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ComEd Ex. 11.0

Independent Investigation:

Material Condition Assessment and Benchmarking Study of the Commonwealth Edison Company Delivery System with Respect to February 2011 Storm Damage

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1. Introduction and Executive Summary

This report presents Navigant Consulting, Inc.'s (Navigant) independent assessment of the performance of ComEd and its system in response to the severe winter storms experienced on February 1-2, 2011. In that context, it includes a material condition assessment of Commonwealth Edison's (ComEd) electric distribution system, a benchmark review of distribution design and maintenance practices, and storm performance resiliency versus electric utilities of comparable size and system configuration. The Navigant Study team was led by Messrs. Eugene Shlatz and Hector Artze, Directors, and Ms. Maggie Duque, Assistant Director.

1.1 Background

Navigant was engaged to conduct an independent, comprehensive investigation of the storms that impacted ComEd's distribution system on February 1st and 2nd of 2011. Navigant's study includes a review and material condition assessment and benchmark study of lines and other equipment in areas affected by these storms. That study specifically focused on aspects of the system's condition relevant to storm damage, and focused on the geographic areas affected, although comparison inspections were made over ComEd's entire distribution system. The report also includes a benchmark comparison of ComEd's reliability performance and design and maintenance practices to other electric utilities with comparable service territory attributes and demographics. Navigant also sought to determine the degree to which relevant ComEd design and maintenance practices comply with Illinois Administrative Codes, national design and safety standards, and prudent utility practices; focusing on the adequacy of the segments of the distribution system impacted by the storm that occurred on February 1st and 2nd 2011.

1.2 Study Objectives

Navigant's primary objective is to assess the adequacy of ComEd's distribution system with respect to its ability to withstand major storms such as those that impacted portions of its service territory on February 1st and 2nd 2011, and to thereby test the validity of criticisms that have been made about the condition of the system and its operation and maintenance. To address these issues, Navigant conducted a comprehensive review and assessment of ComEd's distribution system design, material condition, reliability programs, and equipment performance. Navigant's analysis included a rigorous assessment of the underlying outage causes and equipment impacted by the winter 2011 storm. This report follows an earlier report prepared by Navigant in March 2012, which addressed the adequacy of ComEd's distribution system with respect to its ability to withstand major summer storms, such as those that occurred on six occasions in the summer of 2011.

The approach Navigant applied to ComEd's winter storm review is based on decades of experience of each of the lead consultants responsible for the review. The findings and conclusions presented in this report reflect the knowledge and perspective gained from this experience, which includes similar studies conducted for numerous electric utilities in North America and worldwide, and several regulatory jurisdictions.

Study activities and the tasks that Navigant undertook to perform its independent evaluation are summarized below:

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1) Assess ComEd's relevant physical assets based on a review of distribution design and performance data, and the results of field inspections for areas affected by the storm and comparison areas unaffected by the winter 2011 storms
2) Evaluate ComEd distribution system reliability, including performance benchmarks for normal and major to those experienced by other comparable utilities
3) Benchmark relevant design and construction standards to common utilities practices, including compliance with state of Illinois Administrative Codes and national safety standards
4) Assess the adequacy of ComEd's tree trimming standards and programs, including compliance with Illinois Commerce Commission (ICC) standards, and compared to other comparable utilities
5) Assess the overall adequacy of ComEd's distribution system design, construction, protection, as it relates to winter storm resiliency
6) Provide an overall assessment of whether any of the interruptions that occurred during the February 2011 storm were avoidable

1.3 Methodology

For this study, Navigant conducted four key tasks: The first is a comprehensive review of the storms that impacted ComEd's distribution system in February 2011; the second focuses on the adequacy of ComEd's distribution engineering and design standards; the third is an independent material condition assessment of ComEd's distribution system and equipment; the fourth includes benchmark comparisons of ComEd reliability performance, improvement programs, design standards, maintenance activities, and costs to other comparable utilities. Each task is described in further detail below.

1.3.1 Storm Impact Analysis

The initial phase of review focused on identifying outage causes and equipment impacted by the winter 2011 storm. It includes a rigorous examination of the factors and conditions underlying the number and duration of interruptions to ComEd's customers during the winter 2011 storm.[1] A key objective of this task was to obtain outage data and conditions needed to make a determination of whether any of these interruptions were avoidable. These results are then combined with our assessment of engineering design standards, material condition, and assessment of operation and maintenance (O&M) practices to support such a determination.

[1] ComEd defines an interruption as the failure or operation of a single delivery system component, or the simultaneous failure or operation of physically and directly connected components that results in electric service being lost to customers, subject to certain exceptions (e.g., disconnections for failure to pay bills, or at the request of law enforcement). Although exact wording varies, this definition is consistent with our understanding and use of the term to refer to a condition on the system that causes a loss of service to one or more customers and that resulting loss of service. This is also consistent with how all major benchmarks define and measure interruptions. We use interruption in this sense. We also use the term "customer interruption" to refer to the number of customers affected by an interruption. We use the plural term "total interruptions" or "total customer interruptions" when we refer to all of the interruptions that meet a given criterion, for example, that are caused by damage from a particular storm.

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Our analysis is based on a comprehensive analysis of relevant features of ComEd's system within and outside the areas impacted by the winter 2011 storm. Navigant independently selected a range of feeders for inspection, which included short and longer lines, difference voltage classes, rural and urban segment, primarily overhead versus underground, mostly residential or commercial, and lines in heavily treed versus those located in open areas. We also requested and received from ComEd all data requested needed to conduct a thorough and independent investigation, one supported by records and documentation of ComEd's distribution system condition, design and performance. Importantly, ComEd and its representatives did not recommend specific lines to inspect or avoid, nor did company personnel refuse to supply data to any of our numerous information requests.

1.3.2 Distribution Engineering Standards and Design Review

Navigant reviewed ComEd's transmission and distribution (T&D) design standards to assess the capability of its energy delivery system to withstand major winter storms. Our review includes a review of ComEd's distribution design and planning criteria, loading practices, equipment selection, system protection, and automation. Specific design practices we assessed included:

- Planning and design criteria of the primary distribution system, including consistency among regions served
- Design and physical loading criteria for overhead conductors and devices
- Pole and equipment selection for primary main lines and secondaries; particularly for multi-circuit lines located in areas susceptible to damage
- Fusing and protection practices, both to minimize the likelihood of interruptions and to reduce restoration times
- Use of automated devices and communication systems to improve restoration times. This included an assessment of auto-sectionalizing devices such as line reclosers to isolate faults and transfer line sections to minimize the number of sustained customer interruptions
- Use of insulated or bundled conductor to reduce the number of tree- and ice-related interruptions
- Effectiveness of trimming methods and compliance with ICC standards, including an assessment of the distribution system to withstand tree-related interruptions during major storms
- Consistency and compliance of ComEd distribution design and maintenance practices to Illinois Administrative Codes, National Electric Safety Code (NESC) requirements and industry practices
- Design and maintenance practices as applied to primary and secondary voltage lines

1.3.3 Material Condition Assessment

Navigant reviewed and analyzed ComEd's overhead primary and secondary distribution system, focusing on areas affected by the winter 2011 storm. A review of underground systems and equipment was performed, although not to the same level of detail as overhead systems, as the number of interruption caused by underground failures was small. The material condition assessment also included an investigation of to the adequacy of ComEd's operating and maintenance practices, as the condition of ComEd's power delivery system is dependent on effective maintenance and operations, as well as on prudent design practices and investments. Additionally, Navigant also compared

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distribution system design, construction, operating and maintenance practices, and performance of lines and equipment impacted by the winter 2011 storm to other ComEd regions.

Specifically, Navigant reviewed and analyzed:

- Prior ComEd studies, reports, and investigations that focused on equipment and material condition, including findings and actions taken by ComEd to address deficiencies and gaps
- ComEd reliability records to identify areas of the system where equipment and material-related failure has caused distribution system interruptions, focusing on equipment failure or malfunction cause codes to identify trends and equipment most susceptible to failure
- Asset records to identify age and material standards to assess durability and conformance to current design standards. This task included a review of distribution engineering design practices and standards, focusing on equipment deemed most susceptible to failure based on storm interruption and reliability data
- Distribution inspection and maintenance records, including prior studies, pole inspections reports, cable condition reports, thermal inspections, and other operation and maintenance data that can be used to ascertain equipment condition and consistency with common utility practices
- Information obtained from interviews with ComEd engineering and operations management and supervisory staff to obtain data and information regarding equipment condition or design, and areas of greatest concern to ComEd or to Navigant investigators
- Targeted field inspections for a broad range of overhead and underground distribution facilities, with a representative cross-section of urban versus suburban, short and long feeders, heavily and sparsely treed, high and low load density, and other criterion deemed most suitable as a result of interviews and reliability review
- Vegetation management practices with regard to trimming cycles, clearing standards, contractor selection, field inspection, and program effectiveness
- Benchmark results of ComEd's design, maintenance, and storm recovery practices to those of other comparable utilities using readily available data and the experience of Navigant's experts gained through prior engagements and direct experience

1.3.4 Benchmark Studies

Navigant conducted a series of benchmarking analyses to compare ComEd's reliability performance and spending levels to those of other comparable utilities. Our analysis includes a high-level benchmark comparison of ComEd's system performance and impacts caused by the winter 2011 storm to other utilities subject to similar storms over the past decade. To determine if design, maintenance, and performance were consistently applied throughout ComEd's service territory, we conducted a series of internal benchmark analyses that compared the design, maintenance, and performance of the segments of ComEd's distribution system impacted by these storms to areas unaffected by the storm. We also compared ComEd's planning, design, construction, and protection practices to those of comparable utilities.

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1.3.5 Field Inspections

To support its analysis of ComEd's distribution system practices and reliability performance, Navigant conducted a comprehensive inspection of distribution lines and equipment, both in the areas affected by the winter 2011 storm and of representative lines in the other ComEd regions. Previously, Navigant inspected approximately 500 miles of ComEd distribution during its review and assessment of summer 2011 storms. Navigant selected additional feeders for inspection, with an objective to include a representative cross-section of distribution lines impacted by the winter storm. Selection criterion included short and long feeders, urban and suburban, low and high number of storm interruptions, single and multi-circuit construction, with and without line reclosers, and lines with a higher percentage of primary underground lines. In total, the facilities inspected included a diverse mix of well almost 700 miles of feeders, including approximately 400 miles and 300 miles of overhead lateral and mainline feeder segments, respectively, located in over 20 municipalities and related unincorporated areas including both areas affected by storm outages and, for comparison purposes, areas not significantly affected. We also observed facilities in place along and near these lines including substations, primary transformers, secondary connections, other switchgear and communications equipment, disconnect and reclosing devices, and grounding and protection equipment. Appendix A (CONFIDENTIAL) presents more specific data for each feeder inspected in the affected and non-affected areas for both the summer and winter 2011 storms.

Navigant obtained maps to compare field inspection results to one-line diagram details, and to ensure that a mix of three-phase main line, and single- or two-phase laterals were inspected. For all inspections, Navigant sought to inspect at least 50 percent of the total feeder. ComEd's personnel, mostly Reliability Engineers, accompanied Navigant on the inspections. Several hundred photographs were taken, with annotated entries highlighting the type and attributes of the equipment or lines inspected at each location. Detailed inspection reports are retained with our workpapers.

1.4 Executive Summary

Based on its independent investigation and analysis of ComEd's distribution system and the storm that impacted ComEd's customers on February 1st and 2nd of 2011, Navigant offers the following findings and conclusions.

(1) The interruptions that occurred as a result of the winter 2011 storm were unavoidable.

Navigant's independent investigation of the winter storm resulted in a determination that the body of interruptions that occurred during the winter 2011 storm also were unavoidable, and the damage that occurred was due to events outside of ComEd's direct or indirect control. In addition, in virtually all cases evidence was available to allow us to assess the interruptions individually. Notably, each of the distribution lines experiencing interruptions during these storms had been trimmed in accordance with the ICC's target 4-year cycle, resulting in a relatively small number of tree-related interruptions. Using results from our summer storm review, supplemented by design factors related to interruptions that occurred in February 2011, our review of ComEd's distribution design standards, confirmed by field observation, unequivocally indicates system design and construction is consistent with prudent and common utility standards. Consistent with findings in

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our report on the summer 2011 storms, we did not observe any violations or inconsistency with Title 83 of Illinois Administrative Code 305 and NESC requirements referenced within the Code. In many areas, such as targeted reliability initiatives and distribution automation, ComEd has adopted industry best practices. Navigant's findings and conclusions are supported by over 75 years of collective experience evaluating electric utility distribution systems, including post-storm performance evaluation and recommendations.

The following provides specific evidence, analysis, and data supporting this statement:

- Over 80 percent of the interruptions were weather related, many caused by broken phase wires and conductor contact due to high winds, windborne debris, and ice and snow buildup. The remaining 20 percent is mostly equipment that was damaged, burned or experienced flashover as a result of snow and ice buildup that compromised equipment insulation properties. Notably, less than five percent of total customer interruptions were directly caused by tree related outages.
- Each of the feeders where tree-related interruptions occurred had previously been trimmed in the prior four years. This excludes trimming on secondary lines or services that are not generally ComEd's responsibility. However, because the number and duration of customer interruptions caused by trees on secondaries and services was *de minimums*, the issue of whether secondary lines and services should be trimmed is rendered moot, and suggests ComEd's current trimming policies are prudent.
- Field inspection results confirm that ComEd meets the ICC's trimming and design standards, including phase and ground clearances. Moreover, at the time of actual observation, virtually all primary distribution lines inspected maintained adequate trimming and phase clearances when inspected.
- The results of high-level benchmark studies for utilities impacted by comparable storms indicate the amount of equipment damaged and duration of interruptions is consistent with statistics of other utilities. Notably, national standards such as the NESC do not require utilities to design and construct distribution systems to withstand weather conditions that ComEd experienced in early February of 2011. In fact, the conditions that ComEd's distribution system experienced during the winter storm exceeded the NESC "heavy" design threshold for northern Illinois that ComEd has adopted.
- Lastly, and perhaps most important, the ability of ComEd crews to travel to lines was severely hampered by snowdrift-laden roads and highways that blocked vehicular traffic, thereby lengthening the duration of the interruptions. ComEd crews had to contend with the same highway bottlenecks that made passage difficult for the general public, municipal personnel and electric utility restoration crews alike.

(2) ComEd's overhead distribution system is designed and constructed consistent with or above commonly accepted utility practice. Further, these practices are followed consistently throughout ComEd's service territory.

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ComEd's distribution design standards are consistent with or exceed those of utilities with comparable service territory attributes and customers served. In all areas reviewed, confirmed by field inspections, ComEd's distribution system is designed and constructed in accordance with Title 83 of the Illinois Administrative Code, National Electric Safety Code, and common and prudent utility practice. We did not observe any clear violations of these codes and practices. The size and capability of key distribution equipment, including poles, wires, transformers and cable, are appropriately sized for the function they provide, and are properly maintained. The spacing of conductor and span lengths are consistent with common electric utility practices and compliant with Illinois Administrative and national electric safety codes. Regular patrol and inspection of lines help detect potential reliability problems so that they may be proactively addressed, and emergent code violations immediately addressed. Protection practices meet or exceed industry practices, including extensive use of reclosers and employment of auto-sectionalizing loop schemes, minimize number of customers are impacted by interruptions, and restoration times are expedited.

Navigant's conclusions are based on and supported by the following findings and observations.

- The majority of ComEd's overhead three-phase, 12.47 kV and 4.16 kV distribution lines are wood-pole, cross-arm construction. The majority of lines have span lengths of 200 feet or less, which reduced the incidence of phase-to-phase contact that otherwise would have occurred if spans were longer.
- The design and construction of lines and equipment in areas within and outside of areas impacted by the winter storm appeared consistent. The use of mid-line and auto-sectionalizing reclosers on 34.5 kV subtransmission[2] and 12.47 kV distribution lines was evident in all areas inspected, and further supported by ComEd's records.
- ComEd has aggressively implemented distribution automation over the past 10 to 15 years. Since the early 2000s many 34.5 kV subtransmission lines have been equipped with auto-sectionalizing devices and communications systems designed to automatically detect and isolate faults, and rapidly restoring unaffected line sections to adjacent feeders. Over the past seven years, ComEd has also installed over 200 auto-sectionalizing loop schemes in addition to other reclosers on its primary distribution lines. The company reports these devices collectively reduced customer interruptions by over 1 million minutes in 2011. The recently enacted Energy Infrastructure Modernization Act ("EIMA") will enable a significant and long-term increase this investment.
- Navigant views ComEd's distribution automation program as an industry leading best practice. The use of reclosers for auto-sectionalizing is superior to SCADA-controlled, three-phase load break disconnect switches, as it does not rely on remote switching from dispatch control; a process that can be extremely cumbersome, and difficult to track and manage during major storms.

[2] By subtransmission, ComEd refers to lines of greater than feeder voltage (12.47kV, for ComEd), but below voltages associated with bulk power, transmission, and high-voltage distribution (69 kV and some 138kV lines for ComEd) circuits. Practically, for ComEd, this means subtransmission refers to 34.5 kV lines.

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- There is minimal bundled conductor or tree wire used on ComEd's primary distribution system. Navigant does not believe use of bundled conductor or tree wire would have materially reduced either the number or duration of customer interruptions, as many outages were caused by ice and snow build up which caused lines to break or come into direct contact with adjacent conductors. Navigant recognizes the insulating properties of bundled conductor would have likely reduced the number of instances of conductor contact. However, Navigant also believes the additional weight of the bundled conductors, coupled with snow and ice buildup, would have caused bundled conductors to break away from their supporting poles or fail at junctions and endpoints, as well due to the large size and higher weight of the insulated conductor (*e.g.*, greater surface area for ice buildup). However, ComEd is expanding the use of bundled conductor on line sections with high tree-related outage exposure.

(3) The condition of ComEd's overhead distribution system is consistent with or above commonly accepted utility practice. This finding is supported by reliability performance that is superior to other utilities and which continues to improve. Proactive maintenance and targeted maintenance, implemented cost-effectively, are factors supporting this finding. In short, ComEd is effectively managing its distribution assets.

ComEd has effectively managed its distribution assets to ensure reliability is not degraded by lines or equipment that is improperly maintained or applied. The institution or regular maintenance inspections and targeted reliability programs are designed to proactively identify and address potential problems. This includes identifying and quickly addressing equipment that is broken or creates clearance violations that could affect safety or reliable performance. Although some equipment is several decades old, its condition and ability to perform well under normal storms is assured by these proactive efforts. This finding is underscored by the continued reduction in the defective equipment cause code for overhead distribution and overall improvement in reliability performance measured by commonly accepted reporting metrics.

Our conclusions are supported by the following:

- In the areas affected, Navigant did not identify any lateral primary distribution line segments fed directly from main line sections that were not equipped with fuses. There are some very short overhead line sections not directly connected to the main line section that are unfused. However, Navigant does not view this finding as significant, as interruptions on short, lateral tap lines not connected to the main line feeder do not materially increase either the number or duration of customer interruptions.
- Pole inspection records indicate that less than three percent of poles inspected annually are rejected. Of those that are rejected, all poles listed as priority replacements have been replaced, reinforced, or assigned corrective maintenance work orders; typically shortly after the inspection. Where applicable, ComEd installs C-Trusses on poles, a cost-effective process that significantly extends the lives of poles. Of the remaining poles are fumigated or otherwise treated with decay retardants. These practices are consistent with common utility practice. These practices likely

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contributed to the very low number of poles that broke during the winter storm, despite heavy ice and snow buildup, and wind gusts that exceeded 60 mph.

- ComEd's vegetation management policy for subtransmission lines does not allow for any overhang or canopies (it is allowed over lower voltage lines, subject to clearances). Notably, many 34.5 kV subtransmission lines contain one or more 12.47 kV or 4.16 kV distribution lines attached directly below the 34.5 kV lines. These lower voltage distribution lines will also share in any benefit from the greater clearance. Notably, the amount of tree-related interruptions was modest – less than 5 of total interruption minutes.
- ComEd has instituted a proactive maintenance inspection program designed to identify potential reliability problems. Every feeder is inspected at least every 4 years, covering a wide range of potential conditions that could degrade reliability if otherwise not detected and mitigated. Navigant confirmed that 97 percent of the distribution feeders experiencing interruptions during the storm of winter 2011 was inspected within the prior 4 years. These include devices in need of repair, damaged equipment, deteriorated poles and crossarms, low clearances, failed lightning arresters, missing fuses and other items prescribed for inspection. Navigant views ComEd's proactive maintenance inspection program as an industry best practice, and likely prevented some interruptions and reduced the duration of others during the winter 2011 storm.
- The company has instituted a series of processes designed to ensure quality assurance (QA) and ongoing improvement for distribution reliability and performance. These include key reliability and maintenance programs for vegetation management, reliability initiatives, maintenance inspections, and post-storm inspection and review.
- The QA processes Navigant reviewed appear to be properly managed, as we confirmed that compliance in each of these areas was very high. For example, over 99 percent of scheduled trimming was completed within the ICC-mandated four-year cycle. Similarly, 97 percent of scheduled feeder maintenance inspections were completed within ComEd's internal four-year cycle.

(4) A benchmark comparison of ComEd's reliability performance is consistently above industry averages. Industry data and statistics for major storms confirm the damage and interruptions ComEd experienced is comparable to other utilities.

Benchmark studies indicate ComEd's reliability performance is superior to those of comparable utilities. ComEd's reliability performance over the past three years is in the first or second quartile for SAIFI and SAIDI. Similarly, ComEd's reliability performance versus the IEEE survey benchmark is better than most of the utilities included in the survey. ComEd's reliability performance over the past three years meets or exceeds those of comparable utilities. When measured on the basis of frequency, duration, and customer minutes, ComEd reliability metrics, exclusive of storms, falls within the first or second quartile of over two dozen utilities included in the peer group. ComEd's reliability performance also exceeds those of other reporting utilities in the state of Illinois.

Supporting data and benchmark results are supported by the following facts:

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- Benchmark studies indicate ComEd's reliability performance is superior to those of comparable utilities. ComEd's reliability performance over the past three years is in the first or second quartile for SAIFI and SAIDI. Similarly, ComEd's reliability performance versus the IEEE survey benchmark is better than the most of the utilities included in the survey.
- ComEd's reliability performance over the past three years meets or exceeds those of comparable utilities. When measured on the basis of frequency, duration, and customer minutes, ComEd reliability metrics, exclusive of storms, falls within the first or second quartile of over two dozen utilities included in the peer group. ComEd's reliability performance also exceeds those of other reporting utilities in the state of Illinois.
- Electric utility distribution lines, both for ComEd and utilities in general, are not designed to withstand damage caused by the level of ice buildup and winds that occurred during the February 2011 storm; nor does the NESC specify design standards to withstand ice loadings and winds of the magnitude that occurred during several of the winter 2011 storm. Storm surveys confirm code specifications.
- ComEd's spending for distribution O&M is comparable to the benchmark utility group. These findings are based on number of customers served or kWh sold. The data indicates the company is managing costs while achieving favorable reliability performance.
- The wind speeds during the winter 2011 storms exceeded 60 mph in some areas, at or above applicable design standards, and within ranges where an experienced electric utility engineer would not be surprised by extensive damage. Despite the severe weather, there was very little pole damage resulting from the winter storm.
- A benchmark comparison of utilities storm performance in the last two decades demonstrates ComEd's equipment failures and customers affected were similar or lower than other utilities impacted by storms with wind speeds comparable to those that repeatedly impacted northern Illinois in 2011. The many contributing factors that caused significant damage and numerous interruptions to ComEd customers that clearly were unavoidable.

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2. Winter 2011 Storm – Impact Analysis

2.1 *Overview*

Navigant performed an independent review and analysis of ComEd's interruption data for the winter storm that impacted many segments of its service territory on February 1st and 2nd 2011. These storms produced winds speeds of up to 60 miles per hour (mph) and approximately 225 lightning strokes. Up to 20 inches of snow and 8 foot drifts caused damage to lines and equipment, and inhibited crews from accessing lines for repair and restoration, thereby lengthening the duration of customer interruptions. Navigant's review and reliability analysis was performed using unaltered storm interruption data provided by ComEd; that is, to ensure independence, Navigant did not make any changes or adjustments to cause code or equipment entries. Table 1 summarizes the total number of interruptions, customer interruptions, and customer interruption minutes for the two-day winter storm.

Table 1. Interruption Statistics

Storm Date	Total Number of Interruptions	Total Customer Interruptions (CI)	Total Customer Interruption Minutes (TCMI)
February 01, 2011	788	176,831	74,805,366
TOTAL	788	176,831	74,805,366

Table 2 summarizes the equipment ComEd replaced or repaired during the winter storm. Notably, the number of poles replaced is an exceedingly small fraction of the total number of poles located on feeders that were impacted by the storms; approximately 600 feeders experienced sustained interruptions.

Table 2. Replacement and Repair Statistics

Equipment Category	Quantity	Unit
Poles & Guy Wires	9	Number
Cross Arms and Braces	5	Number
Overhead Conductor, Connectors & Terminations	412	Sections
Underground Cable	17	Sections
Distribution Transformers	29	Number
Cutouts & Fuses	266	Number
Substation Bus & Breakers	19	Number
Other Devices & Equipment	36	Number

2.2 *Interruption Statistics*

Figure 1 illustrates the combined totals for total customer minutes of interruption (TCMI) for the winter storms by voltage class. The majority of TCMIs occurred on 12.47 kV primary distribution feeders, with a smaller amount on 4.16 kV feeders, and negligible amounts on secondary lines and services (typically, 120/240v or 277/480v). A relatively small percentage of the total TCMIs occurred on 34.5 kV subtransmission and none on the 138 kV transmission system.

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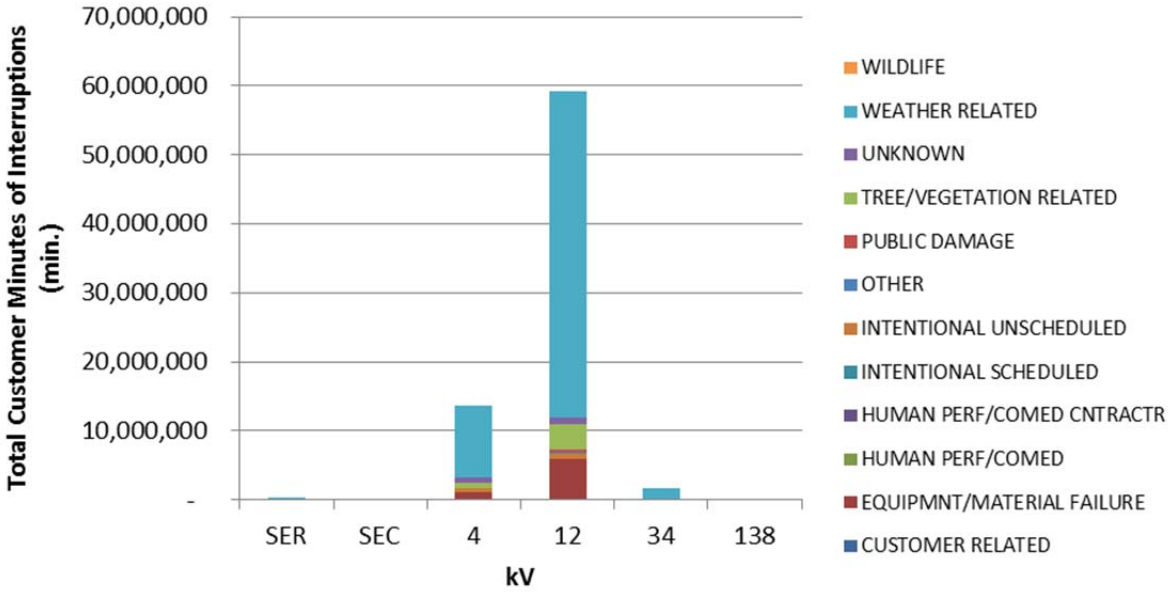
Figure 1. Total Customer Minutes of Interruption by Voltage



2.3 *Interruption Causes*

Table 3 indicates the large majority of total TCMI for the winter storm was due to two primary causes: weather and overhead equipment damage. The data indicates that over 80 percent of the interruptions were due to these two causes, an expected result given the buildup of ice and snow, and very high winds imposed on ComEd's overhead distribution system. The majority of weather-related TCMI was due to conductor flashover or failure. Of these, the large majority of customer interruptions were on distribution lines operating at primary voltages (mostly 12 kV) – interruptions to secondary and service lines due to all causes constitute less than one percent of the total minutes of interruption. The other major outage cause code (but far below weather) is overhead equipment damage, mostly as a result of ice and snow build up that contaminated lines and reduced Basic Impulse Levels (BIL), resulting in flashovers or equipment failure. The data from Table 3 is also depicted in Figure 2 that follows.

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Table 3. Customer Interruptions by Cause Code

Cause Category	Cause Detail	Number of Interruptions	Customers Interrupted
Tree Related	Limb Broken - Primary	44	4,926
	Limb Broken - Service Drop	18	18
	Tree Contact - Primary	17	1,125
	Tree Contact - Service Drop	3	3
	Uprooted Tree - Primary	5	934
	Uprooted Tree - Secondary	0	0
	Uprooted Tree - Service Drop	2	2
	Limb Broken - Secondary	0	0
	Tree Contact - Secondary	0	0
	Tree Related Total	89	7,008
Weather Related	Wind / Tornado	256	39,808
	Lightning	12	1,603
	Extreme Cold	2	2
	Ice / Snow	247	78,180
	Weather Related Total	517	119,593
Underground Equipment Related	Underground Failure	13	1,980
	Malfunction	23	5,825
	Underground Equipment Related Total	36	7,805
Intentional	Emergency Repairs	30	11,649
	Protection of System Integrity	0	0
	Intentional Total	30	11,649
Overhead Equipment Related	Malfunction	21	5,471
	Broken Fuse Link	5	166
	Contamination	44	16,755
	Overhead Equipment Related Total	70	22,392
Unknown or Animal Related	Unknown	20	5,121
	Squirrels	0	0
	Birds	0	0
	Animal - Other	0	0
	Total Unknown or Animal Related	20	5,121
Other	Other	9	1,422
Public	Vehicles	11	1,740
	Dig-in by Others	0	0
	Accident by Others	0	0
	Fire	0	0
	Vandalism	0	0
	Foreign Object	1	73
	Public Total	12	1,813
ComEd/Contractor Personnel-Errors	Switching Error	1	20
	Dig-in by ComEd	0	0
	Accident by ComEd Contractor	0	0
	ComEd/Contractor Personnel-Errors Total	1	20
Transmission and Substation Equipment Related	Substation Equipment	2	6
Customer Related	All	2	2
Total		788	176,831

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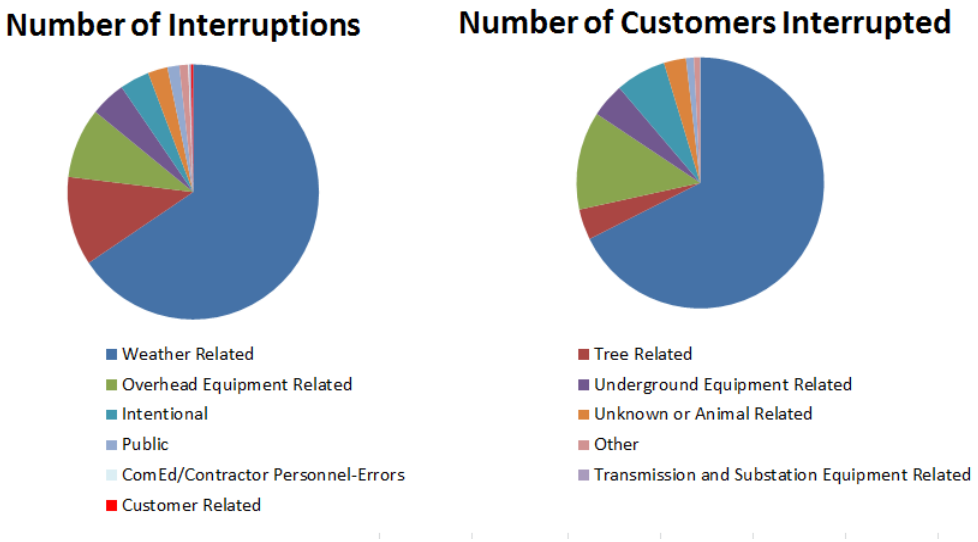
Figure 2. Number of Interruptions and Number of Customers Interrupted by Cause Code



Compared to the summer 2011 storms, the February 2011 blizzard resulted in far fewer tree-related interruptions, in part because there were a much smaller number of uprooted trees. Similar to summer 2011 study results, Section 3 confirms that trees along each feeder where tree-related interruptions occurred were previously trimmed within the four years prior to the storms. Storm statistics outlined above suggest that the number and duration of interruptions would not have materially increased even if trees along all sections of primary lines has been removed or further cut back, as less than five percent of the customer interruption minutes were caused by tree-related interruptions. Notably, a very small number of customer interruption minutes were caused by trees on secondary lines and services, lending further credence to the finding that trees are a minor factor in terms of total customer interruptions involving secondaries and services during storms.

2.4 Equipment Damage

Table 2 presents equipment that failed or was damaged during the winter 2011 storm, obtained from ComEd's reliability data base. The number of poles that were completely severed or broken was less than 10, a small fraction of the total number of poles in the affected areas. Similarly, the number of broken cross arms also was negligible in terms of total customer interruptions. Primary wire failures or contact-related flashover dominated damage statistics caused nearly 50 percent of the total customer interruptions and over 60 percent of the customer interruption minutes. ComEd records indicate several hundred wire sections or insulators were broken, or experienced phase-to-phase or phase-to-ground contact. Much of the phase-to-phase contact was due to conductor galloping caused by heavy wind imposed on ice-laden conductors.[3]

[3] A well understood phenomena associated with ice buildup on one side of electric conductors is the aileron affect; that is, ice laden conductors act as an aerofoil, causing conductor to gallop when winds are imposed. The low-frequency galloping results in phase-to-phase contact and damage to insulators and connectors if sustained over extended periods of time. Storm damage statistics appear to correlate quite well with galloping phenomena. ComEd reliability engineers also provide anecdotal evidence obtained by line crews and field personnel that conductor galloping occurred extensively during the winter 2011 storm.

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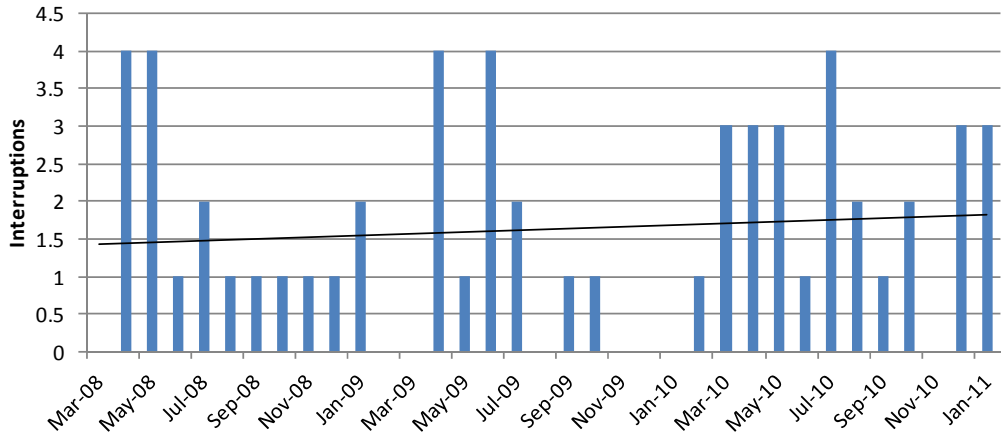
The modest number of damaged transformers and other devices was caused mostly by devices with broken insulators, broken connections and devices that fell to the ground. Other pole-related damage includes numerous cross-arm brackets, broken wires, and broken arresters, all of which, in the experience of the engineers that conducted the inspections, commonly fail during major storms on electric utility overhead systems.[4]

Unlike the summer 2011 storms, ComEd experienced several substation equipment failures. ComEd reports that these were flashover events caused by snow drifts up to 10 feet and ice buildup on bus insulators and circuit breakers. That such events occurred at all provides evidence of the severity of the winds and icing associated with the winter storm.

2.5 Tree-Related Interruptions

Because some of the interruptions were tree-related, Navigant conducted an analysis similar to that applied to the summer 2001 storms to test the premise that tree-related interruptions should increase as the time since the date of the last trimming increases.[5] If this premise cannot be confirmed, it is highly likely that many of the tree-related interruptions that occurred during the winter 2011 storm also were caused by large limbs falling onto lines that typically are beyond the ComEd's trimming clearance standards. To assess the relationship between tree-related interruptions and prior trimming cycles, Navigant compared the number of interruptions during the winter 2011 storm as a function of last date trimmed. Results are presented in Figure 3 for total customer interruptions and minutes.

Figure 3. Tree-Related Interruptions by Trim Date



[4] The three Navigant inspectors collectively have almost 50 years' experience working for electric utilities in engineering or operating functions. The years they have worked as industry consultants on comparable issues adds decades to this experience profile.

[5] Because the number of tree-related interruptions was far less for the winter storm, the level of confidence in the results is lower than results of the summer 2011 storm analysis.

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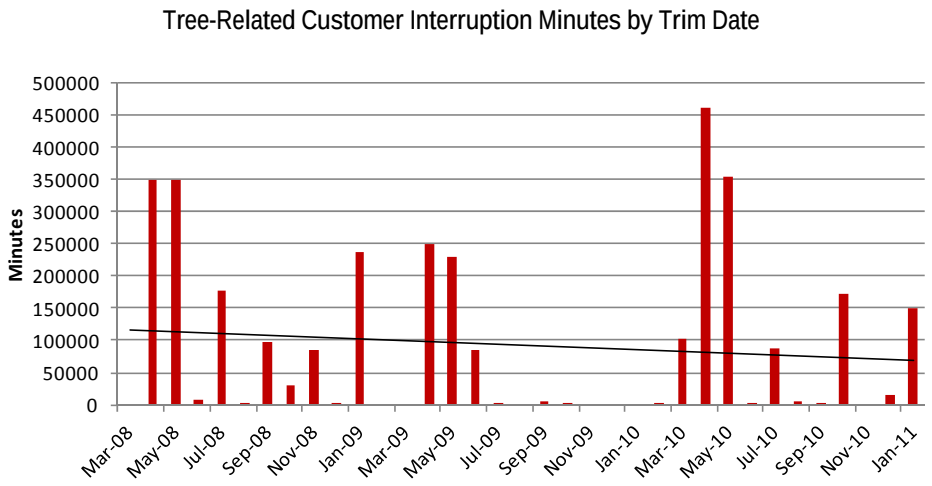
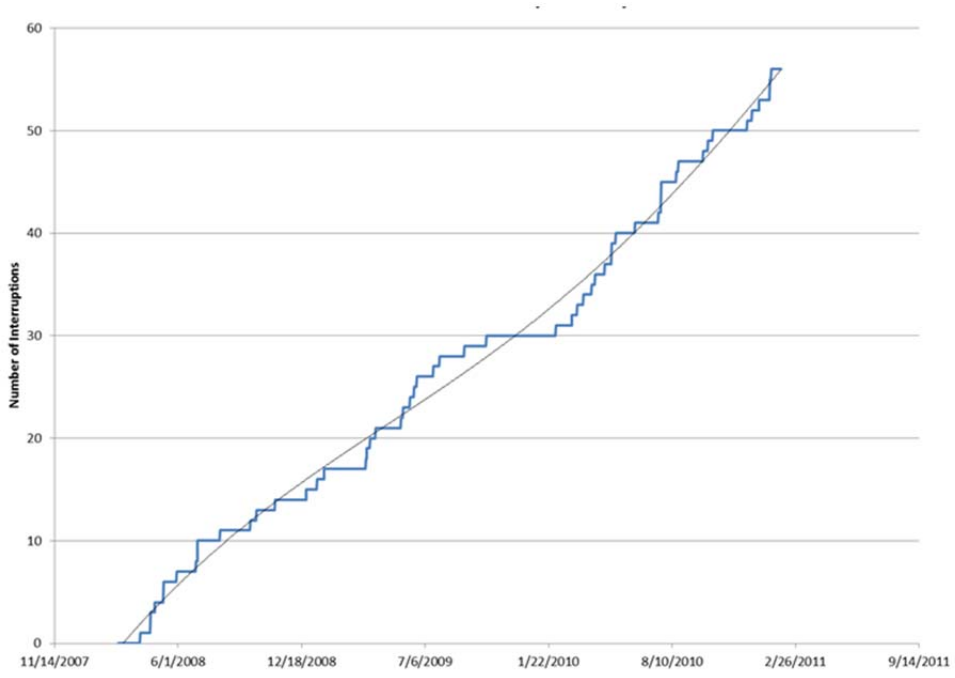


Figure 4 presents the above results on a cumulative basis. Using data provided by ComEd, trim dates for each circuit with a tree-related outage were determined. The data was then divided into monthly buckets based upon the trim date for each circuit. The number of interruptions for each month then was calculated and plotted in Figure 4. Results indicate a highly linear relationship, when a flatter line in the earlier years (e.g., higher number of interruptions in 2007 and 2008) would be expected if tree-related interruptions during the storms were caused by limbs within the ICC trim zones. Similar to summer 2011 storm results, the above trends suggest tree-related interruptions were independent of whether or not the trees along the feeder were recently trimmed or had been trimmed several years earlier.

Figure 4. Cumulative Tree-Related Interruptions by Trim Date



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A statistical analysis was performed using a P-Test to test the hypothesis that the trim date does not correlate to the number of interruptions on a circuit.[6] Similar to results obtained for the summer 2011 storm analysis, the chart confirms an absence of correlation between trim date and subsequent interruptions; that is, the trim date is not correlated to the number of interruptions that resulted during these outages.

2.6 Summary

Most of the damage to ComEd's distribution system and resulting interruptions was weather-related, much of it caused by broken phase wires or wires that came into contact due to ice buildup and high winds. Additionally, the buildup of ice and wet snow on insulators and bushings caused insulator flashover or equipment failure. A modest number of interruptions were lightning-related, resulting failures of terminations, padmount equipment, and underground cable caused by lightning surges. The large majority of interruptions, measured in customers interrupted and customer interruption minutes, occurred on main-line segments and laterals operating at primary voltages. Relatively few customer interruption minutes occurred on lines operating at secondary or service voltages. The primary damage on ComEd's distribution system was broken wires, and equipment and conductor that experienced flashover, each symptomatic of damage that can occur when wind speeds reach 60 mph on ice-coated conductors and devices.

The amount of damage ComEd's distribution system experienced is not unusual or inconsistent with damage reported by other utilities during major winter storms, as the damage was a consequence of conditions outside of ComEd's control and common distribution design standards. Specifically, overhead distribution design standards are not intended to withstand ice and wind loading that ComEd primary distribution lines experienced, even though ComEd's system is built to a heavy loading NESC standard. (*See* NESC Rule 250(B)) Further, statistical analyses confirm that tree-related interruptions did not correlate with the last trim date, adding further credence to visual evidence that trees, limbs and debris outside of clearance zones established by ComEd were the most likely cause for the relatively small number of tree-related interruptions that occurred during the storm. Similarly, damage to cross arms, devices, and appurtenances appear to have been caused by ice and snow buildup that caused flashover and associated failures.

[6] A p-value was obtained through using the Data Analysis TookPak in Excel.

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3. Distribution Design Standards

3.1 Overview

Navigant reviewed ComEd's distribution design practices and standards. We also interviewed ComEd's engineering and planning personnel to determine how these practices are implemented, and if these practices are consistent with state of Illinois Administrative Codes and national safety standards. Navigant also performed field inspections of numerous feeders to confirm the system is constructed consistent with documented practices and visually assess the condition of these assets; the latter is covered in greater detail in Section 4. Navigant also reviewed distribution loading practices to assess the degree to which equipment may be overloaded or stressed, thereby compromising reliability.

Most of our review focuses on overhead distribution, as the large majority of interruptions occurred on the overhead distribution lines. It also includes comparison of ComEd's design and construction practices to those of other similar utilities, identifying areas where ComEd's practices exceed or are below those of these utilities. It includes an assessment of design and equipment selection practices with regard to withstand capability during major winter storms, and the standards and criterion utilities typically apply to enhance resiliency to damage and storm-related interruptions.

3.2 Overhead Distribution Design

The majority of ComEd's overhead three-phase, 12.47 kV and 4.16 kV distribution lines are wood pole, cross-arm construction. Standard cross arm length is 8 feet, consistent with common utility practices to ensure sufficient separation of phase conductors. Most single-phase lines are wood-pole construction, typically with pole-top insulators. Typical span lengths are 200 feet or less; often less than 150 feet in urban and suburban areas.[7] ComEd often uses ally-arms for some three-phase lines where trees or other barriers are near or within the right-of-way, or to maintain tangent construction without supplemental guying. Many overhead primary distribution lines are double circuit, 12.47 kV or 4.16 kV, or secondary lines; mostly underbuild construction. There were a few instances where Navigant observed three or more primary distribution lines on the same pole. This is typically done where rights-of-way are limited to multiple circuits must follow the same route.

In all towns inspected, field inspection results confirmed that many three-phase main line sections and lateral taps are located in rear lots or alleys. Many of these lines, particularly those in residential areas, are located in heavily treed areas, with mature species and limbs that often formed a canopy above overhead lines. Figure 5 illustrates one example of this type of construction.

[7] Span length is a significant factor in ice storms, as the additional weight caused by ice loading and the large diameter gallop envelope for longer spans make them more susceptible to phase-to-phase contact or separation from line terminations.

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Figure 5. Three-Phase Rear Lot Overhead Distribution (Arlington Heights)

There is minimal bundled conductor (ComEd also refers to this as "spacer cable") or tree wire used on the primary distribution system. Navigant does not believe use of bundled conductors or tree wire would have significantly reduced either the number or duration of customer interruptions, as the additional weight caused by ice laden conductors and high forces caused by winds likely would have resulted in disconnected wires from dead-end connections and terminations. ComEd reported that it is currently installing bundled conductors in areas most susceptible to damage by tree limbs. Several of these installations were observed during our inspections of feeders affected by summer and winter 2011 storms.

ComEd's current design standard for distribution lines is based on 83 Illinois Administrative Code Part 305 and the NESC; portions of Part 305 incorporate NESC requirements. The segment of ComEd's service territory affected by the winter 2011 storm fall within NESC's region for a heavy loading design standard.[8] Navigant did not conduct independent analyses to determine whether ComEd's distribution facilities are fully in compliance with these standards. Nonetheless, we did not detect any clear or obvious violations of these codes during field inspections; but caution that a determination of compliance should be based on a series of engineering calculation of line loadings based on equipment strength, wind velocity, pole attachments, and other factors that cannot be determined by field observation alone.[9] Further, distribution construction standards for equipment operating at utilization

[8] NESC heavy loading design standard is based on 0°F, a 4 lb. per square foot wind plus ½ inch of ice for structures or poles under 60 feet tall.

[9] ComEd's Engineering Standard Practice (ESP) manual provides detailed specifications and calculations that are used to determine the size, rating, and application of equipment that should be selected given loading conditions, protection requirements, location, and other factors that engineers and designers consider in the design and construction of overhead and underground distribution systems. Navigant reviewed ESP Volume V – Distribution, dated July 29, 2011 as part of this review. Volume V contains over 1,300 pages addressing all components of overhead and underground primary and secondary distribution design, including 34.5 kV lines.

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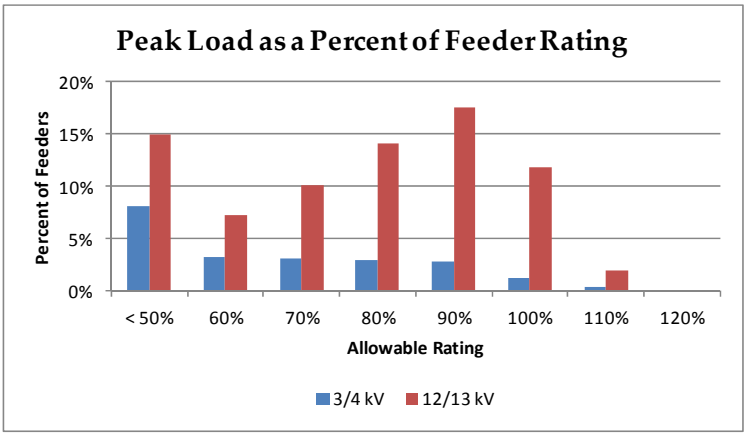
voltages - 12.47 kV and 4.16 kV dominate ComEd's system - do not apply to damage caused by storms and winds of the magnitude experienced during the winter 2011 storms. Poles greater than 60 feet in height are subject to NESC standards for extreme weather – poles of this size and class typically are used for transmission, which for ComEd, was relatively unaffected by the storms.

ComEd's distribution planning criteria specifies that the system should be designed with sufficient reserve capacity and ties to feeders fed from an adjacent substation to enable load transfer at peak, either for maintenance or when outages occur. ComEd's current overhead conductor standard specifies use of 477 AAC for three-phase lines; several older lines are equipped with 266 AAC, ComEd's prior design standard. Most single-phase overhead lines use 1/0 AAAC conductor; or #2 AAAC, #4CU, or #6CU on older lines. These wire sizes limit loading (and outage exposure for each feeder) to about 10 - 12 MW. Emergency rating is higher but reserved for back-up as ComEd planning criteria specifies that sufficient feeder capacity should be available to enable load transfer via feeder ties.

Figure 6 presents ComEd feeder peak loads as a percent of long-term allowable rating (as opposed to short –term emergency rating). The profile confirms ComEd is properly managing feeder loads, as the distribution is consistent with those Navigant has observed at other utilities. Each year, a small percentage – typically three to five percent – of feeders are upgrades or new feeders added due to load growth or other factors such as feeder reconfiguration.

Figure 6. Distribution Feeder Loading Profile[10]



Navigant confirmed the presence of multiple feeder tie points (designated as EMC's) on virtually all of the feeders inspected. Many of these feeder ties are auto-sectionalizing loop schemes, designed to transfer loads from unfaulted line segments to feeders fed from adjacent substations. Other automatic reclosers are mid-feeder fault isolation devices. The tie points where auto-sectionalizing schemes are employed typically are equipped with reclosers. All other distribution ties are manually operated devices, usually single blade disconnects. Gang-operated, three-phase devices typically are used for

[10] These data represent loads under hypothetical extreme hot weather; that is, actual loads are adjusted to conform to the 90th percentile for weather. Average peak weather loading is typically 10% less than the extreme hot weather loading. Winter peaks are significantly less than summer peaks.

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34.5 kV subtransmission lines or on 12.47 kV lines that are not readily accessible by ground crews or from bucket trucks.

3.3 Underground Distribution Design

The distribution feeders Navigant inspected typically included a mix of overhead and underground lines. In urban areas, the percentage of underground lines often was higher. At most substations, feeder exits are underground; in some areas, up to one mile or longer. Several feeders are mostly overhead main line construction, with underground laterals tapped off the main line via riser poles, particularly in newer subdivisions. Each of the riser poles serving laterals was equipped with arresters and fuses. However, some feeders with mostly underground construction (laterals) experienced a large number of customer interruptions for line faults on main line sections during the winter 2011 storm. In many locations inspected, underground lateral taps are fed from three-phase overhead main line sections. In some cases, the main lines contained a mix of overhead and underground construction, with one or more "dips" traversing the main line right-of-way. Padmount switchgear was evident on many feeders with three-phase underground construction, which improves switching flexibility and better isolation and restoration of service for underground faults. These design practices are consistent with those of other large utilities that Navigant has inspected.

3.4 Protection Practices

To identify and confirm distribution protection practices, Navigant interviewed ComEd's engineering staff, reviewed distribution one-line diagrams, and conducted field inspections. In regions impacted by the storm and system wide, ComEd's protection practices conform to those typically employed by utilities with similar feeder length and outage exposure. These include use of line fuses on lateral taps and auto-transfer schemes using mid- and end-of-line reclosers. Field inspection and feeder data confirm that longer lines serving a large number of customers are protected by line reclosers; many of them are part of an auto-sectionalizing scheme. Field observations confirm the presence of many reclosers and auto-sectionalizing schemes (Figure 7 illustrates one example).

Figure 7. Intelli-Rupter on 12.47 kV Line (Joliet)

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Navigant did not observe any unfused lateral taps fed from main line feeder sections in any of the regions inspected. There are some very short line sections not directly connected to the main line section that were unfused. However, Navigant does not view this finding as significant, as interruptions on these short line segments do not materially increase the number or duration of customer interruptions, as the line tap from the main line section is fused and the substation breaker does not trip.

ComEd reports that it implemented an aggressive program in the early to mid-2000's to install fuses on untapped laterals, focusing on those with greatest reliability exposure first; for example, lateral taps off main line sections. ComEd also includes unfused laterals in its maintenance inspection forms, discussed in greater detail in Section 4. Once detected, ComEd's engineering staff reviews the finding to determine if it is necessary or practicable to install the fuse.[11] Navigant believes institution of these programs and ongoing quality assurance are two of the primary reasons why it did not detect any missing fuses on laterals taps from main line sections.

For distribution lightning protection, ComEd's practices include installation **of lighting arresters** every 600 feet (at 4 kV and 12 kV), either via arresters on line transformers, devices, risers, or line terminations. Where none of these conditions or equipment exists, arresters are installed every 600 feet in lighting-prone areas – on distribution lines (Figure 8).[12] This is consistent with and in some cases, exceeds common utility practice. Most ComEd distribution lines rated 12.47 kV or below do not include shield wires, also consistent with common utility practice. However, many 34.5 kV subtransmission lines, which use taller poles, contain single overhead shield wires. The 34.5 kV lines with primary underbuild provide an added level of protection for distribution lines. Navigant's field inspections confirm the consistent application of lightning protection practices in the areas inspected.

Figure 8. Distribution Lightning Arresters (Rockford)

[11] The company may elect to not install a fuse if the lateral is very short with few customers potentially impacted by interruptions, or where the fuses cannot coordinate with upstream devices. These types of exclusions are consistent with common utility practice.

[12] The presence of lightning arresters on line segments typically protect lines from interruptions due to induced lightning strikes. Lightning arresters generally cannot avoid interruptions for most direct lightning strikes due to the large amounts of energy that must be dissipated. However, equipment damage is minimized via use of arresters that may fail, but nonetheless absorb much of the energy caused by direct lightning strikes.

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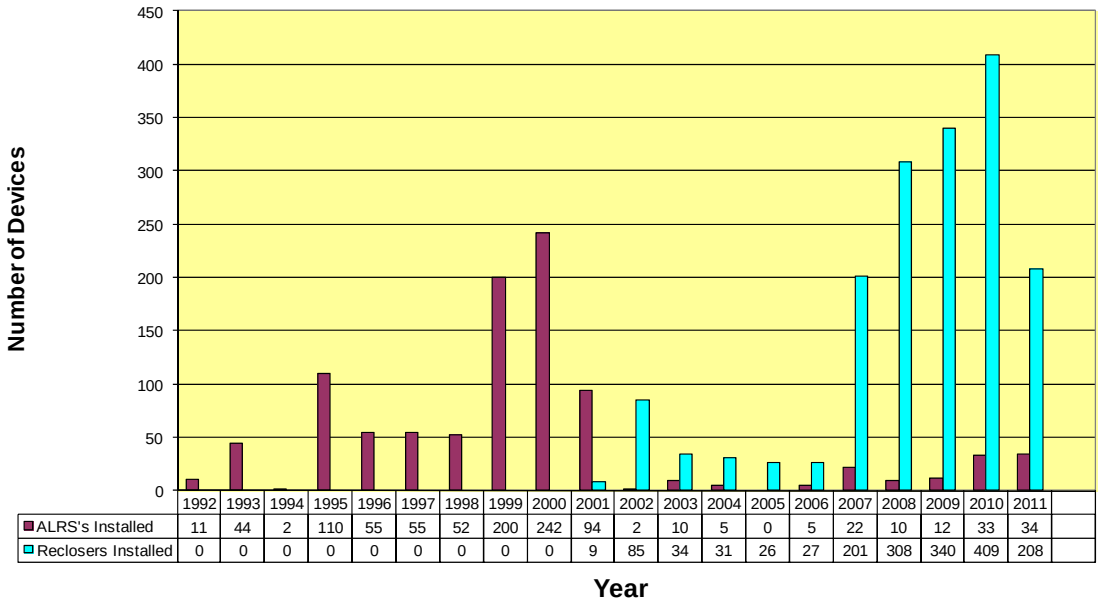
3.5 *Distribution Automation*

ComEd is recognized as an industry leader in distribution automation for subtransmission applications. In the mid to late 1990s, the company installed SCADA-Mate auto-sectionalizing reclosing circuit breakers on 34.5 kV lines throughout its service territories. More recently, the company has expanded the program to include mid-stream reclosers and auto-sectionalizing loop schemes on its 12.47 kV distribution system. Figure 9 presents the number of 34.5 kV and 12.47 kV devices installed over the past two decades. ComEd reports that the EIMA will provide the funding necessary to systematically install newer and more capable Smart Grid DA devices.

Figure 9. ComEd Distribution Automation Devices Installed



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ALRS's Installed	11	44	2	110	55	55	52	200	242	94	2	10	5	0	5	22	10	12	33	34
Reclosers Installed	0	0	0	0	0	0	0	0	0	9	85	34	31	26	27	201	308	340	409	208

Over the past seven years, ComEd has installed over 200 auto-sectionalizing loop schemes on primary distribution lines, with well over 1000 reclosers installed system wide. ComEd reports the installation distribution class auto-sectionalizing has reduced customer interruption minutes by over one million in 2011. It proposes to aggressively continue installation of reclosers and auto-loop schemes, targeting feeders based on outage exposure, number of customers within sectionalizing zones, and estimated savings in customer minutes.

Over the past few years, ComEd has begun to install single-phase fuse saving devices (also referred to as "Trip Savers") as part of a pilot program evaluation, including installations on feeders impacted by the February 2011 blizzard. These devices replace conventional fuses, with the advantage of providing automatic single-shot reclosing for temporary faults. Figure 10 illustrates these devices on a three-phase lateral tap and on a single phase lateral tab. ComEd's reliability engineers report the initial installations have performed well and the program is expected to continue.

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Figure 10. Fuse-Saver Sectionalizers

3.6 Non-Affected Areas

ComEd's distribution design practices are comparable to those we have evaluated or observed at other North American utilities serving a mix of urban and suburban load. Although some of the lines and equipment are in the newer subdivisions in outlying areas, we did not observe any distinct difference in the design or construction of lines in areas affected by the winter 2011 storm to other parts of the system. Asset records, field observation, and statistics confirm main line and lateral line sections are comparable in length, and equipped with reclosers and fuses in a consistent manner, with few observable inconsistent applications of these practices.

3.7 Summary Assessment

ComEd's distribution design standards are consistent with or exceed those of utilities with comparable service territory attributes and customers served. In all areas reviewed, confirmed by field inspections, ComEd's distribution system is designed and constructed in accordance with Title 83 of the Illinois Administrative Code, NESC, and common and prudent utility practice. We did not observe any clear violations of these codes and practices. The size and capability of key distribution equipment, including poles, wires, transformers, and cable, are appropriately sized for the function they provide, and are properly maintained. Regular patrol and inspection of all lines ensure potential reliability problems are proactively addressed and emergent code violations immediately addressed. Protection practices meet or exceed industry practices, including extensive use of reclosers and employment of auto-sectionalizing loop schemes, ensuring that the minimum number of customers is impacted by interruptions and restoration times are expedited.

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4. Material Condition Assessment

4.1 Overview

Navigant's condition assessment of ComEd's distribution system included a rigorous and independent review of key data, field observations and design factors, all of which are essential to formulating consistent and defendable findings and conclusions. Sources include asset registry data, performance history, design standards, maintenance records, ICC reports, and other relevant system records and documentation; supplemented by information obtained in interviews with those responsible for managing and implementing these processes and field inspection observations. Navigant focused on areas impacted by the February 2011 blizzard, and compared these data and statistics to areas unaffected by these storms.

4.2 Distribution System Assessment

Table 4 compares key distribution statistics for distribution feeders in areas affected by the February 2011 blizzard to those located in ComEd's entire service territory. The table indicates that distribution feeders impacted by the winter 2011 are longer and serve more customers, on average, to those located in unaffected areas. In particular, the length of lateral line segments are well above the system average, indicating that many feeders impacted by the winter storm are located in the more rural and suburban areas of the system, where there are fewer trees and lines are more likely to experience the full force of blizzard level winds. However, the table also indicates a higher level of automation, based on the higher percentage of reclosers installed.

Table 4. Distribution System Statistics

Distribution Lines and Equipment	Total ComEd Distribution System	Areas Affected by Winter 2011 Storms	Areas Affected Versus Total System (Percent)
Total Number of Feeders	5,022	586	12%
Total Number of Customers	3,799,887	637,915	17%
Total Main Line Miles	27,334	4,658	17%
Overhead	14,510	3,000	21%
Underground	12,824	1,658	13%
Total Lateral Line Miles	33,524	7,170	21%
Overhead	17,206	4,653	27%
Underground	16,318	2,517	15%
Total Line Miles	60,858	11,827	19%
Overhead	31,716	7,653	24%
Underground	29,142	4,175	14%
Average Circuit Length Main Line	5.44	7.95	146%
Average Number of Customers Main Line Mile	139	137	99%
Average Circuit Length Laterals	6.68	12.23	183%
Number of Reclosers	1,828	375	21%
Main Line Circuits with Reclosers	1,087	218	20%

Note: Distribution statistics based on primary circuit line miles

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The average age of ComEd's overhead distribution transformers, system wide, is about 25 to 30 years. The average age of transformers in the northern region is just under 20 years. Overhead transformers are inspected every four years as part of the company's maintenance inspection program. This is consistent with or above common utility practice.

Figure 11. Age Distribution: Transformers

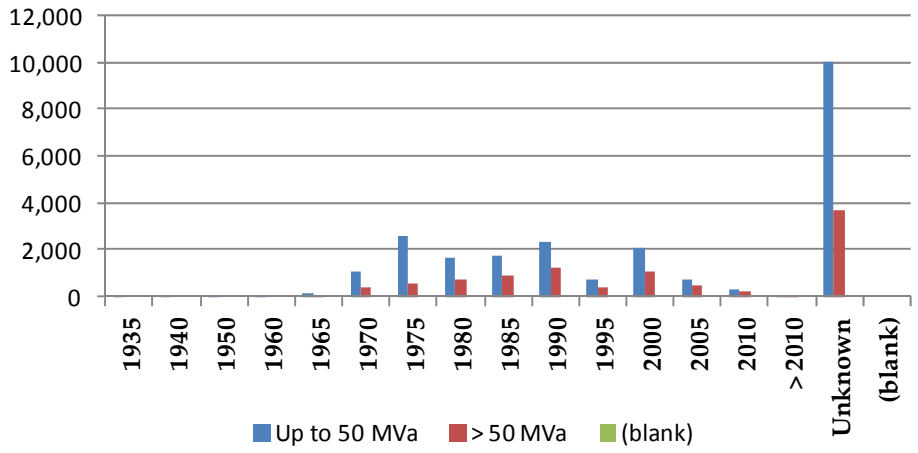
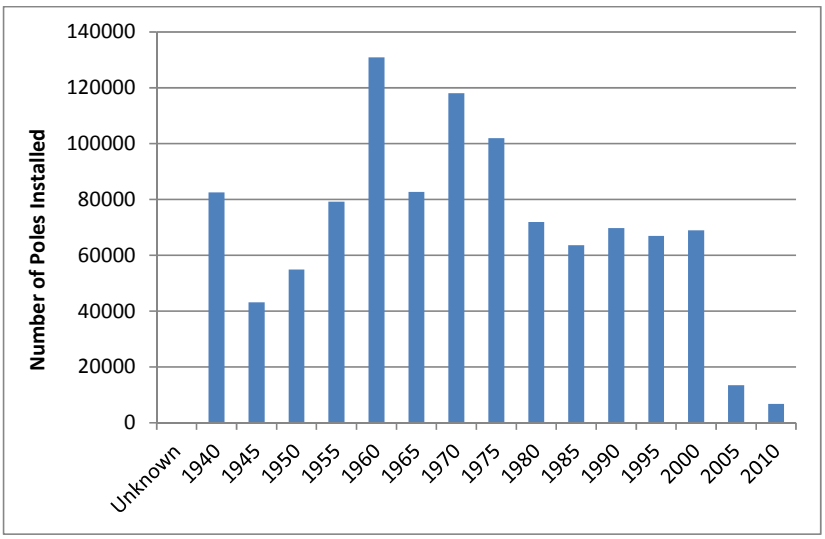


Figure 12 presents the age of ComEd's distribution poles for the entire system. The average age of ComEd's distribution poles, system wide, is about 42 years. Pole inspection records indicate that about three percent of poles inspected annually are rejected. Of those that are rejected, all poles listed as priority replacements have already been replaced or reinforced or are in the current workplan (*i.e.,* the replacement or reinforcement process is underway). This is consistent with common utility practice.

Figure 12. Pole Age Distribution



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4.3 *Reliability Improvements & Performance Review*

4.3.1 Reliability Improvement Programs

ComEd has instituted a series of programs and measures designed to enhance reliability performance. Some of these programs have been in place for several years; some are relatively new, such as those crafted based on smart technologies. Most of these programs, described below, provide reliability benefits for both normal conditions and storms.

4.3.2 Targeted Reliability Improvements

ComEd's reliability improvement program is designed to maximize reliability improvements at the lowest cost. It includes capital and O&M programs targeted to feeders with the greatest opportunity for reliability improvement. Specific initiatives, in addition to miscellaneous reliability improvements, include:

- Worst 1% Feeder Program
- Cable Diagnostic Testing
- Circuit Capacity Improvement
- Customer Targeted Program
- Distribution Automation Program
- Underground Cable Program
- Pocket Reliability Program

Collectively, these programs, along with pro-active maintenance, appear to have directly contributed to an improvement in reliability metrics over the past five to ten years. They likely contributed to a reduction in both the number and duration of interruptions that otherwise would have occurred during the February 2011 blizzard. For example, reinforcing poles, installing auto-sectionalizing loop schemes, replacing damaged equipment and targeted lightning protection each are important factors for enhancing storm durability. However, substantial amounts of weather-related damage can occur to even the most durable distribution equipment from, for example, uprooted trees and large fallen limbs in the summer or ice loading in the winter.

Some utilities have sought to employ storm hardening to its distribution system, such as installing higher-class poles, larger cross arms, bundled conductor and relocating lines underground. Navigant's experience is that these measures are difficult to justify economically, particularly for existing equipment where replacement can be very expensive if applied system wide. Other options such undergrounding overhead lines can be exceedingly expensive, particularly for three-phase primary distribution lines, where each fault interrupts the greatest number of customers.[13] The undergrounding of single-phase lateral tap lines is less expensive, but results in far less reliability benefit due to the lower number of customers served on these line segments. Storm hardening typically is most cost effective when applied to new construction or scheduled replacements.

[13] Prior Navigant studies indicate the cost of overhead to underground relocation, applied system-wide to large urban utilities similar to ComEd can cost in the billions of dollars.

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4.4 *Maintenance Practices & Procedures*

4.4.1 Vegetation Management

ComEd's Vegetation Management (VM) program for overhead distribution lines is based on ICC requirements, which requires electric utilities to trim every primary distribution line, at minimum, every four years. ComEd is not required to trim trees located near low voltage service lines. Further, ComEd performs interim spot trimming on feeders where vegetation management issues are identified from reliability records, scheduled maintenance inspections, or field observation. ComEd's compliance with the ICC's targets exceeds 99 percent that all circuits get trimmed in four years, and has processes in place to ensure feeders meet this standard. Ongoing construction and other non-ComEd activities that limit access typically account for the remaining one percent.

Further, ComEd's VM policy for subtransmission lines does not allow for any overhang. Notably, many 34.5 kV subtransmission lines include one or more 12.47 kV or 4.16 kV distribution lines attached directly below the 34.5 kV lines. These lower voltage distribution lines would share in any benefit from this practice.

4.4.2 Pole Inspection Program

Since 1996, ComEd has inspected well over 1 million of the 1.4 million distribution poles on its system. The remaining 400,000 typically are newer poles installed for new loads or line extensions and are therefore given a lower inspection priority. The company has a goal to achieve a ten-year inspection cycle that it will maintain prospectively once reached. A ten-year inspection cycle is consistent for utilities located in decay zones comparable to northern Illinois.[14] ComEd employs Osmose® to perform and treat poles, a firm well recognized and employed within the utility industry and other industries using wood products.

Table 5 summarizes the composite results of these inspections, which indicate that less than 1 percent of the poles are deemed as priority replacement, indicating the pole must be replaced (less than 1,000 annually). This replacement rate is at or below those of other utilities Navigant has evaluated. Of the non-priority poles rejected, which includes those that should be addressed within one year, many of these are reinforced with C-Trusses, a low-cost alternative to complete pole replacement (Figure 13). Most of the remaining 96 percent of poles inspected are treated with decay retardants or pole wraps to extend asset life.

Table 5. Distribution Pole Inspections

	Year Last Inspected	Poles Inspected	Reject[15]		Non-Reject
			Priority	Non-Priority	
Total System	1996 - 2007	1,223,948	0.89%	3.04%	96.07%

[14] The North American Wood Pole Council has a rating system that establishes deterioration or decay zones on a scale of 1 to 5, with 1 as the lowest decay zones, 5 the highest. ComEd's service territory is mostly within zone 2, which is designated as a moderate deterioration zone. Pole inspection intervals typically correlate with zone designations; those in deterioration zone 1 or 2 typically have ten-year inspection cycles or longer. http://www.woodpoles.org/documents/TechBulletin_EstimatedServiceLifeofWoodPole_12-08.pdf

[15] Priority replacement is assigned when less than one-third of the original pole shell strength remains; non-Priority when less than two-third, but more than one-third of the original shell strength remains.

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Navigant views ComEd's practices of inspecting and treating poles to extend their service lives, and replacing poles only when tests indicate replacement is the only cost-effective option, as consistent with utility asset management practices and pole inspection processes. ComEd's actual practices are in contrast to recommendations in some states that ostensibly suggest poles should be replaced when they reach an age threshold – 40 to 50 years. This would markedly increase the pole replace rate, at significant cost, applying criterion unsupported by inspection results, internal strength measurements, and remaining pole life based on commonly accepted engineering principles and prudent utility practices.

Figure 13. C-Truss Pole Reinforcement (Rockford)

4.4.3 Maintenance Inspections

ComEd has instituted a proactive maintenance inspection program designed to identify potential reliability, performance, or safety issues. Every feeder is inspected at least every four years. Navigant confirmed that each of the distribution feeders experiencing interruptions during the winter 2011 storms was inspected within the prior four years.

The inspections include identifying issues that would otherwise exacerbate the number and duration of storm interruptions if not proactively addressed by these inspections. These include devices in need of repair, damaged equipment, deteriorated poles and crossarms, low clearances, failed lightning arresters, missing fuses, grounding (including cut ground wires) and other items prescribed for inspection. Table 6 lists the 25 items that appear on inspection sheets. Inspections are provided a second set of severity codes for each of these codes, ranging from 10 for items in need of immediate repair or replacement, to 40 for inclusion as a corrective maintenance work order. Code 10 designations must be addressed within

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24 hours, Code 20 within 14 to 30 days and Code 30 within 30 to 60 days, respectively. Appendix B presents a more detailed array of these codes and severity levels.[16]

Table 6. Overhead Maintenance Inspections

Maintenance Inspection Items				
Poles	Slack Span (Primary)	Tie Wire	Non-Oil Term	Guy Wire
Pole-Top Extension	Arms (Crossarm / Alley)	Connector	Wildlife Protection	Highway / Railroad Crossings
Conductors (Primary)	Arm Brace	Arresters Needed (Number)	Fault Indicators	Labeling
Conductors (Secondary)	Insulators / Deadends	Fuse / Cutout	Grounding	Clearance
Conductors (Neutral / Static)	Pin	Equipment (Trf/Reg/Pot/Recl/Cap)	U-Guard	Vegetation

Navigant views ComEd's proactive maintenance inspection program as an industry best practice and it likely prevented some interruptions and reduced the duration of others during the winter 2011 storms. Several, if not most, of the items on the list are susceptible to storm-related failure or faults, including vegetation. Notably, ComEd's maintenance inspection personnel visually inspect all lines experiencing more than 100 customer interruptions following a storm, and all feeder lock-outs.

ComEd also employs several reliability engineers, whose sole responsibility is to identify and devise solutions for potential reliability issues based on feeder reliability data, field observations, customer complaints, performance history, and other sources. Many of these engineers accompanied Navigant's field inspectors. Feedback received from these engineers confirmed they are always on the "lookout' for reliability problems.

4.4.4 Thermography

In addition to the two- and four-year inspection cycles outlined in Table 6, ComEd performs a similar set of thermography inspections to detect hot spots and other areas of higher-than-normal heating, such as those associated with loose connections, hidden corrosion, and pending internal devices failures. Many utilities perform thermography, particularly for transmission and subtransmission. Navigant views ComEd's program as an industry best practice as it is performed regularly for all distribution feeders; not just on a targeted basis or to address isolated reliability or performance problems. Thermography likely reduced the number of interruptions that otherwise would have occurred during the winter 2011 storm, as loose connections or corroded terminations susceptible to heating also are most likely to break when loaded with ice and snow.

[16] Maintenance Inspectors are provided a document titled "Overhead Distribution Circuit Inspection Criteria," which has photographs and illustrations of typical conditions and codes that should be assigned for each of these conditions.

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4.4.5 Quality Assurance

Navigant determined that the manner in which the reliability programs and initiatives have been established and implemented have contributed significantly to the quality assurance and continuous improvement of the overall reliability performance. This is evidenced by the overall improvement of key reliability indicators (SAIFI, CAIDI) to 1st and 2nd quartile in the benchmarking studies presented in Section 5.

In order to significantly improve the outcome of a process, there are two key components to assess: (1) The overall population of outcomes (reflected in the process average); and (2) the variation of the process (seen in the outliers or population tails) - ComEd's reliability programs focuses on both. The Maintenance Inspections, Distribution Automation, and Cable Diagnostic Testing are examples of reliability programs to improve the process average. The Worst 1 % Feeder Program, Worst Chronic Feeder Programs, and Customer Targeted Program are examples of initiatives to narrow the variation. Focusing on worst performing feeders and customers/equipment with higher number of failures is a best practice, contributing to the overall performance improvement. Com Ed consistent emphasis on the worst performing feeders have resulted in considerable improvement in this area, where now the worst feeders being addressed are experiencing on average 4.5 to 5.5 failures per year. It must be noted that to significantly impact an outcome indicator based on so many different input variables requires strong attention to details and focused on consistent plans and execution.

Continually re-evaluating plans, monitoring and controlling the execution, and acting on the non-performing parts of the process are critical components of continuous improvement. Navigant observed, through interviews and review of documented procedures, these important steps are functioning well, constituting a strong management process and quality control. ComEd has carefully detailed annual plans which include targets and monthly indicators that are tracked by management as part of the monthly indicator review meetings. Additionally, they conduct daily conference calls to review the previous day's findings as well as customer concerns.

During Navigant's field inspections, the Navigant team was accompanied by reliability engineers, and it was evident that ComEd's personnel are very familiar with the feeders and system infrastructure. A sense of "ownership" of their respective areas was apparent. On the infrequent occasion when an issue was identified, ComEd's personnel were proactive in documenting it and taking action.

4.5 Summary Assessment

ComEd's distribution system is comparable to many of those we have evaluated or observed at other North American electric utilities serving a mix of urban and suburban load. Distribution overhead design practices, which include use of 8-foot cross arm construction with Class 3 poles as a standard for three-phase main lines, with few very long spans, is consistent with common utility practices for well built systems. In certain areas, many segments of distribution lines observed during our inspections were located along heavily treed rights-of-way in back lots or back alleyways. However, effective vegetation management programs, pro-active maintenance, and targeted reliability improvements, coupled with ongoing quality assurance has caused reliability to improve over the last decade.

ComEd has effectively managed its distribution assets to ensure reliability is not degraded by lines or equipment that is improperly maintained or applied. The institution of regular maintenance inspections

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and targeted reliability programs are designed to pro-actively identify and address potential problems. Although some equipment is several decades old, its condition and ability to perform well under normal storms is assured by these pro-active efforts. This finding is underscored by the continued reduction in the defective equipment cause code for overhead distribution. Although underground cable failures have increased, they were not a major factor during the winter 2011 storms. ComEd has implemented an underground cable and infrastructure upgrade program, targeted to circuits and cable sections with high failure history or known to be susceptible to failure.

The results of the above and the review of ComEd's distribution design in Section 3 and interruption statistics provides evidence that the large majority of interruptions – well over 95 percent based on reliability data - that occurred during the winter 2011 storms were unavoidable, as the damage that occurred was due to events outside of ComEd's direct or indirect control. Further, one would not expect to find evidence that every interruption is unavoidable, which is the case for all electric utilities crews and staff during major storms. Notably, each of the distribution lines experiencing interruptions during the storm had been trimmed in accordance with ICC standards. Further, our review of ComEd's distribution design standards, confirmed by field observation, unequivocally indicates system design and construction is consistent with prudent and common utility standards. Notably, we did not observe any violations or inconsistency with Illinois Administrative Code 305 or NESC requirements. In many areas, such as targeted reliability initiatives and distribution automation, ComEd has adopted industry best practices. Navigant's findings are supported by over 75 years of collective experience evaluating electric utility distribution systems and post-storm performance.

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5. Benchmark Analysis

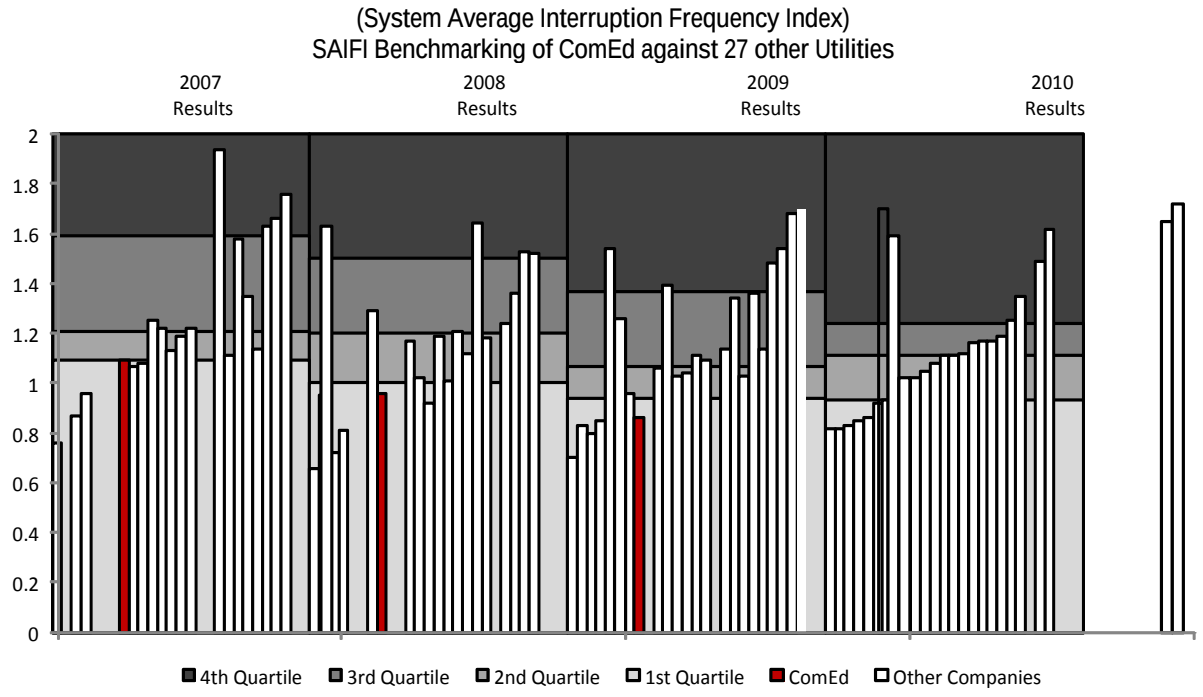
5.1 Objectives

Navigant examined two benchmarking sources in order to determine ComEd's performance relative to industry peers across the U.S. and among all Illinois utilities. Navigant's examination of the benchmark results were focused on commonly used reliability indices including: SAIDI, SAIFI, and CAIDI; as well as O&M costs. Further, Navigant benchmarked equipment damage based on publically available data for tropical cyclones over the last two decades.

5.2 27-Company Peer Group Reliability Benchmark

As part of its quality program, ComEd participates in an annual benchmark with a group of similar utilities from across the U.S. The graphs below present the 2007 through 2010 results for SAIFI, CAIDI, and SAIDI relative to the peer companies. The results for ComEd are highlighted in red and performance quartile bands are indicated with various shades of gray.

Figure 14. Reliability Benchmark – Outage Frequency



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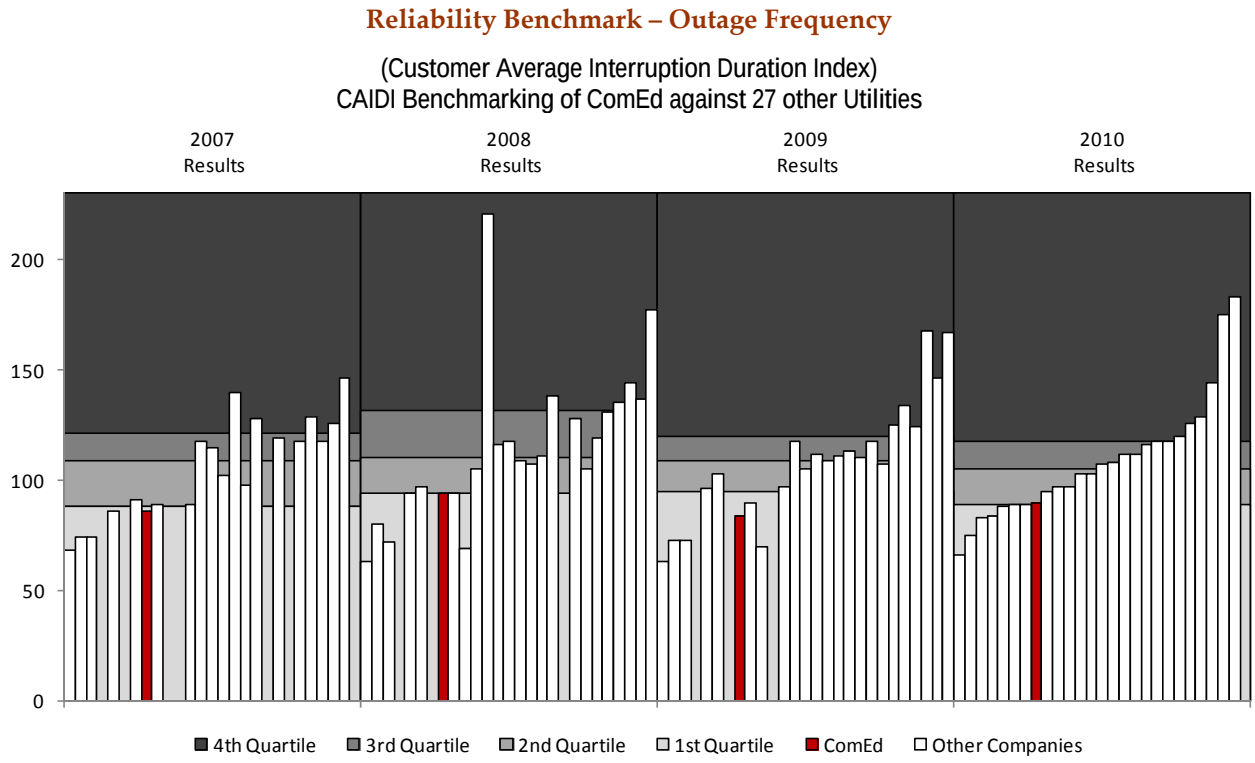
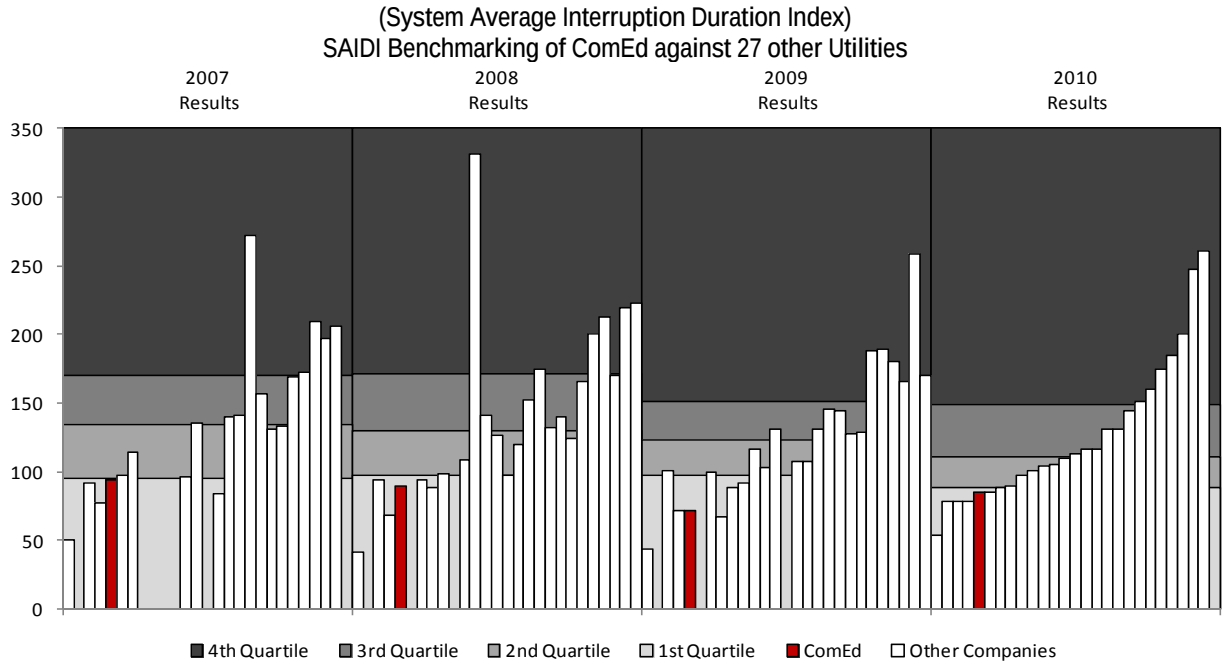


Figure 15. Reliability Benchmark – Outage Frequency



The indices in this benchmark were calculated using the IEEE Std. 1366-2003 2.5 Beta Method which excludes major events and planned interruptions. Not all the companies in the benchmark reported their results every year and some did not measure a particular metric.

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The results of the benchmark show a steady performance by ComEd over the period from 2007 to 2010. ComEd results for SAIFI and CAIDI placed them among the companies in the first quartile from 2007 to 2009 and at the top of the second quartile in 2010. ComEd's results for SAIDI placed them among the companies in the first quartile throughout the entire reporting period. These results suggest a sustained and well above average reliability performance consistent with a well maintained system.

5.2.1 Benchmark Companies

ComEd benchmarks performance versus a 27-company peer group comprised of anonymous utilities comparable in size or system attributes.[17] Instead, the companies have been identified by a number. Only ComEd is identified by name. The characteristics considered in the selection of the peer group panel members include:

Primary

- Approximately 1 million or more customers
- Availability of operating and financial data
- T&D operations

Secondary

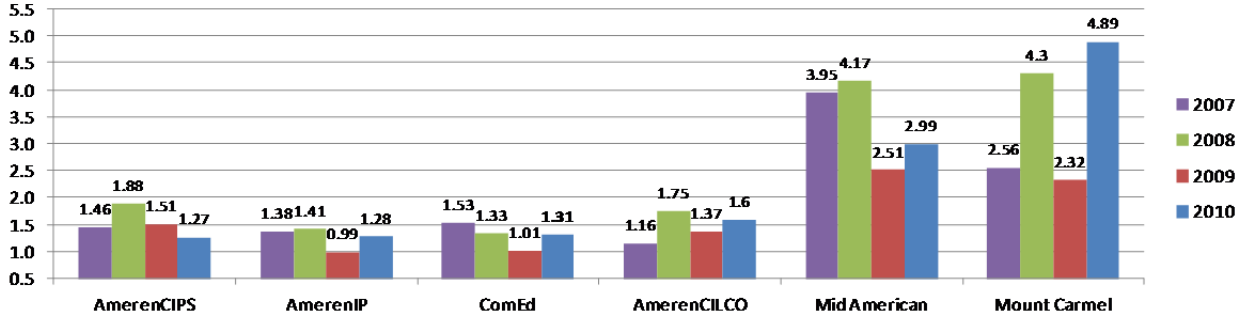
- Publicly held utility
- Integrated utility (gas and electric)
- Operations in multiple states

5.3 Illinois Commerce Commission (ICC) Reliability Benchmarks

As part of ComEd's reporting requirements, ComEd participates in an annual reliability benchmark that includes all the utilities serving customers in Illinois. This benchmark includes SAIFI and CAIDI reliability metrics (including storm data). Figure 16 and Figure 17 present the results from 2007 to 2010.

Figure 16. Reliability Benchmark – Outage Frequency

(System Average Interruption Frequency Index for Illinois State Utilities)



[17] Data provided by the 27 utilities in the peer group is confidential, as participating utilities do so on the condition that company-specific data is not disseminated to third parties.

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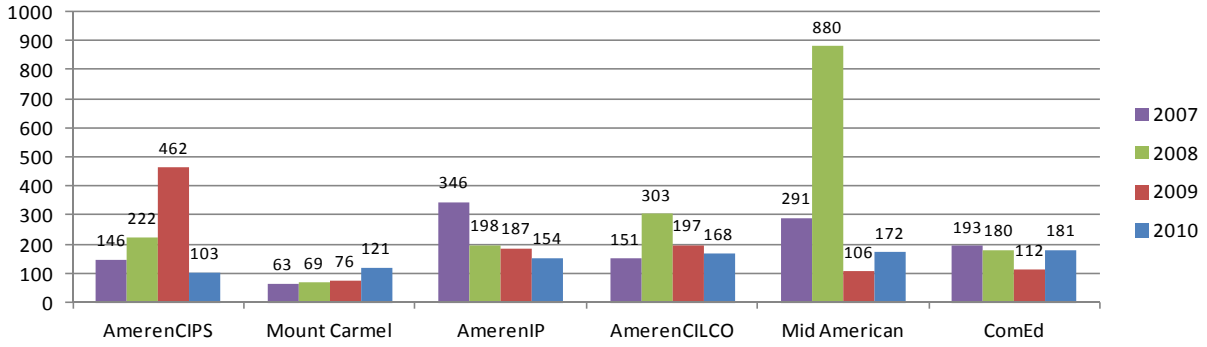
Figure 17. Illinois Utility Reliability Benchmark – Outage Duration

(Customer Average Interruption Duration Index for Illinois State Utilities)



The metrics in this Benchmark were calculated using Commission rules which includes outages lasting more than one minute, and excludes certain outages specified in 83 Illinois Administrative Code Chapter 1 Section 411 (i.e. Customer Related Outages).

The results of the Benchmark show a steady performance by ComEd over the period from 2007 to 2010. ComEd SAIFI and CAIDI results placed them in first and second place among major utilities (those with 80,000 or more) in 2008 and 2009 respectively. ComEd SAIFI results placed them in third place in 2010. CAIDI results 2010 placed them in fifth place as a result of the June 18, 2010 Storm which struck Northern Illinois and impacted over 540,000 customers increased CAIDI by 54 minutes. These results also suggest a sustained and well above average reliability performance consistent with a well maintained system.

5.3.1 Benchmark Companies – ICC Reliability Benchmark

The Benchmark includes utilities that have electric customers in Illinois including: AmerenCIPS, Mount Carmel, AmerenIP, AmerenCILCO, Mid American, and ComEd.

5.4 Benchmark Costs- 27 Company Peer Group

ComEd's spending for distribution O&M is comparable to the O&M spending of the 27-company peer group in ComEd's benchmark (please see description of peer group provided in section 5.2.1). Figure 18 compares ComEd's O&M annual spending to the 27 benchmarked utilities based on dollars per customer.

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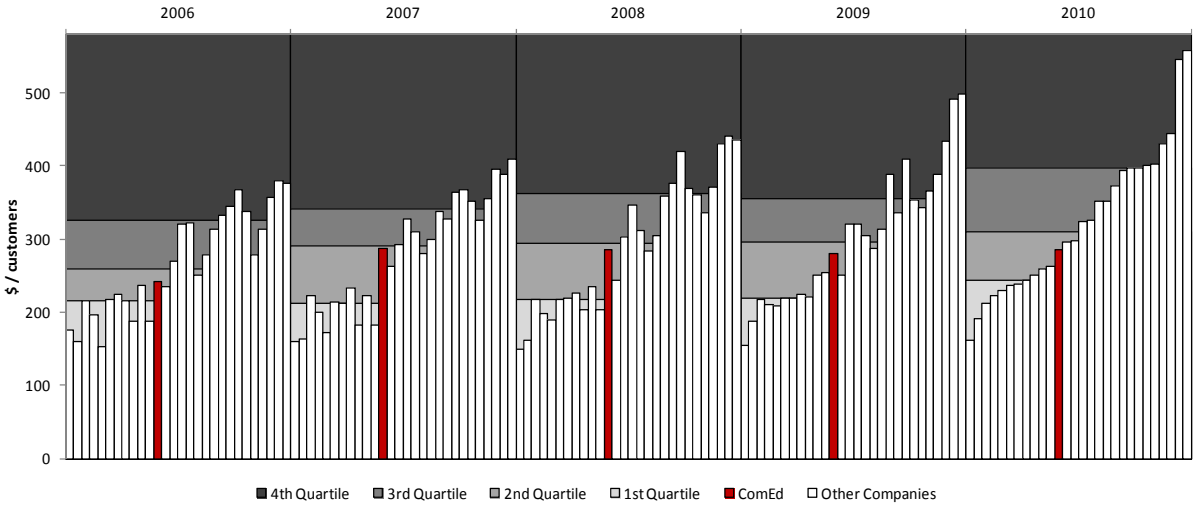
Figure 18. O&M Benchmark versus 27 Other Utilities



The cost benchmark results indicate ComEd's spending for O&M is slightly below the average. Navigant views these results as very favorable. ComEd has implemented a comprehensive O&M program, described in detail in prior sections. The ability to implement comprehensive O&M programs, several of which Navigant deems as best practices, suggests that spending is carefully managed and targeted to areas that provide the greatest reliability and performance benefits per dollar spent. Notably, major spend components like vegetation management as well as maintenance inspections are performed in a cycle that is at, or shorter than, those of other comparable utilities outside of Illinois.

5.5 Major Storm Benchmark

A comparison of performance during major winter storms is difficult to benchmark as no two storms are exactly the same. Electric utility distribution lines are not designed to withstand damage caused by excessive snow, ice, wind, lightening, uprooted trees and airborne branches or debris; nor does the NESC specify distribution design standards to withstand weather elements of major storms. Nonetheless, Navigant's experience indicates that favorable restoration trends for normal events often are a good indicator of how the system will perform during major storms. It is possible to establish a reasonable performance benchmark based on available storm restoration data and understanding of the storms' effect on utility infrastructure. Further, Navigant's review of ComEd's 2011 winter storm performance indicate an above average performance outcome in both number of customers impacted and outage duration.

Major natural weather events are difficult to predict, even after they've occurred it is difficult to fully document or understand the causes and effects of what transpired due to the focus by restoration crews and support staff to restore service to customers as soon as possible. Despite the attention paid to restoration, ComEd was able to accurately record interruption causes and equipment damage, largely due to the processes it has established to ensure the data is collected and fully reviewed.

From the interruption statistics and data obtained from outside sources, the following facts underscore the severity and impact of the winter 2011 storm:

- The storm is the third largest on record at Chicago (O'Hare) with 20.2 inches of snow

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- There were 229 recorded lightning events - unusual for a winter storm
- Documented wind gusts of 61 mph with sustained winds speeds of 41 mph on Tuesday, February 1st, and recorded gusts as high as 51 mph on Wednesday, February 2nd at O'Hare airport
- The blizzard created whiteout conditions, limiting visibility and halting traffic. Residents were warned to stay away from the roads until Wednesday afternoon
- The blizzard lasted 27 hours, leaving some motorists stranded for as long as twelve hours Monday on Lake Shore Drive
- Up to 900 cars were stuck in snow "so deep they could not escape". "Overnight, firefighters traveled by snowmobiles to help drivers push their cars to safety"[18]
- ABC News reported that "Illinois officials deployed as many as 700 members of the National Guard to help stranded motorists"
- Across the nation some 5,634 flights were canceled
- Chicago's public schools were closed for the first time in 12 years
- ABC World News with Diana Sawyer reported "A winter storm left a 2,000-mile-long trail of snow and ice from the Midwest to the Northeast and two thirds of the nation facing downed power lines, shuttered highways and thousands of airport cancellations." [19]

The 2011 Winter Storm impacting ComEd on February 1st and 2nd was extraordinary in all respects. Table 1 and Table 2 summarize the number and duration of interruptions, and resulting damage. Given the catastrophic nature of the weather, which included a mix of lightning, sustained high mph winds, wet snow, and blizzard-like conditions, Navigant views these interruption statistics as favorable,. Navigant is confident that any other utility under similar circumstances would have suffered similar or a greater amount of damage and customer interruptions.

Storms and their effect on a utility's infrastructure are difficult to predict precisely since there are many factors to consider, and many are not easily measured or consistently tracked by the industry. However, it is possible to establish a reasonable perspective based on available data and understanding of storms' effect on utility infrastructure. In a report prepared for Edison Electric Institute (EEI) in January 2004, Mr. Brad Johnson, an Independent Energy Advisor for EEI, compiled and examined utility data from 44 major storms that occurred between 1989 and 2003 (of the 44 major storms, 23 are ice and snow winter storms). The report suggests major equipment damage, such as damaged poles, transformers replaced, and miles of conductor installed, is a reliable and consistent way to compare the severity of storms. The report emphasizes that "Ice storms can cause vastly different types of damage—depending on whether they hit when leaves are still on trees, the thickness of the ice, how high the accompanying winds are and whether the ice damages transmission lines as well as distribution lines."

[18] http://abcnews.go.com/US/blizzard-2011-mega-snowstorm-pounds-midwest-snow-ice/story

[19] "Storm Leaves Trail of Snow, Ice, Power Outages, Freezing Temperatures" by Leezel Tanglao, Max Golembo, Ben Forer and Jessica Hopper; http://abcnews.go.com

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Table 7 presents winter storm data that allow us to compare the February 2011 Winter Storm with winter storm events, damage inflicted on the utilities, and restoration performance. Table 7 includes data from utilities across the U.S. over a 10-year period.

Table 7. EEI Major Storm Restoration Survey Results, 1989-2003 -Winter Storms Excerpt[20]

					Damage Estimates		
Winter Storm Event	Date	Peak # of Cust's Out	Outage Duration (Days)	Peak # of Restoration Personnel	Poles Replaced	Tx Replaced	Wire Replaced (Miles)
Snow Blizzard	Mar-93	170,000	7				
Major Ice Storm	Feb-94	224,000	16	2,397	15,565	828	1,037
Ice Event	Jan-96	61,000	4	1,130			
Ice Storm	Feb-96	650,000	8	4,000			100
March-97 Ice Storm	Mar-97	160,000	5	1,110	420	420	100
October-97 Snow and Wind Storm	Oct-97	213,000	4	1,495	670	610	170
Ice Storm	Jan-98	83,400	2	1,098	790	340	80
November-98 Snow & Wind Storm	Nov-98	160,000	3	1,755	860	780	130
Christmas Ice Storm 1998	Dec-98	167,700	5	1,704	525	276	
Ice Storm	Jan-99	120,000	4		100	100	
New Years Ice Storm 1999	Jan-99	109,685	5	837	153	62	
Ice Storm	Jan-99	220,000	4	1,600		250	38
Snowstorm	Jan-00	173,000	5	2,265			
December Ice Storm #1 2000	Dec-00	226,139	8	4,196	1917	174	547
December Ice Storm #2 2000	Dec-00	212,508	8	5,429	1383	123	772
October -01 Snow and Wind Storm	Oct-01	99,000	3	993	580	620	120
March-02 Snow and Wind Storm	Mar-02	93,000	2	1,288	620	270	70
Ice Event	Dec-02	464,000	6	4,477	1322	2196	85
Ice Storm	Dec-02	1,375,000	9	9,500	3,200	2300	549
Arkansas Ice Storm 2002	Dec-02	41,951	5	1,396	463	64	
Ice storm	Feb-03	350,000	5	1,208	212	307	70
April-03 Ice Storm	Apr-03	196,000	6	1,570	600	580	160
Average		253,154	6				
Median		173,000	5				

The peak number of customers out in Table 7 refers to the highest number of customers out at a single point in time, while outage duration refers to number of days between the initial outage to when the majority of customers were restored. The average peak number of customers interrupted for the 23 storms is 253,154 for an average of six days. The median peak number of customers interrupted is 171,500 over five days.

The total number of customers out for ComEd was 176,831; however, the peak number (maximum number of customers out at one point in time) was much lower at 90,000 and this value should be used to compare data that appears in Table 7, the third column of which also indicates peak numbers of customers out of service due to all interruptions. ComEd's 90,000 peak for number of customers

[20] Data extracted from Figure 2, page 7, Brad Johnson "Utility Storm Restoration Response" Edison Electric Institute, January 2004.

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interrupted, and two day average outage duration is well below the benchmark data, where an average of 250,000 customers were interrupted for an average of six days. From this benchmark review, one can infer that ComEd's equipment condition, as well as its operating and maintenance practices were important contributing factors for the lower number of customers interrupted and much shorter outage duration.

Navigant's conclusions and findings are summarized as follows:

- The Winter Storm of 2011 or the "Great Ground Hog Day Blizzard of 2011" or the "Monster Storm" as the newspapers named it was not a typical winter storm. In fact, it was recorded as the third highest winter storm in Chicago with 20.2 inches of snow and winds of 61mph at O'Hare airport.
- With sustained blizzard winds and wind gusts of over 50 mph on the second day of the storm, Wednesday, February 2nd, it was challenging to safely reach equipment in areas that needed restoration.
- Considering the catastrophic nature of the 2011 blizzard and by comparing the peak number and duration of customers interrupted, one can conclude that ComEd's equipment condition, design standards and the operating and maintenance practices were a major factor contributing to the fewer number of customers interrupted and lower restoration times.
- No two storms are alike, increasing the difficulty of evaluating the equipment damage between events and utilities. Further, there are significant differences between winter and summer storms and their impact on utilities infrastructure. Areas with high vegetation density are most vulnerable since uprooted trees and flying branches have significant consequences that cannot be avoided. Such is the case for ComEd in most of the areas impacted by the summer 2011storms. However, in the case of ComEd's 2011 winter storm, the 40 to 60 mph sustained wind speeds, numerous lightning strokes, and up to 20 inches of snow contributed to the number of outages, and most important, outage restoration duration, which was greatly hampered by the lack of visibility, road closures and lack of accessibility during the first few days of the storm.

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6. Vegetation Management

ComEd's four-year trimming cycle and clearance standards for distribution lines, which is in accord with ICC targets, are comparable to practices employed by other utilities. Importantly, ComEd has implemented a vegetation management quality assurance program, actively managed, that ensures feeders are trimmed on cycle; post-trimming inspections are performed to ensure trimming cut-back standards are met. Spot trimming is performed when reliability data indicates need for supplemental trimming. Navigant field inspections confirmed that trees appeared properly trimmed, as we found minimal evidence of trees or limbs in direct or near contact with primary distribution lines.

ComEd's program is managed by personnel with arboricultural backgrounds, and the company reports that it continually investigates methods for improving trimming methods. For example, the degree of cut back without damage to tree health often is dependent on tree species. Field observations confirm significant cut back on durable species. ComEd also has pro-actively worked with cities and towns that it serves to adopt practices that serve their common respective interests. For example, ComEd has successfully promoted use of low profile species in town rights-of-way below lines that improve overall appearance, but avoid growth into the overhead conductor.

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Appendix A. Feeders Inspected

TOWN NAME	Total Miles	OH Lat. Miles	OH ML Miles	OH Tot Miles	UG Lat. Miles	UG ML Miles	UG Tot Miles	Cust's	Comm Cust's	No. of Recl's	Voltage
AFFECTED AREAS											
Morton Grove	10	2	3	5	2	3	5	947	158	0	4/12 kV
Arlington Hts	10	1	3	5	1	4	5	1672	177	2	4/12 kV
Highland Park	15	4	5	9	1	5	6	741	98	0	4/12 kV
Elmhurst	18	4	6	10	2	6	8	787	152	0	4/12 kV
Elmhurst	14	7	4	11	1	2	3	1423	30	3	4/12 kV
Joliet	9	3	5	8	0	1	1	1103	154	2	4/12 kV
Joliet	13	4	3	7	6	0	6	1339	104	1	4/12 kV
Joliet	16	7	6	13	1	1	3	1706	98	2	4/12 kV
Joliet	6	2	4	6	0	0	0	631	61	0	4/12 kV
Chicago	7	3	4	6	1	1	1	2735	200	2	4/12 kV
Chicago	11	4	3	4	3	7	7	2196	143	0	4/12 kV
Chicago	2	2	1	2	13	1	1	538	27	0	0
Bridgeview	10	2	6	9	10	0	1	1110	134	1	4/12 kV
Burr Ridge	15	3	5	9	2	3	6	1050	35	2	4/12 kV
Frankfort Twn	27	6	5	7	0	7	20	1427	296	2	4/12 kV
South Elgin	18	12	4	5	26	2	12	1090	39	0	4/12 kV
Wheeling	15	1	2	5	5	8	10	1156	173	2	4/12 kV
Des Plains	13	71	5	11	75	1	2	1365	53	2	4/12 kV
S. Barrington	52	3	9	21	0	6	31	408	43	1	4/12 kV
Ela Township	14	2	2	3	1	6	11	477	133	0	4/12 kV
Subtotal	293	142	85	155	152	63	138	23901	2308	22	
UNAFFECTED AREAS											
Morton Grove	9	3	4	7	2	2	2	933	24	0	4/12 kV
Morton Grove	6	1	2	4	0	1	2	296	5	0	4/12 kV
Glenview	12	2	4	8	1	2	5	899	164	1	4/12 kV
Evanston	3	1	1	1	10	1	1	1088	92	0	4/12 kV
Evanston	8	2	2	4	1	4	5	2377	112	2	4/12 kV
Arlington Hts	19	5	5	6	1	3	13	2617	152	3	4/12 kV
Arlington Hts	10	2	4	6	7	3	4	1099	129	2	4/12 kV
Rolling Meadows	12	3	5	9	1	2	3	1304	52	0	4/12 kV
Rolling Meadows	19	1	6	8	0	4	11	1075	266	2	4/12 kV
Park Ridge	13	4	5	9	2	3	4	1342	136	0	4/12 kV
Park Ridge	2	5	1	2	7	0	0	350	350	0	4/12 kV
Park Ridge	13	0	5	9	12	2	4	1313	127	1	4/12 kV
Lake Forrest	19	1	5	9	0	2	9	1218	43	1	4/12 kV
Lake Forrest	24	6	1	1	0	11	23	570	59	0	4/12 kV
Highland Park	3	0	1	2	1	1	1	162	6	0	4/12 kV
Niles	11	1	4	10	0	1	1	1272	44	0	4/12 kV
Niles	5	1	2	2	2	2	3	201	69	0	4/12 kV
Elmhurst	3	1	1	2	1	2	2	319	24	0	4/12 kV
Schaumburg	11	9	1	2	21	7	9	199	36	0	4/12 kV
Romeoville	9	7	1	2	17	6	7	54	53	0	4/12 kV
Homer Glen	43	5	11	19	7	2	23	775	64	0	4/12 kV
Palos Park	34	6	7	14	3	3	20	911	40	0	4/12 kV
Mokena	24	11	7	12	1	5	12	1530	236	2	4/12 kV
Rockford	13	8	3	10	15	0	3	977	17	2	4/12 kV
Rockford	23	3	10	20	2	2	3	1403	78	1	4/12 kV
Rockford	32	2	6	14	0	3	18	1642	53	1	4/12 kV
Chicago	9	1	3	5	1	1	3	2291	130	0	4/12 kV
Oak Park	9	97	5	7	114	2	2	2094	135	3	4/12 kV
LaGrange	4	145	1	2	156	1	2	493	16	0	4/12 kV
Subtotal	401	355	111	207	415	80	194	30804	2712	21	
TOTAL	694	498	195	362	567	143	332	54705	5020	43	

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Appendix B. Overhead Inspection Checklist

CM-CE-P321-R0001	Rev. 5						
OVERHEAD DISTRIBUTION CIRCUIT INSPECTION CHECKLIST							
Circuit #: _____	*Town* _____	*Inspection Date:* _____		*Inspected by:* _____			*Cycle:* _____
Page _____ *of* _____	*DMC Office:* _____	*QS-Pole#* _____		*Geographical Location:* _____			
	A	B	C	D	E	F	G
01-Pole	Excess Lean (40)	Pole Step Removed	Pole Steps (20)	Replace (20)	Replace (40)	Top Split (20)	Top Split (40)
02-Pole Top Extension	Broken (30)						
03-Conductors (Primary)	> 2 Splices/Span Bare Cond	> 2 Splices/Span Covd Cond	Aerial Cable Damage (30)	Aerial Cable Jacket Damage (40)	Aerial Cable Lashing Damage (40)	Bracket/Spacer Damage (30)	Damaged (30)
04-Conductors (Secondary)	Damaged (40)	Floating (40)	Lashing Damaged (40)	Spreader Damaged (40)			
05-Conductors (Neutral / Static)	> 2 Splices/Span Bare Cond	> 2 Splices/Span Covd Cond	Damaged (30)	Debris Non-tracking on Static (40)	Floating (20)	Floating (30)	
06-Slack Span (Primary)	Auto's In Slack (30)	Excessive (30)					
07-Arms (Crossarm / Alley)	Broken (20)	Damaged (40)					
08-Arm Brace	A-Arm Replace 1 (20)	A-Arm Replace 2 (20)	X-Arm Replace 1 (40)	X-Arm Replace 2 (20)	X-Arm Replace 3 (20)	X-Arm Replace 4 (20)	
09-Insulators / Deadends	Broken (30)	Broken (Deadend) (30)	Tracking (30)	Tracking (Deadend) (30)	34kV Polyethylene (40)		
10-Pin	Replace Arm Pins (20)	Replace Arm Pins (40)	Replace Ridge Pin (20)	Replace Ridge Pin (40)			
11-Tie Wire	Broken (30)	Covered Cond.Radio Free (Black Top) (40)	Covered Cond.Clamp Top (40)	Covered Cond. Metal Tie (40)	Improperly Installed (40)		
12-Connector	Eyebolt Stirrup 34kV Only (40)	Splice < 1Ft Tie/Rod (40)	34kV Connect-O-Switch (40)				
13- Arresters Needed (Number)	Need New #_____ (40)	Replace Non-MOV @ Term Pole #_____ (40)	Replace #_____ (30)				
14 Fuse / Cutout	AB Chance w/SS Hood#_____	Blown at Cap Bank (40)	Damaged (30)	DBU Fuse - Clear Label Blue Cap (40)	GE Durabutte - Non porcelain (40)	Unfused Tap	
15-Equipment (Trf/Reg/Pot/Recl/Cap)	Damaged Bushing (40)	Damaged Case (40)	Leaking (20)	Leaking (40)	LTD Damaged (40)	Switch Damaged (40)	Unused
16-Non-Oil Term	Damaged Non-lead Term (40)	Tag Damaged Lead Term (20)	Tag Lead Sleeve Slip (20)				
17-Wildlife Protection	Broken/Damaged (40)	Improperly Installed (40)	Needed/Missing or Bird Guard Only (40)				
18-Fault Indicators	Improper Install Location (40)	Improper Type (40)	Not Facing Ground (40)	Not On Bare Conductor (40)	Replace #__ (40)	Too Close to Other (40)	
19-Grounding	Broken (40)	Equip GRD Needed (40)	Molding Damaged (40)	Molding Replaced	Need New Nonexistent (40)	Not Conn To Sys Neut. (40)	Rod Exposed (40)
20-U-Guard	Ground / Bond (40)	Primary Needed (40)	Secondary Needed (40)				
21-Guy Wire	Broken (40)	Insulator Needed (40)	Insultr GF (Grandfathered)	Insultr Location Improper (40)	Marker Needed (40)	Marker Replaced #_____	Slack (40)
22-Highway / RR Crossings	Type B-Const. Needed (40)						
23-Labeling	Replaced						
24-Clearance	Check Primary (20)	Check Primary (30)	Check Primary (40)	Check Secondary or Neutral (20)	Check Secondary or Neutral (40)	Check Service (20)	Check Service (40)
*25-Vegetation ***	Primary (Contact)	Primary (Dead Limb Over)	Primary (Near)	Secondary (In Between Tri/quadraplex Conds)	Secondary (Into Open Wire)	Vine Growth	Vine Snipped

	A	B	C
26-Truck Access	Yes	No	
27-Mainline / Tap	On Mainline	On Fused Tap	
28-Dogs or Bees	Bees	Both	Dogs
29-Osmose Red Tag	Yes		
30-Arm Size			
31-Latitude			
32-Longitude			
33-Cable Term Metal Rack	Yes		
34-Direction	Horizontal	Vertical	
35-Meter Window	Replaced		
36-P10 Call In	Yes		

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