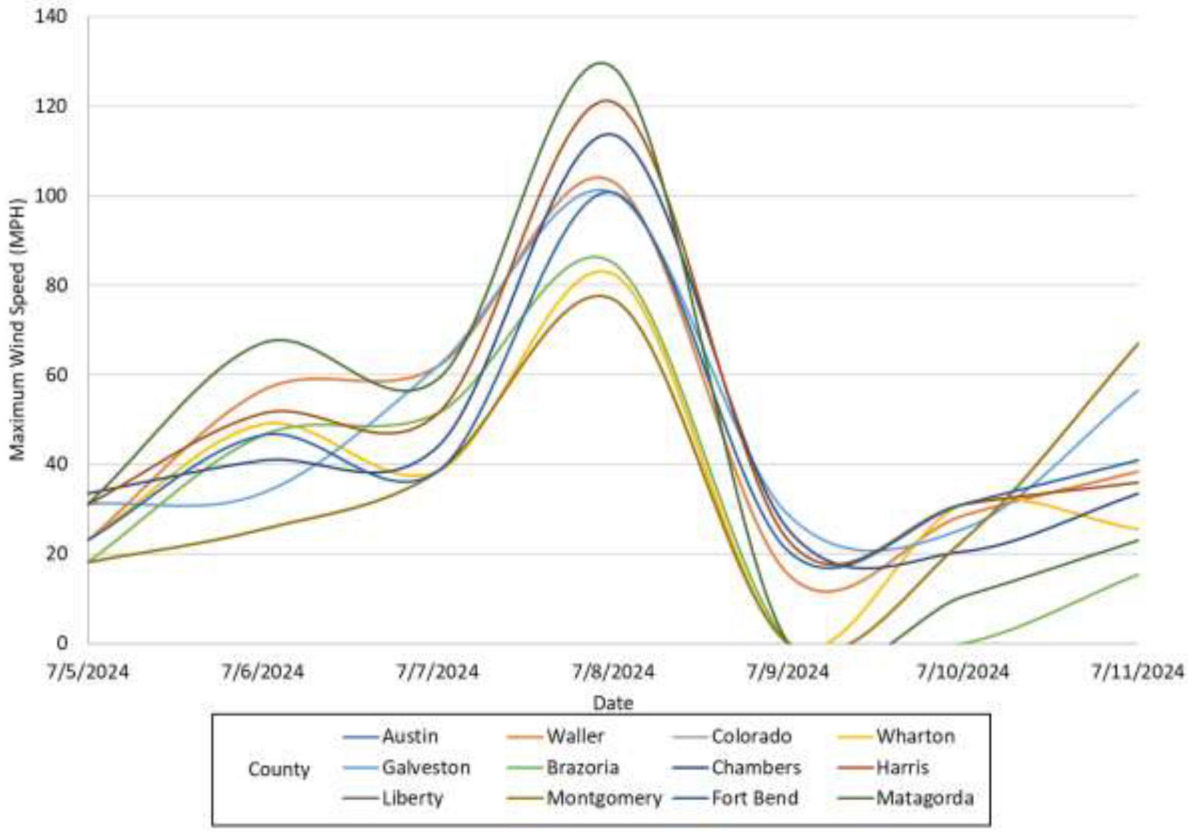
Hurricane Beryl made landfall in Texas on July 8th, 2024, near Matagorda County, where the highest wind speed was reported. Figure 4-10 shows the maximum wind speed reported was approximately 128 mph in Matagorda County.

Figure 4-10. Wind Speeds During Hurricane Beryl



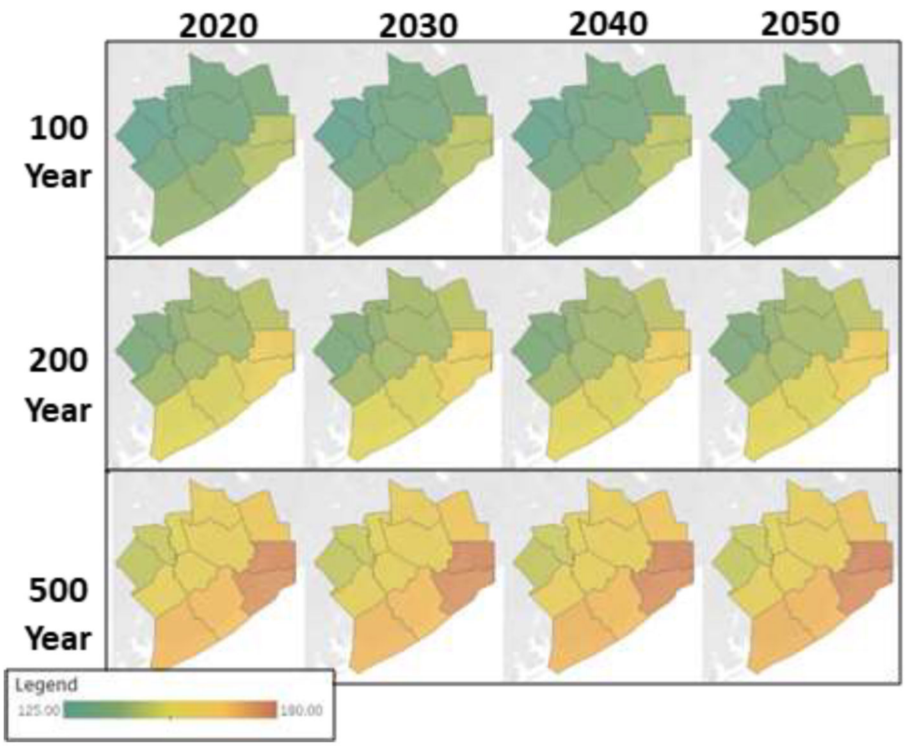
Source: **Guidehouse analysis, with inputs from NOAA Weather Stations and NCEI.**

4.2.1.2 Future Forecast Risk Profile

Guidehouse's forecast of high winds focused on hurricanes given that historical evidence indicates higher wind speeds experienced during those events relative to tornadoes. While the science for forecasting future hurricane events remains uncertain with respect to the frequency of events, it is possible to forecast the intensity of wind events.[24] Our analysis using the RCP4.5 scenario shows maximum wind speeds increasing from 2020 to 2050 for nearly all the counties served by CenterPoint Houston for 100-year, 200-year, and 500-year events (Figure 4-11). By 2030, almost all counties begin experiencing maximum wind speeds exceeding 87 mph for a 500-year event, with coastal counties experiencing wind speeds exceeding 99 mph. By 2050, nearly all counties in CenterPoint Houston's territory will experience wind speeds exceeding 93 mph with coastal counties approaching 112 mph for a 500-year event.

[24] Emanul, K., (2017 March 1). *Will Global Warming Make Hurricane Forecasting More Difficult?* Bulletin of American Meteorological Society. https://doi.org/10.1175/BAMS-D-16-0134.1

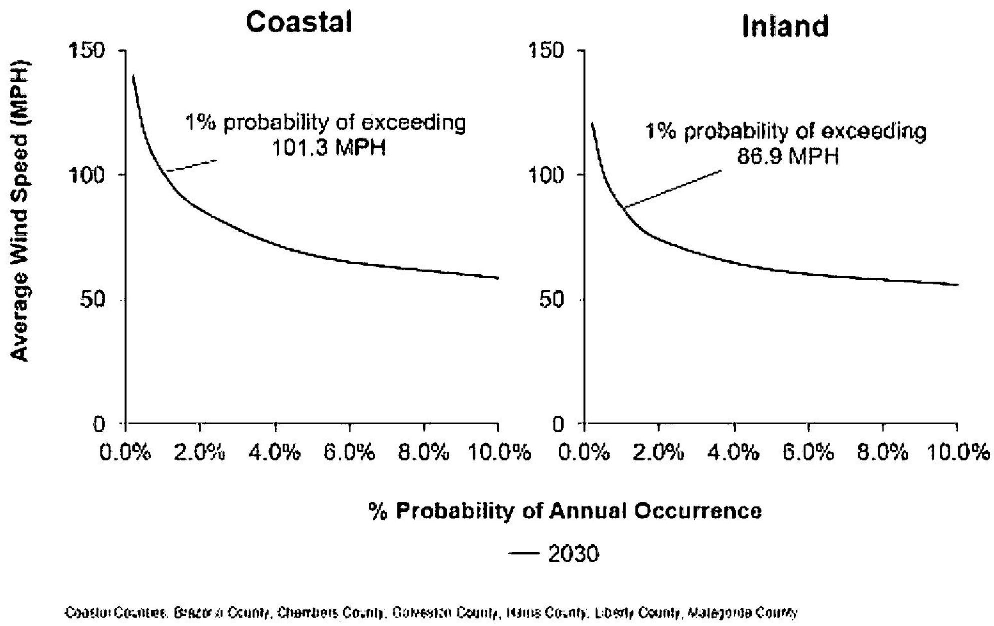
Figure 4-11: Maximum Annual Wind Speeds ("KPH") 2020-2050



Color changes may be too subtle to notice visually. Refer to absolute numbers in the descriptive text.
Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

Guidehouse used the projected wind speed for return periods between 10-year and 500-year events to calculate probabilities of exceeding different wind speeds, as shown in Figure 4-12. Wind thresholds of 70 mph are considered critical for existing non-hardened poles based on our previous experience and have a probability of exceedance of 4.5% in coastal counties and 2.7% in inland counties by 2030 under the RCP 4.5 climate scenario. If we use the RCP 8.5 scenario for 2030, these probabilities of exceedance are about the same- at 4.3% for coastal counties and 2.6% for inland counties. This lack of difference is unsurprising because this is a 2030 timeframe. Climate scenarios start differing from each other only in a 20 to 30-year timeframe.

Figure 4-12: Probability of Annual Occurrence – Wind Speeds in 2030



Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

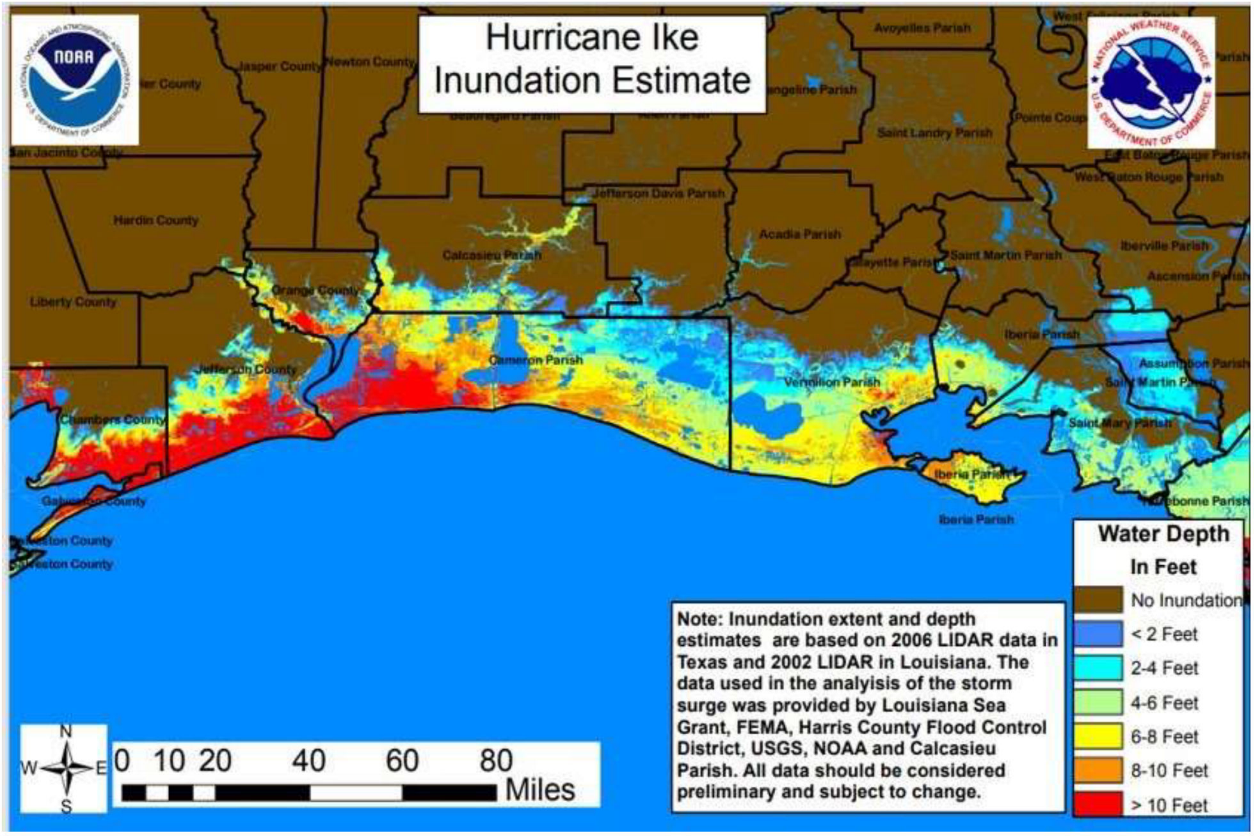
4.2.2 Flooding Risk Profile

CenterPoint Houston's service area is subject to several types of flood risks, including extreme precipitation-driven flash floods, riverine floods, and coastal storm surge-driven floods. The frequency and intensity of flood events in CenterPoint Houston's service area have been rising, similar to other parts of the U.S. For example, parts of the Houston metro region have experienced three 500-year floods in just the last twenty years.

4.2.2.1 Historical Evidence

Of the 12 historic events analyzed, Hurricanes Ike, Harvey, and Nicholas, as well as Tropical Storm Imelda, resulted in significant flooding. During Hurricane Ike, Galveston, Chambers, and Jefferson counties were exposed to the highest level of coastal flooding, resulting in a significant number of electric T&D assets being at risk of exposure to inundation of over 10 feet of water (Figure 4-13).

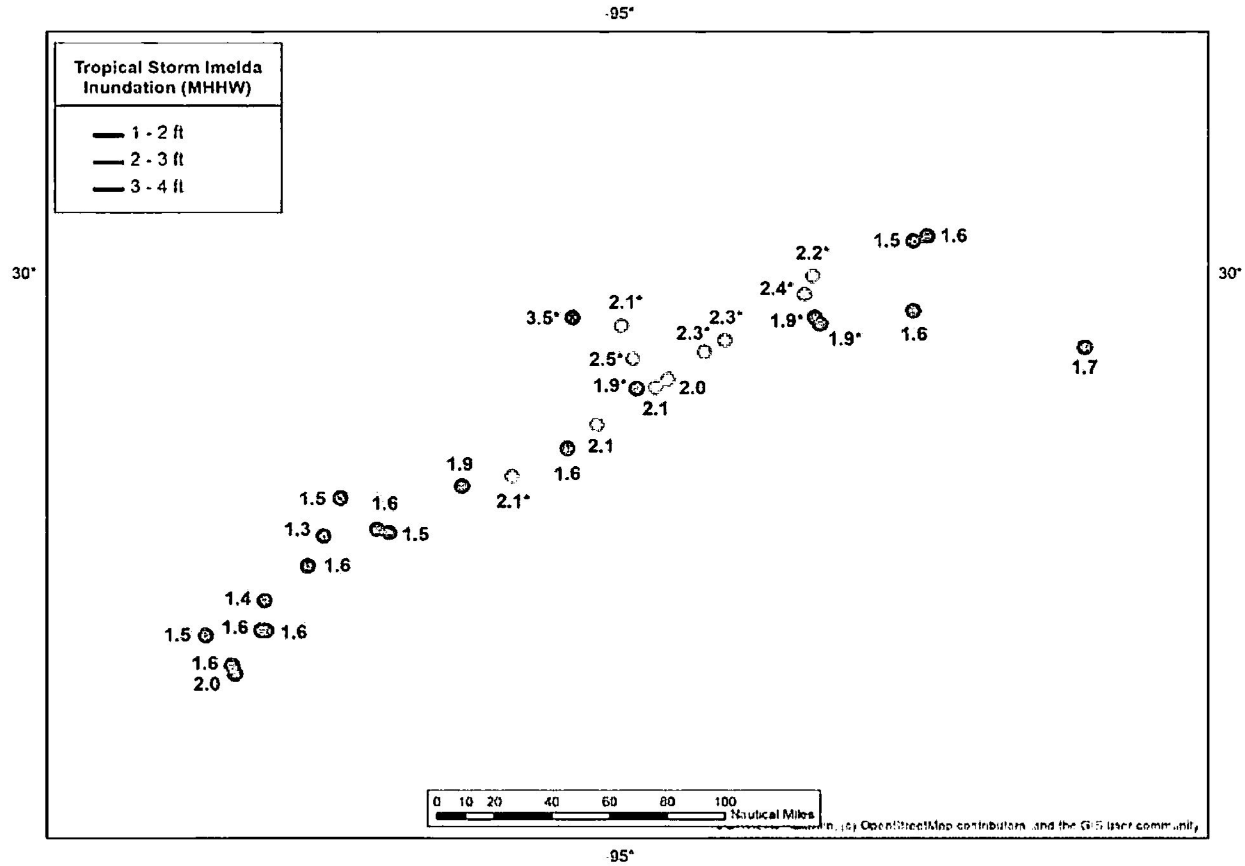
Figure 4-13: Hurricane Ike Inundation Estimates from NOAA



Source: NOAA. (2008). Hurricane Ike Inundation Estimate.

During Tropical Storm Imelda, high levels of rainfall and minor storm surges resulted in floods along the coastal and inland counties of southeastern Texas. Within CenterPoint Houston's service area, Matagorda County experienced the highest levels of rainfall (44.29 inches); however, Jefferson County experienced the most significant amount of flood damage at around 3 to 4 feet of inundation (Figure 4-14).

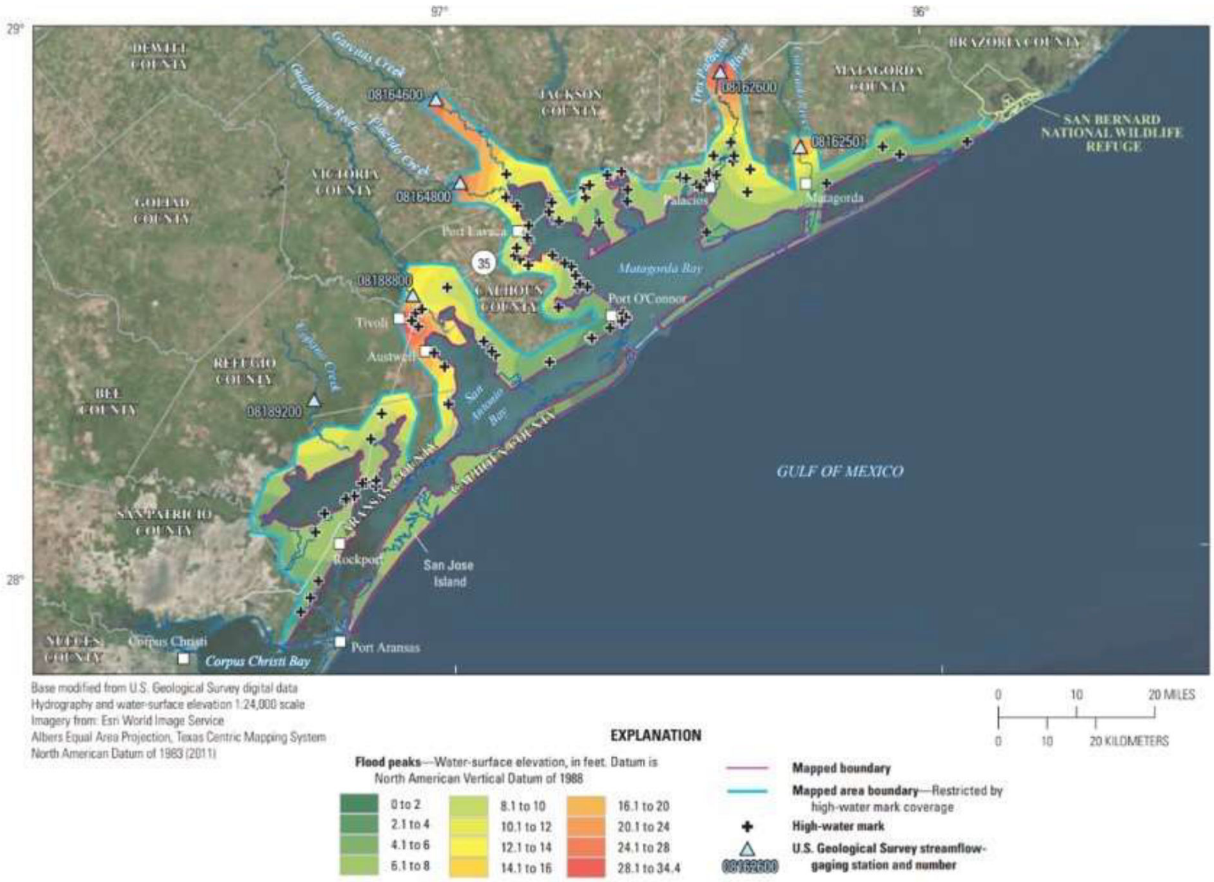
Figure 4-14: Tropical Storm Imelda Inundation Estimates from NOAA



Source: NOAA. (2020 February 7). *National Hurricane Center Tropical Cyclone Report.* (p.25). Tropical Storm Imelda - National Hurricane Center.

During Hurricane Harvey, high levels of rainfall and coastal storm surges caused floods along the coastal and inland counties of southeastern Texas, resulting in inundations of 6 to 30 feet (see Figure 4-15). Within CenterPoint Houston's service area, 17 substations flooded, causing eight substation outages that collectively resulted in loss of service for 1,081,288 customers.

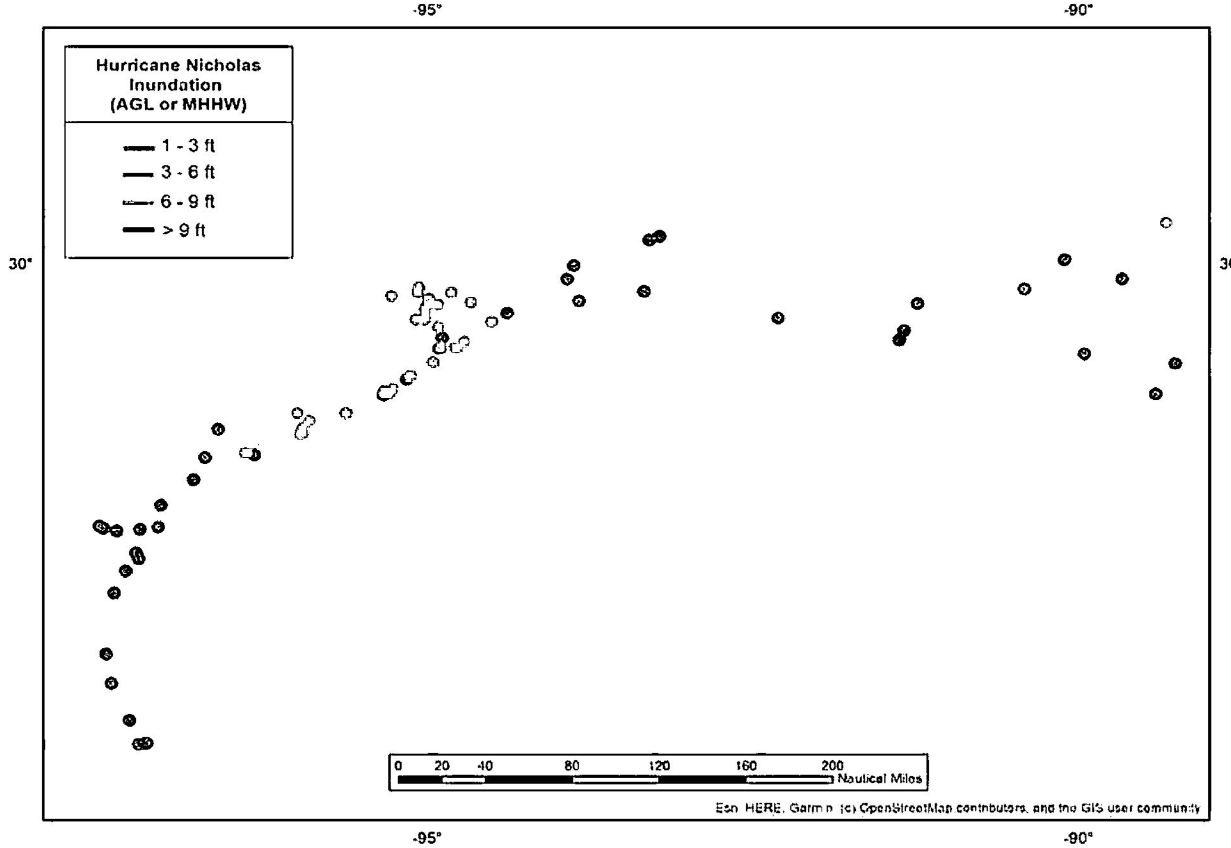
Figure 4-15: Hurricane Harvey Inundation Estimates from USGS



Source: USGS. (2018). *Characterization of Peak Streamflows and Flood Inundation of Selected Areas in Southeastern Texas and Southwestern Louisiana from the August and September 2017 Flood Resulting from Hurricane Harvey.* (p.41). Scientific Investigations Report 2018–5070.

During Hurricane Nicholas, high tides, in combination with storm surges resulted in flood levels of up to 9 feet. The counties of Brazoria, Galveston, and Harris were hit hardest by the floods (Figure 4-16).

Figure 4-16: Hurricane Nicholas Inundation Estimates from NOAA



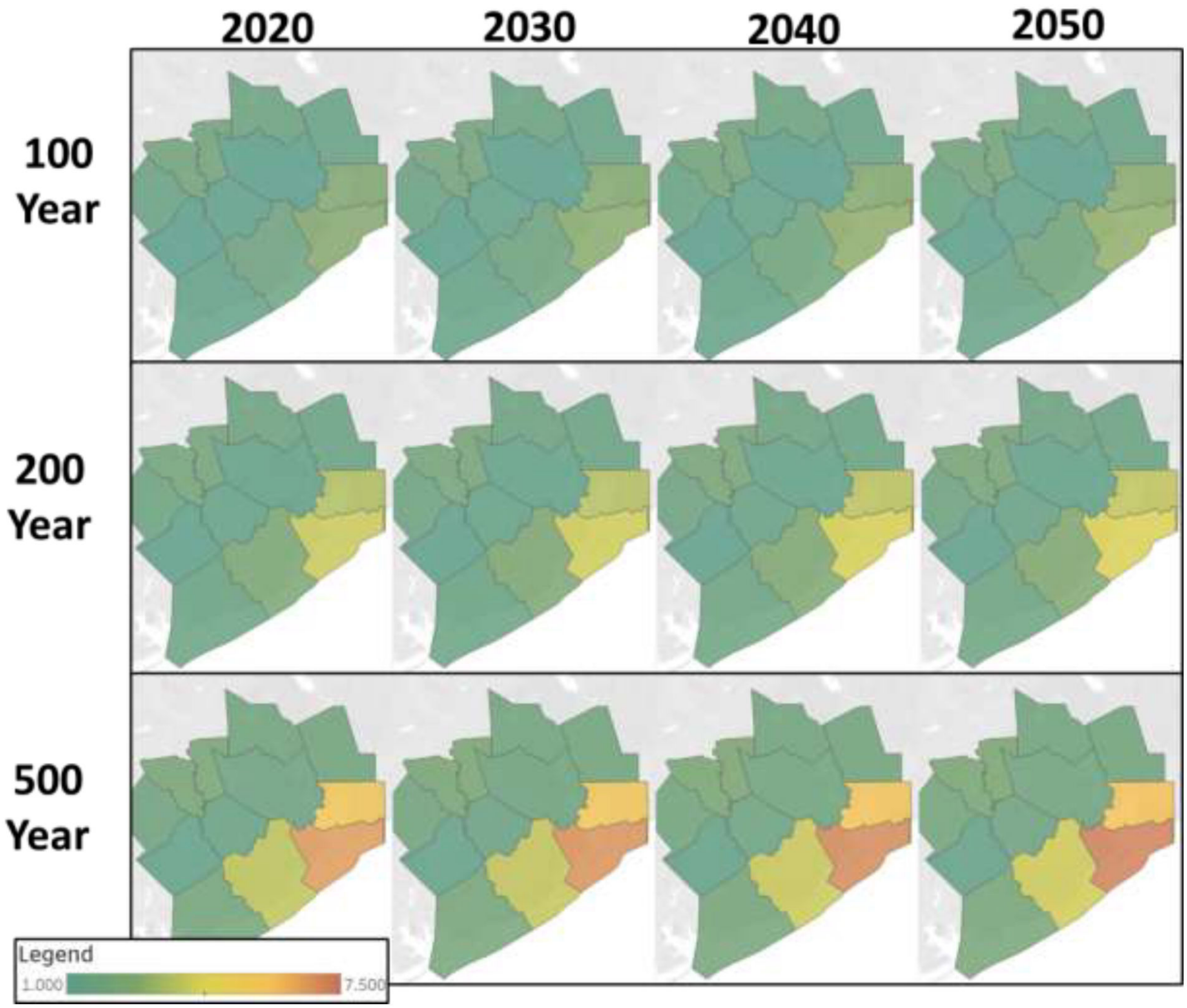
Source: NOAA. (2022 March 28). *NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT*. (p.44). Hurricane Nicholas.

4.2.2.2 Future Forecast Risk Profile

Flood risk varies significantly by location and elevation.[25] County averages and locational (*i.e.*, resolution under 3280 ft) projections reveal different but complementary information. Our analysis shows that the mean flood depths as well as flooded fractions (*i.e.,* percentage of buildings flooded) at the county level are projected to increase from 2020 to 2050 for nearly all the counties for 100-year, 200-year, and 500-year events (Figure 4-17 and Figure 4-18). Galveston and Matagorda counties are projected to experience the highest average flood depth due to their proximity to the coast and lower elevation. Nearly all buildings in Galveston counties are projected to flood should a 200-year or 500-year flood occur in 2030. Over 30% of buildings are expected to flood in Harris and Fort Bend counties should a 200-year or 500-year flood event occur in 2030.

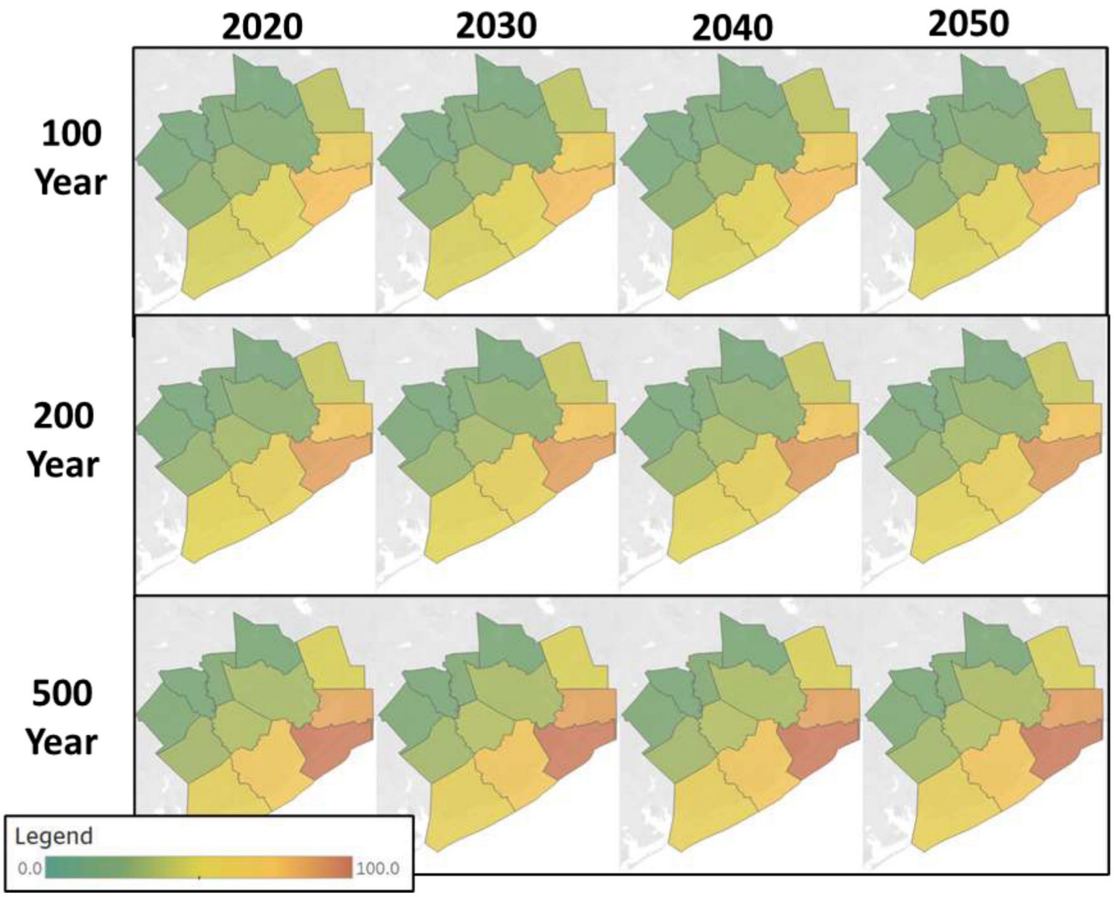
[25] Water Resources Research (2020 September). *Implications of Using Global Digital Elevation Models for Flood Risk Analysis in Cities* [DEM Flood Risk Analysis]. https://doi.org/10.1029/2020WR028241

Figure 4-17: Forecast Flood Depth 2020-2050 (meters)



Color changes may be too subtle to notice visually. Refer to absolute numbers in the descriptive text.
Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

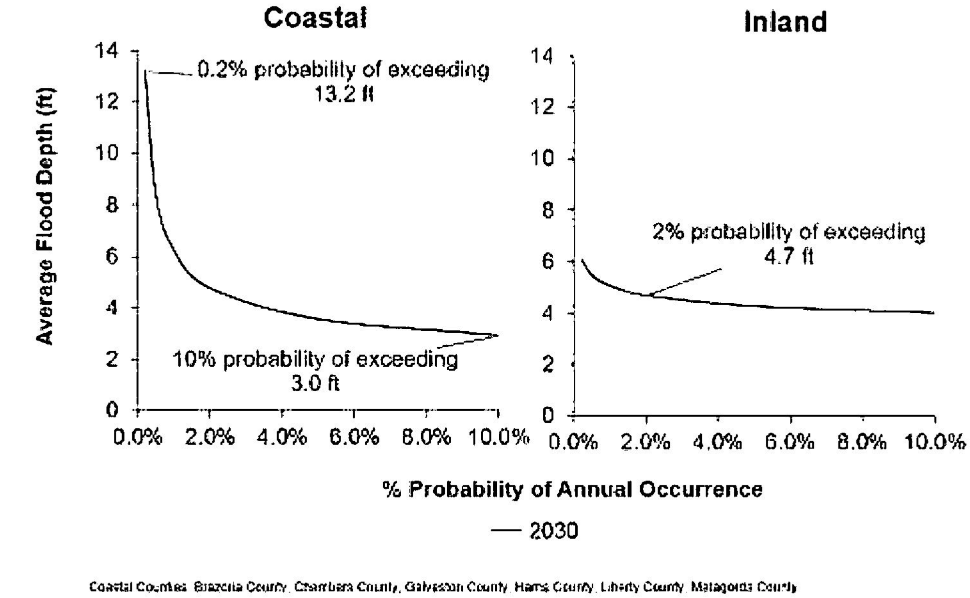
Figure 4-18: Forecast Flooded Fraction 2020-2050



Color changes may be too subtle to notice visually. Refer to absolute numbers in the descriptive text.
Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

Guidehouse used the projected flood depths for return periods between 10-year and 500-year events to calculate probabilities of exceeding different flood depths, as shown in Figure 4-19. Flood depths of 4 feet are deemed critical for failure of substation components such as switches and breakers and have a probability of exceedance of 3.6% in coastal counties and 1.2% in inland counties by 2030 using the RCP4.5 scenario. If we use the RCP 8.5 scenario for 2030, these probabilities of exceedance are 3.8% for coastal counties and 11.2% for inland counties. Given that this is a 2030 timeframe, this relative lack of difference, especially for coastal counties, is unsurprising. Climate scenarios start differing from each other only in a 20 to 30-year timeframe.

Figure 4-19: Probability of Annual Occurrence: Flood Depths in 2030



Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

4.2.3 Extreme Temperature Risk Profile

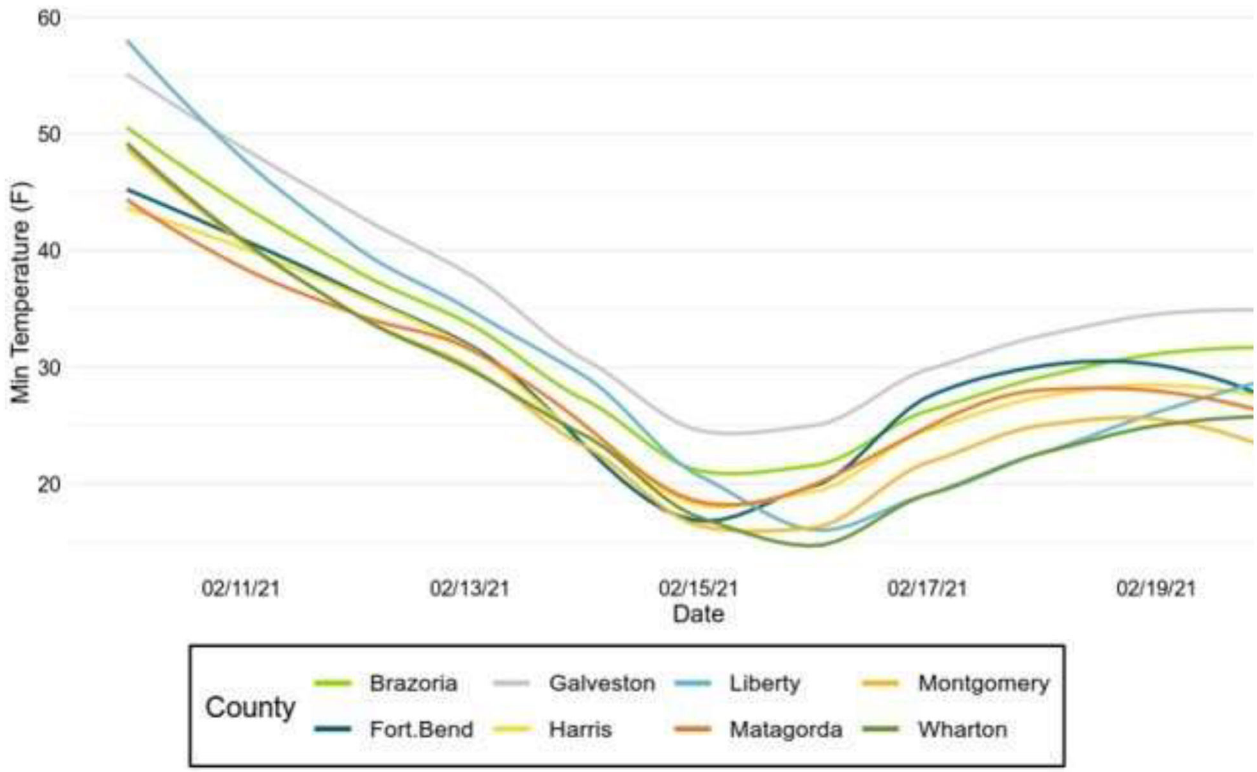
Extreme temperatures can significantly negatively impact utility operations. For example, extreme heat will affect transformer performance and can result in a significant increase in demand, while extreme cold can also result in a significant increase in demand.

4.2.3.1 Historical Evidence and Current Risk Profile

Among the 12 historical weather events analyzed, Winter Storm Uri resulted in the lowest temperatures and days below freezing. NOAA climatological data derived from weather stations shows that temperatures for most counties where the minimum temperature stayed below freezing for multiple days (Figure 4-20). Meanwhile, the maximum temperature for most counties did not exceed 40°F during the worst of the storm (see Figure 4-21). However, Chambers, Austin, Waller, and Colorado counties did not report weather station data for this event, likely due to the storm's disruptions on their operations. The Federal Reserve Bank of Dallas estimated the state's storm-related financial losses associated with Winter Storm Uri to range from $80 billion to $130 billion.[26]

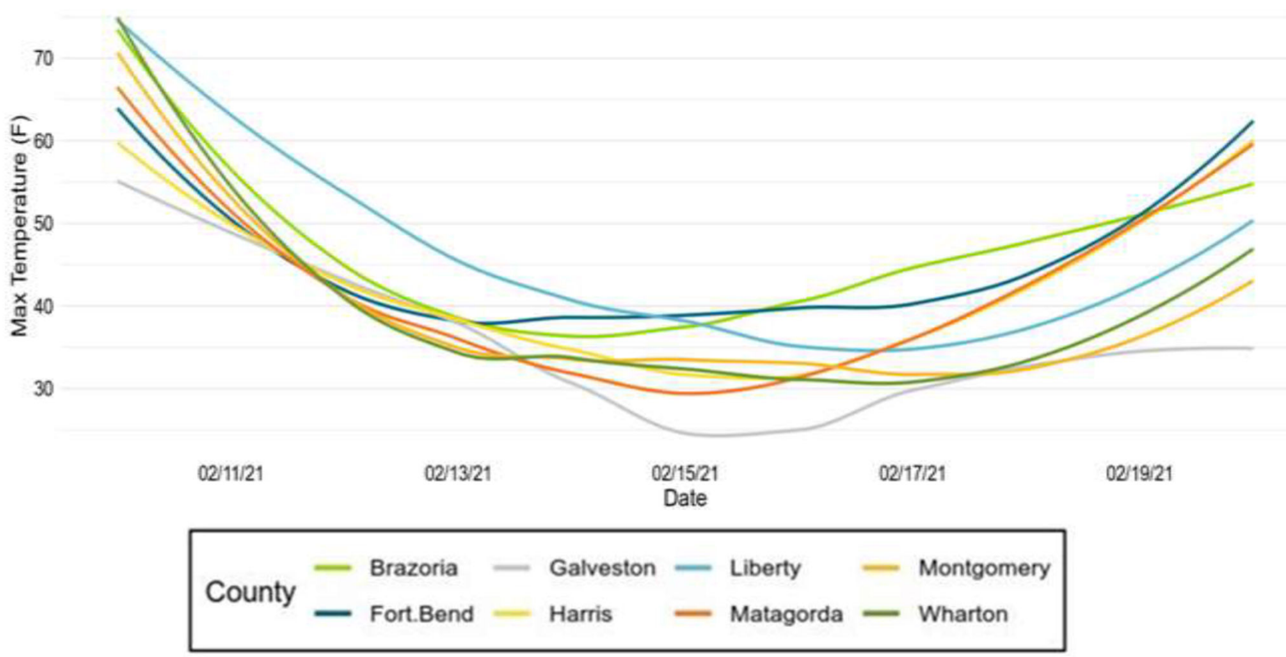
[26] Federal Reserve Bank of Dallas (2021 April). *Cost of Texas' 2021 Deep Freeze Justifies Weatherization.* [Deep Freeze Analysis]. Cost of Texas' 2021 deep freeze justifies weatherization - Dallasfed.org

Figure 4-20: Minimum Temperatures During Winter Storm Uri



Source: Guidehouse analysis, with National Weather Service NOW Database inputs.

Figure 4-21: Maximum Temperatures During Winter Storm Uri

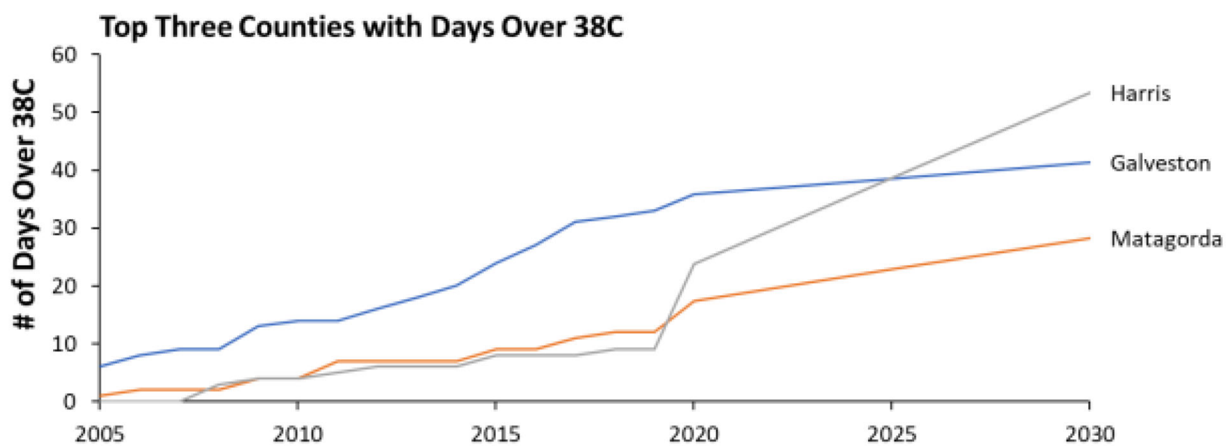


Source: Guidehouse analysis, with National Weather Service NOW Database inputs.

4.2.3.2 Future Forecast Risk Profile

Rising temperatures and extreme heat are more chronic than acute, event-driven risks. Guidehouse has combined historical data and future projections to project change in the number of days exceeding 38°C (100°F) from 2005 to 2030 for Harris, Galveston, and Matagorda counties (see Figure 4-22). These results show a projected increase in the number of days exceeding 38°C for all counties, but the increase for Harris County is particularly prominent, with an expected rise from about 20 to 25 today to over 50 in 2030.

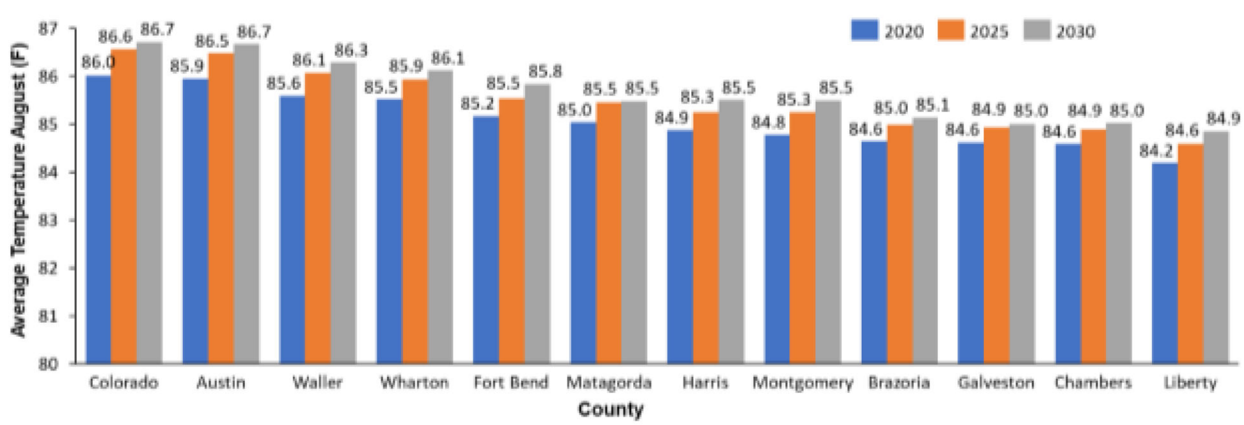
Figure 4-22: Number of Days Exceeding 38°C



Source: Guidehouse analysis, with National Weather Service data inputs.

Instances of chronic temperature rise are concentrated in the summer months. For example, the average temperature in August is projected to rise across CenterPoint Houston's service area, as seen in Figure 4-23. The mean temperature rise for the August average is 1.5°F.

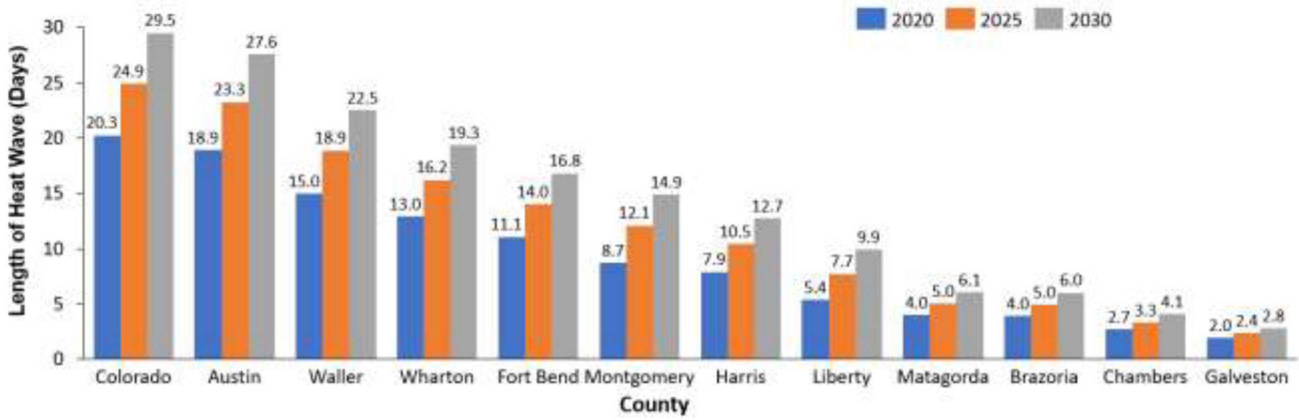
Figure 4-23: Average Temperatures in August 2020-2030 by County



Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

In addition to average temperature increases, heat wave events are also expected to rise in duration with an average increase of 11 days between 2020 and 2030, with Colorado County projected to see an increase of 16 days (Figure 4-24).

Figure 4-24: Length of Heat Waves 2020-2030 by County



Source: Guidehouse analysis, based on Jupiter Intelligence modeling.

In addition to heat events, the category of extreme temperature also includes the risk of drought and extreme cold weather or freeze events. Given the directional trend towards heat waves, the extreme temperature assessment was focused on heat over cold temperature event risks, however, there is evidence that warming temperatures contribute to destabilization of the polar vortex, which may increase the risk of sporadic extreme cold events. Winter Storm Uri (2021) is an example of a polar vortex event with impacts in Texas.

An analysis of drought vulnerability is presented in Section 6.1.6.

4.2.4 Wildfire Risk Profile

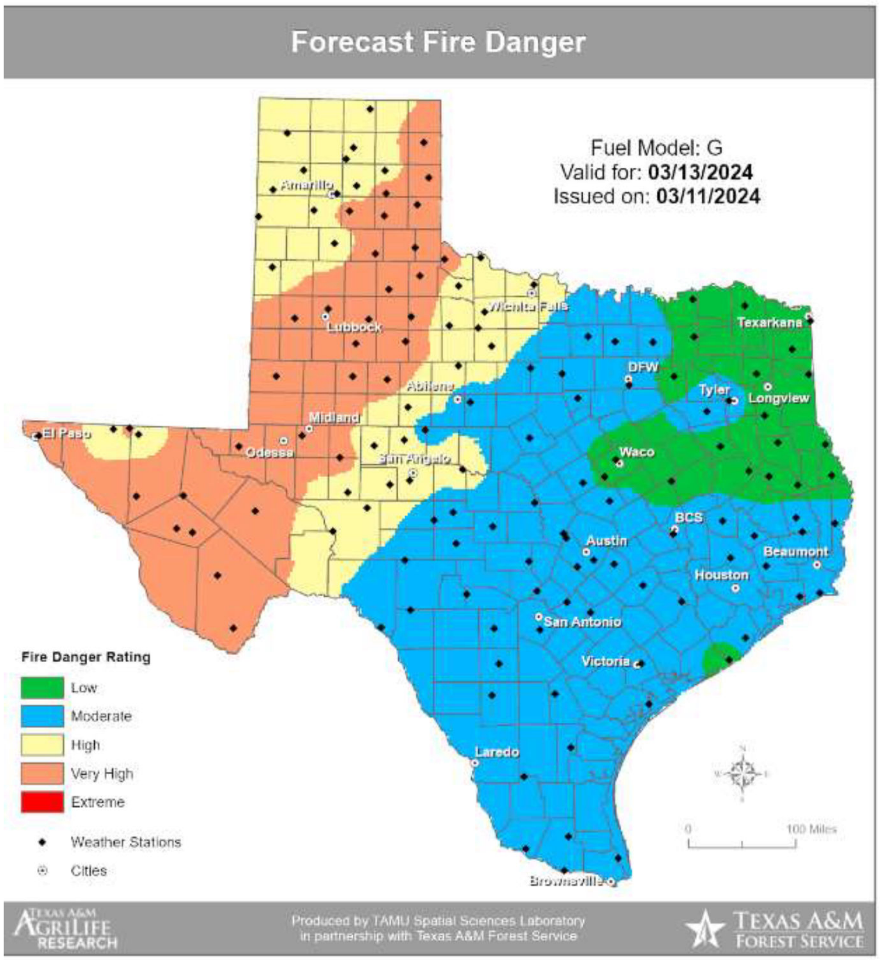
4.2.4.1 Historical Hazard Assessment

Wildfire risk in Texas has historically been low, but rising air temperatures and reduced precipitation have led to drier vegetation, which when combined with high wind speed, can significantly increase the speed and spread of wildfires once ignited. Utilities are at a particularly high risk of being the source of ignition, given that their transmission and distribution systems are primarily located above ground. The Smokehouse Creek Fire that began in February 2024 and continued into March 2024 burned approximately 1 million acres[27] and has been investigated by a special committee of the Texas House of Representatives, which concluded that power equipment caused the initial ignition.[28]

[27] Reuters. (2024 February 29). *Xcel Energy shares fall from potential Texas wildfire liability*. Xcel Energy shares fall from potential Texas wildfire liability | Reuters
[28] Texas House of Representatives. (2024 May 1). *Investigative Committee on the Panhandle Wildfires: 2024 Report*. A Report to the House of Representatives 89th Texas Legislature | Texas House of Representatives

CenterPoint Houston currently uses Texas A&M projections to determine the risk of wildfire spreading in its service area (Figure 4-25). These projections provide a 2- to 4-day forecast to help structure a wildfire response. The conditions shown in Figure 4-25 for March 13, 2024, are representative of the low to moderate wildfire risk in CenterPoint Houston's territory in Spring months.

Figure 4-25: Wildfire Risk Map of Texas for March 13, 2024



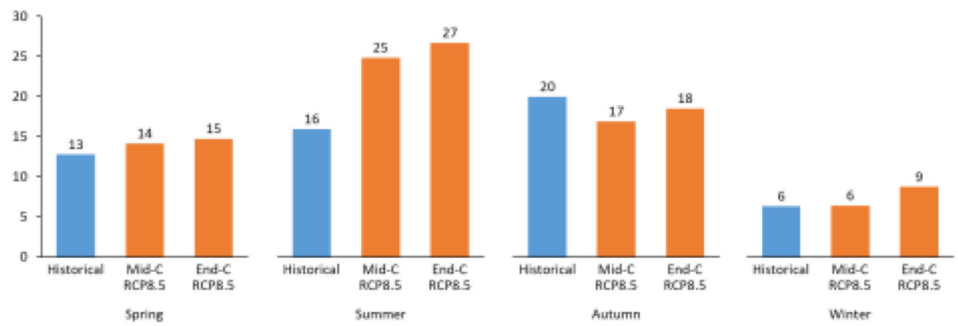
Source: Texas A&M University Forest Service. (n.d.). *FIRE DANGER: OBSERVED & FORECAST FIRE DANGER.* Wildfires and Disasters | OBSERVED & FORECAST FIRE DANGER TFS (tamu.edu).

While the Texas A&M projections are a peer-reviewed and robust data source for near-term wildfire response, a complementary data source may be useful for projecting how this risk will change in the future.

4.2.4.2 Future Hazard Assessment

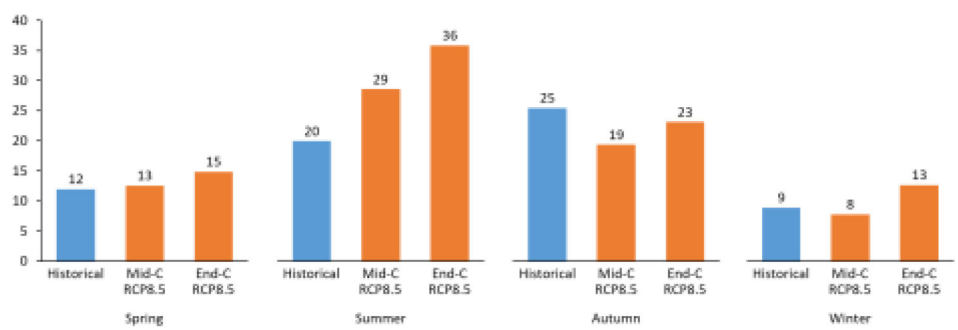
Argonne National Laboratory launched a "Climate Risk and Resilience" tool in 2023 that projects various natural hazards in mid-century and end-of-the-century timeframes on a 12-kilometer ("km") by 12 km resolution. Guidehouse has used the outputs from this tool to develop summary projections for all counties in CenterPoint Houston's territory. Based on these projections, the risk of wildfires will increase over the next few decades. The projected fire weather index ("FWI") from the Argonne National Laboratory for mid-century shows an increase in wildfire risk across CenterPoint Houston's service area in summer months, increasing from a historical medium to mid-century high. However, the risk remains relatively low for spring, autumn, and winter months. FWI is estimated using projected weather conditions such as vegetation dryness and wind speed. An FWI value of 25 or above is considered high for Texas. These projections from Argonne National Laboratory were developed using the RCP8.5 climate change scenario with example results shown in Figure 4-26 and Figure 4-27.

Figure 4-26: Fire Weather Index (FWI) for Harris County Fire Weather Index (FWI) for Harris County



Source: Guidehouse analysis, with Argonne National Laboratory Fire Weather Index data inputs.

Figure 4-27: Fire Weather Index (FWI) for Colorado County: Fire Weather Index (FWI) for Colorado County



Source: Guidehouse analysis, with Argonne National Laboratory Fire Weather Index data inputs.

4.3 Assessment of Physical, Technology, and Cybersecurity Threats

CenterPoint Houston stated that the IT/OT-Cybersecurity Monitoring Program Resiliency Measure is a comprehensive program that will include the deployment of advanced firewalls, passive network sensors, and other cyber technologies to over 400 sites (CenterPoint Houston SRP, Section VI.5.a). Physical and cybersecurity threats are often considered together when assessing risks to IT and OT cyber systems, partly due to the risk of coordinated physical and cyber-attacks (including both cyber systems and the facilities in which they are housed).

4.3.1 Physical Security Risk Profile

The Texas Department of Homeland Security (TDHS) Texas Homeland Security Strategic Plan (THSSP) identifies specific physical security threats to the energy sector, which TDHS cites as a lifeline critical public infrastructure sector.[29] Resiliency is critically important for the electric sector, not only for the operation of its systems but also for other critical infrastructure sectors that all rely on a stable electric supply. In the context of physical security risk, TDHS describes Texas cartels that use military and terrorist tactics to accomplish their goals and expand their control of criminal activities in Texas as a key risk. 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 with 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 communication, and law enforcement's ability to detect planned criminal activity will be challenged as such actors move to more secure communication platforms.[30]

The THSSP report describes statewide intelligence capabilities to reduce the threats of terrorist attacks and criminal activities. From a utility perspective, the CenterPoint Houston IT/OT systems reviewed in this report depend on existing and improved facility-level physical security measures to provide access control protective measures to detect and mitigate the threat of internal or external man-made hazards to its IT/OT systems.

Physical security threats and vulnerabilities for cyber systems represent major concerns from an operational perspective, particularly for enabling technologies such as IT/OT systems that are critical for efficient and effective operations of the CenterPoint Houston electric delivery system.

4.3.1.1 Historical Evidence

Awareness of the need for physical security for electric facilities has increased since an initial sniper attack on a California substation in 2013, which resulted in regulatory action[31] to identify and protect critical transmission substations and their primary control centers. In a FERC ruling, FERC directed the North American Electric Reliability Corporation ("NERC") to develop a mandatory reliability standard to promote physical security initiatives for critical transmission substations and to study the impacts of physical attacks on other transmission substations across the North American electric grid. More recent attacks in 2022 and 2023 disrupted power

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

[30] TDHS. THSSP. (p. 21).

[31] NERC. (2015 July 14). *CIP-014-2: Physical Security* [Transmission System Reliability Standard]. https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-014-2.pdf

in North Carolina, Washington state, and Oregon. At the State level, the California Public Utilities Commission ("CPUC") issued the Physical Security Decision (D.19-01-018). It became the first state to adopt rules to protect its electric distribution grid against terrorist attacks. Since then, state legislators in North Carolina, South Carolina, and Arizona have introduced bills to mandate improved physical security at distribution substations that are not covered by the NERC Standards.

4.3.1.2 Current Risk Profile

In its report on reliability risk priorities, NERC states that physical 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 Bulk Power System ("BPS") and specifically at distribution substations. Vulnerabilities to such events are exacerbated by commodity prices, supply chain constraints, environmental activists, and domestic violent extremists."[32]

Current protective measures to mitigate malicious activities at electric infrastructure facilities have focused on substations 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 attack at Metcalf substation in 2013 that focused on transformers and other critical electrical equipment with long replacement lead times, could significantly impact the safety and well-being of U.S. citizens and the economy.[33] CBS News reported a 71% increase in physical attacks on electric grid facilities in 2022 alone.[34] The Dallas Morning News examined vulnerabilities associated with Texas substations. Citing 25 physical attacks on nationwide electric infrastructure, including one in the El Paso area in 2022, it concluded that a coordinated attack on power infrastructure could cause a cascading failure of the Texas power grid.[35] CenterPoint Houston operates over 300 electric substations and other physical locations, such as control centers, IT data centers, and service centers, containing 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

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[32] NERC. (2023 August 17). (p. 36).

[33] Smith, R. (2014 March 12). *U.S. Risks National Blackout from Small-Scale Attack.* https://www.wsj.com/articles/SB10001424052702304020104579433670284061220

[34] 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/

[35] 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/

systems. The NERC 2023 report cites and promotes the 2023 National Cybersecurity Strategy[36] report "Secure by Design" concept to implement security controls during the design, installation, and construction phases to mitigate the risks of weaker security controls by new entrants to the grid and current participants during the DER interconnection stage. Implementing the "Secure by Design" approach also applies to CenterPoint Houston's proposed technology resiliency measures.

4.3.1.3 Future Forecast Risk Profile

The NERC report on reliability risk priorities indicates that physical and cybersecurity risks are rising while the nature of the attacks continues to evolve.[37] As an example, ballistic attacks on electric facilities using drones as delivery vehicles are an emerging threat. Combining the trends cited above, including the increasing rate of domestic terrorism in Texas and physical security risks in CenterPoint Houston's electric service area, Guidehouse expects physical and cybersecurity attacks to increase in number and severity over the next five years.

4.3.2 Technology & Cybersecurity Risk Profile

The TDHS THSSP report describes cyber threats as follows: "Cyberattacks and intrusions can be used by criminals, terrorists, insiders, and hostile foreign nations to disrupt the 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."[38]

The connection of OT environments to IT networks, the interdependencies between IT systems (*e.g.*, SAP) with the reliable operations of the electric system, and the introduction of a wide variety of Internet of Things (IOT) devices associated with smart grid applications all contribute to the need for electric utilities to continually enhance operational automation, control, efficiency, and, most importantly, security. When CenterPoint Houston implements its planned resiliency measures for digital transformation, greater operational resiliency can be achieved; however, that resiliency can quickly disappear if malicious actors exploit existing and new attack vectors (*e.g.*, compromised credentials, zero-day attacks, poor encryption practices, malware, vulnerability exploitation, misconfigured systems, and trust relationships) that may emerge with increased physical and cyber system interconnectivity.

[37] NERC. (2023 August 17). (p. 32).

4.3.2.1 Current Risk Profile

Cyberattacks across all critical infrastructure sectors have increased over the past five years, with notable examples including the 2021 attack on the Colonial Pipeline (which originates in Houston), numerous operating system vulnerability exploitations, and the rise of malware and ransomware attacks targeting supply chains and other vulnerabilities by foreign and domestic threat vectors. A recent (October 2024) state-sponsored cyber-attack on Operational Technology (OT) systems at a Texas water system underscores the vulnerability of Industrial Control Systems (ICS) across the 16 CISA critical public infrastructure sectors to cyber-attack. Specific to the electrical sector, an earlier (July 2024) ransomware attack created a major data breach at a Texas electrical cooperative trade association, which could potentially create an adverse impact for over 3 million customers. In 2023, Chinese hackers targeted the Texas power grid to lay the groundwork for disruption of critical communications in the event a conflict between the U.S. and China occurs.

4.3.2.2 Future Forecast Risk Profile

As noted above, CenterPoint Houston operates over 400 electric substations and other physical locations. There are approximately 375 IT/OT cyber systems at these locations, which provides a significant digital attack surface for malicious actors. The NERC report on reliability risk priorities identifies physical and cybersecurity risks as rising while the nature of the attacks continues to evolve beyond current protective measures and controls.[39] Additional factors leading to an increased future cybersecurity risk profile for CenterPoint Houston and other electric utilities include the following:[40]

- The emergence of Artificial Intelligence (AI) and machine learning tools deployed by cyber adversaries is likely to increase 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 data use, transmission, and storage.
- Supply chain risks derived from compromise of critical cyber system components during the development and procurement cycles.
- Increasing deployment of DERs and DER aggregators, which are mainly unregulated, presents increased cybersecurity risk to the electric grid because their control systems could become compromised and used as an attack vector into electric systems.[41]
- 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 utility workers' remote work also increases the risk of compromising critical cyber systems, which can be mitigated by hardening telecommunications platforms to protect data in transit.

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

5. CenterPoint Houston System Resiliency Plan Review

5.1 Analytical Approach: Resiliency Measure Reviews and Benefit-Cost Analysis

5.1.1 Overview

Guidehouse performed an assessment of CenterPoint Houston's proposed electric T&D resiliency measures for its SRP covering the years 2026 through 2028. Guidehouse's assessment aims to inform CenterPoint Houston in its refinement of the SRP and provide evidence of the potential value of the proposed resiliency measures. Although some measures may continue for up to 10 to 15 years or longer, CenterPoint Houston's SRP and Guidehouse's evaluation focuses on the costs and benefits of proposed measures over a 3-year period. Guidehouse analyzed each of CenterPoint Houston's proposed SRP measures and projects using the following outline:

- **Project Description** – Provides pertinent details on objectives and rationale supporting the measure. Describes how the measure achieves CenterPoint Houston's SRP objectives, including mitigating the risk of resiliency events. Presents the number of proposed measures and projects and areas targeted, along with amounts spent as of December 2024 and proposed over the 3-year Resiliency Plan.
- **Revisions from the 2025-2027 T&D SRP** – Summarizes changes and updates incorporated into CenterPoint's 2026-2028 T&D SRP. These include removing some measures and adding several new measures, updating capital costs and expenses for measures, revising values for quantities or units installed, and adjusting BCA ratios, CMI savings and restoration costs for each measure.
- **Resiliency Measure Targets** – Summarizes the quantities and costs over the 3-year SRP for each measure.
- **Alternatives Considered** – Describes alternatives CenterPoint Houston considered in lieu of the proposed resiliency measure. Explains why alternatives were determined to be less effective than the proposed resiliency measure(s).
- **Resiliency Measure Metrics and Effectiveness** – Presents metrics and measures CenterPoint Houston proposes to report to the PUCT annually for each resiliency measure. Describes how the reported values will be derived and the relevant data associated with each measure.
- **Benefits Analysis** – Outlines resiliency measure benefits, both quantitative and qualitative. Documents values and assumptions applied to quantify benefits, including BCA ratios when calculated. Qualitative benefits are those associated with societal factors such as regional impacts, economic considerations, public safety, inconvenience,

and impact on critical facilities. A BCA ratio of 1.0 or above indicates that benefits accrued over the asset's life exceed its cost. In contrast, values below 1.0 indicate that the asset's cost exceeds lifetime benefits. For the latter, qualitative benefits are relied upon to support Resiliency Plan measures.

- **Resiliency Measure Assessment and Conclusions** – For each resiliency measure, Guidehouse summarizes its findings based on the preceding sections and provides conclusions as to whether/how the measure achieves SRP objectives.

In addition, Guidehouse summarizes relevant precedents for similar resiliency investments made by other utilities within each resiliency category. The benchmarking assessment is based on two different types of benchmarking analyses, including a survey of peer utilities (Appendix A) and secondary research regarding resiliency planning and investments across different jurisdictions within the United States (Appendix B).

Guidehouse's evaluation of CenterPoint Houston's resiliency measures was performed at the programmatic level. However, CenterPoint Houston, in its SRP, proposes to select individual projects for implementation at the circuit or substation level. Findings from Section 6 provided CenterPoint Houston location-specific values for resiliency measures that include prioritization of individual projects over the three-year SRP. For example, the more detailed asset-level analysis in Section 6.3.4 identifies specific substations with potential benefits from Flood Control mitigation, while Section 6.3.1 identifies individual distribution circuits that CenterPoint Houston should consider for the Distribution Circuit Resiliency measure.

Consistent with the above, CenterPoint Houston has transitioned from an asset-centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency as well as structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. These mitigations, when optimized at the project level, require the consideration of interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practice and measures success as a product of regional performance as opposed to individual asset performance.

5.1.2 Revisions from the 2025-2027 T&D SRP

Guidehouse's approach to deriving resiliency measure benefits in the current SRP is essentially the same as the approach in the prior SRP. In addition to measures that have been added or eliminated, values and assumptions Guidehouse applied to derive BCA ratios and CMI savings have been updated. Updates include revised costs for proposed investments from 2026 through 2028 for measures included in the prior SRP and additional costs for new measures in the current Plan. The Value of Lost Load (VoLL) has increased from $25,000 per MWh to $35,000 as recommended by Commission Staff in its August 28, 2024 memorandum.[42] Most other assumptions applied in Guidehouse's BCA model, such as asset failure rates, restoration intervals, repair, and ongoing maintenance expense for measures that were included in the prior filing, remain unchanged.

Guidehouse has supplemented the program-level analysis of resiliency measures described above with a more granular, locational analysis to identify areas at greatest risk of resiliency events in Section 6. The more detailed analysis identifies climate hazards within two-mile hexagonal areas for wind-related events and nearly exact locations for flood risk. Approximately 3,300 hexagonal areas are assigned, covering the entirety of CenterPoint Houston's service territory. The mapping of climate hazards to each hexagon allows for feeder-level customer interruption forecasts and site-specific flood inundation at individual substations. It supports CenterPoint Houston's selection of individual projects within each measure at specific locations. The methodology and assumptions for the circuit-level and site-specific flooding analysis are described in greater detail in Section 6.

CenterPoint Houston has revised the grouping of resiliency measures from asset type and technology to resiliency event categories such as wind and flooding. Guidehouse, accordingly, has grouped its evaluation of resiliency measures using the resiliency events categories established by CenterPoint Houston. Because certain resiliency measures produce overlapping benefits for more than one event category, the BCAs for some measures have more than one BCA component. In these instances, the BCAs are combined on a weighted basis to produce a single BCA ratio. Figure 5-1 highlights how some measures mitigate impacts from more than one resiliency event category.

[42] PUCT in Memorandum dated August 28, 2024, confirmed use of $35,000 per MWh based on a study prepared by the Brattle Group on behalf of ERCOT. Project No. 55837, Chairman Gleeson Memorandum, (Aug. 28, 2024).

Figure 5-1: Relationship of Natural Hazards to Resiliency Measures

5.1.3 Methodology Used for Review of Natural Hazard and Physical Attack Resiliency Measures

Guidehouse critically reviewed each of CenterPoint Houston's proposed resiliency measures to determine whether the measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP. A key objective of our assessment was to determine the effectiveness of each measure in mitigating the impact of major storms and extreme weather events on CenterPoint Houston's transmission and distribution system. Guidehouse analyzed each measure following good utility practice and quantified the extent to which each measure reduces outage exposure and duration of interruption of electric service. An important element of our assessment of mitigation effectiveness was the consideration of future forecast risk attributed to major storms and other extreme weather events, as described in Section 4. For example, Guidehouse incorporated the projected increase in flood inundation levels in various parts of CenterPoint Houston's service area by 2030 into its analysis of the potential benefits of flood mitigation measures. A similar approach was applied for measures impacted by high wind events.

To derive the benefits from resiliency measures, Guidehouse collected relevant data from CenterPoint Houston to analyze assets at risk of failure during major storms and extreme weather events. This included identifying the likelihood of equipment failure and the extent to which inoperable systems will negatively impact reliability. Guidehouse interviewed CenterPoint Houston subject matter experts to obtain details on resiliency measure selection and historical data used to assess effectiveness. Guidehouse then derived benefit-cost ratios using a BCA approach for each resiliency measure. The BCA approach is a lifecycle analysis of resiliency measure costs and benefits. The BCA provides a consistent measure to determine if the estimated benefits (translated into monetary value) outweigh the estimated costs, suggesting that the measure is worthwhile to pursue. We also compared CenterPoint Houston's proposed measures with industry practices based on a peer utility benchmarking study described in Appendix A.

5.1.3.1 Assumptions

Conducting BCA necessarily requires assumptions to be made, both general and resiliency measure specific. Flood inundation, temperature, and wind speed forecasts for 2030 described in Section 4.2 are also incorporated into the quantitative analysis. General assumptions that typically are applied to determine BCA values include:

- Resiliency measure costs for which CenterPoint Houston seeks PUCT approval are those projected for 2026 through 2028.
- Qualitative resiliency measure benefits include customer satisfaction, regional economic impacts, environmental benefits, media attention, public safety, and avoidance of terrorist threats.
- BCA ratios are derived based on the net present value (NPV) of costs over the 3-year SRP with benefits derived over the life of the measure.[43]
- Value of Lost Load (VOLL) is $35,000/MWh for all resiliency measures.
- Average customer load is 6 kW.
- Load growth is 2% annually unless otherwise specified for individual resiliency measures or location.
- Weighted average cost of capital (WACC) is 6.51%.
- Annual inflation is 2%.

Societal, environmental, and other non-utility impacts are addressed qualitatively. Specific assumptions for each resiliency measure are documented in the applicable resiliency measure review sections below.

5.1.3.2 Overview of Data and Modeling Tools Used

Guidehouse used its proprietary benefit-cost model to derive BCA values as its primary tool. The model applies the assumptions and methods described above, together with storm and other extreme weather event forecasts from Section 4.2 to derive risk factors for each measure. Risk factors evaluated in the benefit-cost model include:

- **Circuit and Equipment Failure Rates**—The decrease in failure rates achieved by measure during major storms and extreme weather events. This includes the reduction in failure rates achieved by replacing or upgrading at-risk circuits, equipment, and facilities on T&D circuits and substations.

[43] Assumed to be 20 years for derivation of BCA ratios.

- **Outage Duration** – The decrease in outage duration achieved by resiliency measures during storms and extreme weather events.
- **Collateral Damage** – The avoidance of the additional cost incurred, caused by equipment failure on nearby devices, *e.g.*, catastrophic substation transformer failures that cause adjacent transformers to fail.
- **Restoration Cost** – The savings in crew labor, truck rolls, and trouble order processing achieved by resiliency measures.
- **O&M** – The decrease (or increase for new equipment installed) in O&M resulting from the resiliency measure.
- **VOLL** – As defined in Section 5.1.3.1.
- **Economic Assumptions** – As defined in Section 5.1.3.1.

The application of the assumptions outlined above to derive BCAs for each CenterPoint Houston resiliency measure by event category is presented in Section 5.2.

5.1.4 Methodology Used for Review of Technology & Cybersecurity Resiliency Measures

Guidehouse critically reviewed each of CenterPoint Houston's proposed resiliency measures to determine whether the measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP. A key objective of our assessment was to determine the effectiveness of each resiliency measure by applying the NIST 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."[44] This definition is commonly used within the cybersecurity field as evidenced by its use in the 2021 Cybersecurity and Infrastructure Security Agency: Infrastructure Security Division ("CISA-ISD") report on Lessons Learned from the Regional Resiliency Assessment Program.[45] The NIST built on this by further expanding this definition, 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."[46] This extension captures cyber resilience from the business process cyber system perspective.

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[44] 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

[45] 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

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

5.1.4.1 NIST Framework Methodology

Due to uncertainty and the evolving nature of cyber threats, the International Energy Agency (IEA) recommended the use of a common framework to provide consistency in assessing risks associated with disparate systems within their operating environments. IEA recommended five potential frameworks,[47] including the Department of Homeland Security Cybersecurity Capability Maturity Model (C2M2, which evaluates the maturity of an organization's cybersecurity capabilities), the NIST CSF (described in detail below), 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). In addition, the ERCOT uses industry best practices, including the NIST CSF, to shape security policies, develop cybersecurity programs, identify cyber threats, and mitigate the impacts of cyber intrusions.[48]

The CSF is a set of best practices and recommended controls commonly used in the electric utility industry at the international, federal, and state levels to guide cybersecurity and resiliency activities and the assessment and mitigation of cybersecurity risks as part of an organization's overall risk management process. Based on professional judgment, fitness for the resiliency assessment at hand, and a current trend within the NERC and the FERC to align NERC Critical Infrastructure Protection (CIP) Reliability Standards in the North American electrical grid with the CSF,[49] Guidehouse developed and applied a comparative analysis of CSF best practices with analyses and reviews of applicable functions and security solutions included in the Technology Resiliency Measures included in CenterPoint Houston's SRP.

The NIST CSF[50] consists of three primary components:

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 the 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

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[47] 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

[48] ERCOT. (2023 March). *Protecting ERCOT's Electric System from Cyber Attacks.* https://www.ercot.com/files/docs/2019/09/17/Cybersecurity_One_Pager_FINAL.pdf

[49] Marron, J., Copstein, A, & Bogle, D. (2021 September 29). *Benefits of an Updated Mapping between the NIST CSF and the NERC Critical Infrastructure Protection Standards* [NIST CSWP 21 White Paper]. https://doi.org/10.6028/NIST.CSWP.21

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

characteristics of their approach to managing cybersecurity risk, which will help in prioritizing and achieving cybersecurity objectives, including resiliency objectives.

While reviewing CenterPoint Houston's SRP measures for IT and OT cyber systems, Guidehouse applied a qualitative comparative analysis[51] between the NIST CSF Core functions, categories, and sub-categories and the features described by CenterPoint Houston in documentation and interviews or inferred by professional judgment for each of the technology resiliency measures included in CenterPoint Houston's SRP. Correlations at the NIST CSF function level were identified and applied to develop qualitative benefit analyses.

For some business-oriented IT cyber systems, Guidehouse also applied a qualitative comparative analysis between the NIST CSF functions and features described by CenterPoint Houston in documentation and interviews or inferred by professional judgment for each of the technology resiliency measures included in CenterPoint Houston's SRP. In addition to correlations at the NIST CSF Function 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."[52] 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.[53]

5.1.4.2 Assumptions

Physical and cybersecurity 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.[54] Depending on the rigor of the underlying data collection instrument, each of these cost factors may or may not be included in the cost of data breach statistics described below.

The IEA reports that utilities in the critical gas and electricity infrastructure sectors were subjected to an average of 504 weekly cyberattacks per organization in 2020, which increased to 736 weekly cyberattacks in 2021 and 1,101 cyberattacks in 2022.[55] While most of these

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

[52] 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

[53] CISA-ISD. (*Part 1*, p. 8)

[54] 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/

[55] 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

attacks were likely unsuccessful, utilities may not have the capability to detect, deter, defend, and recover from successful attempts. This upward trend, coupled with recent FBI reports[56] on increasing cyber intrusion activity by nation-state actors on critical public infrastructure indicates CenterPoint Houston Energy's risk of a successful cyberattack is likely to increase substantially over the next five years.

In addition, Statista reports that the average cost of data breaches in the U.S. increased steadily from $5.4 million dollars in 2013 to $9.48 million dollars in 2023.[57] This upward trend indicates a strong probability that the annual average cost of a single data breach will continue to increase over the next five years. IBM reported similar annual averages for overall 2023 data breach costs in the U.S.[58] IBM further identified a 23% increase in the average cost of a data breach between 2022 and 2023.[59] In addition, IBM reported that the cost of a data breach escalates substantially with longer detection times and increased system downtime.[60]

Combating these deleterious impacts requires a comprehensive approach to physical and cybersecurity 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."[61] This finding aligns with CenterPoint Houston's current approach to implementing diverse physical and cybersecurity 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."[62] Guidehouse concurs with this statement; the more CenterPoint Houston integrates physical and cyber systems into its overall operational model, the more critical a robust defense-in-depth cybersecurity strategy becomes to develop a strong and resilient network.

IEA identifies the difficulties of identifying clear monetary benefits for developing cyber resiliency, "It remains questionable whether an outcome-based approach can be fully relied upon as a reasonable strategy for the resilience of critical infrastructure. The situation differs from that in grid development, where an investment can be motivated by system modeling analysis showing reduced operational costs or higher reliability and where the actual impact on

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56 FBI.gov. (2024 January 31). *China's Hackers Have Entire Nation in Their Crosshairs, FBI Director Warns*. https://www.fbi.gov/news/stories/china-s-hackers-have-entire-nation-in-their-crosshairs-fbi-director-warns [See also FBI.gov. (n.d.). *The China Threat*. https://www.fbi.gov/investigate/counterintelligence/the-china-threat]

57 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.

58 IBM. (2023). *Cost of a Data Breach Report* [IBM Technical Report, Figure 3, pp. 11-12]. https://www.ibm.com/reports/data-breach

59 IBM. (Figure 4, p. 13)

60 IBM. (p. 7).

61 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

62 Claroty. (2022 December 20). *How Cyber-Physical Security Maximizes ROI* [Technical Blog]. https://claroty.com/blog/how-cyber-physical-system-security-maximizes-roi

grid losses or interruption durations can be measured. A cyber resilience investment can hardly ever be weighed against a monetizable [sic] benefit or proven to be effective in retrospect by demonstrating prevented attacks. It is exactly because simply setting targets is not a realistic option that cybersecurity policies for the electricity sector are a complex issue for policymakers."[63]

Accordingly, Guidehouse considered "avoided cost" as a benefit of each of the resiliency measures analyzed below without itemizing specific costs. The more salient analysis regards the resilience impact of each measure since each avoids cost by detecting, deterring, or mitigating successful attacks. While Guidehouse reviewed the physical and cybersecurity resiliency measures included in CenterPoint Houston's SRP individually, it should be noted that the benefit of these 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 measures can increase exponentially as more measures are adopted (*i.e.*, the whole is greater than the sum of its parts).

5.2 Review of Natural Hazard and Physical Attack Resiliency Measures in CenterPoint Houston's System Resiliency Plan

The following sections present Guidehouse's assessment of CenterPoint Houston's proposed SRP measures related to natural hazards and physical security. Each resiliency measure reviewed includes a description, proposed metrics to define effectiveness, alternatives considered, quantitative and qualitative benefits, and summary assessment and conclusions. The benefits analysis section for each proposed CenterPoint Houston resiliency measure describes the approach and assumptions Guidehouse used to derive project valuation using the following two measures: benefit-cost ratio (referred to as BCA below) and CMI reduction. Results for measures where BCA ratios are derived are summarized in Table 5-1 using a VOLL of $35,000/MWh.

Table 5-1 presents the estimated total CMIs reduced for each of CenterPoint Houston's resiliency measures from 2026 through 2028 and the annual CMI each resiliency measure is projected to achieve by 2028.[64] Over the 3-year Plan, cumulative CMI savings are estimated to be 1309 million. By 2028, annual CMI savings are estimated to be 628 million.

Appendix C presents resiliency measure specific and subtotals per BCAs categories for VOLLs ranging from $5,000/MWh to $65,000/MWh. Composite BCAs range from a low of 0.8 for a VOLL of $5,000/MWh to 9.3 for a VOLL of $65,000/MWh.

[63] International Energy Agency [IEA]. (2020 October). *Power Systems in Transition: Challenges and opportunities ahead for electricity security* (IEA Technical Report, *Cyber Resilience - Policy and regulatory approaches* section, p. 45).

[64] The annual CMI value for 2028 is typically higher than the 3-year average as the aggregated quantity of measures undertaken increases each year.

Table 5-1: Resiliency Measure Costs and Benefits

Resiliency Measure[65]	Resiliency Measure No. (RM)	3-Year Capital Cost ($MM)	3-Year O&M Expense ($MM)	BCA Ratio	3-Yr CMI 2026-2028 (million)	Annual CMI 2028 (million)
Extreme Wind						
Distribution Circuit Resiliency	RM - 1	$513.4	$0.0	12.1	263.0	133.4
Strategic Undergrounding	RM - 2	$860.0	$0.0	2.8	81.1	51.0
Restoration IGSD	RM - 3	$107.3	$0.5	19.3	97.0	48.5
Distribution Pole Replacements/Bracing	RM - 4	$251.6	$0.0	9.9	121.0	60.8
Vegetation Management	RM - 5	$0.0	$146.1	3.7	137.0	22.9
Transmission System Hardening	RM - 6	$1,467.3	$0.8	3.9	223.8	122.5
69kV Conversion Projects	RM - 7	$369.3	$0.0	2.7	65.5	27.6
S90 Tower Replacements	RM - 8	$118.4	$0.0	9.4	59.5	23.8
Coastal Transmission Resiliency	RM - 9	$177.3	$0.8	2.0	7.8	7.8
Group Subtotal		**$3,864.6**	**$148.1**	**5.5**	**1055.7**	**498.3**
Extreme Water (Flood)						
Substation Flood Control	RM - 10	$43.8	$0.0	2.1	3.9	2.0
Control Center Facility Upgrades	RM - 11	$7.0	$0.0	15.2	2.5	2.5
MUCAMS	RM - 12	$10.8	$0.0	1.3	0.6	0.2
Distribution Mobile Transformers	RM - 13	$30.0	$0.0	3.0	3.9	2.0
Group Subtotal		**$91.6**	**$0.0**	**3.3**	**11.0**	**6.6**
Extreme Temperature (Freezing)						
Anti-Galloping Technologies	RM - 14	$14.0	$1.0	7.1	5.3	2.6
Group Subtotal		**$14.0**	**$1.0**	**7.1**	**5.3**	**2.6**
Extreme Temperature Heat)						
Distribution Capacity Enhancement/Substations	RM - 16	$579.6	$0.0	5.6	138.1	70.6
MUGS Reconductoring	RM - 17	$245.0	$0.0	1.4	13.6	7.4
URD Cable Modernization	RM - 18	$128.4	$0.0	2.2	13.0	6.5
Contamination Mitigation	RM - 19	$144.0	$6.0	2.4	15.7	7.9
Substation Transformer Fire Barriers	RM - 20	$9.0	$0.0	4.0	1.5	0.7
Digital Substation	RM - 21	$31.8	$0.0	1.8	1.2	0.7
Group Subtotal		**$1,137.8**	**$6.0**	**3.8**	**183.1**	**93.8**
Physical Attack						
Substation Physical Security Fencing	RM - 26	$18.0	$0.0	21.8	17.6	8.8
Substation Security Upgrades	RM - 27	$19.4	$0.1	28.7	25.1	12.5
Group Subtotal		**$37.4**	**$0.1**	**25.4**	**42.7**	**21.3**
Situational Awareness						
Advanced Aerial Imagery/Digital Twin	RM - 33	$18.4	$2.0	4.8	10.8	5.1
Group Subtotal		**$18.4**	**$2.0**	**4.8**	**10.8**	**5.1**
Totals		**$5,163.8**	**$157.2**	**5.0**	**1,309**	**628**

*Average BCA weighted by resiliency measure cost
Source: Guidehouse BCA of CenterPoint Houston's proposed resiliency measures

In addition to the resiliency measure-specific metrics described in this section of the report, CenterPoint Houston proposes to track and report to the Commission annual restoration times, restoration cost, and reliability performance during resiliency events as actions of overall effectiveness of resiliency measures included in its SRP. The annual reports to the Commission will document changes in the impact of resiliency events to customer reliability, damage to T&D assets and associated restoration cost, which is generally consistent with metrics being used by other utilities based on benchmarking provided in Appendix A and Appendix B.

5.3 Extreme Wind

5.3.1 Measure Category Summary

The largest number of resiliency measures are designed to mitigate wind-related resiliency events and are listed in Table 5-2. These measures include reinforcement of both transmission and distribution assets. Wind-related events include hurricanes, tornadoes, and microbursts. All distribution pole, and transmission pole or tower measures are assigned to the wind event category. The largest proposed investment in the current SRP is for mitigation of wind-related events. It focuses heavily on the use of stronger poles and towers capable of withstanding much higher wind velocities and reduced susceptibility to breakage due to fallen trees and debris.

All transmission measures are assigned to the extreme wind category, except for physical security measures for transmission substations in Section 5.7 and the Anti-Galloping measure (freeze event) in Section 5.5.3. TripSaver® was removed as CenterPoint Houston expects to complete the installation of these devices on targeted distribution laterals prior to 2026. The selection of specific poles and circuits for reinforcement is based on the asset-level analysis presented in CenterPoint Houston's SRP and Guidehouse's circuit and location-based climate hazard analyses in Section 6.

Table 5-2: Extreme Wind Resiliency Measures Costs and Benefits

Resiliency Measure[66]	Resiliency Measure No. (RM)	3-Year Capital Cost ($MM)	3-Year O&M Expense ($MM)	BCA Ratio	3-Yr CMI 2026-2028 (million)	Annual CMI 2028 (million)
Extreme Wind						
Distribution Circuit Resiliency	RM - 1	$513.4	$0.0	12.1	263.0	133.4
Strategic Undergrounding	RM - 2	$860.0	$0.0	2.8	81.1	51.0
Restoration IGSD	RM - 3	$107.3	$0.5	19.3	97.0	48.5
Distribution Pole Replacements/Bracing	RM - 4	$251.6	$0.0	9.9	121.0	60.8
Vegetation Management	RM - 5	$0.0	$146.1	3.7	137.0	22.9
Transmission System Hardening	RM - 6	$1,467.3	$0.8	3.9	223.8	122.5
69kV Conversion Projects	RM – 7	$369.3	$0.0	2.7	65.5	27.6
S90 Tower Replacements	RM - 8	$118.4	$0.0	9.4	59.5	23.8
Coastal Transmission Resiliency	RM - 9	$177.3	$0.8	2.0	7.8	7.8
Group Subtotal		**$3,864.6**	**$148.1**	**5.5**	**1055.7**	**498.3**

5.3.2 Benchmarking

Peer Utility Benchmarking Survey

The peer utility benchmarking survey, discussed in Appendix A, indicates that ten (10) of eleven (11) respondent utilities address extreme windstorms through their resiliency plans, and seven (7) address aging infrastructure (Figure A-5). Both issues are addressed in CenterPoint Houston's proposed measures to address extreme wind risks.

Eight (8) utilities indicated that a primary goal of the resiliency measure is to decrease the impact of major events (Figure A-4), while three (3) indicated that reduced restoration time was a primary goal. Of CenterPoint Houston's proposed measures to address extreme wind risks, most help to reduce the impact of major events, while some (*e.g.*, Restoration IGSD) also help to reduce restoration time.

Figure A-3 indicates that, of 11 respondents, most include transmission substations (8), transmission lines (8), distribution substations, (8), and distribution lines (10) within their resiliency measures. CenterPoint Houston proposes measures to address extreme wind risks to both transmission and distribution infrastructure.

All respondent utilities include infrastructure hardening investments in their resiliency programs, and the specific types of investments align significantly with the types of measures CenterPoint proposes to use to address extreme wind risks. As depicted in Table 5-3, all or most of the nine (9) utilities that responded to the question include line/circuit rebuilds (9), pole replacements (9),

[66] This table comprises the subset of measures for which Guidehouse has performed BCA and estimated CMI savings. Other measures included within CenterPoint Houston's SRP are excluded from this table.

undergrounding (7), reconductoring (5), and smart grid upgrades (7) such as Restoration IGSD, while nearly half include conversion projects (4).

Table 5-3: Resiliency Survey Investment Types (Extreme Wind Measures)

Type of Investment[67]	Respondent Utility Company ID								
	102	103	106	107	108	109	114	122	123
Line/Circuit rebuilds	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pole replacements	✓	✓	✓	✓	✓	✓	✓	✓	✓
Undergrounding of key lines or portions (*e.g.,* freeway crossings)	✓	✓	✓		✓	✓		✓	✓
Conversion projects – *e.g.,* from 69kV to 138kV	✓	✓				✓		✓	
Reconductoring projects	✓	✓		✓	✓		✓		
Smart grid upgrades	✓	✓	✓	✓		✓	✓	✓	

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

Jurisdictional Benchmarking

The jurisdictional benchmarking report, provided as Appendix B, also indicates that the types of measures CenterPoint proposes to address extreme wind risks are common measures across jurisdictions. Of the 17 states in Table B-4, a majority have included pole replacement/hardening (14), undergrounding (13), vegetation management (10), and transmission (10) measures within proposed investments or generally consider them to be within scope. Some specific examples include:

- Hawaii includes upgrading wind criteria, upgrading structures, and using enhanced construction materials as part of their hardening process.
- Connecticut includes system hardening such as stronger wood poles, steel poles, and fiberglass cross arms as part of its resiliency efforts.
- New Jersey identified in its scope outage management system upgrades and grid modernization communication systems.
- Virginia includes intelligent grid devices, and operations and automated control systems as part of their resiliency efforts.
- Florida includes pole inspections and replacements as part of their resiliency efforts.
- Hawaiian Electric identified enhanced vegetation management as one of the three top priority items for resiliency programs, particularly in critical grid areas susceptible to damage from wind and falling debris.
- In Massachusetts, Eversource launched a vegetation resiliency pilot program.
- In Louisiana, Entergy's 10-Year Resiliency Plan, designed to improve overall system resilience from 2024 to 2033, includes vegetation management as a critical priority.

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[67] This table includes only the subset of resiliency measures included in the survey that are most closely associated with the measures included by CenterPoint Houston within this risk category (Extreme Wind). These were not categorized as such within the survey, and respondent utilities may categorize them differently. The full list of surveyed measures is included in Figure A-2.

- DTE's Distribution Grid Plan specifically includes 4.8kV Hardening in their infrastructure resilience and hardening efforts.
- Further, Entergy's 10-Year Resiliency Plan proposes approximately 9,600 distribution and transmission projects that will collectively harden more than 269,000 structures over 11,000 line-miles.

Within Texas, SRPs submitted by other utilities have included similar measures to those that CenterPoint Houston is proposing to address extreme wind risks. Hardening overhead, underground, and substation distribution infrastructure, as well as vegetation management, have been common across utilities' SRPs, and some utilities have included transmission hardening measures as well.

5.3.3 Distribution Circuit Resiliency

5.3.3.1 Resiliency Measure Description

CenterPoint Houston's Distribution Circuit Resiliency measure is responsive to the increased frequency and severity of extreme wind resiliency events. It is designed to replace and improve pole strength by meeting current NESC design standards on circuits where a substantial number of poles were installed under the prior standard at the time of construction but do not meet CenterPoint Houston's current and higher extreme wind and ice design standards. This resiliency measure includes the utilization of fiberglass poles, new conductor on some line sections, new hardware, and the removal/replacement of poles and equipment.

Assets on distribution circuits that CenterPoint Houston targets for resiliency upgrades include the installation of more robust poles, new conductors, and associated equipment on line sections where poles are those susceptible to failure from trees falling on conductors during extreme wind events and that fail because they do not meet current engineering design standards. CenterPoint Houston's Distribution Circuit Resiliency measure is one of the primary initiatives included in its SRP in terms of level of investment. Poles that are upgraded will meet CenterPoint Houston's current extreme wind and ice design standard. All wood poles will be replaced with composite fiberglass poles designed to withstand additional loading caused by trees falling on overhead conductors. The circuits chosen for the upgrade will be prioritized based on the risk of falling trees derived via LiDAR analysis, those that serve critical facilities (*e.g.*, hospitals, water treatment plants, police stations), support mobile generation, or that serve underserved communities. Circuit selection and pole placement location will be further enhanced with the full implementation of Digital Twin technology presented in Section 5.9.3.

5.3.3.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to increase spending on the Distribution Circuit Resiliency measure, which will increase the number of circuits upgraded over the 3-year Resiliency Plan. Similar to the Pole Replacement measure, the average cost to upgrade a pole also has increased to reflect current costs. Further, the percentage of poles at risk of failure is adjusted downward by approximately 25 percent to account for the reduction in falling trees resulting from the increase in spending on vegetation management as outlined in Section 5.3.7. Other than for the use of a higher VoLL and adjustment for accelerated vegetation management, all other values applied to derive benefits in Guidehouse's prior report remain unchanged. As noted above, the circuits that CenterPoint Houston will select for upgrades during the implementation phase will be informed by Digital Twin technology and the detailed risk analysis outlined in Section 6.3.1.

5.3.3.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for Distribution Circuit Resiliency are presented below.

- Number of poles targeted: **25,000** for an average of approximately **8,300** poles per year
- Total project cost: **$513.4 million** over the 3-year Plan

5.3.3.4 Alternatives Considered

The only viable alternative to replacing poles that do not meet CenterPoint Houston's current design standard is to only replace poles that need immediate or near-term replacement, such as those targeted in the Pole Replacement/Bracing measure. This option was rejected since it is more costly than proactive replacement.

5.3.3.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. These mitigations, when optimized at the project level, require the consideration of interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.

3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.3.3.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Distribution Circuit Resiliency measure on both a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of sustained interruptions avoided on distribution circuits targeted for rebuild, the average number of customers or load at risk, and the estimated time to restore service. The failure rate of individual poles caused by falling trees where rebuilds are proposed is 3.5% per year, which is consistent with the wind speed and event frequency forecasts described in Section 4.2.1. The estimated average number of customers at risk is 1,093, and the average restoration time is 18 hours.[68] Other benefits include reduced truck roll costs and crew labor to restore service. The Distribution Circuit Resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by 263.0 million and 133.4 million annually by 2028. From these assumptions, Guidehouse derived a BCA of 12.1.

2. **Qualitative Benefits** – The potential that poles not meeting CenterPoint Houston's current design standard will fail during major storms and other extreme weather events is significant, particularly during high wind events. For systemwide storms that cause many outages due to pole failures, the number of customers who may experience lengthy interruptions is also high. The ability of stronger poles to materially reduce the impact of extended outages, when coupled with other resiliency measures, collectively reduces the economic impact and disruption of critical load during resiliency events.

5.3.3.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Distribution Circuit Resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The replacement of poles conforms to CenterPoint Houston's current and higher extreme wind and ice loading standard. It will result in fewer failures and sustained circuit interruptions during high-wind events.

[68] Assumes two poles fail for each event for a total restoration time of 18 hours.

- CenterPoint Houston's pole upgrade and replacement criteria ensure that the appropriate pole type and size are selected based on locational factors and application.
- Guidehouse's analysis of the Distribution Circuit Resiliency measure produced a BCA that confirms the project is cost-effective.
- Based on prior Guidehouse experience with other utilities and peer utility benchmarking survey results, installing more robust poles is consistent with practices deployed at other utilities.

5.3.4 Strategic Undergrounding

5.3.4.1 Resiliency Measure Description

CenterPoint Houston's Strategic Undergrounding resiliency measure is designed to achieve two objectives. The first is to replace wood poles and accessory equipment on overhead distribution lines at freeway crossings that are at risk of failure during major storms and other extreme weather events or that could result in significant outages if damaged.[69] Replacement poles will be concrete for overhead crossings and meet CenterPoint Houston's extreme wind and ice design standard.[70] For underground crossings, terminal poles will be replaced with fiberglass poles. Prioritization of freeway crossing upgrades will consider the condition, load at risk, and customer outage exposure. A typical crossing appears in Figure 5-2.

Figure 5-2: Typical Freeway Crossing

Source: CenterPoint Houston photo of a crossing at I-10 and Dwight St.

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[69] Some overhead line reinforcements will remain overhead; however, other freeway locations may require underground relocation of overhead line crossings, such as those where the use of concrete poles is not feasible.

[70] The concrete poles will require new insulators, brackets, and other ancillary equipment. For some crossings, the existing conductor may also need to be replaced.

The second objective is to relocate at-risk overhead three-phase and a small number of lateral distribution line segments underground. At-risk overhead line segments are those that are susceptible to outages caused by vegetation and debris during resiliency events or those that are located in difficult-to-access locations such as heavily congested highways and rear lot corridors. Three-phase line overhead segments that CenterPoint Houston proposes to relocate underground include those that serve a large number of customers and that experienced circuit lockouts during Hurricane Beryl in July 2024.

5.3.4.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to significantly expand the Strategic Undergrounding measure to include both overhead to underground conversions for (1) freeway crossings, and (2) three-phase main line sections and lateral line sections. Spending on the Strategic Undergrounding measure has increased significantly, both due to the inclusion of overhead to underground conversions and an increase in the number of highway crossing relocations over the 3-year SRP. The criteria that will be used to identify and select highway crossings to be relocated have been revised to emphasize the undergrounding of overhead lines on highway crossings. The quantitative analysis below describes the criteria that will be applied to select other overhead lines to be relocated underground. Also, distribution circuits that CenterPoint Houston will select for upgrades during the implementation phase will be informed by the detailed risk analysis outlined in Section 6.

5.3.4.3 Resiliency Measure Targets

The circuits targeted for overhead to underground conversion for freeway crossings and overhead relocation are listed separately.

Freeway Crossings

CenterPoint Houston's proposed SRP investments to convert overhead crossings to underground freeway crossings are presented below.

- Number of freeway crossings targeted: **6** per year (**18** total), the number of overhead lines replaced with overhead lines and those relocated underground is about **19** per year and **57** total
- Total resiliency measure cost: **$60 million** over the 3-year Plan (**$300,000** for each overhead crossing, **$1 million** for each underground crossing)[71]

Overhead to Undergrounds Circuit Relocation

[71] The exact number of overhead versus underground freeway crossing replacements will be determined based on site specific engineering and operational analysis. Accordingly, program costs may vary from current estimates.

CenterPoint Houston's proposed SRP investments to convert three-phase and lateral overhead line sections underground are presented below.

- Number of overhead line segments targeted: **37 miles** of three-phase main line sections per year and **111 miles** over the 3-year SRP, which includes a small number of laterals per year, respectively
- Total resiliency measure cost: **$800 million** over the 3-year Plan

5.3.4.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, determined viable alternatives to the reinforcement of freeway crossings, such as installing new, more resilient non-wood non-wood-engineered poles or relocating the lines underground. CenterPoint Houston proposes to relocate crossings underground where concrete poles with hardened overhead lines are not feasible, or where there are multiple crossings at one location. It is possible to terminate the line at dead-end poles adjacent to the highway with one termination connected to an alternate circuit. However, this alternative requires the availability of a nearby alternate distribution circuit source to be a cost-effective option, making opportunities to reconfigure freeway crossings limited. CenterPoint Houston will consider this alternative where feasible.

For other overhead lines, the most viable alternative to undergrounding is to continue operating these lines as overhead circuits. The second option is to reconfigure circuits to minimize impact in the event a failure takes place. These two alternatives also do not meet CenterPoint Houston's core objective to harden and make these circuits more resilient. The number of opportunities to reconfigure is also limited due to design criteria that require transfer (also known as tie) capability to another circuit for much of its distribution system. These two options also contradict the PA Consulting Hurricane Beryl after-action recommendation to increase underground circuits to harden and make the circuits more resilient.

5.3.4.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.3.4.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Strategic Undergrounding resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Measure benefits are derived separately for overhead highway crossings and other (non-highway) overhead to underground line relocations.

   Highway Crossings

   Key assumptions include estimates of the average number of sustained, storm-related interruptions avoided on crossings where poles will be replaced, the average number of customers or load at risk, and the estimated time to restore service. The failure rate of circuits where rebuilds are proposed is 2% inland and 5% in coastal areas for a wind speed threshold of 70 mph, as described in Section 4.2.1. The estimated average load at risk is 8 MW for 12 kV crossings and 19 MW for 35 kV, with an average restoration time of 4.5 hours. Other benefits include reduced costs for truck rolls and crew labor to restore service absent the presence of replacement poles. The Strategic Undergrounding/Freeway Crossings resiliency measure is projected to reduce cumulative CMIs over the 3-year SRP by approximately 2.2 million and 1.1 million annually by 2028. From these assumptions, Guidehouse derived a BCA of 1.0.

   Overhead Line Relocation

   Key assumptions include estimates of the average number of sustained, storm-related interruptions avoided for overhead lines that will be relocated underground, the average number of customers or load at risk, and the estimated time to restore service for three-phase and single/two-phase laterals. The failure rate of circuits where rebuilds are proposed is 2% inland and 5% in coastal areas for a wind speed threshold of 70 mph, as described in Section 4.2.1. The estimated average load at risk for three-phase main lines is 8 MW for 12 kV lines and 19 MW for 35 kV, with an average restoration time of 18 hours for main line segments and 36 hours for laterals during resiliency events. Other benefits include reduced costs for truck rolls and crew labor to restore service if these lines were to remain overhead. The overhead line relocation component of the Strategic Undergrounding resiliency measure is projected to reduce cumulative CMIs over the 3-year SRP by approximately 78.9 million and 49.9 million annually by 2028. For these assumptions, Guidehouse derived a BCA of 3.0.

The composite BCA for the Strategic Undergrounding measure is 2.8.

2. **Qualitative Benefits** – The potential that poles meeting the heavy loading standard will avoid failure and associated customer interruptions during major storms and other extreme weather events is significant, particularly during high wind events. For systemwide storms that cause a large number of customer outages on overhead lines due to pole failures, the number of customers that may experience lengthy interruptions can be high. Restoration intervals are higher for highway crossings due to increased restoration times for coordinated repairs with traffic management personnel. Further, emergency vehicles need access to freeways during major storms and other extreme weather events. When a wire is down across a highway, emergency response personnel (*e.g.*, police, fire, ambulance, or national guard) do not have access to respond to make life-saving rescues. The ability of stronger poles to materially reduce the impact of extended outages, when coupled with other resiliency measures, collectively reduces the economic impact and disruption of critical load during major storms and other extreme weather events. Line failures on major freeways are also highly visible, with attendant media attention and traveler inconvenience.

5.3.4.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Strategic Undergrounding resiliency measure is reasonable and beneficial for inclusion in its SRP for the following reasons:

- It cost-effectively enhances distribution resiliency and minimizes traffic and interruption of consumer travel and commerce, as confirmed by the BCA value calculated by Guidehouse.
- The replacement of poles that conform to CenterPoint Houston's current design standard will result in fewer failures and sustained interruptions during high wind events and storms.
- CenterPoint Houston's Strategic Undergrounding/Freeway Crossings criteria ensures the appropriate pole type and size is selected based on locational factors and application, or when overhead lines are not suitable, will relocate lines underground below the highway.
- The installation of more robust poles is consistent with practices deployed at other utilities to improve resiliency based on prior Guidehouse experience and peer utility benchmarking survey results.

5.3.5 Restoration IGSD

5.3.5.1 Resiliency Measure Description

CenterPoint Houston's Restoration Intelligent Grid Switching Device ("IGSD") resiliency measure is designed to achieve three primary objectives: (1) reduce the number of customers interrupted by faults occurring on main line sections of distribution circuits and restoration time; (2) provide "cut and clear" capability to isolate at-risk distribution line segments located within wildfire risk zone during high hazard conditions; and (3) to disconnect load downstream of critical loads when CenterPoint Houston is required to curtail load when notified by ERCOT of implementation of emergency procedures on the bulk power system.

CenterPoint Houston proposes to install up to 1,086 IGSD devices over the 3-year SRP, either fully automated or remotely operated by distribution system operators. Distribution feeders targeted for IGSD mitigation include locations most susceptible to main line outages with additional consideration of the magnitude of load at risk (*e.g.*, serving greater than 4,000 customers) and service to critical customers or facilities (*e.g.,* hospitals or other facilities providing emergency services during storms)[72]. For Wildfire Mitigation, IGSD locations will be installed at the point where distribution lines transition into wildfire hazard zones. For ERCOT-mandated curtailments, IGSDs will be installed just beyond the location of critical loads, such as hospitals and public health facilities (*e.g.,* sewage treatment plants).

A related technology resiliency measure provides requisite functionality via installing remote equipment to enable communications between the IGSD device and the utility's control systems and distribution control center personnel. The components allow for communications using CenterPoint Houston's 700MHz radio system, along with the LTE Cellular redundant systems, because any public carrier outages to the LTE Cellular system will also affect the redundancy of the IGSD communications package. The package is designed to include a battery backup.

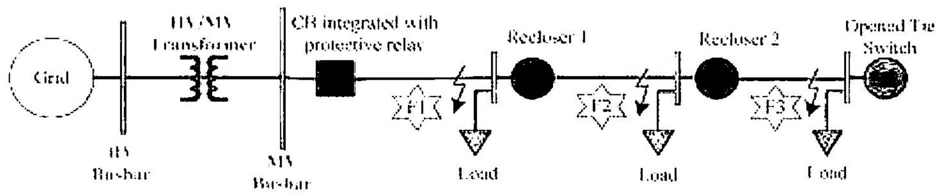
Candidate feeders for IGSD load transfer application require minimum line upgrades and sufficient available capacity to accept loads from adjacent feeders or feeders from another substation following an outage on the main line section of the alternate circuit. Further, both the circuit where the load will be transferred from and the circuit receiving the load (and vice-versa) should have sufficient load on the non-faulted line sections (*e.g.*, at least 800 customers downstream of the device) and higher than average outage exposure to warrant the installation of IGSD. Successful IGSD load transfer occurs when faults located in line sections between the substation breaker and first line recloser are isolated, and the un-faulted line section is transferred to the receiving feeder via closure of the tie transfer recloser.[73] Line reclosers on some circuits will be configured to operate as sectionalizers, for example, in locations where

[72] For example, feeders with main line interruption rates 300% above the average of all other circuits.

[73] Some schemes may utilize motor-operated, gang-connected, three-phase switches with remote access via SCADA communications.

reclosers are unable to coordinate with the substation breaker due to the proximity of the recloser to the breaker. Figure 5-3 illustrates a typical IGSD tie transfer scheme.

Figure 5-3: IGSD Configuration and Tie Transfer Scheme



Source: Energies Journal [74,75]

5.3.5.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to raise spending on the Restoration IGSD measure, which will increase the number of IGSD schemes installed over the 3-year SRP. CenterPoint Houston also proposes to fund IGSD installations for wildfire mitigation and ERCOT load shed events described above. Except for using a higher VoLL, all other values applied to derive benefits for IGSD schemes in Guidehouse's prior report remain unchanged. However, Guidehouse did not derive BCAs for IGSDs that will be used for wildfire mitigation, which is consistent with the evaluation approach outlined in Section 5.1. Similarly, BCAs are not derived for IGSDs that will be used to comply with ERCOT load reduction events since compliance is mandatory and does not result in CMI savings used to derive BCA ratios. Distribution circuits that CenterPoint Houston will select for IGSD during the implementation phase will be informed by the circuit-level risk analysis outlined in Section 6.3.

5.3.5.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments appear below.

- Number of schemes and IGSD installations targeted:
  - **Approximately 300 devices** and about **100 IGSD tie transfer schemes** per year (and **900** total number of devices**, and about 300 schemes** respectively, over 3 years)[76]
  - **50** devices for IGSD wildfire segmentation per year **(150** total over 3 years**)**
  - **12** devices for ERCOT load shed events per year **(36** total over 3 years**)**
- Total project cost (capital and expense):
  - **$107.8 million** for IGSD schemes and **$ 5.9 million** for Telecom support
  - **$19.7 million** for IGSD wildfire segmentation
  - **$4.6 million** for ERCOT load shed events.

[74] Le, D.P., Bui, D.M., Ngo, C.C., & Le, A.M.T. (2018 November 29). FLISR Approach for Smart Distribution Networks Using E-Terra Software—A Case Study. *Energies Journal, 11(12):3333.* https://doi.org/10.3390/en11123333

[75] IGSD schemes commonly are referred to Fault detection, Location, Isolation and Service Restoration or FLISR.

[76] Each IGSD transfer schemes is assumed to require 3 switching devices, one at the midpoint of each feeder, and one at the open tie point between each feeder.

- The associated expense to install the new equipment over three years is **$0.5 million**.

5.3.5.4 Alternatives Considered

Two mitigation alternatives were evaluated as options to IGSD tie transfer schemes (no viable alternatives beyond those listed below are assigned to wildfire circuit segmentation or ERCOT load shed events). These include less sophisticated fault isolation schemes and the installation of new feeders to reduce outage exposure.

1. **Fault Isolation Devices** – In lieu of IGSD transfer schemes, CenterPoint Houston evaluated the benefits of installing line reclosers and switches on the distribution line section absent tie transfer switches and SCADA communications. These less sophisticated options offer increased reliability by reducing the number of customers interrupted during main line or three-phase faults on major lateral line sections. However, it typically requires longer restoration times for faults that occur between the substation breaker and the first mainline recloser, particularly during major storms and other extreme weather events. CenterPoint Houston has installed numerous reclosers that limit the number of customers interrupted for faults occurring downstream of these reclosers with successful outcomes. CenterPoint Houston now seeks to provide enhanced protection through automation and load transfer schemes at modest incremental cost, and it has targeted many circuits for IGSD in support of its three-year Resiliency Plan.

2. **Reconfigure or Construct New Feeders or Substations** – Constructing new distribution feeders to reduce customer outage exposure on existing circuits through reconfiguration and permanent load transfer is a viable alternative on some circuits. Still, typically, it is less cost-effective than the installation of IGSD. The former requires costly construction of new circuits or substations and increases outage exposure on the newly built distribution lines and substations. The reconfiguration of existing circuits and construction of new circuits or substations is a viable alternative when new circuits are needed to serve incremental load. CenterPoint Houston will construct new circuits during the next three years but does not propose to include these investments in its SRP.

5.3.5.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.3.5.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed IGSD Installation resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of sustained interruptions avoided on main line circuits targeted for IGSD installations under both resiliency events and normal weather events, along with the number of customers or load at risk and estimated time to restore service for outage occurring on main line circuit sections. The average number of interruptions per main line feeder is 1.16 annually, which includes an upward adjustment of 10% using the results of the wind analysis presented in Section 4.2. The load at risk averages between 4 MW for 12kV circuits and 8 MW for 34.5kV circuits per line section. Average customer restoration times are 2 hours 42 minutes for normal weather events, and 10 hours 51 minutes during major storms and other extreme weather events. Average restoration costs vary depending on distance from work location and hours for repair, with savings of $5,000 during normal weather events and $10,000 in savings for resiliency events for each IGSD scheme. Annual maintenance expense for the IGSD devices is $2,733 per scheme. The IGSD resiliency measure is projected to reduce cumulative CMIs over the 3-year SRP by approximately 97.0 million and 48.5 million annually by 2028. On a systemwide basis, Guidehouse derived a BCA of 19.3.

   Qualitative Benefits – The potential to avoid lengthy customer interruptions via IGSD, either via manual or fully automated switching, underscores the value of the measure. For systemwide storms that impact many circuits, the number of customers that may experience sustained interruptions during major storms and other extreme weather events (which could be avoided through IGSD schemes) can be high. The ability of

IGSD schemes to materially reduce the impact of outages during major storms and other extreme weather events, coupled with other resiliency measures, collectively reduce the economic impact of major storms and other extreme weather events within CenterPoint Houston's service territory. It should also result in faster restoration of critical loads at relatively low cost. IGSD also provides a cost-effective approach to minimizing the impact of ERCOT load shed events on critical customers and supports CenterPoint Houston's Wildfire Mitigation measure.

5.3.5.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's IGSD Installation resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The IGSD resiliency measure should significantly reduce the number of sustained customer interruptions and restoration times during major storms and other extreme weather events at a relatively low cost, resulting in a favorable BCA.
- The installation of IGSD schemes is consistent with practices deployed at other utilities based on peer utility benchmarking survey results presented later in this report.
- IGSD is a low-cost approach to reduce the number of customers impacted by wildfire events and to comply with ERCOT load shed events.
- CenterPoint Houston's proposed investment in low-cost automation also underscores its commitment to applying automation technology to enhance the resiliency of its power delivery system.

5.3.6 Distribution Pole Replacement/Bracing

5.3.6.1 Resiliency Measure Description

CenterPoint Houston's Pole Replacement/Bracing resiliency measure is designed to replace poles identified during scheduled inspections as not meeting CenterPoint Houston's minimum remaining strength criteria.[77] Poles are replaced or braced to meet CenterPoint Houston's current extreme wind and ice loading design standard.[78] Although existing poles meet the design standard in effect when they were installed, they may not meet changes in the design standard due to increased extreme weather severity and frequency. The estimated percentage of wood poles proposed to be replaced with stronger wood poles or upgraded to steel or fiberglass or braced is 77%, and those braced is 23%, with 69% on lateral line sections and 31% on main line feeders. The pole type, class, and height of replacement poles are based on several conditions specified in CenterPoint Houston's Distribution Pole Replacement Guidelines

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[77] The Pole Replacement/Bracing program is adjunct to the Distribution Circuit Rebuild program. The primary distinction is that pole replacements for circuit rebuilds includes replacement of poles on circuits that meet minimum strength requirements but are not compliant with CenterPoint's current heavy loading design standard.

[78] To meet the current design standard for each region, other equipment such as crossarms, insulators and brackets located on these poles may need to be replaced or upgraded. Lines with small conductor (e.g., #4 or #6 wire) may be replaced with high rated conductor.

presented in Table 5-4. To improve pole resiliency strength in high wind conditions and to expand the life of new poles, CenterPoint Houston has introduced composite (fiberglass) and metal (ductile iron) poles, in addition to traditional wood poles. However, the optimal pole selection will be determined based on a site-specific evaluation by engineering and operational personnel.

Table 5-4: Circuit Rebuild Installation Guidelines

	Wood	Fiberglass	Ductile Iron
Circuit North of US59/HWY 90 (110 MPH)	CL 2	X	X
Circuit South of US59/HWY 90 (132 MPH)	CL 2	X	X
Lateral Poles (110 & 132 MPH)	CL 4	X	X
Secondary Poles (110 & 132 MPH)	CL 6	X	X
IGSD			X
Regulator Rack (Exterior Poles)			X
Transformer Banks (>250's)			X
Double Circuit Poles		X	X
Junction Poles		X	X
Substation Getaway (within 1st Section)		X	X
Capacitor Banks		X	X
Pole Top Switches		X	
Three Phase Terminal Poles		X	

Source: CenterPoint Houston.

5.3.6.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to increase spending on the Targeted Pole Replacements/Bracing measure, which will increase the number of wood poles replaced, upgraded, or braced over the 3-year SRP. Except for the use of a higher VoLL and a change in the percentage of replacements versus bracing, all other values applied to derive benefits in the prior SRP remain unchanged. The criteria that CenterPoint Houston will use to identify and select wood poles to be replaced or braced during the implementation phase will be informed by the circuit-level risk analysis outlined in Section 6.3.2.

5.3.6.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for Pole Replacements/Bracing are presented below.

- Number of poles targeted for bracing: approximately **2,300** per year (**7,000** total over 3 years)[79]

[79] 2,300 poles will be targeted to be analyzed annually to determine whether bracing is sufficient to meet the wind loading requirements (based on location) or if an upgraded pole is the preferred method.

- Number of wood poles replaced with upgraded wood poles: **approximately 7,300** per year (**22,000** total over 3 years)
- Number of poles upgraded to fiberglass: approximately **330** per year (**1,000** total over 3 years)
- Total project cost: **$251.6 million** over the 3-year SRP

5.3.6.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, concluded that the only alternatives to replacing or bracing poles that have deteriorated below CenterPoint Houston's minimum strength criteria are to adopt a lower design standard or reactively replace the poles after they have failed. Both options were rejected as non-viable as CenterPoint Houston is required to meet the minimum NESC requirements, and both options also only offer a reactive replacement of poles, which does not harden or make them more resilient to extreme weather events.

5.3.6.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.3.6.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Pole Replacement/Bracing resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of sustained, storm-related interruptions avoided on distribution main lines and laterals where poles will be replaced/braced; the average number of customers or load at risk, and the estimated time to restore service. The failure rate of existing poles where rebuilds are proposed is adjusted for wind speeds and event frequency forecasts described in Section 4.2.1, which shows a 2% probability of exceeding 70 mph inland and a 5% probability of exceeding 70 mph in coastal counties in 2030. Of individual pole failures, 25% are assumed to result in an interruption of customer load.[80]

   These forecasts are similar to the information in a Florida Power and Light filing, which showed the measured failure rate for non-hardened poles during Hurricane Irma to be 0.2%15. The estimated average load at risk is 3.9 MW, with an average total restoration time of 18 hours per failure event. Other benefits include reduced costs for truck rolls and crew labor to restore service without replacement poles. The Pole Replacement/Bracing resiliency measure is projected to reduce cumulative CMIs over the 3-year SRP period by 121.0 million and 60.8 million annually by 2028. From these assumptions, Guidehouse derived a composite BCA of 9.9.

2. **Qualitative Benefits** – The potential that poles meeting the heavy loading standard will avoid failure and related customer interruptions during major storms and other extreme weather events is significant, particularly during high wind events. For systemwide storms that cause a large number of outages due to pole failures, the number of customers that may experience lengthy interruptions can be high. The ability of stronger poles to materially reduce the impact of extended outages, when coupled with other resiliency measures, collectively reduces the economic impact and disruption of critical load during resiliency events.

5.3.6.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Pole Replacement/Bracing resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- It cost-effectively hardens distribution circuits.
- Pole replacement/bracing to meet CenterPoint Houston's extreme wind and ice design standard will result in fewer failures and sustained interruptions during high wind resiliency events.

[80] Accounts for wind direction and multiple poles that may fail during a resiliency event.

- CenterPoint Houston's pole replacement criteria ensure that the appropriate pole type (wood, fiberglass, or ductile iron) is selected based on locational exposure to storm events and strength requirements.
- Based on prior Guidehouse experience and peer utility benchmarking survey results, installing more robust poles is consistent with resiliency practices deployed at other utilities.

5.3.7 Vegetation Management

5.3.7.1 Resiliency Measure Description

CenterPoint Houston's Vegetation Management ("VM") resiliency measure is designed to reduce critical load customer outages during resiliency events, as measured by SAIDI performance for critical load circuits during resiliency events (*i.e.*, Major Events as defined by the PUCT). Currently, CenterPoint Houston's proactive VM budget for 2024 is $25 million. CenterPoint Houston proposes to increase annual spending by approximately $48 million for each year of its 3-year SRP period by accelerating trim cycles for virtually all distribution circuits from five to three years, with the objective to reduce major event VM SAIDI below its five-year historical average (2019-2023) of 52.5 minutes by 40 percent.

5.3.7.2 Revisions from the Prior System Resiliency Plan

As noted above, CenterPoint Houston proposes to increase spending on the Vegetation Management measure as proposed in the prior SRP; the current Plan proposes to decrease the trim cycle for all overhead distribution circuits from five years to three. Except for the use of a higher VoLL and an increase in the number of circuits trimmed on a three-year cycle, all other values applied to derive benefits in the prior SRP remain unchanged. The criteria for identifying and selecting circuits have shifted from targeting circuits serving critical load to essentially all overhead distribution circuit line segments.

Reductions in SAIDI for critical load circuits will be achieved by conducting vegetation management on a three-year cycle versus CenterPoint Houston's current five-year cycle. CenterPoint Houston proposes to perform additional VM on 11,700 miles of main and lateral line sections annually on its 4.16kV, 12.47kV, and 34.5kV distribution circuits. Unlike the prior Vegetation Management resiliency measure that included capital investments, all incremental spending for the current measure is expensed.

5.3.7.3 Resiliency Measure Targets

CenterPoint's proposed SRP incremental costs and miles trimmed for Vegetation Management appear below:

- Number of circuit miles targeted**: 3,900** overhead circuit miles per year and (**11,700** total over the 3-Year Plan)
- Total measure 3-year cost (all expenses): **$146.1 million**

5.3.7.4 Alternatives Considered

The only viable option is to perform reactive tree trimming on distribution main and lateral line sections serving critical loads where tree-caused outages have already occurred, and the potential for additional tree-related outages is high. CenterPoint Houston did not pursue this alternative as it would not likely lead to a measurable reduction in SAIDI because trees would not be proactively trimmed or removed prior to outages.

5.3.7.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. These mitigations, when optimized at the project level, require the consideration of interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.3.7.6 Benefits Analysis

The primary benefit of CenterPoint Houston's Vegetation Management measure is the reduction in CMI measured by SAIDI during resiliency events. Unlike other measures focusing on capital investments, targeted VM is expensed with most benefits achieved during the year targeted VM is performed. Further, the actual reduction in SAIDI for this resiliency measure will be determined following the completion of the work for each year of the SRP period. Guidehouse's analysis assumes CenterPoint Houston will meet its targeted annual SAIDI reduction of 40 percent by 2028 to meet the five-year average VM SAIDI target. The Vegetation Management measure is projected to reduce cumulative CMIs over the 3-year SRP by approximately 137.0 million and 22.9 million annually by 2028. For the 3-year Targeted Critical Circuit VM measure, Guidehouse derived a BCA ratio of 3.7.

5.3.7.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Vegetation Management resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The proposed resiliency measure is expected to provide significant value to CenterPoint Houston's customers. The likelihood of substantially lowering SAIDI is high from accelerated tree trimming.
- The proposed measure is consistent with practices deployed at other utilities based on peer utility benchmarking survey results presented later in this report.
- Implementation of reduced cycles for vegetation management helps avoid the significant negative economic and societal impacts associated with widespread, lengthy customer outages during high wind resiliency events. The additional spend on critical load circuits also avoids interruptions for critical load customers (*e.g.*, hospitals and police, fire, and EMS stations) offers to the communities they serve.

5.3.8 Transmission System Hardening

5.3.8.1 Resiliency Measure Description

CenterPoint Houston's Transmission System Hardening resiliency measure is targeted at two sets of resiliency upgrades. The first is designed to replace wooden poles (single pole and H-Frame) on line segments where a substantial number of poles do not meet CenterPoint Houston's current wind loading design standard for new 138kV structures[81]. The second is to replace or reinforce double-circuit 345kV towers that do not meet CenterPoint Houston design criteria. Although existing poles and towers met the design standards in effect when they were built, CenterPoint Houston has since modified their design standard in response to increased extreme weather severity and frequency. CenterPoint Houston proposes to replace wood poles with concrete poles, metal monopole poles, or lattice towers that include installation of galloping conductor mitigation; 345kV towers will be replaced with steel monopoles. Both 138kV and 345kV conductors will be upgraded to a higher rating in several line sections as determined by CenterPoint Houston's asset-based analysis in its SRP. The transmission line segments that CenterPoint Houston proposes to harden include line sections most susceptible to failure during high wind and other resiliency events such as ice storms (*i.e.,* freezing).

[81] Most of CenterPoint Houston's 69kV transmission lines are wood pole construction. The replacement of 69kV poles is addressed in CenterPoint Houston's 69kV Conversion Projects resiliency measure.

CenterPoint Houston's Transmission System Hardening resiliency measure (along with 69kV and 138kV Conversions and Tower Replacements) is one of its key resiliency measures based on the proposed level of investment. The poles replaced will meet CenterPoint Houston's current wind loading standard. Figure 5-4 presents typical 138kV wood pole structures proposed for hardening.

Figure 5-4: **Examples of Transmission 138kV Wood Structures**

5.3.8.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to increase spending on the Transmission System Hardening measure, which will increase the number of wood structures replaced over the 3-year Resiliency Plan. In addition, the current SRP includes the replacement of at-risk double-circuit 345kV towers. Targeted upgrades include the replacement of all wood poles with monopoles by the end of 2028 and several hundred 345kV towers. It also includes the installation of larger conductors on most circuits where poles or towers are replaced to enhance grid resiliency further. Except for using a higher VoLL, all other values applied to derive benefits for wood pole 138kV structure upgrades in the prior SRP remain unchanged – all values for 345kV tower replacements are new. The criteria that will be used to identify wood structures that need to be replaced also remain unchanged. However, the wood and tower structures and conductor upgrade that CenterPoint Houston will select for replacement during the implementation phase is now based on other factors, such as line ratings and transmission network upgrades required to support the regional grid during resiliency events; additional details are provided in CenterPoint Houston in its SRP.

5.3.8.3 Resiliency Measure Targets

CenterPoint Houston's proposed Transmission System Hardening measure replacement quantities and investment amounts appear below.

- Miles of transmission targeted: Approximately **160 miles** over the 3-year SRP
- Number of Structures targeted: 1,715 structures (**1,473** wood poles and **242** towers, respectively)
- Total project cost (capital and expense): **$1,468 million** over the 3-year SRP period
- The annual expense to install the new structures is **$750,00** total over the 3-year SRP

5.3.8.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated three alternatives to replacing wooden transmission structures with steel or concrete poles. First, CenterPoint Houston evaluated using single, stronger wooden poles, but they offer only offer a marginal increase in system resiliency. Further, new wooden H-frame are an obsolete Company design standard and are not viable options for resiliency. Second, an alternative to replacing poles is to relocate lines underground. This option is a viable option but was rejected as cost prohibitive for the entire existing 138kV transmission lines since the cost of undergrounding transmission lines is $20 million per mile, which is 5 to 10 times more costly than overhead lines and the cost to underground all distribution circuits is also cost prohibitive at 2 to 5 times the cost of overhead lines per mile. Third, CenterPoint Houston could reduce outage exposure on at-risk lines by constructing new lines to operate at the same or higher voltage along the same or new rights-of-way. These new lines would be built to a higher capacity line rating to meet future load growth. This alternative is being discussed but has not yet been adopted and accepted by ERCOT and other Transmission System Providers.

5.3.8.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

For substations and transmission assets, these mitigations were primarily structural enhancements, such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements that are more asset-centric.

Measurements:

1. Percent of planned asset installations completed by County

2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.3.8.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Transmission System Hardening resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with project-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of avoided sustained interruptions on transmission circuits targeted for structure replacement(s) during high wind resiliency events, the average number of customers or load at risk, and the estimated time to restore service. For 138kV wood poles, the failure rate of line sections where new structures are proposed is 0.2% annually, derived based on the wind severity and frequency analysis for tornadoes or microbursts described in Section 4.2. The likelihood that a severe wind event will cause two 138kV poles to fail (*e.g.*, an N-2 event) is estimated at 25%. The estimated average cost to replace a wood pole or structure with a steel or concrete monopole and to reconductor circuits is $700,000. The estimated average load at risk is 175MW, with an average restoration time of 48 hours.[82] The estimated average time to repair damaged lines is 5 days during extreme wind events.

   For 345kV towers, the failure rate of line sections where new steel monopole, double-circuit structures are proposed is 0.2% annually. This is derived from the wind severity and frequency analysis for tornadoes or microbursts described in Section 4.2. The likelihood that a severe wind event will cause load loss for a double-circuit 345kV tower failure (*e.g.*, a common model contingency event) is estimated at 25%.[83] The estimated average cost to replace a wood pole or structure with a steel or concrete monopole and to reconductor circuits is $2.1 million. The estimated load at risk is 729MW, with an average restoration time of 72 hours. During extreme wind events, the estimated average time to repair damaged lines is 5 days or longer.

   Measure benefits include reduced costs for truck rolls and crew labor to restore service absent the presence of replacement poles. The Transmission System Hardening resiliency measure is projected to reduce total CMI over the 3-year SRP period by approximately 224 million and 123 million annually by 2028. From these assumptions, Guidehouse derived a composite BCA of 3.9.

2. **Qualitative Benefits** – The potential for single wood poles or steel towers to fail and cause customer interruptions during extreme wind resiliency events is relatively low.

[82] Load at risk is based on the contingency events impact on more than one line, as CenterPoint's transmission system is designed to meet first contingency planning criteria without loss of load.

[83] Value accounts for the likelihood that other transmission lines may simultaneously fail during extreme wind events.

However, for systemwide events that cause multiple wood poles or double-circuit 345kV steel towers to fail, the likelihood of customer interruptions substantially increases. The installation of steel monopoles for both 138kV and 345kV lines is expected to materially reduce the threat of extended outages and customer interruptions during contingency events. When coupled with other transmission and distribution resiliency measures, transmission hardening is expected to materially reduce the economic impact associated with load disruption during resiliency events. The societal impact of outages from transmission line failures on a widespread basis could have severe consequences, ranging from the loss of critical infrastructure (*e.g.,* water and sewage treatment), law enforcement challenges, and public safety, among other societal impacts. If left unaddressed, some lines proposed for hardening may contribute to a degradation of reliability and operational integrity of the high voltage transmission grid during resiliency events.

5.3.8.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Transmission System Hardening resiliency measure is reasonable and beneficial for inclusion in its SRP for the following reasons:

- The replacement of wood poles with steel or concrete structures and galloping conductor abatement conforms to CenterPoint Houston's wind loading standard for 138kV and 345kV transmission structures and will result in fewer line failures and interruption of critical load during extreme wind resiliency events.
- CenterPoint Houston has targeted transmission line sections with a high percentage of wood poles and steel towers that do not meet its current wind loading design standard and are susceptible to outages during extreme wind resiliency events.
- Guidehouse's analysis of CenterPoint Houston's Transmission System Hardening resiliency measure produced a BCA that confirms the measure is cost-effective.
- The installation of more robust steel monopoles is consistent with practices deployed at other utilities based on prior Guidehouse experience and benchmark survey results.
- The potential for widespread outages and resulting societal consequences of line failures underscores the criticality of maintaining a reliable transmission network.

5.3.9 69kV Conversion Projects

5.3.9.1 Resiliency Measure Description

CenterPoint Houston's 69kV Conversion Projects resiliency measure is designed to convert 69kV lines on CenterPoint Houston's transmission system to operate at a higher voltage. The measure has several purposes: (1) to remove aged 69kV transformers and replace deteriorated poles or structures that do not meet CenterPoint Houston's current wind loading design standard; (2) to eliminate the need to maintain 69kV spare equipment; (3) provide additional 138kV paths into downtown Houston to relieve high loading on existing 138kV circuits; and (4) further enhance grid resiliency by increasing line~~s~~ ratings and load carrying capability via voltage conversion. For these conversions, CenterPoint Houston proposes to replace wood poles with concrete or metal monopole poles and replace conductors, insulators, and associated hardware.[84]

Over time, CenterPoint Houston proposes eliminating or converting its entire 69kV network to operate at 138kV. The transmission line segments that CenterPoint Houston proposes to convert as part of its SRP include those most susceptible to failure during resiliency events. CenterPoint Houston's 69kV Conversion Projects resiliency measure is one of CenterPoint Houston's primary resiliency initiatives based on the level of investment. Poles and structures that are replaced and upgraded to operate at 138kV will meet CenterPoint Houston's current wind loading standard from ASCE 7-16 and is based on the 100-year MRI Exposure C or D (dependent on proximity to the Gulf of Mexico).

5.3.9.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to increase spending on the 69kV-138 kV Conversion measure, which will raise the number of 69kV lines and substations converted to operate at 138kV compared to the prior SRP. Except for the use of a higher VoLL, all values applied to derive benefits in Guidehouse's prior report also remain unchanged. Further, the criteria that will be used to identify and select wood structures to be replaced remain unchanged, as virtually all 69kV lines will be converted to 138kV by 2028. However, the prioritization of 69kV circuits that CenterPoint Houston will select for conversion during the implementation phase will be based on locations identified by CenterPoint Houston in its SRP.

5.3.9.3 Resiliency Measure Targets

CenterPoint Houston has prioritized 69kV transmission lines for conversion based on location and weather risk. Conversion measure quantities and investment amounts appear below.

- Number of structures targeted: **462** structures (**14** circuits)
- Total project cost: $**369.3 million** over the 3-year Plan

5.3.9.4 Alternatives Considered

CenterPoint Houston evaluated two alternatives to the proposed voltage conversion projects.

1. **Overhead to Underground Relocation** – One alternative to replacing existing wood poles is to relocate 69kV lines underground. This option was rejected as cost prohibitive as well as prolonging CenterPoint Houston's conversion of its 69kV network. Underground transmission is 5 to 10 times more costly than overhead lines.

[84] CenterPoint will re-use existing conductor when the condition and rating of the conductor is suitable for 138kV operation.

2. **Line Relocation**[85]—CenterPoint Houston could reduce outage exposure on at-risk 69kV lines by relocating lines along new rights-of-way (ROW) with less exposure to resiliency events. However, this option was rejected as it would also prolong CenterPoint Houston's conversion of its 69kV network. Further, this option was eliminated from consideration due to added cost, the desire to retain existing ROWs, and limited opportunities for relocation.

5.3.9.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

For substations and transmission assets, these mitigations were primarily structural enhancements, such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements that are more asset-centric.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.3.9.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed 69kV Conversion resiliency measure on both a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits**[86] – Key assumptions include estimates of the average number of sustained interruptions avoided on transmission circuits targeted for conversion during resiliency events,[87] the average number of customers or load at risk, and estimated time to restore service. The failure rate of line sections where hardening and voltage conversion are proposed is 0.2% based on wind speed and frequency analysis described in Section 4.2.1. The likelihood that a severe wind resiliency event will cause two 138kV structures to fail (*e.g.*, an N-2 event) with loss of load is estimated at 10%.

[85] CenterPoint has and will continue to evaluate the viability of underground relocation online segments on a case-by-case basis.

[86] Additional benefits include the potential to defer transmission capacity related to load growth, but not included in BCA totals.

[87] Guidehouse assumes for purposes of this study that the number of avoidable transmission pole failures during normal weather is far lower than major storms and other extreme weather events.

The cost to replace each 69kV structure is $75,000. The estimated average load at risk is 75 MW, with an average restoration time of 48 hours.[88] Other benefits include reduced costs for truck rolls and crew labor to restore service absent the replacement of 69kV wood pole structures. The 69kV Conversion measure is projected to reduce total CMI over the 3-year Resiliency Plan by approximately 65.5 million and 27.6 million annually by 2028. From these assumptions, Guidehouse derived a BCA ratio of 2.7.

2. **Qualitative Benefits** – The potential for a 69kV wood pole structure to fail during high wind resiliency events is significant. The number of customer interruptions would be high for systemwide events that cause multiple transmission line outages. The capability of upgraded lines with stronger poles to reduce the threat of extended outages is high. When coupled with other T&D resiliency measures, converted transmission lines is expected to materially reduce the economic impact and disruption of critical load during resiliency events. The societal impact of outages from transmission line failures on a widespread basis could have severe consequences, ranging from the loss of critical infrastructure (*e.g.*, water and sewage treatment), law enforcement challenges, and public safety, among other societal impacts.

5.3.9.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's 69kV Conversion resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- Upgrading 69kV lines to meet CenterPoint Houston's current wind loading standard will result in fewer line failures and interruption of critical load during high wind resiliency events.
- CenterPoint Houston has targeted transmission line conversion, which will enhance resiliency by increasing line ratings, increasing backup capability when other lines are out of service, and providing the capability to serve future growth.
- Guidehouse's analysis of CenterPoint Houston's 69kV Conversion measure produced a BCA ratio that confirms it is cost-effective; the additional benefits associated with increased capacity rating and elimination of a voltage class no longer in use, while not quantified, further support the measure.
- The conversion of lower voltage transmission to operate at higher voltage is consistent with practices deployed at other utilities based on prior Guidehouse experience.
- The potential for widespread outages and resulting societal consequences of transmission line failures underscores the criticality of maintaining a reliable transmission network.

[88] Load at risk is based on contingency events that impact more than one line, as CenterPoint's transmission system is designed to meet first contingency planning criteria without loss of load.

5.3.10 S90 Tower Replacements

5.3.10.1 Resiliency Measure Description

CenterPoint Houston's S90 Tower Replacements resiliency measure is designed to replace transmission 90-degree corner lattice towers with concrete or steel poles on circuits vulnerable to high wind resiliency events (*e.g.*, tornadoes and microbursts). All towers targeted for replacement are rated 345kV. CenterPoint Houston proposes replacing transmission towers that have deteriorated or cannot meet CenterPoint Houston's current wind loading standard. CenterPoint Houston's S90 Tower resiliency measure is one of CenterPoint Houston's primary resiliency initiatives based on the level of investment. Towers replaced with steel monopoles will meet CenterPoint Houston's current National Electric Safety Code ("NESC") wind loading standard and is based on the American Society of Civil Engineers ("ASCE") 7-16 wind map and 100-year Mean Recurrence Interval ("MRI"), Exposure C or D (dependent on the proximity to the Gulf of Mexico). The failure rate of S90 towers where asset hardening is proposed is 0.2% based on wind speed and probability of tower failure based on the analysis from Section 4.2.

Figure 5-5 depicts typical transmission towers before and after replacement. To improve resiliency, lattice towers will be replaced by stronger steel or concrete monopoles.

Figure 5-5: Typical Transmission Towers Before and After Replacement

Source: CenterPoint Houston.

5.3.10.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to increase spending on the S90 Tower Replacement measure, which will increase the number of towers replaced compared to the prior SRP. Except for using a higher VoLL and lower tower replacement cost, all values applied to derive benefits in Guidehouse's prior report also remain unchanged. The criteria that will be used to identify and select wood structures to be replaced also remain unchanged. However, the wood structures that CenterPoint Houston will select for replacement during the implementation phase will be based on locations identified by CenterPoint Houston in its SRP.

5.3.10.3 Resiliency Measure Targets

The following presents CenterPoint Houston's proposed SRP investments for S90 Tower Replacement resiliency measures.

- Number of towers targeted: **22** in 2026, **10** in 2027, and **5** in 2028 (**37** total).
- Total project cost: **$118.4 million** over the 3-year Plan

5.3.10.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated two alternatives to the proposed replacement of S90 towers. One alternative to replacing lattice towers is to relocate overhead lines underground. This option was rejected as cost-prohibitive (as seen in the pole replacement program) for almost all transmission lines constructed with towers, as relocating 345kV tower lines is prohibitively expensive.

Another alternative that CenterPoint Houston considered is constructing new transmission lines to operate at the same or higher voltage (along the same or new rights-of-way). These new lines would be built to a higher capacity line rating to meet future load growth. This alternative is being discussed but has not yet been adopted/accepted by ERCOT and other TSPs.

5.3.10.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

For substations and transmission assets, these mitigations were primarily structural enhancements, such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements that are more asset-centric.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.3.10.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed S90 Tower Replacements resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with project-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of sustained interruptions avoided on transmission lines with towers targeted for replacement with steel monopoles during resiliency events, the average number of customers or load at risk, and estimated time to repair damaged towers. The failure rate of line sections where new towers are proposed is 0.2% annually and is based on the wind severity and frequency analysis for tornadoes from Section 4.2. The likelihood of load loss for a common mode, double contingency (N-2) failure on a tower line is estimated at 75%. The estimated average load at risk is 729 MW, with an average restoration time of 60 hours. The estimated time to repair the damage is 5 days during extreme weather conditions. Other benefits include reduced costs for truck rolls (and tracked vehicles, where applicable) and crew labor to restore service absent the replacement of S90 lattice towers. The Transmission Tower Replacements resiliency measure is projected to reduce total CMI over the 3-year Resiliency Plan by approximately 59.5 and 23.8 million annually by 2028. From these assumptions, Guidehouse derived a BCA ratio of 9.4.
2. **Qualitative Benefits** – The likelihood that new steel monopoles will withstand high wind resiliency events such as tornadoes and microbursts is significant. For resiliency events that cause multiple 345kV transmission tower failures, the potential for major load loss and lengthy interruption of service to a large number of customers is very high, as noted above, and underscores the need to replace S90 lattice towers with new, more robust steel monopoles. When coupled with other T&D resiliency measures, new steel monopoles materially reduce the economic impact and disruption of load during resiliency events. The societal impact of outages from transmission line failures on a widespread basis could have severe consequences, ranging from the loss of critical infrastructure (*e.g.*, water and sewage treatment), law enforcement challenges, and public safety, among other impacts. Some towers targeted for replacement, if left unaddressed, may contribute to a degradation of reliability and operational integrity of the transmission grid during region-wide resiliency events.

5.3.10.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's S90 Tower Replacements resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The replacement of S90 lattice towers with steel monopoles that meet CenterPoint Houston's current extreme wind loading standard will cause fewer line failures and interruption of load during high wind resiliency events.

- CenterPoint Houston intends to replace all remaining S90 lattice towers on its system as they are highly vulnerable to failure during high wind events, which are expected to occur with increasing frequency and velocity over time.
- Guidehouse's analysis of the S90 Tower Replacements resiliency measure produced a BCA that confirms it is cost-effective.
- The installation of more robust steel monopoles is consistent with practices deployed at other utilities based on prior experience and peer utility benchmarking survey results.
- The potential for widespread outages and resulting societal consequences of 345kV common mode transmission line failures underscore the criticality of maintaining a reliable transmission network.

5.3.11 Coastal Resiliency Projects

5.3.11.1 Resiliency Measure Description

CenterPoint Houston's Coastal Resiliency Upgrades include large-scale line upgrades in coastal areas. These upgrades are designed to prevent the loss of electric supply to coastal areas following the loss of critical transmission supply lines and/or significant power quality issues. A loss of transmission lines for a common mode failure of a transmission circuit due to high winds or corrosion could result in an extended interruption of electricity supply to coastal areas.[89]

CenterPoint Houston proposes upgrading existing lines to improve the resiliency of supply to coastal areas. The poles and towers that are replaced on overhead lines will meet CenterPoint Houston's current wind-loading design standard. The second initiative includes the rerouting of a single transmission line and building a new transmission circuit to mitigate power quality concerns. The second initiative is designed to avoid a loss of critical lines that could cause unacceptable low voltages and overloads, with a loss of radial feeds to industrial customers and generator shut down with up to 1,100 MW of load at risk; this second segment will continue beyond 2028, with most costs incurred outside of the 3-year SRP.

5.3.11.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to decrease spending on the Coastal Resiliency Upgrades measure to reflect a shift in the project schedule[90] and revisions in equipment and component costs. The number of lines and substations that will be added or upgraded over the 3-year Resiliency Plan remains unchanged for the project's first segment; however, the project's second phase now begins in 2028 with completion beyond the SRP time period. Except for

[89] Also referred to as an N-1-1 contingency event. Defined by the North American Electric Reliability Corporation (NERC) as "A sequence of events consisting of the initial loss of a single generator or transmission component (Primary Contingency), followed by system adjustments, followed by another loss of a single generator or transmission component (Secondary Contingency). The forced outage of a double-circuit transmission line in excess of 0.5 miles in length is defined by ERCOT as a Credible Single Contingency.

[90] The first segment of the measure will be operational by 2028; the second will continue beyond 2028.

using a higher VoLL and the measure cost, all values applied to derive benefits for the first phase of the measure from the prior SRP also remain unchanged. Further, the criteria that CenterPoint Houston will use to identify and select structure design for lines to be replaced or added is unchanged.

5.3.11.3 Resiliency Measure Targets

The cost of the first segment and initial investment in the second phase of the measure over three years is $ **178.1 million,** including expenses. The cost of constructing the new facilities is **$750,000**.

5.3.11.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated two alternatives to the proposed upgrades to the transmission system serving certain coastal portions of CenterPoint Houston's service area.

The first alternative considered was third-party construction of conventional generation, such as combustion turbines, or alternative energy resources, such as energy storage. While viable, there would be considerable challenges and a long timeline for third-party owners to obtain a permit for interconnecting a generation resource. Similarly, the size of an energy storage system large enough to meet load under contingency conditions would be extremely costly. Further, each source could be subject to failure during major floods and storm surges.

Second, new lines additional to this measure could be located either underwater or overhead to the coastal islands; however, this option was rejected due to environmental impacts and relatively high costs. Further, these alternatives did not economically resolve the contingency exposure for a loss of transmission lines.

5.3.11.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency as well as structural hardening at a discrete asset level.

For substations and transmission assets these mitigations were primarily structural enhancements such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements which are more asset centric.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.3.11.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Coastal Resiliency Upgrades measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits**[91] – Key assumptions include estimates of the frequency of sustained interruptions for common mode tower failures during high wind resiliency events,[92] the average load at risk, and estimated time to restore service – benefits are quantified only for the first segment of this measure. The failure rate of line sections where hardening is proposed is 0.2 percent based on the wind speed and frequency analysis described in Section 4.2.1. The likelihood that a severe wind event will cause two structures or lines to fail (*e.g.*, an N-2 event) at each location is estimated at 20 percent. The estimated average load at risk is 250 MVA with an average restoration time of up to 120 hours.[93] Other benefits include reduced costs for crew labor to restore service absent the upgrades, including the time and cost associated with installing mobile generators at $25 million per event. The Coastal Resiliency Upgrades measure is projected to reduce total CMI over the 3-year Resiliency Plan by 7.8 million annually by 2028. From these assumptions, Guidehouse derived a BCA ratio of 2.0.
2. **Qualitative Benefits** – The ability of new and reinforced lines to avoid significant load loss and customer interruptions during resiliency events is significant. Absent these upgrades, if a major storm were to cause tower failure(s) with the loss of two lines, the potential loss of electric supply would be high. The ability of new transmission lines to reduce the threat of extended outages is equally high. The societal impact of outages affecting coastal area load could have severe consequences, ranging from the loss of critical infrastructure (*e.g.*, water and sewage treatment), law enforcement challenges, and public safety, among other societal impacts.

5.3.11.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Digital Substation resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

[91] Additional benefits include the potential to defer transmission capacity related to load growth, but not included in BCA totals.

[92] Guidehouse assumes for purposes of this study that the number of avoidable common mode transmission tower failures during normal weather is far lower than major storms and extreme weather events.

[93] Load at risk is based on the contingency events impact of more than one line section, as CenterPoint's transmission system is designed to meet first contingency planning criteria without loss of load. Restoration of load on the islands based on installation of mobile generation.

- The introduction of grid modernization initiatives, such as those associated with digitization and automation, is consistent with leading utility practices based on Guidehouse's experience advising clients in North America and worldwide.
- As implementation proceeds, CenterPoint Houston's Digital Substation resiliency measure should enhance the reliability and resiliency of its system while lowering the cost of constructing new substations over the long term.

5.4 Extreme Water

5.4.1 Measure Category Summary

Resiliency measures included in the flood event category are presented in Table 5-5 and includes Major Underground Communications Monitoring System (MUCAMS) and Mobile Substations in addition to those presented in the prior SRP filing. These measures include elevating substations located in flood-prone areas along the coast and along waterways subject to high water levels during hurricanes and sustained rainfall, and a concrete wall around the perimeter of CenterPoint Houston's back-up distribution control center. Mobile Substations provide back-up to substation equipment that fails or is otherwise removed from service during extreme water events, while MUCAMS enhances the reliability of communications networks needed to monitor the status of secondary grid and spot networks in Downtown Houston, the Texas Medical Center, and large area loads The substations selected for elevation are based on site-specific flood hazard potential described in Section 6.3.4, which identifies the magnitude and criticality of the load at risk.

Table 5-5: Extreme Water Resiliency Measures Costs and Benefits

Resiliency Measure[94]	Resiliency Measure No. (RM)	3-Year Capital Cost ($MM)	3-Year O&M Expense ($MM)	BCA Ratio	3-Yr CMI 2026-2028 (million)	Annual CMI 2028 (million)
Extreme Water (Flood)						
Substation Flood Control	RM - 10	$43.8	$0.0	2.1	3.9	2.0
Control Center Facility Upgrades	RM - 11	$7.0	$0.0	15.2	2.5	2.5
MUCAMS	RM - 12	$10.8	$0.0	1.3	0.6	0.2
Distribution Mobile Transformers	RM - 13	$30.0	$0.0	3.0	3.9	2.0
Group Subtotal		**$91.6**	**$0.0**	**3.3**	**11.0**	**6.6**

94 This table comprises the subset of measures for which Guidehouse has performed BCA and estimated CMI savings. Other measures included within CenterPoint Houston's SRP are excluded from this table.

5.4.2 Benchmarking

Peer Utility Benchmarking Survey

The peer utility benchmarking survey, discussed in Appendix A, indicates that seven (7) of eleven (11) respondent utilities address flood risks through their resiliency plans (Figure A-5). As a coastal utility with a history of extreme water events, flood risk is particularly notable for CenterPoint Houston.

Eight (8) utilities indicated that a primary goal of the resiliency measure is to decrease the impact of major events (Figure A-4), which aligns with CenterPoint Houston's Substation Flood Control measure, while three (3) indicated reduced restoration time was a primary goal, which aligns with CenterPoint Houston's Control Center Flood Control and MUCAMS measures. As indicated in Figure A-2, four (4) of the nine (9) utilities who responded to the question include raising substations within their resiliency programs, and four (4) include data center facilities upgrades.

Jurisdictional Benchmarking

The jurisdictional benchmarking report, provided as Appendix B, also indicates that the types of measures CenterPoint proposes to address extreme water risks are common measures across jurisdictions. Of the 17 states in Table B-4, a majority (9) have included substation flood control proposed investments or generally consider them within scope, while many of the other states have a relatively low risk of flooding associated with coastal storms. Some specific examples include:

- Hawaiian Electric identifies flood mitigation and re-locating equipment outside flood-prone areas as part of their resiliency efforts.
- In 2022, the New Jersey Board of Public Utilities approved PSE&G's proposed investment in electric substation flood mitigation as part of their Energy Strong Program.

Further, the jurisdictional benchmarking analysis indicates that several jurisdictions plan to mitigate at-risk substations located within 100-year floodplain levels using location-based flood probabilities combined with asset elevation data, similar to the approach CenterPoint Houston took for its SRP.

Within Texas, Texas-New Mexico Power (TNMP) – which has a service area on the Gulf Coast adjacent to CenterPoint Houston – also included flood mitigation measures within its SRP.

5.4.3 Substation Flood Control

5.4.3.1 Resiliency Measure Description

CenterPoint Houston's flood control resiliency measure is designed to protect at-risk substations vulnerable to flooding along shorelines that previously have or are expected to encounter high water conditions, and that can damage or cause critical equipment to fail or mis-operate. Substations most susceptible to flooding are either located along the Gulf Coast shoreline or adjacent to rivers and streams, as presented in Section 6.3.4. Several CenterPoint Houston substations have experienced high water conditions in prior storms, some of which have caused equipment to fail, resulting in extended outages and costly repairs. For example, Hurricane Harvey caused severe flooding throughout CenterPoint Houston's service territory, with 17 substations experiencing significant inundation, including 8 substations taken out of service as a precautionary measure. To address this risk, CenterPoint Houston proposes to raise vulnerable substation equipment such as protective relays, switchgear, and remote terminal units (*i.e.*, SCADA communications) to at least 2 feet above the design flood based on 500-year flood likelihood within floodplains.

The Substation Flood Control measure will raise and/or replace the substation site telecommunication huts to the same level as the correlating control house to increase the resilience of the devices transmitting substation data to systems and individuals that monitor the substation in real time. Without this information, CenterPoint Houston would not have operational visibility into the substation, thus hindering its ability to make operational decisions during a resiliency event.

As discussed in Section 4.2.2, the projected impact of flooding and extent of CenterPoint Houston's service area included in the 100-year, 200-year, and 500-year floodplain is expected to increase over time, as evidenced by historical increases in flood depth and flooded fraction thus placing more substations at risk of flooding. For example, Guidehouse's analysis indicates most substations in Galveston are at risk of flooding for a hypothetical 500-year flood. Under CenterPoint Houston's resiliency measure, equipment sensitive to flooding will be elevated 2 feet or higher above the design flood elevation levels via permanent structures. Substations targeted for flood control mitigation in CenterPoint Houston's service area include locations most susceptible to flooding with additional consideration of the magnitude of load at risk and service to critical customers or facilities (*e.g.*, hospitals or facilities providing emergency services during storms).

5.4.3.2 Revisions from the Prior System Resiliency Plan

CenterPoint Houston proposes to increase spending on the Flood Control measure as proposed in the prior SRP, resulting in twelve substations proposed for elevation over the 3-year Resiliency Plan. Except for using a higher VoLL and higher cost per substation, all other values applied to derive benefits in Guidehouse's prior report remain unchanged. The criteria that will be used to identify and select substations to be elevated also remain unchanged. However, the substations that CenterPoint Houston will select during the implementation phase will be informed by the detailed location-based risk analysis outlined in Section 6.3.4.

5.4.3.3 Resiliency Measure Targets

CenterPoint Houston's proposed investments for this resiliency measure are presented below.

- Number of substations targeted: **4** per year (**12** total)
- Total project cost: **$43.8 million** with an included **$4.8 million** in OT support.

5.4.3.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated three alternatives to elevating substations.

First, impermeable barriers that prevent water intrusion can be placed outside of the fence perimeter. Some utilities and other industries have installed perimeter barriers to limit water intrusion during high water events, but often only as a short-term measure. CenterPoint Houston is proposing to install perimeter barriers as an interim measure in some strategic substation locations until the completion of permanent upgrades. The installation of perimeter barriers is also dependent on the permeability of the ground around the substation and is not a viable long-term solution.

Second, high-velocity pumps capable of draining large volumes of water during heavy rains or floods can be installed along with containment facilities at sensitive equipment locations. CenterPoint Houston eliminated this option from consideration because, while these systems are effective for modest rainfall, they are ineffective during major water events like floods or hurricanes.

Third, relocating existing or constructing new substations to areas located above the floodplain are possible options. However, the cost of purchasing the land for new locations and the relocation or new construction is relatively high compared to the other alternatives considered. Thus, CenterPoint Houston eliminated this option from consideration. Further, these conditions do not exist for any of the substations proposed for flood control mitigation by CenterPoint Houston in its current 3-year SRP. However, relocation may be a suitable option for some substations included in future SRPs.

Finally, as discussed above, the alternative to raising telecommunications huts at raised substations is to perform reactive repairs each time water damages the hut and dispatch necessary personnel to maintain substation operational visibility during high water events. This option requires significant monitoring and use of company personnel. Raising telecommunications huts preemptively is a superior alternative regarding cost, efficacy, personnel allocation, and reducing customer outages during high water events.

5.4.3.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level using an array of best practice project type alternatives.

Substation and transmission asset mitigations were primarily structural enhancements, such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements that are more asset-centric.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.4.3.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Flood Control mitigation resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1, with measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include the likelihood that future flooding events will inundate sensitive equipment to levels that will cause equipment to fail or mis-operate. Water levels 2 feet above ground level for most substations place critical equipment at risk.[1] The probability over the next 10 years that these conditions will likely occur at the twelve substations proposed for mitigation averages 3.0%. Of these events, 20% are expected to cause damage to substation equipment. The amount of load at risk that could be mitigated by CenterPoint Houston's flood control mitigation resiliency measure is 75 MW (average load served from 12.47kV and 34.5kV substations), with an average restoration time of 36 hours.[2] Other benefits include the avoided cost of repairs and crew time required to restore service, estimated at $500,000 per flooding event. The Substation Flood Control resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 3.9 million and 2.0 million annually by 2028. From these assumptions, Guidehouse derived a BCA of 2.1.
2. **Qualitative Benefits** – The potential for multiple substations to fail during a major flood with attendant lengthy outages would have widespread economic and societal consequences. Substations serving critical loads and the resulting impact on industries and businesses served by these substations would be consequential. As described in Section 4.2.2, the frequency of major flood events in CenterPoint Houston's service area has increased over time and is expected to continue increasing.

5.4.3.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Substation Flood Control resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The proposed solution provides significant value to CenterPoint Houston customers. The likelihood of severe flooding is high, resulting in a robust BCA.
- The proposed measure is consistent with practices deployed at other utilities based on peer utility benchmarking survey results presented later in this report.[95]
- Implementation of flood control measures at substations helps avoid the significant negative economic and societal impacts of widespread, lengthy outages.

5.4.4 Control Center Flood Control

5.4.4.1 Resiliency Measure Description

CenterPoint Houston's Control Center ("AOC") Facility Upgrade resiliency measure is designed to protect the backup control center from damage caused by major floods or storm surges. The Control center facility is located within the Harris County floodplain and is susceptible to flooding for 500 years or greater events. The AOC is also located downstream of an earthen dam. If the dam were breached, the Control center facility would be inundated with water.[125] The AOC is a critical facility as it provides essential backup to CenterPoint Houston's primary operations control center. It can also function as CenterPoint Houston's primary distribution operations center for the entire CenterPoint Houston footprint when needed. Flooding would result in the loss of critical data and functionality of monitoring devices and control systems. Damage would be extensive as servers, control stations, and other facility equipment would be damaged beyond repair. Most importantly, a loss of the Control center facility would jeopardize CenterPoint Houston's ability to maintain continuous contingency support of critical operating systems. CenterPoint Houston proposes constructing a concrete wall around the facility to mitigate exposure to flood damage.

The cost to build the flood wall is **$7 million**. Construction will be completed by 2028.

5.4.4.2 Revisions from the Prior System Resiliency Plan

The only revision to the prior SRP is an increase in the VoLL from $25,000 per MWh to $35,000 per MWh.

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[95] An example of a utility that has installed comparable flood mitigation is FirstEnergy's Jersey Central Power & Light operating company, which recently reported on its efforts to enhance flood protection for substations as described here: FirstEnergy. (2023 February). *High and Dry: JCP&L Substation Investments Keeping Electricity Flowing During Storms* [FirstEnergy Substation Flood Control]. https://www.firstenergycorp.com/newsroom/featured_stories/jcpl-substation-investments-keeping-electricity-flowing-during-storm.html

5.4.4.3 Resiliency Measure Targets

CenterPoint Houston proposes to complete fence construction by 2028.

5.4.4.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, considered alternatives for the Control Center Flood Control Resiliency Measure that included building a new control center in a different location, the use of temporary flood containment walls, or the use of pumps to mitigate damage from flood waters.

The new facility would be significantly more costly than building a concrete wall and was removed as an option due to economic infeasibility. Temporary walls were found to be effective in a temporary (short-term) flooding situation but were not as robust during an event that would inundate the control center with water. The temporary walls were consequently removed as an option due to their lack of full-time effectiveness. High-velocity pumps were also a useful alternative in a temporary (short-term) flooding event but could be inundated with water and potentially fail. Consequently, these were not a viable option for the potential elevation and duration of the extreme water event that could likely occur at this location.

5.4.4.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Substations and transmission asset mitigations were primarily structural enhancements, such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements that are more asset-centric.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.4.4.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Control Center Facility Upgrades resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include the likelihood that absent perimeter fencing, future flooding events will inundate sensitive equipment to levels that will cause systems or equipment to fail. The amount of load at risk of an extended outage avoided by CenterPoint Houston's Control center facility Upgrade resiliency measure is 5,000 MW, with restoration times extended by 1 day.[126] Other benefits of this project include avoiding load loss, shorter restoration times, avoidance of the cost to repair systems and equipment at the Control center facility, avoiding repairs and crew time required to restore service, and recovery of lost data from servers. The cost to repair a damaged AOC is estimated at $20 million. The Control center facility Upgrade is expected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 2.5 million annually by 2028. From these assumptions, Guidehouse's analysis of CenterPoint Houston's Control center facility Upgrade derived a BCA of 15.2.
2. **Qualitative Benefits** – The potential for extended outages due to a loss of the primary and backup control centers could have widespread economic and societal impacts on CenterPoint Houston's customers, critical loads, and industries and businesses. As described in Section 4.2.2, the frequency of major flood events in CenterPoint Houston's service area has increased and is expected to continue to rise over time.

5.4.4.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Control Center Facility Upgrade resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The AOC has a critical role in service restoration during storms. While the likelihood of a simultaneous malfunction of the primary and backup control centers is low, the consequences would be severe. The loss of visualization and control of the transmission and distribution system would hinder operations staff, likely resulting in extended outages.
- The low cost of preventing such an event through the proposed upgrade resulted in a favorable BCA value.
- The proposed measure is consistent with practices deployed at other utilities based on Guidehouse experience and familiarity with control center backup facilities.
- Implementation of the Control Center Facility Upgrades resiliency measure avoids the significant negative economic and societal impacts associated with extended outages if the AOC were to become inoperable due to flooding simultaneously with the malfunction of CenterPoint Houston's primary operations control center.

5.4.5 MUCAMS

5.4.5.1 Resiliency Measure Description

CenterPoint's Major Underground Communications and Monitoring System (MUCAMS) measure is designed to improve the reliability of its communication network for major underground electric assets located in the secondary grid and spot networks in Downtown Houston, the Texas Medical Center, and several large industrial complexes. Near-term upgrades planned by CenterPoint include replacing older vintage, at-risk copper communication wire with its current standard of fiber optic cable, primarily in downtown Houston, including areas supporting primary radial and secondary grid networks. Copper cable is at risk of failure during major flooding events and is considered an obsolete communication path. If such failure were to occur, this would jeopardize the ability of CenterPoint's distribution operation center personnel to have visibility to monitor equipment status, faults, and operations remotely.

System operators' inability to remotely monitor a portion of the system during a resiliency event due to communications failures could slow down the identification and response to system issues, resulting in longer restoration times. These planned communication system upgrades will better enable CenterPoint to reliably monitor equipment loading, voltage, water levels, relay status (and remote adjustments, where applicable), equipment malfunction, fault location, and switch status during resiliency events such as flooding events.

5.4.5.2 Revisions from the Prior System Resiliency Plan

None. MUCAMS was not included in CenterPoint Houston's prior SRP filing.

5.4.5.3 Resiliency Measure Targets

CenterPoint's proposed SRP investments for MUCAMS appear below:

- Number of cable segment locations targeted: **106** per year (**318** total) over 11 of 12 ring networks
- Total measure cost: **$10.8 million**

5.4.5.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated the following two alternatives to MUCAMS fiber optic installation: continuing with less sophisticated copper communications and installing new radio frequency radios to improve situational awareness within the major underground distribution system.

First, in lieu of fiber optics installation, CenterPoint Houston could continue to install copper conductors for communication in locations where the MUCAMS could offer coordination with other devices. The copper conductor offers similar connectivity (although not as great a distance) and provides the same functionality as the existing system for most faults but has reduced communications information and visibility from the control centers. Therefore, CenterPoint Houston eliminated this from consideration as a preferred alternative.

Second, constructing new radio frequency communications to improve situational awareness could be a viable alternative to the major underground distribution system. This solution is also typically far less reliable than its copper wire counterpart as it requires line-of-site communication and the use of an antenna, which would require mounting above ground. Further, this would likely result in greater communications outages on the newly built communications platform as there could be interference, antenna, connection, and/or radio issues.

5.4.5.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.4.5.6 Benefits Analysis

The primary benefit of CenterPoint's MUCAMS measure is the improved reliability of the underground cable communications system. Guidehouse views communication systems as an essential functional capability required for electric utilities and, therefore, does not support reporting traditional quantitative benefits. Thus, measure benefits are described qualitatively.

1. **Quantitative Analysis** – The value of MUCAMS is based on the reduced time to detect and respond to a spot or grid network equipment failure resulting from a loss of communications from the existing copper wire at one or more locations within CenterPoint Houston's 12 network rings serving grid and spot network load in Downtown Houston, Texas Medical Center, and large industrial load. The average load within each network is 87.5 MW, with load at risk at individual grid network vaults at 1 MW. The average number of annual faults is 1.6 per network ring or 3.7 percent failure rate per network transformer. The percent of failures that result in load loss is estimated at 10 percent, with an 8-hour increase in repair time due to loss of communications. The MUCAMS measure is expected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 0.6 million and 0.2 annually by 2028. From these assumptions, Guidehouse's analysis of CenterPoint Houston's Control center facility Upgrade derived a BCA of 1.3.
2. **Qualitative Benefits** – CenterPoint's MUCAMS measure is intended to improve the reliability and functionality of its communication network serving underground electric equipment. Specific applications and features include more reliable communications and enhanced equipment monitoring in network vaults. The measure can be classified as a resiliency measure because it will improve real-time system monitoring, visualization, and control of underground equipment during major flood events. Over the long term, the MUCAMS measure should enhance the resiliency of CenterPoint's system, particularly for urban areas serving critical loads. Targeting improvements in underground networks is particularly beneficial for resiliency as underground networks typically require longer restoration times than overground networks.

5.4.5.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint's MUCAMS measure meets the PUCT's proposed requirements as it improves its communications infrastructure's reliability, resiliency, and functionality, particularly during freezing or flooding events when the load at risk is high. Although the BCA is low compared to other measures, these findings support Guidehouse's position that the measure is consistent with the PUCT's proposed resiliency requirements and statutory objectives. The transition to fiber optics communications to support enhanced monitoring, visualization, and control functions is consistent with leading practices for electric utilities based on Guidehouse's experience advising clients in North America and worldwide.

5.4.6 Mobile Substations

5.4.6.1 Resiliency Measure Description

CenterPoint Houston's Distribution Mobile Transformers is designed to provide back-up to substation transformers or equipment failure during resiliency events, for example, transformer failure caused by repeat close-in faults on distribution circuits. The measure also ensures there are enough mobile devices available for transport to substations as some of the mobile substations are needed to provide temporary supply to related substation upgrades such as the 69kV to 138kV Conversion measure and Distribution Capacity Enhancement/Substations. Each mobile substation is equipped with two trailers, one for the transformer and the second for breakers and ancillary equipment. They will be placed in locations that ensure ready access and transport to substations within CenterPoint Houston's service territory.

5.4.6.2 Revisions from the Prior System Resiliency Plan

None. CenterPoint Houston's prior SRP did not include the Distribution Mobile Transformers replacement measure.

5.4.6.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for mobile substations are presented below.

- Number of purchases targeted: **2** per year (**6** total over 3 years)[12]
- Total project cost: **$30 million** over the 3-year Plan

5.4.6.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated two alternatives to mobile substations.

First, installing secondary transformers at substations to allow for additional load and switching capabilities along multiple circuits to pick up load from circuits being fed from a compromised substation. However, this is a very expensive and complex process and is not feasible in a timely fashion. It also does not make substations fully resilient (extreme water issues remain even with additional transformers).

Second, another option is to leave the substations as-is and install temporary generation along circuits to supply power to customers. This option would provide power to customers, but it is noisy, would consume quite a bit of fuel for a process that lasts several months/years, and is environmentally unfriendly. This may also have regulatory concerns, adding further to this not being viable.

Overall, the most reliable and economically feasible solution is to have mobile substations on standby to react in the event of a high-impact, low-frequency event. This would allow power to be restored quickly for customers served by the impacted substation.

5.4.6.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.4.6.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Distribution Mobile Transformer resiliency measure on both a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of transformer and equipment failures during resiliency events, the average number of customers or load at risk, and the estimated time to repair equipment. The failure rate of substations where mobile devices could be installed is 1.5%. Of these failures, 40 percent are assumed to result in an interruption of customer load. The estimated average load at risk is 75 MW, with an average restoration time of 72 hours. Other benefits include reduced crew labor costs to restore service without the installation of mobile devices. The Distribution Mobile Transformer resiliency measure is projected to reduce cumulative CMIs over the 3-year SRP by approximately 3.9 million and 2.0 million annually by 2028. From these assumptions, Guidehouse derived a composite BCA of 3.0.

2. **Qualitative Benefits** – The potential for lengthy and costly repairs when cables fail during extreme weather events is significant. For systemwide storms that cause multiple

substation equipment failures, the number of customers that may experience lengthy interruptions also can be high. The installation of mobile substations during these events will materially reduce the impact of extended outages. When coupled with other resiliency measures, collectively, it will reduce the economic impact and disruption of customers served by distribution substations' resiliency events.

5.4.6.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Distribution Mobile Transformer resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- It cost-effectively minimizes the risk of lengthy customer interruptions caused by failure of distribution substation equipment during resiliency events.
- The purchase of mobile substations provides increased flexibility and requisite backup capacity during substation expansion or upgrades.
- The measure produces a favorable BCA ratio.
- Based on prior Guidehouse experience and peer utility benchmarking survey results, the purchase of mobile transformers is a common utility practice.

5.5 Extreme Temperature (Freeze) Measures

5.5.1 Measure Category Summary

The extreme temperature (freezing) category targets measures presented in Table 5-6 that mitigate the impact of exceptionally low temperatures on CenterPoint Houston's distribution assets. It includes three measures, each of which was not addressed in the prior SRP. One is the installation of dampeners on transmission lines to avoid conductor slapping and damage during ice storms.

The second expands the IGSD measure to enhance distribution circuit tie transfer capability that is constrained due to increased line loading due to extended cold temperatures. The third is to address higher-than-expected substation distribution transformer loading caused by extended cold temperatures such as those experienced during the Uri extreme cold weather event in February 2021; for example, increased contemporaneous space heating loads.

Table 5-6: Extreme Temperature (Freeze) Resiliency Measures Costs and Benefits

Resiliency Measure[96]	Resiliency Measure No. (RM)	3-Year Capital Cost ($MM)	3-Year O&M Expense ($MM)	BCA Ratio	3-Yr CMI 2026-2028 (million)	Annual CMI 2028 (million)
Extreme Temperature (Freezing)						
Anti-Galloping Technologies	RM - 14	$14.0	$1.0	7.1	5.3	2.6
Group Subtotal		**$14.0**	**$1.0**	**7.1**	**5.3**	**2.6**

5.5.2 Benchmarking

Peer Utility Benchmarking Survey

The peer utility benchmarking survey, discussed in Appendix A, indicates that seven (7) of eleven (11) respondent utilities address extreme temperature risks through their resiliency plans (Figure A-5), and eight (8) utilities indicated that a primary goal of the resiliency measure is to decrease the impact of major events (Figure A-4), which aligns with CenterPoint Houston's proposed Extreme Temperature (Freeze) measures. Seven (7) utilities indicated investment in transmission lines, which aligns with Anti-Galloping Technologies (Transmission), while ten (10) indicated investment in distribution lines, which aligns with the Loadshed IGSD measure.

Jurisdictional Benchmarking

The jurisdictional benchmarking report, provided as Appendix B, also indicates that the types of measures CenterPoint Houston proposes for Extreme Temperature (Freeze) are employed by peer utilities. For example, Oncor sought to address both extreme cold and heat in its SRP, and it accordingly included Automated Feeder Switches, which aligns with CenterPoint Houston's Loadshed IGSD measure.

In relation to the Microgrids Pilot Measure, of the 17 states in Table B-4, a majority (10) include microgrids and/or other distributed energy resources.

5.5.3 Anti-Galloping Technologies (Transmission)

5.5.3.1 Resiliency Measure Description

CenterPoint Houston's Anti-Galloping Technologies measure is designed to reduce the number of phase-to-phase conductor contacts on 138kV transmission lines during extreme cold weather events. Conductor contact occurs when lines experience sinusoidal galloping caused by ice build-up and high winds. CenterPoint Houston proposes installing dampeners and sensors on 138kV lines subject to galloping; for example, those following corridors are perpendicular to the

[96] This table comprises the subset of measures for which Guidehouse has performed BCA and estimated CMI savings. Other measures included within CenterPoint Houston's SRP are excluded from this table.

prevailing wind direction. Transmission lines throughout CenterPoint Houston service territory are subject to icing, as cold weather conditions have, and are expected to occur in all regions.

5.5.3.2 Revisions from the Prior System Resiliency Plan

None. CenterPoint Houston's Anti-Galloping Technologies measure was not included in the prior SRP.

5.5.3.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for anti-galloping technologies is presented below.

- Number of air spoilers targeted: approximately **25** per year (**75** total over 3 years)
- Number of sensors targeted: approximately **25** circuit miles per year
- Total project cost: **$15 million** over the 3-year Plan

5.5.3.4 Alternatives Considered

One alternative investigated was drone technology that leverages a device to effectively "break" the ice, thereby mitigating the lift of the conductor, which causes galloping. Other Utilities have succeeded with these drones in breaking ice from conductors to resolve ice accumulation. This is similar to our current methodology in that it is reactive and "breaks up" the ice after it has formed and is not a preventative measure (i.e. not proactive but reactive). The reactive nature made this non-viable.

A special conductor was also considered. This conductor is configured to prevent ice from forming and provide wind to lift it. However, the cost of this conductor is significantly higher for existing lines as it requires reconductoring the entire circuit, so it was not considered a viable alternative.

A third alternative was expanding the distance between conductors. This is an expensive option as it would require significant reconfiguration, even rebuilding, of tower structures, making it unviable.

5.5.3.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Substations and transmission asset mitigations were primarily structural enhancements such as elevating substations above inundation levels or replacing existing transmission structures with designs capable of withstanding higher wind speeds. The discrete nature of these projects results in efficacy measurements that are more asset-centric.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent of resilient power delivery asset failures projected to fail during a Resiliency Event
3. Percent of resilient power delivery asset failures occurring during a Resiliency Event

5.5.3.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Anti-Galloping Technology resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of conductor contacts causing load interruptions, the average number of customers or load at risk, and the estimated time to inspect and repair conductor contact and restore service for loss of load events. The number of galloping events causing contact where dampeners are proposed is 0.1% per mile. Of these contacts, 25% are assumed to result in an interruption of customer load. The estimated average load at risk is 175 MW, with an average restoration time of 36 hours. Other benefits include reduced costs for truck rolls and crew labor to repair damaged conductors (via splices) and restore service absent the installation of dampeners. The Anti-Galloping Technology replacement resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 7.6 million and 4.9 million annually by 2028. From these assumptions, Guidehouse derived a BCA of 2.4.

2. **Qualitative Benefits** – Although the probability of catastrophic failure of conductor galloping is low, the potential for extensive customer interruptions when transmission conductors cause multiple lockouts during extreme cold weather events is high. For systemwide storms that cause a large number of outages due to concurrent failures or lockouts, the potential for affected customers to experience lengthy interruptions before repairs are made can also be high. Installing dampeners on at-risk lines will materially reduce the number of conductor contacts during resiliency events. When coupled with other resiliency measures, collectively will reduce the economic impact and disruption of customers impacted by extreme cold resiliency events.

5.5.3.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Anti-Galloping Technologies resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The proposed solution provides significant value to CenterPoint Houston customers. The likelihood of conductor contact is high on certain transmission lines subject to galloping during extreme cold events.
- The proposed measure is consistent with practices deployed at other utilities based on Guidehouse experience and knowledge of utility practices.
- The measure produced a robust BCA due to the relatively low cost of installing dampeners.
- Implementation of anti-galloping measures on at-risk transmission helps avoid the significant negative economic and societal impacts associated with widespread, lengthy outages caused by concurrent conductor failures or circuit lockouts.

5.5.4 Loadshed IGSD

5.5.4.1 Resiliency Measure Description

The Loadshed IGSD measure is designed to enable CenterPoint Houston's control center personnel to selectively interrupt lower priority loads on less critical line sections in response to an ERCOT mandated load reduction event. IGSD systems will be used to isolate less critical sections of distribution circuit load via the opening of reclosers located downstream of critical loads.

5.5.4.2 Revisions from the Prior System Resiliency Plan

None. CenterPoint Houston did not include Loadshed IGSD in the prior SRP.

5.5.4.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments appear below.

- Number of schemes and IGSD installations targeted:
  - **Approximately 300 devices** and about **100 IGSD tie transfer schemes** per year (and **900** total number of devices**, and about 300 schemes** respectively, over 3 years)[97]
  - **50** devices for IGSD wildfire segmentation per year **(150** total over 3 years**)**
  - **12** devices for ERCOT load shed events per year **(36** total over 3 years**)**
- Total project cost (capital and expense):
  - **$107.8 million** for IGSD schemes and **$ 5.9 million** for Telecom support
  - **$19.7 million** for IGSD wildfire segmentation
  - **$4.6 million** for ERCOT load shed events.

[97] Each IGSD transfer schemes is assumed to require 3 switching devices, one at the midpoint of each feeder, and one at the open tie point between each feeder.

- The associated expense to install the new equipment over three years is **$0.5 million**.

5.5.4.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated two alternatives to load shed IGSD devices: installing switches and interrupting higher priority loads.

First, in lieu of load shed IGSD devices, CenterPoint Houston could install manual pole-top switches on main circuits and lateral taps in locations where these could isolate loads from upstream service. These switches provide the same isolation as load shed IGSD devices but are manual, require time to send a crew to the location to operate, and have no communications information and visibility from the control centers. Therefore, CenterPoint Houston eliminated this from consideration as an alternative.

Second, simply leveraging the substation breaker to operate and disconnect everyone along a circuit (including critical customers identified) is not a viable option as the intention is to shed load when called upon by ERCOT while continuing to feed these critical customers and isolate other loads from the circuit.

5.5.4.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.

4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.5.4.6 Benefits Analysis

Not applicable as CenterPoint Houston is obligated to comply with ERCOT load reduction events.

5.5.4.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Loadshed resiliency measure is reasonable and beneficial for inclusion in its SRP. It is a low-cost approach to ensuring that distribution circuits serving critical loads that are not classified as relay-exempt are not interrupted in response to an ERCOT load reduction event.

5.5.5 Microgrids Pilot

5.5.5.1 Program Description

Guidehouse conducted an overall qualitative assessment of CenterPoint Houston's proposed Microgrid Pilot Program. Guidehouse did not complete a quantitative assessment because CenterPoint Houston proposes this measure as a demonstration project to gain learnings and determine the costs, benefits, and implementation challenges for such projects before considering a greater investment. One of the key objectives of the pilot is to test and evaluate the integration of large microgrids into CenterPoint Houston's distribution system to determine their capability to serve large loads, including City centers, reliably. CenterPoint Houston's investment in microgrid interconnections will be limited to distribution protection and monitoring systems needed to operate complex microgrid systems in both stand-alone and parallel operating modes.

Findings from the pilot could help inform future BCAs to determine if such investments are cost-effective for a more broad application as part of CenterPoint Houston's future distribution plans. Guidehouse agrees that a microgrid pilot project is a reasonable first step to take to determine if microgrids are a worthwhile investment. Microgrid projects are commonly included in electric utility planning efforts, often initially in the form of pilot projects, as evidenced in the jurisdictional benchmarking discussed later in this report.

5.5.5.2 Revisions from the Prior System Resiliency Plan

CenterPoint Texas proposes to increase spending on the Microgrid Pilot due to the greater complexity of pilot programs that developers are expected to propose to CenterPoint Houston. These proposals are expected to include multiple independently owned generators and interconnections serving large area loads. These proposals may require upgraded protection systems and new distribution line segments to deliver microgrid generator output to serve load while operating in stand-alone mode.

5.5.5.3 Program Targets

CenterPoint Houston proposes to support the development and evaluation of Microgrid pilot projects at locations proposed by independent developers.

5.5.5.4 Alternatives Considered

Not applicable as a pilot program.

5.5.5.5 Program Metrics and Effectiveness

CenterPoint Houston will report annually to the PUCT progress reports and evaluation of pilot program objectives.

5.5.5.6 Benefits Analysis

As a pilot program, benefits are not quantified. CenterPoint Houston's customers, over time, will realize benefits as microgrids are pursued by customers and developers as a backup source of supply during resiliency events. Learnings achieved via the pilot program, including operational, economic, and safety factors, are necessary to support the integration of microgrids into behind-the-meter locations for CenterPoint Houston's customers, including critical load centers.

5.5.5.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Microgrids Pilot Program is reasonable and beneficial for inclusion in CenterPoint Houston's SRP, as it supports CenterPoint Houston's long-term strategy to support independent developers and customer initiatives to diversify supply options and continuity of electricity service during resiliency events. The experience and insights gained from these pilots will ensure future Microgrid projects can be reliably integrated into CenterPoint Houston's transmission and distribution system and operated following Company practices and standards.

5.6 Extreme Temperature (Heat)

5.6.1 Measure Category Summary

The Extreme Temperature (Heat) category targets measures presented in Table 5-7, to mitigate the impact of extended dry periods and extremely high temperatures on CenterPoint Houston's distribution assets. It includes prior and new measures, with Distribution Capacity Enhancement/Substations, URD Cable Modernization and Saltwater Contamination as new, and Wildfire Mitigation, Substation Fire Protection Barriers, and Digital Substation carry-overs to the prior SRP. However, the Wildfire Mitigation measure includes fewer individual approaches to mitigation than the prior SRP, with some options, such as Strategic Undergrounding and Vegetation Management, overlapping with other event categories. CenterPoint Houston proposes to undertake a technology-focused approach, such as advanced analytics, to proactively detect nascent wildfires before they spread to major events. Similarly to the prior SRP, Guidehouse did not derive a BCA ratio for Wildfire Mitigation as the impact of wildfire events extends beyond those affecting CenterPoint Houston's electric assets and ratepayers.

Table 5-7: Extreme Temperature (Heat) Resiliency Measures Costs and Benefits

Resiliency Measure[98]	Resiliency Measure No. (RM)	3-Year Capital Cost ($MM)	3-Year O&M Expense ($MM)	BCA Ratio	3-Yr CMI 2026-2028 (million)	Annual CMI 2028 (million)
Extreme Temperature Heat)						
Distribution Capacity Enhancement/Substations	RM - 16	$579.6	$0.0	5.6	138.1	70.6
MUGS Reconductoring	RM - 17	$245.0	$0.0	1.4	13.6	7.4
URD Cable Modernization	RM - 18	$128.4	$0.0	2.2	13.0	6.5
Contamination Mitigation	RM - 19	$144.0	$6.0	2.4	15.7	7.9
Substation Transformer Fire Barriers	RM - 20	$9.0	$0.0	4.0	1.5	0.7
Digital Substation	RM - 21	$31.8	$0.0	1.8	1.2	0.7
Group Subtotal		**$1,137.8**	**$6.0**	**3.8**	**183.1**	**93.8**

5.6.2 Benchmarking

Peer Utility Benchmarking Survey

The peer utility benchmarking survey, discussed in Appendix A, indicates that seven (7) of eleven (11) utilities address extreme temperature risks through their resiliency programs, and four (4) utilities address wildfire risks (Figure A-5). Both issues are addressed in CenterPoint Houston's proposed Extreme Temperature (Heat) measures.

Eight (8) utilities indicated that a primary goal of the resiliency program is to decrease the impact of major events (Figure A-4), while three (3) indicated that reduced restoration time was a primary goal. Of CenterPoint Houston's proposed measures to address extreme temperature (heat) risks, most help to reduce the impact of major events, while some (*e.g.*, Digital Substation) also help to reduce restoration time.

Figure A-3 indicates that, of 11 respondents, most include transmission substations (8), transmission lines (8), distribution substations (8), and distribution lines

[98] This table comprises the subset of measures for which Guidehouse has performed BCA and estimated CMI savings. Other measures included within CenterPoint Houston's SRP are excluded from this table.

(10) within their resiliency programs. CenterPoint Houston proposes measures to address extreme temperature (heat) risks to transmission and distribution infrastructure.

As depicted in Figure A-2, all respondent utilities include infrastructure hardening investments in their resiliency programs, seven (7) of nine (9) respondents include grid modernization, and the specific types of investments align significantly with the types of measures CenterPoint proposes to use to address extreme wind risks. As depicted in Table 5-8, most of the nine (9) utilities that responded to the question include undergrounding (7), smart grid upgrades (7), digital OT systems (5), substation automation (6), monitoring of assets (5), and use of monitoring cameras/communications (5).

Table 5-8: Resiliency Survey Investment Types (Extreme Temperature/Drought Measures)

Type of Investment[99]	Respondent Utility Company ID								
	102	103	106	107	108	109	114	122	123
Undergrounding of key lines or portions (*e.g.*, freeway crossings)	✓	✓	✓		✓	✓		✓	✓
Smart grid upgrades	✓	✓	✓	✓		✓	✓	✓	
Digital substation OT systems	✓	✓				✓	✓	✓	
Substation automation	✓	✓	✓			✓	✓	✓	
Monitoring of assets	✓	✓				✓	✓	✓	
Use of monitoring cameras, communications	✓	✓	✓				✓	✓	

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

Jurisdictional Benchmarking

The jurisdictional benchmarking report, provided as Appendix B, also indicates that the types of measures CenterPoint proposes to address extreme temperature (heat) risks are common measures across jurisdictions. Of the 17 states in Table B-4, a majority include undergrounding (13), vegetation management (10), and transmission (10) measures within proposed investments or generally consider them within scope.

Utilities such as Southern California Edison and NV Energy employ similar measures to those proposed by CenterPoint Houston, including measures to monitor and predict wildfire risk, reduce the likelihood of wildfire events associated with electricity infrastructure, detect wildfire events, protect infrastructure from fire damage, reduce outage impacts associated with wildfire events, and accelerate recovery times. Notably, utilities such as Southern California Edison have spent several billion dollars on wildfire mitigation and are expected to continue aggressively pursuing extensive wildfire mitigation measures as outlined in recent plans filed with the California Public Utility Commission.

Within Texas, SRPs submitted by other utilities have included significant investments in wildfire mitigation measures similar to those that CenterPoint Houston is proposing to address extreme temperature (heat) risks. Additionally, TNMP – which has a service area on the Gulf Coast

[99] This table includes only the subset of resiliency measures included in the survey that are most closely associated with the measures included by CenterPoint Houston within this risk category (Extreme Temperature (Heat)). These were not categorized as such within the survey, and respondent utilities may categorize them differently. The full list of surveyed measures is included in Figure A-2.

adjacent to CenterPoint Houston – also included contamination mitigation within its SRP, and Oncor included cable injection within its SRP, which aligns with CenterPoint Houston's URD Cable Modernization measure.

5.6.3 Distribution Capacity Enhancement/Substations

5.6.3.1 Resiliency Measure Description

CenterPoint Houston's Distribution Capacity Enhancement/Substations measure is designed to enhance distribution tie transfer capability, an essential capability needed to minimize the number and duration of customer interruptions during resiliency events, particularly those experiencing high loadings during extreme weather events when electricity usage is high. The measure includes increasing distribution substation capacity via higher rated or additional power transformers and the installation of new 12.47kV and 34.5kV distribution circuits to unload existing circuits to provide for full transfer capability, accomplished via IGSD schemes as outlined in Section 5.5.4. The measure also provides tie transfer capability on distribution circuit islands, defined as circuits supplied by substations that cannot be transferred to circuits due to the absence of adjacent substations needed to enable transfers. Further, it supports the 69kV to 138kV Conversion measure by installing new distribution circuits on new or upgraded substations converted from 69kV supply lines to 138kV.

5.6.3.2 Revisions from the Prior System Resiliency Plan

None. CenterPoint Houston's prior SRP did not include the Distribution Capacity Enhancement/Substations measure.

5.6.3.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for distribution capacity upgrades are presented below.

- Number of new distribution substations: **4-5** per year (**19** total over 3 years)
- Number of substations with capacity enhancements: **1** total over 3 years
- Number of new distribution circuits: **17** per year (**26 34.5kV circuits and 25 12.47kV circuits** total over 3 years)
- Number of distribution circuits with capacity enhancements (e.g., voltage conversion from 12.47kV to 34.5kV): **1-2** per year (**5** total over 3 years)
- Total project cost: **$579.6 million** over the 3-year SRP

5.6.3.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, determined that three possible alternatives to Distribution Capacity Enhancement/Substations were available. First, while installing batteries within a circuit could mitigate distribution capacity constraints (to an extent), it is not a viable, cost-effective, long-term solution considering current battery technology's limited capacity and operational duration. Two other options include customer-owned generation and demand response programs that incentivize distribution customers (affecting only distribution systems) to reduce load and mitigate distribution constraints. However, no regulatory or market framework exists at this time. The Microgrid Pilot Program being proposed in limited capacity within this SRP is similar to the abovementioned alternatives as well.

Finally, CenterPoint Houston could enhance substation and distribution circuit capacity to convert distribution circuits to operate at a higher voltage. While conversion is an option for some 12.47kV circuits (CenterPoint Houston proposes to convert some 12.47kV circuits to operate at 34.5kV for this measure) it is not viable in areas where most circuits operate at 12.47kV, if CenterPoint Houston needs to convert numerous other circuits to operate at 34.5kV. Existing 34.5kV circuits targeted for capacity upgrades cannot be converted to operate at a higher voltage as CenterPoint Houston design standards include lines rated 4kV to 34.5kV.

5.6.3.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.6.3.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed Distribution Capacity Enhancement/Substations resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of sustained faults avoided on distribution main lines where distribution circuit capacity will be enhanced, the average number of customers or load at risk per protective zone, and the estimated time to repair line failures and restore service. The failure rate of existing main lines where enhancements are proposed is 158% or 1.58 outages on main line sections per year – this value accounts for reductions in outages via the transfer of load on longer line sections to new shorter circuits at each substation. Of these failures, all are assumed to result in an interruption of customer load. The estimated average load at risk is 12 MW, with an average restoration time of 18 hours. Other benefits include reduced costs for truck rolls and crew labor to restore service absent the replacement of at-risk distribution circuits. CenterPoint Houston's Distribution Capacity Enhancement/Substations replacement resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 138.1 million and 70.6 million annually by 2028. From these assumptions, Guidehouse derived a composite BCA of 5.6.
2. **Qualitative Benefits—**The potential for lengthy and costly repairs when main line distribution circuits experience sustained faults during extreme cold weather events is significant. For systemwide storms that cause a large number of outages during cold temperatures, the number of customers who may experience lengthy interruptions can be high. The increase in distribution and substation capacity will materially reduce the impact of extended outages and, when coupled with other resiliency measures, collectively will reduce the economic impact and disruption of customers served by circuits utilizing underground cables during resiliency events.

5.6.3.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Distribution Capacity Enhancement/Substations resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- The proposed solution provides significant value to CenterPoint Houston customers. The likelihood of distribution circuit outages is high on circuits where enhancements are proposed, and existing distribution substation and circuit capacity are insufficient to enable full tie transfer capability during extreme cold weather events.
- The measure produced a favorable BCA.

- The proposed measure is consistent with practices deployed at other utilities based on peer utility benchmarking survey results presented later in this report.
- Enhancing capacity at substations helps avoid the significant negative economic and societal impacts of widespread, lengthy outages.

5.6.4 **Major Underground (MUG) Reconductor**

5.6.4.1 Resiliency Measure Description

CenterPoint Houston's Major Undergrounding Reconductor resiliency measure is designed to replace the three-phase Paper-in-Lead Cable (PILC) [100] and Cross-Linked Polyethylene (XLPE) cable that is at risk of failure during extreme weather events. Extreme weather can accelerate cable failure precipitated by voids in cable insulation or splices. CenterPoint Houston proposes to replace the XLPE cable installed during the 1970s and early 1980s that is at greater risk of failure due to insulation breakdown.[101] Similarly, the PILC cable CenterPoint Houston proposes to replace is typically more than 50 years old and susceptible to failure. During extreme weather events, the increased loading from high demand causes the insulating capability of cables to further weaken with failure resulting from voltage-initiated dielectric breakdown. At-risk cable will be replaced with Ethylene Propylene Rubber (EPR) cable, CenterPoint Houston's current standard for three-phase duct bank systems. Prioritization of MUG cable will consider cable condition, load at risk, and customer outage exposure. All cable sections that will be replaced are located in concrete duct banks below City streets.

5.6.4.2 Revisions from the Prior System Resiliency Plan

None. The MUG replacement measure was not included in CenterPoint Houston's prior SRP.

5.6.4.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for pole replacements is presented below.

- Miles of MUG cable targeted: **approximately 7.3 miles** per year (**22 miles** total over 3 years)
- Total project cost: **$245 million** over the 3-year Plan

5.6.4.4 Alternatives Considered

The only viable alternative is to continue operating with existing cable, which CenterPoint Houston rejected as it does not meet its objective to harden the distribution system to withstand resiliency events.

[100] Most PILC is located in downtown Houston serving secondary grid and spot networks.

[101] The failure of pre-1970's vintage cable is an industry-wide issue. Utilities across the U.S. are proactively replaced cable due to a high number of failures.

5.6.4.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency as well as structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.6.4.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed MUGS Reconductor resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of cable faults avoided on distribution main lines where major underground cables will be replaced, the average number of customers or load at risk, and the estimated time to repair underground cables and restore service. The failure rate of existing PILC and XLPE cables where replacements are proposed is estimated at 1%. Of these failures, all are assumed to result in an interruption of customer load. The estimated average load at risk is 12 MW, with an average restoration time of 72 hours. Other benefits include reduced costs for truck rolls and crew labor to restore service absent the replacement of the at-risk cable. The MUG Replacement resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 13.6 million and 7.4

million annually by 2028. From these assumptions, Guidehouse derived a composite BCA of 1.4.

2. **Qualitative Benefits** – The potential for lengthy and costly repairs when cables fail during extreme weather events is significant. Using a higher-rated cable that meets CenterPoint Houston's EPR standard will materially reduce the impact of extended outages and, when coupled with other resiliency measures, collectively will reduce the economic impact and disruption of customers served by circuits utilizing underground cable during resiliency events.

5.6.4.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's Major Underground Replacement resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- It cost-effectively hardens at-risk three-phase, mainline underground distribution circuits.
- The replacement of at-risk cables will result in fewer failures and sustained interruptions during extreme weather events.
- The aged XLPE and PILC cable that CenterPoint Houston proposes to replace is consistent with industry practices.
- Replacing existing cable with CenterPoint Houston's current standard (EPR) provides increased assurance of resilient operation.
- Increasing the rating of MUG cable enhances tie transfer capability during resiliency events.
- Based on prior Guidehouse experience and peer utility benchmarking survey results, the replacement of at-risk PILC and XLPE cable is consistent with resiliency practices deployed at other utilities.

5.6.5 URD Cable Modernization

5.6.5.1 Resiliency Measure Description

CenterPoint Houston's URD Cable Modernization resiliency measure is designed to harden URD cable spans at risk of failure during extreme weather events. Extreme heating can accelerate cable failure due to faults caused by voids in the cable insulation. During extreme weather events, cable loading and heating due to higher-than-expected loadings can accelerate void growth in URD cable with failure resulting from voltage-initiated dielectric breakdown. Similar to the MUGS Reconductoring measure, at-risk URD cable sections were typically installed in the 1970s and early 1980s, where cable insulation had been compromised with voids. At-risk URD cable sections will be replaced or injected with a silicon-based material that will fill voids in the surrounding cable insulation, thus increasing the dielectric strength of the cable. Vendors provide 10 to 15-year guarantees on cable life following injection – CenterPoint

Houston's prior URD cable injections have performed favorably and support the continuation of the measure on new URD spans. Prioritization of URD cable injection will consider cable condition, load at risk, and customer outage exposure.

5.6.5.2 Revisions from the Prior System Resiliency Plan

None. The URD Cable Modernization measure was not included in CenterPoint Houston's prior SRP.

5.6.5.3 Resiliency Measure Targets

CenterPoint Houston's proposed SRP quantities and investments for URD Cable Modernization measure are presented below.

- Number of URD cable spans targeted: **approximately 11,500 spans** per year (**34,500** total over 3 years)
- Total project cost: **$128.4 million** over the 3-year Plan

5.6.5.4 Alternatives Considered

The only viable alternative is to continue operating using existing cable, which CenterPoint Houston rejected as it does not meet its objective to harden the distribution system to withstand resiliency events.

5.6.5.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.

3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.6.5.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's proposed URD Cable Modernization resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates of the average number of cable faults avoided on distribution main lines and laterals where URD cable sections will be injected, the average number of customers or load at risk, and the estimated time to repair underground cable and restore service. The average cost per URD span injection is approximately $7,000, well below the cost of URD cable replacement. The failure rate of URD cable sections where proposed replacements are estimated at 2.0%. Of these failures, all are assumed to result in an interruption of customer load. The estimated average load at risk is 0.1 MW, with an average restoration time of 18 hours. Other benefits include reduced costs for truck rolls and crew labor to restore service absent the replacement of the at-risk cable. The URD Cable Modernization resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 13.0 million and 6.5 million annually by 2028. From these assumptions, Guidehouse derived a composite BCA of 2.2.

2. **Qualitative Benefits** – The potential for lengthy and costly repairs when cables fail during extreme weather events is significant. For systemwide events that cause a large number of outages due to URD cable failures, the number of customers that may experience lengthy interruptions can also be high. The use of cable injection will materially reduce the impact of extended outages and when coupled with other resiliency measures, collectively will reduce the economic impact and disruption of customers served by URD circuit sections during resiliency events.

5.6.5.7 Resiliency Measure Assessment and Conclusions

Guidehouse concludes that CenterPoint Houston's URD Cable Modernization resiliency measure is reasonable and beneficial for inclusion in CenterPoint Houston's SRP for the following reasons:

- It cost-effectively hardens at-risk URD distribution circuit sections.
- The replacement or injection of at-risk URD cable will result in fewer failures and sustained interruptions during high-temperature resiliency events.

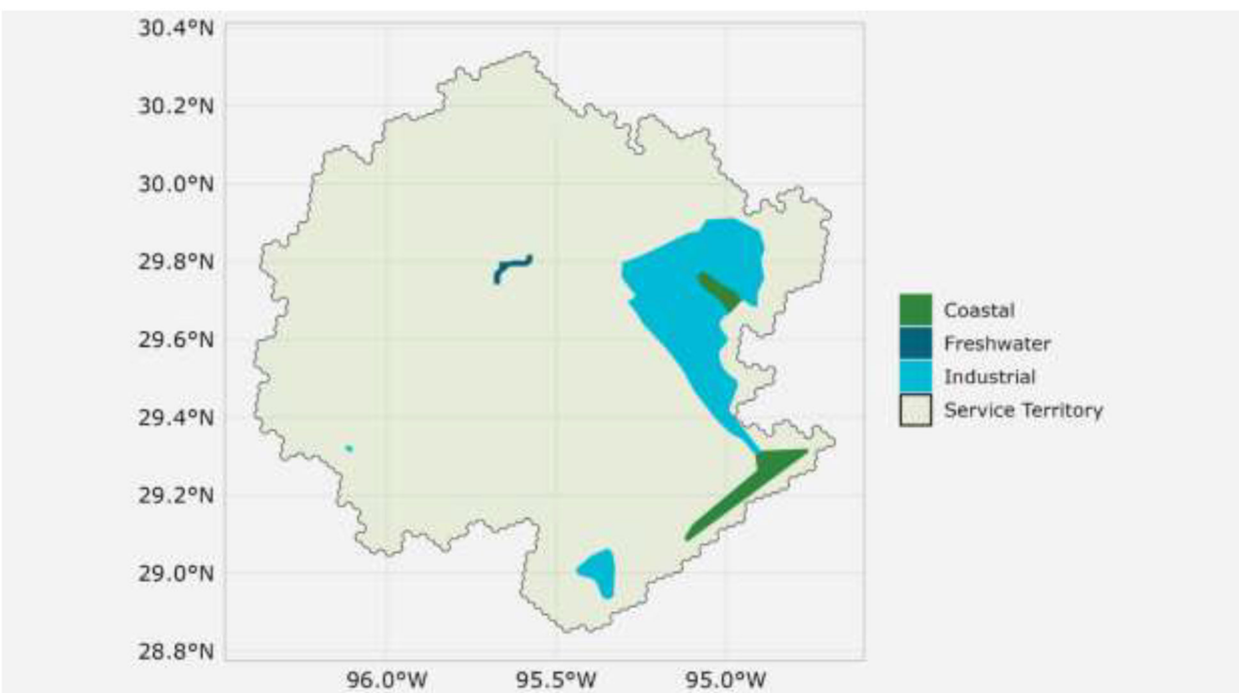
- Injecting or replacing at-risk URD cable provides increased assurance of resilient operation.
- Based on prior Guidehouse experience and peer utility benchmarking survey results, cable injection as an alternative to replacement is consistent with resiliency practices deployed at other utilities.

5.6.6 Contamination Mitigation

5.6.6.1 Resiliency Measure Description

CenterPoint Houston proposes to replace porcelain insulators and associated hardware in substations and poles and insulators on distribution circuits located within contamination zones (Figure 5-6). Contamination zones are located mostly one mile offshore from the Gulf Coast and along channels separating nearby islands from the mainland where salt build-up is prominent. Approximately 42 substations and 180 distribution circuits are located within CenterPoint Houston's saltwater contamination zones. At-risk insulators include porcelain post and bell insulators and cutouts, particularly those located on distribution circuits with wood poles and crossarms. Outages typically occur after lengthy arid periods during which highly conductive salt accumulates on the insulator; and then followed by wind-laden moisture or fog, leading to loss of basic insulation level (BIL) and flashover to ground. Substation insulator flashovers have occurred mostly on 138kV and 345kV high-side transmission trident design structures, although bus insulators and equipment bushings are also at risk.

Figure 5-6: Contamination Zones



Contamination Mitigation centers on replacing poles, porcelain insulators, and hardware on distribution circuits with fiberglass poles and fiberglass or polymer insulators, selected based on cross-arm and stand-off bracket configuration. Substation porcelain insulators (and mounting hardware) on trident structures will be replaced with insulators pre-coated with salt-resistant coatings. Each of these measures is expected to significantly reduce contamination-related outages and the need for insulator washing. As noted in Section 4.2.3, the number and duration of arid intervals as measured by the SPEI drought index are expected to increase modestly over the next several decades, thus increasing the number of flashovers in saltwater contamination zones absent mitigation. Results are presented separately for substation and distribution circuit insulator replacements.

5.6.6.2 Revisions from the Prior System Resiliency Plan

The Contamination Mitigation measure was not included in the prior SRP filed in Docket 56548.

5.6.6.3 Targeted Substations and Distribution Circuits

The estimated three-year cost for the Contamination Mitigation resiliency measure and investment quantities are presented below.

- Number of substations targeted: **4-5 substations** per year (**13** total)
- Number of distribution circuits targeted: **6-7** per year (**20** total) with 6,600 poles and 11,500 insulators replaced over 3 years
- Total project cost (capital and expense): **$21 million** for substations and **$129 million** for distribution circuits
- Total installation expense: $**6** million over the 3-year SRP

5.6.6.4 Alternatives Considered

In reviewing the SRP, CenterPoint Houston, in collaboration with Guidehouse, evaluated continuing with a less sophisticated timeframe for power washing during drought conditions as an alternative to the Coastal Contamination measure.

In lieu of predictive analytics and more sensing, CenterPoint Houston could continue with time-based washing, which has been effective but not necessarily cost-effective. Power washing at specific time intervals is effective and does remove deposits, but it does not account for windspeeds that deposit more contaminated material (salt) and could result in tracking occurring more or less frequently depending on windspeeds and sediment in the air. Therefore, CenterPoint Houston eliminated this option from its consideration of alternatives.

5.6.6.5 Resiliency Measure Metrics and Effectiveness

CenterPoint Houston transitioned from an asset-centric program-based approach to a project-based approach, using co-optimized sets of project types to address resiliency challenges specific to geographic regions in its service area. Using an array of best practice project type alternatives, different project types were selected in each area to enhance resiliency and structural hardening at a discrete asset level.

Distribution system mitigations are focused on areas of higher predicted damage concentration to maximize overall system restoration efficiency. When optimized at the project level, these mitigations require considering interdependencies between mitigations contemplated for the same distribution feeder/area. For example, strategic undergrounding changes the need for automation and vegetation management frequency. As a result of using the co-optimized project-based approach, CenterPoint Houston will use efficacy measures that capture the complementary nature of project-based system resiliency plans. This approach is consistent with industry best practices and measures success as a product of regional performance instead of individual asset performance.

Measurements:

1. Percent of planned asset installations completed by County
2. Percent change in predicted damage based on the event type.
3. Normalized total system restoration performance during Resiliency Events pre- and post-completion of mitigation projects based on the event type.
4. Normalized restoration performance of predicted high damage concentration area compared to Normalized total system restoration performance pre- and post-completion of mitigation projects during Resiliency Events based on the event type.

5.6.6.6 Benefits Analysis

Guidehouse evaluated the benefits associated with CenterPoint Houston's Saltwater Contamination Upgrades resiliency measure on a quantitative and qualitative basis. The quantitative analysis adheres to the BCA methodology described in Section 5.1 with resiliency measure-specific inputs and assumptions described below.

1. **Quantitative Benefits** – Key assumptions include estimates on the number of insulator flashovers and the percentage of flashovers that will lead to equipment damage and interruption of load. The analysis accounts for the increase in flashover risk over time due to the increased duration of arid intervals. The probability that substation insulators will flashover is 0.6% with 10% resulting in interruption of load. The amount of load at risk for substations and distribution circuits is estimated at 175 MW and 4 MW, respectively. Restoration time is estimated at 48 hours for substations and 8 hours for distribution circuits, respectively. Other benefits include reduced O&M expense for insulator washing and the avoided cost of repairs and crew time required to restore service for substation and distribution circuits following flashover events. The Saltwater Contamination Upgrades resiliency measure is projected to reduce cumulative CMIs over the 3-year Resiliency Plan by approximately 15.9 million and 7.9 million annually by 2028. From these assumptions, Guidehouse derived a composite measure BCA of 2.4.