Oklahoma Corporation Commission's

Inquiry into Undergrounding Electric Facilities

in the State of Oklahoma

Prepared and Submitted by

Oklahoma Corporation Commission

Public Utility Division Staff

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Acknowledgement

The Public Utility Division (PUD) Staff (Staff) of the Oklahoma Corporation Commission (Commission) thanks the electric utilities that participated in this fact-gathering project for their willingness to share information and to openly discuss issues affecting electric customers in the State of Oklahoma. Their input was invaluable to the development of this report. The Staff would also like to thank Gary McManis and other members of the Oklahoma Climatological Survey Group, Mr. Fred Liebe, deputy director of the Oklahoma Office of Emergency Management, Mr. Dean Sherrick, operations superintendent for Edmond Electric, and the many others who contributed to this report. Without the effort and willingness to openly discuss this important issue, the following report would not have been possible.

Executive Summary

The purpose of this report is to gather, develop and provide the Oklahoma Corporation Commission with relevant information to assist the Commissioners in making an informed decision as to what actions, if any, should be taken regarding future plans and development to protect electric plant in the State of Oklahoma from weather events to assure reliable service for state electric customers.

The need for this study surfaced when on December 8 and continuing through December 10, 2007, the State of Oklahoma experienced one of the most disruptive ice storms in the state's history. The Commission's Customer Service Division reported the storm resulted in more than 600,000 homes and businesses across the state being without electric service. Many customers were without electric service for several days while others were without service for a week or more. The Oklahoma State Medical Examiner's Office reported 29 storm-related fatalities. Of this total, nine died in house fires, two died of carbon monoxide poisoning, and two died of hypothermia (there were also 16 deaths related to motor vehicle accidents directly resulting from the storm). The deaths not occurring in vehicle accidents are directly attributable to power outages as electric customers engaged in various risky tactics to keep warm in their powerless homes. There was also one lineman injured and hospitalized as a result of an injury related to power restoration efforts. This storm followed by less than 12 months another "storm of the century" in which rural portions of Oklahoma suffered even greater physical damage to the electricity infrastructure, although loss of life was less and the homes and businesses affected were fewer.

Following this storm and cleanup efforts, the Oklahoma Corporation Commission conducted a meeting on January 7, 2008, to discuss the impact of severe storms on state utilities. More specifically, the meeting was conducted to discuss advantages, disadvantages, and feasibility of moving more aggressively to bury power lines, as well as the impact burying electric lines may have on electric customers across the State of Oklahoma. The meeting was attended by city and county officials, state lawmakers, and representatives from various environmental groups, electric utilities and cooperatives, and telephone companies, as well as the general public.

As a result of the Commission's meeting and the overall interest in addressing storm outage issues, the Commission's Public Utility Division Staff made a review of various studies on the topic of undergrounding. The review included a study completed by the Edison Electric Institute and other studies completed for and by the states of Florida, Maryland, North Carolina, Virginia and Michigan. The Michigan Public Service Commission produced the most recent study in the review on November 21, 2007.

Staff's review of this issue also included meeting on January 10 and January 15, 2008 with representatives from Oklahoma's two largest investor-owned electric utilities, Public Service Company of Oklahoma (PSO) and Oklahoma Gas and Electric Company (OG&E), to gain additional insight about the potential of undergrounding electric transmission and distribution facilities. On January 16, 2008, Staff issued an extensive data request to all retail electric utilities and cooperatives operating in the State of Oklahoma, in order to gain additional information about utility operations and activities affecting utility response to storm outages. The Staff also met with members of the Oklahoma Climatological Survey on February 1, 2008, to discuss the impact of severe weather conditions and the frequency of such conditions, which will likely continue to have a negative impact on Oklahoma's electrical plant and Oklahoma customers. On February 15, 2008, Staff held a meeting with Mr. Fred Liebe, deputy director of the Oklahoma Department of Emergency Management to understand the role of DEM in disaster situations and its involvement with the electric utilities and cooperatives. Information was also gathered from Oklahoma Forestry Services within the State Department of Agriculture, Food and Forestry, the Oklahoma Insurance Department, the Highway Traffic Safety Office within the Department of Public Safety, and the Oklahoma Tax Commission.

Information gathered from the various in-depth commission studies that were analyzed, clearly indicated that requiring electric utilities to underground all of their facilities is generally not a feasible solution. The cost to underground all transmission and distribution facilities in any state would likely run into the billions of dollars, and the potential impact on customers would be significant, to say the least approaching thousands of dollars per customer.

No public utility commission has found a funding mechanism that will permit undergrounding of electric facilities to be completed on any sort of universal or fast track basis. However, commissions have attacked this problem by addressing very specific parts of the electric grid, e.g., poorly performing circuits, lines along road rights of way undergoing construction, all secondary line extensions, etc.

The potential financial impact of undergrounding all electric facilities is generally accepted to be in the billions of dollars, which would cause an enormous and impractical burden to customers. For example, there are approximately 8,551 miles of main (or feeder) distribution lines and approximately 34,600 miles of lateral distribution lines in Oklahoma. Using information supplied in response to the Staff's January 16, 2008 data request, the cost to underground existing overhead main and lateral distribution lines is estimated to be between $435,000 and $2.5 million per mile, depending on certain conditions, resulting in an estimated statewide cost of $30.5 billion to underground only distribution lines.

The $30.5 billion does not include burial of transmission lines, which require special treatment due to heat-dissipation issues not present with distribution lines. Oklahoma has approximately 7,500 miles of transmission facilities. Oklahoma electric utilities had a difficult task estimating the cost to underground these facilities in their response to Staff's data requests. Moreover, Edison Electric Institute states, "Overhead transmission lines are much more difficult to place underground and were not considered as part of this report." In fact, of all the out-of-state reports that Staff reviewed, only the 2005 Florida study estimated the cost to underground transmission facilities. When the Florida study was conducted, the State of Florida had about twice as many miles of transmission line as currently reported in Oklahoma. The 2005 study reported that to underground existing overhead transmission lines in Florida would cost an estimated $51.8 billion or approximately $3.6 million per mile. Using Florida's estimated cost to bury transmission lines as a surrogate, the cost to underground Oklahoma's electric transmission lines could easily reach $27 billion. To put these numbers into perspective, consider that the State Equalization Board's determination of funds available for legislative appropriation in Fiscal Year 2009 is approximately $7 billion, making the estimated cost of burying all electric lines in Oklahoma more than six times the annual State budget. The cost is also roughly four times the total value of all centrally assessed public utility assets in the State, as determined by the Tax Commission. Monthly electric bills would have to increase $80 to $260 for 30 years to pay for the cost of burial; contingent upon how much of the electric network is placed underground.

The following is a comparison of the advantages of each type of conductor system:

Table 1: Overhead/Underground Comparison

Overhead Systems	Underground System
▪ Cost: Overhead conductors' number one advantage. Significantly less cost especially during initial construction. ▪ Longer life: 30 to 50 years vs. 20 to 40 for underground lines. ▪ Reliability: Shorter outage duration because of faster fault-finding and faster repair. ▪ Loading: Overhead circuits can more readily stand overload conditions.	▪ Aesthetics: Underground conductors' number one advantage. Much less clutter. ▪ Safety: Fewer opportunities for public contact with system components. ▪ Reliability: Significantly fewer short and long outage durations. ▪ O&M: Overall lower maintenance because of less vegetation management expense, but other issues must be considered. ▪ Longer Reach: Less voltage loss because reactance is lower.

Summary of Staff Recommendations

It is commonly accepted that undergrounding electric lines is an extremely expensive undertaking. However, targeted undergrounding along with other hardening remedies could have a significant impact on the hardships that result from a major ice storm and the electric outages that typically follow. Legislative, administrative, and personal actions are needed to create a hardened power system in Oklahoma. The PUD Staff believes that the following recommendations should be given consideration as an alternative to harden the network without incurring the enormous cost associated with full undergrounding:[1]

1. Require more aggressive vegetation management;
2. Bury all new lateral distribution lines except where low population density makes it impractical;
3. Bury existing lateral distribution when requested by a majority of customers in a neighborhood;
4. Identify fully urbanized main distribution lines and require burial when wire is replaced;
5. Require utilities to underground distribution lines when relocating for major road and highway projects;
6. Harden all highway-crossing electric lines identified as causing disruptions during storms because of falling on the roadway;
7. Require utilities to erect self-standing poles in strategic locations for transmission lines and targeted distribution lines;
8. Harden worst-performing circuits;
9. Bury drop lines and/or create a pilot program to test newly available "service entrance disconnect systems";
10. Create incentives for "smart-grid" installations allowing for rerouting of electric power around downed lines, transformers, and other equipment;
11. Encourage back-up self-generation for businesses and residences; and
12. Require back-up self-generation for vital services.

[1] The recommendations are more completely explained beginning at page 23.

Background & Introduction

The December 2007 Ice Storm

The financial cost of the December ice storm is difficult to measure because several economic components must be considered. The Department of Emergency Management reported 29 people died because of the storm, with 13 of those deaths directly attributable to the loss of electricity, as Oklahomans either employed makeshift means to heat their homes or simply went without heat. Nine people died in house fires, two died from carbon monoxide poisoning, and two more died from hypothermia. A crude monetary value can be applied to those lives, resulting in a cost of $58.5 million.[2] Staff's random, scientific telephone survey of Oklahomans disclosed personal losses caused by power outages. Statistical treatment of the survey-provided figures shows that residential customers alone suffered some $780 million in losses from the storm.[3] The State Insurance Commissioner reported $54 million in insured losses, but claims are still being processed. Insurance is not expected to cover a large amount of the residential losses because individual losses did not exceed policy deductibles.

Regulated utilities have asked the Commission to allow recovery of $108 million in storm losses. This figure does not include federal government aid to cooperative electric utilities. Consumers responding to the Commission's online poll question why utilities do not insure for losses such as in the two 2007 ice storms:[4]

> In my business career, we planned for business interruptions and bore the costs ourselves or through insurance.
>
> When I went to school, they said that company should set aside some of their profits for repair, upgrades and insurance.

[2] During interviews, the University of Oklahoma Economics Department and the Oklahoma State University Agricultural Economics Department informed Staff a "generic life" is typically valued at $4.5 million for cost/benefit analysis.
[3] Staff wishes to thank Public Service Company of Oklahoma and Oklahoma Gas and Electric Co., who paid Evolve Research Strategies to conduct the scientific telephone survey using Staff's questions. The survey results are appended to this report.
[4] The online survey was completed by 1,340 respondents.

While federal law allows cooperatives to receive Federal Emergency Management Agency assistance for such storm losses, the private insurance industry—following cataclysmic losses in Hurricane Andrew and other widespread storms—has stopped writing affordable insurance policies to cover electric utilities' catastrophic weather-related losses.[5]

It is even more difficult to determine the storm's impact on the business community. Sales tax collections for December were higher than had been anticipated before the storm struck. In part, this increase was due to increased hardware store sales of items, such as generators, and restaurant sales of prepared meals. Looking at only sales tax figures and trends, the storm resulted in a $152 million increase in retail activity; however, many of the businesses responding to Staff's online questionnaire reported losses from the power outage. While the small number of responding businesses did not allow meaningful statistical manipulation to determine overall losses, two-thirds of those commercial enterprises that did respond reported suffering a mean average of $18,686 in decreased revenues. Almost one-fifth of the responding businesses reported a mean average increase of $15,250 in revenues. It was not possible to determine industrial economic performance during the storm, as most of the responding commercial enterprises were small businesses.

General

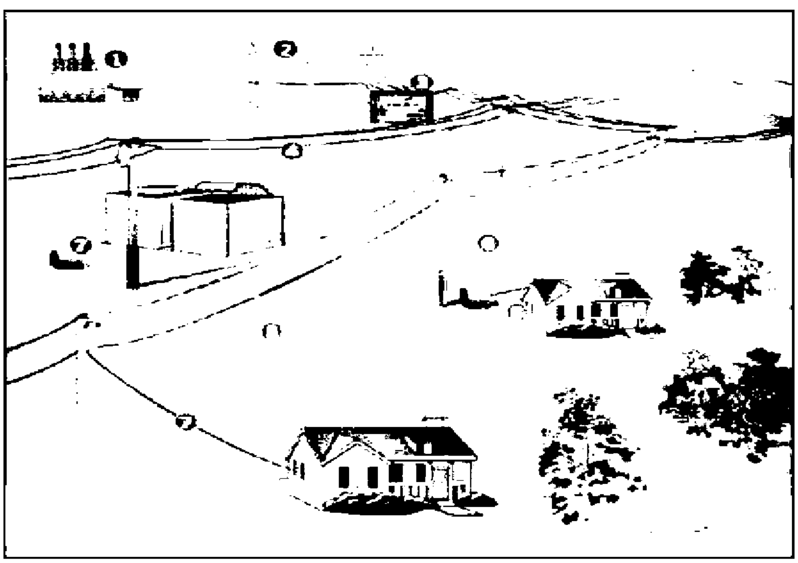
Traditional overhead electric lines suspended by utility poles can be seen all across this nation. Utility poles and their suspended facilities are inclined to suffer damage from storms, tree limbs, animals, and automobile accidents. Their exposure to the elements provides numerous opportunities for utility customers to experience outages. Downed power lines are certainly much more than an inconvenience to the public; they are a safety hazard that can produce severe injury and death. Overhead electric facilities are generally hit hard by severe storms, but the most widespread damage happens when severe icing occurs along with high winds. Ice, which weighs 57 pounds per cubic foot,

[5] This information was provided through telephone interviews with numerous insurance providers and utility risk managers.

typically forms on overhead electric lines during periods of freezing rain. When ice develops on an overhead line with the presence of high winds the ice forms into the shape of a "wing," and gives "lift" to the electric line, and causes the line to start moving. In the more extreme cases, electric lines will move severely up and down, which is referred to as a "galloping line." The combination of the heavy ice and wind creating movement in overhead electric lines is often sufficient to snap the supporting poles and causing outages to customers.

Overhead lines for electric, cable television and telecommunications, obstruct the public's view of the environment and have been characterized as an eyesore. Many benefits are to be gained from burying existing overhead utility lines, arguably the most significant being the improved aesthetics. Many individuals, subdivisions and municipalities want utility lines removed from sight; however, people do not like the transformers and pedestals left behind where undergrounding has occurred. While improved aesthetics is an important reason for burying utility lines, it is difficult to quantify the economic benefits, even though they are real and numerous.

Delivering Electricity

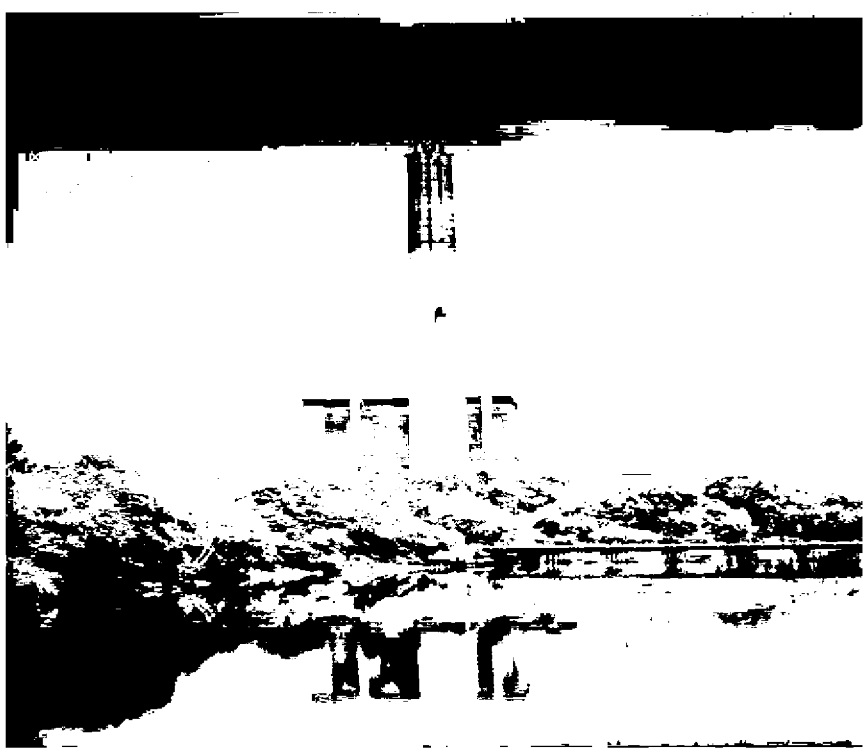


Source: http://www.duke-energy.com/about-energy/delivering_electricity.asp; 2/2008
(Numbers in the graphic correspond to the numbered paragraphs in the following explanation.)

Delivering electricity is made possible by sophisticated systems that transmit huge volumes of high-voltage electricity from generating stations. Along the way to a home or business, the high-voltage electricity is transformed into lower-level voltages suitable for the electrical system of a home or business.

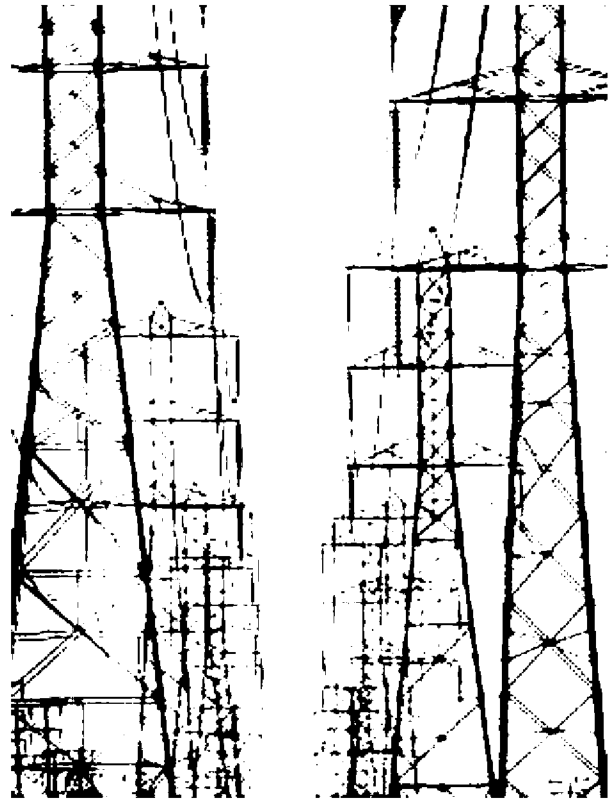
1. Power Generating Stations:

Electrical power (base generation) is traditionally produced at a generating station using fossil fuels (coal or gas), hydropower or nuclear fuel. Renewable power sources such as wind, solar, hydropower and biomass, which typically have a much smaller megawatt generating capacity, produce power to meet peak demand. Oklahoma has 67 power generating stations within its boundaries, 16 of which are operated by investor owned utilities, while the remaining 51 are owned by the Grand River Dam Authority, independent power producers, the federal government, and municipalities.



Photograph by C. Bergesen

Coal Fired Power Plant



2. Transmission Lines:

Electric transmission lines are the transport highways to move electricity from generation sources to concentrated areas of customers. From there, the distribution system moves the electricity to where the customer uses it at a business or home. These systems are unique because they are designed to move this energy at the speed of light since there is no long-term storage capability for electricity, like natural gas or other commodities.

3. Substations:

Substations, which consist of banks of electrical equipment, convert transmission line voltage to higher levels for movement to other transmission lines or lower levels that are appropriate for distribution power lines, which are used in local communities. Substations also control the flow of electricity and protect the lines and equipment from damage.

- Step-down Transmission Substation:

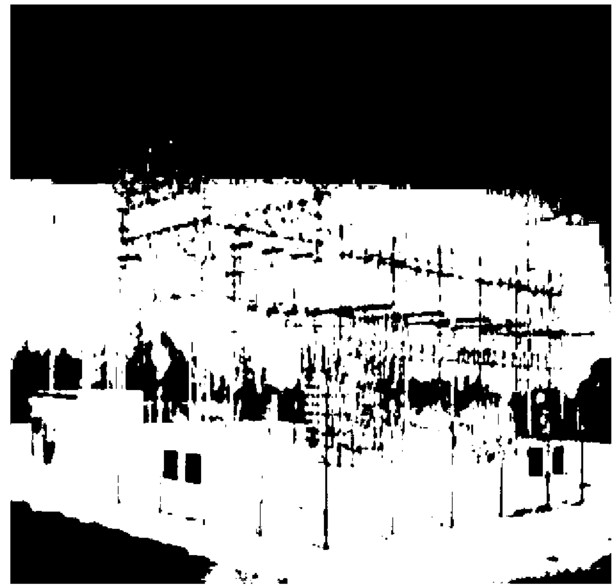
  These substations are located at switching points in an electrical grid. They connect different parts of a grid and are a source for sub-transmission lines.

- Step-up Transmission Substation:

  They receive electric power from a nearby generating facility and use a large power transformer to increase the voltage for transmission to distant locations.

- Distribution Substation:

  These are located near end user customers. A distribution substation is a power distribution center that steps down transmission voltages (46,001 volts to 750,000 volts) to a primary distribution voltage (2,100 volts to 46,000 volts) with power transformers. Most distribution lines radiate from this center at lower level voltages for use by end user customers.



Distribution Substation

4. Distribution Power Lines:

Distribution power lines, which can be installed above ground or underground, carry between 2,100 and 46,000 volts of electricity to a neighborhood. The distribution system supports retail electricity markets. Local or state government agencies, such as the Oklahoma Corporation Commission, are heavily involved in the electric distribution business, regulating prices and rates-of-return for shareholder-owned distribution utilities.

The greatest challenge facing electric distribution systems is responding to rapidly changing customer needs for electricity. Increased use of information technologies, computers, and consumer electronics has lowered the tolerance for outages, fluctuations in voltages and frequency levels, and other power quality disturbances.

Aerial distribution lines

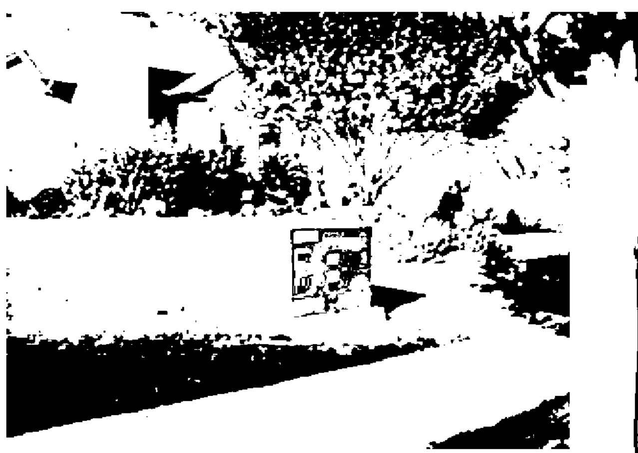
5. Customers:

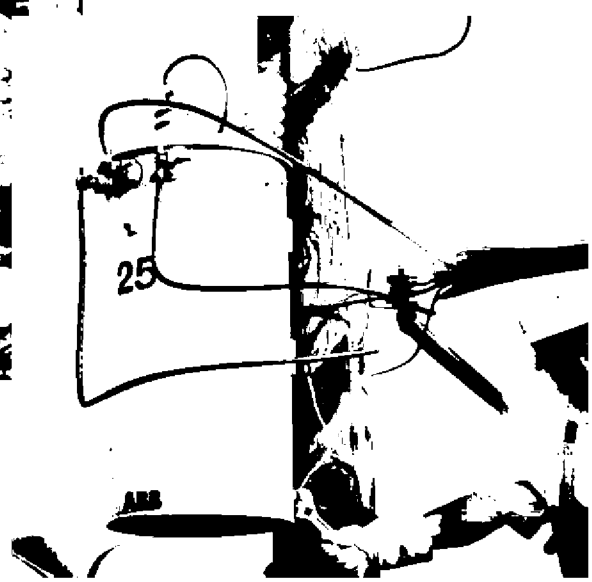
End user customers include homes, businesses, and buildings. Electric utilities have a multitude of classes of customers and rate schedules, e.g., residential, commercial, industrial, power and light, large power and light, municipal and governmental street lighting, municipal pumping, oil and gas, public school, churches, etc.

6. Transformers:

Electric transformers convert the distribution level voltage to levels that can be used inside a home or business. This voltage is carried from the transformer through an underground or overhead power line to the end user customer.

Pad-mounted Transformer for Underground System

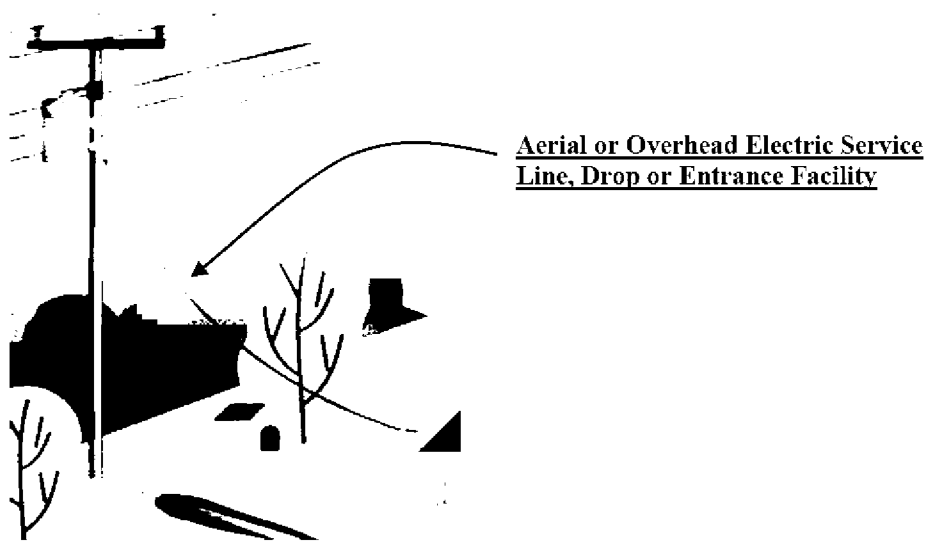




Aerial or Overhead Transformer

7. Service Line, Service Drop or Service Entrance:

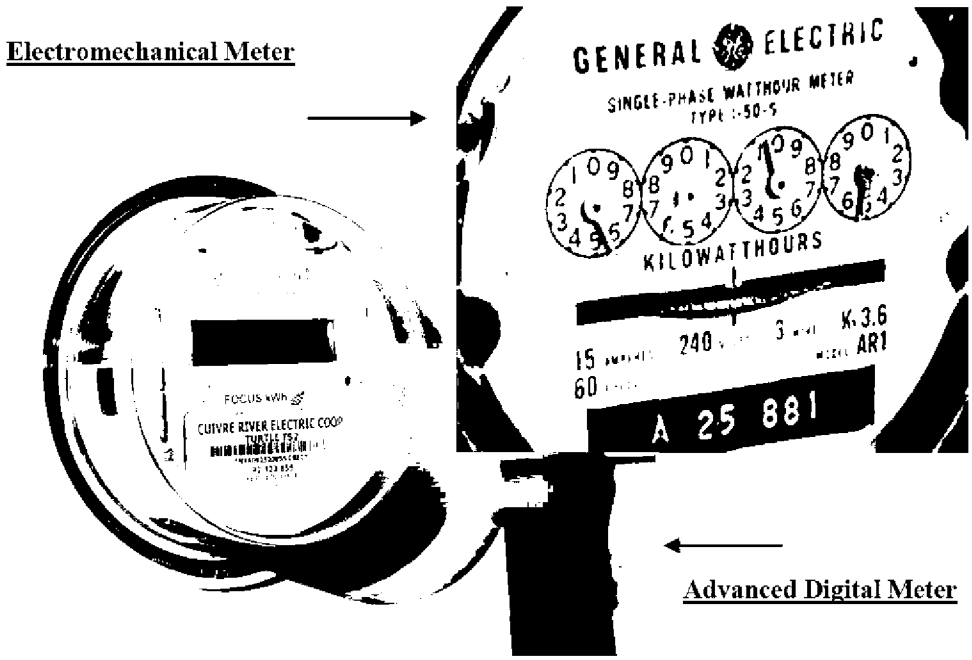
This facility is that portion of the electric distribution plant that connects the "electric grid or network" directly to the customer's home or business. Voltage ranges from 120 to 480 volts. These facilities extend from the distribution transformer to the customer's location. A service line, drop or entrance facility can be above or below ground. Underground services have a riser connection at the distribution pole.



8. Meter:

An electrical meter is typically located on the outside of the customer's home or building, and it provides usage data for billing purposes. Advanced meter reading (AMR) systems enable utilities to read meters remotely, without having to physically visit and manually read each meter.

In most AMR systems, a module, which is attached inside an electric, natural gas or water meter, sends energy usage information through wireless transmissions or over power lines to a data collection device. This information is then sent to a central processing facility, where the meter data is integrated with the utility's customer information and billing systems, resulting in the production of a usage bill for the utility's customers. This type of metering technology is essential for the ultimate success of demand side management programs (DSM).



The Cost of Undergrounding Electric Lines

Undoubtedly, the number one reason why there has not been more extensive undergrounding of utility facilities in this country is simply the costs associated with the task. Every study Staff analyzed, without exception, indicated that the cost to bury all of the main and lateral distribution facilities within the boundaries of any state would run into the billions of dollars. The following table summarizes the projected cost of undergrounding in each of the studies analyzed by Staff and as computed for Oklahoma:

Table 2: Other States' Undergrounding Costs

State/Year of Study	Overall Estimated Cost	Population	Estimated Cost Per Person	Land Area (in Square Miles)	Estimated Cost Per Square Mile
Florida/2005 (Transmission & Distribution)	$94.5 Billion	15,982,378	$5,913	53,927	$1,752,369
Maryland/2000 (Distribution Only)	$9.9 Billion	5,296,486	$1,869	9,774	$1,012,891
Michigan/2007 (Distribution Only)	$56.0 Billion	9,938,444	$5,635	56,804	$985,846
North Carolina/2003 (Distribution Only)	$41.0 Billion	8,049,313	$5,094	48,711	$841,699
Virginia/2005 (Distribution Only)	$83.0 Billion*	7,078,515	$11,726	39,594	$2,096,277

Source: Studies conducted by named states and 2000 U.S. Census. These figures do not include carrying costs.

* Does not include estimated $11 billion for telecommunications and cable television.

Table 3: Oklahoma's Undergrounding Costs

Extent of Line Burial	Overall Estimated Cost	Population*	Estimated Cost Per Person	Land Area (in Square Miles)	Estimated Cost Per Square Mile
Oklahoma/ 2008 (Transmission & Distribution)	$57.5 Billion	3,450,654	$16,664	68,667	$837,375
Oklahoma/ 2008 (Distribution Only)	$30.5 Billion	3,450,654	$8,839	68,667	$444,173

Source: Utility Responses to OCC Data Requests and 2000 U.S. Census. These figures do not include carrying costs.

* To be consistent with reports for other states, Oklahoma's population figure in this chart comes from the 2000 Census; however, if the Census Bureau's 2007 population estimate (3,617,316) is used, Oklahoma's per person cost of transmission and distribution burial would be $15,896, and the per person cost for distribution-only would be $8,432.

Based upon the regulated electric utilities and cooperatives that responded to Staff's data requests, there are approximately 8,551 miles of main distribution lines, and about 34,600 miles of lateral distribution lines in Oklahoma. The data request resulted in cost projections from $435,000 to $580,000 per mile for lateral distribution and up to $2.5 million per mile for main distribution. Using this information, the cost to underground existing overhead lateral distribution lines in Oklahoma can be conservatively estimated at $500,000 per mile, or an estimated statewide cost of approximately $17.3 billion to bury only lateral distribution lines. Likewise, using an average cost of $1.54 million to bury a mile of main distribution line, the estimated cost of placing all main distribution lines underground is $13.2 billion. This results in an estimated cost to underground all distribution lines at a staggering $30.5 billion.

There are a number of important factors that should be considered when determining the feasibility of placing high-voltage transmission lines underground. Conductors (known generally as wires) suitable for undergrounding are much more expensive, costing 10 to 14 times as much per foot as overhead conductors, depending on the voltage of the line. The expensive design is necessary to minimize damage from water and to meet insulation and heat dissipation requirements. Costs for burying the conductors vary depending on the voltage level and whether the line is placed in an urban, suburban or rural area. The type of soil is also an important factor; sand and clay are relatively easy to trench, while trenching rock is extremely difficult and expensive.

In some cases higher voltage lines must be placed in concrete encased conduit to protect them from dig-in damage and possible injury or death resulting from dig-ins. Typical trenches for high-voltage lines are five to eight feet in depth and four feet in width.

Underground cable is much thicker and heavier than overhead conductors designed to carry the same amount of power (see picture below). As such, only short segments of cable can be pulled through conduit, thus requiring splices and underground access vaults every few thousand feet, depending on voltage requirements.

The photo below illustrates the comparative sizes of a 230 kV underground cable and a 230 kV overhead conductor. The larger underground cable weighs about 10 times as much as the smaller overhead conductor per foot and is about four times as thick. Three such cables are required, one for each phase of the three-phase transmission system. Since additional time is necessary to repair underground facilities, a fourth cable is often included when undergrounding transmission lines so that three-phase power can be maintained in the event that one of the other three cables fails.

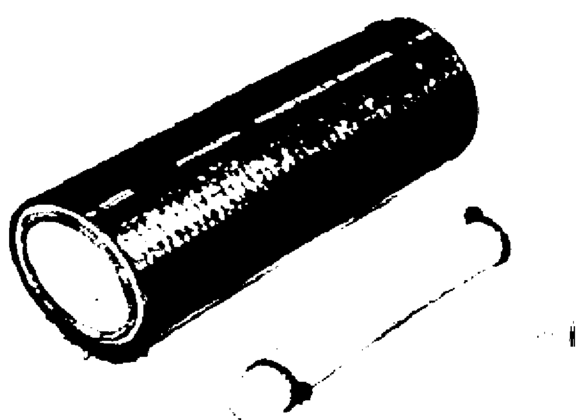


Photo from "Underground in Florida" March 2005

Finding and repairing underground transmission line failures usually takes considerably more time than doing so for overhead lines. Since a transmission line affects far more customers than lower voltage distribution lines, any problems with an underground transmission line will result in vastly more customer outage hours than is the case with distribution feeder lines. In addition, some studies show that the life expectancy of underground lines may be less than that for overhead; so future replacement costs may be higher with underground facilities.

Most overhead high-voltage transmission towers and lines are less susceptible to damage from weather than the lower voltage distribution lines because of their greater structural strength. Heat along the transmission line makes ice accumulation less of a problem than on distribution lines. Also, the greater height of higher voltage transmission facilities makes them less susceptible to damage from falling trees. Thus, there is less benefit from undergrounding transmission lines than undergrounding distribution lines to avoid weather-related problems such as wind and falling trees.

Only the Florida study estimated the cost to underground transmission facilities; because of the various complexities associated with transmission lines, likewise, none of the companies in Oklahoma submitted cost data to underground transmission lines. The Florida study projected the cost to underground transmission lines at an enormous $3.6 million per mile. Admittedly, Florida's costal terrain creates some significant challenges for undergrounding any facility, but additional complexities associated with burying transmission lines caused most states to reject the idea of undergrounding transmission lines outright. For these reasons most of the studies reviewed by Staff did not consider the undergrounding of transmission lines. Using Florida's estimated cost to bury transmission line as a surrogate, the cost to underground Oklahoma's electric transmission lines could easily be an estimated $27 billion. Bringing the total cost of placing distribution and transmission lines underground in Oklahoma to an estimated $57.5 billion.

When looking at whether to engage in such a costly endeavor, the Commission must determine a cost/benefit ratio, which in this instance is simply a comparison of the cost to bury the lines with the cost of damages caused by power outages. Such a comparison produces a negative cost/benefit ratio and therefore speaks against complete burial of the Oklahoma electric grid. Assuming unrealistically that Oklahoma will have storm-related damage equal to the December experience every year for the next 30 years and will experience retail sales as shown by December's tax reports, the total cost of storm damage for the next three decades would be almost $28 billion. This projected loss does not equal the cost of complete burial or even of undergrounding only the distribution system—even without counting carrying costs for the long-term burial project. While weather predictions indicate a likelihood of more prevalent ice storms in the future, such predictions do not assume yearly catastrophic events or the same widespread magnitude as the December storm. Looking at the losses more reasonably, indicates the expense of either complete undergrounding or burial of just the distribution system is not even close to being cost effective.

Advantages of Undergrounding Electric Lines

There are many potential benefits related to the undergrounding of electric facilities as opposed to placing lines overhead. In reviewing available studies on the subject of underground electric facilities, the following are some of the more significant advantages to undergrounding:

- Improved aesthetics (significant issue in some areas);
- Less damage to electric plant resulting in fewer outages from storms;
- Fewer lost electricity sales, day-to-day and after storms;
- Reduced vegetation management costs;
- Improved utility/customer relationship related to vegetation management;

- Fewer motor vehicle accidents with utility poles (could be offset by vehicle accidents involving pad-mounted transformers);
- Improved safety from reduced live wire contact;
- Fewer outages related to animals; and
- Fewer momentary interruptions.

Improved aesthetics appears to be a primary issue in many undergrounding projects. The aesthetic appearance of underground utility facilities is generally accepted as an improvement versus overhead facilities. Some studies indicated that improved aesthetics not only comes from the removal of unsightly poles and lines, but also from reductions in tree and vegetation trimming. However, to improve aesthetics by removing poles and lines there must be a coordinated effort among all utilities that share pole space. In some cases when an electric utility buries its cable the poles that remain are simply "topped." The telecommunications and/or cable television facilities remain on the pole, and these companies assume maintenance for the structure.

In most cases, utilities, i.e., electric, telephone, and cable television coordinate the undergrounding of facilities; however, one utility initiates an undergrounding project does not imply that all facilities in the area will follow. Undergrounding of electric facilities does not completely eliminate all visual impacts in an area. Where undergrounding of electric facilities does occur, the result is generally the placement of a pad-mounted transformer. In some applications, primarily existing subdivisions, when electric facilities are buried it might be necessary to replace inaccessible back-lot aerial facilities with accessible street-side underground facilities. The result is a pad-mounted transformer in the front yard of a homeowner (see picture on page 7 of this report) that creates another set of aesthetic issues.

Burying electric facilities does not eliminate all risks of outages due to storms, but significant reductions in the number of outages are realized when compared to overhead facilities. Based upon data in a study completed by the Virginia State Corporation Commission, it was reported underground electric circuits experienced only 20 to 25 percent of the outages that were experienced by aerial circuits. A North Carolina Utilities Commission study reported underground systems experienced approximately half of the outages experienced on overhead systems. Detroit Edison and Consumers Energy reported to the Michigan Public Service Commission that the frequency of outages on their underground systems is only 17 and 30 percent respectively, of the overhead system outage frequency. In many cases it is extremely difficult to classify outages on an electric circuit because both overhead and underground facilities are utilized in furnishing electric service. Monitoring equipment can be installed to identify where an outage has occurred, but to do so is a fairly expensive venture.

Another benefit of undergrounding electric facilities is the reduction in vegetation management cost, e.g., tree trimming. Information obtained via responses to Staff's initial data request indicated that the investor-owned and regulated electric cooperatives in Oklahoma spent an estimated $63 million in 2007 on vegetation management. These same companies indicated that as a general rule they attempt to maintain a four-year vegetation management cycle, meaning that they typically trim enough foliage such that they only need to touch an area once every four years. This is certainly impacted by the type of vegetation, length of the growing season and the amount of rainfall experienced. The Corporation Commission receives many consumer calls each year complaining about the manner and extent of tree trimming by electric utilities. Reducing the amount of tree trimming is likely to reduce the amount of friction between the utility and its customers regarding the amount of trimming required and the frequency of trimming. Although undergrounding electric facilities may reduce operation and maintenance expenses associated with vegetation management, it is uncertain if the overall level of operation and maintenance expenditures would be reduced because of undergrounding efforts.

Improved safety benefits of underground facilities include fewer motor vehicle accidents with utility poles and fewer incidents involving human contact with downed live wires. The removal of utility poles would eliminate the occurrence of vehicular pole collisions; however, the use of ground-level pad-mounted transformers creates a new risk for motor vehicles. The risk of collisions with pad-mounted transformers is far lower than with poles, simply because there are fewer pad-mounted transformers associated with underground facilities than there are poles associated with overhead electric plant. Another element is the fact that pad-mounted transformers are typically placed farther back from streets than are utility poles.

Disadvantages of Undergrounding Electric Lines

Just as there are advantages to undergrounding electric facilities, there are also disadvantages. In addition to costs, following are the most frequently mentioned disadvantages:

- Potentially stranded asset cost associated with overhead facilities;
- Exposure from dig ins—accidental excavation of underground power lines;
- Longer duration when an outage does occur;
- Potentially shorter conductor lives;
- Higher operating and maintenance costs; and
- Increased utility employee work hazards.

In addition to the enormous construction costs of converting overhead lines to underground, there are also some "not-so-obvious costs" which must be mentioned. When a utility converts an electric facility that has not been fully depreciated to an underground line, there is a stranded asset cost. The Michigan Public Service Commission study compares this potential situation to "tearing down a house that still has an existing mortgage." The Michigan study also affirms "For regulated utilities, FASB (Financial Accounting Standards Board) Statement 71 allows the stranded costs associated with prudent investments to remain capitalized, resulting in the potential for rates to reflect simultaneous cost recovery for both the original overhead system and the new underground system."

Increased utilization of underground facilities would likely lead to increased safety incidents relating to dig-ins. Dig-ins are extremely hazardous to heavy equipment operators as well as the backyard gardeners. Typically, electric lines are buried at least 48 inches below ground, so the backyard gardener isn't likely to contact a line; however, as topsoil erodes or builders lower final grades on a yard this level of safety reduces and accidents are likely to happen. Even if a severe accident does not occur, contacting an electric line with a backhoe or shovel will likely result in a fault on the circuit, which almost always results in service interruptions to electric customers. The Michigan study estimated that there are at least 3.5 times more third-party damages per mile of installed underground system than third-party damage on the overhead system. There are additional safety risks associated with inspections and routine maintenance for underground facilities as the work must be done in an enclosed spaced instead of out in the open as is the case for overhead facilities. Because all the cable and the equipment in a cabinet is completely out of sight, examining it to determine if it is safe is much more difficult to do and a much more time-consuming process. It also poses much greater risk to utility employees. By comparison, the overhead system is very visible from some distance and it is much easier to recognize unsafe conditions that need to be repaired.

Outages on underground systems generally occur less often than they do on overhead systems, but when they do occur, they tend to be much longer in duration. Empire District, in responding to Staff's inquiry stated:

> [W]hile underground facilities do result in fewer outages due to trees directly involving what would have been overhead; outages that result from lightning, dig-ins, cable insulation failure, etc. result in much longer restoration times, much greater expense and are especially troublesome to property owners whose landscaped yards are impacted.

The above position is generally supported by all of the Oklahoma electric utilities responding to Staff's inquiry.

Likewise, the Edison Electric Institute's "Out of Sight, Out of Mind?" study, which summarized several of the state studies, indicates that in Virginia, underground outages require approximately 2.5 times longer to repair than overhead outages. The Report to the Public Service Commission of Maryland supports this same position by stating:

> Most System Average Interruption Duration Index (SAIDI) values in case studies over the period 1996-1998 support the proposition of increased durations of underground outages. Typically, the outage times associated with an occurrence of a section of overhead line may

> be 1 to 2 hours. The outage time associated with the outage of a comparable section of underground line may be 3 to 6 hours.

The Michigan study also supports this position by citing Consumers Energy and Detroit Edison as indicating that outages on the underground portion of circuits lasted at least 30 to 70 percent longer than outages on overhead circuits. The North Carolina study indicated typical underground outages require 145 minutes to repair compared to 92 minutes for overhead outages. Without exception, all studies indicated that underground facilities have fewer outages per mile than overhead facilities; however, when an outage does occur it undoubtedly takes longer to repair on underground facilities.

In addition, some studies show that the life expectancy of underground lines may be less than that for overhead lines, so future replacement costs will likely be higher with underground facilities. A well-maintained overhead system has a life expectancy of more than 50 years, primarily because individual components are easy to replace. The life expectancy of underground cable installed today is thought to be greater than 30 years. However, other components of the system, such as surface-mounted equipment, may have less than 30 years of useful life.

Underground facilities typically have shorter life spans than overhead conductors and equipment. During discussions with OG&E and PSO, both companies indicated that overhead facilities have a life expectancy in the range of 50, or perhaps 60 years, but underground facilities, while their life span may be getting longer with engineering improvements, have an anticipated life in the range of 30 years. The North Carolina Study indicates that "equipment lifetimes vary for a variety of reasons, but, in general, industry experience supports this general ratio: overhead facilities tolerate the wear and tear of normal service for roughly 60 percent longer than their equivalent underground equipment."

Underground costs can quickly inflate with obstructions such as roads, driveways, above- and below-grade obstructions including trees, soil stability and rock content, and the presence of other utilities. Also, difficulty in acquiring easements could drive the costs of all facilities higher. These differences in capital costs need to be taken into consideration not only at the point of new circuit construction, but also when considering replacement costs for failures, maintenance, and system upgrades. The higher capital costs also must be considered when looking at total life cycle costs which include replacement at the end of useful life as underground facilities have a shorter life span than overhead facilities.

It is somewhat unclear how undergrounding of electric lines will impact the overall level of operation and maintenance (O & M) costs. The first thought is that O & M cost will decline due to reductions in vegetation management costs and lower interruption rate of circuits served with underground lines. However, the other side of the coin indicates that outages are generally longer when underground facilities fail. It takes longer to find the fault and it takes longer to repair the trouble, which will tend to increase O & M costs. Probably a good way to look at O & M costs associated with undergrounding is to assume a minor reduction in overall expenses, but the better initial view would be to assume no change in expense levels.

Does Undergrounding Improve Reliability?

Accurately measuring electric reliability is difficult. Most measures of electric reliability focus on two factors:

- SAIFI (System Average Interruption Frequency Index) - the frequency with which a customer sustains a power outage, i.e., the number of power outages per year, or the number of outages per year for a mile of distribution circuit.
- SAIDI (System Average Interruption Duration Index) - the duration of power outages, i.e., the number of minutes per year a customer is without power.

For most utilities, it is extremely difficult to track the number of outages that occur on their systems and to determine the number of customers impacted by these power outages. Utility switching actions, for example, can result in momentary outages that last only a fraction of a second.

Comparing the reliability of overhead power lines to underground power lines is even more difficult. Many utility outage-reporting systems do not separately track overhead and underground systems, which is typically the case with Oklahoma electric utilities and cooperatives. Another problem in trying to evaluate underground lines is that most underground circuits have at least some component above the ground. Installing monitoring equipment to distinguish between outages on the overhead and underground components of the same circuit can be prohibitively expensive.

A review of this data indicates that the frequency of outages on underground systems can be substantially less than for overhead systems; however, when the duration of outages is compared, underground systems lose much of their advantage.

Care should be taken in placing too much confidence in a single point estimate, like $1 million per mile, as an indicator of undergrounding costs. A number of variables exist in determining the ultimate cost of placing an existing cable underground, including the power rating of the cable, soil conditions, and whether the cable will be located in a rural, urban, or residential area.

Other studies also have examined the cost of undergrounding large electric distribution systems. In 2003, the North Carolina Utilities Commission estimated it would take the state's three investor-owned utilities 25 years to underground all of their existing overhead distribution systems at a cost of approximately $41 billion. This six-fold increase in the existing book value of the utilities' current distribution assets would require a 125 percent rate increase.

Customer Requests for Undergrounding & Who Pays

The number of customers in existing subdivisions who request the undergrounding of electric lines has been rather limited. Typically, these requests come from residential customers who want the electric utility to bury "drop" or "service" lines in the customer's backyard or side-yard. Electric utilities have not kept extensive records of customers' requests to bury electric service; however, there is some information available which indicates that there are a few customers who are willing to pay for the undergrounding of the electric lines connected to their homes. OG&E estimates that annually between 500 and 600 customers make undergrounding requests and probably 90 percent of these requests are from residential customers. Of these requests, OG&E estimates that more than 90 percent follow through with the undergrounding request. This high take rate is likely the result of a minimal charge from OG&E to underground the facilities if added load is expected from the requesting customer. OG&E reported that to bury an existing overhead drop line in an existing residential subdivision costs approximately $1,950.

PSO indicates that on average they have approximately 434 residential and commercial customers placing requests to underground electric lines annually, with roughly 100 actually following through once the cost is quoted. For both OG&E and PSO the annual requests to underground electric lines is less than one percent of their customer base and customers who follow through are even less.

Edmond Electric, in Edmond Oklahoma, began an undergrounding project in July 2004 to convert nearly 500 residents in the Henderson Hills subdivision to buried electric cable in conduit. The primary justification for the project was to improve reliability because poles in the area were beginning to rot and the area had a high numbers of outages. Edmond Electric planned to bear the costs of undergrounding the existing distribution system; however, homeowners were responsible for the cost to install a new meter to connect to the new underground service. The average cost for the new meter base installation was approximately $400. Of the 500 residents who were served by power lines moved underground, 250 chose not to pay the $400 for the meter base conversion. According to Mr. Dean Sherrick, Edmond Electric's distribution supervisor, for each of these customers, Edmond Electric was required to install a new pole to bring the underground service above ground and then run an overhead drop line to the customer's existing meter base. This situation seems to indicate that, generally, if customers were not willing to bear the cost for the new meter base, then they would not have much tolerance in bearing the cost necessary to bury all of Edmond Electric's distribution facilities. In fact, what started out to be a five-year project to bury all of Edmond Electric's distribution facilities has been halted for budget reasons. Still Edmond Electric has been able to target areas needing repair dollars, and through their efforts, they have buried 500 miles of distribution lines of the 800 miles in their system.

In a survey, paid for by OG&E and PSO and using PUD queries, 401 households were contacted in the Oklahoma City and Tulsa metro areas regarding the December 2007 ice storm. When asking the person responsible for paying the electric bill about their willingness to pay to bury electric lines, just over 50 percent of the customers indicated that they were willing to pay more than $1.00 to support this effort and 25 percent were willing to pay more than $2.50. Even though this may not sound like much of a willingness to support an undergrounding program, this research along with information gained from other studies indicates that residential customers place a value on undergrounding their utilities and a significant number are willing to pay something to have their power lines placed underground. However, there is a significant disparity between the public's perception of what it should cost for undergrounding and what it actually costs. The survey also indicated that 65 percent of the customers surveyed were willing to pay something for undergrounding. OCC's unscientific online poll provided similar results. This should be viewed as a positive sign that consumers are keenly aware that to initiate a program to bury electric lines does not come without some cost attached.

New subdivisions, however, are somewhat of a different situation. For the most part, new subdivisions have been undergrounding electric lines for some time now. According to the Edison Electric Institute's study, "[E]ven with its high cost and lack of economic justification, undergrounding is very popular across the country. In nine out of 10 new subdivisions, contractors bury power lines." During Staff's discussions with

OG&E and PSO, both companies indicated they have been placing electric lines underground in new residential subdivisions, on a fairly widespread basis, since the mid 1970s. Generally, electric utilities charge developers for placing electric lines underground. The cost to the developer is usually the difference in the utility's cost of placing lines overhead versus burying them underground. In the case of Edmond Electric, it requires the developer to open and close the trench for electric lines and Edmond Electric provides the conduit and electric conductor. It is believed that developers are paying to bury electric lines more for aesthetics reasons rather than for reliability purposes. Besides any costs that the developer incurs to bury utilities, i.e., electric, cable-TV, telecommunications, water and gas, are simply added to the price of their houses. So in new subdivisions, electric customers are paying to bury electric lines, but when it's hidden in the price of the home, then it is much easier to accept.

As outlined earlier in this report, undergrounding electric lines is extremely expensive and to pass these costs directly on to customers would be devastating. For example, taking the estimated costs to underground all transmission and distribution lines in Oklahoma, i.e., $57.5 billion, equates to nearly a $260 per month increase in the average customer's electric bill. There are other alternatives to "hardening" the electric grid without having to bury all electric facilities or even all distribution lines. The next section outlines some of these alternatives.

Recommendations

As the Commission, electric utilities and customers decide how to address the problems arising from the December ice storms, it is important to keep the situation in perspective. As noted by one respondent to OCC's online survey:

> The ice storm was an extraordinary event. We should seek moderate ways to improve prevention without becoming extreme.

As other respondents to the Staff's online questionnaire noted, however, the December storm was not the only weather event to topple power lines:

> Tulsa has endured several ice storms over the last 20 years, with associated large power losses.
>
> We don't even need a storm of the magnitude of the December ice storm; just the wind blowing like it has the last couple of days creates outages
>
> A microburst went through our neighborhood a couple of years ago. The result was a power line lying in our swimming pool.
>
> I find high winds affect my power just as much.
>
> I have many interruptions and outages due to thunderstorms, ice storms and cars hitting the power poles.
>
> Our street lost power eight times during various rain showers in 2007.
>
> I've lived in Oklahoma for the past three winters and have experienced six power outages. It took seven days before service was restored [in December 2007]. Every outage was a result of wires on poles or transformers.
>
> After the ice storm repairs, I am now on Day 3 of the NEW outage! I AM SICK OF THIS!!!

Reliability is at issue in times of foul weather, but the solution to the problem is not so easy as to say, "Bury the lines." Very few of the studies reviewed by Staff have gone so far as to make any specific recommendations on this topic, other than to say undergrounding electric plant is not cost effective, a fact recognized by some customers:

> I don't feel that for the amount of time I was without power, the increase in my utility bill would be worth paying for underground lines. That would be a huge undertaking for the utility company, especially the huge transmission lines.

If Oklahoma had started undergrounding electric lines 25 years ago, the Commission probably would not be talking about it now. There is a need to address electric outages caused by storms, and undergrounding electric lines does not have to be the only solution. Given the critical role that electricity plays in today's high-tech society, even a momentary power outage is an inconvenience, e.g., data that was not saved to a computer in a timely manner. Extended power outages present a major hardship and can be catastrophic in terms of public health, and safety consequences and the overall economic losses.

The Commission's PUD Staff recognizes undergrounding electric lines is extremely expensive; however, targeted undergrounding along with other remedies can have a significant impact on the hardships resulting from a major electric outage. Following are Staff's recommendations for the Commission to consider:

Staff recommends institution of legislative and rulemaking processes to determine feasibility, support, and exact requirements for 12 measures. Some of these measures seek to prevent power line disruptions; others seek to provide quicker response to line downings, and the remainder seek to ameliorate the effects of outages:

Outage Prevention

1. Require more aggressive vegetation management.

Tree trimming to protect power lines is a volatile issue. While 89 percent of the people surveyed by telephone said they would support additional pruning if it would reduce electrical outages, Commission experience has been that electric customers are irate when their trees and shrubs are trimmed by public utilities. As a response to this opposition, electric utilities typically only "trim for growth." This means vegetation management attempts merely to keep trees from growing into power lines until the next cycle of trimming. Today, the major utilities are on a four-year cycle of trimming trees for growth. Such practices result in power lines sometimes going through tunnels in tree canopies, which, may collapse during ice storms. Such pruning also allows strong winds to blow branches into power lines, causing disruptions. In addition, municipalities and code officials have not been as proactive in enforcing ordinances and zoning restrictions prohibiting the planting of large-growing specimens in utility easements and under power lines.

In the December 2007 ice storm, ice-laden branches and sometimes-entire trees falling onto power lines caused most failures. Oklahomans responding to the Commission's online questionnaire recognized this vegetation problem:

> I think it is because of the tree trimming previously done that I was only without power for a few days instead of a week. Burying all the lines is expensive, and it would be more efficient to trim trees.
>
> Most power outages are caused from trees or limbs in power lines. Why do these people plant trees around power lines? People who plant trees around power lines or allow trees to grow up into power lines should be held accountable.
>
> Trimming trees should be the homeowners' responsibility and should be enforced by the utilities commission.
>
> Do not bury power lines underground. Do not let trees grow under power lines. Cut down trees that are currently growing under power lines.
>
> There has to be legislation and penalties to stop people from planting and/or allowing foliage to interfere with power lines. It is not fair to have others pay for the negligence of the few.
>
> I think that people should be fined if a power outage happened because they failed to keep their trees out of the wires.
>
> I think trees planted in the utility easement should be killed. The way they trim the trees makes them come back and grow more aggressively than before. People and business should be prohibited from planting in the utility easement.

At the same time, many respondents disagreed with vegetation management:

> They had recently clear-cut a strip nearly 30 feet wide under all the power lines in my area, which took out over one acre of trees on my property alone, some outside the zone that was permitted. While helpful during the ice storm, it was overkill.
>
> I think the options of trimming trees more often and trimming additional foliage are not great options for homeowners because it lowers property values and is not very environmentally friendly.
>
> Let's get rid of the tree trimmers that cause the unsightly damage to our remaining trees and have to continue to trim year after year. Bury the electrical lines!

Public response to OCC's online questionnaire was mostly negative to the idea of additional tree trimming, with more than half of the respondents stating they would not want to pay more for vegetation management. Many individuals also complained about the "butchering" of trees by crews. Only 38 percent were willing to have more trimmed from their trees. While the online poll was not scientific, it provides an indication of what the most strongly held opinions are on the issue.

Staff recommends the Commission require electric utilities to trim vegetation near aerial power lines for ice and wind rather than for growth. The current four-year cycle should remain the same. Since most growth occurs in the first year after trimming and because arborists recommend smaller cuts if trimming is done more often, shortening the vegetation management cycle to three years or less would simply increase labor costs without creating additional benefit.

Staff also recommends the Commission urge municipalities to enforce more fully existing ordinances and zoning restrictions meant to protect the electric grid.

Utilities support more aggressive vegetation management so long as cost recovery is allowed but have expressed concern about customer complaints.

2. Bury all new lateral distribution lines except where low population density makes it impractical.

Customers' aesthetic desires are driving most residential property developers to bury lateral distribution lines in new subdivisions; however, state utilities report some developers continue to place distribution lines above ground. The cost of burying lines during new construction is approximately 10 percent higher than the cost of installing aerial distribution.

Electric customers generally support burial of power lines in new subdivisions:

> There is no reason not to require all new developments to have underground utilities. We lived up north and all of our utilities were underground and did not have near the amount of power outages as we have in Broken Arrow.
>
> You should make it mandatory for new housing additions to have all wiring underground and to begin with heaviest hit areas as far as where to begin work on putting wiring underground.

Utilities indicated they are already burying most new lateral distribution lines and do not oppose burial of new lateral distribution in all urban residential subdivisions. They generally opposed burial of lateral distribution in commercial development because such properties are typically not as clearly planned as residential areas when initial services are installed. They also opposed burial of lateral distribution lines in rural subdivisions with larger lots. In areas of low population density, requiring long runs of underground lateral lines may not be cost-effective and could make future expansion more expensive.

3. Bury existing lateral distribution when requested by majority of customers in a neighborhood.

As stated above, ice-laden trees were the major cause of power outages in the December 2007 storm. Trees tend to be a more mature and a bigger problem in existing neighborhoods rather than in new developments. In these older areas, power lines are typically overhead.

> Future utility expansion should require underground wires and existing above ground wires should be replaced as funds allow. Replacement should be prioritized based on emergency service requirements and frequency of outages.
>
> We live in a neighborhood with underground cables but the trunks providing power to our area were affected and therefore we lost our power. Also, how can you put a monetary number on trying to live in your home without lights and heating, etc.?
>
> Maybe neighborhoods served by a line could share a one-time fee to bury the line. They really do need to be buried.

For all the reasons stated in Recommendation No. 2, burying distribution lines in existing neighborhoods makes sense; however, the cost is much greater because of driveways, fences, swimming pools, storage sheds, and permanent buildings sitting on utility easements. Because Oklahoma's larger urban areas have eschewed alleys where utility lines typically are run in other states, access to power lines is difficult. Oftentimes there is not enough room between houses or commercial buildings to drive excavation equipment or trucks needed to bury distribution lines.

When electrical wires are buried in these older developments, it is often necessary for utilities to abandon the old easement and place conductors underground in the front yards along public street rights-of-way. To avoid excessive customer disruption, driveway destruction, and landscape damage, burial is accomplished through directional drilling rather than trenching. This drilling is more expensive than digging an open trench.

Various neighborhoods have asked for their distribution lines to be placed underground. Typically the electric utilities oblige when all or a super majority of residents request the burial. Utilities, however, often decide against burial when a vocal minority opposes the effort. Staff recommends requiring electric utilities to bury lateral distribution lines in existing neighborhoods when a majority of property owners request it and are willing to pay for it.

Utilities have voiced support for this concept.

4. Identify fully urbanized main distribution lines and require burial when wire is replaced.

Burial of lateral distribution lines will not solve the problem of storm-related power outages completely. Lateral distribution lines are the wires running through neighborhoods. Feeder or main distribution lines bring power from substations to the lateral distribution network. As many Oklahomans recognized in the ice storms and in tornadic weather, leaving main distribution lines above ground means these lines will continue to be Mother Nature's targets:

> Our lines were buried just prior to this outage and because the feeder lines weren't buried we were still without power for days, so bury the feeder lines.
>
> We live in a neighborhood with underground cables but the trunks providing power to our area were affected and therefore we lost our power. Also, how can you put a monetary number on trying to live in your home without lights and heating, etc.?
>
> Please bury all lines back to the substations and not just in neighborhoods.
>
> At the very least, when lines are being replaced underground lines should be used.

Utilities opposed burial of main distribution lines because they believe underground lines limit flexibility. When feeder lines are buried, new lateral lines for the latest real estate developments are harder to install than when the main lines remain overhead. With aerial lines, the utility can hook lateral lines in at almost any location and with a minimum of equipment. With buried main lines, the utility can hook in new lateral lines only where a "junction box" has been buried along the line. When a junction box is not in the right place, additional equipment and time is required to dig up the main line and install the junction.

In the country's largest population centers, power lines are buried for safety, traffic, and esthetic reasons. New connections do not tend to be an issue because the areas are already fully developed. Even when existing buildings are removed to make way for new structures, the lateral connections remain available. In Oklahoma's densest population centers, the same benefits can be realized without unnecessarily limiting utility flexibility by burying feeder distribution lines as they are replaced in the normal course of business.

Utilities also oppose such burial because easements or rights of way are often narrow, making burial difficult. Staff notes aerial lines on such easements continue to require maintenance and repair, resulting in the blocking of a lane of traffic or other accommodation to work needs.

Staff recommends the Commission require main distribution lines in fully developed urban areas to be buried when the conductor is replaced in the normal course of business.

5. Require utilities to underground main and lateral distribution lines when relocating for major road and highway projects.

The American Association of State Highway and Transportation Officers reports approximately 1,000 people lose their lives in the United States every year because of automobile accidents involving utility poles. In Oklahoma, a utility pole was the first thing struck in 822 vehicle accidents in 2006, the latest year for which statistics are available. Ten of those accidents were fatal, and another 286 people were injured, according to the Oklahoma Highway Safety Office.

> When repairing or replacing, why don't they go ahead and bury the lines. The widening of NW 36th Street [in Oklahoma City] was the perfect opportunity to do this but they refused. I never really understood their reasoning for not doing it at that time.

As stated in Recommendation No. 4, burial of lateral lines without burying main distribution lines reduces the size of the weather target, but does not prevent outages. When lines must be replaced anyway and construction equipment is already on the scene, it makes sense to bury lines being moved to make way for new or widened roads. Staff recommends burial of distribution lines when they must be relocated for road projects.

Again, utilities opposed burial of main distribution lines because they believe underground lines limit flexibility and because easements or rights of way are often narrow. Staff reiterates its statements from Recommendation No. 4 and believes judicious planning of junction box locations can solve future development issues.

6. Harden all highway-crossing electric lines identified as causing disruptions during storms because of falling on the roadway.

The Department of Emergency Management reported problems arise with delivering emergency services to various areas in the state when ice storms, thunderstorms, or high-speed straight-line winds fell power lines crossing highways and main county roads. The electrified wires serve as roadblocks for ambulances, fire trucks, and other emergency vehicles. They also block evacuation routes. Respondents to the Commission's online questionnaire reported similar problems and suggested solutions:

> Cross-country power poles broke, and the lines fell across the only road to our area. The neighborhood was isolated for more than a day as result. This was due to ice on the lines, not trees. Better-constructed poles should be required.

> Underground is the only way to prevent the danger of "downed broken lines" across streets and in yards and fires from broken lines, as well as public contact with them.

> Besides the ice storm, several times a year someone knocks into the utility pole that serves our neighborhood with their car, bringing it down in the right-of-way and causing power outages. Windstorms and hail and thunderstorms do the same thing. In this day and age we should have buried lines.

While placing road-crossing power lines underground would solve the problem of energized lines blocking emergency vehicles and evacuation routes, burial is not the only viable solution. In the December 2007 ice storm, the only utility poles that went down were wooden poles, according to the utilities' responses to Staff data requests. It appears these poles were mostly single shafts without supporting structures, such as guy wires or buttresses. Self-standing structures may also solve the problem of power lines blocking roads. Such structures are often steel but may be wood. They are constructed so they do not rely on other poles along the line to remain standing. In addition to avoiding energized lines on highways, they prevent line cascades, which pull extended lengths of wire and poles down when one pole fails.

Staff recommends utilities work with emergency service personnel to identify problem sites. Staff also recommends utilities determine whether line burial or erection of self-standing structures would better and more cost-efficiently prevent future failures.

Utilities generally opposed burial of power lines crossing roads but were open to hardening such sites with self-standing structures.

7. Require utilities to erect self-standing poles in strategic locations for transmission lines and targeted distribution lines.

During the December 2007 storm, some outages resulted from the failure of power poles. As stated in Recommendation No. 6, all such failures involved wooden poles. None involved either metal or concrete poles. Occasionally, a collapsing pole's pull on the lines causes a cascade of falling poles. A well-known example of such a cascade occurred along State Highway 74 between Crescent and Oklahoma City during the 1990s. These cascade failures require significant time to repair.

Respondents to the Commission's online questionnaire noticed the wooden pole problem:

> High voltage lines with wooden poles should be replaced with metal poles as needed. Many lean 10-15 degrees from vertical.
>
> It seems that most of the damage during storms is poles going down. What would be the cost to electric customers if steel poles were used?

Metal and concrete poles[6] are more expensive to buy and considerably costlier to install than wood; however, industry information indicates non-wooden poles last longer and require less maintenance. Given the higher initial cost, it is not practical to require

[6] Manufacturers also supply fiberglass poles, but there is insufficient information on the performance of such poles to make any recommendation about them.

wholesale replacement of wooden utility poles with either metal or concrete. Electric utilities already use some of these poles after case-by-case consideration of load, location, importance, and other factors.

This discretion should remain with the utility. Staff, however, believes a similar approach as stated in Recommendation No. 6 is appropriate here. Staff recommends the Commission require utilities to erect self-standing structures in strategic locations for transmission and main distribution lines.

Utilities are non-committal on this recommendation until the know more about the sites.

8. Harden worst performing circuits.

As part of their reliability programs, electric utilities identify troublesome circuits where outages occur more often than on the rest of the system. Typically, the 10 worst circuits receive special attention each year—mostly in the form of more intensive vegetation management. Usually the special attention addresses the outage problem, and the circuits fall off the worst performing list.

Many circuits continue to have problems, as reported to the Commission's online questionnaire:

> I have many interruptions and outages due to thunderstorms, ice storms and cars hitting the power poles.
>
> Our street lost power eight times during various rain showers in 2007.
>
> We lose power whenever the wind blows. Flickers mean the breaker; every clock and appliance with a clock has to be reset. This can happen several times in one day. Often we come home to a very hot house; our alarm system had to be removed.

Staff recommends that the Commission direct electric utilities to continue such programs and to expand them so that the 10 worst performing rural circuits and the 10 worst performing urban circuits are identified each year and addressed. Staff also recommends the Commission require utilities to consider burial of these circuits as well as more aggressive vegetation management or other solutions.

Utilities indicated support for this recommendation.

Outage Prevention and Quick Response to Disruptions

9. Bury drop lines and/or create a pilot program to test newly available service entrance disconnect systems.

Among the major problems experienced in the December 2007 ice storm was damage to customers' electric service entrances. In aerial applications, electric service is connected to a building by running a drop line from the utility pole to a weather head usually located on the structure's roof. The wire runs from the weather head to an electric meter typically attached to the outside wall immediately under the weather head. From the meter, electric service runs into the customer's building. If a tree or heavy, ice-laden branch falls on the drop line, enough force may be exerted to pull the weather head and meter off the building. This happened often during the ice storm.

When a customer's service entrance is damaged, the electric utility may bring the neighborhood grid back on line but cannot reconnect the customer until a licensed, private electrician reinstalls the weather head and meter. In December, a shortage of qualified electricians meant many customers' power could not be restored when utility lines were fixed.

Utilities do not engage in vegetation management to protect drop lines because these lines are located solely on the customers' property. Homeowners especially are loath to allow the electric company to trim carefully landscaped shrubs and trees. Property owners themselves do not generally engage in proper vegetation management to protect drop lines and service entrances.

If service is provided through an underground line, the problem of ripping out weather heads and meters does not exist. As one respondent to the Commission's online questionnaire said:

> I believe the fact that my service drop was buried was the reason I was only out for two days and not five to eight days for persons with overhead service drops.

Staff originally believed the solution to this problem was to require all new and existing drop lines to be buried. Staff continues to recommend burial of new drop lines[7] and services when existing lateral distribution lines are buried; however, for existing aerial drop lines where lateral distribution remains overhead, Staff recommends the Commission authorize utilities to engage in pilot programs to test a new device appearing to offer protection for service entrances. The device is a quick-release connector that sits on the utility pole. The customer's drop line runs from the connector to the weather head. If a certain amount of pressure is placed on the drop line, the quick-connection device releases the line before enough force can be applied to rip the weather head and meter from the building. The downed line itself is de-energized, removing an electrocution hazard. While power is lost, one utility employee in a short time can reconnect it. The cost of the device is about $80 compared to $1,200 to $2,000 to bury an existing drop line.

Because it is relatively new, the device does not yet have a track record. In Oklahoma, the City of Duncan and Tri-County Electric Cooperative serving the Panhandle are just beginning to install the devices. Staff recommends creation of a pilot program for regulated utilities to determine whether the device will help in the quick restoration of power during outages and to learn whether the instrument can survive Oklahoma's weather without corrosion or accidental disconnection.

Utilities have mixed reactions to burial of drop lines. They have indicated a willingness to engage in pilot studies of quick-connect devices.

Quick Response to Outages

10. Create incentives for "smart-grid" installations allowing for rerouting of electric power around downed lines, transformers, and other equipment.

[7] Technically once a service line is buried, it is no longer a "drop" line; however, the term is used here because it is understood to include all power lines running from a lateral distribution line to a single customer.

"Smart grid" is a term used to describe a variety of automated, communicative and, computer-enabled innovations for the electricity distribution system. While many of these developments have to do with metering and are aimed at providing customers and utilities with real-time information about electric usage and rates, other advances provide potential solutions for weather-related outages.

Currently, aerial transmission lines deliver power in one direction, while underground systems are looped and can deliver electricity in both directions. Smart grid systems loop aerial lines so power can be routed around downed power lines. In the normal aerial system, power flows from a substation to Point A, then to Point B, Point C and Point D. If the line goes down at Point B, power will not run to Points C and D even though all lines at those points are operational. With a looped system, delivering power in all directions, switches will automatically trip at Point B and cause the electricity to retrace its path to Point A, then find Point F, travel to Point E and then to Points D and C, providing power to everyone with intact lines.

One utility doing business in other states and Oklahoma has tested such a system in Texas. In the past during severe outages, the utility took at least three days to restore power to 80 percent of its customers. Today, the same 80 percent can be online in less than 90 seconds because of looping and smart grid innovations.

Today, an electric utility does not know where the power is off until customers call. Smart grid allows the distribution system itself to report where it is out. In addition, customers do not know exactly where a problem exists or what that problem is, but smart grid innovations allow the system to diagnose itself and pinpoint the transformer or pole where the outage has occurred. These automated notifications permit utilities to respond more efficiently and to get the system back online more quickly.

Staff recommends the Commission create programs and tariffs requiring electric utilities to begin the process of installing smart grid systems to allow faster response to power outages.

Utilities are beginning tests with Smart grid installations.

Amelioration of Outage Effects

11. Encourage back-up self-generation for businesses and residences.

Oklahomans, as many Americans, have become dependent on electric utilities for the basic necessities of life. All-electric homes are not easily heated during power outages, and even buildings with gas-fired furnaces most often rely on electricity to operate furnace igniters and blowers. When homeowners attempt to operate makeshift heaters in their homes during long-lasting outages, they often do so inexpertly, leading to the previously mentioned deaths from carbon monoxide poisoning and fires. The following comment from the Commission's online questionnaire responses were typical:

> It was a great hardship on this household. Temperature in the house was 38 degrees. We are total electric and had to haul water for cooking over candles, livestock, flush toilets, etc. I never want to experience that again.
>
> We were out for several days with a newborn. It was difficult to keep him warm. This was very frightening.

As seen from the Commission's scientific telephone survey and responses to its questionnaire, many families buy food in bulk and expect to be able to store it in electricity-powered refrigerators and freezers. The most prevalent type of loss reported to the Commission from the December 2007 power outage was spoiled food, with 52 percent of those who said they had some type of economic injury reporting food loss.

Many individuals also rely on residential electricity to operate life-sustaining equipment:

> My mother-in-law was staying with us at the time. She requires an electrical oxygen machine while sleeping at night. She developed breathing problems, and we had to call an ambulance to come take her to the hospital.
>
> I depend on oxygen and a ventilator which all need electric power to work. This has become primarily a matter of public safety, health, and welfare and is no longer just about the utilities and how much it will cost to bury the lines.

> I have to sleep under a CPAP [continuous positive airway pressure machine] every night and wasn't able to do that. I also have other medical conditions that required electricity. I do not want to go through another outage that lasts 11 days!

At their workplaces, huge numbers of Oklahomans are dependent on electricity to operate the engines of commerce—not just manufacturing machines but also office computers:

> We lost power at my business for five days. We are a 24-hour service. Employees had to work in the dark by candlelight. They wore coats and gloves, and we were all very cold. We purchased two generators to keep a limited number of computers working.
>
> I lost my job because of the storm. I worked for a dental office that was new. They were without power for a week and they lost a lot of money, so I was let go. I was the last person to be hired, so, of course, the first one to be let go.
>
> Power outage at work required two generators to power computers and phones as needed to continue to serve homebound patients with nursing service. I worked in very cold rooms with blankets and lanterns to keep medical service to Tulsa residents.

If businesses were operating, many employees were unable to go to work because of lack of transportation or other common workday needs:

> All service stations should be required to have generators on line to pump gas.
>
> My lost leave was not due to power outage at my home but at our day care. I had to use vacation to stay home three days before the day care had electricity, although I still had to pay day care.
>
> Even the school my daughter goes to lost power for a couple of days.

Other problems arose, as well:

> This severely limited my ability to continue my education at Tulsa Community College. Considering buses didn't run and the school shut down due to the ice storm with loss of power, I felt that I lost money that I paid out of pocket to get my education.
>
> I got to work, but my house was broken into during the storm.

Many Oklahomans see a need to return to the self-sufficiency of earlier days. They urge the use of generators:

> People need to be more self-reliant and take some responsibility to be prepared for emergencies. For most people, a few days without power is an inconvenience. I do realize that the elderly and sick do need help.
>
> People should be prepared by having a generator available along with a transfer switch.
>
> Power suppliers need a "generator program" similar to power surge devices installed by them to assist clients. Sell generators installed for simple usage by clients.
>
> If Oklahoma would invest in local alternatives, such as incentives for homeowner solar or wind, or back-up generators, it would help. Net metering would help in such situations if the immediate grid could utilize the electricity.
>
> If power lines cannot be buried in this area, a substantial discount for residential members in the area should be given for electric or gas generators.
>
> We were lucky and didn't lose meat and other things because of a generator.

One of these respondents had a novel idea about generation:

> Have wind energy scattered across the cities like that of "cell towers." I'm willing to pay extra.

Self-generation of electricity is a feasible response to power outages, but the installation of these generators must be done carefully. During the December 2007 power failure, many Oklahomans purchased gasoline-powered electric generators at hardware stores. Others obtained natural gas-powered devices. The first concern with local generation is connection to the state's electricity grid. Improper connection can lead to feedback along power lines, resulting in death to linemen and damage to utility plant. The second concern comes from amateur installations, which, leads—especially in case of gasoline- or diesel-powered generators—to carbon monoxide poisoning inside buildings. A third concern arises from improper connection leading to burnout of a structure's electric system, leading to destruction of appliances, as well as building fires.

Despite these concerns, properly installed self generation may provide full building power or, at a cheaper cost, just enough electricity to operate a gas furnace igniter and blower, as well as a refrigerator, a lamp or two, and a very small number of essentials, such as ventilators. In rural areas, such generators can operate on wind power, solar cells,[8] or propane. In urban areas, such generation can come from solar cells or natural gas. Each area could also employ gasoline or diesel generators. In all cases, however, generators should be professionally installed to avoid damage to either the owners and their property or to utility employees and property.

Self-generation has additional benefits. It may be an efficient demand-side management tool, reducing peak loads and, in larger applications, perhaps even base load. If wind and solar options are used, the State's carbon footprint can be reduced. Dispersal of generating plant provides some resiliency for the power system in natural and manmade disasters.

Staff recommends creation of funding mechanisms to assist property owners in installation of professionally connected local generation by wind turbines, photovoltaic cells, natural gas generators, and gasoline- or diesel-powered generators. These funding mechanisms could be similar to energy loan programs for education and government facilities available currently through the State Energy Office within the Department of Commerce or the state sales tax exemption for electricity purchased to mine coal. (*See* 68 Okla. Stat. § 1359[13]). Such funding mechanisms would require legislative action such as creation of a tax credit or deduction; working with mortgage lenders or bonding authorities to create reduced-interest loans, or providing return to utilities for long-term financing backed with appropriate property liens. Special attention will need to be given low-income customers' needs.

In meetings with Staff, utilities have not opposed or supported self-generation for purposes of dealing with power outages; however, the utilities have urged installation be performed by professionals to avoid danger to linemen and the power system.

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[8] Solar and wind generators would work best with inclusion of storage batteries.

12. Require back-up self-generation for vital services.

It should go without saying that providers of vital services must include response to power outages in their emergency contingency planning. Sadly, this is not always the case in Oklahoma. At least one utility reports some hospitals have purchased generators but never hooked them up. Many nursing homes with patients using life-sustaining equipment powered by electricity have no back-up generation at all. While most hospitals appear to have emergency generators, the same is not true of nursing homes and retirement centers:

> Long-term care facilities are health care facilities and are just as important as hospitals to many. Long-term care facilities need to be a priority.
>
> As a nursing home, we also had to deal with the psychological effects on the residents. Some residents went home with their families. Those with dementia or physical impairments faced greater challenges with low light, etc.

Some municipalities, water companies, and rural water districts also have failed to provide emergency generation for water treatment plants. The Department of Emergency Management (DEM) reports every ice storm brings calls from small water providers requesting one of the department's handful of small generators. These generators are not large enough to operate the plant but can keep water moving enough to prevent freezing that would severely damage water treatment facilities. While large water systems apparently have invested in back-up generation, small systems have not. In a widespread ice storm or in drastically frigid temperatures, reliance on distant DEM generators may be insufficient.

Not all small water suppliers have sophisticated water treatment plants; some rely on clean groundwater sources requiring little, if any, treatment. Staff recommends the Commission require water utilities it regulates who have a water treatment facilities also have sufficient back-up generation to keep plants from freezing in the event of a power outage. Staff recommends the Commission urge legislative action to protect the water supply of communities whose systems are not regulated by the Commission.

Staff also recommends legislative action to protect vulnerable hospital and long-term care facility residents in the event of a power outage.

Staff has studied police and fire department responses to electricity failures and has not found a need for recommendation. Emergency call centers (911 operators) have back-up generation. Police response is adequately protected because assignments are made from the 911 center directly to police officers in vehicles. Fire departments also appear to have communications regardless of grid power issues and have made contingency plans for opening fire station overhead doors so they may respond to emergencies during outages.

As in the case of Recommendation No. 11, utilities have not opposed or supported self-generation for purposes of dealing with power outages; however, the utilities have urged installation be performed by professionals to avoid danger to linemen and the power system.

Conclusion

Any Commission decision made to expand the undergrounding of electric plant in the State of Oklahoma must certainly consider the overall cost of such a project and its impact on the state's electric consumers, as well as both the advantages and disadvantages of having more electric plant in the ground.

Electric power is essential to a modern society. Economic prosperity, national security, and public health and safety cannot be achieved without it. Communities that lack electric power, even for short periods, have trouble meeting basic needs for food, shelter, water, law, and order.

Placing existing power lines underground is expensive. Undergrounding the entire state's existing overhead transmission and distribution lines could cost well over $50 billion and take decades to complete. The average cost of undergrounding existing overhead distribution lines is conservatively estimated to be in the range of $500,000 per mile and of the studies reviewed, the costs could actually be closer to $1 million per mile. This is five to 10 times the cost of a new overhead distribution line.

While the push continues for undergrounding electric lines, particularly after extended power outages caused by major storms like the ice storms of January and December 2007. The reliability benefits that would result from undergrounding are uncertain, and there appears to be little economic justification or general customer support for paying the required premiums. Residential customers place a value on undergrounding their utilities and are willing to pay an incremental cost to have their power lines placed underground. It appears, however, that there is a large gap between the public's perception of what it should cost for undergrounding and what it actually costs. When faced with the real costs of undergrounding, it appears many individuals prefer to keep their overhead service and their money in their pockets. This isn't to say that the undergrounding of existing overhead power lines will not continue in certain situations, justified primarily by aesthetic considerations, not reliability or economic benefits. Many consumers simply want their power lines placed underground, regardless of the costs.

The challenge for this Commission is in determining how to best protect the Oklahoma electric consumer during major outage periods, what projects should go forward to assist consumers, who will benefit from these projects and of course how will these projects be financed.

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Appendix A: Summary of Underground Studies

Edison Electric Institute Report

One of the most comprehensive reviews is the Edison Electric Institute's summary of previously completed studies on undergrounding published in January 2004. Some of EEI's findings are:

1) Burying overhead power lines would cost about 10 times what it costs to install overhead power lines.
2) Underground power systems have fewer outages but the outages last longer.
3) Reliability benefits associated with burying existing overhead power lines are uncertain and in most instances do not appear to be sufficient to justify the high costs.

One of the most interesting features of EEI's report is its summaries of innovative programs that communities and local governments have adopted to help pay for burying their overhead power lines. These include special assessment areas, undergrounding districts, and state and local government initiatives.

When a community establishes a "special assessment area," subscribers pay extra on their monthly bill to fund the underground project. These areas are typically created through a petition of the majority of the property owners in the area. For example, Commonwealth Electric in Massachusetts has used special assessments since 1970 to fund burial efforts in historic communities such as Nantucket.

Another approach, employed in California and Oregon, is the establishment of "underground districts." The California Public Utilities Commission collects a percentage of revenue from wire-based utilities for a special undergrounding fund. To receive these funds, a community must form an undergrounding district, approved by at least 70 percent of the property owners in that district. The property owners must also agree to pay the $500 to $2,000 it costs to connect their homes to a new underground system.

Investor-owned Hawaii Electric has a program where it pays for up to one-third of the cost to place existing neighborhood electric distribution lines underground. Hawaii electric will undertake the conversion as part of a community or government-initiated underground project, subject to public utility commission approval.

Another investor-owned utility, South Carolina Electric and Gas (SCE&G) has established a special undergrounding program, approved by the South Carolina Public Service Commission. Under the program, if a local municipality agrees to contribute a matching amount, SCE&G contributes five percent of the gross receipts it is obligated to pay to the municipality. This money goes into a special underground fund.

Florida Study

In October 2004, the staff of the Committee on Utilities and Telecommunications, Florida House of Representatives, requested a study proposal from the FPSC on the cost of undergrounding electric facilities in Florida. In a letter dated October 20, 2004, the FPSC outlined three possible levels of study, which, depending on the detail desired, would require differing times to complete: 90 days, 120 days, and 180 days. A 90-day study would rely more heavily on updating and extrapolating data from previous work done by the FPSC and information drawn from studies performed by other states, countries, and professional organizations. Additional time, up to 180 days, would be required for a more comprehensive study involving the collection and analysis of current cost and reliability data from Florida utilities and input from interested parties. In subsequent communications with the House staff, the FPSC offered to provide in the shortest time possible a preliminary estimate of the cost to convert, over a period of ten years, existing investor-owned utility transmission and distribution facilities from overhead to underground. As indicated, the proposed analysis would address only investor-owned utilities and would not include underground cost estimates for municipal and rural electric cooperative electric utilities. The results of this preliminary analysis were to be provided prior to the start of the 2005 Legislative Session.

The purpose of this analysis was to develop a ballpark estimate of the cost for investor-owned electric utilities to place existing electric transmission and distribution facilities in Florida underground. Only the direct costs to the electric utility are considered. The cost estimates contained herein were developed primarily from an extrapolation of historic data for investor-owned electric utilities. The five investor-owned electric utilities in Florida account for approximately 78 percent of statewide electricity sales.

Maryland Task Force Study

Since 1969 all new low-voltage electric and telephone lines have been buried underground based on the Maryland Public Service Commission's determination that it was in the interest of public health and safety. Utilities are permitted to recover through rate structure the cost of undergrounding new low-voltage electric and telephone distribution lines.

In 2003, the Maryland Task Force was charged by the legislature with making recommendations on how to facilitate and lower the cost of relocating overhead utility lines underground. Similar studies had been conducted in Maryland in response to severe weather related power outages in 1999. These earlier studies estimated the costs of undergrounding existing overhead power lines at $900,000 per mile, or 5 to 10 times the cost of installing overhead lines. In addition, the useful life of underground cable is about 30 years, compared to 50 years for overhead. In a report prepared in 2000, one of the conclusions reached was that overhead lines offered a much less expensive method of providing reliable service. The example offered to illustrate this point is that if a 10 percent return were imputed to the great amounts of capital freed up by building overhead instead of underground lines, the earnings alone would pay for substantial ongoing overhead maintenance.

The Maryland Task Force reviewed these studies and reported that their findings regarding cost and benefits do not differ substantively from the prior studies. The Task Force made three recommendations:

(1) The Attorney General should solicit an opinion and clarification from the Internal Revenue Service on the applicability of the Contributions in Aid of Construction (gross-up tax). This tax represents approximately 27.4 percent of the cost of undergrounding, and there are conflicting opinions regarding the applicability of the tax. Undergrounding projects being completed primarily for aesthetic purposes are subject to the tax. However, undergrounding projects that are undertaken for public safety reasons would not be defined as an addition to capital, and not a Contribution in Aid of Construction, and thus should not be subject to the gross-up tax.

(2) The Maryland Department of Planning should serve as a clearinghouse to assist local jurisdictions and groups that are interested in undergrounding. Although current law and regulations provide a framework for implementing an underground plan, there is no place an interested party can go to get comprehensive advice on the most effective and low-cost ways to complete an undergrounding project.

(3) Local governments, State and local highway authorities, Maryland Department of Planning, and owners of overhead facilities should identify opportunities for undergrounding in construction and repair planning, and all parties should work closely to coordinate undergrounding activities. This would increase efficiency and reduce overall project costs by allowing the placement of multiple utilities in a single trench when construction activities may already be planned for other reasons.

Michigan Study

On May 31, 2007, the Commission issued an order in Case No. U-15279 directing the Michigan Staff to study the costs and benefits of extending the Commission's underground line policy. The study was to include poorly performing circuits, all secondary line extensions, and road rights-of way undergoing construction. The study would analyze costs and benefits, as well as make recommendations for extending the policy.

The current underground rules (R 460.511 – R 460.519) require underground placement for: (1) new distribution systems in residential subdivisions in the lower peninsula, (2) extensions of commercial and industrial lines in the lower peninsula, or (3) where required by ordinance in heavily congested business districts, or (4) at the utility's convenience. The developer or customer pays the additional cost of undergrounding for items (1), and (2), or if the customer requests that lines be placed underground. There is no initial cost to the specific customer or developer for items (3) or (4).

In Michigan, a decision to place facilities underground involves four considerations: (1) aesthetics, (2) frequency of interruption, (3) duration of interruption, and (4) cost. The first is the most obvious, but also the most difficult to quantify. Obviously, an environment without overhead power lines is more aesthetically pleasing, but the degree of improvement is dependent upon the remaining aspects of the environment, (overhead lines in an industrial area have less impact than in a pristine wilderness), as well as the proverbial "eye of the beholder." In addition, remaining utility poles with overhead cable, telephone, or other wires may also challenge improved aesthetics.

With respect to frequency of interruption, it is clear that underground lines are less susceptible to interruption because of storm damage, trees falling, ice coating, etc. Conversely, when an interruption does occur, underground lines require more time to repair due to added complexity in locating faults, the need to dig up the facility, more complicated repairs, and the need for specialized training or equipment.

With respect to cost, underground lines cost significantly more than overhead lines, but the exact difference depends upon the type of line, location, and specific characteristics of the facilities.

Nonetheless, an increased cost for underground of $1 million per mile is a good rule of thumb applicable not only in Michigan but in the rest of the country as well.

From the above, it is clear that the decision to underground involves a tradeoff between the benefits of improved aesthetics and reduced frequency of interruption versus longer outages and increased cost. No one answer is applicable to all situations.

Undergrounding has a huge price tag. But, are the expected benefits worth the price? Michigan utilities implement distribution reliability improvements to their poorly performing overhead circuits each year that improve the frequency of outages, without increasing the duration of outages, and at significantly less cost than converting those circuits to underground.

Undergrounding for the sake of reliability does not appear to be economically justified. “The bottom line – reliability benefits associated with burying existing overhead power lines are uncertain and in most instances do not appear to be sufficient to justify the high price tag that undergrounding carries.

North Carolina Utilities Commission Public Staff Report

After a major ice storm caused unprecedented power outages to over two million electric utility customers, the Public Staff of the North Carolina Utilities Commission investigated the feasibility of replacing the existing overhead distribution lines of the state’s three investor-owned utilities with underground lines. In its report, released in 2003, the Public Staff concluded that replacement would be prohibitively expensive, costing approximately $41 billion, nearly six times the net book value of the utilities’ current distribution assets. In addition, it would take approximately 25 years to complete the replacement.

The ultimate impact of the capital costs alone on an average residential customer's monthly electric bill would be an increase of more than 125 percent. Rates would also be impacted by the higher operating and maintenance costs associated with direct-buried underground systems, particularly in urban areas, where underground conductors are four times more costly to maintain than overhead facilities. In addition to the impact on the cost of providing utility service, conversion to underground would impose costs on individual customers, municipalities, and other utilities. While these costs have not been quantified, they could be significant, the North Carolina Public Staff concluded.

Although underground systems are more reliable than overhead systems under normal weather conditions, they are not impervious to damage (for example, dig-ins and water intrusion). The repair time for underground systems is almost 60 percent longer than for overhead systems when damage does occur. Consequently, the North Carolina Staff did not recommend that the utilities undertake the wholesale conversion of their overhead distribution systems to underground.

The North Carolina Public Staff recommended that each of the utilities begin to:

(1) Identify the overhead facilities in each region it serves that repeatedly experience reliability problems based on measures such as the number of outages or number of customer hours out of service.

(2) Determine whether conversion to underground is a cost-effective option for improving the reliability of those facilities.

(3) And develop a plan for converting those facilities to underground in an orderly and efficient manner, taking into account the outage histories and the impact on service reliability.

The report also recommended that the North Carolina utilities continue their current practices of:

(1) Placing new facilities underground when the additional revenues cover the costs or the cost differential is recovered through a contribution in aid of construction,

(2) Replacing existing overhead facilities with underground facilities when the requesting party pays the conversion costs.

(3) Replace overhead facilities with underground facilities in urban areas where factors such as load density and physical congestion make service impractical from overhead feeders.

Virginia State Corporation Commission Study

The Virginia State Corporation Commission (VSCC) released its study of placing utility distribution lines underground in January 2005. The Virginia General Assembly had directed VSCC to conduct the study, partly in response to damage caused to existing overhead utility lines by Hurricane Isabel in September 2003. The study concluded that a comprehensive statewide relocation initiative does not appear to be reasonable from an economic viewpoint.

The VSCC study found that the primary advantages of underground utility lines are aesthetics and overall improved reliability. Underground circuits eliminate the need for most tree trimming maintenance, eliminate vehicular crashes with utility poles, reduce some electrical hazards, and nearly eliminate the need for extensive restoration efforts after major storms.

However, the VSCC report states that the wholesale replacement of overhead utility distribution lines would be prohibitively expensive for local and state governments, utilities, and ultimately consumers who would pay the costs, either directly or indirectly, in the form of prices, taxes, or utility rates.

In Virginia, there are 96,830 miles of overhead electric distribution lines owned by investor-owned utilities and electric cooperatives serving 3.1 million customers. The cost associated with placing these overhead electric utility distribution facilities underground was estimated by utilities to be over $80 billion. This equates to approximately $800,000 per mile of overhead line with an average cost per customer of $27,000. Assuming a total investment by electric utilities of $80 billion to relocate currently existing overhead distribution lines to underground, the annual levelized revenue requirement on a per customer basis would be approximately $3,000 per year over the life of the facilities. However, the VSCC notes that cost estimates provided by the utilities are based on simplifying assumptions as opposed to detailed engineering studies; therefore, actual costs could vary significantly from such projections.

In public comments received by the VSCC for the study, residential customers overwhelmingly favored placing utilities underground. But in follow-up questions, these same customers generally indicated they were not willing to pay enough to fully fund the work.

The VSCC concluded that a major relocation initiative could take decades to complete and encounter complications from conflicts with other existing underground utilities. Attaining new easements for utilities could involve significant time, negotiations with property owners and potential legal proceedings.

In the preparation of the study, the VSCC invited the participation of interested parties, including local governments, utility companies, industry groups, and consumer organizations. It was the general consensus of this group that decisions concerning the placement of lines underground can be implemented most effectively at the local level. The VSCC concluded localities would be able to judge each individual project on its merits and based on local citizens' values and willingness to pay. Localities would be in the best position to determine the most appropriate funding of such projects, coordinate work among utilities, and classify projects in a way that affords favorable tax and tariff treatment.

Appendix B: Oklahoma Climatological Survey,

The Increased Frequency Of Significant Oklahoma Ice Storms Since 2000

Prepared for the Oklahoma Corporation Commission

by

The Oklahoma Climatological Survey

April 24, 2008

Warming of the surface and lower portions of the atmosphere has possibly led to an increased frequency of significant ice storms across Oklahoma over the last eight years. Six storms with ice depositions of more than one inch have occurred since the turn of the millennium. Those six storms caused catastrophic damage to electric utility infrastructure in virtually every region of the state, with damages totals of more than one billion dollars. The warming at the surface is evident in a time-series of statewide average winter (December-February) temperature since 1896 (**Figure 1**). This warming is also indicated by the Fourth Assessment Report (FAR) of the Intergovernmental Panel on Climate Change (IPCC), which noted an increase in winter temperatures at the surface and the lower and mid-troposphere across most of the United States and the northern hemisphere (IPCC, 2007). While seemingly paradoxical, the hypothesis that a warming winter climate could lead to an increased frequency of ice storms is consistent with our current understanding of the atmospheric temperature profile required for freezing rain formation.

Nevertheless, the evidence of a link between a warming winter climate and an increase in ice storms is anecdotal at this time. However, the observed increase in frequency since 2000 suggests that significant ice storms will continue to affect Oklahoma for the foreseeable future. Should the climate continue to warm as projected by climate models (IPCC, 2007), the possibility exists that freezing rain and ice storm events could eventually begin to decrease in Oklahoma. The annual average temperature in Oklahoma is projected to increase by 1° to 1.5°C by the 2020s, and 2.5° to 3.5°C by the 2090s (IPCC, 2007).

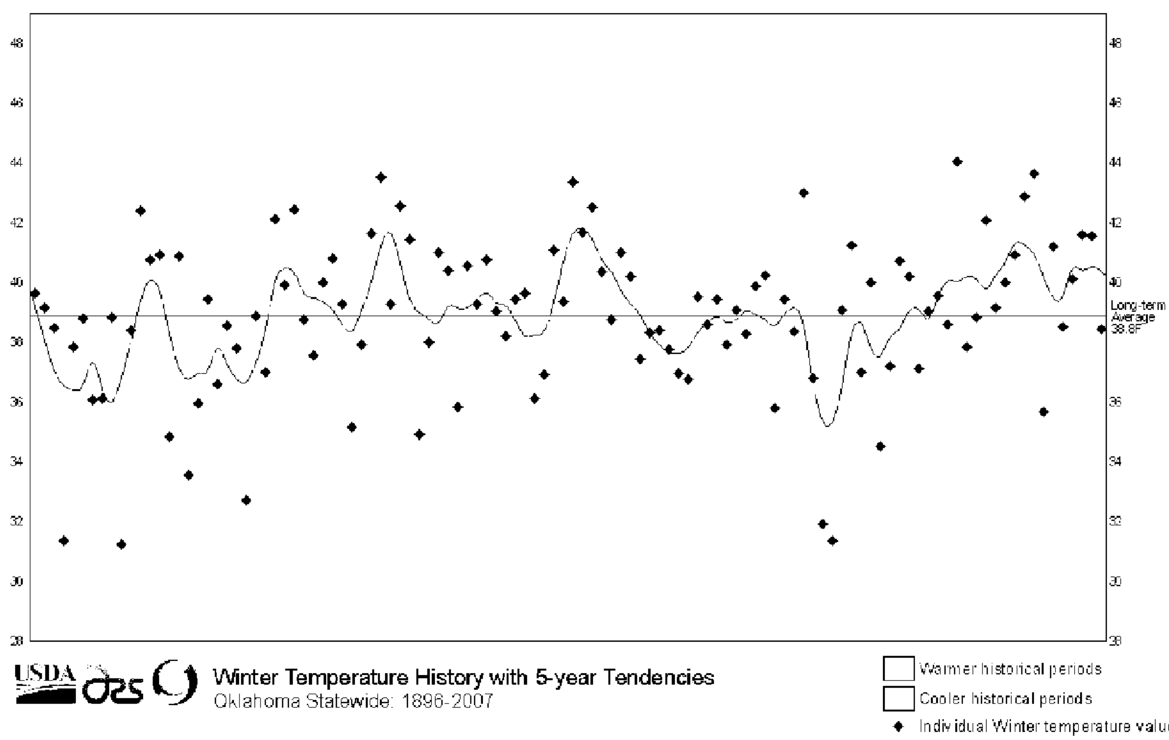
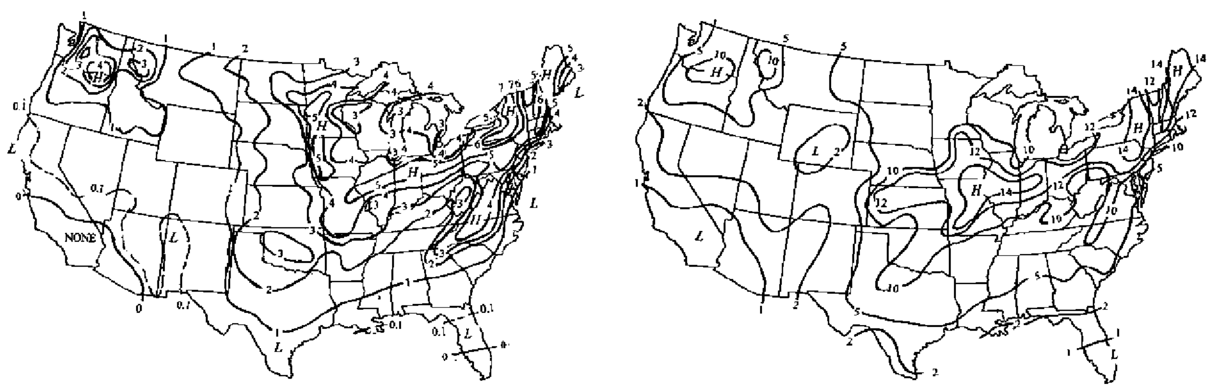


Figure 1. Oklahoma statewide average winter temperatures for the period 1896-2007.

Freezing Rain

Freezing rain is a distinct wintertime hazard in Oklahoma. Its presence in even slight amounts can disrupt travel and lead to accident-related fatalities. Previous studies have shown that most areas of the state would normally experience about three days with freezing rain per year (**Figure 2**), and a maximum of about 10 days (**Figure 3**) (Changnon and Karl, 2003). The exact frequency of significant ice storms prior to 2000 is uncertain, but an examination of newspaper accounts and historical weather documents places that frequency at approximately once per decade.



Figures 2 and 3. The average annual number of days with freezing rain (left) and the maximum number of freezing-rain days recorded in any year (right). Both figures based on years between 1948 and 2000 (Changnon and Karl, 2003).

The NWS considers an ice storm with greater than 0.25 inches (0.63 cm) of ice accumulation a significant episode that would trigger an ***ice storm warning***. The resulting ice accumulation can down power lines and poles, causing millions of dollars in damages and widespread power outages. Power line damage can occur with as little as a quarter-inch of ice and 15 mph winds, as indicated by the Sperry-Piltz Utility Ice Damage Index (**Table 1**). Significant damage can occur with as little as a quarter-inch of ice and winds greater than 25 mph.

Freezing Rain Formation

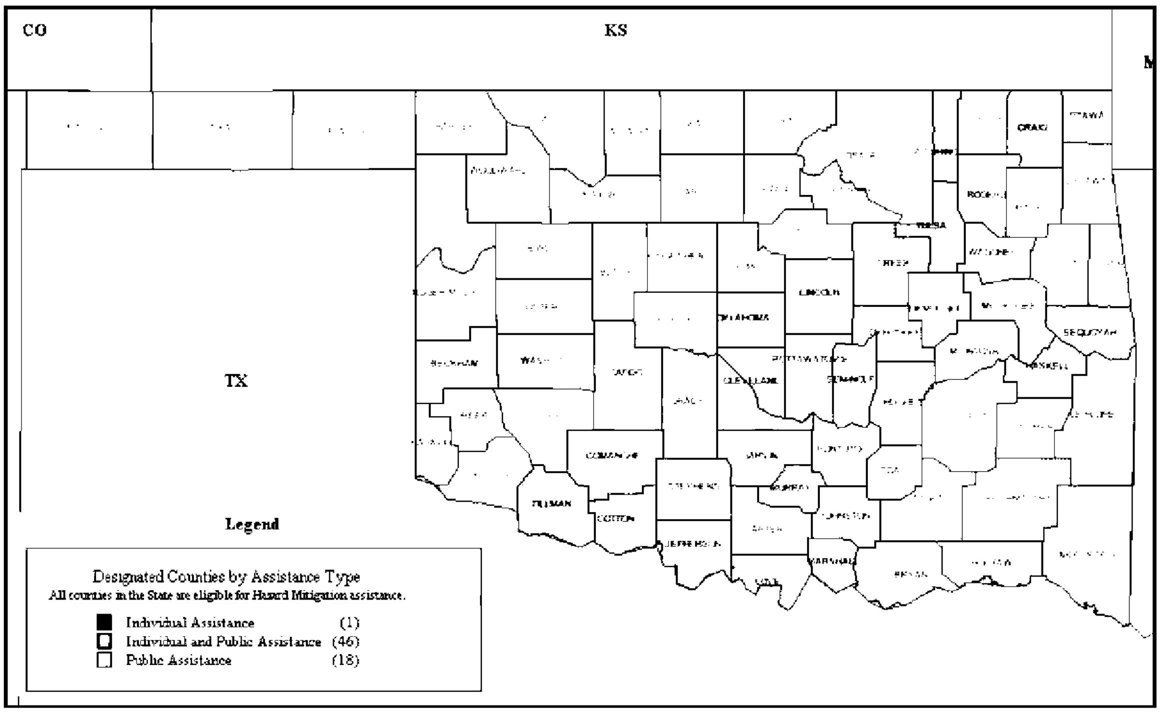
Freezing rain develops as falling snow encounters a layer of warm air deep enough for the snow to completely melt and become rain. As the rain continues to fall, it passes through a thin layer of cold air just above the surface and cools to a temperature below freezing. However, the drops themselves do not freeze, a phenomenon called supercooling. When the supercooled drops strike the frozen ground or an exposed surface, they instantly freeze and form a thin film of ice. Whether freezing rain forms from the cold rain or not depends critically on the characteristics of the surface cold air layer. If the layer is too thick or too cold, it will refreeze the rain into ice pellets, or sleet. If the cold layer is too warm or too shallow, the rain will continue to the ground as normal rain and will not freeze unless the temperature of the ground or some other surface it contacts is well below freezing. Thus, warming of the lower atmosphere over time could produce a favorable environment for freezing rain formation.

Table 1. The Sperry-Piltz Utility Ice Damage Index. The categories are based upon combinations of precipitation totals, temperature and wind speed. Utility systems may be able to handle moderate ice accumulations, but stressed lines under wind forces are more likely to break. Therefore, one inch of ice may be a Level 2 or Level 3 ice event, but if wind speed exceeds 25 mph, it becomes a Level 5 event.

Ice Index	Radial Ice Amount (inches)	Wind (mph)	Damage and Impact Descriptions
1	< 0.25	15-25	Some localized utility interruptions possible, typically lasting only 1 or 2 hours maximum.
	0.25-0.50	< 15	
2	< 0.25	>= 25	Scattered utility interruptions expected, typically lasting less than 8-12 hours maximum.
	0.25-0.50	15-25	
	0.50-1.00	< 15	
3	0.25-0.50	>= 25	Numerous utility interruptions, with some damage to main feeder lines expected with outages lasting from 1-3 days.
	0.50-0.75	15-25	
	0.75-1.00	< 15	
4	0.50-0.75	>= 25	Prolonged & widespread utility interruptions, with extensive damage to main distribution feeder lines and possibly some high voltage transmission lines. Outages expected to last more than 3 to 5 days.
	0.75-1.00	15-25	
	1.00-1.50	< 15	
5	0.75-1.00	>= 25	Catastrophic damage to entire utility systems. Outages could last from one week to several weeks in some areas.
	1.00-1.50	15-25	
	> 1.50	< 15	

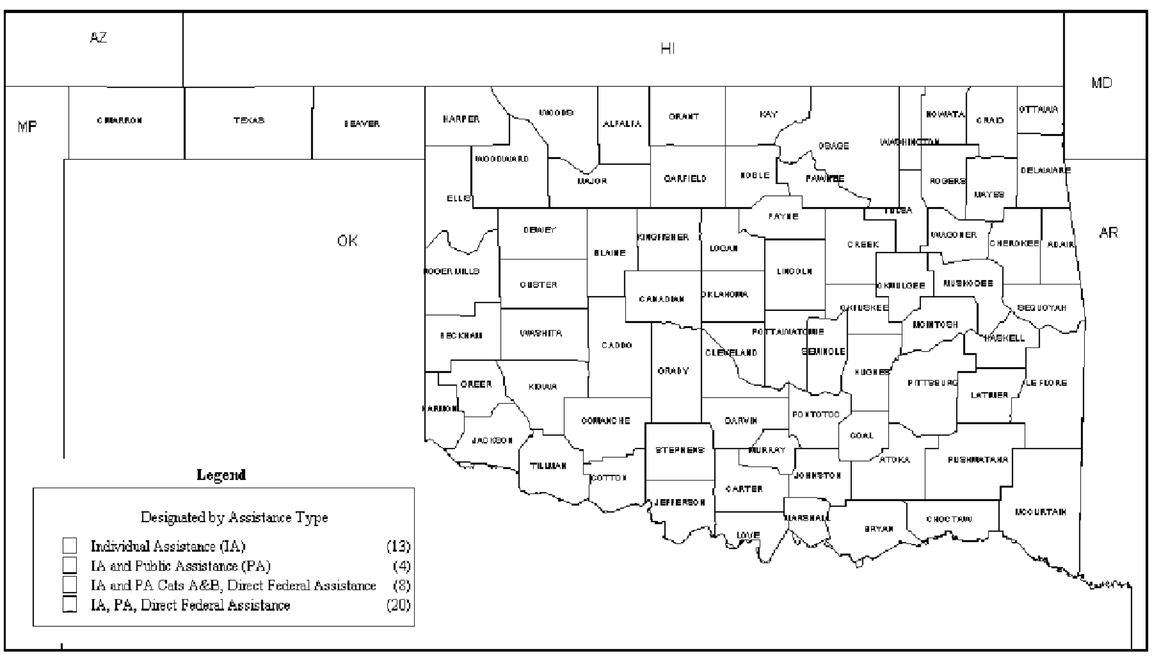
Significant Oklahoma Ice Storms 2000-2007

December 25-27, 2000 (Sperry-Piltz Level 4): Major snow and ice storms struck statewide, especially powerful in southeast quarter. Power was lost to at least 120,000 homes and businesses, including 90% of the residents of McIntosh, Latimer, and Pittsburg counties. Extended power outages also led to disruptions of local water supplies in several areas. At least 27 fatalities were attributable to the extreme weather conditions, which extended well into January 2001. Total property damage in the state was approximately $170 million.



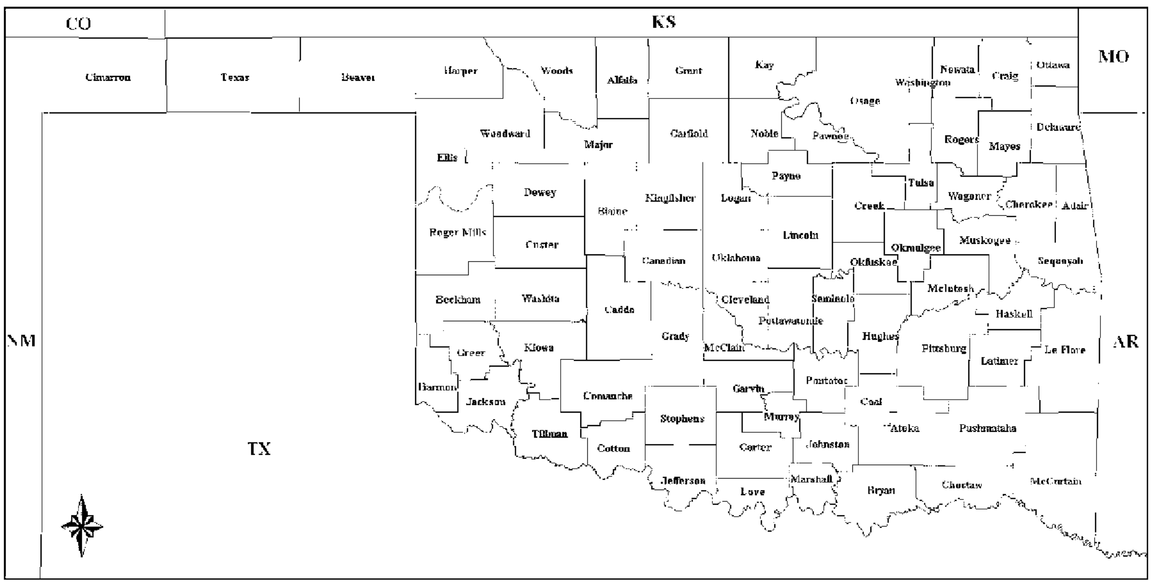
Sixty-seven Oklahoma Counties designated as federal disaster areas following the December 2000 ice storm, making them eligible for federal aid (map courtesy of FEMA).

January 28-30, 2002 (Sperry-Piltz Level 5): This powerful winter storm wreaked havoc on the northwestern half of the state, and none suffered more than the state's power suppliers. The storm left over $100 million of damage in its wake, leaving some 255,000 residences and businesses without power. A week after the icy system exited the state, 39,000 Oklahoma residents were still in the dark as utility companies worked around the clock to replace snapped poles and downed power lines. Enid, a city of 47,000, was entirely without electricity for days. Power companies estimated that power could be lost for up to two months in some rural areas of northwestern Oklahoma. Southwestern Oklahoma State University in Weatherford closed its doors for only the 4^{th} time in its 100-year history. The Oklahoma Association of Electric Cooperatives reported over 31,000 electrical poles destroyed due to the ice. With about 20 poles per mile on an average electrical supply line, that results in over 1,550 miles of destroyed power supply capabilities, enough to stretch from Oklahoma City to New York City. Electric power was not fully restored to all Oklahoma City residents until February 10^{th}, 11 days after the brunt of the ice storm exited the region. Three weeks after the event, 2,320 customers remained without power. The most serious casualty in the wake of the ice storm, however, was the toll in human lives. Seven fatalities were directly attributable to the effects of the late-January storm. Four died in traffic accidents on the icy roadways, while two others died of asphyxiation while trying to get warm in enclosed spaces. Another resident died when a large tree branch crushed him as he tried to clear his residence of debris.



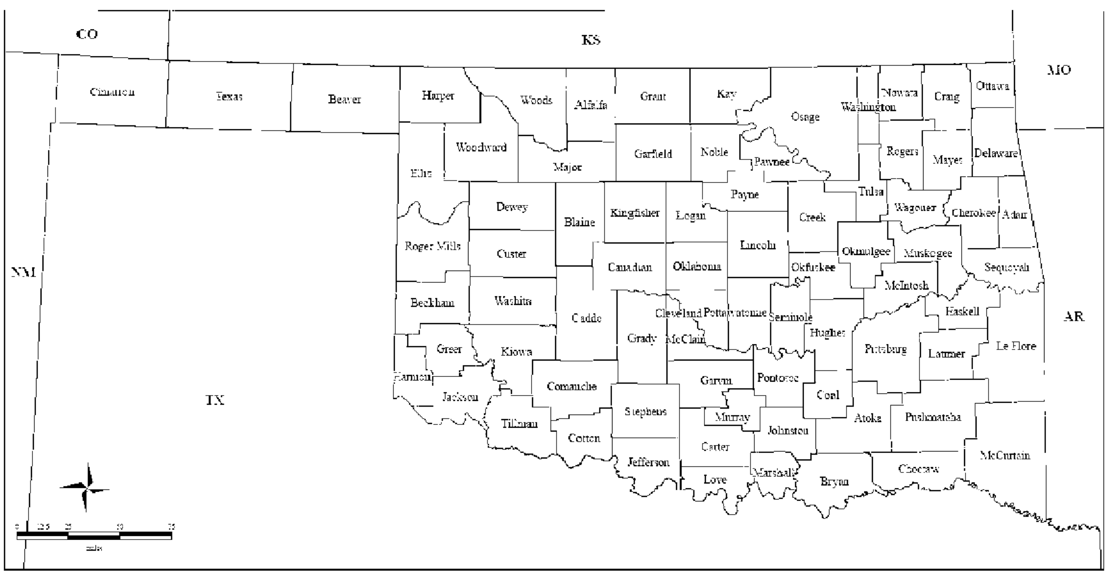
Forty-five Oklahoma Counties designated as federal disaster areas following the January 2002 ice storm, making them eligible for federal aid (map courtesy of FEMA).

December 3, 2002 (Sperry-Piltz Level 5): The third significant ice storm in as many years, this icy blast left a damage footprint in a narrow band from west central to north central Oklahoma. Areas north of the icing region generally received 2-6 inches of snow, with some areas reporting more than eight inches. Moderate to heavy rainfall occurred to the south. The main impact of the ice storm was damage to electrical distribution systems. Because much of the area impacted by the storm is rural, the primary victims of the storms were members of rural electric cooperatives (RECs). About 30,000 REC customers were without power for some time during the storm. According to the Oklahoma Association of Electric Cooperatives, REC losses were about $4.5 million. Other power suppliers were impacted also. At the storm's peak, about 25,000 Oklahoma Gas & Electric (OG&E) customers lost power.



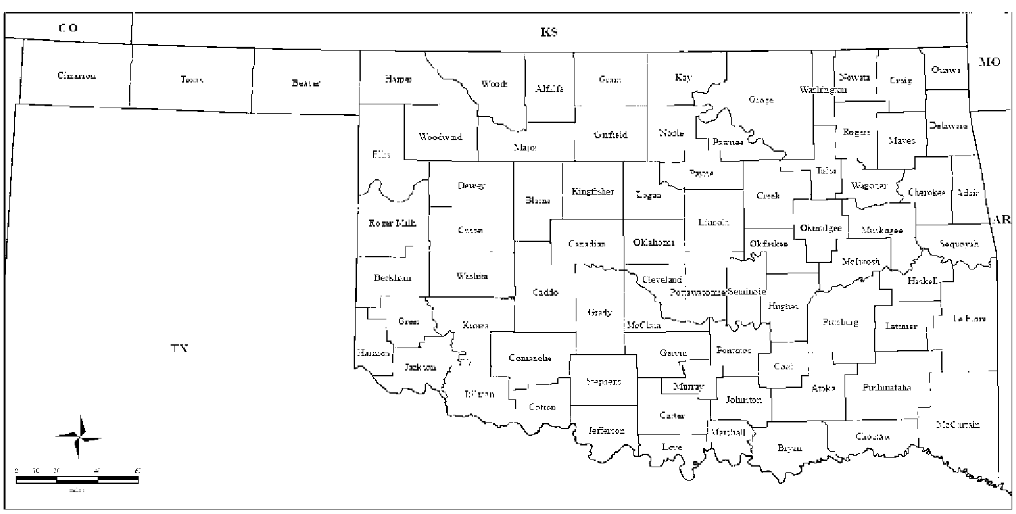
The fourteen counties included in the FEMA Disaster Area 1452, as defined by the Federal Emergency Management Agency, for the Ice Storm of December 3, 2002 (map courtesy of FEMA).

December 18-20, 2006, and December 28-29, 2006 (Sperry-Piltz Level 5): This event was actually a combination of two separate winter storms that struck the Oklahoma Panhandle over the year's final two weeks. These storms occurred in the state's most sparsely populated region, but the damage they did was still quite significant. The first storm struck on the 19th and 20th with moderate freezing rain across the western half of the Panhandle. Up to an inch of ice accumulation was noted in Guymon by the 20th with heavy tree damage and widespread power outages. Peak power outages topped out at about 10,000 customers. The Texas County towns of Guymon and Goodwell were hardest hit by the ice storm. Areas to the west received about one-half of an inch of ice, in general. Two-to-four inches of snow fell following the ice, complicating repair efforts. Those efforts were barely finished when a more powerful storm hit the area December 28-30. Heavy snow and high winds created blizzard conditions in the western Panhandle, where drifts were measured up to 20 feet high. Those winds, which gusted up to 55 mph, combined with ice thicknesses of 1.5 inches to produce widespread damage to power utility equipment once again in Texas County. Sustained winds were measured at 40 mph. About 700 power poles were lost in this second storm. More than 20,000 customers were without power at the storm's peak. In all, the two storms caused well over $2 million in damage to power utilities.



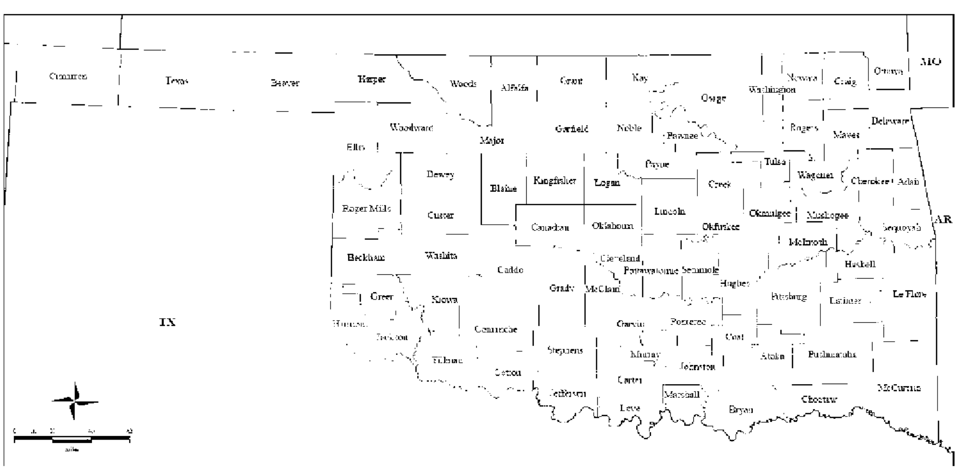
The three Panhandle counties included in the FEMA Disaster Area 1677, as defined by the Federal Emergency Management Agency, for the Ice Storms of December 2006 (map courtesy of FEMA).

January 12-15, 2007 (Sperry-Piltz Level 5): This storm caused catastrophic damage to the power systems in the eastern one-third Oklahoma, where ice accumulations were more than three inches in localized areas. Thirty-two deaths were linked to this storm: 19 perished in traffic accidents, eight succumbed to hypothermia, and three died due to accidental falls on the ice. Points northwest avoided widespread damage since most of the precipitation fell as snow and sleet. An arctic cold front moved into northeastern Oklahoma during the late evening hours of the 11th and had finally passed through the southeastern portion of the state by the evening of the 12th. A strong upper level low pressure system moved into the southern Rockies and several disturbances translated across the Southern Plains bringing periods of heavy sleet and freezing rain to the region. The initial precipitation began around daybreak on the 12th and the final round occurred on the 14th. |A devastating swath of one to three inch ice amounts fell in an estimated 60 to 80 mile wide band from roughly Atoka to McAlester to Muskogee to Grove. An estimated 120,000 electric customers were without power due to downed power poles and power lines within this swath, some of which were without power for more than two weeks. A total of 15,000 customers from McAlester alone lost power. The worst damage to the public infrastructure from the storm in eastern Oklahoma occurred in Muskogee County ($10.5 million), Pittsburg County ($7.5 million), McIntosh County ($6 million), Haskell County ($5 million), Delaware County ($3 million), Wagoner County ($2 million), Mayes County ($1.5 million), and Cherokee County ($1 million).



Counties included in the FEMA Disaster Area 1678, as defined by the Federal Emergency Management Agency, for the Ice Storm of January 12-15, 2007 (map courtesy of FEMA). Some counties were included for other than ice storm damage.

December 8-11 (Sperry-Piltz Level 5): A devastating ice storm affected a large swath of Oklahoma beginning on the 9th and continuing through the 11th over parts of the area. The storm left behind a trail of severe damage to trees and power lines, which in turn led to the worst power outage in Oklahoma history (in terms of the number of people impacted). This was because the worst of the ice storm affected the urban corridor from near Lawton, to Oklahoma City, to Tulsa, and northeast into Missouri. The storm began with a strong cold front that moved through the northern half of Oklahoma on the 8th, and then moved south through the rest of the state during the day on the 9th. South of the front, an almost tropical airmass was in place with temperatures in the 60s and 70s. Showers and thunderstorms were ongoing over central and southwest Oklahoma early on the 9th, but were developing and moving above a layer of freezing air at the surface. However, as the cold front moved south, the cold air undercut the thunderstorms, which became the start of many waves of freezing showers and thunderstorms. The very moist airmass south of the front continued to move over top of the shallow cold airmass through 11th. This classic setup created one of the most costly ice storms in Oklahoma history. By the time the storm had ended, over one inch of ice had accumulated over a good portion of Oklahoma. At least 27 deaths were reported statewide, mainly due to hundreds of automobile accidents, although some were due to prolonged cold air exposure or carbon monoxide poisoning. Tree, power line and power pole damage was widespread statewide, which resulted in hundreds of thousands without power. At the peak of the event, more than 641,000 electric customers were without power, amounting to over one million people. Even with a huge relief effort, more than 150,000 residents were still without power one week later. Fallen power lines created another hazard as the broken lines sparked structure fires. Fire departments responded to over 100 structure fires in all. The local economy took a huge hit as the ice storm hit during a key weekend for holiday sales. The pecan crop loss alone was estimated at $25 million statewide. Shelters were opened across the state for people who did not have electricity, which many took advantage of. The storm cleanup was estimated to cost at least $200 million statewide. Cities were expected to remove over 750,000 cubic yards of debris. – NCDC Storm Event Database



Counties included in the FEMA Disaster Area 1735, as defined by the Federal Emergency Management Agency, for the Ice Storm of January 12-15, 2007 (map courtesy of FEMA).

Historical Oklahoma Ice Storms

- **January 1, 1993:** An upper-level storm system brought sleet and freezing rain to much of Oklahoma. Surface air temperatures were well below freezing so roads quickly became ice covered and dangerous. Roads remained ice covered until temperatures rose above freezing late in the morning on the 2nd. Numerous traffic accidents occurred and a few power outages were reported. In Oklahoma City, a 35-car pileup occurred around 2 a.m. on the 1st. A man was killed just west of Guymon when he lost control of his pickup and it collided with another vehicle. Near Durant, a woman lost her life when her vehicle slid off the road and hit a tree. Another woman lost her life in Oklahoma City when the car she was riding it hit a semi-trailer. The car was then hit by another vehicle and burst into flames. In Pontotoc County, a man died after his car slid off the road and hit a tree. The storm also caused problems for those flying as two 737s slid off icy runways at Will Rogers Airport. Many other flights were either delayed or canceled. – NCDC Storm Event Database

- **December 1987:** A large snow and ice storm caused more than $10 million in damages across the northwestern two-thirds of the state. About 114,000 customers were left without power and tree damage was severe. All flights to and from Will Rogers World Airport in Oklahoma City were cancelled, and several large broadcast antennas collapsed.

- **December 1937:** A significant ice storm struck southeastern and eastern Oklahoma, a mere 30 years after statehood in December of 1937. Considerable damage was done to trees, shrubs, and electric, telephone, and telegraph wires. Damages were totaled at a then-substantial $250,000. One elderly Muskogee resident claimed of the storm: "Seems like that one lasted a month."

SOURCES

1) Archived data from the Oklahoma Mesonet
2) Archived NWS cooperative observations from the Oklahoma Climatological Survey
3) The archives of The Daily Oklahoman, (1901-Current)
4) The archives of The Tulsa World (1989-Current)
5) The National Climate Data Center's (NCDC) Storm Events Database
6) The Federal Emergency Management Agency (FEMA)
7) The National Weather Service (NWS) Forecast Office in Norman, Oklahoma
8) The NWS Forecast Office in Tulsa, Oklahoma
9) The NWS Forecast Office in Amarillo, Oklahoma
10) Sid Sperry, Director of Public Relations & Communications, Oklahoma Association of Electric Cooperatives (OAEC)
11) Steve Piltz, Meteorologist-in-Charge (MIC), NWSFO, Tulsa, Oklahoma

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Changnon, S., and T. Karl, 2003: Temporal and Spatial Variations of Freezing Rain in the Contiguous United States: 1948–2000. *J. Appl. Meteo.,* 42, 1302–1315.

IPCC, 2007*: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Appendix C: Oklahoma Climatological Survey,

Oklahoma's Tornado Threat

A report prepared for the Oklahoma Corporation Commission

By

The Oklahoma Climatological Survey

April 24, 2008

Oklahoma's distinction as the epicenter of Tornado Alley is well deserved, a result of the sheer number of tornadoes it has experienced. This dubious honor has been punctuated by the lost lives and damaged property from the violently rotating columns of air, seemingly so common in the state. Oklahoma has experienced 839 "significant" tornadoes – rated at least F2 on the Fujita Scale – since 1950, the beginning-point of accurate tornado statistics.

The Fujita Scale of tornado Intensity. The Fujita Scale is used to rate the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure. A new "Enhanced Fujita Scale" was implemented in February 2007 to better reflect damage indicators.

F-Scale Number	Wind Speed (mph)	Typical Damage
F0	40-72	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	73-112	Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	113-157	Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	158-206	Roof and some walls torn off well constructed houses; trains overturned; most trees uprooted
F4	207-260	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
[illegible]	[illegible]	[illegible] and carried considerable distances to disintegrate; [illegible] air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.

The state's tornado statistics (1950-2007) are staggering:

- 3078 tornadoes
- An average of 54 tornadoes per year
- An average of 14 significant tornadoes per year
- 274 dead and 4267 injured
- Over $3 billion in damage

Tornadoes have a minimal effect on the power industry in general, save for large outbreaks and the most intense singular – or violent (F4-F5) – tornadoes. The "footprint" – or area affected – of tornado damage is much smaller than that of ice storms. Arguably the worst tornado outbreak in the state's recorded history struck the Oklahoma metropolitan area on May 3, 1999. In that storm, 145,000 customers lost power. Therefore, it is violent tornadoes or large outbreaks that are of most concern. Outbreaks of that magnitude are exceedingly rare, however. Violent tornadoes like those that populated the May 3 outbreak account for only one percent of all tornado reports across the country. Of Oklahoma's 3078 tornadoes since 1950, only 55 have been of violent intensity.

Patterns

Tornado counts for a specific area, such as a county, are affected by several factors, including: size of the area, population base, and location. Some counties in Oklahoma have counts that reflect those factors quite well, as shown in **Figure 1**. Oklahoma and Tulsa counties both have high counts with 92 and 69 reported tornadoes, respectively. Caddo and Osage Counties, both very large areas, have high counts as well, at 96 (the state's highest) and 69, respectively. Anomalies do exist, however. Kay County, neither large nor overly populous, has the state's third greatest total with 88 tornadoes.

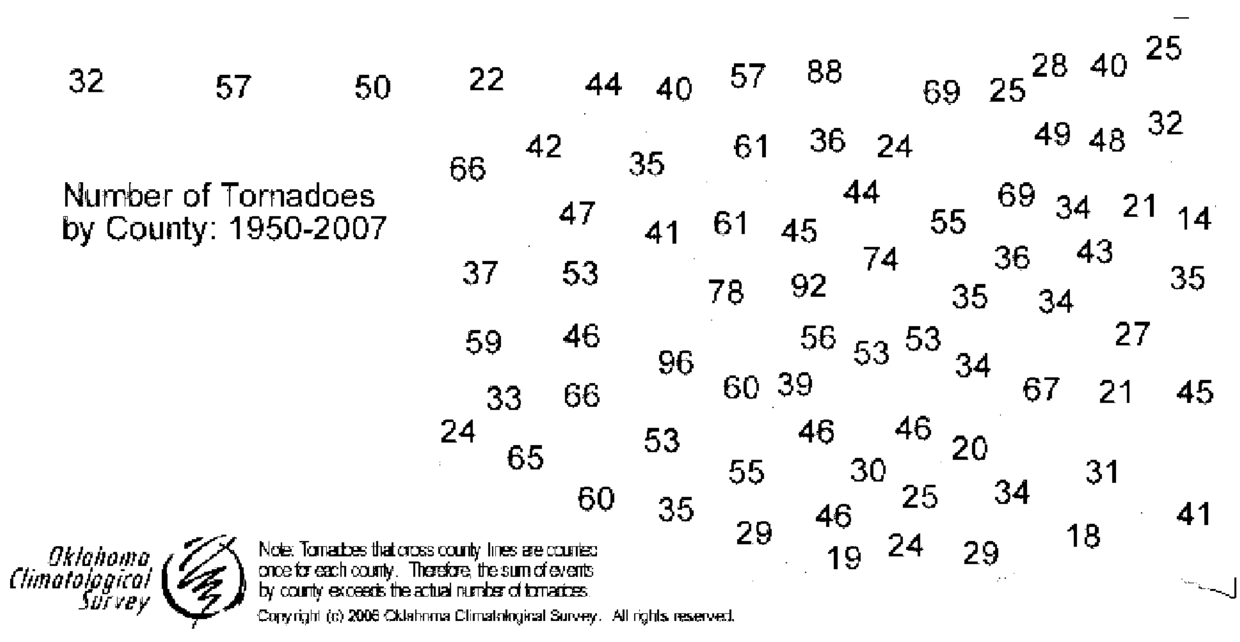

Figure 1. The number of Oklahoma tornadoes by county, 1950-2007. Tornadoes that cross county lines count once for each county they pass through.

Trends

While the total number of tornadoes per year has held steady **(Figure 2)**, the more important statistical trend, that of significant tornadoes, has been decidedly downward **(Figure 3)**. The reason for this decrease is not necessarily due to a change in atmospheric conditions, but possibly a by-product of the method used by the National Weather Service (NWS) to determine a tornado's strength. The NWS did not implement the Fujita Scale as a classification scale until 1973, so classifications of tornadoes, which occurred during the 1950s and 1960s after the fact required the use of fading recollections and accounts of tornadic damage.

Conclusion

The tornado statistics for Oklahoma indicate that the most serious threat from tornadoes to the electrical power industry is overwhelmingly due to violent tornadoes or large outbreaks. Tornado events of this nature are exceedingly rare, however. While the number of reported tornadoes has been fairly steady recently, the number of significant tornadoes reported has decreased. Because tornadoes are random, every county in Oklahoma is at risk and there is a high probability of future tornadoes occurring. Little is known about the effects of climate change upon tornadoes, so future risks should be considered equivalent to current threat levels.

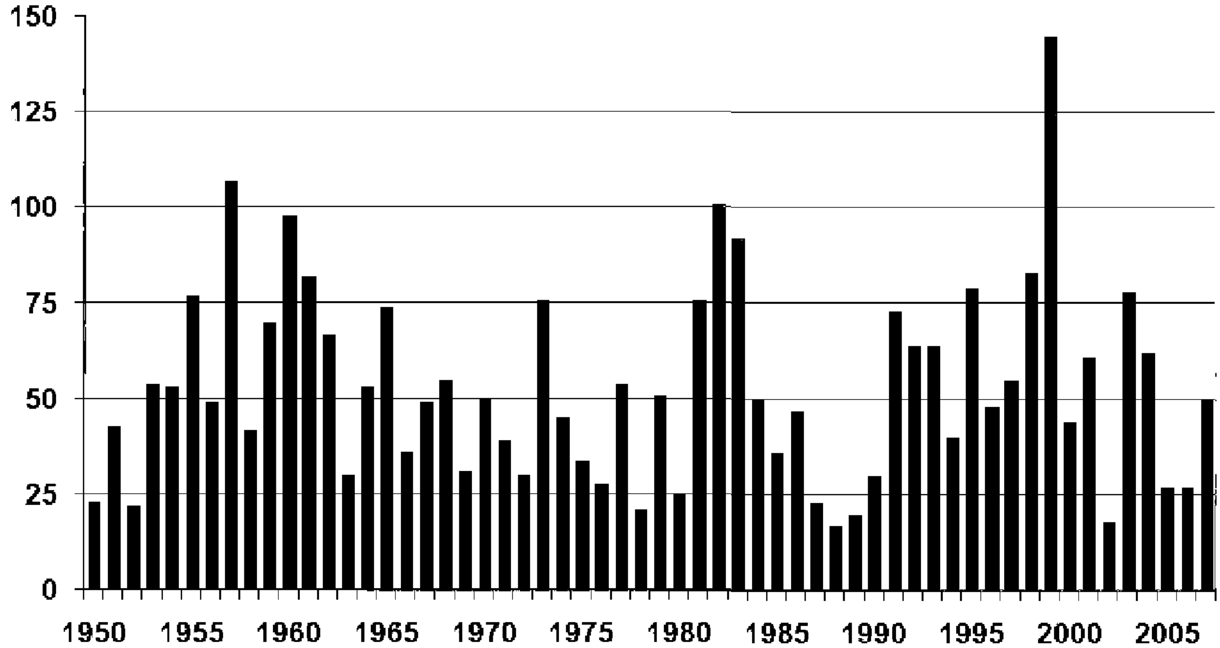

Figure 2. Oklahoma tornado reports by year, 1950-2007.

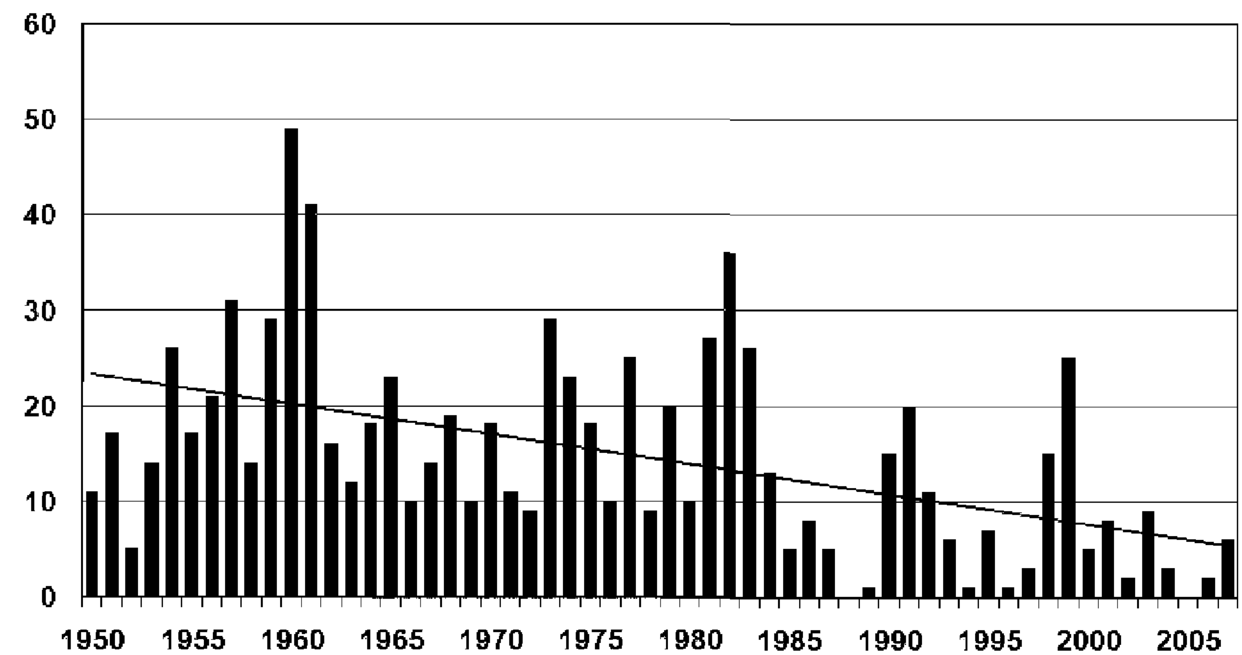

Figure 3. Oklahoma significant tornado reports by year, 1950-2007. A significant tornado is one that is rated at least an F2 on the Fujita Scale.