NARUC Winter Policy Summit

Staff Electricity Subcommittee

NARUC Winter Policy Summit

Staff Subcommittee on Electricity/Reliability

Distribution Poles and Lines – How Strong is Strong Enough?

Moderator	*Speaker*
Ryan Laruwe **Michigan Public Service Commission**	**Nelson G. Bingel, III** **Chairman - NESC**

EPRI – Electric Power Research Institute

- **First Distribution Grid Resiliency Project (3 years)**
  - Xcel conducted pole drop testing to evaluate:
    - Fiberglass crossarms
    - New arms on old poles
    - Pole top pins (bolt and lag)
    - Wire sizes (#6, #2, 1/0)
  - AEP Tappan Lake Distribution Line Testing
- **Second Distribution Grid Resiliency Project (in year 2)**
  - Testing at EPRI Lenox site using poles to simulate trees falling
    - 60 ft class 2 pole dropping the butt on the wires

AEP Tappan Lake, Ohio Testing

Lessons Learned

- Hard to predict what is going to fail on existing construction
- Working to learn how to design failure points that minimize time and cost of restoration
- Insulator ties tend to be too strong
  - Hand ties or pre-formed ties hold much stronger than necessary
  - A new Hendrix clamp style insulator has ceramic jaw inserts that allow the wire to slip
    - Also has a nylon head that shears off when the tension is right
- Spacer cable messenger is stronger than desired

Lessons Learned

- AEP distribution standards
  - Medium loading district is inadequate
    - Use Heavy within the Medium District
  - Only use Heavy or Light loading criteria
  - Reduce allowable pole strength by 25% in trying to make it the strongest component
  - Within 5 miles of a coastal region
    - Use 150 mph with Load and Strength Factors of 1 at the coast
    - Step wind back to 130 mph and 120 mph as move inland

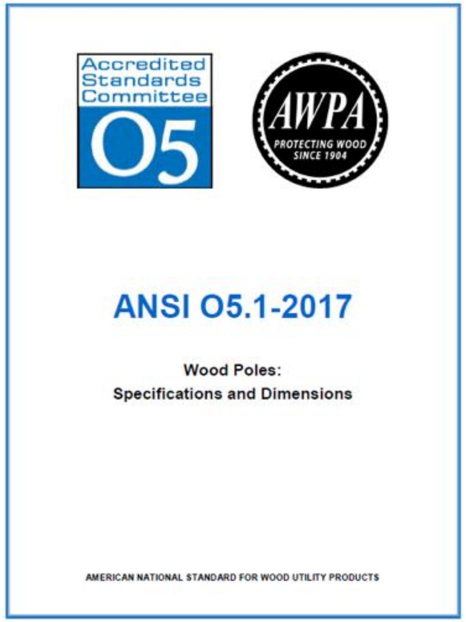
System Performance

- **Safety**
  - Systems built to NESC criteria are considered to have adequate safety
- **Reliability** (electrical)
  - Indices measure the number, frequency, duration, etc. of outages *(without major storms)*
- **Resiliency**
  - How well a system withstands a major storm to minimize service interruptions
  - How quickly service is restored

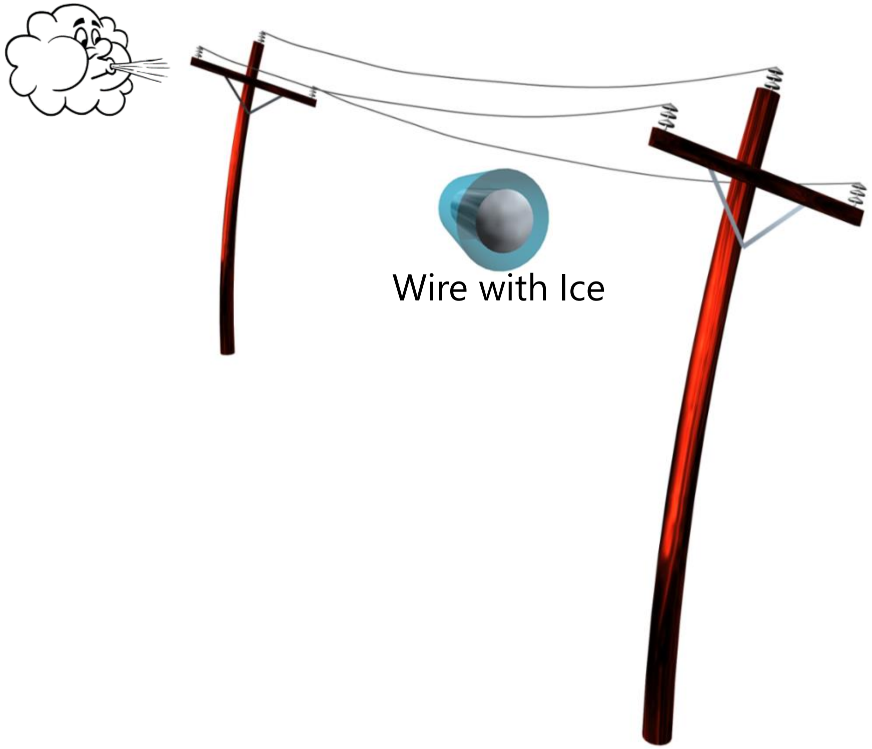
System Performance

- **System Resiliency depends on many factors**
  - Smart grid communication
  - Sectionalizing
  - Redundancy
  - Preparedness
  - Mutual assistance agreements
  - ……….
  - **Structural resiliency**
  - ……….

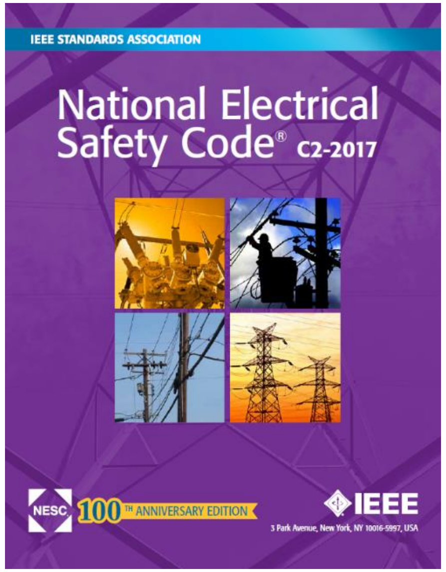
Design for Bending Loads



Strength

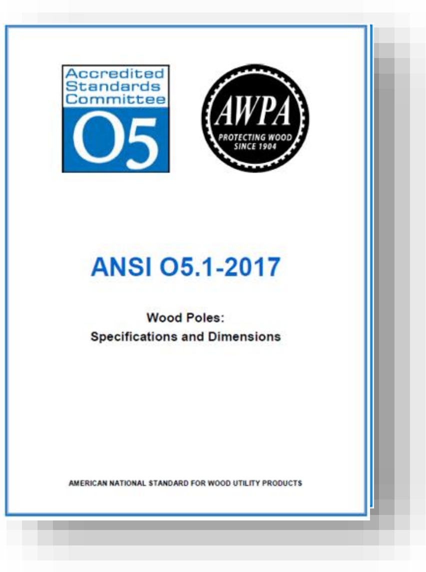


Load



Bending Capacity > **Bending Load**

Class Loads


Accredited Standards Committee O5

AWPA PROTECTING WOOD SINCE 1904

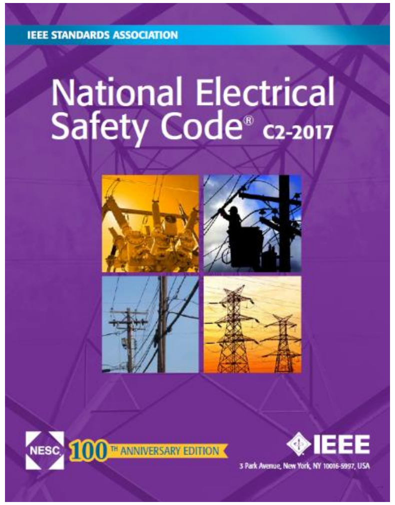
ANSI O5.1-2017

Wood Poles:
Specifications and Dimensions

AMERICAN NATIONAL STANDARD FOR WOOD UTILITY PRODUCTS

Class	Horizontal Load (lb)	
10	370	Telco
9	740	
7	1,200	
6	1,500	
5	1,900	Distribution
4	2,400	
3	3,000	
2	3,700	
1	4,500	Transmission
H1	5,400	
H2	6,400	
H3	7,500	
H4	8,700	
H5	10,000	
H6	11,400	

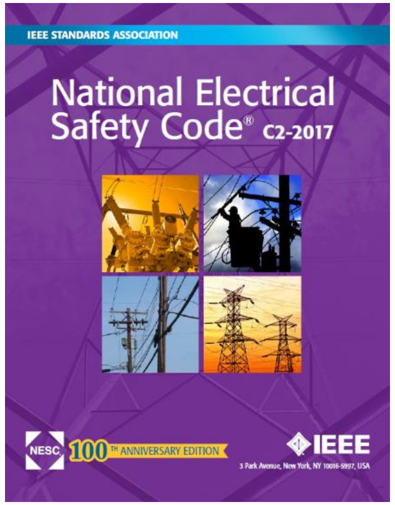
National Electrical Safety Code



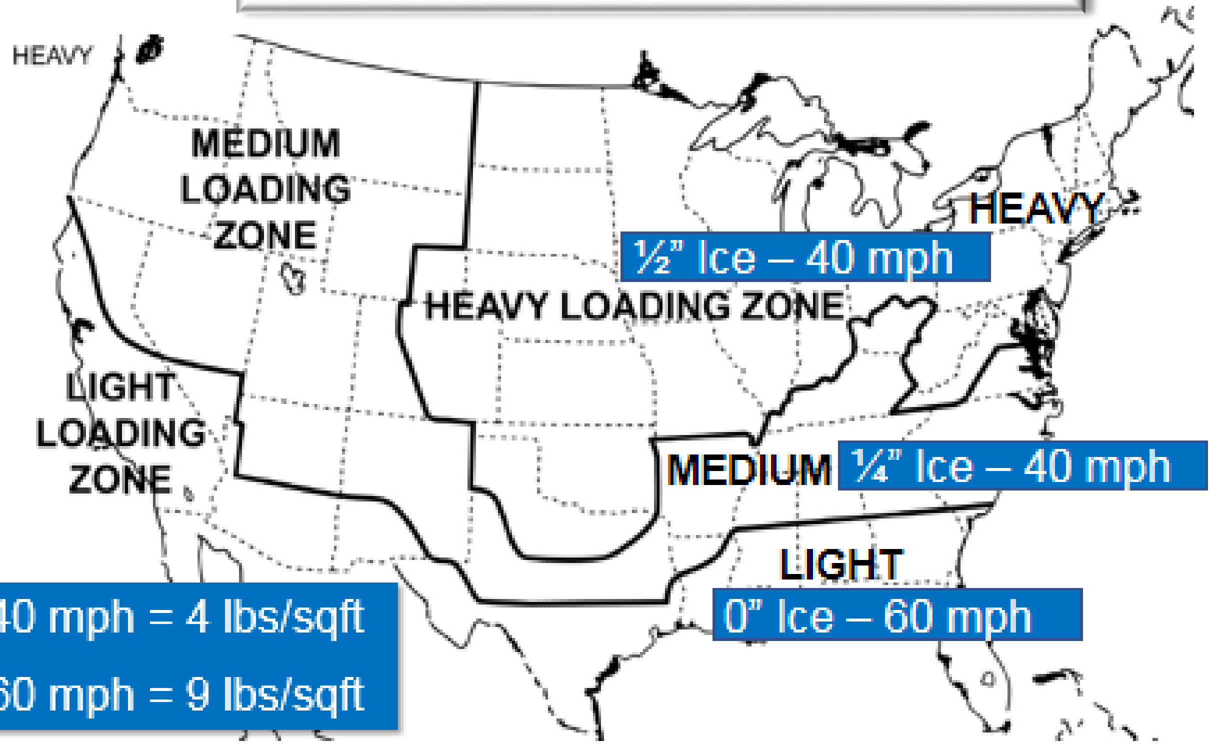
- **Provides construction criteria**
  – for Overhead & Underground lines
    - Wind
    - Ice
    - Grade of Construction
    - Strength Factors
    - Load Factors
    - Clearances
    - Grounding
- The NESC is not a complete "How To" design guide

Initial Structural Resiliency depends on:

Loading District & Grade of Construction



NESC Loading Districts



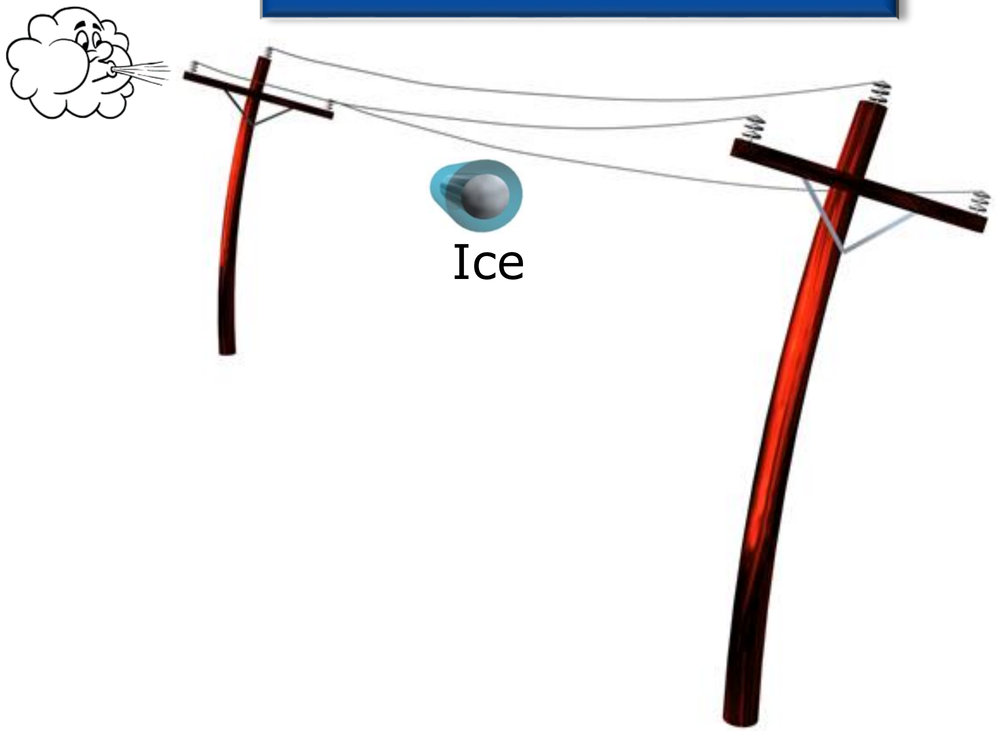
40 mph = 4 lbs/sqft

60 mph = 9 lbs/sqft

Initial Structural Resiliency depends on:

Loading District & Grade of Construction

District Ice & Wind



NESC Grade of Construction

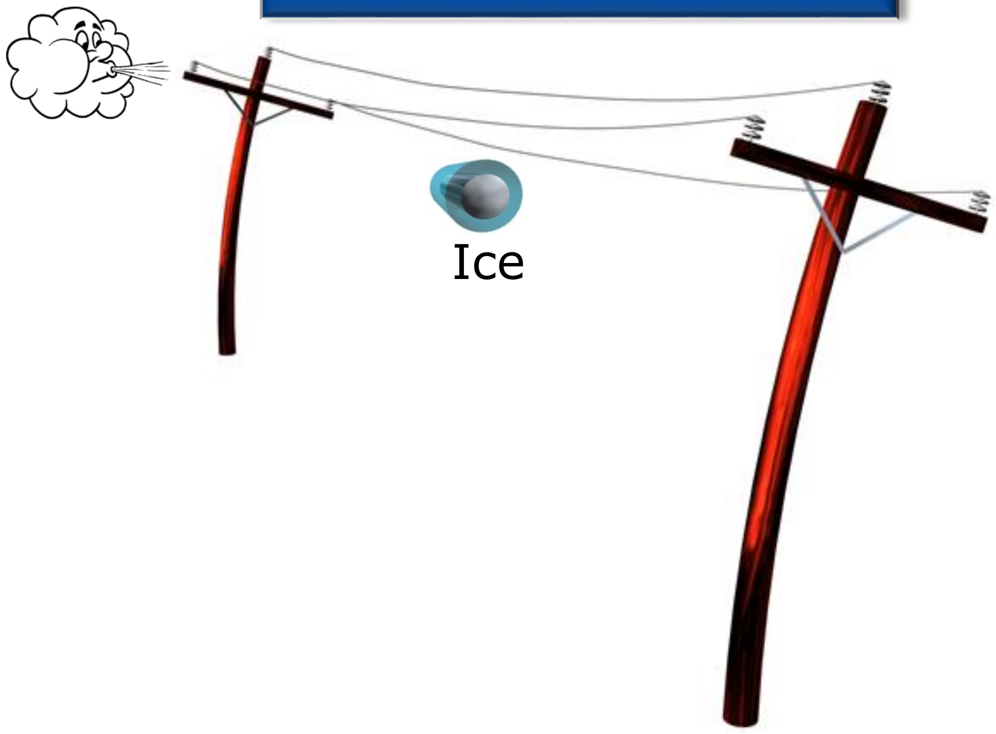
Grade C: District Load x **2.06**

Example Pole: Class 5 (**1900** lb tip load)

Initial Structural Resiliency depends on:

Loading District & Grade of Construction

District Ice & Wind



NESC Grade of Construction

Grade C: District Load x **2.06**

Example Pole: Class 5 (**1900** lb tip load)

Grade B: District Load x **3.85**

Example Pole: Class 2 (**3700** lb tip load)

Initial Structural Resiliency depends on:

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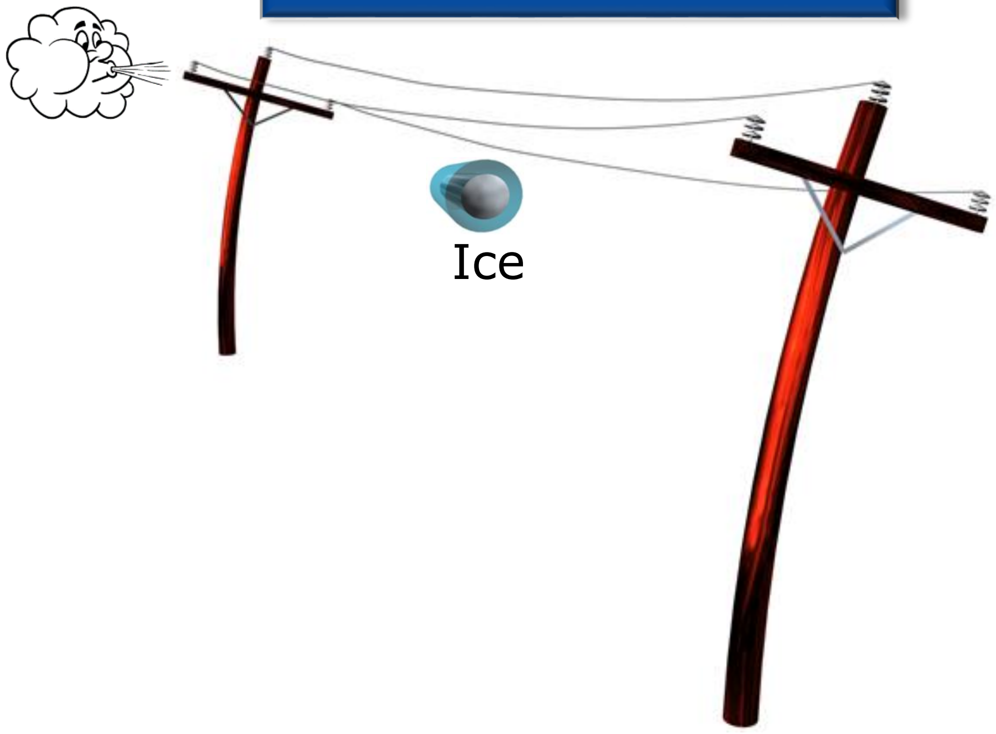


NESC Grade of Construction

Grade C: District Load x **2.06**

Example Pole: Class 5 (**1900** lb tip load)

Grade B: District Load x **3.85**

Example Pole: Class 2 (**3700** lb tip load)

Not every distribution pole is loaded to 100%

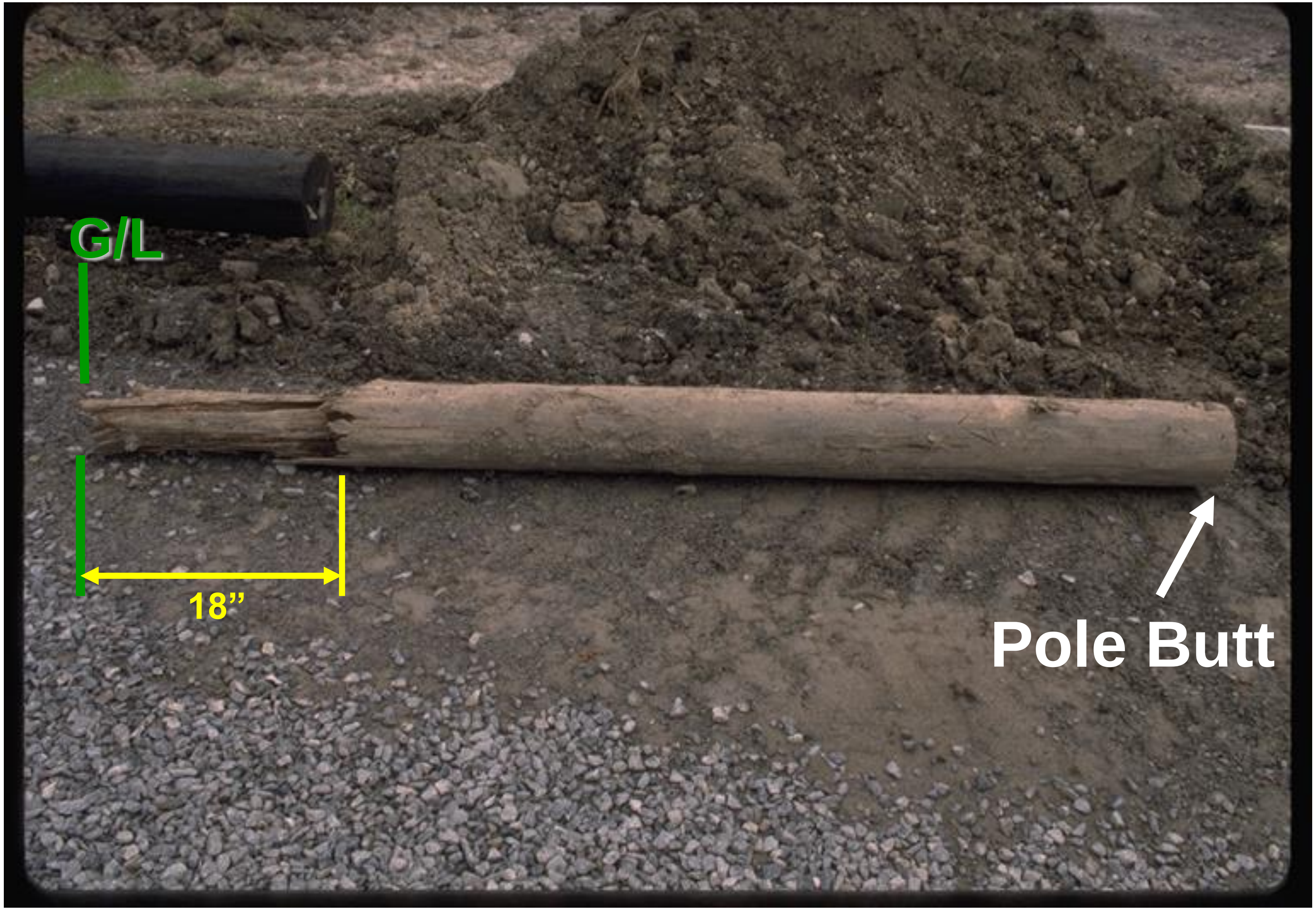
Wood Pole Aging Process

Decayed but Serviceable

Greater than 67% remaining strength

Below Code Required Strength

67% or less


G/L
18”
Pole Butt

Subsequent Structural Resiliency depends on:

Maintenance

Wood Poles may Decay just below Ground
(Out of Sight)

Groundline Decay causes a direct reduction of the Pole Capacity

The Effectiveness of Pole Maintenance Programs Varies Greatly

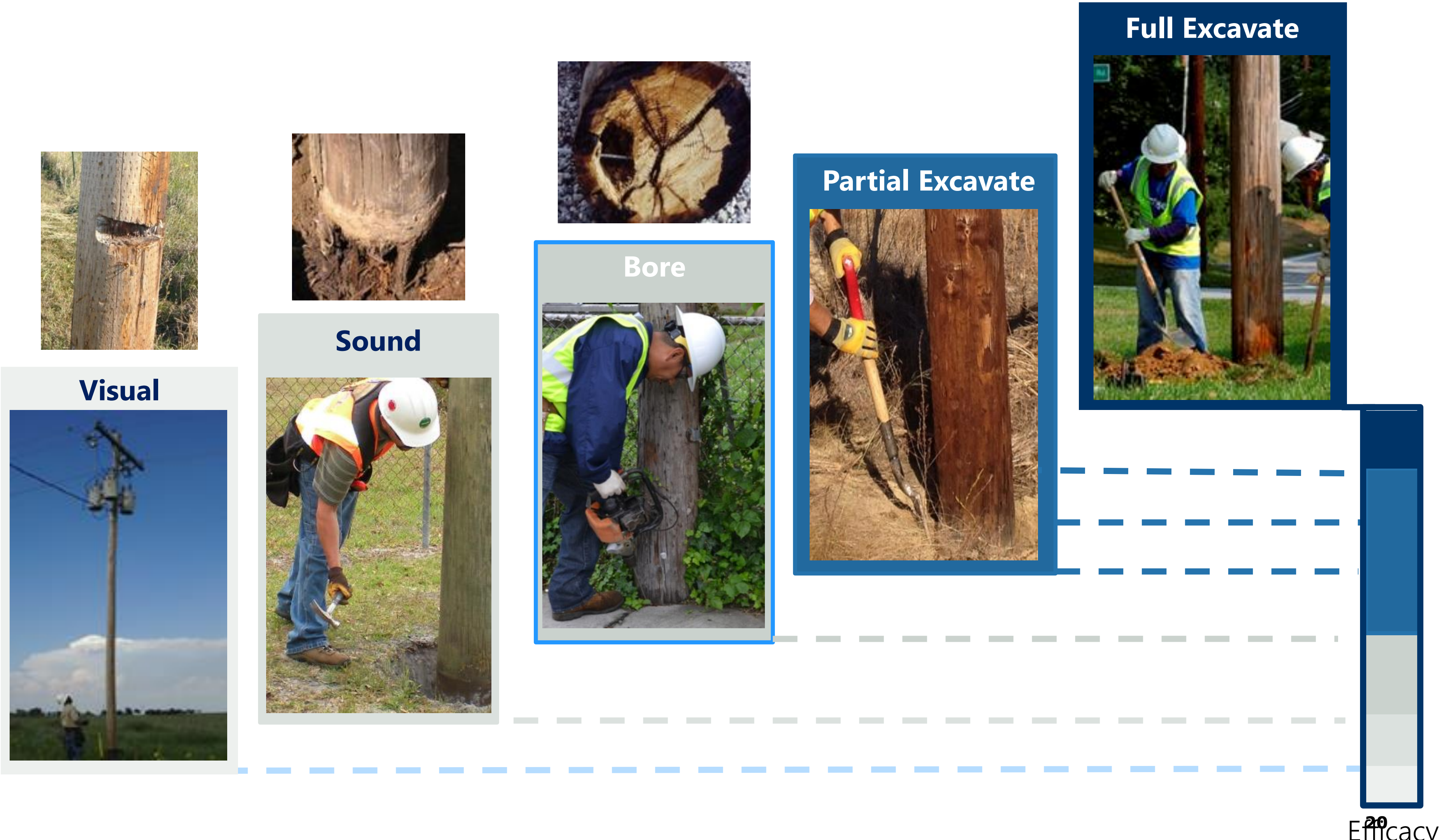
From

Finding a Small Portion of the Poles Below Code Strength

To

Finding 98% of all Decayed Poles and Extending Pole Service Life

Pole Inspection Techniques



Pole Inspection Techniques

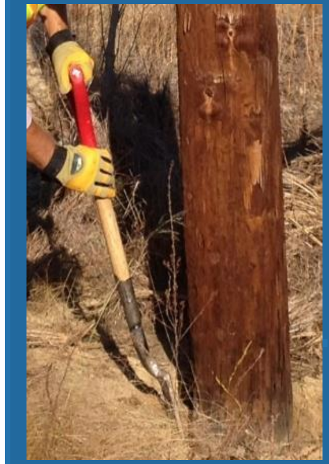
Remove Decay

Apply Preservatives

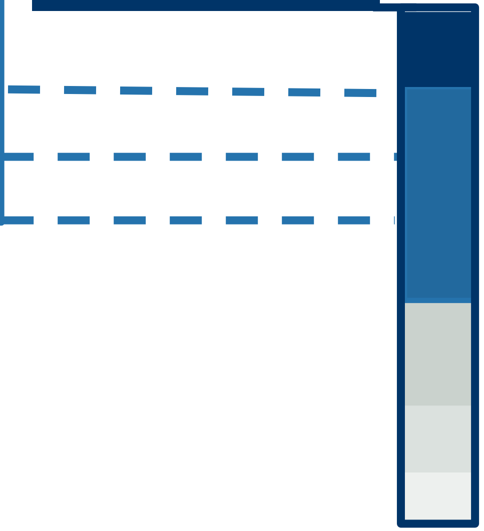
O&M

CapEx

Partial Excavate



Full Excavate



Efficacy

Pole Conditions

No Decay

Decayed but Serviceable

> 67% remaining strength

Below Code Required Strength

67% or less

The Effectiveness of Pole Maintenance Programs Varies Greatly

From

Finding a Small Portion of the Poles Below Code Strength

To

Finding 98% of all Decayed Poles and Extending Pole Service Life

Evaluate Wood Pole Management Programs

North American Wood Pole Council – Mobile App

WOODPOLES.ORG

Decay Zone	Factor
Decay Zone 1	
Decay Zone 2	
Decay Zone 3	
Decay Zone 4	
Decay Zone 5	

Species	Factor
Southern Pine	
Douglas Fir	
Red Cedar	
Lodge Pole	
Western Pine	
Northern Pine	

Inspection Types	Factor
None	
Visual	
Sound & Bore	
Pull-back excavation	
Partial excavation	
Full excavation	

Preservative Treatment	Factor
External Paste	
Liquid Void Treatment	
Fumigant	
Solid Rods	
None	

Maintenance Cycle	Factor
None	
8 Years	
10 Years	
12 Years	
> 12 Years	

Evaluate Wood Pole Management Programs

North American Wood Pole Council – Mobile App

WOODPOLES.ORG

G/L Restoration	Factor
Yes	
Limited	
No	

Capitalization	Factor
Preservative Treatment	
Pole Restoration	
None	

Avg System Age	Factor
20-25	
26-30	
31-35	
36-40	
41-45	
46-50	
51-55	
56-60	

% Poles Replaced Annually	Expected Pole Life
0.1%	1,000
0.2%	500
0.4%	250
0.6%	167
0.8%	125
1.0%	100
1.5%	75
2.0%	50

8,000 poles per year replaced
1,000,000 poles total
= 0.8% = 125 year expected life

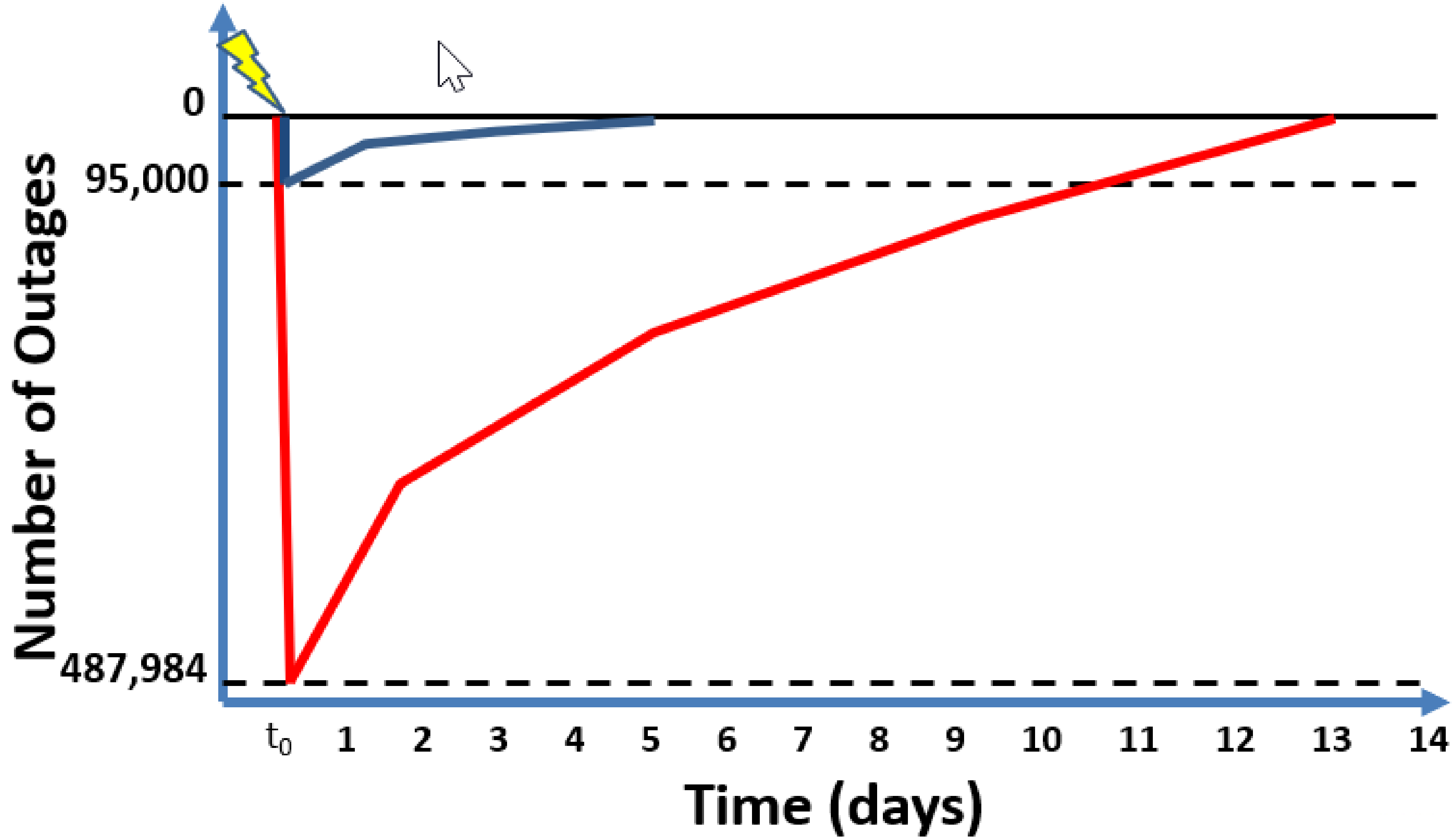
Structural Resiliency in Major Weather Events

Neighboring Utilities Impacted by the Same Hurricane

	Utility "A"	Utility "B"	
Pole Inspection Reject Accuracy	98%	30%	
	Actual Numbers	Factored Numbers	
Wood poles replaced	152	2,790*	18x
Number of Peak Outages	95,000	487,984*	5x
Cost of Restoration	$20 M	$310 M*	16x
Time of Restoration	100% in 5 days	100% in 13 days	

* Factored for having 60% more poles

Utility A and B Graphically Showing Resiliency



4G and 5G Small Cells on Wood Poles

Resiliency of the wood pole plant is critical for both:

ELECTRICITY AND WIRELESS TELECOMMUNICATIONS

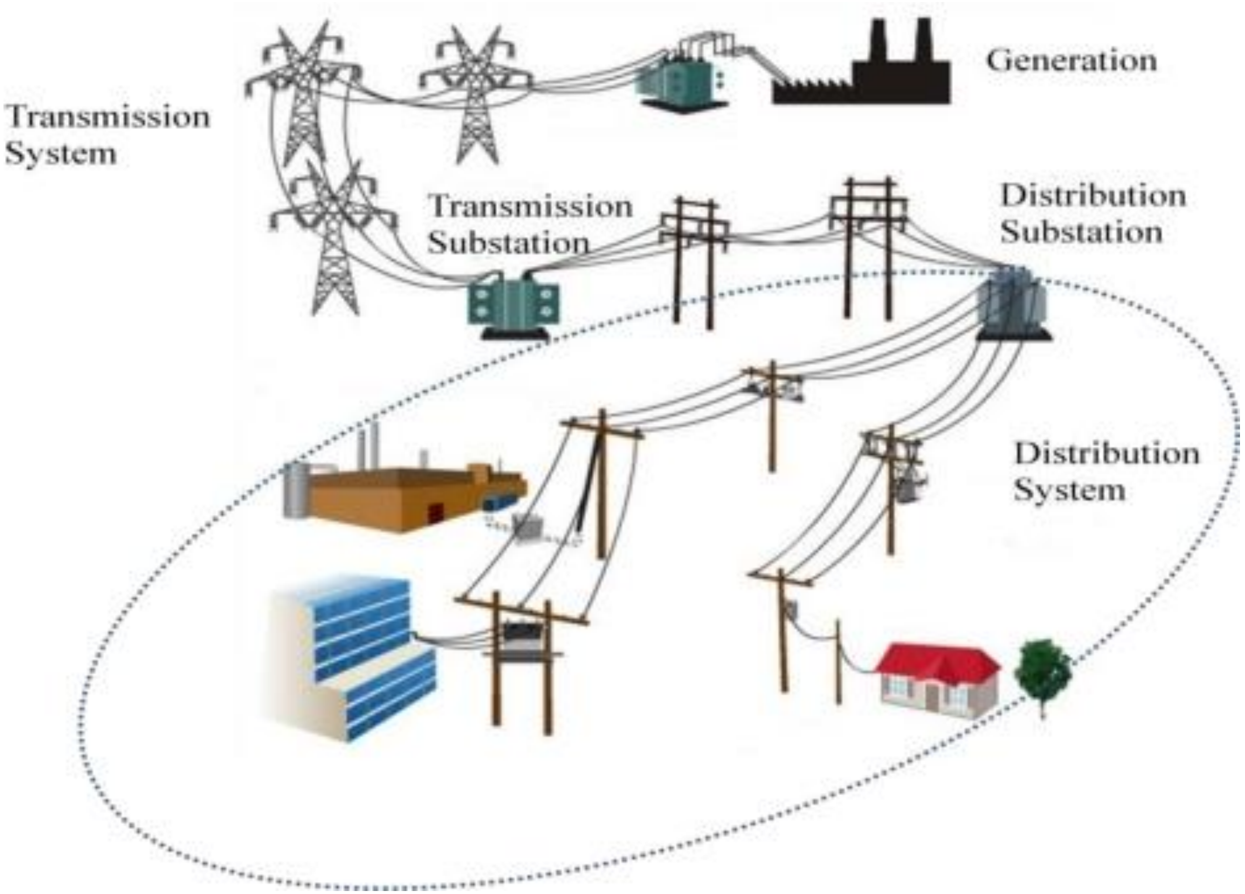
Should the NESC mention Resiliency?

- Not mention at all
- Make reference to extreme storm without mentioning resiliency
- Mention system resiliency and the role of structural resiliency
- …………..

Maintenance in the NESC

-

Electric Supply Stations - Substations



Electric Supply Stations - Substations

Section 12.
Installation and maintenance of equipment

120. General requirements

A. All electric equipment shall be constructed, installed, and maintained so as to safeguard personnel as far as practical.

B. The rules of this section are applicable to both ac and dc supply stations.

121. Inspections

A. In-service equipment

Electric equipment shall be inspected and maintained at such intervals as experience has shown to be necessary. Equipment or wiring found to be defective shall be put in good order or permanently disconnected.

2017 NESC pg 47

Electric Supply Stations - Substations

120 Part 1: Safety Rules for Electric Supply Stations 123A

Section 12.
Installation and maintenance of equipment

121. Inspections

A. In-service equipment

Electric equipment shall be inspected and maintained at such intervals as experience has shown to be necessary. Equipment or wiring found to be defective shall be put to good order or permanently disconnected.

2017 NESC pg 47

Overhead Lines

Section 21.
General requirements

214. Inspection and tests of lines and equipment

A. When in service

1. Initial compliance with rules

   Lines and equipment shall comply with these safety rules when placed in service.

2. Inspection

   Lines and equipment shall be inspected at such intervals as experience has shown to be necessary.

2017 NESC pg 78

Overhead Lines

210 Part 2: Safety Rules for Overhead Lines 214A5a

Section 21.
General requirements

214. Inspection and tests of lines and equipment

A. When in service

2. Inspection
Lines and equipment shall be inspected at such intervals as experience has shown to be necessary.

2017 NESC pg 78

Overhead Lines

Existing 2017 Language

2. Inspection

Lines and equipment shall be inspected at such intervals as experience has shown to be necessary.

Overhead Lines

Existing 2017 Language

2. Inspection

Lines and equipment shall be inspected at such intervals as experience has shown to be necessary.

Example of Proposed 2022 Language

2. Inspection and Maintenance

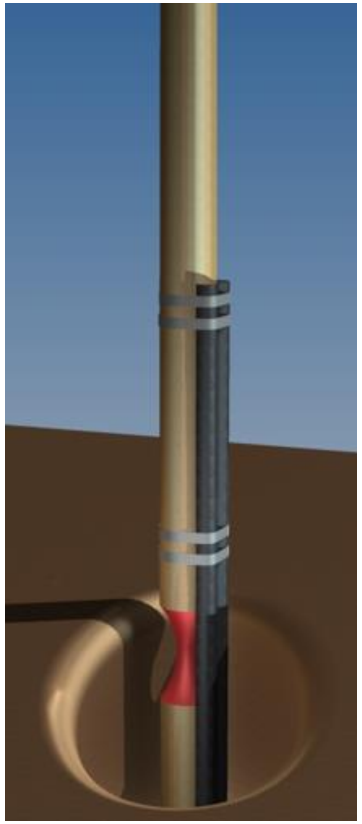
Lines and equipment shall be inspected and maintained to retain the electrical and structural integrity at such intervals that align with industry good practice.

Florida Power & Light

- 2006-2014 Florida Power & Light’s Program
  - 1,200,000 poles Excavated & Inspected
  - Applied preservative treatment
  - Restored 30,000 poles with strength below code
  - Replaced remaining poles below code strength
  - Upgraded 18,000 wood poles to harden lines
  - Replaced some wood poles with concrete or steel poles

Florida Power & Light

- 2006-2014 Florida Power & Light's Program



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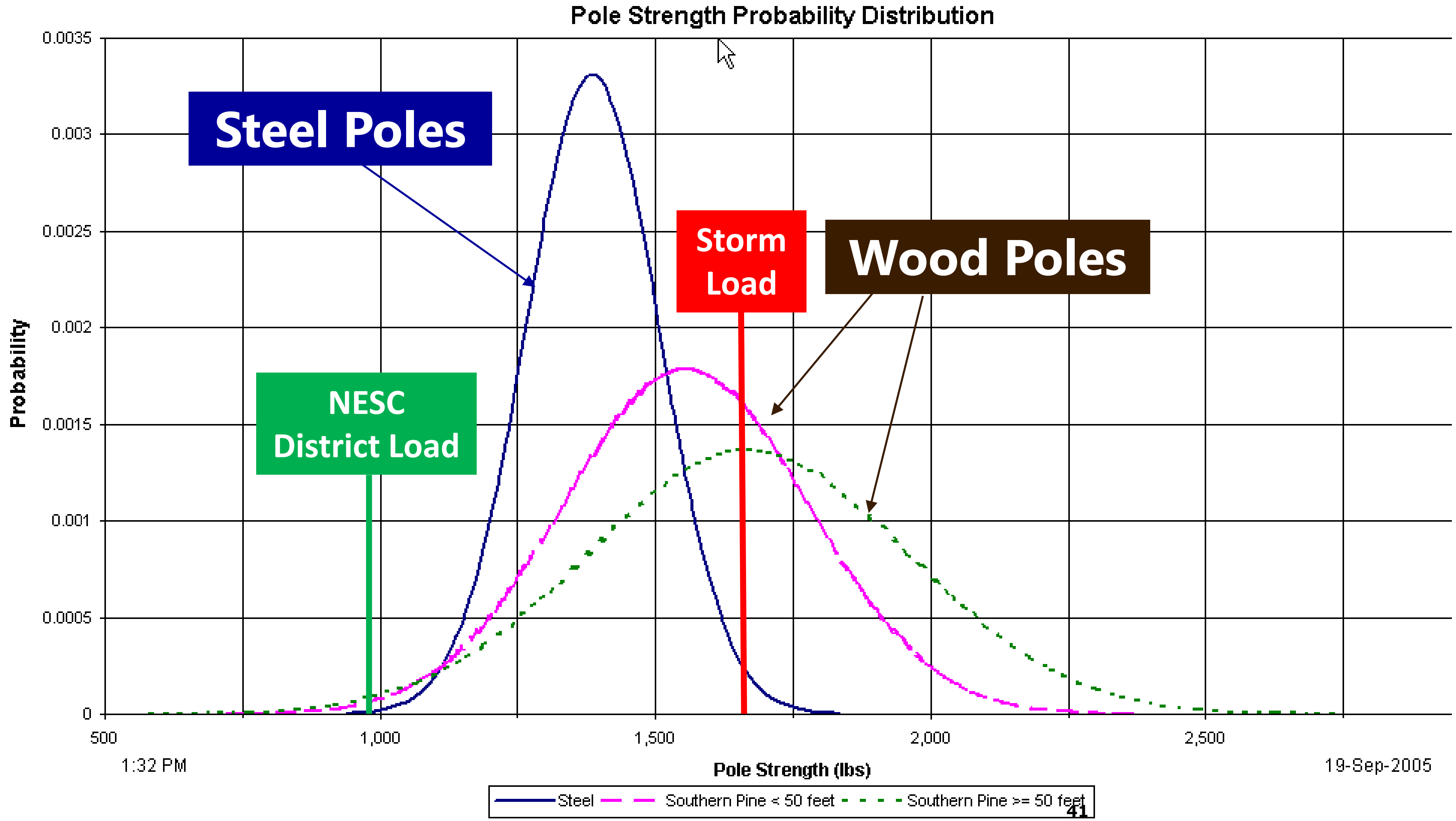
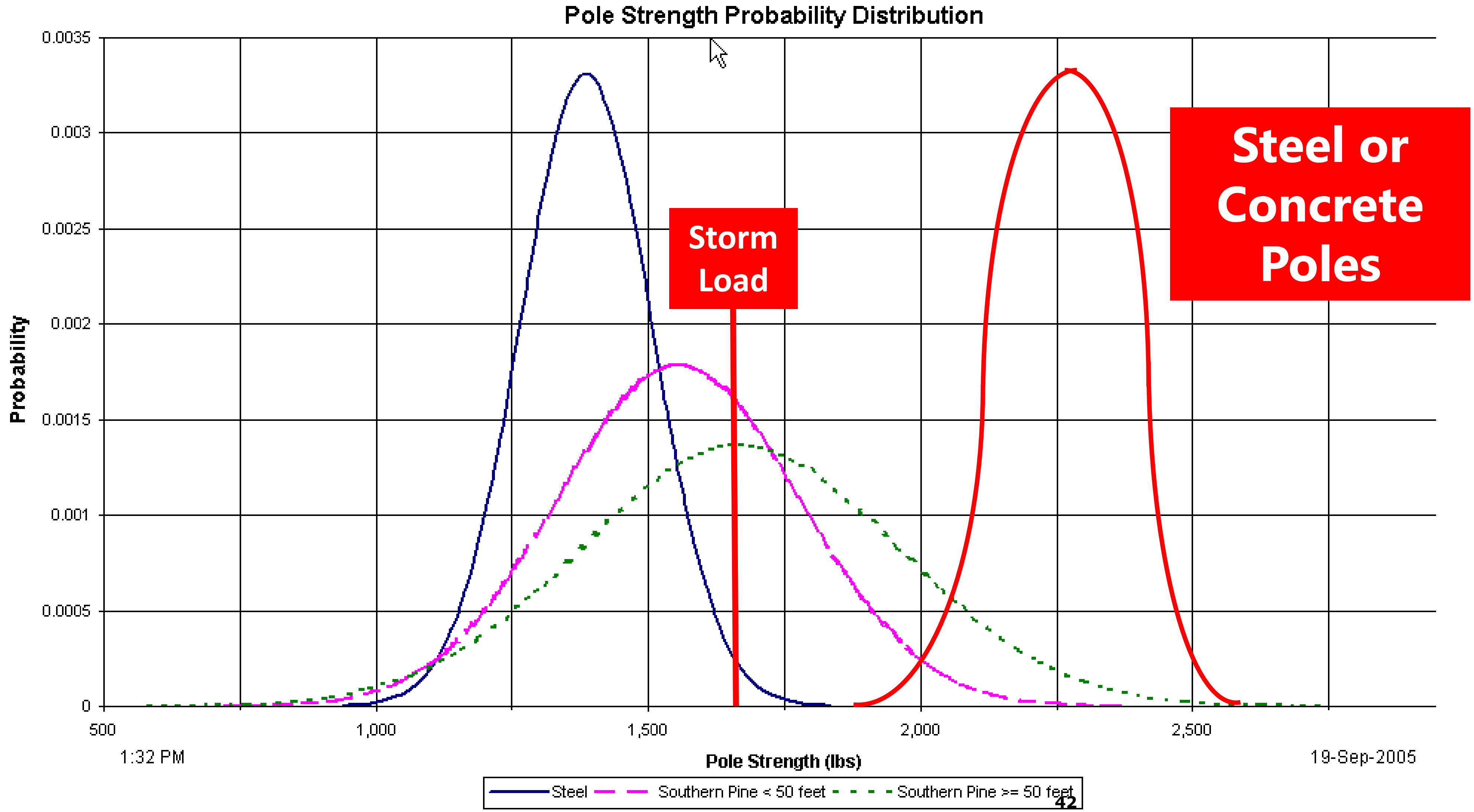
Wood Poles vs Steel and Concrete Poles



Wood Poles vs Steel and Concrete Poles



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Florida Power & Light Territory

Florida Power & Light

2005 – Hurricane Wilma (Cat. 3)

10,000+ wood poles failed

4% of outages were fixed in 1st day

2016 – Hurricane Matthew (Cat. 3)

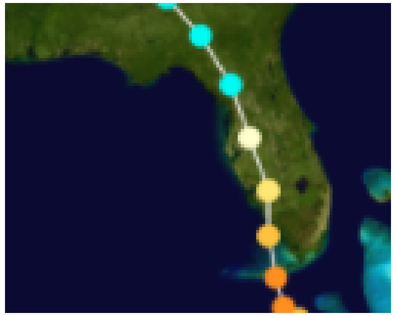
~500 poles failed due to trees, 0 to wind

98.7% restored by end of 2nd day

2017 – Hurricane Irma (Cat. 3)

~1,200 poles failed due to trees, 0 to wind

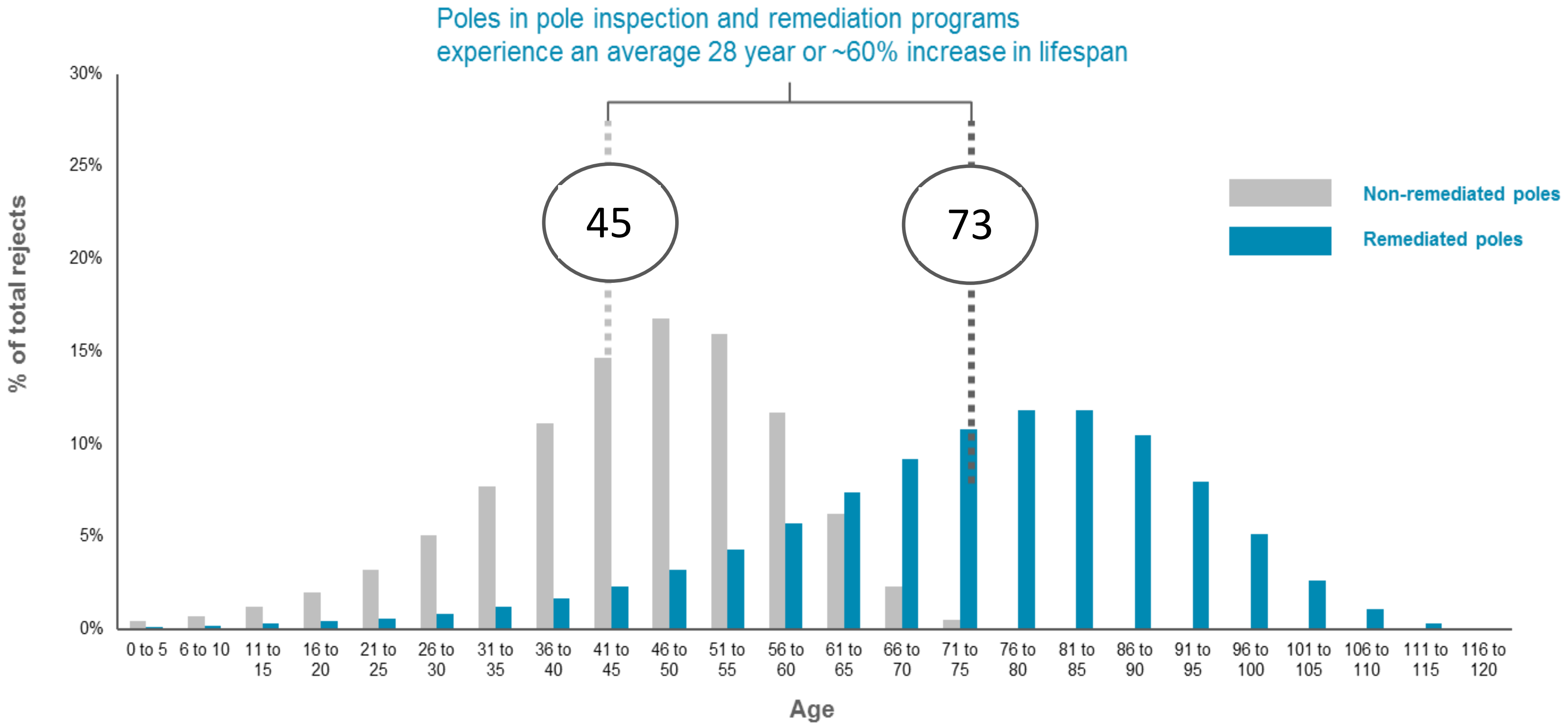
40% of outages were fixed in 1st day



Life Extension of the Asset

-Projected General Linear Model-

Projecting reject rates for poles past age 50 shows an even larger life extension due to pole inspection and remediation



Reject rates were modeled using a best fit general linear model based on decay rates for poles ages 0 to 50

Present Value Revenue Requirement (PVRR)

-Wood Pole Life Extension-

1. The pole is 40 years old and is a reject for not having been treated
2. The utility's average replacement cost is $4,000
3. There is a 10% O&M charge in the replacement cost
4. Other financial assumptions…

Average service life of pole	40
Book life (depr. schedule) of pole	40
Net salvage value	-30%
Depreciation rate (comp)	3.25%
Book depreciation rate	2.50%
Tax rate	35.0%
Annual depreciation for RR	$ 130.00
Average pole replacement cost	$ 4,000
Debt % in capital structure	57%
Equity % in capital structure	43%
Kd	4.420%
Ke	10.20%
Total K, after tax	6.03%
O&M in Replacement	5%

Present Value Revenue Requirement (PVRR) will show:

A new pole cost the ratepayer much more than $4,000.

Revenue Requirement Yr 1

$$\boldsymbol{Revenue\ Requirement} = \overbrace{(Rate\ Base\ \times ROR)}^{A} + \overbrace{OpEx}^{B} + \overbrace{Depr}^{C} + \overbrace{Tx}^{D}$$

$$\boldsymbol{Revenue\ Requirement} = 217.08 + 400 + 120 + 55.62$$

$$\boldsymbol{Revenue\ Requirement} = \$792.70\ year\ 1$$

<u>That was year #1 out of 40+ years</u>

1. Adjust metrics for depreciation, OpEx, etc. and repeat…
2. Total revenue requirement = **$9,747.92**

Ratepayer benefit

A utility company pole replacement cost of **$4,000** costs ratepayers **$9,748**

If poles last 16 years longer,

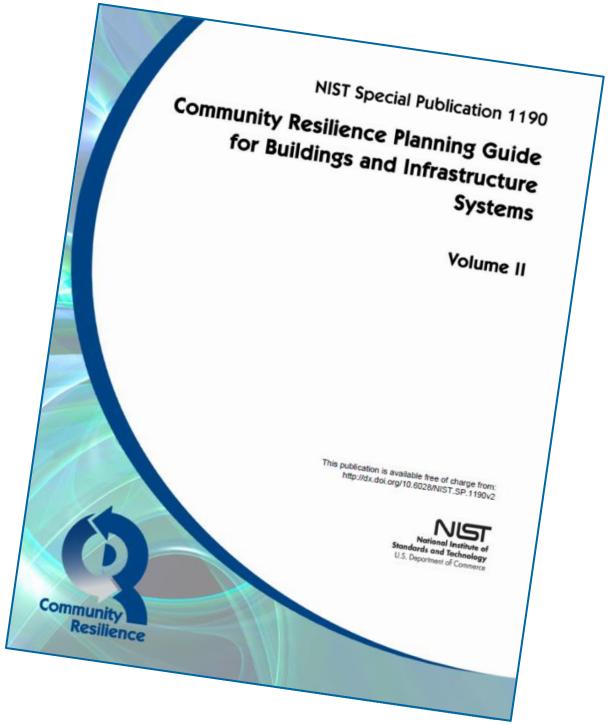
$9,748 buys the ratepayer **56** years of service life, not **40**

a **40% improvement**

Focus on Grid Resiliency

NIST – Disaster Resilience Framework

- **Define** community-based disaster **resilience** for the **built environment**
- **Identify consistent performance goals and metrics for buildings and infrastructure** and lifeline systems to enhance community resilience
- **Identify existing standards, codes, guidelines**, and tools that can be implemented to enhance resilience, and
- **Identify gaps in current standards, codes, and tools** that if successfully addressed, can lead to enhanced resilience.



- Industry testing for fallen tree resiliency
- NESC construction criteria establish initial structural resiliency
- Subsequent structural resiliency depends on pole management
- Structural resiliency is critical to electric and wireless systems
- Pole maintenance programs vary greatly
- New mobile app is coming to rate a pole maintenance program
- No Overhead Line maintenance requirement in the NESC
- Should the NESC mention resiliency
- PVRR for pole replacements (with and without supplemental preservatives)
- Focus on Grid Resiliency

For more information, contact:

Nelson Bingel
Chairman - NESC
nbingel@nelsonresearch.net
(678) 850-1461

IEEE STANDARDS ASSOCIATION
IEEE

Staff Subcommittee on Electricity/Reliability

Distribution Poles and Lines – How Strong is Strong Enough?

Moderator

Ryan Laruwe
Michigan Public Service Commission

Speaker

Nelson G. Bingel, III
Chairman - NESC

Appendix

NIST – National Institute of Standards and Technology

- Founded 1901
- Non-regulatory federal agency –
  - U.S. Department of Commerce
- Technology, measurement, and standards
- 3,000 Scientists, engineers, technicians
- 2,700 Associates: academia, industry, govt agencies

NIST -

The electric codes that are adhered to by the Investor-Owned Utilities (IOUs) who design and construct the Transmission assets is the National Electric Safety Code (NESC); Sections 24 (Grades of Construction), 25 (Loading Requirements) and 26 (Strength Requirements). While this is truly a safety

While this is truly a safety code, it is applied for use as a design code in lieu of other guidance.

their own standards for their respective systems. And while most all exceed the minimums set forth by the NESC, the question that exists is whether the baseline set forth in the NESC addresses the performance desired for resiliency when considering all hazards (flood, wind, seismic, ice, and other natural hazards and man-made threats).

…the question that exists is whether the baseline set forth in the NESC addresses the performance desired for resiliency when considering all hazards (flood, wind, seismic, ice …….)

In a similar fashion, but working from a different set of criteria, the Co-operatives and Municipalities responsible for Distribution assets use the design manuals/standards from the Rural Utilities Service (RUS). The RUS distribution line design manuals consist of RUS bulletins 1724-150 through 1724-154. These refer to the identification of critical loads/customers and poles/equipment. In all cases, each utility is applying more constringent wind and ice loading conditions from these codes.

NIST

Rule 250C

The ASCE 7-10 wind maps were revised to better represent the wind hazard. …. However, these maps are currently not used by the NESC based on a decision by their code committee to retain the use of the ASCE 7-05 wind maps.

Rule 250C

Most distribution structures are lower than the 60 ft height limitation, therefore, most utilities will not design their distribution lines to the ASCE 7 criteria (something that may want to be reconsidered depending upon performance of these systems during hurricanes and tornadoes over the past 2 decades).

NIST

Recommendations

Regulatory bodies for design and construction from the building sector and the energy sector need to discuss the magnitude and criteria of the hazards the buildings and infrastructure are designed to resist.

More can be done. In addition to reliability initiatives, improved planning, and response efforts to natural

Recommendations

If the general building stock is designed to resist higher level events with minimal damage, there will be greater pressure on the energy infrastructure to be on-line immediately after disasters and events occur.

Chapter 7, Page 20 of 22

NIST –

Listed under their area of expertise, NIST's new disaster resilience fellows are:

Community Resilience Planning

Chris Poland, Chris D. Poland Consulting Engineer, Canyon Lake, Calif.

Electrical Power Infrastructure

Erich Gunther, EnerNex, Knoxville, Tenn.

Stuart McCafferty, GridIntellect, Huntsville, Ala.

Emergency Planning and Response

Jay Wilson, Hazard Mitigation Program Coordinator, Clackamas County, Ore.

Societal Dimensions of Disasters

Liesel A. Ritchie, University of Colorado Boulder, Natural Hazards Center, Boulder, Colo.

Transportation Infrastructure

Joseph Englot, HNTB, New York, N.Y.

Theodore Zoli, HNTB, New York, N.Y.

Water Infrastructure

Kevin M. Morley, American Water Works Association, Washington, D.C.

Donald Ballantyne, Ballantyne Consulting LLC, Seattle, Wash.

Calculating the Ratepayer Impact of Pole Life Extension Programs

Three basic ways to show financial value to a utility:

1. Reduction in OPEX / total cost of ownership
2. Shareholder benefit (e.g. increased IRR)
3. Ratepayer benefit (e.g. reduced PVRR)

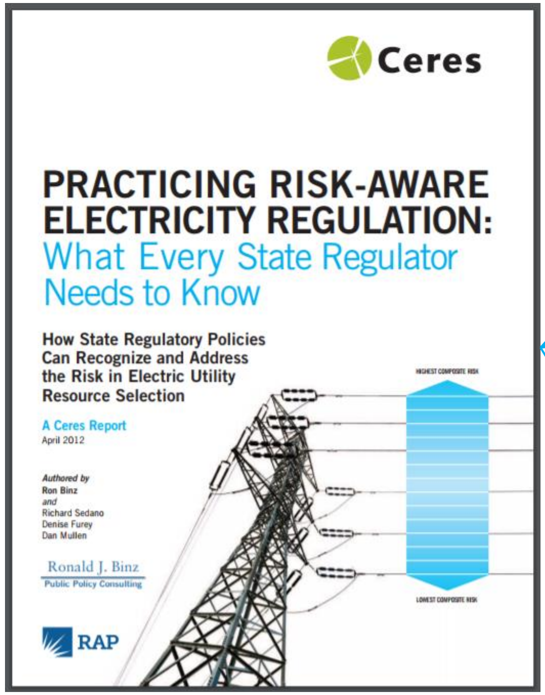
PVRR = Present Value of Revenue Requirements

- PVRR is the best way to reflect the total current and future costs that the ratepayer will incur, in today's dollars.

Scope of this discussion:

- Ratepayer impact
- How to accurately determine cost of service (revenue requirements)
- How to show benefit in a way that regulators are expecting to see it

What Are Regulators Thinking About?



[Link: Ceres Risk Mgmt Guide for Utility Regulators]()

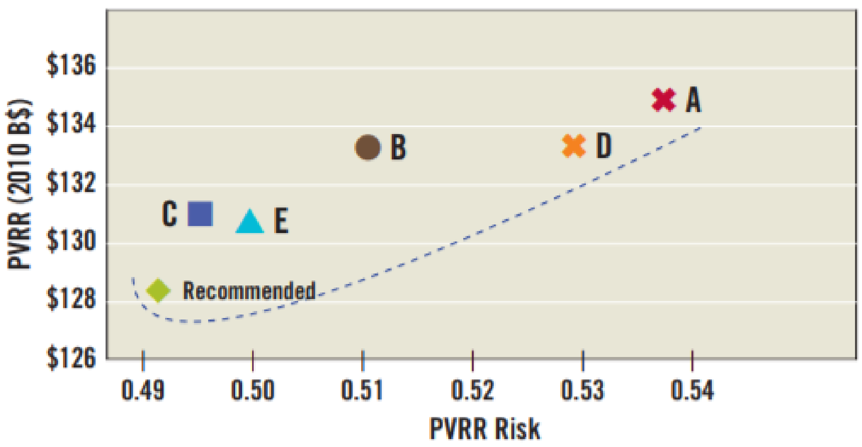
Effectively managing risk is not simply achieving the least cost today, but rather is part of a strategy to minimize overall costs over the long term.

The planning process should seek to discover as much as possible about future conditions, and the door should be opened to interveners of all stripes.

More than ever, ratepayer funding is a precious resource.

Figure ES-5

TVA ANALYSIS OF RESOURCE PLAN COSTS & FINANCIAL RISK



- Strategy A: Limited Change in Current Resource Portfolio
- Strategy B: Baseline Plan Resource Portfolio
- Strategy C: Diversity Focused Resource Portfolio
- Strategy D: Nuclear Focused Resource Portfolio
- Strategy E: EEDR (Energy Efficiency/Demand Response) and Renewables Focused Resource Portfolio

Example of a utility replacing a pole:

1. The pole is 40 years old and is a reject for not having been treated
2. The utility's average replacement cost is $4,000
3. There is a 10% O&M charge in the replacement cost
4. Other financial assumptions…

Average service life of pole	40
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Annual depreciation for RR	$ 130.00
Average pole replacement cost	$ 4,000
Debt % in capital structure	57%
Equity % in capital structure	43%
Kd	4.420%
Ke	10.20%
Total K, after tax	6.03%
O&M in Replacement	5%

Present Value Revenue Requirement (PVRR) will show:

A new pole cost the ratepayer much more than $4,000.

Design of the Regulation:

1. Make the current ratepayer pay an equitable share of past/current/future cost of the infrastructure they are currently using

2. Spread out the cost of the infrastructure across its useful life

Key Things To Understand:

1. Even though utilities pay for something today, the true cost to the ratepayer must be modeled over future years

2. Regulators care about avoiding future cost increases…a strong business case will show how a modest investment today will save major costs in the future (and not the other way around)

Calculating the Cost of Service / Revenue Requirement

$$\boldsymbol{Ratepayer\ Cost}\ = Revenue\ Requirement$$

$$\boldsymbol{Revenue\ Requirement} = \overbrace{(Rate\ Base\ \times ROR)}^{A} + \overset{B}{OpEx} + \overset{C}{Depr} + \overset{D}{Tx}$$

Rate Base = (undepreciated) book value of the asset

ROR = "rate of return"; the cost to finance rate base (debt & equity), a.k.a. WACC

OpEx = annual operating costs (O&M)

Depr = depreciation expense (straight line is used in rate making)

Tx = corporate income tax

Revenue Requirement – Year 1

$$\boldsymbol{Revenue\ Requirement} = \underbrace{(Rate\ Base\ \times ROR)}_{A} + \underbrace{OpEx}_{B} + \underbrace{Depr}_{C} + \underbrace{Tx}_{D}$$

A = Rate Base * Rate of Return

A = (Capital component of pole replacement cost) * WACC

A = ($4,000 *90%) * 6.03%

A = $3,600 * .0603

A = $217.08

Revenue Requirement – Year 1

$$\boldsymbol{Revenue\ Requirement} = \underbrace{(Rate\ Base \times ROR)}_{A} + \underset{B}{OpEx} + \underset{C}{Depr} + \underset{D}{Tx}$$

B = O&M component of the pole replacement

B = $4,000 * 10%

B = $400

Revenue Requirement – Year 1

$$\boldsymbol{Revenue\ Requirement} = \underbrace{(Rate\ Base\ \times ROR)}_{A} + \underbrace{OpEx}_{B} + \underbrace{Depr}_{C} + \underbrace{Tx}_{D}$$

C = Depreciation Expense

C = [Book value of asset] / Useful life (yrs)

C = [CAPEX – salvage value] / Useful life (yrs)

C = [$3,600 – (-$1,200)] / 40

C = $4,800 / 40

C = $120

Revenue Requirement – Year 1

$$\boldsymbol{Revenue\ Requirement} = \underbrace{(Rate\ Base\ \times ROR)}_{A} + \underbrace{OpEx}_{B} + \underbrace{Depr}_{C} + \underbrace{Tx}_{D}$$

D = Annual income tax

D = Shareholder profit * Tax rate

D = [Equity Investment * ROE] * Tax rate

D = [$3,600 * 43% * 10.2%] * 35%

D = $157.90 * 0.35

D = $55.62

Revenue Requirement – Year 1

$$\boldsymbol{Revenue\ Requirement} = \overbrace{(Rate\ Base\ \times ROR)}^{A} + \overset{B}{OpEx} + \overset{C}{Depr} + \overset{D}{Tx}$$

$$\boldsymbol{Revenue\ Requirement} = 217.08 + 400 + 120 + 55.62$$

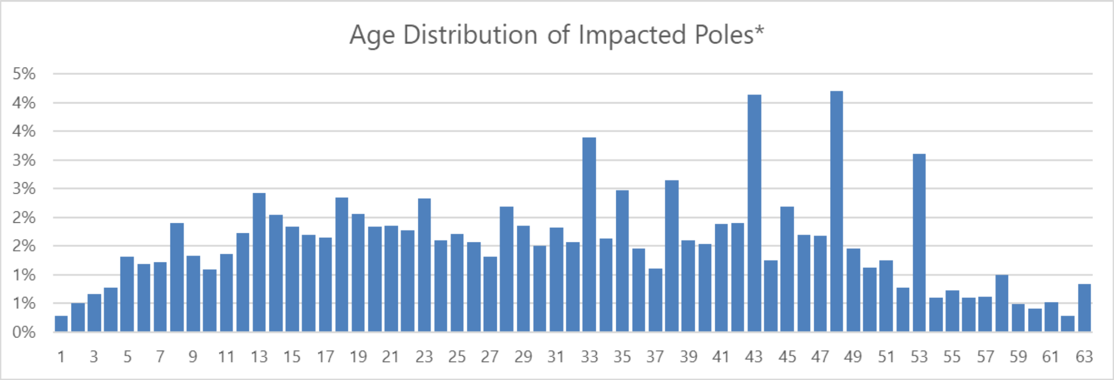
$$\boldsymbol{Revenue\ Requirement} = \$792.70^{*}$$

<u>That was year #1 out of 40+ years</u>

1. Adjust metrics for depreciation, OpEx, etc. and repeat…
2. Total revenue requirement = **$9,747.92**

Knowing the true cost to ratepayers for a new pole, the savings from life extension can be calculate as follows?

1. Assume a conservative average life extension of 16 additional years
2. Instead of replacing the pole today, we could have waited 16 more years
3. Review age distribution to estimate future revenue requirements:
   a. Without pole treatment
   b. With pole treatment (including program costs)



4. Calculate the present value of the <u>difference</u> between 3.a and 3.b

A utility company pole replacement cost of **$4,000** costs ratepayers **$9,747.92!**

If we make poles last 16 years longer, that $9,747.92 buys the ratepayer 56 years of service life, not 40…**a 40% improvement**

Staff Electricity Subcommittee