Figure 6-13. Corrosive Areas by Type

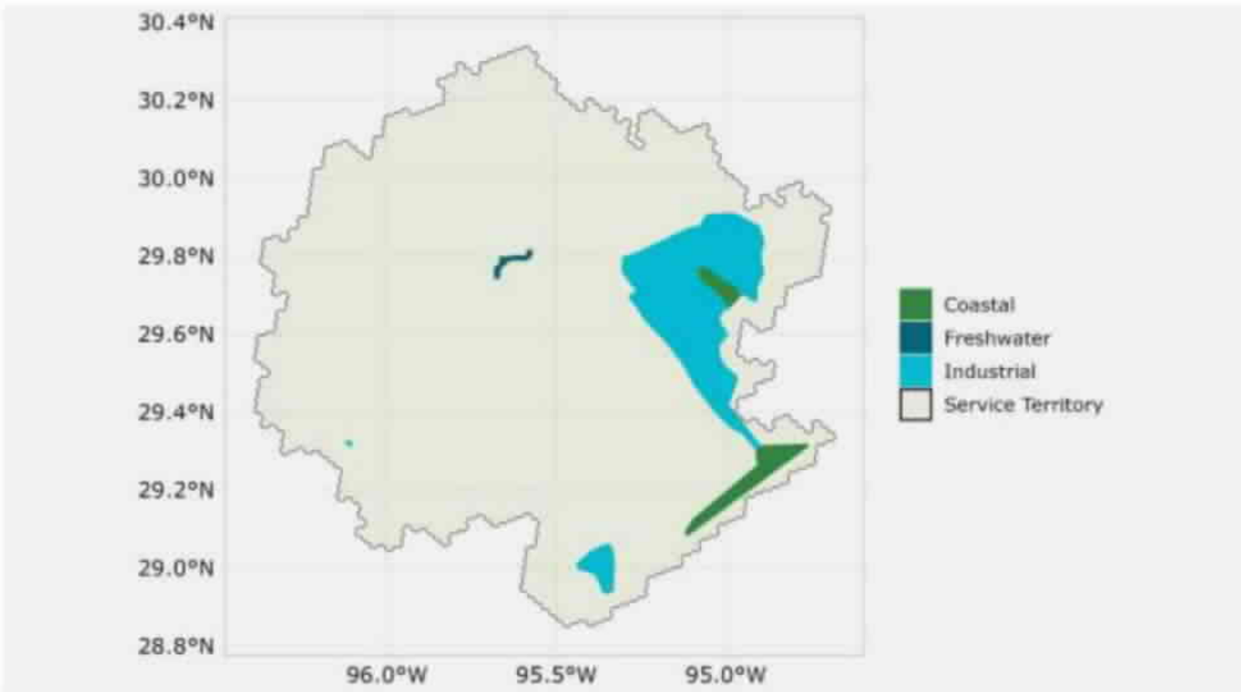
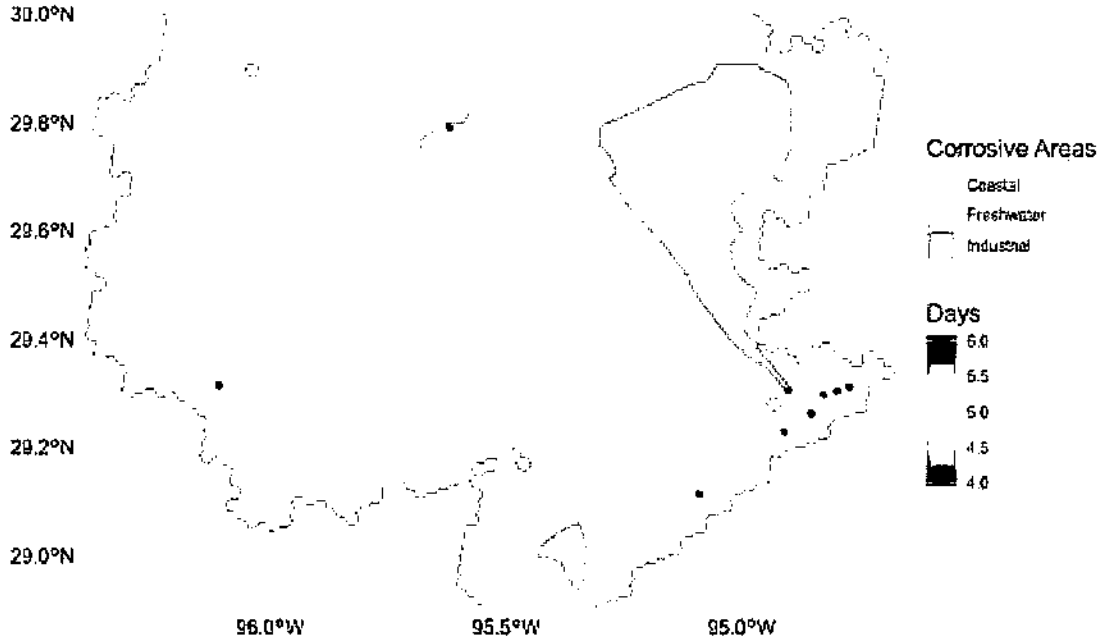


Figure 6-14 shows the drought metrics for substations within corrosive areas in 2050. Coastal corrosive areas have the highest drought values in each year, increasing from 4.64 in 2025 to 5.78 in 2050. Eight substations fall within this area. Industrial corrosive areas contain the most substations (22%, or 60 substations) and are at risk of relatively high drought, with values increasing from 3.92 days in 2025 to 4.85 days in 2050. The substation within the freshwater corrosive area is at a slightly lower risk of drought than substations outside of coastal areas but still shows an increase of nearly 30% from 2025 to 2050 (3.35 days to 4.26 days).

Figure 6-14. Rolling Average Days with SPEI Below -2 by Substation and Corrosive Area in 2050 (SSP2-4.5)



6.2 Circuit-Level Criticality and Measure Impacts Approach

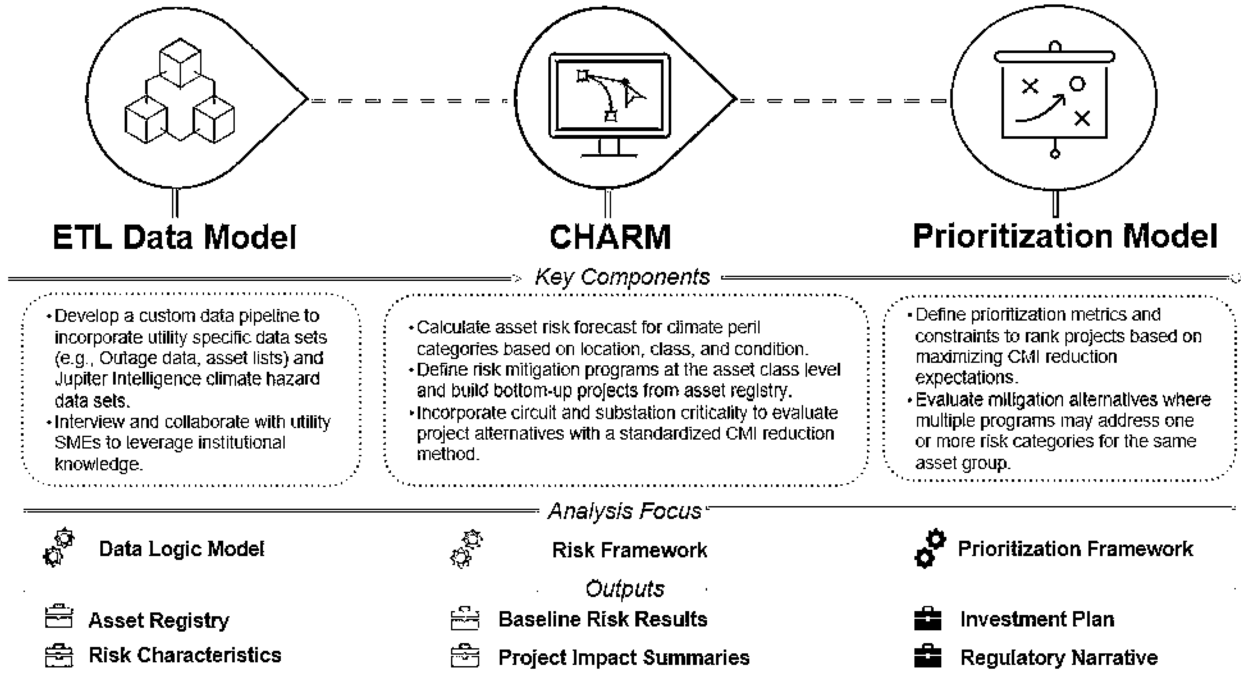
To identify recommendations for CenterPoint Houston's locational analysis discussed in the SRP, Guidehouse collected and integrated various asset and circuit data sources with the results of the climate vulnerability assessment to estimate circuit-level measure impacts in reductions in CMI. Guidehouse utilized a customized Climate Hazard and Asset Risk Mitigation (CHARM) model to analyze CenterPoint Houston's resiliency risk at the asset level for a baseline scenario and investment alternatives, allowing for comparison and locational prioritization of projects.

The CHARM model approach employs three primary steps including:

- Development of a utility data model.
- Configuration of the CHARM model for selected climate hazards and asset classes.
- Defining a prioritization scheme and analysis of each measure in the model framework (Section 6.3).

Figure 6-15 provides an overview of the CHARM model methodology, which complements CenterPoint Houston's project selection by applicable measures.

Figure 6-15. Overview of CHARM Project Analysis Methodology



A subset of CenterPoint Houston's measures were selected for circuit-level analysis and locational project evaluation based on each measure's characteristics. Measures selected for evaluation are primarily asset-driven, will be deployed across a subset of total circuits (*i.e.*, require prioritization), are sensitive to the spatial granularity of the climate vulnerability assessment, and have been modeled by CenterPoint Houston using capabilities described in the SRP. For certain measures where spatial validation is necessary, however, the use of the CHARM model is not optimal, Guidehouse developed custom methodologies to rank potential projects as described in each measure overview in Section 6.3.

The results of Guidehouse's circuit-level analysis are compared to CenterPoint Houston's project implementation plan for 2026-2028 to identify recommendations of additional locations that may be exposed to resiliency risk in the mid- to long-term outlook based on the vulnerability assessment to augment CenterPoint Houston's internal model results and prioritization methods. Where differences in results exist, Guidehouse and CenterPoint Houston SMEs reviewed each model's selections. Explanations for these variations between model results are described in each measure overview in Section 6.3.

Expected lifetime reductions in CMI due to mitigating outages caused by extreme wind, extreme water, and wildfire are the primary metrics used to rank project locations within each evaluated measure. Asset-level risk to these climate hazards is calculated and aggregated to the project level for baseline and mitigated scenarios. Projects are defined as an instance of a measure described in Section 5 impacting applicable asset classes on a circuit main, a circuit's laterals, or at a substation. Table 6-4 outlines sources used to develop circuit-level customer impacts in addition to those used in the vulnerability assessment.

Table 6-4. Circuit Criticality and Risk Data Inputs

Data	Contents	Source
Distribution Outage Data	Distribution outages between 2019 and 2023[126]	CenterPoint Houston
Customers Counts by Circuit-Section	Downstream customer counts per distribution circuit section	CenterPoint Houston

The following sections describe how CenterPoint Houston's data and the results of the climate vulnerability assessment were used to develop expected lifetime CMI reductions from mitigation project alternatives for circuits and substations.

6.2.1 Asset Registry

The asset registry contains the list of assets in CenterPoint Houston's service territory necessary for the circuit-level analysis. The CHARM model calculates CMI reductions at the asset-level, based on the asset registry, then aggregates to expected CMI reduction per project (*i.e.*, circuit or substation and measure) for the assets associated with a particular measure. Four asset types were included in the circuit-level analysis: Distribution Poles, Distribution Overhead Lines, Distribution Underground Lines, and Substations. These asset types were selected as they are most commonly associated with the most recent 5 years of OMS data filtered to applicable resiliency cause codes, and they are addressed under CenterPoint Houston's programs. Each asset in the registry is assigned an asset class (*e.g.*, "Distribution Pole – Lateral – Three Phase – Wood") to model asset replacements for resilience-based measures. Table 6-5 shows asset counts and fields for analyzed asset types.

Table 6-5. Asset Counts

Asset Type	Asset Class Fields	Asset Count
Distribution Pole	Main vs Lateral, Phase, and Material	1,187,058
Distribution Overhead Line	Main vs Lateral and Phase	891,789
Distribution Underground Line	Main vs Lateral and Phase	809,148
Substation	NA	267

In addition to the asset classes, each asset in the registry is associated with a specific "Investment ID" to denote the circuit or substation the asset supports. The asset registry also contains each asset's location, the expected number of customers interrupted if that asset fails, and a map of the location-specific climate forecast data. The expected number of customers

[126] OMS data is used to derive annual expected inputs from a rolling 5-year average, therefore partial year 2024 data was excluded.

interrupted (CI) during an outage at an asset's grid location was developed using distribution outage data. Customer counts by circuit section were used for locations without empirical data.

6.2.2 Criticality

The criticality of an asset is calculated as the average interruption duration due to wind, flood, or storm outage events multiplied by the asset's CI. When combined with the annual probability of a climate hazard event exceeding the asset's failure threshold, the resulting value is CMI. Guidehouse leveraged CenterPoint Houston distribution outage data to calculate the average interruption duration for resilience-related outage causes (*i.e.*, "HURRICANE", "TORNADO", "STRONG WIND", and "RISING WATER") and then by dividing the total CMI by the total CI per circuit. Criticality values were assigned to distribution substations by averaging the mean outage duration for each associated circuit. Criticality values for transmission substations were assigned using assumptions based on station voltage. 69kV substations were assumed to serve three distribution substations, or equivalently, 36 circuits, using the median distribution circuit CI. Similarly, 138kV and 345kV substations were assumed to feed six and twelve distribution substations, or 72 and 144 distribution circuits, respectively.

6.2.3 Applying Climate Vulnerability Assessment

Guidehouse developed wind and flood annual failure probabilities per asset using the combination of asset class failure thresholds and Jupiter Intelligence's climate forecast.

Asset class failure thresholds represent the maximum physical stress from a climate peril that an asset can be exposed to without failing (*i.e.*, mph wind gusts or feet of flooding). Modeled failure thresholds match those used in the BCA analysis to maintain consistency between programmatic screening methodologies and project prioritization.

Table 6-6. Asset Class Failure Thresholds[127]

Asset Class	Wind Gust for Repair/Replace	Flood Depth for Repair/Replace
Distribution Pole - Wood	70 mph	NA
Distribution Pole – Non-Wood	132 mph	NA
Distribution Overhead Line	70 mph	NA
Distribution Underground Line	NA	NA
Substation Equipment	NA	4 ft
Substation Equipment-Elevated	NA	Variable

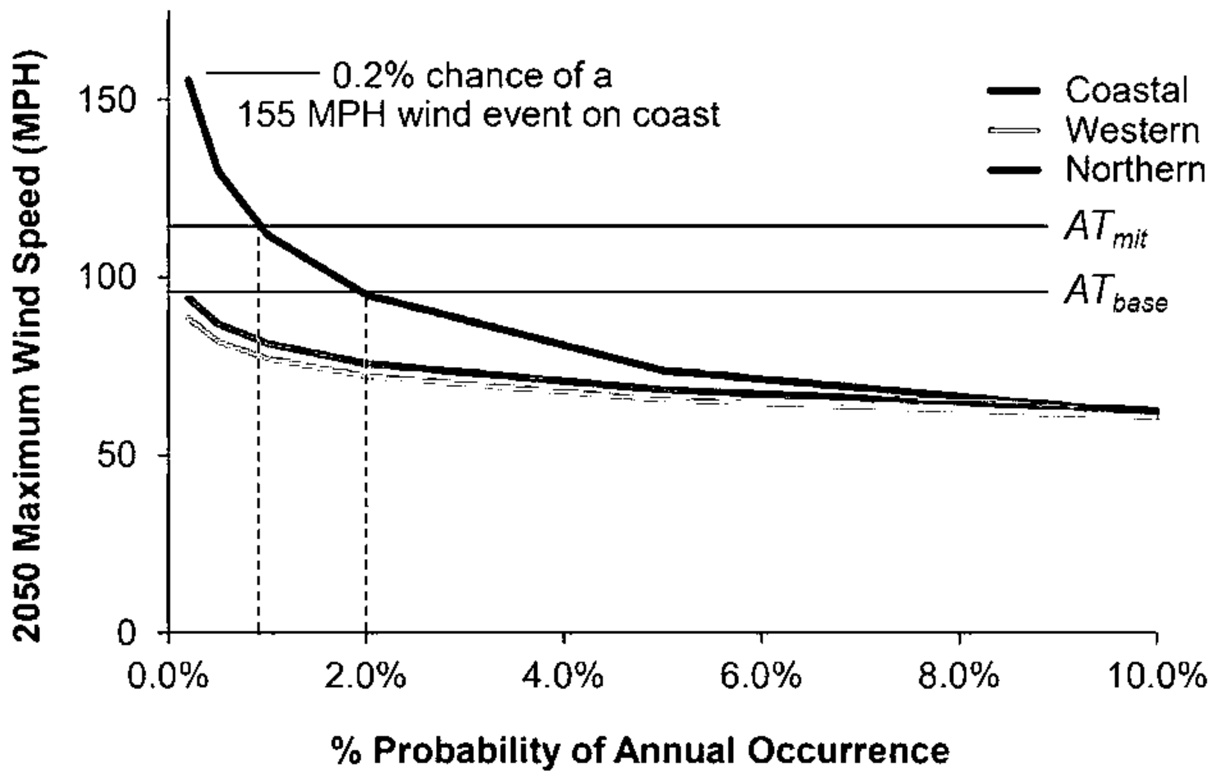
[127] Failure thresholds set to match program-level BCA assumptions. Substation elevation flood depth threshold set to reduce location risk to zero based on program design criteria.

Using the underlying data from the vulnerability assessment provided by Jupiter Intelligence, Guidehouse constructed wind and flood failure probabilities in four steps:

1. Convert Jupiter Intelligence data return periods into continuous probabilities of occurrence.
2. Interpolate the Jupiter Intelligence forecast from 5-year intervals to the annual forecasts.
3. Combine each asset's location and climate-peril failure thresholds with the location-specific Jupiter climate forecast.
4. Identify each asset's annual hazard probability.

Figure 6-16 provides an illustrative example of how annual probabilities of failure are calculated. In this case, baseline assets (AT_{base}) in the Western and Northern regions are not vulnerable to wind at any forecasted return interval. However, baseline assets in the Coastal region are expected to experience winds above their failure threshold, which is a 2% annual probability. A hardened version of the asset (AT_{mit}) increases the failure threshold and reduces this annual probability to around 1%, reducing risk by half.

Figure 6-16. Example Asset Annual Probability of Failure Identification



6.2.4 Model Calibration

Model calibration to historical observations is an important step in developing accurate system risk forecasts. Uncalibrated modeled baseline CMI forecasts at the asset level are summed and compared to the average annual system-wide CMI for the most recent 5-year period. A calibration factor, theta, is calculated by dividing the historical system CMI by the calculated system CMI in the first year of analysis. The historical system CMI is developed by filtering the distribution outage data to resilience-related outage causes and averaging the annual CMI from 2019 to 2023. This process estimates hard-to-measure factors impacting total system outages that are not incorporated into a model at this level of granularity. For example, the potential for covariance between collocated grid assets during an outage event will likely lead to an overstatement of CMI in the uncalibrated model run, as CI does not scale linearly based on the number of assets on a circuit experiencing an outage during the same event. Calibrating the model supports focus on trends in risk over time due to climate vulnerability and assess areas where deviations from historical trends are expected.

6.2.5 Measure Impacts

Guidehouse worked with CenterPoint Houston to develop an asset class map that identifies target assets for each measure and defines their replacement. For example, the undergrounding measures target overhead wires and replace them with underground cable along with pole removal. There are three modes for reducing resiliency risk through implementing resiliency measures. These are (1) reducing the frequency of outage events, (2) reducing the number of customers impacted by an outage, and (3) reducing the duration of an outage. Each measure targets one or more of these modes. Figure 6-16 provides an example of how an asset deployed through a mitigation program may have a higher climate peril failure threshold and, therefore, a lower annual probability of failure, addressing mode 1. Other resiliency measures such as IGSD deployment or relocating lines to easier-to-access areas may reduce the number of customers interrupted by an outage or their duration but not reduce the total expected number of outage events.

The asset registry allows for flexible identification of program-applicable assets in the actual quantities currently existing in CenterPoint Houston's territory and assigns them the criticality associated with their grid location. The model calculates expected CMI for a mitigation scenario where all program-applicable assets on an investment ID are identified and replaced with their mapped resilient asset. Baseline and mitigated scenario CMI results are then subtracted to identify the expected reduction in lifetime CMI (lifetime defined by the expected asset life for the asset being replaced) from the mitigation investment. In this way, the model yields expected lifetime CMI reductions tailored to the existing assets, chosen measure replacements, and locational climate peril forecasts, allowing for prioritization.

6.3 Implementation Plan

For resiliency measures that target specific assets and, therefore, require the identification of priority project locations, CenterPoint Houston developed a prioritized list of implementation activities under their 2026-2028 plan. The prioritization methods vary by measure to address the unique risk variables inherent to each measure's targeted mitigation efforts. This section contains an overview of the mitigation measures within each measure, outlines CenterPoint

Houston's prioritization methods, and compares these to Guidehouse's circuit-level analysis and findings.

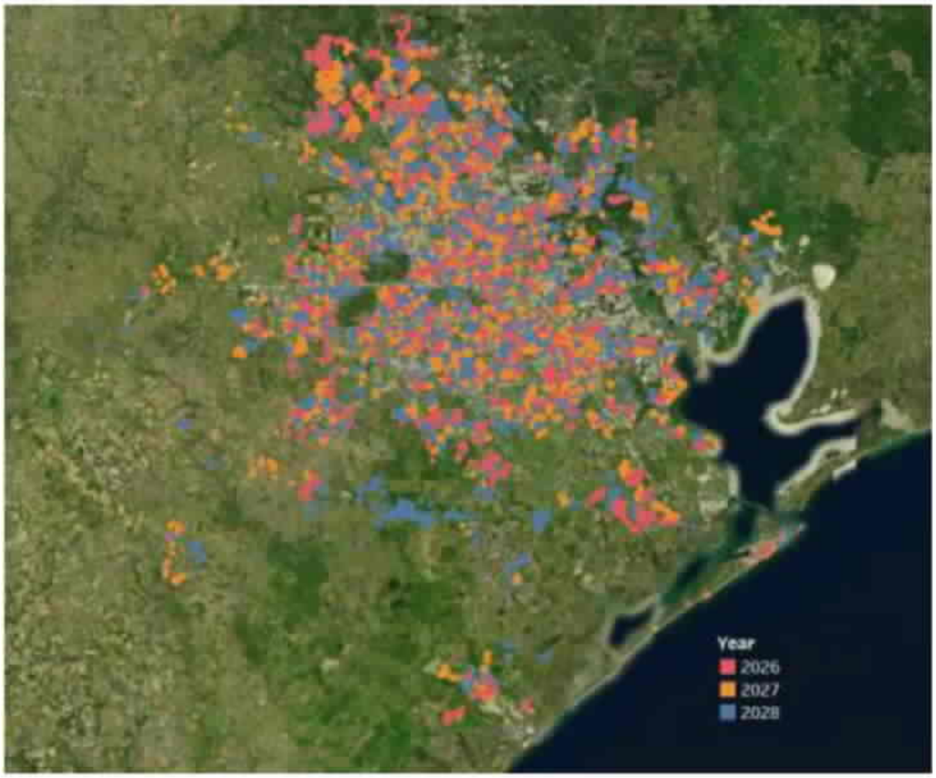
Not all measures in CenterPoint Houston 2026-2028 SRP are included in this section. Excluded measures are those that are not primarily asset-driven, will be deployed across all applicable circuits (*i.e.*, do not require prioritization), or are not sensitive to the spatial granularity of the climate vulnerability assessment. Guidehouse focused its analysis on distribution circuits, as opposed to transmission circuits, because there are more grid locations with applicable resiliency measures and greater potential for competing mitigation options on the distribution system.

6.3.1 Distribution Circuit Resiliency

As described in Section 5.3.3.1, the Distribution Circuit Resiliency Measure addresses risk from extreme wind by replacing and improving pole strength to meet current NESC design standards on circuits where a substantial number of poles were installed under the prior standard at the time of construction. Primarily non-wood engineered structures are utilized as replacement, based on their higher extreme wind failure threshold compared to wood poles.

CenterPoint Houston based its circuit prioritization for the Distribution Circuit Resiliency Measure on the number of customers served, fall-in risk, and inaccessibility across the circuit section, obtained through an analysis of LiDAR data. Additional consideration was taken for circuits that serve load to critical facilities such as hospitals, water treatment plants, and police stations or that support underserved communities. CenterPoint Houston will continue to enhance its locational analysis of high-risk circuit sections through the implementation of its Digital Twin technology. Figure 6-17 shows the results of this prioritization based on fall-in risk, inaccessibility, and criticality for each of the three plan years.

Figure 6-17. CEHE Distribution Resiliency Circuit Rebuild Results



To model the expected circuit-level impacts on lifetime CMI reductions from implementing the Distribution Circuit Resiliency Measure on each of CenterPoint Houston's circuit mains and laterals, Guidehouse identified wood poles—subject to risk at lower wind speeds—and modeled the replacement of these with non-wood structures. The resulting reduction of annual failure probability is scaled by circuit criticality and the expected lifetime of the replacement assets to calculate the prioritization metric unique to each circuit. Guidehouse divided each circuit into quartiles based on lifetime CMI reduction. Figure 6-18 provides a circuit map for each quartile.

Figure 6-18 Guidehouse Analysis Distribution Circuit Resiliency Quartiles

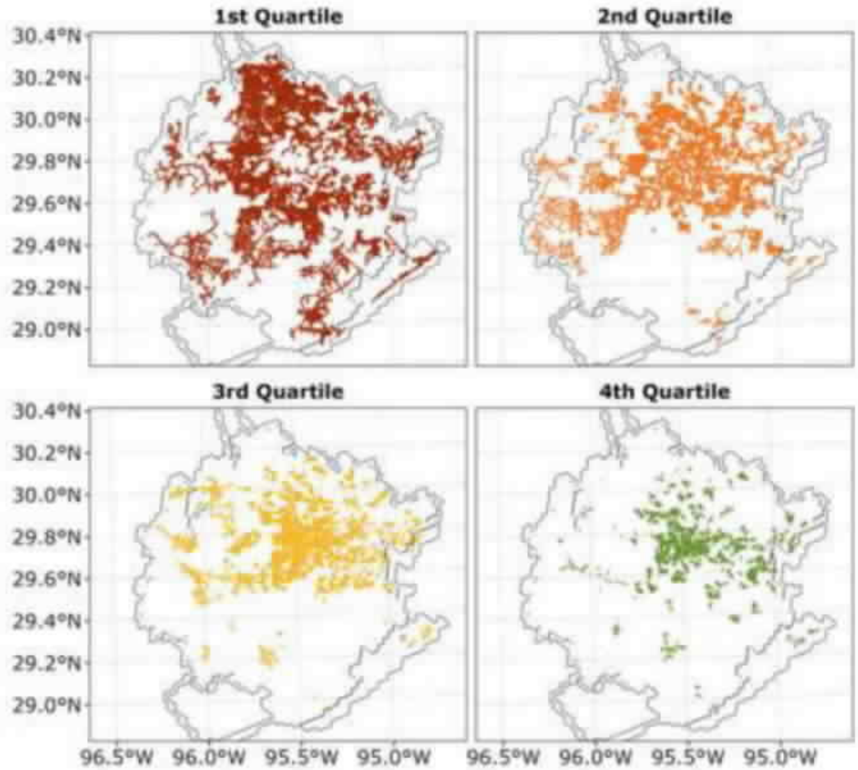
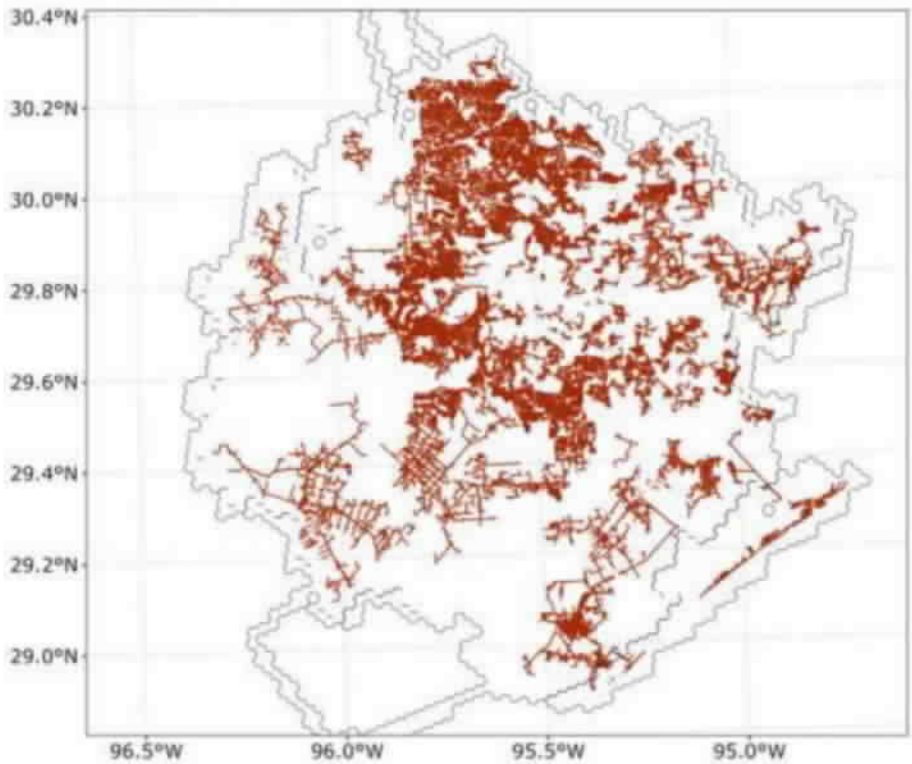


Figure 6-19 shows a detailed view of the top quartile circuits for Distribution Circuit Resiliency based on Guidehouse's analysis.

Figure 6-19 Guidehouse Analysis Distribution Circuit Resiliency Top Quartile



There is a relatively uniform distribution of first quartile circuits across CenterPoint Houston's territory based on this analysis focused on extreme wind forecast distributions across the territory and circuit criticality. As noted in Section 6.1.4, wind speeds are expected to exceed 70 mph—the threshold used to estimate wood pole vulnerability—at the 1/100-year return interval for all hexagons. Therefore, measures focused on reducing risk from extreme wind may be effective across the territory. Guidehouse's use of locationally-specific extreme wind forecasts to identify asset risk highlights the potential for CMI reductions through implementing the Distribution Circuit Resiliency measure on targeted first quartile circuits in Galveston and along the coast. These locations are not identified as having high risk in CenterPoint Houston's analysis due to their lack of fall-in risk; however, the potential for extreme winds alone in this region poses a physical threat to poles.

Guidehouse recommends that CenterPoint Houston incorporate locationally specific extreme wind forecasts to augment its existing highly granular fall-in risk and inaccessibility analysis. CenterPoint Houston may review targeted circuits that are expected to experience extreme winds exceeding asset design thresholds but that have low fall-in risk as an additional category for inclusion in its risk matrix.

6.3.2 Distribution Pole Replacement/Bracing

As described in Section 5.3.6.1, the Distribution Pole Replacement/Bracing Measure targets the replacement of poles identified during scheduled inspections as not meeting CenterPoint Houston's minimum strength criteria or health score. The replacement/bracing measure targets reductions in risk from extreme wind. Once a pole is identified as being at risk, three possible projects may occur:

1. Pole Upgrades: Upgrade wood poles to non-wood poles (fiberglass or ductile iron), focusing on areas with high fall-in risk and considering high section customer counts. Fall-in risk is identified from a LiDAR study.
2. Pole Bracing: Dependent on the health score of the poles to determine if it can be braced successfully.
3. Pole Like-for-like Replacement: If a pole cannot be braced and does not meet pole upgrade criteria, it is eligible for a like-for-like replacement. Additionally, poles located near roads that could be braced are replaced instead.

CenterPoint Houston prioritized the Distribution Pole Replacement/Bracing Measure based on the results of its most recent pole inspection data.

Due to the asset-level targeted nature of this measure, rather than circuit-level, and the requirement of detailed field information to determine the most appropriate treatment per pole, Guidehouse did not prioritize expected lifetime reductions in CMI for this measure. However, Guidehouse notes that CenterPoint Houston's targeted pole replacements align with high criticality and risk areas identified in the Distribution Circuit Resiliency measure. This, combined with the pre-screening of poles based on objective health scores, assures that the most detailed available condition and criticality information are being used to prioritize activities in the 2026-2028 plan. CenterPoint Houston should continue to implement the pole inspection measure and update their prioritization across an increasing number of circuits. Additionally, CenterPoint Houston should consider the trade-offs between competing measures when identifying poles for replacement or bracing. For example, if a circuit section will be targeted for underground conversion in a later year, it may not be cost-effective to implement pole replacement or bracing activity in that area regardless of health scores.

6.3.3 Strategic Undergrounding

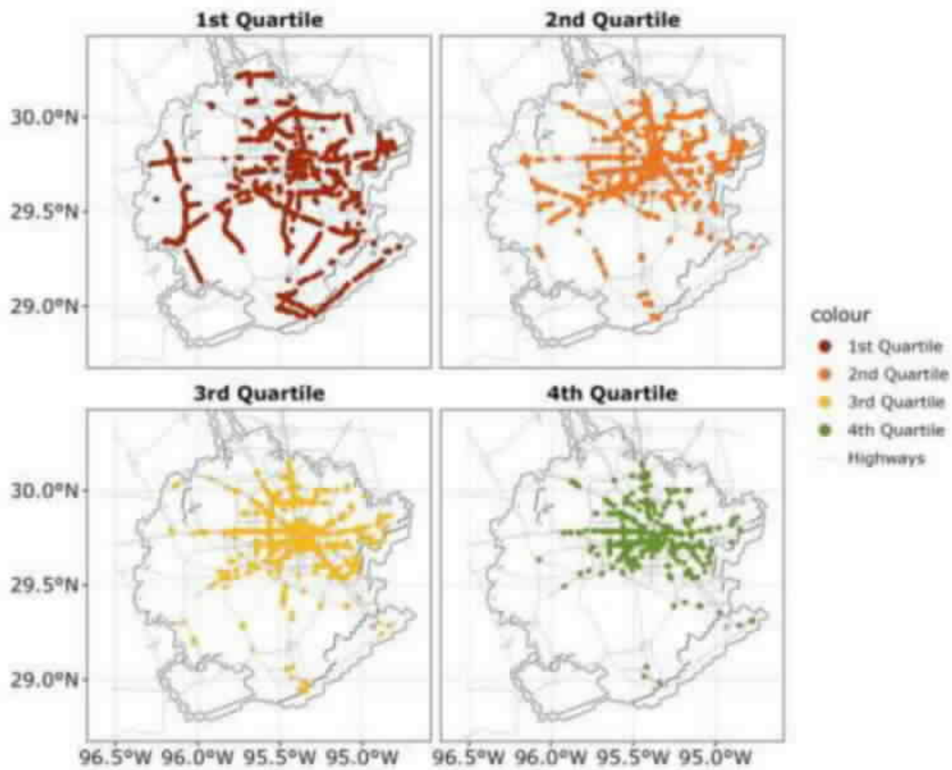
As described in Section 5.3.3.1, the Strategic Undergrounding Measure contains two primary components. Overhead-to-underground conversions include (1) freeway crossings and (2) main-line and lateral section conversions. These measures target risk mitigation from extreme wind events, specifically those that cause significant vegetation and debris contact with utility infrastructure. Additionally, this measure focuses on reductions in outage duration by targeting sections located in areas that have been historically challenging to access, such as rear lot corridors.

CenterPoint Houston based its circuit prioritization for the Freeway Crossings Strategic Undergrounding Measure on condition, load at risk, and customer outage exposure. CenterPoint Houston has identified freeway-crossing undergrounding projects distributed across the major highways leading into and surrounding Houston, with a particular focus on evacuation routes for the 2026-2028 plan.

Guidehouse identified poles and overhead conductors applicable to the Freeway Crossing Strategic Undergrounding by applying a filter to assets within a 40-meter radius of the centerline of freeways. To estimate the expected circuit-level impacts on lifetime CMI reductions from implementing this measure at locations identified with applicable assets, Guidehouse modeled replacing these assets with underground conversion, reducing extreme wind risk. The resulting reduction of annual failure probability is scaled by circuit criticality and the expected lifetime of the replacement assets to calculate the prioritization metric unique to each circuit. Guidehouse divided each circuit into quartiles based on lifetime CMI reduction.

Figure 6-20 shows the asset locations for the Freeway Crossing Strategic Undergrounding measure quartiles. Locations within Houston and the surrounding freeways show an even distribution of locations with no single freeway region containing a disproportionate density of 1st quartile projects, however, due to the increased coastal wind intensities discussed in Section 6.1.4, the Galveston area shows high CMI reduction potential through freeway crossing undergrounding.

Figure 6-20. Guidehouse Analysis Freeway Crossing Quartiles



Guidehouse recommends that CenterPoint Houston incorporate locationally specific extreme wind forecasts to augment its existing highly granular fall-in risk and critical customer analysis. CenterPoint Houston should review targeted freeway crossings that are expected to experience extreme winds exceeding asset design thresholds but that have low fall-in risk as an additional category for inclusion in its risk matrix.

CenterPoint Houston based its circuit prioritization for main-line conversions on second circuit sections with high fall-in risk, as identified in the LiDAR study. The second main-line section of circuits impacts a higher number of downstream customers than other downline sections and is, therefore, considered to have high criticality.

To model the expected circuit-level impacts on lifetime CMI reductions from implementing the Strategic Undergrounding Measures on each of CenterPoint Houston's mains and laterals, Guidehouse identified poles and overhead conductors—subject to risk due to extreme wind speeds—and modeled the replacement of these with underground conversions including the removal of poles. The resulting reduction of annual failure probability is scaled by circuit criticality and the expected lifetime of the replacement assets to calculate the prioritization metric unique to each circuit. Guidehouse divided each circuit into quartiles based on lifetime CMI reduction.

Figure 6-21 shows the circuits by quartile for three-phase main-line strategic underground conversions. First quartile circuits are concentrated on the outskirts of Houston. Additionally, there are a significant number of high-impact circuits in the northern portion of CenterPoint Houston's territory near the transmission corridors. Certain top quartile circuits are located throughout the southeastern region of the territory and along the coast of Galveston. Figure 6-22 shows the circuits by quartile for lateral strategic underground conversions. First quartile circuits are similarly distributed to mains. The impact of the strategic undergrounding measures is primarily correlated to wind probability exceeding 70 mph. All of CenterPoint Houston's assets are expected to be exposed to this severity of extreme wind at the 1/100-year return interval, with some assets in the coastal regions exposed to much greater severities. Additionally, highly vegetated regions in the north are subject to increased risk of failures of overhead equipment.

Figure 6-21. Guidehouse Analysis Main-line Strategic Undergrounding Quartiles

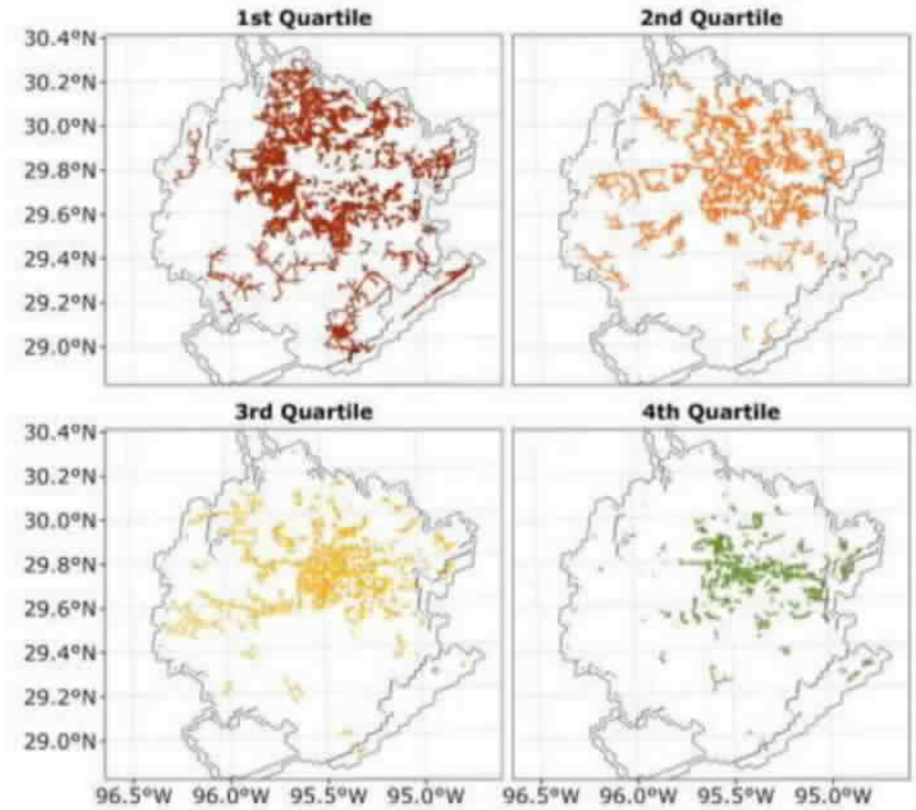
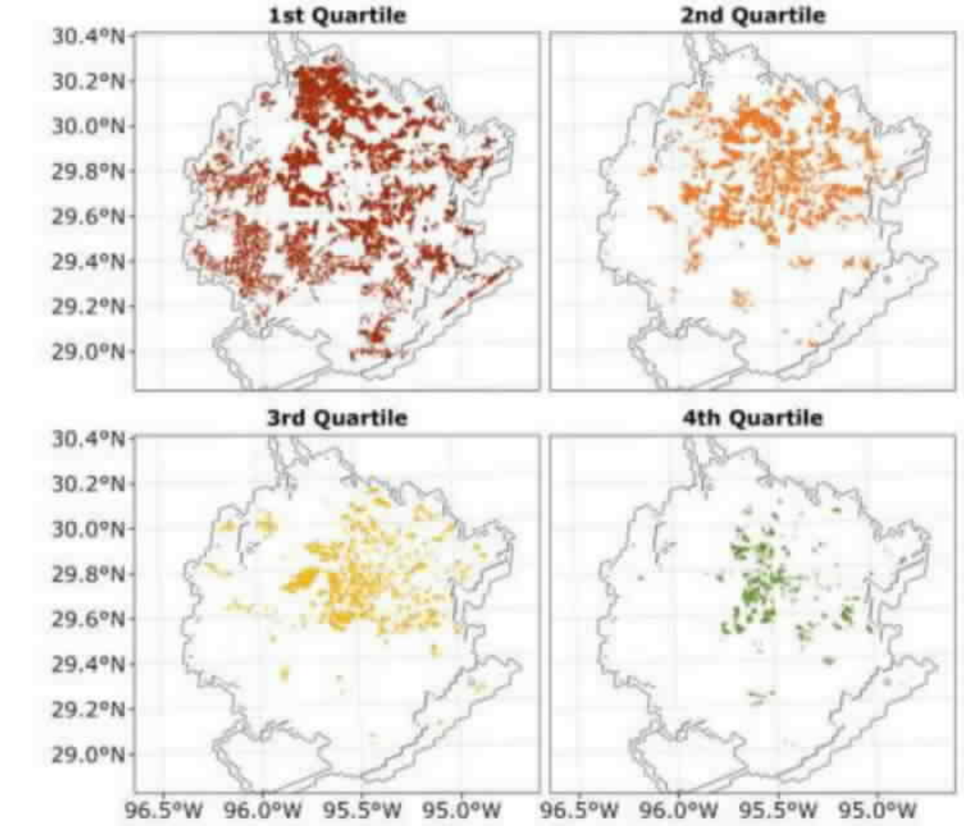


Figure 6-22. Guidehouse Analysis Lateral Strategic Undergrounding Quartiles



6.3.4 Substation Flood Control

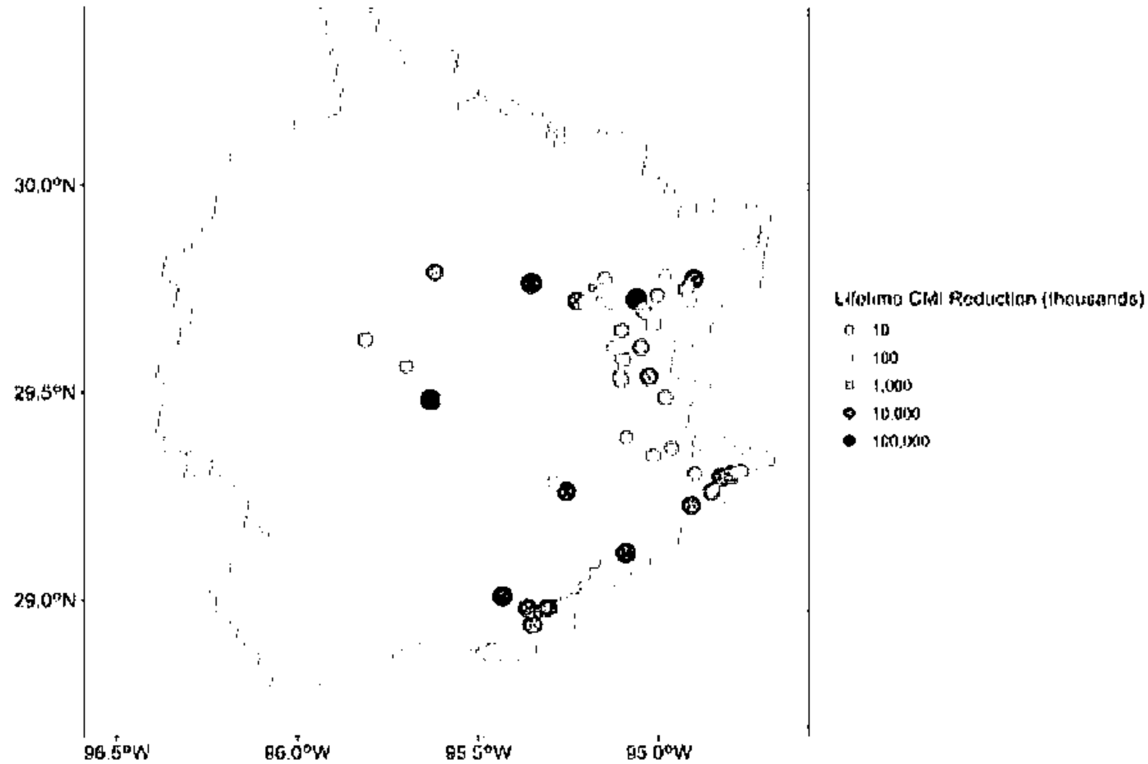
As described in Section 5.4.3.1, the Substation Flood Control Measure addresses flood risk by elevating vulnerable substation equipment such as protective relays, switchgear, and remote terminal units. The measure will differentially raise equipment at each substation to be at least 2 feet above the design flood based on the 500-year flood likelihood within floodplains.

CenterPoint Houston based its substation prioritization for the Substation Flood Control on geographical location (*i.e.*, location within a floodplain. For substations deemed at risk, deployment prioritization will be based on the load at risk and how many critical facilities a substation serves. CenterPoint Houston plans to implement this measure at four substations per year for a total of 12 in the SRP.

Guidehouse analyzed substations to prioritize resilience investments using the CHARM model as described in Section 6.2. Distribution substation criticality was determined based on the customer count and historical outage duration for each circuit served by an individual substation. Due to system networking, it was not feasible to directly link transmission substations to downstream customers. As a result, transmission substation criticality was assigned based on station voltage.

Using the CHARM model, Guidehouse assessed the addressable CMI risk from a flood at each substation location, assuming outages would occur with local flood depths exceeding 4 ft. Figure 6-23 shows the results of the substation flood control prioritization analysis. There are 51 substations with addressable flood risk.

Figure 6-23. Substation Flood Control Results



The substations with the greatest addressable flood risk are distributed throughout the southeast quadrant of CenterPoint's service area in coastal areas or near inland waterbodies. Site vulnerability is highly sensitive to local topography and proximity to waterways. As noted in Section 6.1.3, 8% of substation and service center sites are vulnerable to 100-year flood depths of 3 ft or greater by 2050. Guidehouse used location-specific inundation risk probabilities to identify which sites would provide the greatest reduction in expected CMI from flood control measures. CenterPoint Houston identified candidate sites based on historical field observations and prioritized sites based on counts of critical and total customers.

Guidehouse recommends that CenterPoint Houston incorporate location-specific flood depth probabilities into the site prioritization to augment their existing prioritization criteria. CenterPoint Houston should consider including the expected CMI reduction for each site as a metric that accounts for customer exposure and the probability of damage from flood events.

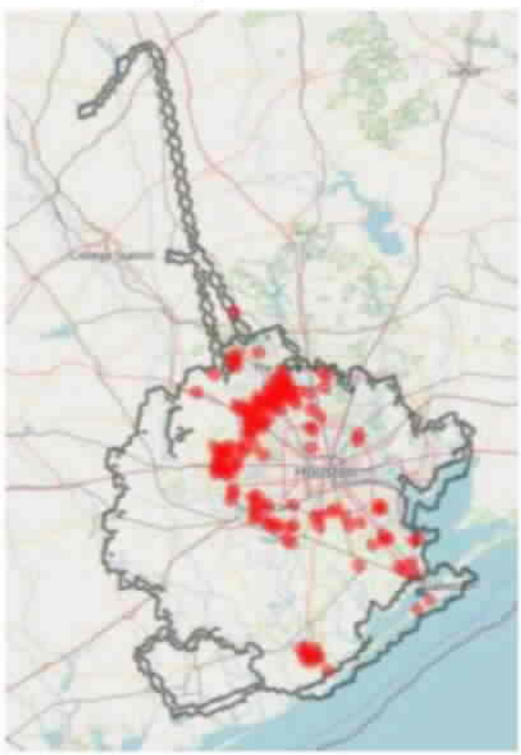
6.3.5 Wildfire Mitigation

As described in Section 5.6.9, the Wildfire Mitigation Measure includes a variety of measures to reduce the potential for transmission and distribution facilities to cause destructive wildfire in susceptible areas. The list of applicable measures includes vegetation management, fire detection cameras, wildfire modeling and analytics, strategic undergrounding, and IGSD. The measure is focused on reducing the societal risk of wildfire, including the potential loss of life and damage to homes and other non-utility-owned structures.

CenterPoint Houston developed circuit-level prioritizations using approaches that vary for distinct measures within the Wildfire Mitigation Measure. For all measures, CenterPoint Houston focused the circuit prioritization within wildfire-prone areas based on concentrations of biomass that could provide fuel during periods of sustained drought as identified by the USA Wildfire Potential Index. CenterPoint Houston developed IGSD prioritization areas upstream of high-fire-risk circuit sections to allow targeted public safety power shutoffs to limit customer impact.

As described in Section 6.1.5, Guidehouse identified priority areas for wildfire mitigation measures using location-specific estimates of wildfire probability and societal vulnerability, including potential harm to people, buildings, and agriculture. The areas with the greatest wildfire vulnerability are depicted in Figure 6-24. They are concentrated in the wildland-urban interface around the perimeter of the Houston metropolitan area, as well as near the cities of Lake Jackson (Brazoria County) and Katy (tripoint of Harris, Fort Bend, and Waller counties).

Figure 6-24. Areas with Highest Wildfire Vulnerability (top 5%)



The Guidehouse prioritization results differ somewhat from the CenterPoint Houston prioritized areas for wildfire monitoring cameras. The differences may be explained by CenterPoint Houston's focus on biomass concentrations, which may not correspond with areas with greater societal vulnerability.

Guidehouse recommends that CenterPoint Houston consider the joint distribution of societal vulnerability and location-specific probability of catastrophic wildfire in their wildfire measure prioritization within and beyond the plan period. CenterPoint Houston should review the list of priority areas identified by Guidehouse as those with the greatest expected loss and incorporate them into planning processes.

6.3.6 Vegetation Management

As described in Section 5.3.7, the Vegetation Management Measure involves trimming and tree removal to reduce exposure to fall-in and other tree-related interruptions. CenterPoint Houston proposes moving from a 5-year trim cycle on all overhead distribution circuits to a 3-year cycle. In addition, CEHE is proposing to conduct additional out-of-cycle trimming on targeted main and lateral lines serving critical loads and with the greatest exposure to vegetation encroachment. CenterPoint Houston based its circuit prioritization for the Vegetation Management Measure on a system-wide analysis of vegetation fall-in risk using LiDAR.

Guidehouse developed a list of prioritized circuits for vegetation management based on several factors, including vegetation encroachment status, exposure to extreme wind events, and circuit criticality. Guidehouse assessed vegetation encroachment status at the aggregate, circuit-level, using data identifying the length of circuit mileage within one of several vegetation encroachment ranges (*e.g.*, 0-15 ft). The encroachment data, which was provided by CenterPoint Houston, had been developed based on an analysis of satellite imagery.

Guidehouse assessed exposure to extreme wind events using the approach described in Section 6.1.4 and assessed circuit criticality using the approach described in Section 6.2.2.

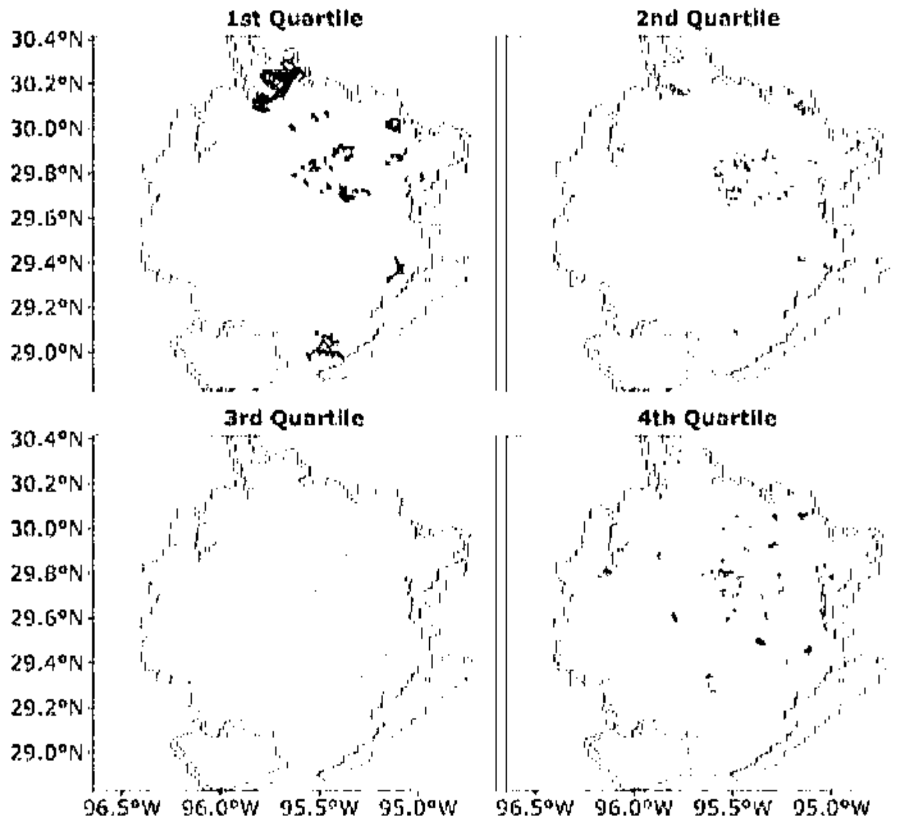
Guidehouse ranked potential circuit-level vegetation management investment candidates based on expected baseline CMI risk using asset failure probabilities that vary with the degree of vegetation encroachment. For example, a circuit with high vegetation encroachment (100% of circuit mileage within 0-15 ft) is vulnerable to experiencing outage events during a 45-mph wind event. A circuit with zero vegetation encroachment is not expected to experience an outage event until wind speeds reach 70 mph. Guidehouse assumed that failure thresholds would vary linearly as a function of vegetation encroachment between these extremes.

Guidehouse selected for prioritization those circuits with high vegetation encroachment (0-15 ft) in greater than 50% of the length of the circuit. Subsequently, circuits were ranked by their expected CMI risk.

Figure 6-7 in the Vulnerability Assessment report section depicts an overlay of 1-in-100-year wind speeds with the boundaries of hexagon areas within the top 10% in terms of share of circuit mileage with vegetation encroachment. The vulnerability assessment identified priority areas near the northern service territory boundary and several clusters parallel to the Gulf Coast.

Figure 6-25 depicts the results of the circuit-level analysis ranked by CMI risk. The upper left panel shows circuits with the greatest CMI risk, defined as those in the top quartile among circuits with high vegetation encroachment in greater than 50% of circuit mileage. The results are generally consistent with the findings of the vulnerability assessment. There is a large cluster of high-priority areas in the north, with smaller clusters in the east and parallel to the coast. Some circuits near central Houston also have high vegetation encroachment and CMI risk.

Figure 6-25. Vegetation Management Circuit Prioritization Results



CenterPoint Houston's vegetation management prioritization was derived using granular LiDAR data identifying specific points of vegetation encroachment. Guidehouse's prioritization was derived using location-specific wind vulnerability and circuit-level vegetation encroachment estimates based on satellite imagery data. The satellite imagery derived vegetation encroachment estimates may be less precise than the LiDAR data source.

Guidehouse recommends that CenterPoint Houston review the Guidehouse prioritization results and consider the interactive effects of wind exposure and vegetation encroachment in their prioritization of circuits for vegetation management measures.

7. Summary of Findings and Recommendations

7.1 Findings

Guidehouse's risk assessment indicates that the frequency and magnitude of extreme weather events such as high winds (*e.g.*, hurricanes), floods, and extreme temperatures, as well as physical and cybersecurity events, are expected to increase over time in CenterPoint Houston's service territory. High-level findings are summarized in Section 1.1, while Section 4 details Guidehouse's risk assessment, and Section 6 describes circuit-level risk characterization for specific measures.

Guidehouse finds that the resiliency measures included in CenterPoint Houston's SRP are appropriate for inclusion in CenterPoint Houston's SRP and generally follow best practices for resiliency planning. Section 1.3 summarizes Guidehouse's overall assessment for Natural Hazard and Physical Attack measures, while Section 1.4 provides an overall assessment for Technology & Cybersecurity measures, and Section 5 provides an assessment for each individual measure.

7.2 Recommendations

7.2.1 Recommendations from the 2025-2027 T&D SRP

During the develop of CenterPoint Houston's' 2025-2027 T&D SRP, Guidehouse provided a variety of recommendations for CenterPoint Houston's consideration, which were documented in the Guidehouse report that was filed with CenterPoint Houston's prior SRP in Commission Docket No. 56548. CenterPoint Houston incorporated many of those recommendations into the development of its prior SRP.

Since then, in developing its current 2026-2028 T&D SRP, CenterPoint Houston has further addressed Guidehouse recommendations from the prior SRP. Changes associated with Guidehouse's prior recommendations include the following:

1. **Increase locational resolution of risk analysis.** Guidehouse recommended that CenterPoint Houston further assess risk by conducting climate forecasts at a more granular level, both to identify areas of CenterPoint Houston's service territory at greatest risk to extreme events and to target projects within each measure using the results of the more granular forecast. In response, CenterPoint Houston directed Guidehouse to conduct more granular climate forecast and identify measure benefits at the circuit level for extreme wind events and specific locations for substations for extreme water events. CenterPoint Houston's proposed measures in the current SRP were selected based on the more granular climate forecasts and risk assessment.
2. **Consider additional measures to address heat and wildfire risks.** Guidehouse recommended that CenterPoint Houston consider including measures that address the

impact of rising temperatures on transformer derating in future resiliency plans. For its current SRP, CenterPoint Houston has included measures such as URD Cable Modernization (RM-18) to address heat risks and has included a variety of measures targeted at mitigating wildfire risk (including measures RM-22 through RM-25), and CenterPoint Houston's selection of wildfire-related measures was informed in part by additional benchmarking research performed by Guidehouse.

3. **Identify additional restoration automation opportunities.** Guidehouse recommended to CenterPoint Houston continue to assess and identify opportunities to automate restoration of the distribution system during resiliency events. In its current SRP, CenterPoint Houston is proposing the Spectrum Acquisition measure (RM-28) to replace existing communication networks, several of which are essential to enable increased monitoring and automation assets associated with other measures within its SRP.
4. **Consider non-traditional generation and storage investments.** Guidehouse recommended that CenterPoint Houston consider over the long term (beyond the 3-year investment horizon) potential opportunities for alternative resiliency measures such as local generation and storage technologies in lieu of traditional investments. Since its prior SRP, CenterPoint Houston has provided additional detail and justification regarding its microgrid pilot, supporting its longer-term vision to pursue diverse technology to enhance system resiliency.

7.2.2 Recommendations for SRP Implementation

While many of Guidehouse's recommendations for CenterPoint Houston's prior SRP focused on the prioritization and selection of measures to include, Guidehouse's recommendations for CenterPoint Houston's current SRP are generally focused more on the implementation of proposed measures.

Guidehouse's recommendations for CenterPoint Houston's use of high-resolution locational risk analysis to inform prioritization of specific project investments include the following:

1. **Compare prioritization results.** For the measures included in Section 6.3, Guidehouse recommends that CenterPoint Houston conducts a comparison of their prioritization results to the prioritization results developed by Guidehouse.
2. **Incorporate locational wind forecasts.** Guidehouse recommends that CenterPoint Houston incorporate locationally-specific extreme wind forecasts to augment their existing highly granular fall-in risk and inaccessibility analysis. CenterPoint Houston may review targeted circuits that are expected to experience extreme winds exceeding asset design thresholds but that have low fall-in risk as an additional category for inclusion in their risk matrix.
3. **Incorporate locational flooding risk.** Guidehouse recommends that CenterPoint Houston incorporate location-specific flood depth probabilities into the site prioritization to augment their existing prioritization criteria. CenterPoint Houston should consider

including the expected CMI reduction for each site as a metric that accounts for both customer exposure and the probability of damage from flood events.

4. **Incorporate locational wildfire probability and impact.** Guidehouse recommends that CenterPoint Houston consider the joint distribution of societal vulnerability and location-specific probability of catastrophic wildfire in their wildfire measure prioritization within and beyond the plan period. CenterPoint Houston should review the list of priority areas identified by Guidehouse as those with the greatest expected loss and incorporate into planning processes.
5. **Incorporate wind risk into vegetation management.** Guidehouse recommends that CenterPoint Houston review the Guidehouse prioritization results and consider the interactive effects of wind exposure and vegetation encroachment in their prioritization of circuits for vegetation management measures.

Recommendations for specific measures associated with Natural Hazards include the following:

1. **Explore additional applications and benefits for Digital Substation (RM-21).** Examine in greater detail additional potential benefits associated with the Digital Substation resiliency measure, considering increased value associated with enhanced communications, automation, visualization and operational considerations.
2. **Explore additional applications and benefits for Advanced Aerial Imagery Platform / Digital Twin (RM-33).** Identify additional applications and benefits associated with the Advanced Aerial Imagery Platform / Digital Twin resiliency measure beyond those listed in our report.
3. **Continued development of wildfire mitigation plan.** Considering the high impact of this risk on utility operations, we recommend that CenterPoint Houston continue to develop a detailed wildfire mitigation plan that includes (i) risk assessment to determine which areas of the service area are at highest risk of a wildfire, (ii) operational guidelines such as when and where to conduct power shutoff and restoration, (iii) investment planning that considers best practices such as selective undergrounding, covered conductors, and grid modernization technologies, and (iv) community and first responders outreach programs to keep customers up to date on activities and coordinate wildfire responses.

Finally, recommendations for Technology & Cybersecurity measures, as well as two related Situational Awareness measures (RM-36 and RM-37), include the following:

1. **Spectrum Acquisition (RM-28)** – Evaluate broadband spectrum options with an objective analysis tool to ensure CEHE near-term and long-term goals, as well as other business objectives are achieved.
2. **Data Center Modernization (RM-29)** – When considering any type of data migration, ensure that all on premises options such as application, workflow, and process optimizations are investigated to determine if they can be migrated, as migrating data to any new environment will affect uptime, application reliability, and support overall

resilience. This is due to the eccentricities of any new environment, regardless of cloud-based or on-premise environment option.

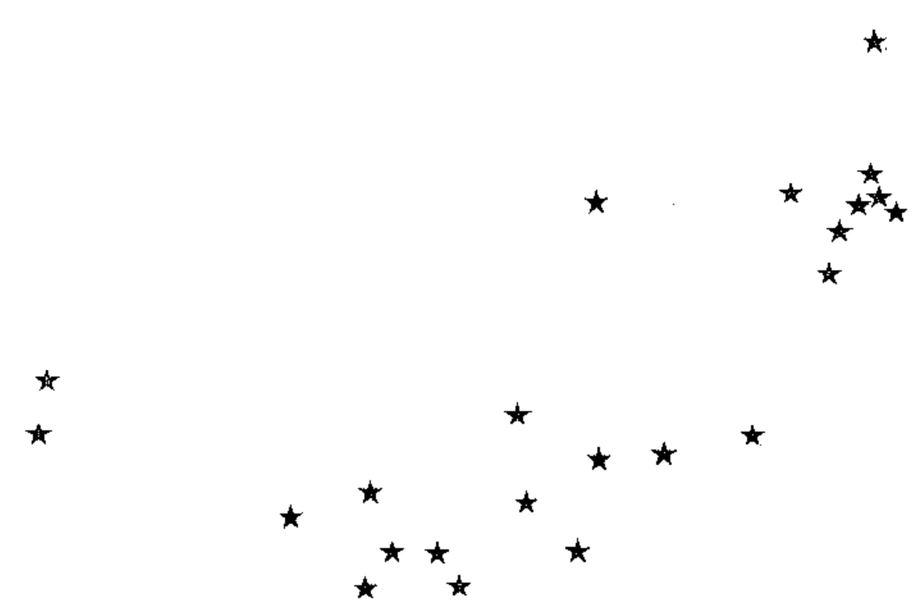
3. **Networking Security & Vulnerability Management (RM-30)** – Investigate if downstream applications support encryption for data-in-transit, as applications that do not support encryption for data-in-transit may be affected in relation to uptime, availability, and general resilience. For vulnerability, review patterns in deployment, such as applications, components, or any other system component that has repeatable settings and configurations so that CenterPoint Houston is aligned to industry general and cybersecurity best practices. For network, analyze network component and system best practices so that CenterPoint Houston's network environment is further logically secured to ensure network zones are locked down and isolated.
4. **IT/OT-Cybersecurity Monitoring Measure (RM-31)** – During implementation and deployment of Splunk and Nozomi, notify all users of the deployment, including detail on expectations to limit false flags while ensuring suspicious events and alerts and unexpected interactions are addressed. For the Splunk Integration, tune ingested information to minimize false alarms and unnecessary resource usage. Lastly, for the Nozomi Integration, refine vulnerability scanning so that only relevant suspicious or anomalous code is present in reports and Nozomi's finding and vulnerability dashboards.
5. **Cloud Security, Product Security & Risk Management (RM-32)** – Develop an objective product and services evaluation tool to ensure CEHE business goals and objectives, including cybersecurity features and functionality, and supply chain risk management are met when selecting and procuring components for installation and support of the CSPSRM resiliency measure.
6. **Voice & Mobile Data Radio System (RM-36)** – Leverage multiple sources of asset (field device) information in accordance with visual checks to ensure all legacy technology is properly tracked and decommissioned. Assets with end-of-life software that are still attached to the system and unaccounted for can either affect uptime/ resilience of the overall system if there is a malfunction, as well as become an attack vector for an external threat.
7. **Backhaul Microwave Communication (RM-37)** – Develop a settings checklist, or asset configuration guide, so settings can be easily replicated and installed on all new field devices, removing the opportunity for incorrect settings being applied. This could potentially impact communication and responses in a weather-driven or other event that could impact the electric distribution and transmission systems.
8. **Further Refine Metrics for Technology & Cybersecurity Measures** – Refine existing metrics as implementation continues in order to determine risks, especially around loss, misuse, or compromise of systems and equipment. This will assist with ensuring CenterPoint Houston is aware of events and trends so that it can take appropriate actions to increase resilience.

Appendix A. Peer Utility Benchmarking Survey

A.1 Resiliency Survey Approach

Guidehouse included a peer utility resiliency benchmarking study in this report. First Quartile, a pre-eminent provider of benchmarking and consulting services to utilities, conducted the survey on Guidehouse's behalf.[128] The resiliency survey was issued to 22 North American electric utilities located in the Southern, Northeastern, and Southwestern U.S., as well as one in Eastern Canada. Most utilities that received the survey are First Quartile's benchmark community participants. The survey group includes utilities operating in geographies and coastal areas such as CenterPoint Houston's. Of the 22 utilities, 11 responded to the survey. Figure A-1 shows the location of each of the utilities that responded to the survey, including CenterPoint Houston. In two instances, the map includes subsidiaries for the responding utility; therefore, it shows more than eleven utilities.

Figure A-1: Map of Resiliency Survey Participant Utilities



Source: Guidehouse analysis, based on First Quartile Resiliency Survey inputs.

[128] Participating utility responses are based upon the status of utility resiliency planning at the time the survey was conducted, which was prior to CenterPoint Houston's 2025-2027 T&D SRP filed in April 2024.

A.2 Resiliency Investment Types

The resiliency survey included questions designed to identify the types of resiliency investments U.S. electric utilities are deploying and the system issues they seek to address through these investments. Figure A-2 presents the responses from nine utilities regarding the types of investments included in their resiliency plans. The responses indicate that CenterPoint Houston's proposed SRP investments align well with industry practice.

Figure A-2: Resiliency Survey Investment Types

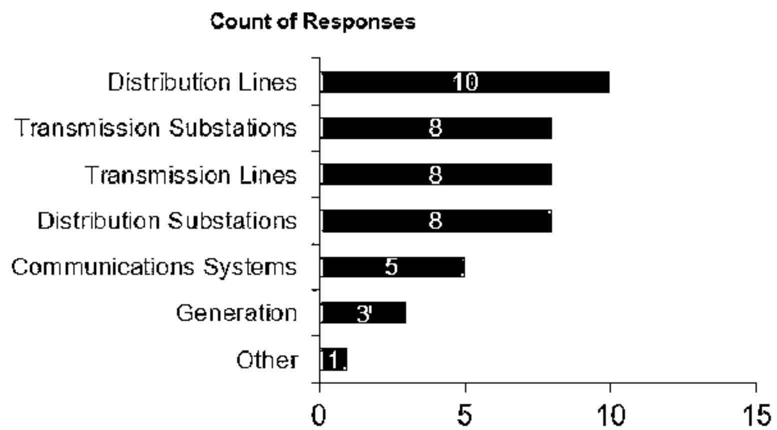
Type of Investment[129]	Respondent Utility Company ID								
	102	103	106	107	108	109	114	122	123
Infrastructure Hardening									
Line/Circuit rebuilds	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pole replacements	✓	✓	✓	✓	✓	✓	✓	✓	✓
Undergrounding of key lines or portions (*e.g.*, freeway crossings)	✓	✓	✓		✓	✓		✓	✓
Conversion projects – *e.g.*, from 69kV to 138kV	✓	✓				✓		✓	
Raising substations	✓	✓	✓		✓				
Reconductoring projects	✓	✓		✓	✓		✓		
Grid Modernization									
Smart grid upgrades	✓	✓	✓	✓		✓	✓	✓	
Smart grid data modifications	✓	✓					✓	✓	
Trip savers	✓	✓		✓		✓			
Digital substation OT systems	✓	✓				✓	✓	✓	
Substation automation	✓	✓	✓			✓	✓	✓	
Situational Awareness									
Monitoring of assets	✓	✓				✓	✓	✓	
Microwave communications	✓	✓					✓	✓	
Voice and mobile data enhancements	✓	✓					✓	✓	
Use of monitoring cameras, communications	✓	✓	✓				✓	✓	
Changes to emergency response plans		✓		✓			✓	✓	
Physical Security									
Substation fencing	✓	✓	✓				✓	✓	
Substation security upgrades	✓	✓	✓				✓	✓	
Technology & Cybersecurity Resiliency									
Threat intelligence and management	✓	✓					✓	✓	
Data Center Facilities upgrades	✓	✓					✓	✓	
Data storage and handling	✓	✓				✓	✓	✓	
Operational data resiliency	✓	✓				✓	✓	✓	
Cyber Security	✓	✓	✓				✓	✓	✓
Cloud based data handling improvements	✓	✓					✓	✓	
Application security							✓	✓	
Telecommunication infrastructure	✓	✓					✓	✓	
Network security	✓	✓					✓	✓	
Other									
Governance risk and compliance tracking		✓				✓	✓		

Source: Guidehouse analysis, based on First Quartile Resiliency Survey inputs.

[129] Categories (highlighted in bold text) assigned within this table have been applied to organize data in this table, but do not necessarily reflect how all respondent utilities would categorize these investments.

The resiliency survey also highlights the types of system components where utilities place the highest investment focus for resiliency initiatives. Figure A-3 indicates that the highest priority resiliency measures are distribution lines, transmission lines, and transmission and distribution substations. Five of the ten utilities prioritize communication systems. These findings are in alignment with CenterPoint Houston's proposed resiliency measures for T&D assets and communication systems described in Section 5.

Figure A-3: Resiliency Survey Investment Per System Components



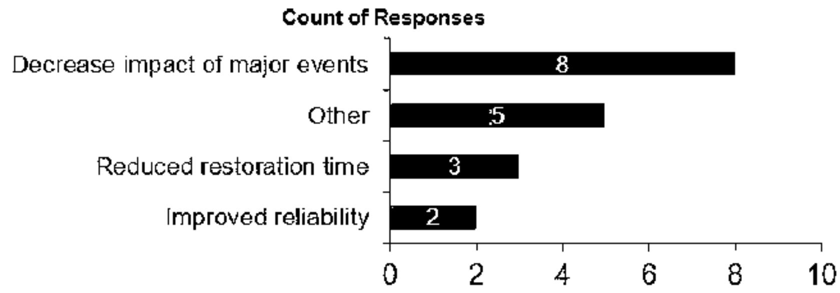
Source: Guidehouse analysis, with inputs from the First Quartile Resiliency Survey.

A.3 Resiliency Measure Goals

The results of the resiliency survey indicate that CenterPoint Houston's SRP goals and priorities align with those of similarly situated electric utilities in North America. CenterPoint Houston's proposed resiliency measures and projects are consistent with the survey group regarding the types of priorities, natural hazards addressed, system impacts mitigated, and plans to measure the effectiveness of individual resiliency initiatives.

Figure A-4 highlights what peer group electric utilities selected as the primary goal of their resiliency measures. The four categories of resiliency measure primary goals include decreased impact of major events, reduced restoration time, improved reliability, and a combination of factors shown as "Other." The "Other" category includes responses such as addressing high-impact and low-frequency events, decreasing restoration costs, supporting asset management and distribution planning goals, and avoiding outages through a stronger and more resilient electric system. Most utilities indicated that the primary goal of their resiliency measure is to mitigate the impact of major events. This finding generally aligns with the goals and objectives of CenterPoint Houston's SRP, as described in the measure reviews in Section 5.

Figure A-4: Primary Goal of Resiliency Program

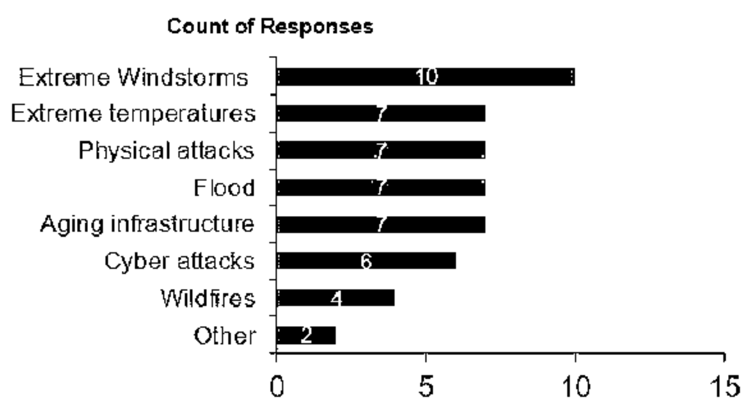


Source: Guidehouse analysis, with inputs from the First Quartile Resiliency Survey.

Figure A-5 shows how utility resiliency survey respondents responded to questions about what hazards are being addressed through their resiliency programs. The survey results also align with CenterPoint Houston's SRP, as evident in this report's list of resiliency measures. CenterPoint Houston's SRP includes circuit rebuild and pole replacement projects, which help mitigate T&D asset damages due to extreme wind speeds while also addressing aging infrastructure.

Other measures included in CenterPoint Houston's SRP, such as the Substation Flood Control resiliency measure and investments to address physical and cybersecurity risks, consistently address the hazards other electric utilities are planning for. Although wildfires are the primary natural hazard concern for some electric utilities, this is historically considered a relatively low risk in CenterPoint Houston's service territory. This historic risk is changing, especially in the summer months, as shown in Section 4.2. The "Other" category in this figure includes additional considerations identified by survey respondents, such as minor flood concerns in transmission and substations but not distribution, flooding in coastal areas, and avoided system overloads in substation transformers, substation switchgear, and along distribution circuits.

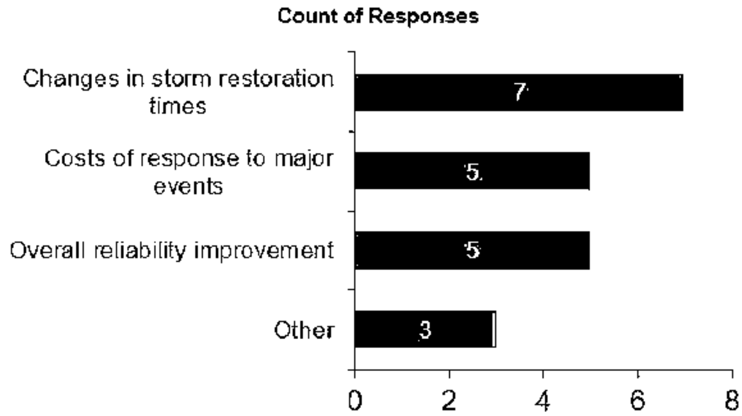
Figure A-5: Hazards Addressed Through Resiliency Program



Source: Guidehouse analysis, based on First Quartile Resiliency Survey inputs.

Figure A-6 reveals how utility resiliency survey respondents measure the effectiveness of individual resiliency initiatives. Most of the responding utilities measure the effectiveness of their resiliency initiatives by monitoring changes in storm restoration times, and many utilities consider the costs of response to major events and overall reliability improvement. The "Other" category included the following additional responses: measuring differences in number of outages on hardened circuits versus past performance and compared to other circuits; tracking length of outages and better recovery from significant rare events; and avoidance of disruption to the T&D system due to those events. CenterPoint Houston plans to track and report to the PUCT the overall effectiveness of the resiliency measures described in Section 5 in alignment with benchmark measures.

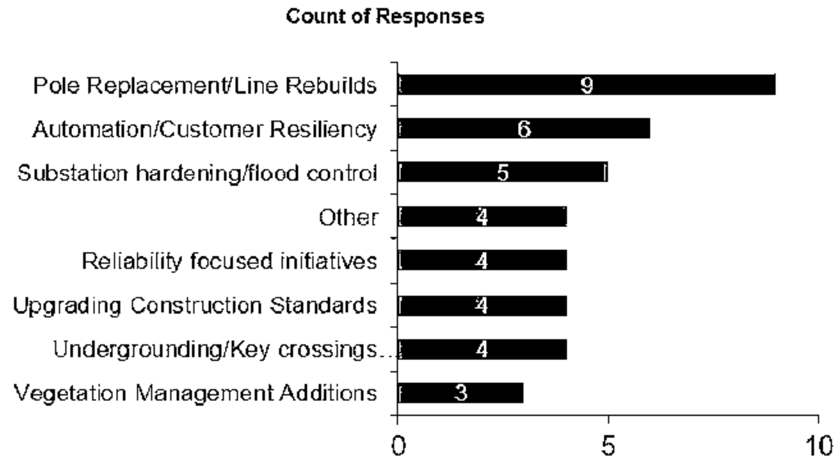
Figure A-6: Measuring the Effectiveness of Individual Resiliency Initiatives



Source: Guidehouse analysis, based on First Quartile Resiliency Survey inputs.

The resiliency survey also helped identify the most frequent occurrences of different types of resiliency investments, with the top eight categories presented in Figure A-7. The three most common resiliency investments are pole replacements and line rebuilds, automation and customer resiliency, and substation hardening and flood control. The "Other" category included the following responses: wildfire mitigation, reliability projects budgeted but not yet executed, and capacity projects addressing preparations for new data centers. CenterPoint Houston's SRP includes resiliency measures that fall under the three most common investments seen in this benchmarking group.

Figure A-7: Top Categories of Resiliency Initiatives



Source: Guidehouse analysis, based on First Quartile Resiliency Survey inputs.

Appendix B. Resiliency Planning Regulatory Jurisdiction Benchmarking

B.1 Executive Summary

The jurisdictional benchmarking analysis provides insights into the range of approaches utilities in different U.S. jurisdictions have taken for planning resiliency-focused investments. This information indicates the types of resiliency investments that are "industry best practices" and examples of how various jurisdictions and utilities approach resiliency planning for the electric utility industry. More specifically, this report covers the following topics for this jurisdictional benchmarking scan:

- Distinctions made between electric grid resiliency and reliability
- Example investments included in electric utility resiliency plans
- Magnitude thresholds used to define resiliency events
- Criteria used to identify the need for resiliency investments
- Methods for determining cost-effectiveness of resiliency investments
- Resiliency planning reporting requirements
- Considerations of equity and environmental justice communities
- Cybersecurity, information technology (IT), and operational technology (OT) investments

Table B-1 summarizes which jurisdictions and utilities are included in this report due to relevant utility investments in resiliency and/or associated policy and regulation. The majority of the benchmarking research was performed before CenterPoint Houston's prior 2025-2027 T&D SRP filed in April 2024. Since then, Guidehouse performed additional benchmarking research to incorporate System Resiliency Plans filed by peer Texas utilities, as well as additional research regarding wildfire investments by peer utilities in other jurisdictions.

Table B-1: Jurisdictions and Utilities Researched for this Report

Jurisdictions	Electric Utilities
California	Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E)
Connecticut	Connecticut Light and Power Company
Florida	Florida Power and Light (FP&L), Duke Energy Florida (DEF), and Tampa Electric Company (TECO)
Hawaii	Hawaiian Electric (HECO) Companies
Illinois	Commonwealth Edison and Ameren Illinois
Louisiana	Entergy
Massachusetts	Eversource
Michigan	Detroit Edison Electric Energy (DTE)
Nevada	NV Energy
New Jersey	Public Service Electric and Gas Company (PSE&G)
New York	Consolidated Edison (Con Edison) and National Grid

Jurisdictions	Electric Utilities
North Carolina	Duke Energy
Ohio	American Electric Power (AEP) Ohio
Oregon, Washington	Avista and PacifiCorp
Puerto Rico	Puerto Rico Electric Power Authority (PREPA)
South Carolina	N/A
Texas	AEP Texas, Entergy Texas, Oncor Electric Delivery, and Texas New Mexico Power Company (TNMP)
Utah	Rocky Mountain Power
Vermont	Green Mountain Power
Virginia	Dominion Energy

Table B-2 provides a summary of types of resiliency investments proposed or are otherwise generally considered "in-scope" for a selection of the jurisdictions researched. Most jurisdictions researched include within scope similar types of distribution investment/programs (referred to as "resiliency measures"), such as pole replacement and hardening, to what CenterPoint Houston proposes in its SRP. Note that other types of investments (*e.g.,* outage management system upgrades, generation infrastructure resiliency) are included in some jurisdictions but are not reflected in Table B-2. Additionally, the assessment is based upon identifying explicit relevant examples from our benchmarking research, so some measures may still be considered in scope in a jurisdiction even if not denoted in Table B-2.

Table B-2: Summary of Types of Resiliency Measures Identified in Sample Jurisdictions

	CA	CT	FL	HI	IL	LA	MI	NV	NJ	NY	NC	OH	OR	SC	TX	VT	VA
Pole Replacement / Hardening	X	X	X	X	X	X	X	X	X	X	X				X	X	X
Substation Flood Control	X			X		X			X	X	X			X	X	X	
Vegetation Management	X	X	X		X	X		X		X			X		X		X
Undergrounding Circuits	X	X		X	X	X	X	X	X	X	X				X	X	X
Substation Physical Security	X									X					X		X
Transmission	X		X	X	X	X	X	X							X	X	X
Cyber Security					X		X				X				X	X	X
DER / Microgrid	X			X						X	X	X	X	X			X

B.1.1 Key Takeaways

Key takeaways and themes identified through this research include:

1. **Electric resiliency planning is observed in many jurisdictions, either driven by policy and regulation or through proactive requests made by investor-owned utilities with their regulator** – Policymakers and electric transmission and distribution utilities across the country are actively involved in electric grid resiliency efforts, regardless of specific topological or climate conditions. The range of in-scope resiliency investments seems to be influenced by which resiliency risks are most prominent in the jurisdiction and whether a competitive generation market exists. In jurisdictions with vertically integrated utilities (*i.e.*, generation, transmission, and distribution service), the scope of resiliency planning often includes distributed energy resources (DERs), microgrids, and/or generation facility resiliency projects.
2. **CenterPoint Houston's proposed System Resiliency Plan aligns with the scope of resiliency measures in Texas and other jurisdictions** – State regulatory commissions have approved resiliency plans with a similar scope to what CenterPoint Houston is filing with the Public Utility Commission of Texas (PUCT). In particular, pole replacement/hardening, substation flood control (particularly in coastal regions), undergrounding, and vegetation management are often within scope.
3. **Many resiliency measures are similar despite differences in primary risk event types** – For example, resiliency risk in many coastal jurisdictions is primarily driven by risks associated with hurricanes and tropical storms. In contrast, other jurisdictions have resiliency risks driven primarily by wildfire events, but many resiliency measures are similar. This is true even within Texas, where risk profiles vary across the state. This is because many of the most common measures help to mitigate several different risk types. Additionally, physical security and cybersecurity risks are ubiquitous across jurisdictions regardless of the extreme weather risk profile.
4. **Many utilities have made investments in IT, OT, and communications systems to improve situational awareness and risk modeling** – While much of the focus on resiliency investments is on hardening infrastructure to reduce the likelihood of failure, it is not possible to completely eliminate this risk, and some level of damage and outages is to be expected from extreme weather events even after hardening infrastructure. Investments in systems to predict, identify, and mitigate equipment failures and outages can improve recovery times (*e.g.*, via fault isolation) and limit the extent of damage (*e.g.*, via power shutoffs). Furthermore, by gathering and analyzing more data associated with resiliency risks and events, utilities can better plan future resiliency investments that effectively target the greatest resiliency risks and associated infrastructure. For example, Southern California Edison and NV Energy have proposed or implemented measures to better identify specific equipment in need of maintenance or upgrades, to identify when and where wildfires are likely to occur and/or spread, and to prioritize future resiliency investments. Texas utilities, including Oncor and TNMP, have included similar investments in their system resiliency plans.
5. **Magnitude threshold can have different meanings depending on utility and location** – A magnitude threshold often refers to a specific wind speed, hurricane category, flood level, or other well-known term used to measure the event's severity. Electric system resiliency plans typically aim to mitigate the risk of electric grid infrastructure failure by ensuring the electric grid infrastructure can withstand a specific magnitude threshold of wind, hurricane,

flood, or other resiliency events. The actual magnitude threshold can vary based on location and geography given the differences in resiliency risk profiles across different locations and geographies. In some jurisdictions, the magnitude threshold is also considered in the context of estimated impacts of the event on the system and customers so that the performance of resiliency measures later be evaluated against those potential impacts identified.

6. **Metrics are commonly used to identify the need for resiliency grid investments and to measure their effectiveness** – For utilities to gain regulatory approval of capital investments in their resiliency plans, utilities typically must demonstrate the need for such investments. One way of demonstrating the need for resiliency investments used in many other jurisdictions is demonstrating that proposed investments can meet certain metrics that determine the need for such investments (*e.g.*, positive benefit-cost ratio). Metrics can be quantitative or qualitative and can often be used to track the performance of resiliency investments over time. Tracking the performance of resiliency investments over time can determine how well they mitigate resiliency event impacts or if additional or new investments may be needed. A key to the success of utility resiliency plans is to have an agreed-upon set of resiliency plan investment metrics with regulators that can be used to demonstrate the need for and effectiveness of resiliency capital investments.
7. **Benefit-cost analysis is a commonly used measure to determine effectiveness** – One of the most common methods of determining the need for resiliency investments is benefit-cost analysis (BCA). A similar approach is risk-spend efficiency (RSE), which helps prioritize resiliency investments based on the level of risk reduction per dollar invested.
8. **Reporting requirements commonly accompany utility resiliency investments** – Utilities typically report progress of resiliency investments as they are being deployed or periodically to regulators and other stakeholders. In addition, utilities typically report the status of how well the mitigation measures of the investments perform against the resiliency events they were deployed to mitigate after investments have been deployed. As a result, certain performance metrics of resiliency investments are made public and analyzed to determine how well resiliency measures mitigate resiliency events, which informs future investment needs.
9. **Equity and environmental justice are considerations that some utilities are beginning to account for in resiliency planning** – The impact of resiliency investments on low-income customers, disadvantaged communities, and/or environmental justice communities is sometimes considered in jurisdictions researched for this report. In those jurisdictions, resiliency investments are generally deployed to positively address the needs of low-income customers and disadvantaged communities while not being overly burdensome from a cost perspective.
10. **Protection against cybersecurity threats is an emerging area for utility resiliency planning** – Cybersecurity risk mitigation is a foundational area of risk management for electric utilities. Utilities in some jurisdictions include cybersecurity or other IT/OT as in-scope resiliency investments. In these jurisdictions, cybersecurity event risk is treated similarly to weather event risk.

B.2 Introduction: Electric System Resiliency Planning Precedent Across Jurisdictions

Over the past several decades, the increased frequency and severity of extreme weather events have led to greater attention by electric transmission and distribution (T&D) utilities and their regulatory bodies on building a more resilient electric system. Many electric utilities are making operational changes to improve the resiliency of their systems during and after extreme weather events, including increasing investment in resiliency-focused programs and projects. Further, the rising risk of physical security and cybersecurity threats has brought these emergent risks into the fold for electric utility resiliency planning and regulation.

Regarding electric sector resilience, the federal government has pursued a number of initiatives and executive orders, including the U.S. Department of Energy (DOE) Partnership for Energy Sector Climate Resilience and State and Local Energy Assurance Planning initiatives, as well as the Federal Energy Regulatory Commission (FERC) and DOE joint effort to incentivize electric utility resilience planning.[130] The U.S. Department of Energy (DOE) has produced numerous resources related to resiliency planning for the electric sector, further demonstrating the increased emphasis on this topic at the national level.[131] Further, electric sector resiliency is a primary component of the Bipartisan Infrastructure Law that passed in late 2021, with $11 billion in grants available for states, tribes, and utilities to enhance the resilience of electric infrastructure against disruptive events such as extreme weather and cyber-attacks.[132] While the Electric Reliability Council of Texas (ERCOT) power region located solely in Texas is outside of FERC's jurisdiction, these examples provide helpful context on how the broader U.S. is considering the importance of resiliency planning.

State governments are also taking action to improve electric utility resiliency. While each state in the U.S. faces unique climate conditions and associated resiliency risk, the trend of increased attention on extreme weather events and cybersecurity is seen across many different parts of the U.S. Examples of such efforts are identified in Table B-3.

[130] MJ Bradley & Associates Issue Brief. (2020 February). *Key Considerations for Electric Sector Climate Resiliency Policy and Investments.* [MJB&A Issue Brief]. (p. 3). mjba_keyconsiderationsforclimateresiliencepolicyandinvestment.pdf (erm.com)

[131] U.S. DOE, Energy Resilience in the Public Sector. https://www.energy.gov/scep/slsc/energy-resilience-public-sector.

[132] U.S. DOE, DOE Fact Sheet: The Bipartisan Infrastructure Deal Will Deliver for American Workers, Families and User in the Clean Energy Future. https://www.energy.gov/articles/doe-fact-sheet-bipartisan-infrastructure-deal-will-deliver-american-workers-families-and-0

Table B-3: Examples of Electric Utility Resiliency Planning Across the United States[133]

State/ Territory	Utility	Description	Relevant Legislation	Relevant Regulatory Dockets
California	All investor-owned utilities (IOUs) and SCE	Various regulatory proceedings in California address resiliency, including climate adaptation and vulnerability assessments (with a focus on disadvantaged communities), equity resilience maps[134], physical risk assessment and mitigation plans for distribution assets, a DER framework that focuses on resilience value, funding for grid safety and resilience, wildfire mitigation plans, and interconnection processes, tariffs, and partnerships to support resilience projects like microgrids.[135] More recently, the state legislature established the Strategic Reliability Reserve Fund to help improve electric grid reliability and resiliency given climate change and the increase in extreme weather events.[136] In 2021, the Wildfire Safety Division within the California Public Utilities Commission (CPUC) was transitioned to a new Office of Energy Infrastructure Safety (Energy Safety). Energy Safety now reviews and approves (or denies) utility Wildfire Mitigation Plans, and CPUC is responsible for ratifying the decision and assessing the prudency of the associated costs.	Senate Bill (SB) 699 (2014) SB 901 (2018) SB 1339 (2018)	Rulemaking on Physical Security of Electrical Corporations Pursuant to Senate Bill 699 (Docket R.15-06-009) Rulemaking to Create a Consistent Regulatory Framework for the Guidance, Planning, and Evaluation of Integrated DERs (Docket R. 14-10-003) Rulemaking to consider strategies and guidance for climate change adaption R.18-04-019 Application of SCE for approval of its Grid Safety and Resiliency Program (Docket A.18-09- 002) Rulemaking to Implement Electric Utility Wildfire Mitigation Plans Pursuant to Senate Bill 901 (Docket R.18-10-007) Rulemaking Regarding Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies (Docket R. 19-09- 009)
California	SDG&E	The CPUC initiated a rulemaking that incorporated a risk-based decision-making framework into utilities' rate cases to prioritize safety, reliability, and security while maintaining just and reasonable rates. As part of this proceeding, SDG&E developed a flexible adaptation pathways framework for adapting to rising sea levels, with adjustable metrics to enable the utility to flexibly adjust the plan as new information is gathered.[137]	SB 379 (2015) SB 246 (2015)	CPUC Rulemaking 13-11-006

[133] This table includes a subset of jurisdictions included within Table to provide specific examples of associated policy, regulatory, and other drivers associated with resiliency planning and investments across jurisdictions.

[134] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders*. [Resilience Guidelines for Oregon]. (pp. 17-18, 24-25). Considerations for Resilience Guidelines for Clean Energy Plans (pnnl.gov)

[135] Pacific Northwest National Laboratories, Bosque Advisors, and Sandia National Laboratories. (2023 September). *Resilient Electric Grid: Defining Measuring, and Integrating Resilience into Electricity Sector Policy and Planning*. [PNNL report on Resilient Electric Grid]. (p. 12). Resilient Electric Grid (pnnl.gov)

[136] London Economics. (2023). (pp. 33-34). *Resilience in the electricity distribution sector and related policy questions*. [London Economics Resilience Report]. Project Documents | Distribution Sector Resilience, Responsiveness & Cost Efficiency | Engage with Us (oeb.ca)

[137] MJB&A Issue Brief. (p. 16).

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State/ Territory	Utility	Description	Relevant Legislation	Relevant Regulatory Dockets
Connecticut	All IOUs	Regulatory proceedings in Connecticut have led to the development of a framework for advancing equitable grid modernization and enhanced resilience through distribution system planning as well as targets and metrics to improve the effectiveness of utility resilience programs.[138]	SB 7 (2018)	Investigation into Distribution System Planning of the Electric Distribution Companies (Docket 17-12-03) Resilience and Reliability Standards and Programs (Docket 17-12-03RE08)
Florida	All IOUs	Florida has a long history of leading in resilience planning, beginning in 1992 when the utility regulator developed its first storm cost risk mitigation plan for IOUs.[139] In 2017, the regulator reviewed electric utility preparedness and restoration activities to identify opportunities to improve resilience.[140] More recently, in 2019, legislation was adopted that requires utilities to submit an electric transmission and distribution storm protection plan on an annual basis looking outward 10 years.[141]	SB 796 (2019)	Review of Florida's Electric Utility Hurricane Preparedness and Restoration Actions (Docket 2017-0215-EU)
Hawaii	All IOUs	Several regulatory proceedings in Hawaii have considered resilience, including 1) grid modernization planning focusing on the resilience value of DERs, 2) a microgrid services tariff to increase resilience and reliability, and 3) an integrated grid planning effort informed by stakeholder engagement on resilience priorities.[142]	House Bill (HB) 2110 (2018)	HECO's Grid Modernization Strategy (Docket 2017-0226) Investigation into Establishment of a Microgrid Services Tariff Pursuant to House Bill 2110 (Docket 2018-01633) Investigation into Integrated Grid Planning (Docket 2018-0165)

138 PNNL report on Resilient Electric Grid. (p. 12).

139 MJB&A Issue Brief. (p. 13).

140 MJB&A Issue Brief. (p. 13).

141 MJB&A Issue Brief. (p. 14).

142 PNNL report on Resilient Electric Grid. (p. 12).

State/ Territory	Utility	Description	Relevant Legislation	Relevant Regulatory Dockets
Illinois	Commonwealth Edison and Ameren Illinois	Several regulatory proceedings have considered resilience, including a microgrid proceeding that identified resilience benefits and the development of resilience metrics as part of a broader set of performance metrics. Additionally, the utility has worked collaboratively with the City of Chicago since 2018 to identify opportunities for increased energy resilience. This included the co-development of the city's first resilience plan to include several goals related to building a more resilient energy system.[143] The Multi-Year Integrated Grid Plan (MYIGP) highlights a set of operating investments designed to meet customer expectations, achieve performance metrics, and support the objectives outlined in Section 16-105.17(d). The investments are driven by four priority areas for the Company's future electric grid vision: Safety and Reliability, Resiliency, Clean Energy Transition, and Customer Experience[144]	Section 16-108.18(e) of the Public Utilities Act (220 ILCS 5/16-105.17) Sec. 16-105.17. MYIGP	Commonwealth Edison Company Petition Concerning the Implementation of a Demonstration Distribution Microgrid (Docket 17-0331) Commonwealth Edison Company Petition for the Establishment of Performance Metrics (Docket 22-0067) Order Requiring Commonwealth Edison to file an Initial Multi-Year Integrated Grid Plan (22-0486) Order Requiring Ameren Illinois Company to file an Initial Multi-Year Integrated Grid Plan (22-0487)
Louisiana	Entergy	In response to the growing frequency and intensity of resiliency events with significant associated outages and recovery costs, The Council of the City of New Orleans established a resolution requiring Entergy New Orleans (ENO) to file a system resiliency and storm hardening plan. In response, ENO developed a 10-year investment plan, including prioritized investments over the first five years, and proposed a Resilience and Storm Hardening Cost Recovery Rider. Entergy Louisiana similarly developed a resilience plan to address resiliency risks for infrastructure outside of the City of New Orleans.	Resolution R-21-401 Resolution R-23-74	System Resiliency and Storm Hardening (Council Docket UD-21-03) Application for Approval of the Entergy Future Ready Resilience Plan (Phase I) (LPSC Docket U-36625)
Massachusetts	Eversource	At the urging of the utility regulator, Eversource has pursued a number of climate mitigation and resilience strategies, including investments in advanced technologies, a vegetation management resiliency pilot, a tree resilience program, and the development of a Climate Adaptation Plan.[145]	N/A	Petition of Eversource Energy for Approval of General Rate Increases and Performance-Based Ratemaking Mechanism (Docket 17-05)

143 MJB&A Issue Brief. (pp. 23-24).

144 Ameren Illinois Multi-Year Integrated Grid Plan. (2023 January). (p. 9). https://www.icc.illinois.gov/docket/P2022-0487/documents/332988/files/580139.pdf

145 MJB&A Issue Brief. (pp. 6-8).

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State/ Territory	Utility	Description	Relevant Legislation	Relevant Regulatory Dockets
Michigan	DTE	Michigan Public Service Commission approved a rate increase for DTE Energy customers, supporting its roadmap to improve reliability and resiliency. DTE's 2023 Distribution Grid Plan included investments aimed at improving reliability and resiliency, accelerating response to customer outages, and increasing grid capacity.[146]	N/A	Michigan Commission's motion for DTE Electric to develop and submit draft five-year investment and maintenance distribution plans (Case U-20147)
Nevada	NV Energy	Legislation requires electric utilities to submit a Natural Disaster Protection Plan every three years to identify and mitigate resiliency risks. NV Energy's filings have primarily targeted wildfire risk and include a wide variety of measures to help identify, prevent, mitigate, and respond to wildfire events and associated risks for electric system infrastructure.	SB 329 (2019)	Application of NV Energy for approval of Natural Disaster Protection Plan for the period 2024-2026 (Docket 23-03003) Application of NV Energy for approval of Natural Disaster Protection Plan for the period 2021-2023 (Docket 20-02031)
New Jersey	PSE&G	Regulator approved funding for hardening/modernizing electric and gas infrastructure to enhance resilience in response to Superstorm Sandy.[147]	Infrastructure Investment Program N.J.A.C. 14:3 2A (2018)	Petition of PSE&G for Approval of the Second Energy Strong New Jersey Program (Docket EO18060629) Value of DERs (Case 15-E-0751)
New York	Con Edison	Following Superstorm Sandy, the regulator approved funding for storm hardening and resilience driven by a Storm Hardening and Resiliency Collaborative. DER valuation as part of the Reforming the Energy Vision initiative also considers resilience benefits.[148] More recently, the utility regulator ordered the utility to develop a Climate Change Vulnerability Study, which included a Conceptual Resilience Management Framework for monitoring "signposts" that will inform the development of flexible solutions and further prioritization of assets and options to increase system-wide resilience.[149] Con Edison developed an analytical framework to evaluate resiliency investments as part of these efforts, including a risk assessment and prioritization model and a cost-benefit analysis model.[150]	Subdivision 29 to Public Service Law 66 (2022)	Rates, Charges, Rules, and Regulations of Con Edison for Electric Service (Case 13-E0030) Proceeding on Motion of the Commission regarding Reforming the Energy Vision (Case 14-M-0101) Proceeding on Motion of the Commission Concerning Electric Utility Climate Studies and Plans (Case 22-E-0222)

[146] Michigan PSC Case No: U-20147. (2023 September). [DTE 2023 Distribution Grid Plan]. (p. 13). *DTE 2023 Distribution Grid Plan.* 0688y00000A4YUXAA3 (site.com)

[147] PNNL report on Resilient Electric Grid. (p. 12).

[148] PNNL report on Resilient Electric Grid. (pp. 12-13).

[149] MJB&A Issue Brief. (pp. 8-10).

[150] London Economics Resilience Report. (pp. 21-27).

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State/ Territory	Utility	Description	Relevant Legislation	Relevant Regulatory Dockets
Puerto Rico	Puerto Rico Electric Power Authority	Regulatory proceedings that consider resilience include: 1) utility's integrated resource plan, which considers resilience through DER investments, and 2) regulation on microgrid development.[151] In 2019, the Puerto Rico Grid Modernization Plan proposed investments to promote resiliency: transmission and substations, distribution, generation and infrastructure, technology, and microgrids.[152]	N/A	Puerto Rico Electric Power Authority Integrated Resource Plan (Docket CEPRAP-2018-0001) Regulation of Microgrid Development (Regulation 9028)
South Carolina	All IOUs	To address lessons learned from Winter Storm Uri in 2021, the regulator requires utilities to assess extreme cold weather threats, impacts, vulnerabilities, and resilience solutions.[153]	N/A	Regarding Measures to Be Taken to Mitigate Impact of Threats to Safe and Reliable Utility Service (Docket 2021-66-A)
Texas	All IOUs	Several utilities have filed transmission and distribution system resiliency plans to mitigate risks associated with extreme weather and other resiliency events. A regulatory framework was established in response to legislation that provides guidance and requirements for regulatory proceedings associated with these filed plans.	HB 2555 (2023) PURA § 38.078	Transmission and Distribution System Resiliency Plans (Docket 55250) Application of Oncor Electric Delivery Company LLC for Approval of a System Resiliency Plan (Docket 56545) Application of Entergy Texas, Inc. for Approval of a System Resiliency Plan (Docket 56735) Application of Texas-New Mexico Power Company for Approval of a System Resiliency Plan (Docket 56954) Application of AEP Texas Inc. for Approval of a System Resiliency Plan (Docket 57057) Application of Southwestern Electric Power Company for Approval of a System Resiliency Plan (Docket 57259)
Virginia	Dominion Energy	The utility developed a grid modernization plan that includes resilience measures such as intelligent grid devices, operations and automated control systems, and grid hardening.[154]	SB 966 (2018)	Petition of Dominion Energy Virginia for Approval of a Plan for Electric Distribution Grid Transformation Projects (Case PUR2018-00100)

[151] PNNL report on Resilient Electric Grid. (p. 13).

[152] Autoridad de Energia Electricia and Central Office for Recovery, Reconstruction and Resiliency. The Grid Modernization of Puerto Rico. (p. 9). Grid Modernization for Puerto Rico (pr.gov)

[153] PNNL report on Resilient Electric Grid. (p. 13).

[154] PNNL report on Resilient Electric Grid. (p. 13).

B.3 Distinction Between Resiliency and Reliability

A common issue regulatory jurisdictions have sought to address as resiliency-focused efforts have emerged in the electric utility industry is clearly defining the distinction between traditional reliability investments (*e.g.*, routine pole replacement at the end of useful life) and resiliency investments. Looking across how this is addressed in jurisdictions examined, resiliency generally refers to the ability of the electric grid to withstand and/or quickly recover from damages caused by extreme weather (including natural disasters), physical security and cybersecurity attacks, or other disruptive events. Reliability, on the other hand, generally refers to the ability of the electric grid to adequately serve load during normal operating conditions.

B.3.1 Electric grid "resiliency" definition examples

The following lists definitions of "resilience" or "resiliency" in different jurisdictions.

- **Connecticut:** Resilience is the ability of the distribution system to withstand and reduce the magnitude and/or duration of disruptive events, including the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event.[155]
- **Hawaii:** Resilience is the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions which can be interpreted as the ability to anticipate, absorb, adapt to, and rapidly recover from a catastrophic event.[156]
- **Louisiana:** Resilience mean the capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimal damage to social well-being, the economy, infrastructure, and the environment.[157]
- **New York:** Resilience is the resistance of a utility's facilities to weather-induced failure or the ability to restore service following a weather-induced service outage.[158]
- **Oregon:** Resiliency is the ability of the system to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions, including the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.[159]
- **Texas:** Per 16 TAC § 25.62(a)(3), a "resiliency event" involves extreme weather conditions, wildfires, cybersecurity threats, or physical security threats that pose a

[155] State of Connecticut Public Utilities Regulatory Authority. *Investigation into Distribution System Planning of the EDCs – Resilience and Reliability Standards and Programs.* (2022 August). (p. 35.) 171203RE08-083122.pdf (state.ct.us)

[156] Hawaiian Electric Resilience Working Group Recap Stakeholder Council Pre-Read. (2021 November). [Hawaiian Electric Resilience Working Group] (p. 3). https://www.hawaiianelectric.com/a/10002

[157] 2023 Louisiana Statewide Resilience Annual Report. (2023). [LA Resilience Report]. (p. 8). https://resilience.la.gov/media/5o0lgdit/statewide-resilience-report-final.pdf

[158] London Economics Resilience Report. (p. 22).

[159] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders.* [Resilience Guidelines for Oregon]. (p. 6).

material risk to the safe and reliable operation of an electric utility's transmission and distribution systems. Per 16 TAC § 25.62(c)(1), a "resiliency measure" is designed to prevent, withstand, mitigate, or more promptly recover from the risks posed to the electric utility's transmission and distribution systems by resiliency events. In resiliency plans filed to date, utilities have commonly referred to these definitions while also referencing definitions from multiple government organizations that align with these definitions.[160]

- **Utah:** Resiliency refers to operating through and recovering from a major disruption.[161]
- **Vermont:** Resiliency is the ability to recover from certain types of disaster and failure, including remaining functional from the customer's perspective while recovering.[162]
- **Virginia:** A resilient grid is one that can self-heal and prevent cascading failure.[163]

B.3.2 Electric grid "reliability" definition examples

The following is a listing of example definitions of "reliability" used in some of the same jurisdictions where this distinction could be identified.

- **Connecticut:** Reliability is the ability of the power system to deliver electricity in the quantity and quality demanded by users.[164]
- **Oregon:** Reliability is the ability of the system or its components to withstand instability, uncontrolled events, cascading failures, or unanticipated loss of system components.[165]
- **Vermont:** Reliability is about keeping the power on and the ability to deliver on the planned outcome to do so.[166]

In Texas, "resiliency" and "reliability" are not explicitly distinguished in 16 TAC § 25.62 or most filed system resiliency plans to date. Nonetheless, it can be inferred that "reliability" applies broadly to customer access to power within certain quality standards, including during typical blue-sky conditions, while "resiliency" is associated with the ability to maintain reliability and safety, specifically concerning extreme weather and security events.

[160] Texas PUCT Docket 55250. Transmission and Distribution System Resiliency Plans. *Order Adopting New 16 TAC § 25.62.* (2024 January). (p. 71-74). https://interchange.puc.texas.gov/Documents/55250_43_1360196.PDF

[161] PacifiCorp 2023 Integrated Resource Plan Volume 1. [PacifiCorp IRP]. (p. 115). 2023_IRP_Volume_I.pdf (pacificorp.com)

[162] Green Mountain Power Final Climate Plan. [GMP Power Climate Plan]. (p. 4). GMP-Final-Climate-Plan-As-Approved.pdf (greenmountainpower.com)

[163] Sandia National Laboratories and Synapse Energy Economics. *The Resilience Planning Landscape for Communities and Electric Utilities.* (2021 April). [Sandia National Lab Report on Resilience Planning Landscape]. (p. 37). https://www.osti.gov/biblio/1782684

[164] State of Connecticut Public Utilities Regulatory Authority. Investigation into Distribution System Planning of the EDCs – Resilience and Reliability Standards and Programs. (p. 35).

[165] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders.* [Resilience Guidelines for Oregon]. (p. 6).

[166] GMP Power Climate Plan. (p. 4).

B.4 Guidance on 'In-Scope" Resiliency Investments

Table B-4 provides a summary of types of resiliency investments proposed or generally considered "in-scope" in other jurisdictions. Most jurisdictions researched include similar types of distribution investment/programs within scope, such as pole replacement and hardening, to what CenterPoint Houston proposes in its SRP. Some jurisdictions also include transmission and cybersecurity investments similar to investments/programs proposed by CenterPoint Houston. Note that other types of investments (*e.g.*, outage management system upgrades, generation infrastructure resiliency) are included in some jurisdictions but are not reflected in Table B-4. Additionally, the assessment is based upon identifying explicit relevant examples from our benchmarking research, so some measures may still be considered in scope in a jurisdiction even if not denoted in Table B-4.

Table B-4: Summary of Types of Resiliency Investments Identified in Other Jurisdictions

	CA	CT	FL	HI	IL	LA	MI	NV	NJ	NY	NC	OH	OR	SC	TX	VT	VA
Pole Replacement / Hardening	X	X	X	X	X	X	X	X	X	X	X				X	X	X
Substation Flood Control	X			X		X			X	X	X			X	X	X	
Vegetation Management	X	X	X		X	X		X		X			X		X		X
Undergrounding Circuits	X	X		X	X	X	X	X	X	X	X				X	X	X
Substation Physical Security	X									X					X		X
Transmission	X		X	X	X	X	X	X							X	X	X
Cyber Security					X		X								X	X	X
DER / Microgrid	X			X						X	X	X	X	X			X

The following provides more specific detail on the types of resiliency investments proposed or otherwise identified as within scope in the jurisdictions researched for this report:

- **California:** Resiliency investments have primarily targeted wildfire mitigation and have included measures associated with hardening, vegetation management, inspections, situational awareness, risk modeling, fault isolation, event response, and backup power to critical loads.
- **Connecticut:** In-scope resiliency investments/programs include system hardening such as stronger wood poles, steel poles, fiberglass cross arms, converting bare wire to covered conductor, vegetation management, and underground circuits[167]

[167] State of Connecticut Public Utilities Regulatory Authority. Investigation into Distribution System Planning of the EDCs – Resilience and Reliability Standards and Programs. (p. 57).

- **Florida:** In-scope resiliency investments/programs include tree trimming, pole inspections, and replacement, hardening of feeders and laterals, and undergrounding[168]
- **Hawaii:** Areas identified within scope include: (1) enhanced vegetation management, particularly in critical grid areas susceptible to damage from wind and falling debris; (2) hardening and reinforcing critical transmission circuits, including upgrading wind criteria and flood mitigation, upgrading structures, and using enhanced construction methods, and materials; and (3) expanding water resistant underground cables and re-locating equipment outside flood-prone areas[169]
- **Illinois**: In-scope resiliency investments include pole replacement/hardening, vegetation management, undergrounding circuits, sub-transmission, and cyber security [170]
- **Louisiana:** Entergy's 10-Year Resiliency Plan presents an infrastructure hardening plan specifically designed to improve overall system resilience over 10 years from 2024 to 2033. The 10-year $9.6 billion plan includes approximately 9,600 proposed distribution and transmission projects that will collectively harden more than 269,000 structures over 11,000 line miles, as well as enhanced vegetation management[171]
- **Michigan:** The in-scope investments/programs in DTE's Roadmap to Improved Reliability (referred to as its Distribution Grid Plan), includes various infrastructure resilience and hardening efforts such as upgrading poles, transformers, and substation equipment. Additionally, underground system improvements, grid modernization, and 4.8kV Hardening are included.[172]
- **Nevada:** In its Natural Disaster Protection Plans, NV Energy has included a wide array of measures that primarily target wildfire risk, including measures associated with hardening, vegetation management, inspections, situational awareness, risk modeling, and event response.
- **New Jersey:** In-scope resiliency investments/programs include electric substation flood mitigation, contingency reconciliation, grid modernization communication systems, and grid modernization advanced distribution management system (ADMS) activities[173]
- **New York:** Resilience investments are categorized into three areas: (1) Resilience-Driven Asset Investments, (2) Incorporation of Resilience Into Planning Design and Operations, and (3) Application of New Technologies[174]

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[168] Florida Public Service Commission Review of Electric Utility Hurricane Preparedness and Restoration Actions. (2018 June). [Florida PUC Review of Electric Utility Hurricane Preparedness]. (p. 9). https://www.floridapsc.com/pscfiles/library/filings/2018/04847-2018/04847-2018.pdf

[169] Hawaiian Electric Resilience Working Group. (p. 13).

[170] Ameren Illinois Multi-Year Integrated Grid Plan. (2023 January). (pp. 105-130).

[171] Entergy Future Resilience Filing One Pager. (2022 December). [Entergy Resilience Filing]. https://cdn.entergy-louisiana.com/userfiles/content/future/Resilience-filing-one-pager.pdf

[172] DTE 2023 Distribution Grid Plan. (pp. 13-14).

[173] New Jersey Board of Public Utilities PSE&G Approval of the Second Energy Strong Program (Energy Strong II). [NJ Board of Public Utilities PSE&G Program]. (p. 6). 9-11-19-2F.pdf (nj.gov)

[174] Con Edison Climate Change Resilience Plan 2023 November). [Con Edison Climate Change Resilience Plan]. (p. 22). Climate Change Resilience Plan (azureedge.net)

- **North Carolina:** In-scope resiliency investments include elevating electrical facilities, undergrounding equipment, and pole management[175]
- **Ohio:** In-scope resiliency investments/programs include portable DERs and microgrids[176]
- **Oregon:** In-scope resiliency investments/programs include system design/modeling, threat analysis, tree trimming, asset redesign, emergency drills, spare equipment, mutual aid agreements, customer-sited generation, and energy efficiency[177]
- **South Carolina:** In-scope resiliency investments include elevating electrical facilities and microgrids[178]
- **Texas:** 16 TAC § 25.62 specifies that in-scope resiliency measures must be associated with hardening, modernization, undergrounding, lightning mitigation, flood mitigation, information technology, cybersecurity, physical security, vegetation management, and/or wildfire mitigation. One or more resiliency plans filed to date have addressed each of these measure types.
- **Vermont:** In-scope resiliency investments/programs include generation projects, undergrounding, and grid hardening[179], transmission and distribution system projects, information technology / operational technology (IT/OT) systems, supervisory control and data acquisition (SCADA) software, geographic information systems (GIS), and microgrids[180]
- **Virginia:** In-scope resiliency investments/programs include intelligent grid devices, operations and automated control systems, grid hardening (*e.g.*, replace and rebuild targeted main feeder segments and implement new vegetation management programs), telecommunications infrastructure, cyber and physical security, and predictive analytics[181]

Figure B-1 below is an example of in-scope National Grid New York resiliency investments defined by project type and mitigated climate hazard.

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[175] United States Government Accountability Office. Opportunities Exist for DOE to Better Support Utilities Improving Resilience to Hurricanes. (2021 March). (p. 8). GAO-21-274, ELECTRICITY GRID: Opportunities Exist for DOE to Better Support Utilities in Improving Resilience to Hurricanes

[176] Public Utilities Commission of Ohio. Application of Ohio Power Company for Authority to Establish a Standard Service Offer in the Form of an Electric Security Plan. (2023 December). [AEP Ohio Electric Security Plan Application]. (p. 15). ViewImage.aspx (state.oh.us)

[177] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders.* [Resilience Guidelines for Oregon]. (p. V).

[178] Ibid.

[179] Green Mountain Power Launches First in Nation 2030 Zero Outages Initiative. (2023 October). Green Mountain Power Launches First in Nation 2030 Zero Outages Initiative - Green Mountain Power

[180] GMP Power Climate Plan. (pp. 5-9).

[181] Dominion Petition to Virginia State Corporation Commission for Approval of a Plan for Electric Distribution Grid Transformation Projects. (2019 January). [Dominion Petition for Approval of Electric Distribution Grid Transformation Projects]. (p. 1). 4dv801!.PDF (virginia.gov)

Figure B-1: National Grid In-Scope Resiliency Investments[182]

Physical Project	Mitigated Climate Hazard	Description
1. Overhead Distribution and Sub-transmission Line Design Upgrades*	Wind Gusts and Ice	Update distribution line standards to move from Class 3 poles to Class 1 for main lines and poles that carry heavy equipment (approximately 8,000 poles/year) and update sub-transmission line standards to use Class 1 poles for single circuit structures, Class H1 for double circuit structures, and Class H2 for double circuit with distribution underbuilds (approximately 900 poles/year).
2. Overhead Transmission Line Design Upgrades*	Wind Gusts and Ice	Build T-Lines to withstand 120 mph wind gusts in high wind areas (46 currently planned) by using more steel and larger foundations. Planned projects include 44–115kV lines and 2–230KV lines (approximately 1,300 circuit miles covered).
3. Distribution Targeted Undergrounding	Wind Gusts and Ice	Targeted undergrounding of 1–2 miles per year of 3-phase main line in highest wind and icing areas.
4. Spare Transmission Line Structures	Wind Gusts and Ice	Purchase 10 T-Line spare structures per division (30 total) designed for 120 mph gusts to speed restoration.
5. Substation Flood Walls	Flooding	Install flood walls at 18 substations in high-risk areas (approximately 17,000 linear feet of flood walls total).
6. Distribution and Transmission Substation Transformer Specification Upgrades*	Extreme Heat	Update transformer spec from 32°C (90°F) to 35°C (95°F). Current plans include 35 distribution projects (81 transformers) and 24 transmission projects (37 transformers) with installs and replacements.

B.5 Magnitude Thresholds Used to Define Resiliency Events

"Magnitude threshold" concerning resiliency events can have multiple meanings based on this jurisdictional research. For example, wind speed, hurricane category designation, level of flood, or type of cyber security event are specific measures or descriptions used to determine the magnitude of the event the utility is planning to withstand. Another meaning of "magnitude threshold" is the magnitude of the impact of a resiliency event concerning the outcomes of a resiliency event, such as loss of customer load, customer outages, restoration times, the dollar amount of electric grid infrastructure damaged, and dollar amount of spend required for restoration efforts. For example, the Connecticut Event Level Matrix shown in Figure B-2 categorizes the "magnitude threshold" (*i.e.*, event level) of a resiliency event using multiple outcome-based criteria.

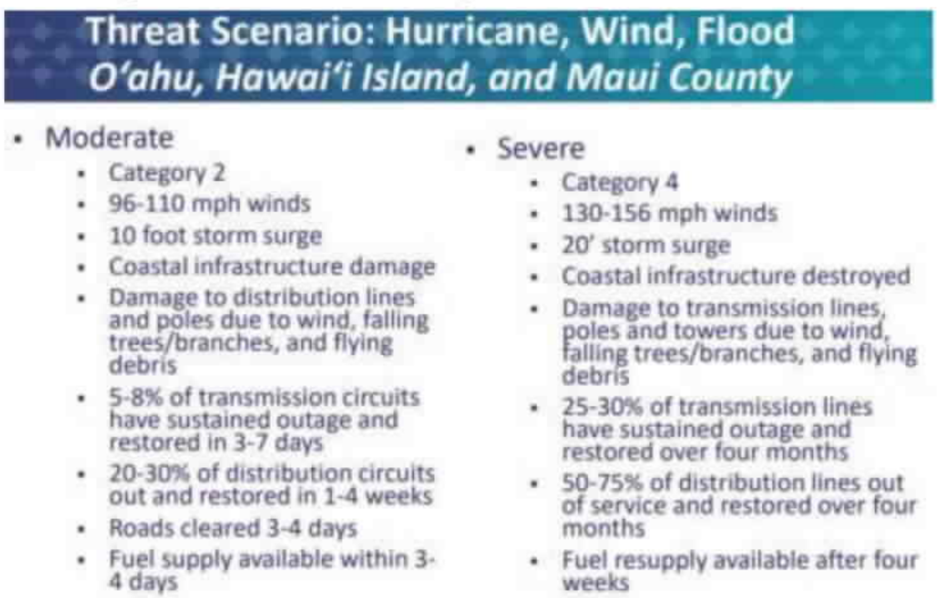
[182] National Grid Climate Change Resilience Plan. (2023 November). (p. 7). https://www.nationalgridus.com/media/pdfs/our-company/national-grid-climate-change-resilience-plan_2023.pdf

Figure B-2: Connecticut Event Level Matrix[183]

Event Level	Customer Outages	Typical No. of Outage Orders	Typical No. of Non-Outage Orders	Typical Lineworker Needs at Storm Onset	Typical Lineworker Needs at Peak	Typical Restoration Duration
5 minor	less than 5,000	n/a	n/a	6 to 12	6 to 18	less than 12 hrs.
5 moderate	5,000 to 10,000	25 to 50	more than 50	12 to 18	106	12 to 24 hrs.
5	10,000 to 31,356	50 to 75	75 to 100	131 to 156	131 to 206	24 to 48 hrs.
4	31,356 to 95,799	75 to 400	100 to 500	156 to 206	156 to 206	2 to 5 days
3	95,800 to 159,967	400 to 1,000	500 to 1,000	216 to 271	216 to 556	5 to 7 days
2	159,967 to 223,549	1,000 to 2,000	500 to 1,000	271 to 436	271 to 646	7 to 9 days
1A	223,549 to 287,421	2,000 to 3,000	1,000 to 2,500	436 to 601	436 to 706	9 to 14 days
1	more than 287,421	more than 3,000	more than 2,500	601 to 1,096	601 to 1,206	more than 14 days

Figure B-3 and Figure B-4 show examples of magnitude thresholds used in Hawaii as part of "threat scenarios" tied to the type of weather-driven or human threat considered. Figure B-5 shows thresholds used in National Grid's Climate Change Resilience Plan for New York.

Figure B-3: Hawaii Magnitude Threshold Examples for Weather-Driven Threat Events[184]



[183] State of Connecticut Public Utilities Regulatory Authority. Investigation into Distribution System Planning of the EDCs – Resilience and Reliability Standards and Programs. (p. 12).

[184] Hawaiian Electric Integrated Grid Planning: Resilience Working Group Meeting. (2019 October). [Hawaiian Electric Integrated Grid Planning: Resilience Working Group]. (p. 35). https://www.hawaiianelectric.com/a/6949

Figure B-4: Hawaii Magnitude Threshold Examples for Human Threat Events[185]

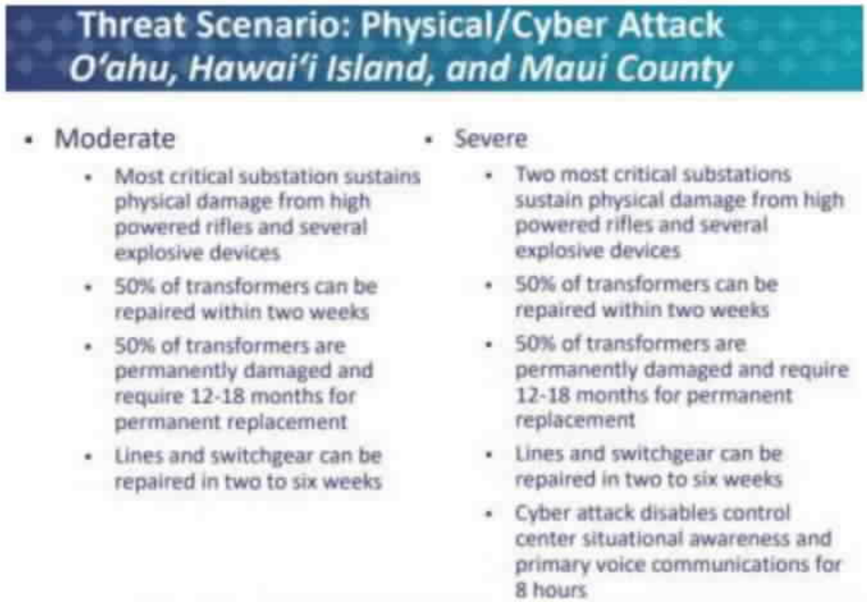


Figure B-5: National Grid Climate Change Resilience Plan Resiliency Thresholds[186]

Operational Project/Program	Mitigated Climate Hazard(s)	Applicable Asset Type	Description
1. Substation Transformer Specification Changes	Extreme Heat	Substations	Due to increasing ambient average and maximum temperatures, transformer specifications will be updated from 32°C (90°F) to 35°C (95°F) for future builds.
2. Update Transmission Structure Standards	Wind Gusts	Transmission	Update transmission structure design guidelines to withstand wind gust projections of up to 120 mph based on structure locations and wind gust maps derived from Massachusetts Institute of Technology (MIT) wind speed projection data.
3. Electric Load Forecasting	Extreme Heat	Distribution	Evaluate climate scenarios in the load forecasting practice.
4. Transmission Facility Rating Methodology Changes	Extreme Heat	Transmission	Update transmission facility rating methodology ambient temperature from present assumption of 35°C (95°F) to 40°C (104°F). Revised facility ratings will be incorporated into transmission system models and used in planning studies.

For filed system resiliency plans within Texas, some differences exist across utilities in proposed event thresholds, as well as corresponding standards to apply to infrastructure investments to enhance system resiliency. For example, Entergy Texas proposed wind loading standards that exceed the National Electric Safety Code (NESC) 250C and noted that its standards may need to increase above national reference standards, which may be viewed as a

[185] Ibid.

[186] National Grid Climate Change Resilience Plan. (p. 7).

minimum standard and may be considered insufficient when evidence demonstrates that the standard does not provide sufficient resiliency within a utility's service area.

B.6 Criteria Used to Identify Need for Resiliency Investments

Many states where electric utilities are active in resiliency planning have defined criteria or metrics to determine which projects qualify and why. In some cases, these criteria or metrics are also used to track performance of the measures over time, the topic of the next section of this report. Table B-5 provides an overview of the types of metrics, both qualitative and quantitative, that regulators and utilities are using to justify investments.

Table B-5: Summary of Common Metrics by State

Criteria	CA	CT	HI	LA	NY	OH	OR	TX	UT	VT	WA
Indirect/Societal Impact		X	X		X		X	X		X	
Customer Outage Time/Metric		X		X	X	X	X	X			X
Natural Hazard/Land Modeling								X	X		
Qualitative Measures	X		X		X	X		X		X	

Electric utilities in California and Utah use qualitative and quantitative consideration metrics for wildfire mitigation and vegetation management programs. For example, SCE, in seeking approval of its Grid Safety and Resiliency Program, included an independent Tree Removal Study by an outside consulting firm to evaluate the need and effectiveness of its current "Tree Calculator" tool for determining where tree removal should be targeted to reduce wildfire risks.[187] PacifiCorp, also to reduce wildfire risk, implemented a fire threat classification for specific conditions and established goals for increased inspection frequencies in high-risk locations and reduced correction timeframes for fire threat conditions.[188] Due to rising threats in Utah, Rocky Mountain Power created a new Fire High Consequence Area (FHCA) rebuild program and justified it by claiming that a comprehensive approach would be the most efficient way to upgrade all equipment on a line at one time and make it more resilient against wildfires. All lines included in the rebuild must be partially in the FHCA, and they use the age of poles as a metric, which is hand-selected for rebuilding based on local knowledge of the infrastructure.[189]

[187] California PUC Application of Southern California Edison Company for Approval of Its Grid Safety and Resiliency Program. (2020 April). [SCE Approval of Grid Safety and Resiliency Program]. (p. 24). 334734573.PDF (ca.gov)

[188] PacifiCorp IRP. (p. 133).

[189] Rocky Mountain Power Utah Wildland Fire Protection Plan to Utah PSC. (2020 June). [Rocky Mountain Power Fire Protection Plan]. (p. 55). 20-035-28_RMP_Wildland_Fire_Protection_Plan.pdf (rockymountainpower.net)

AEP Ohio has used a measure of aging equipment on electric lines as an indicator of need.[190]

Other electric utilities such as Con Edison, Green Mountain Power, and HECO, have taken a similar approach to California electric utilities to evaluate resiliency investments considering their unique risk profile. These utilities use a mix of qualitative and quantitative metrics that help identify investments that avoid the largest number of outages, enhance safety, and/or have the greatest impact on critical load customers. HECO is an example where a stakeholder process was established to determine resiliency investment qualification criteria by forming a Resiliency Working Group. Qualification criteria developed through this process include:

- Reduce the likelihood of power outages during a severe event
- Reduce the severity and duration of any outages that do occur during and after a severe event
- Reduce restoration and recovery times following a severe event
- Reduce critical infrastructure customers' power rapidly to enable mutual support and recovery during an emergency
- Return all customers to service within appropriate times
- Limit environmental impacts of a severe event[191]

Additionally, some utilities such as HECO incorporate the "Bowtie Method" Risk-Threat Assessment process to determine specific prevention and mitigation solutions (see **Figure** B-6).

Figure B-6: "Bowtie Method" Risk-Threat Assessment[192]

Hawaiian Electric considers risk mitigation solutions identified through this process into a Resilience Solution Portfolio. The matrix in Figure B-7 shows how the utility evaluates the options with consideration of scope and potential customer benefits.

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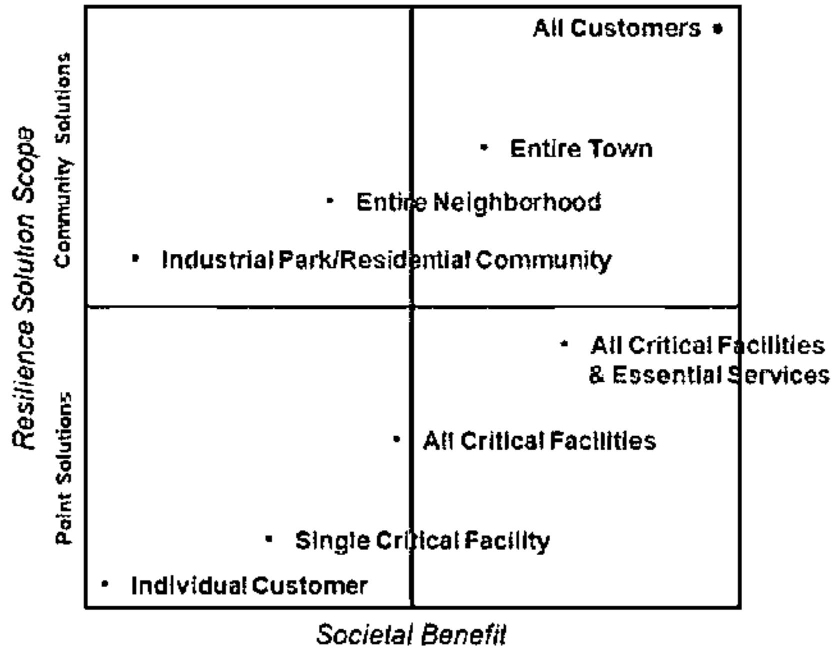
190 AEP Ohio Electric Security Plan Application. (p. 11). ViewImage.aspx (state.oh.us)

191 Hawaiian Electric Resilience Working Group. (p. 4).

192 Hawaiian Electric IGP Resource Adequacy Workplan and Finalized Grid Needs Methodology. (2022 September). [Hawaiian Electric IGP Resource Adequacy Workplan]. (p. 241). IGP Resource Adequacy Workplan and Finalized Grid Needs Methodology (hawaiianelectric.com)

Figure B-7: Resilience Solution Portfolio[193]



Source: De Martini for PNNL

Some jurisdictions/utilities have taken a more data-centric approach to determining the value of resiliency investments, focusing primarily on calculating customer benefits and outage times. For example, PacifiCorp and Avista have begun using the metric "Customers Experiencing Multiple Sustained and Momentary Interruptions" (CEMSMI) to measure reliability and resiliency needs.[194] CEMSMI measures the number of customers experiencing more than a certain number of interruptions a year, including momentary and sustained outages. Another example is the Louisiana Public Service Commission's Storm Resilience Model, which calculates the customer benefit of hardening projects through reduced utility restoration costs, and customer impacts measured by customer minutes of interruption (CMI). The Louisiana Commission prioritizes hardening projects with the highest resilience benefit per dollar invested into the system, determining funding levels based on this measure of customer benefits.[195]
Figure B-8 shows the resiliency framework used by the Connecticut Public Utilities Regulatory Authority (Connecticut PURA), which was established for electric distribution companies to model performance and implement their reliability- and resilience-based capital programs.[196]

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193 Hawaiian Electric IGP Resource Adequacy Workplan (p. 242)

194 U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders.* [Resilience Guidelines for Oregon]. (p. 23).

195 Entergy New Orleans Application for Approval of Future Ready Resilience Plan (Phase 1). [Entergy Future Ready Resilience Plan]. (April 2023). Resilience Investment and Benefits Report (p. 7). Resilience-filing-4-17-2023.pdf (entergy-neworleans.com)

196 State of Connecticut Public Utilities Regulatory Authority. Investigation into Distribution System Planning of the EDCs – Resilience and Reliability Standards and Programs. (p. 61).

Figure B-8: Criteria to Identify and Prioritize Vulnerable Zones[197]

Criteria	Category	Rank
All-in SAIDI (for last four years)	Outage-based	Primary
All-in SAIFI (for last four years)		Secondary
All-in CAIDI (for last four years)		
Major Storm-only SAIDI		
Major Storm-only SAIFI		
No. of Customers per Zone	System Characteristics	
Mainline length		
Density and Type of Vegetation		
Feeder Type: Backbone or Lateral		
Feeder ties		
Site Access Difficulty (e.g., hard to access right-of-ways)		
Municipal Priorities including Blocked Roads	Community Priorities	
No. of Commercial and Industrial Customers per Zone		
Located in Distressed Municipality		
Located in Environmental Justice Community		
No. of Life Support Customers		

For substation upgrades and investments, Green Mountain Power used floodplain modeling and analysis, considering 100-year and 500-year flooding events to determine which facilities should be relocated or rebuilt at a higher elevation at the same site. Projects are prioritized, if they are needed, to address 100-year floodplain levels or have a history of flooding, with additional prioritization given to substations serving a higher number of customers. For resiliency investments related to electric distribution circuit performance improvements, the utility uses criteria to rank circuits based on the magnitude of the impact grid hardening investments will have in terms of number of customers and load served. The project prioritization is then based on a static assessment of these criteria paired with the local experience of field resources and consideration of the ratio of capital dollars spent to customer hours out for each project.[198]

Based on its benchmarking analysis, Figure B-9 shows resilience metrics identified by the Grid Modernization Laboratory Consortium for the Oregon Public Utilities Commission. These metrics were proposed to aid the resilience analysis process, including helping to characterize threats and consequences.[199]

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[197] Ibid.

[198] GMP Power Climate Plan. (p. 7).

[199] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders*. [Resilience Guidelines for Oregon]. (p. 5).

Figure B-9: Consequence Categories for Consideration in Developing Resilience Metrics[200]

Consequence Category	Resilience Metric
Direct	
Electrical Service	Cumulative customer-hours of outages
	Cumulative customer energy demand not served
	Average number (or percentage) of customers experiencing an outage during a specified time period
Critical Electrical Service	Cumulative critical customer-hours of outages
	Critical customer energy demand not served
	Average number (or percentage) of critical loads that experience an outage
Restoration	Time to recovery
	Cost of recovery
Monetary	Loss of utility revenue
	Cost of grid damages (e.g., repair or replace lines, transformers)
	Cost of recovery
	Avoided outage cost
Indirect	
Community Function	Critical services without power (e.g., hospitals, fire stations, police stations)
	Critical services without power for more than *N* hours (e.g., *N*> hours of backup fuel requirement)
Monetary	Loss of assets and perishables
	Business interruption costs
	Impact on Gross Municipal Product or Gross Regional Product
Other Critical Assets	Key production facilities without power
	Key military facilities without power

For proposed system resiliency plans within Texas, utilities have utilized quantitative risk analyses to identify and prioritize resiliency risks, as well as quantitative BCA to help prioritize and justify resiliency investments. In general, the economic benefits of reduced outages have been the primary driver of value. In some cases, locational analysis has been performed to help prioritize specific locations on the network for resiliency investments.

Nonetheless, qualitative considerations have also been important for Texas utilities' system resiliency plans. For example, Texas utilities have consistently relied on more qualitative approaches to risk assessment for cybersecurity-related investments. Additionally, PUCT Staff

200 Ibid.

recommended using a benefit-cost ratio of 0.8 as a standard cost-effectiveness threshold to acknowledge that there are additional benefits associated with resiliency investments that may be difficult to quantify.

B.7 Methods Used to Determine Cost-Effectiveness of Resiliency Investments

Benefit-cost, or cost-benefit, analyses (BCA/CBA) are the most commonly used practices for determining the cost-effectiveness of resiliency investments. Electric utilities across various jurisdictions use this method to measure projected costs against estimated avoided costs. Examples of electric utilities using BCA for resiliency planning include:

- **Duke Energy:** Used BCA to justify their multiyear rate plan (MYRP) for resiliency-focused transmission projects.[201]
- **Entergy New Orleans:** Resiliency filing used a Storm Resilience model to calculate the resilience costs and estimated the benefits of hardening assets in terms of avoided customer minutes interrupted and avoided future storm restoration costs.[202]
- **Dominion**: Ran into challenges with getting regulatory approval for grid hardening investments after the Virginia Utility Commission found that certain programs only benefited 4.3% of Dominion's customer base. Cost-effectiveness was measured as the overall customer impact relative to cost.[203]
- **Con Edison:** At the direction of the New York Public Service Commission, Con Edison a BCA approach for resiliency investments using two models: 1) a risk assessment and prioritization model to measure resiliency efforts in terms of risk reduced per dollar spent and 2) a BCA model that calculates the risk reduction value of resiliency projects.[204] The models included the following components:
    - Location-specific information regarding high-rise residential buildings
    - Location-based flood probabilities combined with asset elevation data
    - Wind damage probabilities from historical wind gust frequency distributions
    - Data on heat wave events
    - Storm hardening project costs
    - Projected outage durations
    - Estimates of asset risk pre-hardening and post-hardening in terms of changes to damage probability or outage duration
- **Texas:** Texas utilities have consistently leveraged BCA to help prioritize and justify proposed resiliency investments. The methodologies have generally been similar,

[201] Application of Duke Energy for Adjustment of Rates and Charges (MYRP) to the North Carolina utilities Commission. (2023 March). [Duke Energy MYRP Application]. (p. 68). ViewFile.aspx (ncuc.gov)

[202] Entergy New Orleans Application for Approval of Future Ready Resilience Plan (Phase 1). [Entergy Future Ready Resilience Plan]. (April 2023). Resilience Investment and Benefits Report (p. 7).

[203] Dominion Petition for Approval of Electric Distribution Grid Transformation Projects. (p. 14).

[204] London Economics Resilience Report. (p. 22).

though some assumptions and approaches have differed. For example, there have been some differences in the assumed value of lost load, and some utilities have approached BCA by measure type while others have performed BCA by network location. Qualitative methods have been used in lieu of BCA when benefits are difficult to quantify (*e.g.*, for cybersecurity investments and some wildfire-related investments).

- **Oregon:** The Oregon Public Utilities Commission engaged the Grid Modernization Laboratory Consortium to help establish a framework for the costs and benefits of resiliency investments for Oregon investor-owned utilities (see below for additional detail).
- **Hawaii and California:** Utilities in Hawaii and California have utilized risk-spend efficiency (RSE) as an alternative metric to a benefit-cost ratio to prioritize resiliency investments based on risk reduction per dollar invested (see below for additional detail).

Figure B-10 and Figure B-11 show defined categories of costs and benefits of resilience investments identified by the Grid Modernization Laboratory Consortium in the report they prepared for the Oregon Public Utilities Commission to help them establish prudent industry resiliency standards for Oregon investor-owned utilities.

Figure B-10: Categories of Costs of Resilience Investments[205]

Type	Impact	Utility System	Host Customer	Community	Society[a]
Project Implementation	Installation, Operation, and Maintenance	X	X	X	
	Transaction	X	X	X	
	Interconnection	X	X	X	
	Financial Incentives	X			X
	Program Administration	X			
	Utility Performance Incentives	X			

[205] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders*. [Resilience Guidelines for Oregon]. (p. 35).

Figure B-11: Potential Benefits of Resilience Investments[206]

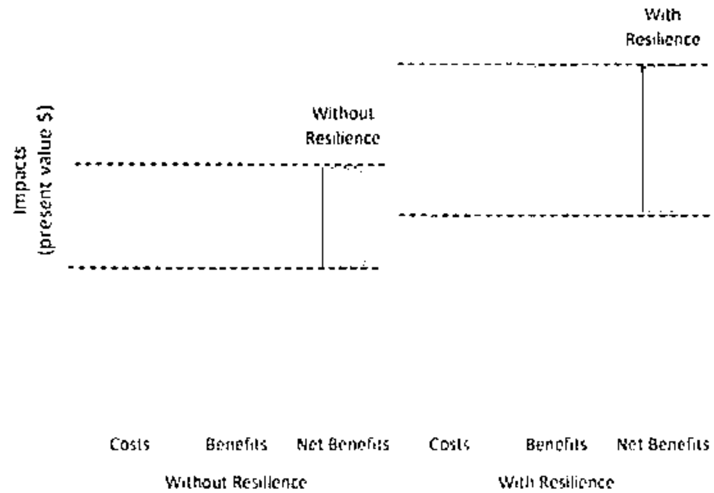
Type	Impact	Utility System	Host Customer	Community	Society
Generation, Transmission & Distribution Energy and Capacity	Reducing Emergency Staff Deployment Costs	X			
	Avoiding Energy Infrastructure Damages	X			
Non-Energy Economic	Avoiding Damages to Goods and Infrastructure		X	X	X
	Avoiding Lower Revenues from Lower Production and Fewer Sales of Goods and Services		X		X
	Reducing Emergency Staff Deployment Costs		X	X	
	Avoiding Departure of Customers Important to the Community			X	
	Avoiding Lost Economic Development, Education, and Recreation Opportunities			X	X
Non-Energy: Public Health, Safety, and Security	Reducing Medical and Insurance Costs	X	X	X	X
	Avoiding Loss of Quality of Life	X	X	X	X

Another example of the concept of BCA being used for resiliency planning is illustrated in Figure B-12, which shows how a battery system can help avoid upgrades to the electric utility's transmission and distribution system. The report that provided this example summarizes that when covered with concrete, the battery is protected from hurricane damages and that "the benefits exceed the costs, with and without the resilience components".[207]

[206] Ibid.

[207] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders.* [Resilience Guidelines for Oregon]. (p.36)

Figure B-12: BCA With and Without Resilience Costs and Benefits[208]



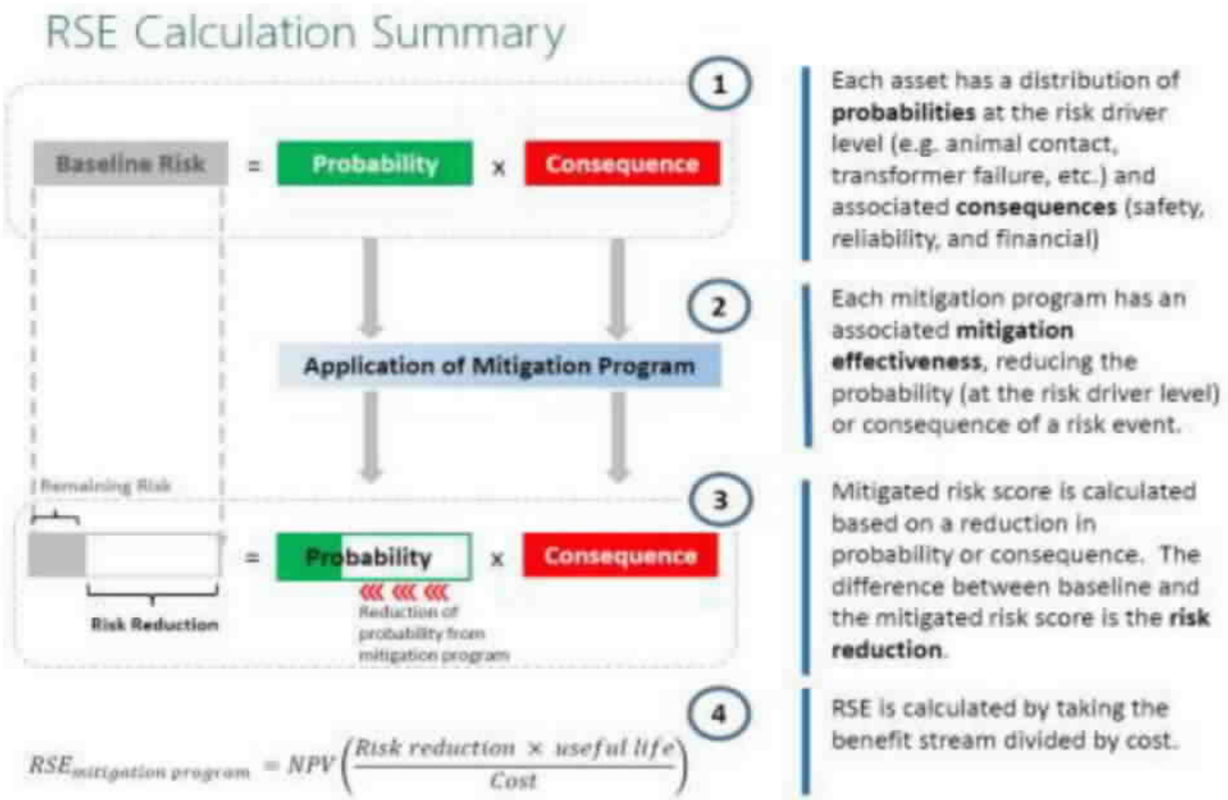
As an alternative to the traditional BCA model, HECO and SCE are examples of utilities that use a risk-spend efficiency (RSE) metric to define the cost-effectiveness of resilience risk reduction solutions. The benefit is expressed in terms of the magnitude of risk reduction, while the costs represent the mitigation expenses (capital and O&M) associated with the project or program (see calculation below, including Figure B-13 which shows a summary of the calculation). This process begins with assessing solution value in terms of community and customer resilience risk reduction measured in customer minutes of interruption (CMI) avoided over the planning horizon.[209] The utility then uses the RSE scores to develop a prioritized solutions list within a defined budget.

$$\text{Risk Spend Efficiency} = \frac{Risk\ Reduction * Number\ of\ Years\ of\ Expected\ Risk\ Reduction}{Total\ Mitigation\ Cost\ (in\ thousands)}$$

[208] Ibid.

[209] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders*. [Resilience Guidelines for Oregon]. (p. 39).

Figure B-13: Risk Spend Efficiency Calculation Summary[210]



B.8 Reporting Requirements

Electric utility resiliency plans approved by state regulatory commissions typically require continued reporting of metrics against the timeline of capital deployment to demonstrate the effectiveness of the capital deployment in mitigating the impact of resiliency events. Con Edison, for example, developed its Climate Resiliency Plan Investment Performance Metrics to track the effectiveness of investments and the implementation of programs.[211] This includes tracking both outcome-based and implementation-based resilience measures on a biennial basis. The outcome-based measures attempt to assess the overall effectiveness of CenterPoint Houston's SRP, while implementation-based measures help assess progress over time using a more traditional project management approach. Outcome-based measures include the impact of major storms, network distribution system resiliency, non-network distribution system resiliency, outage communications, and emergency preparedness). Measures are subject to change over time as more peer-reviewed and benchmarked measures become widely accepted in the utility industry.

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[210] Ibid.

[211] Con Edison Climate Change Resilience Plan. (p. 62).

For example, Con Edison meets with stakeholders at least twice a year and reports every other year on performance measures and the status of resiliency investments.[212] The monitoring and reporting identify lessons learned about the effectiveness of resilience investments, which can be used to determine the need for future investments.[213] To track project status, Figure B-14 shows how Con Edison reports resiliency investments as they are being deployed.

Figure B-14: National Grid Project Implementation Reporting Example[214]

Project Name	Completion Date (Estimated)	Completion Date (Actual)	Planned Cost[34] ($K)	Cost to Date ($K)
Targeted Undergrounding	03/31/2045	In progress	$50,500	$30,000
Spare Transmission Structures	12/21/2026	11/21/2026	$1,500	$1,350
Sugar Hill Station – Transformer upgrade	3/31/2030	Planned	$1,467 ($186)[35]	$800
Transmission Substations Flood Mitigation Program	3/31/2045	In Progress	$16,100	$300
South Oswego to Lighthouse Hill – Transmission line upgrade	11/21/2027	12/21/2027	$960 ($30)	$990

Within Texas, proceedings associated with utility system resiliency plans have helped to establish some guidance for reporting metrics associated with outcomes of approved resiliency investments. Different utilities have proposed different types of metrics, and the PUCT has indicated an interest in having some consistency in metrics across utilities and investment types. In particular, the PUCT has emphasized customer-focused metrics such as avoided CMI reduction and avoided CMI per dollar invested. While avoided CMI may sometimes be difficult to calculate, comparison groups and other methods may be used to provide a reasonable estimate.

B.9 Requirements Related to Equity and Environmental Justice Communities

An important indicator of an effective electric utility resiliency plan is how widespread the customer benefits are shared. In some jurisdictions, utility regulators emphasize the impact on

212 Con Edison Climate Change Resilience Plan. (p. 5).

213 Ibid.

214 National Grid Climate Change Resilience Plan. (p. 46).

disadvantaged and marginalized communities (or similar terms used). For example, the California Public Utilities Commission and Washington Utilities and Transportation Commission have begun to require utilities to individually map vulnerable communities in their service territories and to include them in future climate change assessments and clean energy implementation plans.[215] Another example, on a more local level, is the City of Norfolk, Virginia, which developed a resilience strategy in partnership with the electric utility that targets funding related to hurricane defense and flood risk adaptation, including a special focus on neighborhood resilience, which is a targeted area to alleviate poverty in the city and connect communities.[216]

Another example of equity considerations being made is Con Edison's Climate Change Resilience Plan, which explains how equity is incorporated into their planning process by tracking the impact of outages in disadvantaged communities relative to impacts in other areas of their system. Additionally, the utility works with stakeholders such as the NYC Mayor's Office of Climate and Environmental Justice to support vulnerable areas.[217] In addition, CenterPoint Houston has formed an Environmental Justice Working Group under an executive committee with a plan to release a finalized Environmental Justice Policy Statement to apply an equity lens to resilience-driven investments.[218] Key components of the policy statement include:

- Operations will not disproportionately burden Disadvantaged Communities (DACs)
- Con Edison will work to understand DAC concerns
- Clean energy investments will benefit DACs
- Con Edison will provide opportunities for employment in their clean energy future[219]

National Grid in New York also considers equity and environmental justice when making resiliency investments. It considers how disadvantaged communities may be disproportionately affected by climate change and what it can do to enhance resilient service to those communities.[220] National Grid recognizes the central role of equity in resilience planning and is committed to ensuring equity is appropriately incorporated during investment planning.[221]

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[215] U.S. Department of Energy Grid Modernization Laboratory Consortium. (2022 September). *Considerations for Resilience Guidelines for Clean Energy Plans For the Oregon Public Utility Commission and Oregon Electricity Stakeholders.* [Resilience Guidelines for Oregon]. (p. V).

[216] Sandia National Lab Report on Resilience Planning Landscape. (p. 37).

[217] Con Edison Climate Change Resilience Plan. (p. 4).

[218] Con Edison Climate Change Vulnerability Study. (2023 September). (p. 16). https://www.coned.com/-/media/files/ConEd/documents/our-energy-future/our-energy-projects/climate-change-resiliency-plan/climate-change-vulnerability-study.pdf?la=en

[219] Ibid.

[220] National Grid Climate Change Resilience Plan. (p. 15).

[221] National Grid Climate Change Resilience Plan. (p. 16).

B.10 Consideration of IT, OT, and Cybersecurity Resiliency Investments

Green Mountain Power is an example of a utility that has developed criteria for pursuing IT resiliency investments to keep its existing data centers and control centers reliable and efficient. The utility's investment requirements include:[222]

- **Projects for failover systems:** Selection is based on the ability to provide enhanced levels of redundancy and resiliency to key operational systems that could more easily succumb to extreme weather-related impacts in their current configuration or those that are critical to customer restorations during extreme weather events
- **Communications projects:** Selected based on the ability to provide an additional platform for stakeholder and emergency response information and resource sharing with the utility

Additionally, the utility stated that programs will be concentrated in the following three key areas:

1. Projects that improve the resiliency and durability of communications infrastructures that manage and provide telemetry for grid operations
2. IT projects focused on increasing the uninterrupted functionality and durability of key application infrastructures and devices necessary to serve their customers, including their Outage Management System (OMS), SCADA, and GIS
3. Projects that enhance communication and coordination efforts with municipalities, first responders, and customers during severe weather events

Examples of cybersecurity considerations in other utility resiliency planning efforts include:

- **Duke Energy North Carolina**: Multi-year rate plan includes cybersecurity monitoring as a key requirement in resiliency investments to increase protection against attacks[223]
- **SCE:** The application for approval of its Grid Safety and Resiliency Program was criticized by small business advocates who had concerns about privacy with publicly available weather information and lack of cybersecurity technology[224]
- **Dominion Energy Virginia:** In 2023, the Virginia regulator approved the utility's Phase 3 Electric Grid Transformation Projects, which included investments in advanced metering infrastructure, a customer information platform, voltage optimization enablement, a DER management system and outage management system, and a non-wires alternative pilot.[225]
- **Ameren Illinois:** The expected increase in the number of sensors, potential control points, and reliance on public networks will increase the attack surface for nefarious activities by hackers. As devices proliferate, so does the utility's reliance on monitoring

[222] GMP Power Climate Plan. (p. 7).

[223] Duke Energy MYRP Application. (p. 72).

[224] SCE Approval of Grid Safety and Resiliency Program. (p. 13).

[225] 50 States of Grid Modernization Q1 2022 Quarterly Report Executive Summary. NC Clean Energy Technology Center. (2022 April). (p. 6). Q12022_gridmod_exec_final.pdf (ncsu.edu)

their state and potentially controlling their performance to maintain reliability and resilient grid conditions.[226]

- **Texas:** Multiple Texas utilities, including Oncor and TNMP, have included technology and cybersecurity measures in their proposed system resiliency plans.

[226] Ameren Illinois Multi-Year Integrated Grid Plan. (p. 98).

Appendix C. VoLL Sensitivity Analysis: $5,000/MWh to $65,000/MWh

Table C-1 summarizes the results of BCA sensitivity analysis in which VoLL was varied between $5,000/MWh and $65,000/MWh.

Table C-1: VoLL Sensitivity Analysis

Resiliency Measure	Resiliency Measure No. (RM)	3-Year Total Cost ($MM)	VoLL ($5,000 per MWHr)	VoLL ($9,000 per MWHr)	VoLL ($35,000 per MWHr)	VoLL ($65,000 per MWHr)
Extreme Wind						
Distribution Circuit Resiliency	RM - 1	$513.4	1.8	3.2	12.1	22.5
Strategic Undergrounding	RM - 2	$860.0	0.5	0.8	2.8	5.2
Restoration IGSD	RM - 3	$107.8	2.8	5.0	19.3	35.7
Distribution Pole Replacements/Bracing	RM - 4	$251.6	1.6	2.7	9.9	18.3
Vegetation Management	RM - 5	$146.1	0.6	1.0	3.7	6.7
Transmission System Hardening	RM - 6	$1,468.0	0.6	1.0	3.9	7.2
69kV Conversion Projects	RM – 7	$369.3	0.4	0.7	2.7	5.0
S90 Tower Replacements	RM - 8	$118.4	1.3	2.4	9.4	17.4
Coastal Transmission Resiliency	RM - 9	$178.1	0.3	0.5	2.0	3.8
Group Subtotal		**$4,012.7**	**0.8**	**1.4**	**5.5**	**10.1**
Extreme Water (Flood)						
Substation Flood Control	RM - 10	$43.8	0.3	0.6	2.1	3.9
Control Center Facility Upgrades	RM - 11	$7.0	2.7	4.4	15.2	27.8
MUCAMS	RM - 12	$10.8	0.2	0.3	1.3	2.5
Mobile Substations	RM - 13	$30.0	0.4	0.7	3.0	5.6
Group Subtotal		$91.6	0.5	0.9	3.3	6.1
Extreme Temperature (Freezing)		$0.0				
Anti-Galloping Technologies	RM - 14	$15.0	1.0	1.8	7.1	13.2
Group Subtotal		**$15.0**	**1.0**	**1.8**	**7.1**	**13.2**
Extreme Temperature (Drought)						
Distribution Capacity Enhancement/Substations	RM - 16	$579.6	0.8	1.4	5.6	10.5
MUGS Reconductoring	RM - 17	$245.0	0.2	0.4	1.4	2.6
URD Cable Modernization	RM - 18	$128.4	0.7	0.9	2.2	3.7
Contamination Mitigation	RM - 19	$150.0	0.4	0.6	2.4	4.5
Substation Transformer Fire Barriers	RM - 20	$9.0	0.8	1.2	4.0	7.3
Digital Substation	RM - 21	$31.8	0.4	0.6	1.8	3.1
Group Subtotal		**$1,143.8**	**0.6**	**1.0**	**3.8**	**7.0**
Physical Attack						
Substation Physical Security Fencing	RM - 26	$18.0	3.2	5.7	21.8	40.3
Substation Security Upgrades	RM - 27	$19.5	4.3	7.5	28.7	53.1
Group Subtotal		**$37.5**	**3.8**	**6.7**	**25.4**	**47.0**
Situational Awareness						
Advanced Aerial Imagery/Digital Twin	RM - 33	$20.4	0.7	1.2	4.8	9.0
Group Subtotal		$20.4	**0.7**	**1.2**	**4.8**	**9.0**
Totals		**$5,321.0**	**0.8**	**1.3**	**5.0**	**9.3**

*Average BCA weighted by resiliency measure cost

Source: Guidehouse BCA of CenterPoint Houston's proposed resiliency measure

EXHIBIT ELS-3
Glossary of Acronyms

ADT	Advanced Distribution Technology
BCA	Benefit Cost Analysis
CenterPoint Houston or the Company	CenterPoint Energy Houston Electric, LLC
Commission	Public Utility Commission of Texas
CMI	Customer Minutes Interrupted
CNP	CenterPoint Energy, Inc.
DEM	Digital Elevation Model
DI Apps	Distributed Intelligent Applications
ERCOT	Electric Reliability Council of Texas
GCMs	Global Climate Models
ICC	Illinois Commerce Commission
IEC	International Electrotechnical Committee
IEEE	Institute of Electrical and Electronics Engineers
IGSD	Intelligent Grid Switching Device
kV	Kilovolt
Mph	Miles per Hour
NASA	National Aeronautics and Space Administration
NCEI	National Center for Environmental Information
NESC	National Electrical Safety Code
NJBPU	New Jersey Board of Public Utilities
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and maintenance
OT	Operational Technology
PMR	Pole Mounted Router
Resiliency Event	A low frequency, high impact event that, if not mitigated, poses a material risk to the safe and reliable operation of the Company's transmission and distribution system.
Resiliency Measure	A measure designed to mitigate the risks posed to the Company's transmission and distribution system by a Resiliency Event
SAIDI	System Average Interruption Duration Index
Service Company	CenterPoint Energy Service Company, LLC
T&D	Transmission and Distribution
TDEM	Texas Department of Emergency Management
TMC	Texas Medical Center
UFLS	Under-frequency load shedding
VM	Vegetation Management
VOLL	Value of Lost Load

EXHIBIT 13

THE DIRECT TESTIMONY OF GUIDEHOUSE WITNESS DR. JOSEPH B. BAUGH

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DOCKET NO. 57579

APPLICATION OF CENTERPOINT ENERGY HOUSTON ELECTRIC, LLC FOR APPROVAL OF ITS 2026-2028 TRANSMISSION AND DISTRIBUTION SYSTEM RESILIENCY PLAN	**§ § § §**	**PUBLIC UTILITY COMMISSION OF TEXAS**

DIRECT TESTIMONY OF

DR. JOSEPH B. BAUGH

ON BEHALF OF

CENTERPOINT ENERGY HOUSTON ELECTRIC, LLC

January 2025

TABLE OF CONTENTS

TABLE OF EXHIBITS AND WORKPAPERS

Exhibits	Description
Exhibit JBB-1	Professional Experience of Dr. Joseph B. Baugh
Exhibit JBB-2	Glossary of Acronyms

Workpapers	Description
N/A	

I. SUMMARY OF GUIDEHOUSE'S INDEPENDENT ANALYSIS AND REVIEW

Guidehouse performed two types of independent analysis and review related to technology resiliency measures in CenterPoint Houston Electric, LLC's ("CenterPoint Houston") System Resiliency Plan:

- Qualitative assessment of physical security and cybersecurity risks faced by electric utilities like CenterPoint Houston; and
- Qualitative assessment of the reasonableness of each technology and cyber security resiliency measure considered for inclusion in CenterPoint Houston's System Resiliency Plan ("SRP").

The Guidehouse cybersecurity team reviewed the five CenterPoint Houston technology resiliency measures (RM-28 – RM-32) and two situational awareness resiliency measures (RM-36, RM-37) as depicted in Table 1 and identified the effectiveness and benefits of each resiliency measure in a qualitative comparative analysis process that compared relevant functions and security practices for each resiliency measure with industry best practices located in the National Institute of Standards and Technology ("NIST") Cybersecurity Framework ("CSF").

Summary of CenterPoint Houston's Technology & Situational Awareness Resiliency Measures Addressed by Dr. Baugh

TABLE 1: Technology & Situational Awareness Resiliency Measures

Resiliency Measure	Resiliency Event to be Mitigated	T&D SRP Rule Category	Estimated Capital Costs 2026-2028 (millions)	Estimated O&M Costs 2026-2028 (millions)	Estimated Total Costs 2026-2028 (millions)
Spectrum Acquisition (RM-28)	All	Information Technology	$42.0	$0.0	$42.0
Data Center Modernization (RM-29)	All	Information Technology	$12.7	$1.3	$13.9
Network Security & Vulnerability Management (RM-30)	Cybersecurity Event	Cybersecurity	$7.5	$2.0	$9.5
IT/OT Cybersecurity Monitoring Program (RM-31)	Cybersecurity Event	Cybersecurity/ Modernization	$13.4	$4.2	$17.6
Cloud Security, Product Security & Risk Management (RM-32)	Cybersecurity Event	Cybersecurity	$4.0	$6.0	$10.0
Voice & Mobile Data Radio System (RM-36)	All	Situational Awareness	$20.9	$0.0	$20.9

Backhaul Microwave Communication (RM-37)	**All**	**Situational Awareness**	**$12.7**	**$0.0**	**$12.7**
Total			**$113.1**	**$13.5**	**$126.6**

Guidehouse finds that CenterPoint Houston's SRP appropriately prioritizes technology resiliency measures and situational awareness resiliency measures that help mitigate cybersecurity risk. Guidehouse's physical security and cybersecurity risk assessment confirms that the frequency and magnitude of physical attacks and cyber-attacks is likely to increase over time, suggesting the need for continued resiliency investments in these areas. Given this finding, I also concur with the findings included in Mr. Shlatz' testimony that support CenterPoint Houston's proposed physical security resiliency measures (Substation Physical Security Fencing and Substation Security Upgrades) that also address risks associated with physical attacks on substations.

Further, the peer utility benchmarking survey described in ELS-2 indicates that proposed resiliency measures included in CenterPoint Houston's SRP are consistent with resiliency measures deployed at other utilities.

In summation, I conclude the five technology resiliency measures and the two situational awareness resiliency measures in CenterPoint Houston's SRP are:

- appropriate for addressing the physical security and cybersecurity risks CenterPoint Houston faces;
- aligned with industry best practices; and
- beneficial to customers and communities served by CenterPoint Houston.

II. INTRODUCTION

Q. PLEASE STATE YOUR NAME AND CURRENT POSITION.

A. My name is Dr. Joseph B. Baugh. I have been employed in various capacities by Guidehouse Inc. ("Guidehouse")[1] since 2019, as an Associate Principal in Guidehouse's Energy, Sustainability, and Infrastructure Practice, working primarily on the Cybersecurity and Compliance team. My business address is 111 Congress Avenue, Suite 2500, Austin TX 78701

Q. PLEASE SUMMARIZE YOUR BACKGROUND AND CURRENT RESPONSIBILITIES.

A. I have over 50 years' experience in electric utility and power system operations, including specialization in network and information security associated with electric utility information technology ("IT") and operational technology ("OT") systems. At the onset of my career with cyber systems, I worked at a power generation and electric transmission utility in Arizona for 29 years and was responsible for implementing numerous cyber system and business process improvement projects. After retiring from the utility, I worked at Western Electricity Coordinating Council ("WECC") on the cybersecurity audit team and was responsible for audits, investigations, and evaluations of physical security and cyber systems for compliance with North American Electric Reliability Corporation ("NERC") Critical Infrastructure Protection ("CIP") Reliability Standards. My experience includes implementations, risk assessments and evaluations, as well as multiple audits of electric system reliability and security protective resiliency measures and controls,

[1] Previously, Navigant Consulting, Inc.

including physical and cyber security systems located at power generation facilities, electric substations, and power system control centers.

Over the past five years at Guidehouse, I have been involved in the evaluation of the current states of numerous energy sector clients to manage physical and cyber security risk. These evaluations include assessing current cybersecurity states and program maturity, using common frameworks such as the Department of Energy ("DOE") Cybersecurity Capability Maturity Model ("C2M2") and the NIST CSF, as well as developing feasible recommendations on actions the client can take to achieve a desired target state in alignment with its goals and objectives. I have also developed compliance programs to meet the requirements of new and changing reliability standards. For example, I worked on several projects related to complying with the California Public Utilities Commission Decision 19-01-018 (Physical Security Decision) to improve physical security at electric distribution substations.

Overlapping my tenures at WECC and Guidehouse, I served as an expert witness for WECC in enforcement cases involving violations of the NERC CIP Standards. I hold a Bachelor of Science ("BS") degree in Computer Science from the University of Arizona and a Master of Business Administration ("MBA") degree from the Eller College of Management at the University of Arizona. My Doctor of Philosophy ("Ph.D.") degree was conferred by Capella University. My dissertation examined the impacts of deregulation and other market forces in the electric utility industry on management strategies, organizational structures, and organizational cultures at a non-profit generation and transmission electric cooperative.

I currently hold the NERC Certified System Operator Balancing and Interchange ("NCSO-BI") credential, the Project Management Professional ("PMP") certification, several globally recognized cybersecurity certifications (e.g., Certified Information Systems Security Professional ("CISSP"), Certified Information Systems Auditor ("CISA"), Certified in Risk and Information Systems Control ("CRISC"), Certified Information Security Manager ("CISM"), and the NIST Cybersecurity Professional ("NCSP") – Practitioner" certification. I am one of fewer than 300 Triple Crown holders worldwide of the American Society for Industrial Security ("ASIS") International physical security certifications: Physical Security Professional ("PSP"), Certified Protection Professional ("CPP"), and Professional Certified Investigator ("PCI"). My unique combination of energy sector experience in power system operations, business process improvement, and IT/OT systems, combined with academic and technical training backgrounds, and relevant professional certifications provides a high level of expertise across the 16 CISA critical infrastructure sectors, including the energy sector. This expertise was applied to this engagement with CenterPoint Houston.

Q. ON WHOSE BEHALF ARE YOU TESTIFYING IN THIS PROCEEDING?

A. I am testifying on behalf of CenterPoint Houston.

Q. IS GUIDEHOUSE'S ANALYSIS AND REVIEW OF CENTERPOINT ENERGY HOUSTON ELECTRIC'S SYSTEM RESILIENCY PLAN INDEPENDENT AND UNBIASED?

A. Yes. Guidehouse regularly consults for electric investor-owned, municipal, and cooperative utilities in addition to state and federal agencies. As a matter of practice, Guidehouse is committed to maintaining an independent and unbiased approach to its engagements. Specific to our analysis and review of CenterPoint Houston's SRP, we took the following steps to maintain independence:

- Applying a consistent methodology for assessing the reasonableness of technology resiliency measures proposed for inclusion in CenterPoint Houston's SRP;
- Performing a critical assessment of CenterPoint Houston's proposed resiliency measures to those adopted by other utilities that have successfully implemented resiliency measures. Recommendations were provided to further improve CenterPoint Houston's proposed resiliency measures;
- Providing independent analysis of physical and cyber security risks faced by electric utilities like CenterPoint Houston based on our knowledge and expertise;
- Comparing CenterPoint Houston's resiliency measures to those of leading utility practices obtained from an independent survey of electric utility resiliency measures conducted by a reputable firm with expertise in benchmarking;
- Proposing metrics reporting and effectiveness measures that CenterPoint Houston and the Public Utility Commission of Texas ("Commission") can rely on to determine if CenterPoint Houston's proposed resiliency measures are delivering value to its customers over time; and
- Enhancing the resiliency of physical and cyber security systems associated with CenterPoint Houston's transmission and distribution system, potentially reducing adverse impacts on customers, restoration times, and restoration costs due to outages caused by resiliency events.

Q. HAVE YOU TESTIFIED PREVIOUSLY?

A. Yes, as noted above I served as an expert witness for WECC in enforcement cases involving violations of the NERC CIP Standards. I was also engaged as an expert witness before the PUC-Texas for the CenterPoint Houston 2024 System Resiliency Plan filing. That engagement rolled directly over to the 2025 SRP filing.

III. OVERVIEW OF TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of my testimony is to provide an overview of Guidehouse's independent analysis and review of CenterPoint Houston's SRP with a focus on proposed technology resiliency measures. My testimony that follows provides evidence that the technology resiliency measures CenterPoint Houston proposes over the years 2026 through 2028 are reasonable and appropriate to include in its SRP. Specially, my testimony and exhibits confirm that CenterPoint Houston's proposed technology resiliency measures and the corresponding resiliency-focused investments can provide value to customers and communities located within its service area by reducing adverse impacts on customers, restoration times, and restoration costs due to an outage caused by a resiliency event involving physical or cyber-attack. My testimony also supports the direct testimony of Mr. Ronald Bahr and Mr. Chris Ford as they relate to the evaluation and justification of each CenterPoint Houston SRP technology resiliency measure for which it seeks approval from the Commission.

Q. WHAT QUALIFICATIONS DOES GUIDEHOUSE HAVE AS AN INDEPENDENT EXPERT IN RESILIENCY PLANNING FOR ELECTRIC UTILITIES?

A. Guidehouse has conducted several engagements addressing resiliency planning. Examples include:

1. **Duke Energy Florida** – Guidehouse conducted a detailed analysis of storm hardening investment to support two successive Storm Protection Plans that were approved by the Florida Public Service Commission.
2. **New Jersey Board of Public Utilities ("NJBPU")** – Guidehouse was engaged by

the NJBPU to conduct an independent investigation of Jersey Central Power & Light's emergency storm procedures, restoration practices, and resiliency measures to address customer interruptions caused by Hurricane Sandy. Guidehouse's recommendations were approved by the NBJPU.

3. **AEP Kentucky Power** – Guidehouse recently assessed Kentucky Power's storm reliability performance and proposed resiliency measures to enhance distribution system resiliency. Our assessment included an electric utility benchmark survey similar to the First Quartile benchmarking of resiliency measures.
4. **Commonwealth Edison** – Guidehouse conducted an independent assessment of Commonwealth Edison's maintenance and operational practices in response to an investigation by the Illinois Commerce Commission ("ICC") to address customer interruptions during major storms.

Q. WHAT EXHIBITS HAVE YOU INCLUDED WITH YOUR TESTIMONY?

A. I have prepared or supervised the preparation of the exhibits listed in the table of contents, including Exhibit ELS-2, which is a full-length report for Guidehouse's Independent Analysis and Review of CenterPoint Energy Houston Electric's SRP. With regards to Exhibit ELS-2, my responsibility was primarily focused on the assessment of physical and cyber security threats and review of technology resiliency measures and situational awareness resiliency measures considered for inclusion in CenterPoint Houston's SRP.

Q. WHAT INFORMATION RELATIVE TO THE FIVE TECHNOLOGY RESILIENCY MEASURES AND TWO SITUATIONAL RESILIENCY MEASURES IS CONTAINED IN THE GUIDEHOUSE REPORT PROVIDED AS EXHIBIT ELS-2?

A. The Guidehouse report and analysis includes:

- **Background** – Guidehouse's understanding of resiliency risks CenterPoint Houston must manage and the policy context for how Texas and other states are addressing resiliency of the electric system.
- **Purpose of Guidehouse's Analysis and Review** – Overview of Guidehouse's qualification as an independent expert on resiliency planning for electric systems as well as the objectives and approach taken to perform Guidehouse's independent analysis and review of CenterPoint Houston's SRP.
- **Resiliency Risk Analysis** – Independent assessment of resiliency risks facing CenterPoint Houston's service area, including physical and cyber security threats and vulnerabilities (e.g., cyber threats to CenterPoint Houston's IT/OT systems).
- **System Resiliency Plan Review** – Independent review of CenterPoint Houston's SRP, including benchmarking against best practices in resiliency planning among peer utilities, analysis of potential benefits for resiliency measures included in the SRP, and recommendations provided to CenterPoint Houston based on this review.
- **Benchmark Survey** – Results of independent survey of industry resiliency measures and practices covering a range of resiliency measures, many of which are similar to those proposed by CenterPoint Houston.
- **Summary Findings** – Summary of the findings, conclusions, and recommendations from Guidehouse's independent analysis and review.

Q. WHAT WERE THE OBJECTIVES OF GUIDEHOUSE'S ANALYSIS AND REVIEW OF CENTERPOINT ENERGY HOUSTON'S SYSTEM RESILIENCY PLAN?

A. The purpose of Guidehouse's independent analysis and review of CenterPoint Houston's SRP is to present evidence of the potential need and value of resiliency-focused investments for CenterPoint Houston's service area.

Specific objectives included:

1. Advise CenterPoint Houston on best practices in electric utility resilience planning based on Guidehouse industry expertise and experience working with utilities in other jurisdictions on resiliency planning efforts;
2. Provide independent analysis of human threat risks faced by CenterPoint Houston, including physical and cyber security trends that could be used as evidence of the potential need for investments that address specific physical and cyber security resiliency events; and
3. Conduct an independent review and analysis of CenterPoint Houston's SRP, including all resiliency measures under initial consideration by CenterPoint Houston, to help inform CenterPoint Houston's selection and prioritization of resiliency measures to pursue. This includes a comparison of proposed technology resiliency measures and situational awareness resiliency measures to those adopted by electric utilities in response to physical and cyber security risks.

Q. HAVE YOU REVIEWED THE DIRECT TESTIMONIES OF OTHER CENTERPOINT ENERGY HOUSTON ELECTRIC WITNESSES PROVIDING DIRECT TESTIMONY IN THIS DOCKET?

A. Yes. I have reviewed the testimonies of CenterPoint Energy Houston Electric witnesses

Mr. Ronald Bahr and Mr. Chris Ford. My testimony is consistent with and supports the findings and conclusions provided by each witness, including Mr. Ronald Bahr who addresses two of CenterPoint Energy's technology resiliency measures (RM-28 & RM-29) and two situational awareness resiliency measures (RM-36 & RM-37). This testimony is also consistent with the testimony of Mr. Chris Ford, in regard to three CenterPoint Energy technology resiliency measures (RM-30, RM-31 & RM-32). I have also reviewed the testimony of Guidehouse witness Mr. Eugene L. Shlatz, who addresses certain weather-driven and climate resiliency measures included in CenterPoint Houston's SRP that impact physical security attributes.

Q. HOW IS YOUR TESTIMONY ORGANIZED?

A. My testimony is organized as follows: First, I provide a summary of Guidehouse's independent analysis of resiliency risk attributed to human threats (i.e., physical and cyber security) for CenterPoint Houston's service area, including a summary of how its current and forecasted risk profile justifies the need for resiliency investments. Then, I provide a summary of Guidehouse's independent review and analysis of CenterPoint Houston's SRP for five technology resiliency measures and two situational awareness resiliency measures including qualitative evidence of how those resiliency measures can provide benefits to customers and communities served by CenterPoint Energy in its Houston Electric service area. Next, I present the results of an independent survey of electric utilities that have implemented resiliency measures and programs. Finally, I summarize the findings and recommendations made by Guidehouse to CenterPoint Houston based on our independent analysis and review of its SRP related to technology resiliency measures projects.

IV. APPROACH TO INDEPENDENT ANALYSIS OF CENTERPOINT HOUSTON'S SYSTEM RESILIENCY PLAN

Q. WHAT APPROACH DID GUIDEHOUSE FOLLOW TO CONDUCT ITS ANALYSIS AND REVIEW OF CENTERPOINT ENERGY HOUSTON ELECTRIC'S SYSTEM RESILIENCY PLAN?

A. Guidehouse critically reviewed each of CenterPoint Houston's proposed technology resiliency and situational resiliency measures to determine whether the resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP. The five Technology Resiliency Measures and two Situational Awareness Resiliency Measures in the Company's SRP are intended to enhance the resiliency of the Company's technology infrastructure to withstand and limit interruptions of service during certain Resiliency Events. Weather events that include extreme wind, water, temperatures, or fire, construction impacting network fiber cables, vendor outages, and cybersecurity attacks are types of resiliency events that can affect technology. Please refer to the testimony of Mr. Eugene Shlatz for Resiliency Events related to weather. As noted in the Guidehouse Resiliency Report (Exhibit ELS-2, section 5.1.3.2), it is difficult to quantify the benefits of technology resiliency measures, as they are an enabling function to support the effective operation of electric delivery systems.

A key objective of the Guidehouse assessment was to determine each resiliency measure's effectiveness from a technology resiliency perspective by applying the NIST Cybersecurity Framework. Additionally, Guidehouse applied the Presidential Policy Directive 21 ("PPD-21") definition of resilience, which defines resilience as, "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions [and] the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[2] This definition is commonly used within the cybersecurity field as evidenced by its use in the 2021 CISA Infrastructure Security Division ("CISA-ISD") report on Lessons Learned from the Regional Resiliency Assessment Program.[3] NIST expanded this definition in the context of cybersecurity, stating that resilience is "[t]he ability to anticipate, withstand, recover from, and adapt to adverse conditions, stresses, attacks, or compromises on systems that use or are enabled by cyber resources. Cyber resiliency is intended to enable mission or business objectives that depend on cyber resources to be achieved in a contested cyber environment".[4] This extension captures cyber system resilience from the business process perspective and supports including IT OT cyber systems as part of a balanced organization-wide resiliency plan.

Due to the difficulty of performing quantitative analyses, environmental uncertainty, and the constantly evolving nature of cyber threats, the International Energy Agency ("IEA") recommends the use of a common framework to provide consistency in assessing resiliency risks associated with disparate cyber systems within their operating environments. IEA identified five potential frameworks,[5] including the Electricity Subsector - Cybersecurity Capability Maturity Model (ES-C2M2, which evaluates the maturity of an organization's cybersecurity capabilities), the NIST Cybersecurity Framework (CSF, which is a general resiliency framework for understanding, prioritizing,

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[2] The White House. (2013 February 12). *Presidential Policy Directive – Critical Infrastructure Security and Resilience* [PPD-21, p. 12]. https://www.cisa.gov/sites/default/files/2023-01/ppd-21-critical-infrastructure-and-resilience-508_0.pdf

[3] Cybersecurity & Infrastructure Security Agency: Infrastructure Security Division [CISA-ISD]. (2021 June). *Methodology for Assessing Regional Infrastructure Resilience: Lessons Learned from the Regional Resiliency Assessment Program* [CISA-ISD Technical Report], (p. 8). https://www.cisa.gov/sites/default/files/publications/DIS_DHS_Methodology_Report_ISD%20EAD%20Signed_with%20alt-text_0.pdf

[4] NIST Glossary: *Definition of Cyber Resiliency.* https://csrc.nist.gov/glossary/term/cyber_resiliency

[5] International Energy Agency [IEA]. (2021). *Enhancing Cyber Resilience in Electricity Systems* [see *Table 4. Overview of regularly referred to instruments for cybersecurity in the electricity sector*, pp. 30-32]. https://iea.blob.core.windows.net/assets/0ddf8935-be23-4d5f-b798-3aad1f32432f/Enhancing_Cyber_Resilience_in_Electricity_Systems.pdf

and managing cybersecurity risks), the NISTIR 7628 Guidelines (which focus on smart grid characteristics, risks, and vulnerabilities), ISO/IEC TR 27019 (which is applicable to utility process control systems) and ISO 22301 (which relates to business continuity management). After reviewing these five frameworks, Guidehouse chose the NIST CSF as a common framework to support comparative analyses of resiliency features and functions across the five technology and cybersecurity resiliency measures considered for inclusion in CenterPoint Houston's SRP.

The NIST CSF[6] is a set of best practices and recommended cybersecurity controls commonly used in the electric utility sector to guide cybersecurity activities and the assessment and mitigation of cybersecurity risks as part of an organization's overall risk management processes. The Framework consists of three parts:

1. Framework Core
2. Implementation Tiers
3. Framework Profiles

The Framework Core (the "Core") is a set of cybersecurity activities, outcomes, and informative references that are common across sectors and critical infrastructure. Elements of the Core provide detailed guidance for developing individual organizational Profiles. Through use of Framework Profiles, the Framework helps an organization align and prioritize its cybersecurity activities with its business/mission requirements, risk tolerances, and resources. The Implementation Tiers provide a mechanism for organizations to view and understand the characteristics of their approach to managing

[6] NIST. (2018 April 16). *Framework for Improving Critical Infrastructure Cybersecurity* [v1.1], https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.04162018.pdf

cybersecurity risk, which helps with prioritizing and achieving cybersecurity objectives, including resiliency objectives.

For the review of CenterPoint Houston's SRP resiliency measures for IT and OT cyber systems, Guidehouse applied a qualitative comparative analysis[7] between the NIST CSF Core functions, categories, and sub-categories and the functions and security solutions in the CenterPoint operating environments, as described by CenterPoint in documentation and interviews or inferred by professional judgement, for each of the five technology resiliency measures and two situational awareness resiliency measures included in CenterPoint Houston's SRP. Strong correlations between the proposed resiliency measure's functions and security solutions with a given NIST CSF Function Category practice (e.g., the Asset Management category under the Identify function is coded in the CSF as ID.AM) were identified and applied to determine qualitative benefits of these resiliency measures.

In addition to correlations at the NIST CSF Function Category level, the Guidehouse analysis included a review of redundancy, which aligns with the NERC description of "risk reduction benefits associated with added redundancy, diversity, and minimization of very high-risk assets."[8] The CISA-ISD report also described redundancy as a component of the Mitigation building block for resilience that resists or absorbs negative impact, reduces the severity or consequence of an event, and supports the reliability of infrastructure systems.[9]

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[7] CISA-ISD. (*Comparative Analysis* section, p. 71)

[8] NERC. (2023 August 17). *2023 ERO Reliability Risk Priorities Report* (p. 33). https://www.nerc.com/comm/RISC/Related%20Files%20DL/RISC_ERO_Priorities_Report_2023_Board_Approved_Aug_17_2023.pdf

[9] CISA-ISD. (*Part I*. p. 8)

Guidehouse critically reviewed each of CenterPoint Houston's proposed technology resiliency measures to determine whether the resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP. A key objective of Guidehouse's assessment was to determine the effectiveness of each resiliency measure at mitigating the impact of physical or cyber attacks on CenterPoint Houston's power delivery system. An important element of Guidehouse's assessment was consideration of future forecasted risk attributed to resiliency events as described in Section IV of my testimony. For example, the projected increases in physical and cyber attacks were factors that Guidehouse incorporated into its analysis of potential benefits of CenterPoint Houston's OT Cybersecurity Monitoring resiliency measure.

To complete our assessment, Guidehouse obtained details on CenterPoint Houston's proposed technology resiliency investments and compared CenterPoint Houston's proposed measures with industry best practices based on a peer utility benchmarking survey described in ELS-2.

Guidehouse analyzed CenterPoint Houston's proposed SRP technology resiliency measure investments for each of the following evaluation categories:

- **Resiliency Measure Description** – Guidehouse's understanding of each resiliency measure's objectives and rationale, including how the measure reduces the risk of resiliency events.
- **Revisions from prior SRP** – Provides an indication if the resiliency measure was included in the CEHE 2024 SRP filing.
- **Resiliency Measure Targets** – Describes the business goals and objectives of the resiliency measure and factors that may impact the success of the measure.

- **Alternatives Considered** – Alternatives CenterPoint Houston considered in lieu of the proposed resiliency measure, and why these alternatives were determined to be less effective than the proposed resiliency measure.
- **Resiliency Measure Metrics and Effectiveness** – Resiliency measure metrics and measures CenterPoint Houston proposes to use for each resiliency measure, where applicable.
- **Benefits Analysis** – Qualitative analysis of benefits for each proposed resiliency measure using the NIST CSF to identify key functions and categories that aligned with relevant functions and solutions provided by the proposed resiliency measure.
- **Resiliency measure Assessment and Conclusions** – For each resiliency measure, Guidehouse summarizes its findings and conclusions as to whether and how each resiliency measure achieves SRP objectives.

i. <u>RISK ANALYSIS</u>

Q. WHAT APPROACH DID GUIDEHOUSE FOLLOW TO CONDUCT ITS ANALYSIS OF RESILIENCY RISK FOR CENTERPOINT HOUSTON'S SERVICE AREA?

A. The Technology resiliency measures and Situational Awareness resiliency measures in the Company's SRP are intended to enhance the resiliency of the Company's technology infrastructure to withstand and limit interruptions of service during certain Resiliency Events. Weather events that include extreme wind, water, temperatures, or fire, construction impacting network fiber cables, vendor outages, and cybersecurity attacks are types of resiliency events that can affect technology. Please refer to the testimony of Mr.

Shlatz for Resiliency Events related to weather. Guidehouse researched a variety of public sources for current and historical trends over a five-year period to identify specific physical and cybersecurity risks relevant to the CenterPoint Houston operating environment. The results of this research and analysis of resiliency risk for the five technology resiliency measures and two situation awareness resiliency measures are detailed below.

Q. WHAT SPECIFIC TYPES OF RESILIENCY RISKS DID YOU ANALYZE AND WHY?

A. Guidehouse reviewed increasing trends in physical and cyber attacks in the CenterPoint Houston service area, including physical damage to cyber systems and their host facilities by insider and external actors as well as common cyber attack vectors. Specific resiliency risks included loss or misuse of the technology resiliency measure systems under review and associated adverse impacts to the CenterPoint Houston electric delivery system. These risks were considered during the analysis phase to ensure the applicable resiliency functions and security solutions for each resiliency measure aligned with industry best practices and controls defined by the NIST CSF.

Q. WHAT IS YOUR UNDERSTANDING OF PHYSICAL AND CYBER SECURITY THREATS TO ELECTRIC UTILITIES SUCH AS CENTERPOINT HOUSTON?

A. A review of historical physical and cyber attacks across the electric industry, as described below, indicates CenterPoint Houston cyber systems and their host facilities are subject to both physical damage by bad actors and a wide range of cyber attack methodologies and techniques including:

- Ransomware
- Distributed Denial-of-Service ("DDoS")

- Malware
- Phishing
- Exploitation of known but unpatched vulnerabilities
- Social engineering
- Supply chain attacks
- System misconfigurations
- Missing or poor encryption practices
- Insider threats and external actors via physical and cyber attacks

Resiliency risks associated with these attack methodologies and techniques were analyzed through the comparative analysis of the functions and security solutions of the five technology resiliency measures and two situational awareness resiliency measures under review with the NIST CSF best practices and protective resiliency measures that counter these risks.

Physical and cyber security benefits are difficult to measure with a traditional return on investment ("ROI") calculation as the benefits of security projects are generally realized in avoided costs and other avoided negative impacts. As examples of potential avoided costs and negative impacts, Security Made Simple identifies major cost components related to cyberattacks, including falling stock prices, loss of customers, cyber insurance costs, lawsuits, compliance penalties and sanctions, and business interruption costs.[10] Each of these cost factors may or may not be included in the cost of data breaches statistics described below, depending on the rigor of the underlying data collection instrument.

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[10] Security Made Simple. (2021 August 25). *What does a cyberattack do to a company's value?* https://securitymadesimple.org/cybersecurity-blog/what-does-a-cyberattack-do-to-a-companys-value/

Statista reports the average cost of data breaches in the United States increased steadily from $5.4 million dollars in 2013 to $9.5 million dollars in 2023.[11] This upward trend indicates a strong probability the annual average cost of a single data breach will continue to increase over the next five-year period. IBM reported similar annual averages for overall data breach costs in the U.S.[12] IBM further identified a 2.3% increase in the average cost of a data breach between 2022 and 2023.[13] In addition, IBM reported the cost of a data breach escalates with longer detection times and increased system downtime.[14] Combating these deleterious impacts requires a comprehensive approach to physical security and cyber security efforts. In a 2021 study, Claroty reported, "organizations have internalized the lessons learned from high-profile cyberattacks and are prioritizing cybersecurity by increasing investments and implementing new or updated processes and controls."[15] This finding aligns with the current CenterPoint approach to implement diverse technology resiliency measures. While rejecting a comprehensive approach to cyber resiliency is always an option, Claroty stated, "[t]he cost for critical infrastructure organizations of doing nothing is not tolerable. The longer an organization goes without the right cyber-physical systems security capabilities in place, the more likely they are to experience a major breach."[16] I concur with this statement, as the more CenterPoint integrates technology and cyber systems into its overall operational model, the more critical

[11] Statista (2024 January). *Average cost of a data breach in the United States from 2006 to 2023.* https://www.statista.com/statistics/273575/us-average-cost-incurred-by-a-data-breach/#:~:text=As%20of%202023%2C%20the%20average,dollars%20in%20the%20previous%20year
[12] IBM. (2023). *Cost of a Data Breach Report* [IBM Technical Report. Figure 3, pp. 11-12]. https://www.ibm.com/reports/data-breach
[13] Ibid. (*Figure 4*, p. 13)
[14] Ibid. (p. 7)
[15] Claroty. (2021). *The Global State of Industrial Cybersecurity 2021: Resilience amid Disruption* [White Paper. p. 6]. https://claroty.com/resources/reports/the-global-state-of-industrial-cybersecurity
[16] Claroty. (2022 December 20). *How Cyber-Physical Security Maximizes ROI* [Technical Blog]. https://claroty.com/blog/how-cyber-physical-system-security-maximizes-roi

a robust defense-in-depth cybersecurity strategy becomes to develop a strong and resilient network.

Guidehouse considered "avoided cost" as a benefit of each of the resiliency measures analyzed below without itemizing specific costs. The more salient analysis is regarding the resilience impact of each of the resiliency measures because the benefit of each of them is avoided cost. While Guidehouse reviewed the technology and cyber security resiliency measures included in CenterPoint Houston's SRP individually, it should be noted that the benefit of these resiliency measures is cumulative toward ensuring a strong and diverse cybersecurity posture that identifies, detects, deters, and defends against physical or cyber-attacks and ensures a resilient operational posture that can respond to and recover from any successful attacks. This means that, in general, the benefits of these resiliency measures can increase exponentially as more resiliency measures are adopted (i.e., the whole is greater than the sum of its parts).

ii. <u>BENEFITS ANALYSIS</u>

Q. WHAT WAS THE PURPOSE OF THE BENEFIT ANALYSIS CONDUCTED FOR CERTAIN RESILIENCY INVESTMENTS INCLUDED IN CENTERPOINT HOUSTON'S SYSTEM RESILIENCY PLAN?

A. Guidehouse performed a comparative analysis for the technology to determine the effectiveness of the five Technology resiliency measures and the two Situational Awareness resiliency measures to address the identified physical security and cybersecurity threats, hazards, and vulnerabilities and support the overall resiliency of the CenterPoint Houston electric delivery system.

iii. BENCHMARKING ANALYSIS

Q. PLEASE DESCRIBE HOW THE PEER ELECTRIC UTILITY BENCHMARKING ANALYSIS WAS GENERATED, INCLUDING HOW THE PEER GROUP OF ELECTRIC UTILITIES WAS SELECTED.

A. The benchmarking analysis was designed to solicit responses from a peer group of electric utilities that have implemented resiliency measures. Guidehouse identified resiliency measures to include in the survey questionnaire while an independent contractor[17] prepared survey questions and selected the peer utility group. The resiliency survey included questions designed to identify the types of resiliency investments U.S. electric utilities are deploying and the types of system issues that they are seeking to address through these investments. The survey was conducted "blind," with the identities of participating utilities undisclosed to ensure confidentiality and included the types of resiliency investments being made by survey participants. Specific results for each of the five technology resiliency measures are addressed in the following response. These include identifying responses from participating Electric Utilities for the technology-related resiliency measures included in their resiliency plans as efficient and cost-effective investments to improve transmission and distribution system performance during resiliency events. Additional details on the benchmarking survey are provided in ELS-2.

[17] First Quartile Consulting

V. INDEPENDENT REVIEW AND ANALYSIS OF CENTERPOINT HOUSTON's SYSTEM RESILIENCY PLAN

Q. WHICH RESILIENCY MEASURES IN CENTERPOINT HOUSTON'S SYSTEM RESILIENCY PLAN ARE YOU ADDRESSING IN YOUR TESTIMONY?

A. Guidehouse evaluated the following five technology resiliency measures considered for inclusion in CenterPoint Houston's SRP, as described in Mr. Bahr and Mr. Ford's testimonies:

- Spectrum Acquisition (RM-28)
- Data Center Modernization (RM-29)
- Network Security & Vulnerability Management (RM-30)
- IT/OT – Cybersecurity Monitoring Program (RM-31)
- Cloud Security, Product Security & Risk Management (RM-32)

Guidehouse also evaluated the following two situational awareness resiliency measures considered for inclusion in CenterPoint Houston's SRP, as described in Mr. Bahr's testimony.

- Voice and Mobile Data Radio System Refresh (RM-36)
- Backhaul Microwave Communications (RM-37)

i. RISK ANALYSIS

Q. WHAT IS THE HISTORICAL, CURRENT, AND FUTURE RISK TO CENTERPOINT HOUSTON'S SERVICE AREA FOR PHYSICAL SECURITY EVENTS BASED ON YOUR ANALYSIS?

A. My assessment of the physical security risk to CenterPoint Houston's system is based on my knowledge and expertise in this area as well as research of publicly available documents that provide additional context for the region served by CenterPoint Houston. For example, the Texas Department of Homeland Security ("TDHS") Texas Homeland Security Strategic Plan ("THSSP") identifies specific physical security threats to the energy sector in and around the CenterPoint Houston electric system, which TDHS cites as a lifeline critical public infrastructure sector.[18] Resiliency is critically important for the electric sector not only for the operation of its own systems, but also for the operation of other critical infrastructure sectors that rely on a stable electric supply. In the context of physical security risk, TDHS describes as a key risk for Texas cartels that use military and terrorist tactics to accomplish their goals and expand their control of criminal activities in Texas. Domestic terrorism has become more prevalent in recent years and poses a credible threat to the electric sector as well. In addition, "Texas-based homegrown violent extremists continue to aspire to conduct attacks in Texas, and individuals sympathetic to foreign terrorist organizations continue to provide them material support in the form of recruitment, financial resources, and propaganda. All terrorist actors will continue to utilize digital media to facilitate radicalization/recruitment and communicate, and law

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[18] Texas Department of Homeland Security [TDHS]. (2021 June). *Texas Homeland Security Strategic Plan: 2021-2025* [THSSP: TDHS Technical Report, p. 21]. https://gov.texas.gov/uploads/files/press/HSSP_2021-2025.pdf

enforcement's ability to detect planned criminal activity will be challenged as such actors move to more secure communication platforms."[19]

Historical and Current Physical Security Risk Profile

Given the Centerpoint Houston cyber system footprint, it is particularly susceptible to physical and cyber attacks. In its report on reliability risk priorities, NERC states physical security and cybersecurity risks are rising, and the nature of the attacks continues to evolve: "there has been an uptick in physical security events, including copper theft and ballistic damage, against the BPS [Bulk Power System] and specifically at distribution substations. Vulnerabilities to such events are exacerbated by commodity prices, supply chain constraints, environmental activists, and domestic violent extremists."[20]

Current protective resiliency measures to mitigate malicious activities at electric infrastructure facilities have necessarily focused on substations that have been identified as particularly critical using various threat and vulnerability assessments and physical security plans. Coordinated attacks on multiple substations that target expensive electric elements, such as the sniper attacks at Metcalf substation in 2013 that focused on transformers and other critical electrical equipment with long replacement lead-times, could have a significant impact on the safety and well-being of U.S. citizens and the economy.[21] CBS News reported a 71% increase in physical attacks on electric grid facilities in 2022 alone.[22] Citing 25 physical attacks on nationwide electric infrastructure, including one in the El Paso area in 2022, the Dallas Morning News examined vulnerabilities

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[19] TDHS. THSSP. (p. 21)
[20] NERC. (2023, p. 36)
[21] Smith, R. (2014 March 12). *U.S. Risks National Blackout from Small-Scale Attack.* https://www.wsj.com/articles/SB10001424052702304020104579433670284061220
[22] Sganga, N. (2023 February 22). *Physical attacks on Power Grids rose by 71% last year, compared to 2021.* https://www.cbsnews.com/news/physical-attacks-on-power-grid-rose-by-71-last-year-compared-to-2021/

associated with Texas substations and concluded a coordinated attack on power infrastructure could cause a cascading failure of the Texas power grid.[23] CenterPoint operates over 300 electric substations and other physical locations, such as control centers, IT data centers, and service centers, each of which contain IT/OT cyber systems, providing a large physical attack surface for malicious actors.

From an IT/OT cyber system perspective, the risks of physical attacks are somewhat less, but still significant, due to the impact of physical intrusions and ballistic attacks on critical electric facilities. Most cyber systems associated with electric grid and business operations rely on hardened facilities, such as secure buildings or locked enclosures, to prevent physical damage to critical cyber systems, such as protective relays, SCADA systems, and telecommunications systems.

Future Physical Security Risk Profile

The NERC report on reliability risk priorities indicates physical security and cyber security risks are rising, while the nature of the attacks continues to evolve.[24] As an example, ballistic attacks on electric facilities using drones as a delivery vehicle is an emerging threat. Combining the trends cited above, including the increasing rate of domestic terrorism in Texas and other physical security risks in CenterPoint Houston's electric service area, Guidehouse expects physical attacks on CenterPoint facilities containing IT/OT cyber systems to increase in number and severity over the next five years.

[23] Williams, M. (2023 February 9. *Plots, attacks against power grids are increasing nationwide. How vulnerable is Texas?* https://www.dallasnews.com/news/2023/02/09/plots-attacks-against-power-grids-are-increasing-nationwide-how-vulnerable-is-texas/
[24] NERC. (2023. p. 32)

Q. WHAT IS THE HISTORICAL, CURRENT, AND FUTURE RISK TO CENTERPOINT HOUSTON'S SERVICE AREA FOR CYBERSECURITY EVENTS BASED ON YOUR ANALYSIS?

A. My assessment of cybersecurity risk to CenterPoint Houston's system is based on my knowledge and expertise in this area as well as research of publicly available documents that provide additional context for the region served by CenterPoint Houston. For example, the TDHS THSSP report describes cyber threats as follows: "[c]yberattacks and intrusions can be used by criminals, terrorists, insiders, and hostile foreign nations to disrupt delivery of essential services, mask other attacks, or shake citizens' confidence in the government. Cyberattacks are relatively easy to execute and challenging to disrupt and investigate, as demonstrated in the August 2019 ransomware attack that impacted 23 local government entities in Texas, and the frequency of attacks and intrusions has increased significantly during the past five years. As the cyber threat continues to grow and evolve, a particular concern is the potentially severe consequence of an effective cyberattack against critical infrastructure facilities and systems. Cyber threats could also result in the denial or disruption of essential services, including [electric] utilities."[25]

<u>Historical and Current Cybersecurity Risk Profile</u>

As stated above, cyber attacks across all critical infrastructure sectors have increased in number and severity over the past five years with notable examples including the 2021 cyber attack on the Colonial pipeline system (which originates in Houston), numerous known vulnerability exploitations of poorly patched cyber systems, and the rise

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[25] TDHS. (p. 23)

of malware and ransomware attacks targeting business process cyber systems, supply chains, and other vulnerabilities by foreign and domestic cyber threat vectors.

Future Cybersecurity Risk Profile

As noted above, CenterPoint Houston operates over 400 electric substations and other physical locations. Collectively, these locations host approximately 375 IT/OT cyber systems, which provides a significant digital attack surface for malicious actors. The NERC report on reliability risk priorities identified physical security and cybersecurity risks as rising, while the nature of the attacks continues to evolve beyond current protective resiliency measures and controls.[26] Additional factors leading to an increased future cybersecurity risk profile for CenterPoint and other electric utilities include the following:[27]

- The emergence of Artificial Intelligence ("AI") and machine learning tools being deployed by cyber adversaries is likely to increase both the number and types of attacks, as well as the probability of attack success.
- An increasing trend to virtualize and host critical cyber systems in cloud environments may create additional cyber risk during use, transmission, and storage of data.
- Supply chain risks derived from compromise of critical cyber system components during the development and procurement cycles.
- Increasing deployment of distributed energy resources ("DER") and DER aggregators, which are largely unregulated, presents increased cybersecurity risk to

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[26] NERC. (2023. p. 32)
[27] NERC. (2023. p. 37)

the electric grid because their control systems could become compromised and used as an attack vector into electric systems.[28]

- Increasing lack of a robust cyber workforce requires organizations in the electric sector and other critical infrastructure sectors to rely heavily on automated tools to develop robust cybersecurity defenses.
- Increasing remote work by utility workers also increases the risk of compromise of critical cyber systems, which can be mitigated by hardening telecommunications platforms to protect data in transit.

Considering these trends as well as previously discussed physical security trends of the increasing rate of domestic terrorism in Texas and continued attacks by foreign adversaries, Guidehouse expects cybersecurity risk to increase in CenterPoint Houston's service area absent additional cybersecurity investments. In particular, the risk of coordinated attacks that combine physical and cyber intrusions across multiple facilities is expected to increase.

Q. FOR EACH TYPE OF RESILIENCY EVENT ANALYZED, DOES YOUR ANALYSIS INDICATE THAT RESILIENCY RISK IS EXPECTED TO INCREASE OVER TIME AND THAT RESILIENCY INVESTMENTS ARE NEEDED IN CENTERPOINT HOUSTON'S SERVICE AREA TO REDUCE RESILIENCY RISK AND IMPROVE THE SAFETY, RELIABILITY, AND RESILIENCY OF ITS ELECTRIC SYSTEM?

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[28] NERC. (2022 December). *Cyber Security for Distributed Energy Resources and DER Aggregators*. https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper_Cybersecurity_for%20DERs_and_DER_Aggregators.pdf

A. Yes, my testimony supports the expectation that physical and cyber security risk will continue to increase over time. This is supported by the fact that the average cost of data breaches has trended upward from 2013 to 2023. In addition, the average weekly number of cyber attacks has increased over the past five years.[29] Given the evolving nature of cyber attacks and multiple malicious actors targeting the electric grid, I conclude that physical security and cybersecurity risk will continue to increase over the next five years. This indicates that risk mitigation measures to address these types of resiliency events is becoming increasingly needed for CenterPoint Houston.

CenterPoint Houston's operational and cyber systems are interconnected, thus protective resiliency measures and controls for its systems can better support operational resiliency by developing a "defense-in-depth" strategy that emphasizes redundancy, data confidentiality, integrity, and availability measures, and effective business continuity and disaster recovery planning. The average annual cost of a single data breach and other cyber intrusion has steadily increased from 2013 to 2023 to $9.8 million per incident, with the upper bound for successful attacks, such as ransomware, extending much higher. This trend indicates a strong probability for higher annual avoided costs over the next five-year period through successful resiliency measures for CenterPoint Energy's technology and cyber systems.

ii. <u>BENEFITS ANALYSIS</u>

Q. PLEASE SUMMARIZE THE FINDINGS OF THE BENEFIT ANALYSIS AND HOW THIS PROVIDES AN INDICATOR OF POTENTIAL VALUE OF

[29] Casanovas, M., & Ngheim, A. (2023 August 1). *Cybersecurity – is the power system lagging behind?*. [International Energy Agency Technical Report - *Table: Average number of weekly cyberattacks per organisation in selected industries, 2020-2022*] https://www.iea.org/commentaries/cybersecurity-is-the-power-system-lagging-behind