliability of the system to ensure it can meet mission critical loads. Indicators tied to the robustness attribute assess the reliability of the primary supplier, redundant systems, and distribution systems.

6.1 Primary Utility Supply Reliability

This indicator assesses the reliability of the primary supplier to provide energy and water.

Unplanned Energy and Water Outages from the Primary Supplier

Description: Unplanned energy and water outages from the primary supplier can be an indication of the reliability of the primary supplier. Outages reveal vulnerabilities within the supplier's system. For example, aging infrastructure is often the culprit of mainline water breaks. These unplanned energy and water outages can damage onsite equipment, interrupt operations, and create safety issues. Utilities typically track and make available outage information using the reliability indices such as SAIFI (System Average Interruption Frequency Index). [10]

Performance Tracking: The frequency and/or duration of these unplanned energy and water outages over time can reveal energy and water supply risks, helping to identify remediation actions such as working with the utility provider to improve service reliability or increasing onsite redundancy. Organizations can track annual outage data and compare them with an organization's established standard and review them for potential supply risks. Average annual outages should be tracked over at least a 3-year timeframe as a way to see trends over time. Separate ratings should be determined for electricity, natural gas, other energy supply sources (if any), and water.

Rating Options: The rating options are quantitative; the numbers of average annual outages are tracked separately for energy and water. Another optional rating for consideration is tracking the total duration of outages annually (in hours or days).

[10] SAIFI is the total number of sustained interruptions in a year divided by the total number of consumers and is a useful value for understanding the reliability of your site's utility. There are not similar metrics tracked by water utilities. Therefore, the number of unplanned electricity outages is listed in the resilience library to be commensurate with the water-related metric.

Table 13. Metrics: Unplanned Energy and Water Outages from the Primary Supplier

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has experienced <X unplanned energy outages from the primary supplier per year on average (over a designated timeframe).	**High:** There have been <X unplanned energy outages per year on average.
No: The site has experienced X or more unplanned energy outages per year on average.	**Medium High:** There have been X–Y unplanned energy outages per year on average.
	Medium Low: There have been Y–Z unplanned energy outages per year on average.
	Low: There have been >Z unplanned energy outages per year on average.
WATER	
Yes: The site has experienced <X unplanned water outages per year on average (over a designated timeframe).	**High:** There have been <X unplanned water outages per year on average.
No: The site has experienced X or more unplanned water outages per year on average.	**Medium High:** There have been X–Y unplanned water outages per year on average.
	Medium Low: There have been Y–Z unplanned water outages per year on average.
	Low: There have been >Z unplanned water outages per year on average.

TRN Module Connection: Risk Assessment Module, Action 2 Worksheet – Data quantifying the frequency of electricity and water outages can be leveraged to estimate the frequency and duration of outages that a site can expect to experience. This information is used to identify Grouped Hazards in the TRN's Risk Assessment module. Grouped Hazards are often referred to as an "all-hazards" approach and incorporate hazards defined by the frequency and duration of outages that are not tied to specific causes (e.g., natural hazard events, malicious actions, climate change impacts). However, note that the TRN risk assessment focuses on resilience rather than reliability assessment and, therefore, considers the frequency of outages ranging in duration from 1 hour to 6 months.

6.2 Onsite Distribution System Reliability and Condition

This indicator examines the reliability of sites' onsite energy and water distribution systems. Sites that include multiple buildings usually include distribution for energy and water services that are owned and operated by the site. The overall condition of the distribution systems is an important aspect of a resilient site.

Unplanned Onsite Energy and Water Distribution Outages

Description: Site-owned distribution systems experience unplanned outages just as the utility owned systems do. Unplanned outages can indicate the level of system reliability and reveal vulnerabilities such as poor system condition that may be a result of age, poor maintenance, misuse, and/or damage from weather or accidents. Unplanned onsite distribution system outages can result in lost work time, equipment damage, and pose a risk to critical operations.

Performance Tracking: The number of unplanned outages due to distribution failure provides an indication of the overall onsite distribution system condition. Tracking and reviewing the frequency of these outages and the outage trends over time can provide valuable insights into the condition of the onsite distribution system. The average annual outages should be tracked over at least a 3-year timeframe as a way to see trends over time.

Rating Options: The rating options are quantitative; the average number of annual average distribution outages are tracked separately for energy and water, and tracked relative to established levels set by the organization.

Table 14. Metrics: Unplanned Onsite Energy and Water Distribution Outages

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has experienced <X unplanned energy distribution system outages per year on average (over a designated timeframe).	**High:** There have been <X unplanned energy distribution system outages per year on average.
No: The site has experienced X or more unplanned energy distribution system outages per year on average.	**Medium High:** There have been X-Y unplanned energy distribution system outages per year on average.
	Medium Low: There have been Y-Z unplanned energy distribution system outages per year on average.
	Low: There have been >Z unplanned energy distribution system outages per year on average.
WATER	
Yes: The site has experienced <X unplanned water distribution system outages per year on average (over a designated timeframe).	**High:** There have been <X unplanned water distribution system outages per year on average.
No: The site has experienced X or more unplanned water distribution system outages per year on average.	**Medium High:** There have been X-Y unplanned water distribution system outages per year on average.
	Medium Low: There have been Y-Z unplanned water distribution system outages per year on average.
	Low: There have been >Z unplanned water distribution system outages per year on average.

TRN Module Connection: Risk Assessment Module, Action 2 Worksheet – Data quantifying the frequency of electricity and water outages due to onsite distribution failures can be leveraged to estimate the frequency and duration of outages that a site can expect to experience by combining them with outage frequency estimates based on supply failures. This information is used to identify Grouped Hazards[11] in the TRN's Risk Assessment module.

6.3 Redundant System Reliability

This indicator examines the reliability of sites' redundant systems through operations and maintenance (O&M) practices. Ongoing comprehensive O&M is necessary to provide reliability and operability of the critical energy and water systems to meet user needs. Failure to perform comprehensive O&M can lead to inefficient and/or unreliable operations, as well as increased unplanned failures.

Site O&M Program for Energy and Water Systems

Description: A strategic approach to O&M of critical energy and water systems is the use of predictive maintenance techniques[12] such as infrared thermography, vibration analysis, ultrasonic noise detection, motor current signature analysis. Predictive maintenance attempts to identify and correct component/equipment degradation prior to failure.

[11] Grouped Hazards are often referred to as an "all-hazards" approach and incorporate hazards defined by the frequency and duration of outages that are not tied to specific causes (e.g., natural hazard events, malicious actions).

[12] Find information about predictive O&M in the FEMP Release 3.0, Operations and Maintenance Best Practices, Chapter 6.

Performance Tracking: Developing a predictive maintenance program and completion of identified predictive maintenance practices can reveal the reliability of a site's redundant system at a high level.

Rating Options: The rating options are qualitative; they track energy and water separately.

Table 15. Metrics: Site O&M Program for Energy and Water Systems

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has instituted a predictive maintenance program for critical energy systems components/equipment.	**High:** The site has instituted a predictive maintenance program for critical energy systems components/equipment and is fully using predictive maintenance techniques as appropriate.
No: The site has not instituted a predictive maintenance program for critical energy systems components/equipment.	**Medium High:** The site has developed a predictive maintenance program for critical energy systems components/equipment but is not yet fully using predictive maintenance techniques.
	Medium Low: The site is developing a predictive maintenance program for critical energy systems components/equipment.
	Low: The site is not addressing predictive maintenance of critical energy systems components/equipment.
WATER	
Yes: The site has instituted a predictive maintenance program for critical water systems components/equipment.	**High:** The site has instituted a predictive maintenance program for critical water systems components/equipment and is fully using predictive maintenance techniques as appropriate.
No: The site has not instituted a predictive maintenance program for critical water systems components/equipment.	**Medium High:** The site has developed a predictive maintenance program for critical water systems components/equipment but is not yet fully using predictive maintenance techniques.
	Medium Low: The site is developing a predictive maintenance program for critical water systems components/equipment.
	Low: The site is not addressing predictive maintenance of critical water systems components/equipment.

TRN Module Connection: See next metric.

Energy and Water Redundant System Maintenance

Description: Including redundant systems in a maintenance program is important to ensure that these systems are operating at their designed capacity in the event of an outage. Maintenance of redundant systems is a key input in the TRN to characterize those systems in the vulnerability assessment and, therefore, this input is integral to the risk results obtained from completing the TRN's Risk Assessment screening.

TRN Module Connection: Baseline Development Module, Action 3 Worksheet – Information about whether redundant systems are part of a maintenance program is a key input for the vulnerability assessment in the TRN's risk screening.

7.0 Recovery

Recovery refers to a site's ability to return to or reconstitute normal operating conditions as quickly and efficiently as possible after a disruption and may include carefully drafted contingency plans, competent emergency operations, and having the right people and resources in the right place at the right time.

7.1 Component Inventory

This indicator examines the ability of site personnel to access required components during an outage, which is critical to a site's ability to recover quickly from disruption. This indicator includes two metrics—the site's overall inventory program and the onsite parts supply for specific redundant systems, which are covered in the TRN.

Site Component Inventory Program

Description: This metric helps to determine at a high level whether the site has a robust component inventory program in place that establishes the requirements for energy and water systems.

Performance Tracking: This metric can be tracked by establishing essential elements of an inventory program, including the following:

- Identified parts and accessories that are required for energy systems and water systems (e.g., motors, valves, pumps, filters, leak repair);
- purchasing protocols that includes specifications for purchasing the required parts and accessories; and
- having an inventory tracking system in place that ensures adequate parts and accessories are properly inventoried and tracked so that parts are ordered when necessary.

Rating Options: The rating options are qualitative; the quality of the inventory programs for energy and water are tracked separately.

Table 16. Metrics: Site Component Inventory Program

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has a component inventory program in place for energy systems that includes all essential elements.	**High:** The site has a component inventory program in place for energy systems that includes all essential elements.
No: The site does not have a component inventory program in place for energy systems.	**Medium High:** The site has a component inventory program in place for energy systems, but it does not include all of the required elements.
	Medium Low: The site has initiated a component inventory program for energy systems, but it is not in place.
	Low: The site does not have a component inventory program in place for energy systems.
WATER	
Yes: The site has a component inventory program in place for water systems that includes all essential elements.	**High:** The site has a component inventory program in place for water systems that includes all essential elements.
No: The site does not have a component inventory program in place for water systems.	**Medium High:** The site has a component inventory program in place for water systems, but it does not include all of the required elements.
	Medium Low: The site has initiated a component inventory program for water systems, but it is not in place.
	Low: The site does not have a component inventory program in place for water systems.

TRN Module Connection: See next metric.

Onsite Parts Supply for Energy and Water Redundant Systems

Description: Ensuring that redundant systems have a sufficient parts supply for different outage scenarios is key to determining the duration over which the redundant system can operate successfully and that issues that arise with the redundant system over the course of a long-duration outage can be remedied. Having a sufficient supply of parts is key because it determines how much of the outage can be mitigated and, therefore, is integral to the risk results obtained from completing the TRN's risk screening.

TRN Module Connection: Baseline Development Module, Action 3 Worksheet – Information about the onsite parts supply for redundant systems is a key input for the vulnerability assessment in the TRN's risk screening.

7.2 Restoration Planning

This indicator examines how well sites have planned for quickly and efficiently restoring energy and water after an outage, including priority restoration with primary suppliers and energy and water curtailment plans.

Priority Restoration of Energy and Water Suppliers

Description: Energy and water utilities typically have priority restoration plans in place that identify critical sites with essential and emergency functions and designate them as having high priority for the restoration of energy and water. Sites within an organization that have critical

functions should ideally work with their local suppliers to develop priority restoration agreements.

Performance Tracking: An effective approach to gauging the adequacy of restoration planning is determining whether the energy and water suppliers have complete restoration plans and whether the site has an agreement in place for restoring energy and water. Sound restoration plans should include important elements such as the following:

- complete data on service areas and customer types
- incident levels that define outage types and general response protocols
- communication and coordination strategy during emergencies to define roles and responsibilities
- a prioritized restoration plan that outlines the priority order for service repair and restoration.

Rating Options: The rating options are qualitative; they track whether restoration planning is in place and track energy and water separately.

Table 17. Metrics: Priority Restoration of Energy and Water Suppliers

Binary Rating	Multi-component Rating
ENERGY	
Yes: The primary energy suppliers (electricity, natural gas) have a complete restoration plan in place and the site has a priority restoration agreement with the primary energy supplier.	**High:** The primary energy suppliers have a complete restoration plan that includes essential elements, and a site priority restoration agreement is in place.
No: The primary energy suppliers do not have a complete restoration plan in place and the site does not have a priority restoration agreement with the primary energy supplier.	**Medium High:** The primary energy suppliers have a complete restoration plan, but the site does not have a priority restoration agreement in place.
	Medium Low: The primary energy suppliers have initiated a priority restoration plan, but it is not complete.
	Low: No restoration plan is in place.
WATER	
Yes: The primary water supplier has a complete restoration plan in place, and the site has a priority restoration agreement with the primary water supplier.	**High:** The primary water supplier has a complete restoration plan in place, and a site priority restoration agreement is in place.
No: The primary water supplier does not have a complete restoration plan in place, and the site does not have a priority restoration agreement with the primary water supplier.	**Medium High:** The primary water supplier has a complete restoration plan, but the site does not have a priority restoration agreement in place.
	Medium Low: The primary water supplier has initiated a priority restoration plan, but it is not complete.
	Low: No restoration plan is in place.

TRN Module Connection: Site-Level Planning Module, Action 2 Worksheet – Service Restoration Plans are listed in this worksheet as relevant information to collect to inform the resilience planning process.

Site Energy and Water Curtailment Capability

Description: A site's ability to curtail the energy and water use of non-critical functions during a disruption is a good indicator of how well the site is prepared to quickly recover from a disruption. By curtailing these non-essential loads, energy and water can be prioritized for the critical functions.

Performance Tracking: The level of curtailment capability can be used to track the performance of this metric. A site that has the ability to curtail loads has prioritized the loads that must remain operational during a disruption and established protocols for site facility operators for the actions that are required to reduce non-essential loads. This metric can also be tracked by the percent of non-essential loads that can be curtailed during a disruption.

Rating Options: Qualitative or quantitative options are provided for energy and water separately and tracked against established levels set by the organization.

Table 18. Metrics: Site Energy and Water Curtailment Capability

Binary Rating	Multi-component Rating
ENERGY	
Yes: The site has a curtailment plan in place that has prioritized the non-essential energy loads for curtailment.	**High:** The site has the ability to curtail >X% of non-essential energy loads.
No: The site does not have an energy curtailment plan in place.	**Medium High:** The site has the ability to curtail Y%−X% of non-essential energy loads.
	Medium Low: The site has the ability to curtail Z%−Y% of non-essential energy loads.
	Low: The site has the ability to curtail <Z% of non-essential energy loads.
WATER	
Yes: The site has a curtailment plan in place that has prioritized the non-essential water loads for curtailment.	**High:** The site has the ability to curtail >X% of non-essential water loads.
No: The site does not have a water curtailment plan in place.	**Medium High:** The site has the ability to curtail Y%−X% of non-essential water loads.
	Medium Low: The site has the ability to curtail Z%−Y% of non-essential water loads.
	Low: The site has the ability to curtail <Z% of non-essential water loads.

TRN Module Connection: Solution Development Module, Action 2 Worksheet – Developing a curtailment plan could contribute to an operational resilience solution that would be recorded in the Solution Development module. This could be modeled in the Risk Assessment module by increasing the duration for which a redundant system could support loads at the site because of the decrease in the loads that need to be supported.

7.3 Mission Duplication

Mission duplication is the ability of a site to move critical functions to another location and is an important strategy to implement to quickly restore the mission. Organizations may find this an important resilience indicator because it can help focus investments for sites that do not have this capability. This indicator includes a high-level metric that assesses the general capability to duplicate missions at an alternate location. The TRN also specifically examines this indicator in the Risk Assessment module.

Mission Duplication Capability

Description: Organizations can assess the overall capability of a site to duplicate the mission and thereby reduce the impact on the site's mission(s) in the event of an outage.

Performance Tracking: Mission duplication capability can be tracked by examining the level of mission duplication that can be achieved.

Rating Options: The rating options are qualitative; they track the level of mission duplication capability.

Table 19. Metrics: Mission Duplication Capability

Binary Rating	Multi-component Rating
ENERGY AND WATER	
Yes: The site has the ability to duplicate their mission at another location.	**High:** The site has the ability to fully duplicate their mission at another location.
No: The site does not have the ability to duplicate their mission at another location.	**Medium High:** The site has the ability to duplicate the majority of their mission at another location.
	Medium Low: The site has the ability to partially duplicate their mission at another location.
	Low: The site does not have the ability to duplicate their mission at another location.

TRN Module Connection: See next metric.

Mission Duplication of Critical Functions

Description: In the TRN's Risk Assessment module, mission duplication of critical functions is incorporated as a way to reduce the consequence of an outage on the site. Therefore, mission duplication is integral to the risk results obtained from completing the TRN's risk screening.

TRN Module Connection: Risk Assessment Module, Action 1 Worksheet – Information about the site's ability to duplicate critical functions is a key input for the TRN risk screening.

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