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Demonstration of Decision Tool for Selection of Transmission Poles

Demonstration of Decision Tool for Selection of Transmission Poles

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PRODUCT DESCRIPTION

EPRI and member utilities requested Battelle to develop a comprehensive screening tool (CST) for comparing different types of utility transmission poles by modifying the decision tool previously demonstrated on distribution poles. The completed decision tool permits utilities to evaluate transmission pole options using 26 criteria divided among three evaluation groups for engineering/technical performance, life-cycle cost/economics, and environmental profile. The decision tool allows utilities to evaluate transmission pole options across the full life cycle of the poles, The CST procedures were demonstrated by scoring three treated wood poles (Penta-treated Western Red Cedar, Penta-treated Southern Yellow Pine, and CuNap-treated Douglas Fir) and one non-wood pole alternative (galvanized steel).

The 26 criteria were priority weighted by using the analytic hierarchy process (AHP) and *Expert Choice®* software. For this demonstration, the panel was composed of utility personnel and EPRI contractors from different regions of the United States, so their average priority weights may not emphasize regional issues specific to a particular utility. However, an individual utility can use the same priority weighting process to tailor the criteria weighting factors and, thus, the total weighted score to emphasize their unique priorities. The weighting process was based on two different perspectives to insure acceptance by a broader range of stakeholders: an "Electric Utility" perspective that emphasizes the local and regional issues of more concern to electric utilities and a "National Policy" perspective that emphasizes the national and global issues of concern to national policy makers.

Results & Findings

The customized decision tool was demonstrated to be a viable tool for utility use. Overall, the CST is very good at differentiating the four pole types evaluated when comparing raw (unweighted) scores across a single criterion. Priority weighting the relative importance of each criterion permits summation across all 26 criteria for easier comparison. For the four pole types used in this demonstration, the weighted scores did not show significant differences among pole types using criteria weights under either the Electric Utility or the National Policy perspectives.

The CST can be tailored to the specific regional economic and environmental conditions of an individual utility. The criteria weighting factors can be tailored to emphasize priorities of an individual utility by using the same weighting procedures described for this demonstration. The CST has been demonstrated on four types of transmission poles, but the decision tool is suitable for scoring and evaluating a wide variety of existing and proposed transmission pole types.

Challenges & Objective(s)

The results of this study are intended to assist utility staff in selecting transmission pole options. This report should be extremely useful to utilities because it permits evaluation of different transmission pole types from a life-cycle perspective.

Additional tasks are underway to improve the CST method, including demonstration of the decision tool with four additional distribution pole types and development of web-based scoring software to simplify the scoring process. The web-based software application will permit an individual utility to enter the raw criteria scores that are specific to their regional and economic conditions. It also will permit the utility to tailor the criteria weighting factors from their unique perspective.

Applications, Values & Use

The CST was successfully demonstrated to be a viable tool ready for utility use. Companies need to make good decisions on replacement pole types and materials to balance safety, reliability, environmental, and economic requirements. EPRI is committed to helping utilities continuously evaluate pole systems, especially new pole types with limited or no track records.

EPRI Perspective

This study combines information from four earlier EPRI projects into a single approach for screening transmission pole options. Three earlier EPRI studies separately evaluated criteria for engineering/technical performance (EPRI, 2005, *Assessment of Treated Wood and Alternate Materials for Utility Poles,* 1010144), life-cycle cost/economics (EPRI, 2003, *Which Distribution Pole has the Lowest Life-Cycle Cost?* Draft Technical Update), and environmental profile (EPRI, 2005, *Environmental Profile of Utility Distribution Poles*, 1010143). These approaches were combined in an earlier report (EPRI, 2006, *Demonstration of Decision Tool for Selection of Distribution Poles,* 1012598) as a decision tool to evaluate distribution poles and were modified in this report for use on transmission poles. The purpose of the prior and current screening demonstrations, respectively, on different types of distribution and transmission poles is to show how the tool is used and the relative ease of the scoring process. Since the raw scores and priority weighting used in these demonstrations are based on typical national conditions, there is no expectation that the scores resulting from the demonstration will represent all of the unique regional, ecological, and economic conditions of a specific utility.

Approach

The project team's goal was to modify and demonstrate a previous CST approach used on utility distribution poles for comparing different types of transmission poles. The screening decision tool was demonstrated by scoring four alternatives. The 26 criteria were priority weighted by a demonstration panel, a scientific process, and calculation software. The weighting process was based on two different perspectives (Electric Utility and National Policy) to insure acceptance by a broader range of stakeholders and to permit calculation of a single total for each pole type.

Keywords

Life-cycle analysis
Engineering/technical performance criteria
Life-cycle cost/economic criteria
Environmental criteria
Non-wood poles
Treated wood poles
Utility transmission poles

ABSTRACT

At the request of EPRI and member utilities, Battelle has modified a comprehensive screening tool (CST) previously developed for comparing different types of utility distribution poles to demonstrate its use for evaluating transmission poles. The modified decision tool enables utilities to evaluate distribution or transmission pole options using 26 criteria divided between three evaluation groups. The screening demonstration shows how the tool is used and the relative ease of the scoring process. In this report, the decision tool is demonstrated on four types of 80-foot, Class 2 transmission poles, including three treated wood poles and one non-wood pole. As time and funds permit, different types of distribution and transmission poles are planned for future CST evaluations.

Additional tasks are currently underway to improve the CST method, including development of web-based scoring software to simplify the scoring process. The web-based software application will permit individual utilities to enter criteria scores that are specific to their regional and economic conditions. It also will permit utilities to tailor the criteria weighting factors so they can emphasize their own priorities for engineering performance, life-cycle cost, and environmental priorities.

To balance safety, reliability, environmental, and economic requirements, companies must make good decisions on replacement pole types and materials. EPRI is committed to helping utilities continuously evaluate pole systems, including new pole types with limited or no track records.

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ACQ	Ammoniacal Copper Quat
AHP	Analytic Hierarchy Process
AIRS	Aerometric Information Retrieval System
ANSI	American National Standards Institute
AP	Acidification Potential
ASTM	American Society for Testing and Materials
AWPA	American Wood Preservers Association
CCA	Chromated Copper Arsenate
CFR	Code of Federal Regulations
CIA	Central Intelligence Agency
CPDB	Carcinogenic Potency Database, LLNL database
CST	Comprehensive Screening Tool (decision tool for comparing pole types)
CuNap	Copper naphthenate
DF	Douglas fir
EDM	Engineering Data Management
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FRC	Fiberglas Reinforced Composite
GWP	Global Warming Potential
HCs	Hydrocarbons
HSDB	Hazardous Substances Database, National Library of Medicine database
IARC	International Agency for Research on Cancer
IEEE	Institute of Electrical and Electronics Engineers
IPCC	Intergovernmental Panel on Climate Change
IPCC-TAR	Intergovernmental Panel on Climate Change-Third Assessment Report
IRIS	Integrated Risk Information System, EPA database

IUSI	International Utility Structures, Inc.
LCI	Life Cycle Inventory
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
MSDS	Material Safety Data Sheet
NAAQS	National Ambient Air Quality Standards
NESC	National Electrical Safety Code
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No-observed-adverse-effects-level
NRECA	National Rural Electric Cooperative Association
NYSEG	New York State Electric and Gas Corporation
OSHA	Occupational Safety and Health Administration
PAN	Peroxyl acetyl nitrate
PEL	Permissible exposure limit
Penta	Pentachlorophenol
POCP	Photochemical Oxidant Creation Potential
RCRA	Resource Conservation and Recovery Act
RED	Reregistration Eligibility Decision
ROI	Return on investment
RTECS	Registry of Toxic Effects on Chemical Substances, NIOSH database
RUP	Registered Use Pesticide
SETAC	Society of Environmental Toxicology and Chemistry
SIC	Standard Industrial Code
SRI	Steel Recycling Institute
STEL/CEIL	Short term exposure level/ceiling
SYP	Southern yellow pine
TCLP	Toxic Characteristic Leaching Procedure
TPY	Tons per Year
TRI	Toxic Release Inventory
TWA	Time-weighted average
USGS	U. S. Geological Survey
UV	Ultraviolet
VOCs	Volatile organic compounds

WOE	Weight-of-evidence
WRC	Western red cedar
WWPI	Western Wood Preservers Institute

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1 INTRODUCTION

CST Concept and Prior Demonstrations

The Electric Power Research Institute (EPRI) and member utilities requested Battelle to modify the Comprehensive Screening Tool (CST) previously developed for comparing different types of utility distribution poles in order to demonstrate its use for evaluating transmission poles. The initial concept design for this decision tool was completed in December 2005 (EPRI, 2005a) and focused on identification and description of potential evaluation criteria for each of three major evaluation groups (engineering/technical performance, life cycle cost/economics, and environmental profile). The decision tool was previously demonstrated using two types of treated wood and two non-wood distribution poles (EPRI, 2006). The current project involved modification and demonstration of the CST on four types of transmission poles. The modified decision tool permits utilities to evaluate distribution or transmission pole options using 26 criteria divided between three evaluation groups.

The criteria for the CST are designed for screening different types of distribution or transmission poles planned for a typical “Grade” C pole setting (i.e., not at a crossing). It is assumed that all wood pole types considered for evaluation by the CST meet the engineering criteria specified by the 2007 National Electric Safety Code (NESC) (IEEE, 2006) and the American National Standards Institute (ANSI, 2002) specifications for pole strength and wood pole class dimensions for particular tree species. The ANSI specifications are expected to be updated by the end of 2007. Updated NESC criteria include fiberglass reinforced composite (FRC) poles. Currently, FRC poles are typically designed to meet minimum NESC rules for wood. It is also assumed that treated-wood poles meet the American Wood Preservers Association (AWPA, 2007) specifications according to the Use Category System. The AWPA normally publishes updated specifications each year. Steel distribution poles are assumed to be manufactured from gauge thickness coil steel (typically gauge 11) that meet American Society of Testing and Materials (ASTM) standards.

Purpose of CST Demonstrations and Long Range Plans

The purpose of the prior (EPRI, 2006) and current screening demonstrations, respectively, on different types of distribution and transmission poles is to show how the tool is used and the relative ease of the scoring process. Since the raw scores and priority weighting used in these demonstrations are based on typical national conditions, there is no expectation that the scores resulting from the demonstration will represent all of the unique regional, ecological, and economic conditions of a specific utility. The CST procedures were initially demonstrated on four types of 40-foot, Class 4 distribution poles, including two treated-wood pole types [chromated copper arsenate-treated southern yellow pine (CCA-SYP) and ammoniacal copper quat-treated Douglas fir (ACQ-DF)] and two non-wood pole alternatives [thin-walled galvanized steel and prestressed concrete] (EPRI, 2006). In this report, the decision tool is demonstrated on four types of 80-foot, Class 2 transmission poles, including three treated-wood poles [pentachlorophenol-treated western red cedar (penta-WRC), copper naphthenate-treated SYP (CuNap-SYP), penta-SYP], and one non-wood pole (thin-walled galvanized steel). The pole types and sizes used in both demonstrations were selected to show that the decision tool works for a wide variety of commercially-available utility poles. The selection of pole types was partially dependent on those of interest to cooperating EPRI member utilities, but does not imply that the pole types selected for the demonstrations are any more frequently used or have any greater engineering, cost, or environmental advantages than pole types that were not selected. Additional types of distribution and transmission poles are planned for future evaluation with the CST as time and funds permit.

Additional tasks are underway to improve the CST method, including demonstration of the decision tool with four additional distribution pole types and development of web-based scoring software to simplify the scoring process. A software design guide was prepared for EPRI (2007) that describes the development and performance for a web-based software application that will provide EPRI member utilities with a method to compare different types of utility distribution poles. By automating the CST system, an EPRI member company can more readily determine priority weights and calculate raw (unweighted) scores, which are both needed to calculate a set of final weighted scores.

The web-based software application will permit an individual utility to enter criteria scores that are specific to their regional and economic conditions. It will also permit the utility to tailor the criteria weighting factors from their unique perspective so they can emphasize their own priorities for engineering performance, life cycle cost, and environmental priorities. The user will thus have a choice to calculate the final scores based on a utility-specific perspective for the criteria weighting factors, as well as either of the two different national perspectives developed by a panel for the initial CST demonstration.

Life Cycle Approach

The CST criteria consider the full life cycle of utility distribution or transmission poles, including the three upstream (non-utility-controlled) and two downstream (utility-controlled) life cycle stages (Figure 1-1). The three upstream life cycle stages include raw material acquisition (includes tree farming/harvesting), intermediate materials processing (includes cement, steel, and fiberglass manufacture), and pole manufacture or treatment (includes non-wood pole manufacture and wood pole milling and treatment). The two downstream life cycle stages include pole use/reuse/maintenance and pole recycling/disposal.

Screening Criteria Selected for Three Major Evaluation Groups

The 26 criteria organized by the three major evaluation groups (engineering/technical performance, life cycle cost/economic, and environmental profile) in the CST are listed in Table 1-1. In Section 2 of this report, the basis for scoring each of the 26 criteria is described. A much more detailed description of each criterion is provided in Appendix A, including a discussion of the environmental issue, a definition and rationale for evaluating the criterion, a description of the criterion information requirements and scoring calculation procedures, definition of the five scoring ranges, and description of sources of supplementary information useful for determining the appropriate scoring range. Semi-quantitative scoring ranges have been recommended in this report for all of the 26 criteria. In Section 5, the process used to provide priority weights for each of the 26 criteria based on relative importance is explained, including use of a demonstration panel, the Analytic Hierarchy Process (AHP), and Expert Choice® software.

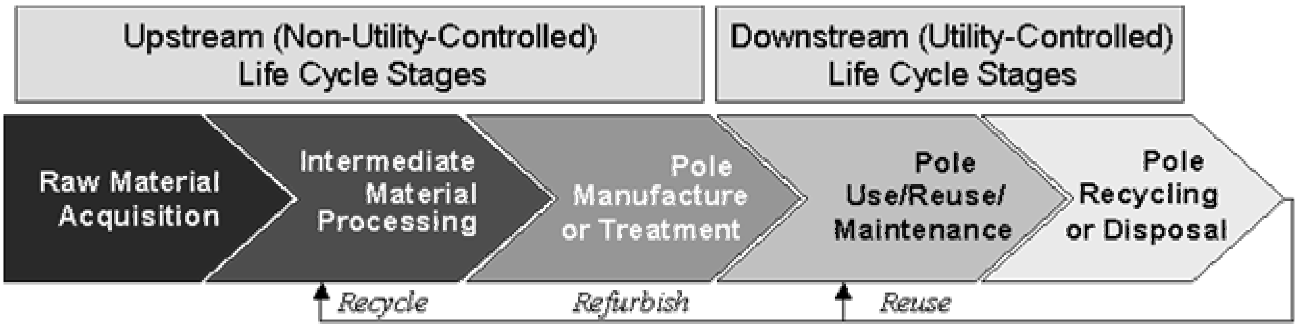

Figure 1-1
Life Cycle Stages of Utility Poles Considered in Evaluation

Table 1-1
Decision Tool Criteria Organized by Three Evaluation Groups

Engineering/Technical Performance Criteria	Life Cycle Cost/Economic Criteria	Environmental Criteria
Expected Service Life with Maintenance	Acquisition Costs at Pole Yard (pole, liner, sleeve, cross arms, hardware, and transport to yard)	Acidification Potential
Regulatory and Treated-Wood Registration Status	Transportation Costs from Pole Yard to Installation Site	Carcinogenicity
Adaptability of Field Procedures and Hardware for Emergencies	Installation Costs	Ecological Habitat Alteration
Equipment Requirements for Transport to Job Site/Install/ Removal	Maintenance Costs During Pole Use (retreatment, inspection)	Energy Use
Handling Protection to Avoid Damage	Disposal Costs	Global Warming Potential
Grounding	Recycle or Reuse Costs	Inhalation Toxicity
Weight/Number for Bulk Transport	Resource Renewability/ Sustainability (including future raw material availability)	Smog Creation Potential
Hardness	Raw Materials Delivery Infrastructure	Recyclability Potential (Post-consumer)
	Manufacturing Capability (pole supply and available facility output)	Toxic Material Mobility upon Landfilling or Incineration

Instructions for Scoring Transmission Poles

The CST has been demonstrated on four types of poles in this report, but the decision tool is suitable for scoring and evaluating a wide variety of existing and proposed transmission pole types. For any given pole type, scores can be developed for each criterion by using the scoring procedures and scoring ranges in Appendix A. Semi-quantitative scoring ranges have been developed for each criterion with scores of 9, 7, 5, 3, and 1, where 9 is the best score and 1 is the worst score. The first step is to determine the quantity of each major component (e.g., pole material, treatment chemicals or coatings, etc.) of a given pole type, based on information from the manufacturer, such as the Material Safety Data Sheet (MSDS). The second step is to score the component materials or entire pole for each criterion using the scoring ranges in Appendix A. These initial scores are multiplied times priority weighting factors, which were developed to assess the relative importance of each criterion by using a demonstration panel of utility personnel and EPRI contractors, a scientific process, and calculation software. The weighting process described in Section 5 for this demonstration was based on two different perspectives (i.e., Electric Utility and National Policy) to insure acceptance by a broader range of stakeholders and to permit calculation of a single total for each pole type. As an option for individual utilities, the criteria weighting factors can be tailored to emphasize utility-specific priorities by using the same weighting procedures described in this report. The final step is to sum the 26 criteria scores times their respective weighting factors in order to determine the overall score for comparing different distribution pole types.

2
BASIS FOR SCORING 26 POLE SELECTION CRITERIA

Engineering/Technical Performance Criteria

The bases for scoring each of the eight engineering/technical performance criteria included in this CST evaluation of transmission poles is discussed briefly below and in more detail in Appendix A. Descriptions of these criteria are based on the CST approach for distribution poles published by EPRI (2006) as Technical Report 1012598. These criteria are designed to score pole types evaluated in prior CST demonstrations on four types of distribution poles, the current CST demonstration on four types of transmission poles, and CST demonstrations underway on four additional types of distribution poles. Thus, the criteria are designed to evaluate a wide variety of distribution and transmission pole types.

Expected Service Life with Maintenance

One of the most highly desirable performance requirements for a utility transmission pole is a long service life before replacement. This criterion discusses the typical (average) number of years that a transmission pole can remain in service without significant loss of strength properties, particularly near the groundline. It assumes an inspection and maintenance program that includes reapplication of preservative treatments (retreatment) or additional groundline protection in the field for both treated wood and steel poles, respectively. To meet AWPA guidelines, retreatment of wood poles should begin at 15 years and continue on a 10-year cycle. Similarly, corrosion monitoring should be performed every 5 to 10 years on galvanized steel poles, depending on the soil corrosivity (Zamanzadeh et al., 2006). In the CST, a service life of greater than 80 years receives the highest score. Decreasing intermediate scores are given for a service life of 80-61, 60-41, or 40-21 years. Pole types expected to last less than 20 years would receive the lowest score and probably would not be considered by utilities. Utilities without a pole inspection and maintenance program (retreatment) should decrease the final score for all pole types by a score modifier. In addition, galvanized steel poles installed in areas where the soil has high corrosion potential should decrease the final score (reduce the expected service life) by a second score modifier.

Regulatory and Treated-Wood Registration Status

This criterion considers the extent of regulations affecting pole disposal and the status of re-registration and/or risk assessments for treatment pesticides. Regulations like the Resource Conservation and Recovery Act (RCRA) subtitle D on municipal landfills [including Toxic Characteristic Leaching Procedure (TCLP) concentration limit exemptions for particular materials], the Clean Air Act restrictions on incinerator emissions, and Federal drinking water, maximum contaminant level (MCL) standards can impact the reuse and/or disposal of a particular utility pole type. Wood poles treated with registered use pesticides (RUP) are not expected to be re-registered until the end of 2007 according to EPA’s (2007a) Schedule for Reregistration Eligibility Decisions (REDs). Human and aquatic toxicology studies, risk assessments, and/or litigation have the potential to change these regulations, exemptions, and re-registration of treated wood poles in the near term or far term, which could influence the desirability of a particular pole type by utilities.

Adaptability of Field Procedures and Hardware for Emergencies

Utility transmission poles need to be adaptable in both procedures and hardware for use in a variety of field situations, including weather emergencies such as tornadoes, hurricanes, and ice storms. The scoring system gives the highest score to wood pole types which are easily adaptable in the field, including use of standard galvanized fasteners and hardware, a standard drill and bit, and standard wrenches and tightening techniques. The second highest score is given to FRC and steel poles. FRC poles can be drilled in the field with a carbide-tipped drill bit. Steel poles can be drilled with a standard drill and bit, but require cold galvanization on the hole. Medium scores are given for treated-wood pole types that require stainless steel fasteners and hardware. The next score below medium is given to square concrete poles, which can be drilled on the centerline of either axis with the use of rotary hammer drills. The lowest score is given to round concrete poles, which require rotary hammer drills and are more difficult to avoid hitting a tendon than a square concrete pole.

Equipment Requirements for Transport to Job Site/Install/Removal

The type of equipment for transportation, installation, and removal of treated-wood transmission poles has remained relatively unchanged for the last several decades. However, different equipment and/or handling techniques may be required in order to protect non-wood pole types (e.g., galvanized steel or concrete) or to handle the increased weight of concrete and some non-treated wood types.

One of the biggest differences for transport of transmission poles to the job site is the use of multiple-axle, extra-long, flatbed tractor-trailer and cab, including a support vehicle for an over length load, that are needed to haul wood and concrete transmission poles 60 feet or more in length that come in one piece. The scoring system for this criterion gives higher scores for lighter pole types, such as thin-walled galvanized steel poles, that come in two pieces. These two-piece transmission poles can be transported by a multiple-axle, regular length, flatbed tractor-trailer and cab that does not need a support vehicle. Galvanized steel poles can utilize standard equipment during installation and removal with little or no need for adaptation except use of webbed straps rather than steel rope choker or strap. Slightly lower scores are given to treated-wood pole types 60 feet or more in length that utilize standard equipment during installation and removal, but must be transported by a multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle. Concrete transmission poles get the lowest score, due to their weight and length. Due to axle weight restrictions, fewer concrete poles can be transported to the job site compared to wood or steel poles. In addition, concrete transmission poles are typically in one piece, so transport to the job site requires a multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle for pole lengths 60 feet or more in length.

Handling Protection to Avoid Damage

Treated-wood utility poles require very little protection during storage, transportation or installation. However, non-wood poles require special protection during storage, transportation and/or handling to avoid chipping, crushing, and friability, e.g. crumpling of steel, cracking of concrete, or delaminating of FRC. The scoring system for this criterion gives higher scores for pole types that do not require special protection during transportation or installation. Intermediate scores will be given to pole types that require limited protection during transportation (e.g., blocking) or loading and unloading (e.g., special slings) to avoid crumpling, cracking, or delaminating. Lower scores will be given to pole types that require extensive protection, including blocking and full length wrap during transport, as well as webbed nylon straps during installation.

Grounding

Some of the non-wood pole alternatives have different requirements for grounding than wood poles. Of the three non-wood alternatives (galvanized steel, concrete, and FRC), only FRC poles have the same requirements for insulation and grounding as wood poles. For example, the 2007 NESC (IEEE, 2006) requires that a separate ground electrode be installed on standard steel poles even if no insulating coating is used below grade. The scoring system for this criterion gives higher scores for pole types that do not require supplemental grounding equipment or insulators in addition to the typical requirements for treated-wood poles. The lowest scores are given to pole types that need both supplemental grounding equipment and insulators not required for treated-wood poles.

Weight/Number for Bulk Transport

The weight and length of a transmission pole has a significant effect on the number of poles that can be transported to the pole yard on a single trailer for bulk transport. The scoring system for this criterion gives higher scores for lighter pole types that come in two pieces, such as thin-walled, galvanized steel poles. These two-piece transmission poles can be transported by a multiple-axle, regular length, flatbed tractor-trailer and cab that does not need a support vehicle. Treated-wood and concrete transmission poles 60 feet or more in length come in one piece and, therefore, must be transported as an over length load using a support vehicle and must obtain an over length permit for each state they cross. Slightly lower scores are given to treated-wood pole types that require multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle. Concrete poles would get the lowest score, due to their weight and length. Fewer concrete poles could be transported to the pole yard on a single truck compared to wood or steel poles due to axle weight restrictions.

Hardness

The hardness of the pole type can affect the climbability and/or ease of drilling of the selected pole type. For this criterion, hardness is defined as the Janka hardness of wood and the physical properties of non-wood poles that make them difficult to drill or climb with gaffs. The scoring system for this criterion gives the highest score for wood pole types with low wood hardness that are easily climbed and drilled. The next highest score is given to chromated copper arsenate (CCA)-treated wood that is harder to climb. Medium scores are given to tropical hardwoods with greater wood hardness factors that make both drilling and climbing difficult and FRC and galvanized steel poles that require a carbide-tipped drill for field drilling and climbing steps. The lowest score is given to round concrete poles that require climbing steps and cannot be easily drilled in the field without a rotary hammer drill and potential damage to structural integrity (e.g., exposure of tendons).

Life Cycle Cost/Economic Criteria

The bases for scoring each of the nine life cycle cost/economic criteria included in the CST evaluation of transmission poles is discussed briefly below and in more detail in Appendix A, and as derived from the CST approach for distribution poles published by EPRI (2006) as Technical Report 1012598. The focus of each of these criteria was on either the expected cost to the utility, or on supply or availability issues which might affect the cost of a transmission pole. For each cost-related criterion, the costs are scored relative to a baseline pole and treatment of the user’s choosing, which for this demonstration was chosen to be Penta-SYP.

Since many of the cost items are specific to utility and supplier, such as transportation cost to the utility which is dependent upon the relative locations of utility and pole vendor, or cost for installation which will be dependent upon the utilitiy’s process or procedures, the cost elements (hourly wage, pole cost, transportation costs, etc.) used for this demonstration are examples of the types of data required. They illustrate the calculation procedures and may not be representative of the actual cost to any particular utility. These criteria are designed to score pole types evaluated in prior CST demonstrations on distribution poles, the current CST demonstration on transmission poles, and potential future CST demonstrations on other types of utility poles.

Acquisition Costs at Pole Yard (pole, liner, sleeve, cross arms, hardware, and transport to yard)

This criterion assesses the relative cost for the pole and associated hardware needed to use the pole. Different substrates (SYP, DF, WRC, or steel) in combination with different preservatives (CCA, ACQ, Penta, or CuNap, as examples) will have varying prices as delivered to the utility. In addition, the pole substrate or preservative may require additional or special hardware for use, e.g. stainless steel hardware for use on ACQ-treated poles, which will affect the cost of the pole. Transportation costs from manufacturer to utility can be a significant cost, since wood poles are over length and may require special permits and transport vehicles. To account for this identical transportation distance of approximately 1800 miles by truck were assumed for each pole type.

Higher scores were given to poles which were less expensive than Penta-SYP; lower scores were given to poles with higher costs than Penta-SYP.

Storage and Transportation Costs from Pole Yard to Installation Site

Because of extreme length, handling requirement to prevent damage, and weight issues, the cost to transport transmission poles may vary considerably by pole type and transport distance. For this work we assumed a 20 mile transport distance by a crew of three. The number of poles per load varied from 7 to 10 for the wood poles, and 16 for the steel poles. Special procedures during transport from pole yard or storage point to point of use were also factored into the cost calculations. This criterion assessed the relative cost of handling and transport of poles from the pole yard to the point of use. Higher scores were given to poles which were less expensive than Penta-SYP, and lower scores to pole types that were more expensive to store and transport than Penta-SYP.

Installation Costs

As with transport, the length of transmission pole, special handling requirements, and weight of the poles may affect the installation cost by requiring special equipment, more personnel, or special procedures. This criterion assesses the relative cost to install each of the different pole types. Higher scores were given to poles which were less expensive to install than Penta-SYP, and lower scores to pole types that were more expensive than Penta-SYP.

Maintenance Costs During Pole Use (retreatment, inspection)

The wood poles will require periodic inspection and in-field retreatment with preservative to reach the maximum expected service life. The steel poles need periodic inspection, with the need for periodic retreatment dependent upon soil corrosivity. These lesser requirements may lead to relative life cycle cost advantages, which this criterion attempts to assess. Higher scores were given to poles which were expected to have lower maintenance costs than Penta-SYP, and lower scores to pole types that were more expensive to maintain than Penta-SYP. Maintenance costs are based on the expected service life of the pole and are not calculated on an annualized basis.

Disposal Costs

At the end of the pole service life there will be different options for disposal of each of the poles which are somewhat dependent upon the pole material and treatment. This criterion assesses the relative costs of disposal for each pole type. This criterion also assesses the costs for any potential remediation or site clean up that might occur with removal of the pole. Since Penta is a known hazardous material, it was judged to have a higher future likelihood of requiring soil remediation at a pole removal site than other wood treatments, and a higher associated cost for this clean up (EPRI, 2003). Materials which are subject to the least disposal restrictions, such as steel, would be expected to receive higher scores since the cost for landfilling or incineration would be lower than treated wood poles, which may have some restrictions on allowable disposal.

Recycle or Reuse Costs

As with disposal, the opportunity to recycle or reuse each of the pole types will be dependent upon the pole material and treatment. Prior to recycling or reuse, some preparation of the pole will be required which might include as little as an inspection for hardware, to testing of treatment levels remaining. The relative costs to prepare the pole for recycle or reuse, as well as any costs incurred by the utility for recycle or reuse of each pole are assessed here. Higher scores were given for materials which require the least preparation prior to recycling or reuse relative to Penta-SYP, such as steel. Lower scores were given for poles which require more preparation.

Resource Renewability/Sustainability (including future raw material availability)

One approach to increasing the environmental friendliness of a product is to use renewable or sustainable materials. This criterion assesses the renewability or sustainability of each of the materials that are part of a pole including any applied preservatives. Renewability and sustainability are judged based on available data on supply or reserves relative to demand or consumption. Renewability and sustainability are measures of the ability to conserve natural capital and should not be confused with the availability of supply. Supply is covered under the criterion Manufacturing Capability, which is a measure of the ability to supply and convert natural capital into economic goods. Materials which are readily renewable receive the highest scores. Materials which are sustainable receive moderate scores. The lowest scores are received by materials in which reserves and current consumption indicate there may be only limited expected time availability.

Raw Materials Delivery Infrastructure

Simply having an adequate supply of raw materials is insufficient if these materials cannot be moved to production or refining operations, or points of sale. This criterion assesses the state of development of the infrastructure, and stability of the government in countries supplying materials for each pole type. Materials originating from countries with long-term stable governments and well developed infrastructure received the highest scores. As the stability of the government decreased and the infrastructure was less well developed the scores were lower. The lowest scores were received by materials originating from politically unstable countries (high political turnover or history of civil unrest) with little or no developed infrastructure.

Manufacturing Capability (pole supply and available facility output)

Building on the previous two criteria, the stable supply of raw materials is also not sufficient to insure an adequate supply of poles. The final piece of infrastructure is the ability to supply the raw materials for poles and convert these materials–wood, iron, zinc, or petrochemicals–into poles. This criterion assesses the pole supply by evaluating the current and future manufacturing capability, including ability to supply wood for poles, for each pole type. Poles with current adequate manufacturing supply received the highest scores, including most treated-wood poles. Poles which required significant construction or installation of manufacturing capability which may require lengthy periods of time received moderate scores. The lowest scores are received by poles for which the time to construct or install additional facilities is so long as to be infeasible, or where demand so far exceeds the forecast supply that there is little expectation of supply ever reaching the potential demand. An example of this might be non-treated wood poles, where the supply is currently very limited, and the time to grow trees of suitable size on the order of 50 to 100 years.

Environmental Criteria

The bases for scoring each of the nine environmental criteria included in the CST evaluation for transmission poles is discussed briefly below and in more detail in Appendix A. Descriptions of the environmental criteria are based on the environmental profile approach for distribution poles published by EPRI (2005a) as Technical Report 1010143 and the CST approach for distribution poles published by EPRI (2006) as Technical Report 1012598. These criteria are designed to score pole types evaluated in prior CST demonstrations on distribution poles, the current CST demonstration on transmission poles, and potential future CST demonstrations on other types of utility poles.

Acidification Potential

Acid deposition is primarily created by the emission of sulfur and nitrogen compounds (Heijungs et al., 1992; Nordic Council, 1992). Acid deposition is a large-scale regional phenomenon that can involve long-distance transport of sulfur- and nitrogen-containing air pollutants. Each of the pole types was scored on the potential for acid production relative to SO_2 by air and water emissions from pole manufacturing. Emissions of acid precursors were determined from the EPA databases Toxic Release Inventory (TRI) and Aerometric Information Retrieval System (AIRS) Executive. The Acidification Potential (AP) scores for emissions were determined from equivalency factors for chemical air emissions contributing to acid rain or water emissions contributing to acidification of surface waters based on the potential amount of H^+ per mass unit relative to the same parameter for SO_2 (Wenzel et al., 1998). The raw AP scores determined for the criteria pollutants SO_2 and NO_2 (identified by AIRS Executive) were subtracted by a score modifier of 2 to get the final AP scores for those pollutants.

Carcinogenicity

Release of carcinogenic air or water emissions can result in suffering and death of humans. Each of the pole types was scored on the potential Carcinogenicity hazard associated with all air and water emissions from the manufacturing life cycle stage (from the TRI and AIRS Executive databases) and the materials in applied preservative treatments and coatings that could leach out during the use life cycle stage. For the use life cycle stage, the primary structural materials that were not expected to contribute to carcinogenicity were excluded from the mass-based calculations. The Carcinogenicity score for the full life cycle is the mean of the average score for carcinogens released during the use stage and the weight-based average score for carcinogens released during the manufacturing stage (EPRI, 2005b).

Carcinogenicity scores are based on the potential carcinogenic risk of a chemical to humans by using peer-reviewed, weight-of-evidence (WOE) conclusions based on laboratory animal testing and epidemiological or case studies in humans. The WOE conclusions are obtained from the

International Agency for Research on Cancer (IARC) and the EPA (ACGIH, 2003). The lowest WOE raw score from these two sources is converted to a final score by subtracting a modifier value based on the oral slope factor (mg/kg/day), which is an indication of cancer potency (LLNL, 2003).

Ecological Habitat Alteration

Ecological Habitat Alteration is an indicator of the potential extent of damage of a product or material upon terrestrial ecosystems. Two factors are considered in the evaluation: the area of ecosystem (land) which is altered from its natural state (successional stage) in the process of collecting a resource, and the amount of time required for the ecosystem to return to its original stage of habitat succession once collecting is stopped. The focus of this criterion is on the raw materials acquisition portion of the life cycle. This includes the growing and harvesting of trees, mining of minerals, and the drilling of and operation of oil and natural gas wells. Higher scores were given to materials for which harvesting or collecting requires impacting only small areas for short periods of time. Lower scores were given to materials that impact large areas for long periods of time. A score modifier was used to improve the score for wood poles that are known to be harvested from forests sustainably managed for biodiversity.

Energy Use

Energy use is assessed by measuring the relative energy used per mass of product produced, the energy intensity. This is a cumulative measure including all the energy used in collecting or harvesting raw materials, transforming those materials into treatments or pole construction materials, and manufacture of the poles. Materials that tend to score high usually require less processing, such as natural materials–wood poles. Materials that score low tend to be highly processed or refined materials–glass, polymer resins, and metals.

Global Warming Potential

The temperature of the earth is determined by the balance of the incoming solar radiation and the outgoing infrared radiation from the earth (Heijungs et al., 1992; Nordic Council, 1992). Atmospheric gases, called greenhouse gases, that absorb infrared radiation are increasing and there is concern that this could result in or contribute to global warming. Each of the pole types was evaluated for the Global Warming Potential (GWP) relative to CO_2 by air emissions from material acquisition and manufacturing. Emissions of greenhouse gases were determined from the EPA databases TRI and AIRS Executive. GWP equivalency factors have been developed for all important greenhouse gases in the Third Assessment Report (TAR) by the Intergovernmental Panel on Climate Change (IPCC, 2001) for different time scales. GWP equivalency factors for the 100-year time scale were used in this evaluation, since it is the time scale most frequently selected. The raw GWP score determined for the criteria pollutant CO_2 (identified by AIRS Executive) was subtracted by a score modifier of 2 to get the final GWP score for CO_2.

Inhalation Toxicity

Manufacturing processes should be utilized which minimize or eliminate toxic air emissions. Likewise, the elimination or minimization of metabolites (e.g., dioxins/by-products from combusted materials) is important. The Inhalation Toxicity criterion assesses the potential toxicity of air emissions from pole manufacturing to the general public, based on the no observed adverse effect level (NOAEL) available on-line from the EPA's (2007b) Integrated Risk Information System (IRIS) database. When the NOAEL was not available, the Occupational Safety and Health Administration (OSHA, 1997) or American Conference of Governmental Industrial Hygienists (ACGIH, 2003) standards were used. The National Ambient Air Quality Standards (NAAQS) can substitute as the NOAEL for criteria air pollutants.

Smog Creation Potential

Photochemical oxidant formation, which is typically associated with the formation of summer smog, is the result of reactions between NO_x and volatile organic compounds (VOCs) or other hydrocarbons (HCs) under the influence of UV light (Heijungs et al., 1992; Nordic Council, 1992). The most well known impacts of smog are visibility problems, eye irritation, respiratory tract problems, and crop damage. The criterion Smog Creation Potential assesses the potential for smog formation relative to ethylene by air emissions from pole manufacturing. Emissions of smog-forming gases were determined from the EPA databases TRI and AIRS Executive. The raw Smog Creation Potential equivalency factors relative to ethylene are from the report by SETAC Europe-Scientific Task Group report edited by Klöppfer and Potting (2002). Because of the high volumes, the raw Smog Creation Potential scores determined for the criteria pollutants SO_2, NO_2, CO, and VOC (identified by AIRS Executive) were reduced by a score modifier of 2 to get the final photochemical oxidant creation potential (POCP) score for each pollutant.

Recyclability Potential (Post-consumer)

The Recyclability Potential criterion deals with the issues surrounding solid waste management and resource depletion by recognizing products that are manufactured of materials that can be recycled. This criterion assesses both the volume of material recycled and the state of development of the recycling infrastructure. For these reasons, common materials that are recycled receive the best scores, such as paper, aluminum, and steel. Materials that are not commonly recycled (e.g., FRC) or for which there is little or no infrastructure (e.g., treated wood) received lower scores. Recyclability Potential was assessed for treated wood poles as a single unit, since the inability to separate treatment from wood resulted in formation of wood fiber with low recycling potential (Felton and DeGroot, 1996). For galvanized steel poles, recyclability was assessed by scoring each pole material individually, as these materials were considered separable.

Only limited data on recyclability potential were found for the pole types evaluated. Data for recyclability of steel poles was obtained from the Steel Recycling Institute (Web site for SRI, 2006). Felton and DeGroot (1996) indicate that the infrastructure for recycling of CCA- and Penta-treated wood products is lacking. Thus, judgments for most of the pole types were prepared based on anecdotal information, engineering assessments, and recycling industry data from US EPA. Note that for both DF and WRC treatment penetration is shallow–just through the sapwood–thus recovery of wood from the pole core or heartwood of the tree may be possible. EPRI is currently sponsoring further studies through The Beck Group on the feasibility of this option. Successful results could increase the scores for some wood pole types considerably.

Recycling has been defined, in accordance with the US EPA's Reduce, Reuse, Recycle hierarchy, as transformation and incorporation of the material into high value products, thus burning wood or plastic for the fuel value, or recycling plastic by mixing grades and types and creating a reduced value product, such as plastic lumber or parking bumpers, are not considered recycling. The use of concrete as rip rap, or fill is also not considered recycling.

Recycling is different than *reuse* of treated-wood poles, such as through donation programs to the public (e.g., for landscaping timbers, structural supports, guard rails, and fence posts) (EPRI, 2001). According to the US EPA Reduce, Reuse, Recycle waste management hierarchy, these donation activities are not considered *recycling* into high value products. Within the CST method, Reuse is a distinct criterion from recycling. The Reuse criterion was not included in this evaluation because it was not expected to show substantial differentiation or discrimination between the pole types. However, EPRI is currently conducting additional research on reuse options for different pole types and treatments.

Toxic Material Mobility upon Landfilling or Incineration

When a product reaches the point of ultimate disposal, the environmental impacts or health risks are proportional to the amount of material that is expected to move from the disposal point and reach the environment. For the Toxic Material Mobility criterion the expected rate at which material migrates from an incinerator or a landfill is assessed. The metric used for the assessment is either the aqueous solubility, for poles that are landfilled, or the Henry's Law constant for poles that are incinerated. Materials which have a higher aqueous solubility (landfill leachate is an acidic aqueous-based solution), or which are more volatile as indicated by a higher Henry's Law constant, are expected to leave the product upon disposal faster than insoluble or low volatility compounds. Thus, water-soluble wood treatments are expected to be much more mobile upon landfilling than oil-based wood treatments. As with many of the criteria, what is assessed is the potential without regard to actual rate mechanism or exposure.

3
FOUR POLE TYPES COMPARED FOR DEMONSTRATION

This section describes the composition of each of the transmission poles evaluated, as well as any assumptions made about the poles or materials of construction. The composition of the poles is especially important because the CST works on the principle that a material carries with it a burden, whose contribution to the potential effects, costs, or impacts of a product is proportional to the mass of material consumed. Four different 80-foot-tall, Class 2 transmission pole types that are commercially available were evaluated: three of preservative-treated wood and one of non-wood material (Table 3-1). Weights for each pole type are based on information from a specific commercial manufacturer. In many cases, the data sources for constituents listed a range of values for a material property. In these instances the mean of the values was used, unless experience or other data indicated another value would provide more accurate results.

Table 3-1
Description of Four Transmission Pole Types (80-foot, Class 2) Compared for CST Demonstration

Pole Type	Manufacturer	Pole Weight (lbs)	Retention Zone	Retention (pcf)
CuNap-treated DF[1]	North Pacific Group	4045[6]	0.75 in or 80% of sapwood[6]	1.5[6]
Penta-treated WRC[2]	McFarland-Cascade	3100[4]	0.3 in to 0.4 in[4]	1.0[4]
Thin-walled, tubular, galvanized-steel	Valmont Co	1711[5]	NA	NA
Penta-treated SYP	Koppers	5338[3]	3 in or 85% of sapwood[3]	0.45[3]

(1) Full-length standard incising
(2) Thermal-full length treatment process
(3) Healy, J. 2007. Director Marketing and Technology, Koppers, Inc., Personal communication with D.P. Evers, Battelle. March 22, 2007
(4) Lonning, L. 2007. McFarland Cascade, Personal communication with D.P. Evers, Battelle, March 27, 2007.
(5) Benest, B.N. 2007. Project Coordinator, Utility Division, Valmont-Newmark Industries, Inc., Personal Communication with D.A. Tolle, April 24, 2007.
(6) Passadore, J. 2007. Manager, Pole & Piling Dept., North Pacific Group, Personal communication with D.P. Evers, Battelle. May 8, 2007. Retention zone is a minimum of 80% of sapwood or 3/4".

CuNap-Treated Douglas Fir Poles

The CuNap-DF pole was comprised of three materials: DF wood (4,022 lbs.), copper naphthenate (10.2 lbs.), and No. 2 Fuel oil as the carrier (12.6 lbs.) (derived from MSDS by Merichem Chemical & Refinery Services, 2001). The total weight of the pole was 4,045 lbs. (J. Passadore, 2007, Personal Communication), yielding a percentage composition as follows: DF, 99.7 percent; CuNap, 0.3 percent; and No. 2 Fuel oil, 0.3 percent. Battelle also assumed that upon disposal the materials of construction of the pole could not be separated in an economically feasible manner. This assumption eliminates any potential for recycling the pole (Felton and DeGroot, 1996). Based on an average of the service life predicted by utilities and estimates calculated from replacement rates, it is estimated that the CuNap-DF poles would have a service life of 41-60 years with retreatment (Mankowski et al., 2002; WWPI, 1997; EPRI, 2003).

Penta-Treated Western Red Cedar Poles

The Penta-WRC pole was comprised of three materials: WRC wood (3,005.7 lbs.), penta (7.86 lbs.), and No. 2 Diesel oil as the carrier (86.41 lbs.) (derived from MSDS by Koppers, 2006). The total weight of the pole was 3,100 lbs. (L. Lonning, 2007, Personal Communication), yielding a percentage composition as follows: WRC, 96.96 percent; penta, 0.3 percent; and No. 2 Diesel oil, 2.8 percent. Battelle also assumed that upon disposal the materials of construction of the pole could not be separated in an economically feasible manner. This assumption eliminates any potential for recycling the pole (Felton and DeGroot, 1996). Based on an average of the service life predicted by utilities and estimates calculated from replacement rates, it is estimated that the Penta-WRC poles would have a service life of 61-80 years with retreatment (Mankowski et al., 2002; WWPI, 1997).

Penta-Treated Southern Yellow Pine Poles

The Penta-SYP pole was comprised of three materials: SYP wood (5,234 lbs.), penta (8.66 lbs.), and No. 2 Diesel oil as the carrier (95.2 lbs.) (derived from MSDS by Koppers, 2006). The total weight of the pole was 5,338 lbs. (J. Healy, 2007, Personal Communication), yielding a percentage composition as follows: SYP, 98.1 percent; penta, 0.2 percent; and No. 2 Diesel oil, 1.8 percent. Battelle also assumed that upon disposal the materials of construction of the pole could not be separated in an economically feasible manner. This assumption eliminates any potential for recycling the pole (Felton and DeGroot, 1996). Based on an average of the service life predicted by utilities and estimates calculated from replacement rates, it is estimated that the Penta-SYP poles would have a service life of 41-60 years with retreatment (Mankowski et al., 2002; WWPI, 1997; EPRI, 2003).

Galvanized Steel Poles

The galvanized steel pole is comprised of three materials: steel (1,599 lbs.), zinc (the galvanizing) (105 lbs.), and polyurethane (additional protection for the buried portion of the pole) (7 lbs.) (B. Benest, 2007, Personal Communication). The two sections of Valmont’s 80-foot, thin-walled, galvanized steel pole are 45 feet (top) and 37.5 feet (butt). The total pole weight is 1711 lbs., yielding a percentage composition as follows: steel, 93.5 percent; zinc, 6.1 percent; and polyurethane, 0.4 percent. Battelle chose a pole galvanized inside and out because these poles are thought to be more prevalent, but weathering steel and painted poles were also options. The polyurethane coating is an option and the manufacturers recommend it for all but very limited cases to help minimize corrosion caused by acidic soils.

The average service life of 61-80 years estimated for galvanized steel poles in this evaluation assumed that (1) the protective coating was not damaged in shipping, handling or installation; (2) a below grade corrosion mitigation program was implemented during the life of the steel poles; and (3) the poles were installed in moderately- or non-corrosive soils. Zinc does a good job of providing long term protection in moderately corrosive and oxidizing soils (Zamanzadeh et al., 2006). On the other hand, in corrosive or highly corrosive soils, even maintenance of coating and use of corrosion resistant backfill may only bring the life expectancy to 50 years. Galvanized steel utility poles have been in use for about 50 years and there is a historical record for related structures like buildings and bridges, which have survived in similar environments for well over 100 years. In addition, two life cycle studies comparing different utility pole types made the assumption that the average service life of galvanized steel is more than 80 years (Erlandsson et al., 1992; EDM, 1997)

Zinc is generally co-mined with lead, leading to some residual levels of lead in the zinc galvanizing. This level is typically less than one percent of the zinc, and so here would represent on the order of 1 lb. lead per pole, comprising on the order of 0.06 percent lead by weight. For this reason and because it is a contaminant in, and not a product of, the galvanizing compound, lead was ignored in the assessment.

4
UNWEIGHTED INDIVIDUAL CRITERIA SCORES COMPARED AMONG POLE TYPES

Engineering/Technical Performance Criteria

The unweighted individual scores for the eight Engineering/Technical Performance criteria are compared and rank ordered in the sections below among the four transmission pole types evaluated using the CST. The unweighted, individual scores for all 26 CST criteria are shown in Table 4-1.

Expected Service Life with Maintenance

Assuming regular maintenance, the one non-wood pole type (galvanized steel with polyurethane butt treatment) and the Penta-WRC pole type are both estimated to have average service lives of 61-80 years. The average service life of 61-80 years estimated for galvanized steel poles in this evaluation assumed that (1) the protective coating was not damaged in shipping, handling or installation; (2) a below grade corrosion mitigation program was implemented during the life of the steel poles; and (3) the poles were installed in moderately- or non-corrosive soils. Zinc does a good job of providing long term protection in moderately corrosive and oxidizing soils (Zamanzadeh et al., 2006), but in corrosive or highly corrosive soils, even maintenance of coating and use of corrosion resistant backfill may only bring the life expectancy to 50 years. Based on an average of the service life reported by utilities and estimates calculated from replacement rates, it is estimated that the Penta-WRC poles would have a service life of 61-80 years with retreatment and Penta-SYP and CuNap-DF poles would have a service life of 41-60 years (Mankowski et al., 2002; WWPI, 1997; EPRI, 2003). The rank order of scores for the four transmission pole types from lowest to highest is: CuNap-DF = Penta-SYP < Penta-WRC = Galvanized Steel.

Regulatory and Treated-Wood Registration Status

For the criterion Regulatory and Treated-Wood Registration Status, the rank order of scores for the four transmission pole types from lowest to highest is Penta-WRC = Penta-SYP < CuNap-DF = Galvanized Steel. The two Penta-treated wood types were given the lowest score, since Penta is a restricted use pesticide (RUP), burning of Penta-treated wood for energy recovery requires a boiler permitted to meet Clean Air Act emission restrictions, and penta is considered highly toxic to aquatic biota. EPA is scheduled to complete the Reregistration Eligibility Decision (RED) for Penta by the end of 2007.

Table 4-1
Matrix of Unweighted, Individual Scores for 26 Criteria by Four Pole Types

Criterion	CuNap-DF	Penta-WRC	Galvanized Steel	Penta-SYP
Service Life with Maintenance	5.0	7.0	7.0	5.0
Regulatory Status	7.0	5.0	7.0	5.0
Emergency Field Procedures	9.0	9.0	7.0	9.0
Equipment Requirements for Transport to Job Site/Install/Removal	7.0	7.0	9.0	7.0
Handling Protection	9.0	9.0	7.0	9.0
Grounding	9.0	9.0	1.0	9.0
Weight/Number for Bulk Transport	7.0	7.0	9.0	7.0
Hardness	9.0	9.0	3.0	9.0
Acquisition Cost	7.0	3.0	7.0	5.0
Transportation Cost	5.0	5.0	5.0	5.0
Installation Cost	5.0	5.0	5.0	5.0
Maintenance Cost	5.0	1.0	5.0	5.0
Disposal Cost	9.0	5.0	9.0	5.0
Reuse or Recycle Cost	5.0	5.0	9.0	5.0
Resource Renewability or Sustainability	5.0	4.9	2.9	4.9
Raw Materials Infrastructure	9.0	9.0	8.9	9.0
Manufacturing Capacity	5.0	9.0	3.0	3.0
Acidification Potential	9.0	9.0	2.2	9.0
Carcinogenicity	6.0	5.8	6.1	5.8
Ecological Habitat Alteration	3.0	3.1	3.0	3.1
Energy Use	9.0	8.9	6.6	9.0
Global Warming Potential	9.0	9.0	5.0	9.0
Inhalation Toxicity	5.0	3.0	5.0	3.0
Smog Creation Potential	3.0	3.0	3.8	3.0
Recyclability Potential	3.0	3.0	8.6	3.0
Toxic Material Mobility	3.2	5.0	9.0	5.0

Adaptability of Field Procedures and Hardware for Emergencies

For the criterion Adaptability of Field Procedures and Hardware for Emergencies, the rank order of scores for the four transmission pole types from lowest to highest is: galvanized steel < Penta-WRC = Penta-SYP = CuNap-DF. The highest scores are given to the three types of treated wood poles, because standard galvanized fasteners, drill, bit, and wrenches can be used. Galvanized steel was given the lowest score, because carbide-tipped drill bits are required to drill holes in the field and cold galvanization is needed on the hole.

Equipment Requirements for Transport to Job Site/Install/Removal

For the criterion Equipment Requirements for Transport to Job Site/Install/Removal, the rank order of scores for the four transmission pole types from lowest to highest is: Penta-WRC = Penta-SYP = CuNap-DF < Galvanized Steel. The highest score is given to galvanized steel, because the poles come in two sections and can be transported on a multiple axle, regular length, flatbed tractor-trailer and cab to the pole site, installation equipment requires very little adaptation except use of webbed straps. The three types of treated wood poles are given the lowest score, because the 80-foot poles must be carried by a multiple axle, extra-long, flatbed tractor-trailer and cab accompanied by an over length load support vehicle. In the Pacific Northwest, both galvanized steel and treated wood poles are often transported to the job site in a Pierce trailer with stinger-steer rear wheels that can be remotely steered separately from the truck cab (D. Swanson, 2007, Personal Communication). A digger derrick (boom truck) is used to offload steel poles from a Pierce trailer.

Handling Protection to Avoid Damage

For the criterion Handling Protection to Avoid Damage, the rank order of scores for the four transmission pole types from lowest to highest is: Galvanized Steel < Penta-WRC = Penta-SYP = CuNap-DF. The highest score is given to the three types of treated wood poles, because no handling protection is required and steel cables and chains are acceptable for binding, choking, and lifting. The lowest score is given to galvanized steel, because it requires limited protection, including blocking (cribbing to maintain separation) during transport and careful handling with webbed straps during installation to avoid dents.

Grounding

For the criterion on Grounding, the rank order of scores for the four transmission pole types from lowest to highest is: Galvanized Steel < Penta-WRC = Penta-SYP = CuNap-DF. The highest score is given to the three types of treated wood poles, because current grounding procedures and equipment are sufficient to ensure adequate grounding. The lowest score goes to galvanized steel (with a polyurethane coated butt), because grounding is recommended using grounding plates and rods (NRECA, 1999; EPRI, 2005c).

Weight/Number for Bulk Transport

For the criterion on Weight/Number for Bulk Transport, the rank order of scores for the four transmission pole types from lowest to highest is: Penta-SYP = CuNap-DF = Penta-WRC < Galvanized Steel. The highest score is given to galvanized steel, since the weight of these 80-foot, Class 2 transmission poles is much lower than equivalent wood poles and the thin-walled, steel poles come in two sections. This means the steel poles can be transported to the pole yard on a multiple axle, regular length, flatbed tractor-trailer and cab without the need for an over length support vehicle. The lowest score is given to the three treated-wood pole types, since their weight is much greater than equivalent steel poles and because the 80-foot, Class 2 transmission poles must be carried by a multiple axle, extra-long, flatbed tractor-trailer and cab accompanied by an over length load support vehicle.

Hardness

For the criterion on Hardness, the rank order of scores for the four transmission pole types from lowest to highest is: Galvanized Steel << Penta-SYP = CuNap-DF = Penta-WRC. The highest score is given to the three treated-wood pole types, because they have a relatively low Janka hardness and are easy to climb and drill. The lowest score is given to galvanized steel, because steel poles require climbing steps or a bucket truck and carbide-tipped drill bits are required to drill holes in the field.

Life Cycle Cost/Economics Criteria

The unweighted individual scores for the nine Life Cycle Cost/Economics criteria are compared and rank ordered in the sections below among the four transmission pole types evaluated using the CST. Note that most of the economic criteria are relative cost criteria with the baseline pole, in this case Penta-SYP, receiving a moderate score (5), with lower cost poles receiving higher scores and vice versa. Much useful background information was derived from reports by NYSEG (1997) and EDM (1997) for the Western Wood Preservers Institute, but due to the age of the data from the 1997 reports, they were only able to provide trends and historical information. Current or recent cost data for some of the criteria were obtained by personal communication with the pole manufacturers.

Acquisition Costs at Pole Yard (pole, liner, sleeve, cross arms, hardware, and transport to yard)

For the wood poles, the primary cost driver was the cost for the pole and not transportation to the utility. Since, for the example, the transportation distance was assumed equal, and the wood poles all required special transportation arrangements, the transportation costs were very similar, varying only because of the number of poles transported per load. The transportation for this demonstration was assumed to be all by truck, since that was how the quotations were provided by the manufacturers. Transport by rail or other potentially less expensive transportation alternatives may be more typical in some situations, but were not evaluated. The galvanized steel poles are one of the more expensive poles, but transportation costs are much less, hence an overall lower acquisition cost. The rank ordering of the four transmission poles from lowest to highest is: Penta-WRC < Penta-SYP < CuNap-DF = Galvanized Steel.

Storage and Transportation Costs from Pole Yard to Installation Site

Very little was found either in the published literature or through personal communications on storage and transportation costs from pole yard to the installation site. The assumptions for this demonstration were that each pole type was stored on a rack, for better access and protection, and that the pole yard or storage site was paved and precipitation runoff was collected and treated prior to release. Steel poles will require cradles lined with webbing for support during transportation, but this cost was assumed to be offset by the over-sized load charges incurred in transporting wood poles to the installation site. A rough estimate on the magnitude of the costs was made for this demonstration, but the utility using this decision tool is cautioned to closely look at their particular situation. The rank ordering is essentially equal for the four transmission poles (CuNap-DF = Penta-WRC = Penta-SYP = Galvanized Steel).

Installation Costs

As with storage and transportation costs, there is very little information available on differences in installation costs due to pole type. Anecdotal information suggests that the equipment used is more than capable of placing any of the four pole types studied here. Steel poles can be pre-drilled by the manufacturer for a variety of construction needs, so typically no field additions are needed (Valmont-Newmark, 2006, Personal Communication; M. Schwenger, 2006, Personal Communication), and this may lead to a lower installation cost. The wood poles may require more time to lift and place, but this is offset by the time required to piece together the steel poles, which come in sections, and the additional time for testing of the pole location to assay the soil corrosivity. The rank ordering is essentially equal for the four transmission poles (CuNap-DF = Penta-WRC = Penta-SYP = Galvanized Steel).

Maintenance Costs During Pole Use (retreatment, inspection)

Maintenance costs were comprised of two primary components, a periodic physical inspection, and any required in-field retreatment. All pole types require some type of periodic inspection. For this demonstration, the wood poles and non-wood poles were assumed to require similar inspection and retreatment intervals (EPRI, 2003, and Zamanzadeh et al., 2006). Wood poles may require a periodic retreatment, approximately every 10 years, beginning at 20 years of service life, in order to maintain optimum performance. Other studies have reported longer retreatment intervals for steel poles. For example, NYSEG (1997) assumed that galvanized steel required treatment about every 20 years, while wood poles were assumed to need retreatment every 10 years starting after 20 years. The costs assumed by NYSEG (1997) for treatment of galvanized steel poles and treated-wood poles were about the same cost per treatment, but were required more often for treated-wood poles. For this demonstration, maintenance costs are based on the expected service life of the pole and are not calculated on an annualized basis. The rank ordering from lowest to highest scoring transmission poles is: Penta-WRC < Penta-SYP = CuNap-DF < Galvanized Steel.

Disposal Costs

Disposal costs are also comprised of two primary components: physical removal of the pole and restoration or remediation of the pole site (the soil surrounding the pole hole). For penta-treated wood poles, there is a small probability that the removal of the pole will require the pole site to be treated as a hazardous waste site, thus requiring remediation (most likely removal of the surrounding soil to the depth of the hole) (EPRI, 2003). This remediation can be very costly and is the primary driver in disposal cost differences between the four pole types studied. For either steel or CuNap-DF poles, there are no expected remediation costs. If remediation of the hole for the penta-treated poles is required, the cost for remediation alone will far exceed the total of all other pole costs. The rank ordering from lowest to highest scoring transmission poles is: Penta-WRC = Penta-SYP << CuNap-DF = Galvanized Steel.

Recycle or Reuse Costs

As with transportation, installation, maintenance and disposal costs, there was sparse anecdotal evidence and little concrete information about recycle or reuse costs (EPRI, 2005c; M. Schwenger, 2006, Personal Communication). The primary cost driver is the expected need for some type of pole preparation and/or inspection prior to releasing the pole to the next user. After some consideration, that cost is not expected to be significantly different for any of the poles relative to the others. Since steel poles are likely to generate income upon recycling (Web site for SRI, 2006; Valmont-Newmark, 2006, Personal Communication), the cost was judged to be lower than for the other pole types, where no income is expected. The rank ordering of the four transmission poles from lowest to highest scoring is: CuNap-DF = Penta-WRC = Penta-SYP << Galvanized Steel.

Resource Renewability/Sustainability (including future raw material availability)

The criterion Resource Renewability/Sustainability is influenced by both the estimated reserve base of a material and the most current production or withdrawal statistics. These values were taken from the Minerals Yearbook (Web site for USGS, 2007). In almost all cases, the criterion scores were heavily influenced by the lack of renewable resources. (Sustainable minerals receive a score of at best 5.) The score for steel was much lower than the other pole types because of both the low sustainability of steel, and the very low sustainability of both the zinc (galvanic coating) and the polyurethane coating (petroleum-based). The rank ordering of the four transmission pole types from lowest to highest scores is: Galvanized Steel << CuNap-DF = Penta-WRC = Penta-SYP.

Raw Materials Delivery Infrastructure

Scores for the Raw Materials Delivery Infrastructure criterion tended to be very high for the pole types evaluated, being dominated by the base materials which are always available in good supply (wood and steel). The scores for many of the minor constituents (or active ingredients in the case of the treated wood poles), tends to be much lower, but since these materials are used in such small weight fractions their scores do not have much influence on the score for the entire pole. In evaluation of this criterion, extensive use was made of the CIA World Factbook (Web site for CIA, 2006), making judgments based on information on stability of the government and state of development of the infrastructure. All four transmission poles have essentially the same score (CuNap-DF = Penta-WRC = Penta-SYP = Galvanized Steel).

Manufacturing Capability (pole supply and available facility output)

Scores for the Manufacturing Capability criterion are heavily influenced by the commonality of the combination of wood and treatment type. Penta-WRC poles are very common, in at least some parts of the country, and so manufacturing capacity exists to furnish or replenish stocks. CuNap-DF poles are very high demand items at the moment but manufacturing capacity has not built to meet demand, so these poles were scored much lower. A similar situation is found for steel poles, where capacity within the steel industry exists, but is currently focused on building products because steel pole demand has historically been low. The steel pole industry likely will require more than 10 years before obtaining the equivalent capacity of the wood pole production industry, based on what we found for concrete poles (M. Schwenger, 2006, Personal Communication). For these large transmission poles wood poles may also be limited in the supply of trees of the required height, especially for some species (e.g., SYP) for which these heights may represent the upper limits of growth. The rank order of the four transmission pole types from lowest to highest is: Galvanized Steel = Penta-SYP < CuNap-DF << Penta-WRC.

Environmental Criteria

The unweighted individual scores for the nine Environmental criteria are compared and rank ordered in the sections below among the four transmission pole types evaluated using the CST.

Acidification Potential

For the criterion on Acidification Potential (AP), the rank order of scores for the four transmission pole types from lowest to highest is: Galvanized Steel << CuNap-DF = Penta-WRC = Penta-SYP. The highest scores are given to the three treated-wood pole types, since there are no emissions during their life cycle that contribute to AP. The lowest score is given to galvanized steel, because manufacturing of galvanized steel results in the release of several chemicals that have an average AP score of 2.2.

Carcinogenicity

For the criterion on Carcinogenicity, the rank order of scores for the four transmission pole types is essentially equal: Penta-WRC = Penta-SYP = CuNap-DF = Galvanized Steel. The lowest scores are given to the two penta-treated pole types, since Penta is emitted in air and water from Penta wood treating facilities and it is highly carcinogenic. Dioxin is also released in air and water from Penta wood treating facilities. However, the dioxin congeners emitted include several that are IARC Group-3 (inadequate evidence of carcinogenicity in humans) and exclude the highly carcinogenic congener, 2,3,7,8,- Tetrachlorodibenzo[b,e][1,4]dioxin (H.M. Rollins Company, Inc., 2005). The average carcinogenicity scores for chemicals released during manufacture and use of CuNap-DF and galvanized steel poles are not substantially different from the two penta-treated pole types (i.e., the difference in raw scores between any of the pole types is less than 1.0).

Ecological Habitat Alteration

The criterion score for Ecological Habitat Alteration is the same for all four transmission pole types: Penta-WRC = Penta-SYP = CuNap-DF = Galvanized Steel. Although forests support different wildlife species during different stages of succession, the mature forest logged for transmission poles supports a unique group of wildlife that do not return to the forest until it returns to the mature forest stage of succession occurring before logging. The typical number of years required to grow trees to the size needed for 80-foot, Class 2 transmission poles varies depending on local growing conditions, but is roughly estimated to be 55-70 years for WRC and DF in the Pacific Northwest (J. Cahill, 2007, Personal Communication) and 80-100 years for SYP grown in the Southeast (J. Zak, 2007, Personal Communication). Southern pines this large are typically found in unmanaged stands which produce more slowly than managed stands that aren't grown for much longer than 35-50 yrs. For this demonstration, it was assumed that the three wood pole types did not come from forests sustainably managed for biodiversity, since only about 25% of private forestland in the United States has been certified for sustainability by one of three organizations (Alverez, 2007). More than 97% of the steel used to make structural steel, including steel utility poles, is recycled (Web site for SRI, 2006) and, therefore, does not come from strip mines. The acquisition of raw materials for each of these pole types, including harvesting trees for transmission poles and mining of metals for treatment chemicals, result in Ecological Habitat Alteration scores of 3 to 3.1.

Energy Use

As might be expected, the wood poles scored exceptionally well, due to the high content of wood that has a very low energy density (energy use per mass of product). The steel poles scored poorly due to the high content of highly refined materials (i.e., steel and zinc for galvanizing), which tend to be energy intensive. The rank order of the four transmission pole types from lowest to highest score is: Galvanized Steel << CuNap-DF = Penta-WRC = Penta-SYP.

Global Warming Potential

For the criterion on Global Warming Potential (GWP), the rank order of scores for the four transmission pole types from lowest to highest is: Galvanized Steel << CuNap-DF = Penta-WRC = Penta-SYP. The three treated-wood poles score much better than the Galvanized Steel poles, since they release almost no global warming gases during manufacture, and carbon is actually sequestered in the trees during growth and in the wood pole during use. During manufacturing, galvanized steel poles release the major criteria pollutant CO_2, which has an intermediate GWP score after applying the score modifier.

Inhalation Toxicity

For the criterion on Inhalation Toxicity, the rank order of scores for the four transmission pole types from lowest to highest is: Penta-WRC = Penta-SYP < Galvanized Steel = CuNap-DF. The lowest scores are given to the two Penta-treated wood poles, since Penta and dioxin are emitted in air during manufacture at Penta wood treating facilities and these chemicals have high inhalation toxicities (low scores).

Smog Creation Potential

For the criterion on Smog Creation Potential, the rank order of scores for the four transmission pole types from lowest to highest is: Penta-WRC = Penta-SYP = CuNap-DF < Galvanized Steel. The lowest scores are given to the three treated-wood pole types, because the pollutants naphthalene and Penta emitted during manufacturing of the three treated-wood poles have slightly lower Smog Creation Potential scores compared to the average score for pollutants released during manufacturing of Galvanized Steel poles even after applying the score modifier for criteria pollutants.

Recyclability Potential (Post-consumer)

The Recyclability Potential criterion recognizes products which can be reclaimed and reprocessed into high value products (which are manufactured of recyclable materials). The score is based on two factors: the size of the market or volume recycled, and existence of an infrastructure. Galvanized steel poles receive the best score because they are commonly recycled into high value products (Web site for SRI, 2006). Materials that are not commonly recycled, such as concrete, or for which there is little or no infrastructure, such as treated wood, receive lower scores.

For many treated wood products, Felton and DeGroot (1996) indicate that the infrastructure for recycling is lacking. This is compounded by regulatory concerns given the toxic or hazardous nature of some of the preservatives, which tends to limit the commercial recycling market. The access to reuse and recycling programs for any of the treated-wood poles is still very locale-specific, which may make any general scoring of Recyclability, such as was performed here, incorrect for a specific utility. Reuse of treated-wood poles through public donation, burning wood or plastic for the fuel value, or reuse of concrete as rip rap or fill are not considered recycling. The rank order of the four transmission pole types had increasing scores in the following order: CuNap-DF = Penta-WRC = Penta-SYP << Steel.

Toxic Material Mobility upon Landfilling or Incineration

For the Toxic Material Mobility criterion, the expected rate at which material migrates from an incinerator or a landfill is based on the aqueous solubility for landfilled poles or the Henry's Law constant for incinerated poles. However, more information is needed regarding direct measurement of the mobility of toxic materials from poles disposed of in landfills. The toxic materials in the galvanizing of steel poles, including zinc, are not expected to migrate in landfill leachate due to their low aqueous solubility, so steel poles were given a score of 9. Copper has a greater aqueous solubility than penta, which has a greater aqueous solubility than zinc. Thus, the rank order of scores for the four transmission pole types from lowest to highest is: CuNap-DF < Penta-WRC = Penta-SYP << Steel.

5
PRIORITY WEIGHTING OF DECISION CRITERIA

Weighting Demonstration Panel

In order to demonstrate the priority weighting process, Battelle convened a demonstration panel of 10 selected representatives that have a combined familiarity with the categories of interest and the transmission poles being evaluated. The demonstration panel was composed of utility personnel (Department of Energy, private utilities, and public utilities) and EPRI contractors, meeting via a Web Conference. The approach was to first apply priority weights to the three major scoring categories (i.e., life cycle cost/economic, engineering/ technical performance, and environmental profile). Then, the team assigned priority weights for the 26 individual scoring criteria that fit under each of these three major categories.

The purpose of the panel was to demonstrate the priority weighting process and provide examples of reasonable results. The resulting priority weights may not be the best fit for all utilities, due to location specific differences, such as proximity to pole manufacturing facilities, soil types, and environmental conditions. However, an individual utility can use the same weighting procedures described for this demonstration to tailor the criteria weighting factors to emphasize their own unique priorities.

Use of AHP and Expert Choice® Software

The Analytic Hierarchy Process (AHP) is a systematic decision support procedure in which a team of experts can assign relative priority to selected criteria of interest. The advantages of the AHP method include the structured nature–the hierarchy–and the fact that the valuation process does not deal with the entire set of scoring criteria at one time, an effort that can be overwhelming, but only with comparing two criteria at a time. The analytic function computes weighting factors from the preferences expressed in the pair-wise comparisons.

Priority weights for the environmental criteria were developed using a software package called Expert Choice™. In addition to computing the weighting factors, the software performed a number of consistency checks on the preferences expressed by the demonstration panel. The Expert Choice, Inc. (Web site for Expert Choice, 2006) provides the following description of the capabilities of the software:

> "At the heart of Expert Choice's solutions is our powerful group decision support software application – Expert Choice 11. Based on the Analytic Hierarchy Process (AHP) and over 20 years of input from thousands of customers, EC provides you with the leading decision

support application used by more than 15,000 users in over 60 countries to help you and your organization achieve:

- Better, faster, more justifiable decisions,
- Organizational and strategic alignment,
- A structured decision-making approach,
- Consensus and improved communication,
- An improved bottom line.

EC11 provides a simple, easy- to-use interface that guides you and your group through the process of:

- Structuring your decision into objectives and alternatives,
- Measuring your objectives and alternatives using pair-wise comparisons,
- Synthesizing objective and subjective inputs to arrive at a prioritized list of alternatives, taking care of all the heavy mathematical lifting."

Results of Weighting for Two Hierarchy/Perspective Combinations

As with earlier studies for EPRI (2005a and 2006), a set of priority weights (based on relative importance determined by the demonstration panel) was developed from two different perspectives. These include an "Electric Utility" perspective that emphasizes the issues of more concern to electric utilities such as technical performance and economics and a "National Policy" perspective that emphasizes the global issues of concern to national policy makers which might include reliability, economics and environmental impact. The results of the weighting exercises are presented in Figures 5-1 and 5-2 and Table 5-1.

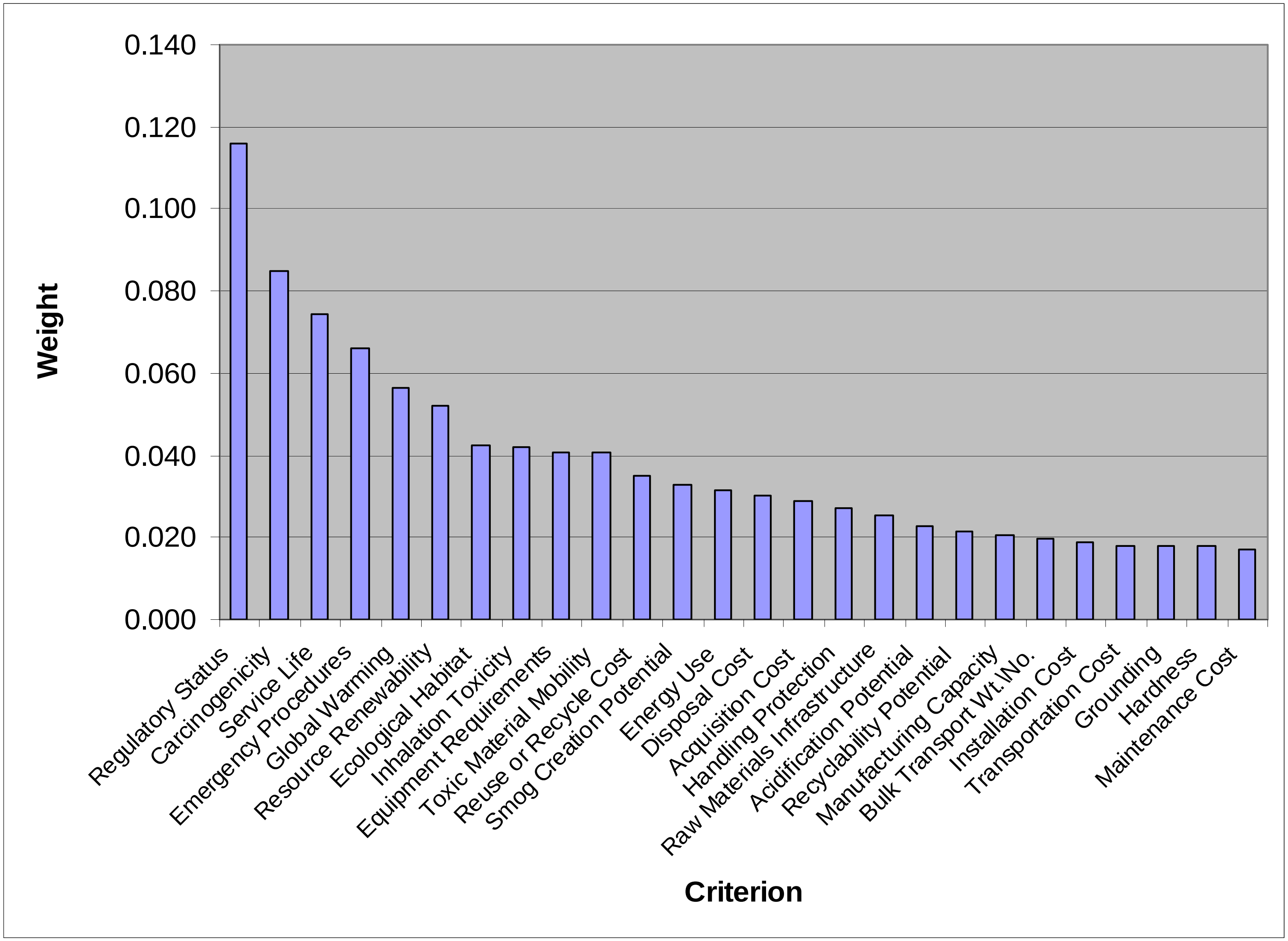

Figure 5-1
National Policy Perspective Priority Weighting

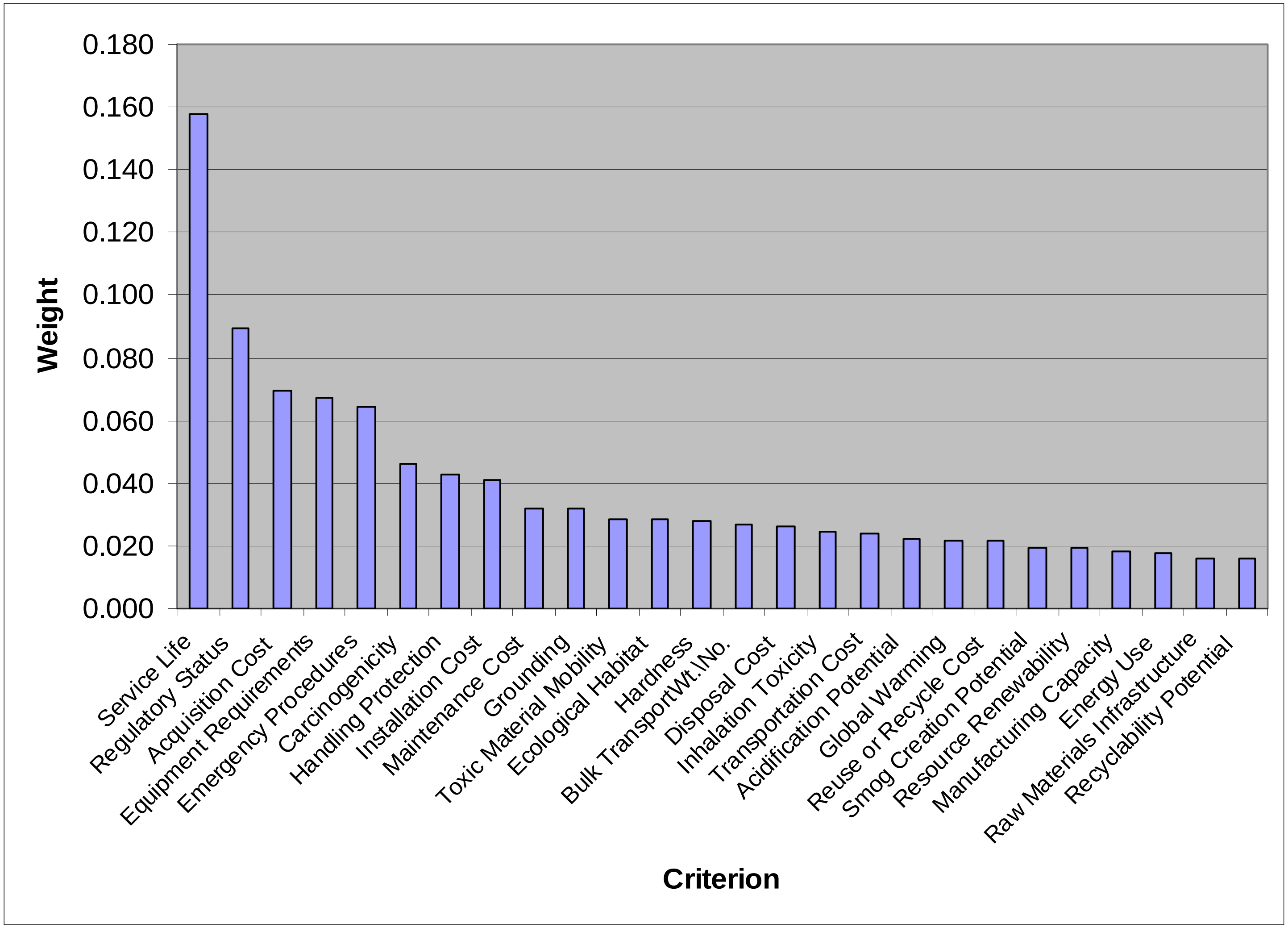

Figure 5-2
Electric Utility Perspective Priority Weighting

Table 5-1
Matrix of AHP Priority Weighting for 26 Criteria by Two Perspectives

Criterion	Policy Perspective	Utility Perspective
Engineering and Technical Performance	**0.379**	**0.509**
Service Life with Maintenance	0.074	0.158
Regulatory Status	0.116	0.090
Emergency Field Procedures	0.066	0.064
Equipment Requirements for Transport to Job Site/Install/ Removal	0.041	0.067
Handling Protection	0.027	0.043
Grounding	0.018	0.032
Weight/Number for Bulk Transport	0.020	0.027
Hardness	0.018	0.028
Life Cycle Cost and Economics	**0.246**	**0.268**
Acquisition Cost	0.029	0.070
Transportation Cost	0.018	0.024
Installation Cost	0.019	0.041
Maintenance Cost	0.017	0.032
Disposal Cost	0.030	0.026
Reuse or Recycle Cost	0.035	0.021
Resource Renewability or Sustainability	0.052	0.019
Raw Materials Infrastructure	0.025	0.016
Manufacturing Capacity	0.020	0.018
Environmental	**0.375**	**0.224**
Acidification Potential	0.023	0.022
Carcinogenicity	0.085	0.046
Ecological Habitat Alteration	0.043	0.028
Energy Use	0.032	0.017
Global Warming Potential	0.056	0.021
Inhalation Toxicity	0.042	0.025
Smog Creation Potential	0.033	0.020
Recyclability Potential	0.021	0.016
Toxic Material Mobility	0.041	0.028

6
OVERALL WEIGHTED, TOTAL SCORES COMPARED AMONG POLE TYPES

Overall Weighted, Total Score Calculation and Limitations

The weighted, total scores for each of the treated wood and non-wood pole types are presented in Table 6-1. These weighted, total scores were calculated by multiplying each of the raw criteria scores by the weighting factor and then summing all weighted criteria scores for a given distribution pole. In general, weighted, total scores that vary by less than one can be considered equivalent when making comparisons.

Table 6-1
Overall Weighted, Total Scores for Four Pole Types Evaluated

Perspective	CuNap-DF	Penta-WRC	Galvanized Steel	Penta-SYP
Electric Utility	6.4	6.1	6.2	5.9
National Policy	6.5	6.1	6.3	6.0

The weighted, total scores should not be used without understanding their limitations and advantages. Although weighted scores are based on accepted procedures to calculate weights (see Section 5), the limitation is that they can be subjective, because they represent the preferences of the demonstration panel who may not offer a valid statistical sample of the population. For this demonstration, the panel was composed of utility personnel and EPRI contractors from different regions of the U.S., so their average priority weights may not emphasize regional issues specific to a particular utility. However, an individual utility can use the same priority weighting process described for this demonstration to tailor the criteria weighting factors, and thus the total weighted score, to emphasize their own unique priorities.

Also, weighted scores are only as accurate as the source data used to determine the impact criteria raw scores. As indicated in Section 4, although some life cycle cost data are based on current known acquisition costs from manufacturers (J. Passadore, 2007, Personal Communication; L. Lonning, 2007, Personal Communication; J. Healy, 2007, Personal Communication; B. Benest, 2007, Personal Communication) and life cycle costs from recent reports (EPRI, 2003 and 2005b). Other life cycle costs were estimated based on expert opinion (D. Swanson, 2007, Personal Communication; D. Leavitt, 2007, Personal Communication; M. Schwenger, 2006, Personal Communication; T. Gentile, 2006, Personal Communication) and/or outdated cost data (NYSEG, 1997; EDM, 1997).

There are also advantages to using the weighted, total scores. Weighting the scores permits them to be summed for easier comparison over all 26 of the engineering performance, life cycle cost, and environmental criteria, particularly when different criteria do not always favor a single pole type. Evaluating weighted, total scores based on two different perspectives (i.e., Electric Utility and National Policy) insures acceptance by a broader range of stakeholders.

Electric Utility Perspective

For this demonstration, the five criteria given the highest priority weighting in the Electric Utility Perspective (see Figure 5-2 and Table 5-1) were Service Life, Regulatory Status, Acquisition Cost, Equipment Requirements for Transport to Job Site/Install/Removal, and Emergency Field Procedures. These five criteria represent 44.9% of the priority weighting. Based on the available data for scoring the criteria, the overall weighted total scores do not show significant differences (a score difference of 1.0 or more) for the Electric Utility Perspective. Since none of the pole types had significant differences in the overall weighted score between the four pole types, it is not possible to develop a rank order for the Electric Utility Perspective, i.e., Penta-WRC = Penta-SYP = Galvanized Steel = CuNap-DF.

National Policy Perspective

For this demonstration, the five criteria given the highest priority weighting in the National Policy Perspective (see Figure 5-1 and Table 5-1) were Regulatory Status, Carcinogenicity, Service Life, Emergency Field Procedures, and Global Warming Potential. These five criteria represent 39.7% of the priority weighting. The raw scores for these criteria tended to offset each other for any given pole type, so that some of the five criteria scores were higher and some were lower for each of the four pole types. Thus, the overall weighted total scores do not show significant differences. Since none of the pole types had significant differences in the overall weighted score between the four pole types, it is not possible to develop a rank order for the National Policy Perspective, i.e., Penta-WRC = Penta-SYP = Galvanized Steel = CuNap-DF.

Sensitivity Analysis

A sensitivity analysis was conducted to examine the potential changes in the overall weighted scores that might result from more or better information, particularly life cycle cost information. We focused on the following criteria: Transportation Cost, Installation Cost, Disposal Cost, and Equipment Requirements for Transport to Pole Site\Installation\Removal.

The sensitivity analysis was conducted in two parts. In the first part, the overall change in the scores for one or more of these criteria were allowed to increase to the maximum (9) or decrease to the minimum (1), calculating the <u>maximum</u> potential change in the overall score (Figures 6-1 and 6-2). In the second part, the <u>likely</u> overall change in the score for each of the criterion was restricted to a maximum of 2 units from its current score, or to the values of 1 or 9, whichever resulted in the least change. Results for the Overall Pole Scores are presented in the following four figures. In each figure, the current score is shown as a diamond and the range in the score is shown with the vertical lines originating from each diamond.

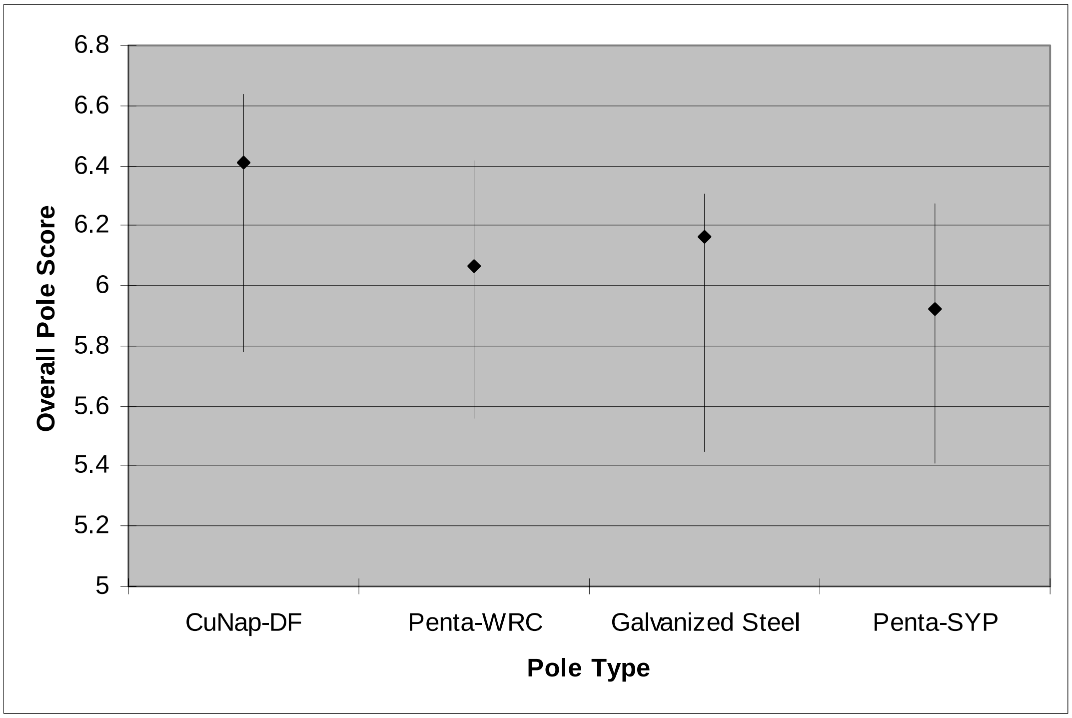

Figure 6-1
National Policy Perspective Sensitivity Analysis Maximum Overall Score Change

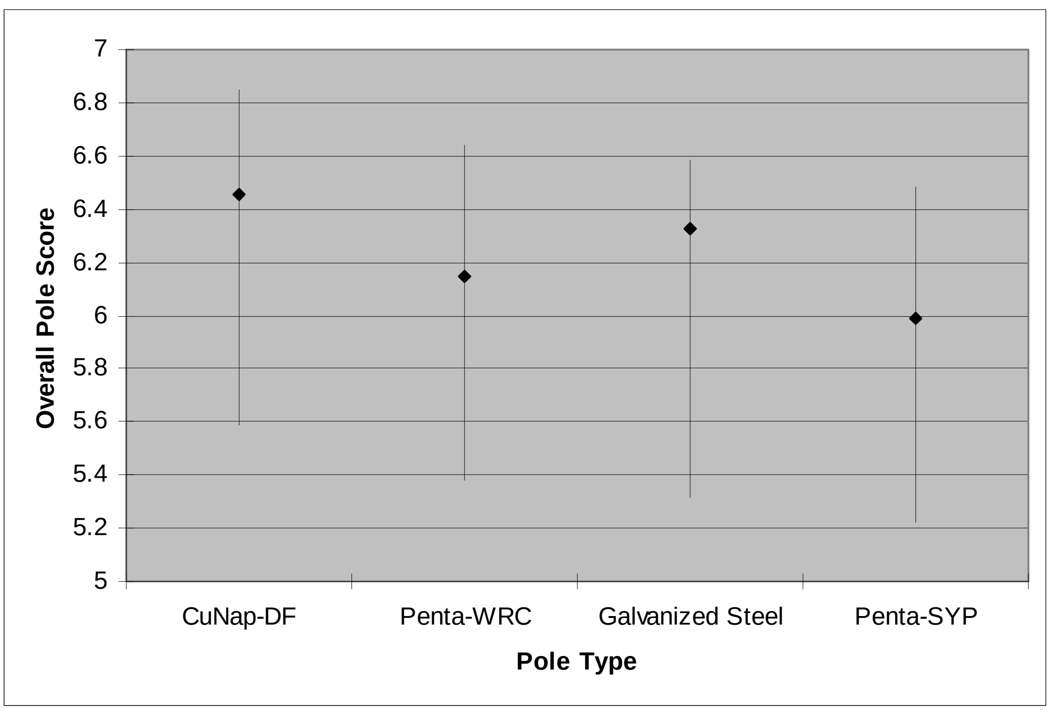

Figure 6-2
Electric Utility Perspective Sensitivity Analysis Maximum Overall Score Change

As can be seen in Figure 6-1, there is no significant difference in the sensitivity analysis results for the maximum overall score change between the pole types from the National Policy Perspective. However, it is possible that a significant difference (scores vary by greater than 1 unit) could occur between two pole types under the unlikely scenario where the score for one pole type increases to the maximum and the score for another pole type decreases to near the minimum. It takes the unlikely scenario where the CuNap-DF or Penta-WRC pole scores increase to the maximum in conjunction with the Penta-SYP pole scores decreasing to near the minimum scores for each of the four criteria examined for a significant difference to result.

As can be seen in Figure 6-2, again there is no significant difference in the sensitivity analysis results for the maximum overall score change between the pole types from the Electric Utility Perspective. However, it is possible that a significant difference (scores vary by greater than 1 unit) could occur between two pole types under the unlikely scenario where the score for one pole type increases to the maximum and the score for another pole type decreases to near the minimum. However, unlike for the National Policy Perspective, many combinations of maximal score increases and decreases are sufficient to create a significant difference between pole types.

As can be seen in Figure 6-3, as with the maximum overall score change results, there is no scenario of increases and decreases in criterion scores which would result in an overall score difference of greater than one. The conclusion from this sensitivity analysis is that for the poles evaluated and assumptions made there is most likely no difference between these pole types from the National Policy Perspective.

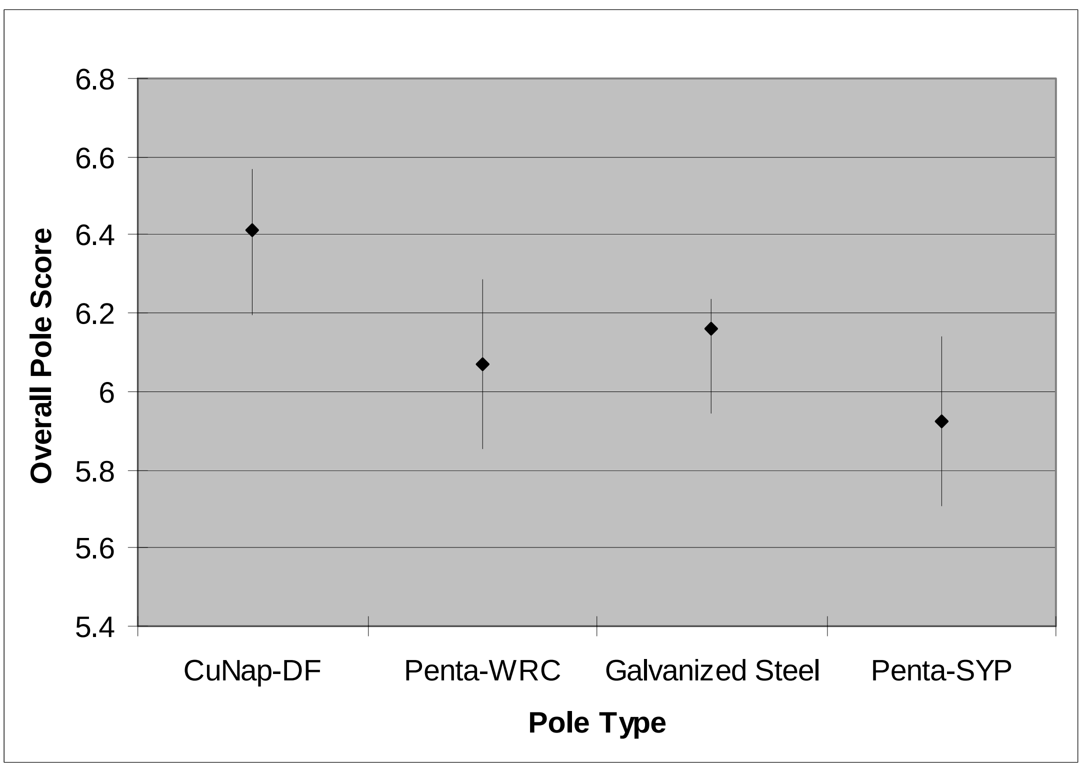

Figure 6-3
National Policy Perspective Sensitivity Analysis Likely Overall Score Change

Figure 6-4 illustrates the overall results of the likely change in overall scores for the Electric Utility Perspective. The original results showed no difference between the pole types (all scores less than one unit apart). However, using the same procedure and assumptions as for Figure 6-3, it is possible the Penta-SYP pole has significantly lower total score compared to the CuNap-DF pole, which is the preferable pole type. However, this happens only under the scenario in which all four criterion scores for the CuNap-DF pole increase by the maximum allowable 2 units and all four criterion scores for the Penta-treated pole decrease by the same amount.

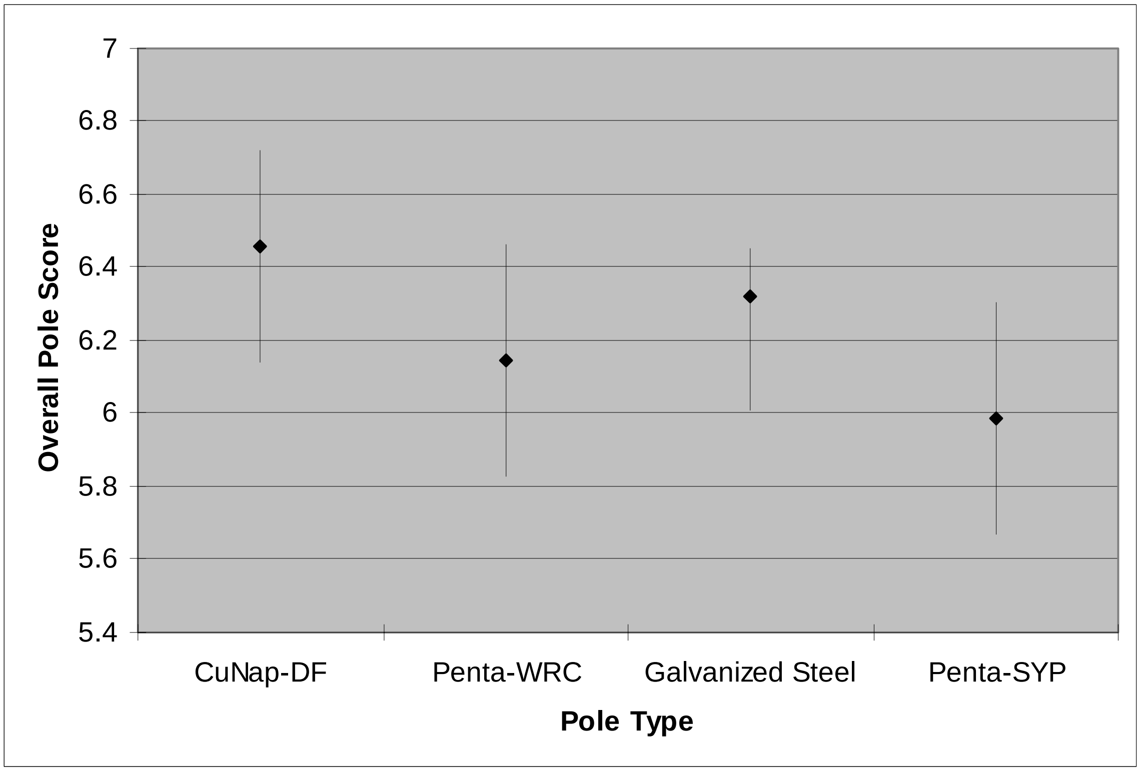

Figure 6-4
Electric Utility Perspective Sensitivity Analysis Likely Overall Score Change

7
DISCUSSION ON POTENTIAL USEFULNESS OF APPROACH TO UTILITIES

Ability to Differentiate Scores among Pole Types

Overall the CST is very good at differentiation of the four transmission pole types evaluated when comparing selected raw (unweighted) individual scores. When comparing the individual raw scores within a single criterion, at least one of the four pole types is significantly different than one or more of the other pole types by a difference of 1.0 or greater in 20 of the 26 criteria. No significant differences in scores were found between the four pole types evaluated for the remaining six criteria, i.e., Transportation Cost, Installation Cost, Raw Materials Infrastructure, Carcinogenicity, Ecological Habitat Alteration, and Smog Creation Potential.

The CST has limited ability to differentiate between the transmission pole types evaluated for the following three life cycle cost/economic criteria: Transportation Cost, Installation Cost, and Reuse or Recycle Cost. Due to the lack of quantitative life cycle cost data and the reality that these operations may not be as different between the four types of poles as perceived when the criteria were developed, it may be useful in the future to consider reevaluating these economic criteria to either change the scoring system, or to consider combining or eliminating some or all of these three life cycle cost criteria.

For the four transmission pole types used in this demonstration, the overall weighted scores did not show significant differences among pole types using criteria weights under either the Electric Utility or the Public Policy Perspectives. However, based on the overall weighted scores from demonstration of the CST on distribution poles (EPRI, 2006), it is very likely that one or both of the two perspectives could show significant differences in the overall weighted scores if other transmission pole types (e.g., creosote- treated wood, CCA-treated wood, or concrete) were included in the demonstration.

Usefulness as a Decision Tool

As indicated in the introduction to this report, the CST is a unique decision tool that permits utilities to evaluate distribution or transmission pole options across 26 criteria divided between three evaluation groups for engineering/technical performance, life cycle cost/economics, and environmental profile. Based on discussions with the demonstration panel of utility experts involved in weighting procedures for both the distribution pole demonstration (EPRI, 2006) and the transmission pole demonstration, it is believed that the 26 criteria in the CST include the criteria considered most important to utilities in selecting between different types of distribution or transmission poles. No other published methodology is available as a single approach that can be used by utilities to semi-quantitatively select between distribution or transmission pole options using 26 criteria across these three evaluation groups of primary interest. The CST permits use of either the individual, raw criteria scores and/or the weighted, total criteria scores as a decision support tool. The decision tool allows utilities to make a comprehensive evaluation of distribution or transmission pole options in an organized and semi-quantitative fashion across the full life cycle of the poles. However, the raw scores and priority weighting used in these demonstrations is based on typical national conditions, there is no expectation that the scores resulting from the demonstration will represent all of the unique regional, ecological, and economic conditions of a specific utility.

The CST is easy to use by following the application procedures in Appendix A and can be tailored to the specific regional economic and environmental conditions of an individual utility. The criteria weighting factors can also be tailored to emphasize engineering performance, life cycle cost, and environmental priorities of an individual utility by using AHP, Expert Choice software, and an expert team selected by the utility.

Instructions for Scoring Pole Types

The CST has been demonstrated on four types of 80-foot, Class 2 transmission poles in this report and four types of 40-foot, Class 4 distribution poles in a prior report (EPRI, 2006), but it can be used to score and evaluate a wide variety of existing and proposed distribution or transmission pole types by using the scoring procedures and semi-quantitative scoring ranges in Appendix A. The first step is to determine the quantity of each major component (e.g., pole material, treatment chemicals, etc.) of a given pole type, based on information from the manufacturer, such as the MSDS. The second step is to score the component materials or entire pole for each criterion using the scoring ranges in Appendix A. These initial raw scores are multiplied times priority weighting factors, which were developed based on relative importance using the AHP. The user can select the priority weights developed by the demonstration panel or by the individual utility. For this demonstration, weighting factors were developed for two different perspectives (i.e., Electric Utility and National Policy) to insure acceptance by a broader range of stakeholders and to permit calculation of a single total for each pole type. The final step is to sum the 26 criteria scores times their respective weighting factors in order to determine the overall score for comparing different distribution or transmission pole types.

Additional tasks are underway to improve the CST method, including demonstration of the decision tool with four additional distribution pole types and development of web-based scoring software to simplify the distribution pole scoring process. When the web-based software application has been developed and tested, an EPRI member company can more easily determine priority weights and calculate raw (unweighted) scores, which are both needed to calculate a set of final weighted scores. The web-based software application will permit an individual utility to enter criteria scores that are specific to their regional and economic conditions. It will also permit the utility to tailor the criteria weighting factors from their unique perspective so they can emphasize their own priorities for engineering performance, life cycle cost, and environmental priorities. The user will thus have a choice to calculate the final scores based on a utility-specific perspective for the criteria weighting factors or to select the weighting procedures described in this report.

8
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A
DEFINITION AND SCORING OF DECISION CRITERIA

Purpose and Extent of Decision Criteria

The Electric Power Research Institute (EPRI) and member utilities requested Battelle to develop a Comprehensive Screening Tool (CST) for comparing different types of utility distribution or transmission poles. The completed decision tool permits utilities to evaluate existing or proposed distribution or transmission pole types using 26 criteria divided between three evaluation groups for engineering/technical performance (eight criteria), life cycle cost/economics (nine criteria), and environmental profile (nine criteria). Only pole types within the same height and wood-equivalent class are compared at the same time. The decision tool allows utilities to make a comprehensive evaluation of distribution or transmission pole options in an organized and semi-quantitative fashion across the full life cycle of the poles, including the three upstream (non-utility-controlled) and two downstream (utility-controlled) life cycle stages.

A detailed description of each of the 26 criteria is provided in this appendix, including a discussion of the issue, a definition and rationale for evaluating the criterion, a description of the criterion information requirements and scoring calculation procedures, definition of the five scoring ranges, and description of sources of supplementary information useful for determining the appropriate scoring range. Semi-quantitative scoring ranges have been recommended in this report for each of the 26 criteria. Although the demonstration described in main text of this report focuses on only four types of transmission poles, the criteria in the appendix have been developed to evaluate a wide variety of types and sizes (height and classes) of both distribution and transmission poles. Thus, the criteria scoring ranges include examples for a wide variety of pole types, including treated wood, non-wood, and non-treated (naturally resistant) wood.

The 26 criteria described below were selected from four earlier EPRI projects and combined into a single coordinated approach for comparing between distribution or transmission pole options. Three earlier EPRI studies separately evaluated criteria for engineering/technical performance (EPRI, 2005a), life cycle cost/economics (EPRI, 2003), and environmental profile (EPRI, 2005b). These approaches were combined in an earlier report (EPRI, 2006) as a single decision tool developed to evaluate distribution poles and were modified in this report so they can also be used on transmission poles. The decision tool is a screening system and focuses on the criteria considered to be most important to utilities by prior studies (EPRI, 2003; EPRI, 2005a; EPRI, 2005b; EPRI, 2006) and provides a means to differentiate between different pole types.

In order to provide a balanced and reasonable screening system, the number of criteria for each of the three major groups was purposely designed to focus on a limited and roughly equal set of the more important criteria (eight or nine criteria in each group). For example, 16 environmental criteria were used in the environmental profile screening system developed earlier (EPRI, 2005b), but these were reduced to only nine criteria in the CST. Some of the original 16 environmental criteria (e.g., Longevity or Durability) were modified to include in one of the other two major groups and some of the environmental criteria considered to be less important by a demonstration panel (EPRI, 2005b) were excluded from the CST.

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Engineering/Technical Performance Criteria

The eight engineering/technical performance criteria included in the CST evaluation are discussed in the subsections below, including a discussion of the issue, a definition and rationale for evaluating the criterion, a description of the criterion information requirements and scoring calculation procedures and modifiers, definition of the five scoring ranges, and description of sources of supplementary information useful for determining the appropriate scoring range. The scoring procedures for each of the eight engineering/technical performance criteria are relatively simple, because they only require selecting one of the scoring ranges (and, when applicable, a score modifier), but do not require the mass-based approach for individual pole components that is required for the environmental criteria.

Issue for Criteria Group

What are the most important engineering and technical performance criteria that need to be evaluated in order to choose between different types of transmission or distribution poles assuming the comparison is made between poles of the same class and height?

Definition/Rationale for Criteria Group

Engineering/Technical Performance criteria include physical, regulatory, and handling characteristics of the poles that make them more or less suitable for use by utilities, including ease of transportation, installation, maintenance, and disposal. The preference is for pole types with minimal or no maintenance and long service lives. As indicated in the main text, it is assumed that all poles under serious consideration will meet relevant NESC, ANSI, ASTM, and/or AWPA guidelines or standards.

Scoring for Criteria Group

Different scoring systems are discussed below for each of the eight Engineering/ Technical Performance criteria, since the focus of each criterion is different. Five scoring ranges have been developed for each criterion with scores of 9, 7, 5, 3, and 1, where 9 is the best score and 1 is the worst score. An asterisk (*) may need to be assigned as the score for some criteria when evaluating pole types where there is insufficient data to even make a reasonable estimate for those criteria, such as certain criteria for non-treated wood poles that have little or no prior use in the U.S. by utilities.

Expected Service Life with Maintenance

Issue

What is the typical number of years that a transmission or distribution pole can remain in service without significant loss of strength properties, particularly near the groundline, assuming an inspection and maintenance program that includes reapplication of preservative treatments or additional groundline protection in the field?

Definition/Rationale

One of the most highly desirable performance requirements for a utility transmission or distribution pole is a long service life before replacement. Although some utilities may not currently have a routine pole inspection and maintenance program, this evaluation criterion assumes that such a program is in place. An inspection program that meets AWPA guidelines for treated-wood poles should start after the line has been in service for about 15 years and continue on a 10-year cycle. When maintenance is indicated, it may involve "in field" application of additional groundline protection. Depending on the pole type, addition of groundline protection may include preservative treatment, coatings, or wraps. The expected service life is most accurately based on historical data from long-term use by utilities, especially for treated-wood poles, but it may also be predicted from some combination of engineering characteristics, short-term utility use, and/or short-term, field research (planted pole) studies. The expected service life should be based on the ability of a pole to function properly without replacement under a wide variety of weather conditions, attack by wood-destroying pests, fungal decay, and soil properties throughout the United States and Canada, excluding utility system modifications, vehicular accidents, tornados, or hurricanes.

An average service life of 61-80 years is estimated for galvanized steel poles assuming installation in moderately- or non-corrosive soils. Zinc does a good job of providing long term protection in moderately corrosive and oxidizing soils (Zamanzadeh et al., 2006). On the other hand, in corrosive or highly corrosive soils, even maintenance of coating and use of corrosion resistant backfill may only bring the life expectancy to 50 years. Galvanized steel utility poles have been in use for about 50 years and there is a historical record for related structures like buildings and bridges, which have survived in similar environments for well over 100 years. In addition, two life cycle studies comparing different utility pole types made the assumption that the average service life of galvanized steel is more than 80 years (Erlandsson et al., 1992; EDM, 1997).

Scoring Procedures and Modifiers

1. The scoring system in Table A-1 is similar to the longevity/durability criterion developed previously for the environmental profile screening system for utility distribution poles (EPRI, 2005), although the criterion described here assumes routine maintenance. In this system, a service life of greater than 80 years receives the highest score. Decreasing intermediate scores are given for a service life of 80-61, 60-41, or 40-21 years. Pole types expected to last less than 20 years would receive the lowest score and probably would not be considered by utilities.
2. As indicated below, utilities without a pole inspection and maintenance program should modify the final score by subtracting two points (Table A-2). Any decrease in the Service Life criterion score for utilities without maintenance programs may be offset by an improved score (lower costs) for the criterion Maintenance Costs During Pole Use (see Section below on Life Cycle Cost/Economic Criteria).
3. A second score modifier (Table A-3) is designed specifically for galvanized steel poles and is based on the understanding that zinc does a good job of providing long term protection in moderately corrosive and oxidizing soils (Zamanzadeh et al., 2006), but in corrosive or highly corrosive soils, even maintenance of coating and use of corrosion resistant backfill may only bring the life expectancy to 50 years.
4. The scoring procedure involves selecting the appropriate scoring range and, if appropriate, applying one or both score modifiers (Table A-2 and/or Table A-3). Thus, the final score is determined by the formula: **Final Score = Raw Score - Modifier Score(s)**.

Table A-1
Scoring Ranges for the Criterion on Expected Service Life with Maintenance

Raw Score	Scoring Range Qualifications	Examples
9	> 80 years of expected service life	Concrete
7	61-80 years of expected service life	FRC, Greenheart, Penta-WRC, Gal. Steel (polyurethane coated butt)
5	41-60 years of expected service life	Most Types of Treated Wood, Mata-mata
3	21-40 years of expected service life	Wallaba, Chestnut
1	< 20 years of expected service life	Mora
*	Insufficient Information	

Table A-2
Modifier Score for Expected Service Life for Utilities without a Pole Maintenance Program

Modifier Score	Modifier Score Definition (applies to treated-wood and non-wood poles)
2	Deduction for utilities without pole inspection/maintenance program

Table A-3
Modifier Score for Expected Service Life of Galvanized Steel Poles

Modifier Score	Modifier Score Definition (applies only to galvanized steel poles)
2	Deduction for galvanized steel poles used in areas with corrosive or highly corrosive soils

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Regulatory and Treated-Wood Registration Status

Issue

What restrictions from regulations and treated-wood registration are in place now for a particular utility pole type and how are these expected to change in the near term (1-5 years) and far term (6-20 years)?

Definition/Rationale

Regulations like the Resource Conservation and Recovery Act (RCRA) subtitle D on municipal landfills [including Toxic Characteristic Leaching Procedure (TCLP) concentration limit exemptions for particular materials], the Clean Air Act restrictions on incinerator emissions, and Federal drinking water maximum contaminant level (MCL) standards can impact the reuse and/or disposal of a particular utility pole type. Wood poles treated with registered use pesticides (RUP) are not expected to be re-registered until the end of 2007 according to EPA's (2007) Schedule for Reregistration Eligibility Decisions (REDs). Human and aquatic toxicology studies, risk assessments, and/or litigation have the potential to change these regulations, exemptions, and re-registration of treated wood poles in the near term or far term, which could influence the desirability of a particular pole type by utilities.

Scoring Procedures and Modifiers

The scoring system in Table A-4 gives the highest score for pole types that have no RCRA regulations or TCLP concentration limits or exemptions for landfill disposal, no Clean Air Act emission restrictions for incineration, no Federal drinking water MCL standards, and no recent toxicology studies, risk assessments, and/or litigation that have the potential to change these regulations in the near term. Medium scores are for pole types with one of these restrictions or where current research and/or near-term RUP re-registration is anticipated to impact pole reuse or disposal by making the emission limits more stringent in the far term. Poles with the lowest scores are those already impacted by all three of these regulations or currently impacted by one regulation and anticipated to be impacted by two regulations and/or re-registration in the near term. The scoring procedure involves selecting the appropriate scoring range based on the relevant regulatory requirements and/or risk issues.

Table A-4
Scoring Ranges for the Criterion on Regulatory and Treated-Wood Registration Status

Score	Scoring Range Qualifications	Examples
9	Pole types that have no RCRA regulations or TCLP limits, no Clean Air Act emission restrictions, no MCL standards, and no RUP	FRC, Concrete, Nontreated Wood
7	Pole types that have no RCRA regulations or TCLP limits, no Clean Air Act emission restrictions, no MCL standards, and no RUP; pole types that leach emissions toxic to aquatic biota during use	Gal. Steel (polyurethane coated butt), CuNap
5	Pole types that have one of the following: RCRA regulations or TCLP limits, Clean Air Act emission restrictions, MCL standards, <u>or</u> RUP, but where current research and/or near-term RUP re-registration is anticipated to impact pole reuse or disposal by making the emission limits more stringent in the far term; pole types that leach emissions toxic to aquatic biota during use	Creosote, Penta, ACQ
3	Pole types that have two of the following: RCRA regulations or TCLP exemptions, Clean Air Act emission restrictions, MCL standards, <u>or</u> RUP, and have studies and/or litigation that could change the remaining regulations in the near term; pole types that leach emissions toxic to aquatic biota during use	CCA
1	Pole types that have three of the following: RCRA regulations (but no TCLP exemption), Clean Air Act emission restrictions, MCL standards, <u>or</u> RUP; pole types that leach emissions toxic to aquatic biota during use	
*	Insufficient Information	

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Adaptability of Field Procedures and Hardware for Emergencies

Issue

Can the selected utility pole type be easily adapted for use in a variety of emergency field situations and equipment configurations, including use of standard galvanized metal fasteners and hardware and use of standard infield drilling and tightening procedures, normally employed for most treated-wood poles?

Definition/Rationale

Utility transmission or distribution poles need to be adaptable in both procedures and hardware for use in a variety of field situations, including weather emergencies such as tornadoes, hurricanes, and ice storms. Emergency use in the field may require drilling new holes to accommodate unplanned types of crossarms, transformers, and other equipment. Holes predrilled by manufacturers may not be in the correct locations for all situations. This poses a problem for some of the non-wood pole types, especially concrete and steel.

In the case of steel, concrete, or FRC poles that are typically hollow, the holes for fasteners and hardware usually are drilled or cut at the manufacturing plant, because they are difficult to drill in the proper manner during infield installation. For example, field drilling of round concrete poles can potentially expose the steel tendons to corrosion or directly damage and weaken the tendons. StressCrete Group (Web site for StressCrete, 2006) makes round concrete poles and suggests that utilities make it standard practice to locate and cast needed holes, apertures, inserts etc. at the time of pole production. To decrease the need for future field drilling of round concrete poles (such as those made by StressCrete and others), they recommend adding extra holes to allow for later expansion of the service. Ken Sharpless at Valmont-Newmark (Personal Communication with Jerry Zak, 2005) reports that round concrete poles can be drilled in the field by using existing holes as a guide, by orientation relative to internal tendons using surface ridges created by the concrete molds, or by stopping drilling if you start to hit a tendon. If you do nick the steel tendon, epoxy can be applied to prevent corrosion. On the other hand, the cables for the square concrete poles, such as those made by Lonestar Prestress Mfg., Inc. (Web site for Lonestar Prestress, 2006), are located so that field drilling is permitted on the centerline of either axis. Field drilling of round or square concrete poles requires the use of a rotary hammer drill rather than the standard drill used on wood poles.

Steel poles can be drilled with a standard drill and bit or using a stepped (or “Christmas tree” bit) (AISI, 2004), but improper drilling may severely weaken the pole, and the new hole will require cold galvanization or some other corrosion inhibitor. FRC poles can be fairly easily field modified using a standard drill with a carbide-tipped bit, but the pole supplier should be consulted to ensure that drill holes are not made in locations that may weaken the pole.

The manufacturers of hollow non-wood poles (e.g., steel, concrete, and FRC) typically recommend that the “optimum” procedure for tightening fasteners is to use torque wrenches to ensure that these hollow pole types are not crushed or weakened beyond design capacity. These special tightening procedures for non-wood pole types require special hardware, training, and tools not required with a solid wood pole.

Standard fasteners and hardware used to attach crossarms, transformers, and other equipment to treated-wood poles are usually made out of galvanized steel to avoid corrosion. For most treated-wood poles, galvanized metal bolts and screws are attached in the field by drilling holes in the wooden poles and tightening them with ordinary wrenches. Use of stainless steel rather than galvanized steel fasteners and hardware is recommended for “optimal” performance with some types of pole treatments (e.g., ACQ) due to reactions of the treatment chemical with galvanizing.

Scoring Procedures and Modifiers

The scoring system in Table A-5 gives the highest score to wood pole types which are easily adaptable in the field, including use of standard galvanized fasteners and hardware, a standard drill and bit, and standard wrenches and tightening techniques. The second highest score is given to FRC and steel poles. FRC poles can be drilled in the field after consulting the manufacturer about locations and use of a carbide-tipped drill bit. Steel poles can be drilled with a standard drill and bit, but require cold galvanization on the hole. Medium scores are given for treated-wood pole types that require stainless steel fasteners and hardware. The next score below medium is given to square concrete poles, which can be drilled on the centerline of either axis with the use of rotary hammer drills. The lowest scores are given to round concrete poles, which require rotary hammer drills and are more difficult to avoid hitting a tendon than a square concrete pole. The scoring procedure involves selecting the appropriate scoring range based on the adapability of field procedures and hardware required for emergencies.

Table A-5
Scoring Ranges for the Criterion on Adaptability of Field Procedures and Hardware for Emergencies

Score	Scoring Range Qualifications	Examples
9	Pole types that use standard galvanized fasteners, drill, bit, and wrenches	Treated-Wood (except ACQ) and Nontreated Wood
7	Poles types that require special carbide-tipped drill bits and torque wenches; or pole types that require cold galvanization of holes and torque wrenches	Gal. Steel (polyurethane coated butt), FRC
5	Pole types that require special fasteners or hardware such as stainless steel	ACQ
3	Pole types which require rotary hammer drills, careful field selection of hole locations, and torque wrenches, but where internal reinforcing features can easily be deduced without manufacturer advice	Concrete (square, e.g., Lonestar Prestress)
1	Pole types which require rotary hammer drills, extreme care in selection of hole location or advice from the pole manufacturer in order to avoid internal reinforcement, and torque wrenches	Concrete (round, e.g., StressCrete)
*	Insufficient Information	

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Equipment Requirements for Transport to Job Site/Install/Removal

Issue

Can the selected transmission or distribution pole type utilize standard equipment for handling during transportation, installation, and/or removal?

Definition/Rationale

The type of equipment for transportation to the job site, installation, and removal of treated-wood transmission and distribution poles has remained relatively unchanged for the last several decades. However, different equipment and/or handling techniques may be required in order to protect non-wood pole types or to handle the increased weight of concrete and some non-treated wood types. Concrete poles are much heavier than treated-wood poles, so fewer poles can be carried per truck and more powerful equipment may be required for installation and removal. Lift points designated by the manufacturer should be used during installation of concrete poles to avoid causing stress cracks, which can result in corrosion of the embedded steel tendons. On the other hand, thin-walled steel poles and FRC poles can be installed with lighter equipment, because they are much lighter than concrete, treated-wood, and non-wood pole types. Steel and FRC distribution poles are light enough to permit hand carrying short distances to tight or difficult spots.

One of the biggest differences for transport of transmission poles to the job site is the use of multiple-axle, extra-long, flatbed tractor-trailer and cab, which may also include a support vehicle for an over length load. Most wood and concrete transmission poles come in one piece and may require special equipment and logistics for proper and safe transport. Moderate scores are given to treated-wood pole types 60 feet or more in length that utilize standard equipment during installation and removal, but must be transported by a multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle.

The scoring system for this criterion gives higher scores for lighter pole types that also come in two pieces, such as thin-walled galvanized steel poles and FRC poles. These two-piece transmission poles can be transported by a multiple-axle, regular length, flatbed tractor-trailer and cab that does not need a support vehicle. Galvanized steel poles can utilize standard equipment during installation and removal with little or no need for adaptation except use of webbed straps rather than steel rope choker or strap.

Concrete transmission poles get the lowest score, due to the combination of both their weight and length. Due to axle weight restrictions, fewer concrete poles could be transported to the job site compared to wood or steel poles. In addition, concrete transmission poles are typically in one piece, so transport to the job site will require a multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle for pole lengths 60 feet or more.

Scoring Procedures and Modifiers

The scoring system in Tables A-6 and A-7, respectively, provides scoring ranges for small poles typically used for distribution poles (Class 4 through 7 and Class 3, 55 feet or less) and for large poles typically used for transmission poles (Class 2 through H6 and Class 3, 60 feet or more).

Table A-5 for small poles (typically used for distribution) gives higher scores for lighter pole types that permit transportation of greater numbers on a pole truck or flatbed trailer to the pole yard and can utilize standard equipment during installation and removal (e.g., digger derrick and pole pullers) with little or no need for adaptation except use of webbed straps rather than steel rope choker or strap. Pole types that utilize standard equipment during installation and removal, but fewer poles can be transported compared to the lightest poles without exceeding axle load laws, are given slightly lower scores. Heavy poles that that can only be transported to the pole yard in very limited numbers without exceeding axle load limits and require large flatbed trailers with twin axles behind a digger derrick and/or a separate cab to pull with a small number of poles from the pole yard to the job site are given the lowest score. The scoring procedure involves selecting the appropriate scoring range based on the equipment requirements for transport, installation, and/or pole removal.

Table A-6 for large poles (typically used for transmission) gives higher scores for lighter pole types that come in two pieces, such as thin-walled, galvanized steel poles. These two-piece transmission poles can be transported by a multiple-axle, regular length, flatbed tractor-trailer and cab that does not need a support vehicle. Treated-wood and concrete transmission poles come in one piece. Thus, when they are 60 feet or more in length they must be transported as an over length load using a support vehicle and must obtain an over length permit for each state they cross. Slightly lower scores are given to treated-wood transmission poles that require multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle. Although concrete poles are rarely used for transmission poles, they would get the lowest score, due to their weight and length. Fewer concrete poles could be transported to the job site on a single truck compared to wood or steel poles due to axle weight restrictions.

Table A-6
Scoring Ranges for the Criterion on Equipment Requirements for Transport to Job Site/Install/Removal for Small Poles (Class 4 through 7 and Class 3, 55 feet or less)

Score	Scoring Range Qualifications	Examples
9	Lightweight fragile poles. More poles can be transported on flatbed trailer or pole truck to the pole yard without exceeding axle load laws due to much lower pole weights. Pole weight permits current installation and removal equipment to be used with little or no need for adaptation except use of webbed straps rather than steel rope choker or strap. Pole fragility requires modified pole trailer (nylon webbing or similar material on pole cradles) with single axle behind a digger derrick to pull a small number of poles from the pole yard to the job site. Poles are light enough to permit hand carrying short distances to tight or difficult spots	Gal. Steel (polyurethane coated butt), FRC
7	Typical weight treated wood and lighter nontreated wood. Current equipment for transportation, installation, and removal are sufficient to manage pole weight and deal with special handling requirements. Poles can be moved from pole yard to job site with pole dollies.	Most Treated-Wood & Lighter Nontreated Wood
5	Heavier weight nontreated tropical hardwoods. Slightly heavier poles that can be transported to the pole yard in slightly reduced numbers without exceeding axle load limits. Pole fragility and slightly heavier weight requires a flatbed trailer with single axle behind a digger derrick to pull a small number of poles from the pole yard to the job site.	Heavier Nontreated Tropical Hardwood
3	Heavyweight, hollow concrete poles. Moderately heavy poles that can be transported to the pole yard in limited numbers without exceeding axle load limits. Pole fragility and moderately heavy weight requires a flatbed trailer with twin axles behind a digger derrick or a separate cab to pull a small number of poles from the pole yard to the job site.	Spun Cast Concrete (StressCrete)
1	Very heavy weight, hollow concrete poles. Very heavy poles that can only be transported to the pole yard in very limited numbers without exceeding axle load limits. Pole fragility and extreme weight requires a flatbed trailer with twin axles behind a digger derrick or a separate cab to pull a small number of poles from the pole yard to the job site.	Prestressed Concrete (Lonestar Prestress)
*	Insufficient Information	

Table A-7
Scoring Ranges for the Criterion on Equipment Requirements for Transport to Job Site/Install/Removal for Large Poles (Class 2 through H6 and Class 3, 60 feet or more)

Score	Scoring Range Qualifications	Examples
9	Lightweight fragile poles in sections; Multiple-axle, regular length, flatbed tractor-trailer with padded pole cradles and cab; No support vehicles	Sectional Thin-walled Gal. Steel, Sectional FRC
7	Typical weight treated-wood and nontreated-wood poles; Multiple-axle, extra long, flatbed tractor-trailer and cab, but no pole cradles; Requires over-size load support vehicles	Full Length, Treated-Wood and Lighter Nontreated Wood
5	Heavier weight, nontreated, tropical hardwood poles; Multiple-axle, extra long, flatbed tractor-trailer and cab, but no pole cradles; Requires over-size load support vehicles	Full Length, Heavier Nontreated Tropical Hardwood
3	Heavyweight hollow concrete poles; Multiple-axle, extra long, flatbed tractor-trailer with padded pole cradles and cab; Requires over-size load support vehicles	Full Length, Spun Cast Concrete (StressCrete)
1	Very heavy weight, hollow concrete poles; Multiple-axle, extra long, flatbed tractor-trailer with padded pole cradles and cab; Requires over-size load support vehicles	Full Length, Prestressed Concrete (Lonestar Prestress)
*	Insufficient Information	

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Handling Protection to Avoid Damage

Issue

Does the selected utility pole type require special protection to avoid chipping, crushing, and friability during storage, transportation, and/or installation?

Definition/Rationale

Treated-wood utility poles require very little protection during storage, transportation or installation. However, non-wood poles require special protection during storage, transportation and/or handling to avoid chipping, crushing, and friability, e.g. crumpling of steel, cracking of concrete, or delaminating of FRC. These three non-wood pole types require transport with good buffers/blocking between poles and special slings for loading and unloading. If steel poles get chips, dents, or cracks from improper handling during transportation or installation, it could result in early failure from corrosion or buckling. For FRC poles, special protection may be required during trucking, such as blocking and full length wrap, since an undamaged surface is crucial for good field performance. If the surface of the pole is damaged during trucking or installation, it can expose resin and fibers to UV light, which degrades the FRC. Blocking during transport and careful handling with manufacturer-installed lift points during installation is important for concrete poles, because the cracking stress in spun cast concrete poles may be as low as 40% of concrete rupture strength.

Scoring Procedures and Modifiers

The scoring system in Table A-8 gives higher scores for pole types that do not require special protection during transportation or installation. Intermediate scores are given to pole types that require limited protection during transportation (e.g., blocking) or loading and unloading (e.g., special slings) to avoid crumpling, cracking, or delaminating. Lower scores are given to pole types that require extensive protection, including blocking and full length wrap during transport, as well as special slings during installation. The scoring procedure involves selecting the appropriate scoring range based on handling protection requirements.

Table A-8
Scoring Ranges for the Criterion on Handling Protection to Avoid Damage

Score	Scoring Range Qualifications	Examples
9	No handling protection required; binding, choking, and lifting acceptable using steel cables and chains	Treated-Wood & Nontreated Wood
7	Limited protection required by blocking (cribbing to maintain separation) during transport and careful handling with webbed straps during installation to avoid dents	Gal. Steel (polyurethane coated butt)
5	Intermediate protection required, including blocking during transport and careful handling with manufacturer-installed lift points and/or webbed straps during installation to avoid cracking	Concrete
3	Extensive protection required, including blocking and full length wrap during transport, as well as webbed nylon straps during installation	FRC
1		
*	Insufficient Information	

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Grounding

Issue

Does the selected transmission or distribution pole type have greater requirements for grounding compared to a typical treated-wood pole?

Definition/Rationale

In typical Grade C construction with wood poles embedded six feet into the ground, approximately 4 poles per mile are grounded. However, some of the non-wood pole alternatives have different requirements for grounding than wood poles. Of the three non-wood alternatives (steel, concrete, and FRC), only FRC poles have the same requirements for insulation and grounding as wood poles. Although steel poles are inherently conductive, they are typically galvanized and have a polyurethane coating at ground level to prevent corrosion. In fact, the 2007 NESC (IEEE, 2006) requires that a separate ground electrode be installed on standard steel poles even if no insulating coating is used below grade. Also, the National Rural Electric Cooperative Association (NRECA, 1999) recommends that polyurethane-coated steel poles should be grounded with 1/4-inch grounding plates, 5/16-inch galvanized strand connected to a 5/8-inch grounding rod 8 feet long, and cathodic protection. Also, steel poles require better insulators than are required on wood poles. NESC (IEEE, 2006) considers a direct-embedded concrete pole with reinforcing steel or prestressed strands to be an adequate existing ground electrode, although StressCrete (Website for StressCrete, 2005) recommends that concrete poles be considered the same as steel poles for grounding purposes. Additional grounding for concrete poles, such as a supplemental ground rod, is only required if the footing resistance exceeds 25 ohms. This is why most concrete poles are furnished with a ground lug plate about 12 inches from the ground line.

Scoring Procedures and Modifiers

The scoring system in Table A-9 gives higher scores for pole types that do not require supplemental grounding equipment or insulators in addition to the typical requirements for treated-wood poles. The lowest scores are given to pole types that need both supplemental grounding equipment and insulators not required for treated-wood poles. The scoring procedure involves selecting the appropriate scoring range based on grounding requirements.

Table A-9
Scoring Ranges for the Criterion on Grounding

Score	Scoring Range Qualifications	Examples
9	Current grounding procedures and equipment are sufficient to ensure adequate grounding of pole.	Treated Wood, Nontreated Wood, FRC
7	Only very slight additional grounding procedures are required (the use of higher gauge grounding wire, or larger grounding rod, as examples) to ensure adequate grounding of pole.	
5	Pole requires special grounding procedures (more frequent grounding, or special pole or grounding equipment preparation, as examples). No special grounding or insulating equipment is required.	
3	Pole requires special grounding or insulating equipment at top or bottom of pole (cabling, wiring, grounding plates or lugs, grounding rods, insulators, as examples).	Concrete
1	Pole requires special grounding procedures (more frequent grounding, or special preparation, as examples), and special grounding or insulating equipment at both top and bottom of pole (cabling, wiring, grounding plates or lugs, grounding rods, insulators, as examples)	Gal. Steel (polyurethane coated butt)
*	Insufficient Information	

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Weight/Number for Bulk Transport

Issue

For a utility pole, is the average air dry weight of the selected pole type more or less than a treated-wood pole made of southern yellow pine or other baseline pole?

Definition/Rationale

The weight and length of a large utility pole (Class 2 through H6 and Class 3, 60 feet or more typically used for transmission) has a significant effect on the number of poles that can be transported to the pole yard on a single trailer for bulk transport. The scoring system for this criterion gives higher scores for lighter pole types that come in two pieces, such as thin-walled, galvanized steel poles. These two-piece transmission poles can be transported by a multiple-axle, regular length, flatbed tractor-trailer and cab that does not need a support vehicle. Treated-wood and concrete transmission poles 60 feet or more in length come in one piece and, therefore, must be transported as an over length load using a support vehicle and must obtain a over length permit for each state they cross. Slightly lower scores are given to treated-wood pole types that require multiple-axle, extra-long, flatbed tractor-trailer and cab with a support vehicle. Although concrete poles are rarely used for transmission poles, they would get the lowest score, due to their weight and length. Fewer concrete poles could be transported to the pole yard on a single truck compared to wood or steel poles due to axle weight restrictions.

The weight of a small utility pole (Class 4 through 7 and Class 3, 55 feet or less usually used for distribution) has a significant effect on the number of poles that can be transported on a typical pole truck to the pole yard. Concrete is the heaviest pole type currently used as a distribution pole. Many non-treated tropical hardwoods are heavier than North American species used as treated-wood or non-treated wood poles. However, the potential weight disadvantage of tropical hardwoods might be balanced if wood strength is so great that smaller diameter tropical woods can be used in pole classes that normally require a larger diameter North American species. Thin-walled steel and FRC poles are the lightest pole types currently under consideration as distribution poles. The number of steel poles hauled on a pole truck is dependent on volume rather than weight.

Scoring Procedures and Modifiers

The scoring system in Tables A-10 and A-11 give higher scores for pole types, such as thin-walled steel and FRC with the lowest weight, which permit a large number of poles to be hauled in a standard pole truck to the pole yard. Pole types with the greatest weight (i.e., concrete) are given the lowest score. The scoring procedure involves selecting the appropriate scoring range based on pole class and size, using Table A-10 for small poles (typically used for distribution) and Table A-11 for large poles (typically used for transmission).

Table A-10
Scoring Ranges for the Criterion on Weight/Number for Bulk Transport for Small Poles (Class 4 through 7 and Class 3, 55 feet or less)

Score	**Scoring Range Qualifications**	**Examples**
9	Lightweight fragile poles; Very high number transported to pole yard in a standard pole truck with padded cradles	Thin-walled Gal. Steel, FRC
7	Typical weight, treated-wood and nontreated-wood poles; High number transported to pole yard in a standard pole truck	Most Treated-Wood and Lighter Nontreated Wood
5	Heavier weight, nontreated, tropical hardwood poles; Intermediate number transported to pole yard in a standard pole truck	Heavier Nontreated Tropical Hardwood
3	Heavyweight, hollow concrete poles; Low number transported to pole yard in a standard pole truck	Spun Cast Concrete (StressCrete)
1	Very heavy weight, hollow concrete poles; Very low number transported to pole yard in a standard pole truck	Prestressed Concrete (Lonestar Prestress)
*	Insufficient Information	

Table A-11
Scoring Ranges for the Criterion on Weight/Number for Bulk Transport for Large Poles (Class 2 through H6 and Class 3, 60 feet or more)

Score	Scoring Range Qualifications	Examples
9	Lightweight fragile poles in sections; Multiple-axle, regular length, flatbed tractor-trailer with padded pole cradles and cab; Intermediate number transported to pole yard, because two sections per pole, but no support vehicles needed	Sectional Thin-walled Gal. Steel, Sectional FRC
7	Typical weight treated-wood and nontreated-wood poles; Multiple-axle, extra long, flatbed tractor-trailer and cab, but no pole cradles; Intermediate number transported to pole yard, but requires over-size load support vehicles	Full Length, Treated-Wood and Lighter Nontreated Wood
5	Heavier weight, nontreated, tropical hardwood poles; Multiple-axle, extra long, flatbed tractor-trailer and cab, but no pole cradles; Low number transported to pole yard and requires over-size load support vehicles	Full Length, Heavier Nontreated Tropical Hardwood
3	Heavyweight hollow concrete poles; Multiple-axle, extra long, flatbed tractor-trailer with padded pole cradles and cab; Very low number transported to pole yard and requires over-size load support vehicles	Full Length, Spun Cast Concrete (StressCrete)
1	Very heavy weight, hollow concrete poles; Multiple-axle, extra long, flatbed tractor-trailer with padded pole cradles and cab; Extremely low number transported to pole yard and requires over-size load support vehicles	Full Length, Prestressed Concrete (Lonestar Prestress)
*	Insufficient Information	

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Electric Power Research Institute (EPRI). 2006. *Demonstration of Decision Tool for Selection of Distribution Poles*, Technical Report 1012598. EPRI, Palo Alto, CA.

Leavitt, D. 2007, Senior Vice President, Leavitt's Freight Service, Personal Communication with D.A. Tolle, May 1, 2007.

Hardness

Issue

Does the hardness of the pole type affect the climbability and/or ease of drilling of the selected pole type?

Definition/Rationale

The hardness of the pole type can affect the climbability and/or ease of drilling of the selected pole type. For this criterion, hardness is defined as the Janka hardness of wood and the physical properties of non-wood poles that make them difficult to drill or climb with gaffs. The softest tropical hardwood (Wallaba) is more than 100% harder than the hardest North American softwood (southern pine). These tropical hardwood species may be difficult to climb, drill, and frame in the field. Non-wood poles (steel, concrete, or FRC) require installation of steps at the manufacturing site and cannot be climbed with the gaffs used by lineman on wood poles. The holes for fasteners and hardware on non-wood poles are usually drilled or cut at the manufacturing plant, because they are difficult to drill properly during infield installation. FRC poles can be field modified using carbide-tipped drills, but the pole supplier should be consulted to ensure that drill holes are not made in locations that may weaken the pole.

Scoring Procedures and Modifiers

The scoring system in Table A-12 gives the highest score for wood pole types with low wood hardness that is easily climbed and drilled. The next highest score is given to CCA-treated wood that is harder to climb. Medium scores are given to tropical hardwoods with greater wood hardness factors that make both drilling and climbing difficult and FRC that requires carbide-tipped drills and climbing steps. The lowest score is given to round concrete poles that require climbing steps and cannot be easily drilled in the field without potential damage to structural integrity (e.g., exposure of tendons in concrete poles or the requirement for field galvanizing of steel poles). The scoring procedure involves selecting the appropriate scoring range based on Janka hardness of the pole.

Table A-12
Scoring Ranges for the Criterion on Hardness

Score	Scoring Range Qualifications	Examples
9	For wood poles: >0-1000 lbs Janka Hardness; pole types easily climbed with gaffs and easily drilled	Cedar, Chestnut, CuNap-DF, Penta-WRC, Penta-SYP
7	For wood poles: >1000-2000 lbs Janka Hardness or pole types harder to climb with gaffs and drill	Wallaba, CCA-SYP
5	For wood poles: >2000-3000 lbs Janka Hardness and pole types very hard to climb with gaffs and hard to drill For non-wood poles: requires carbide-tipped drill bit and installation of climbing steps	Greenheart, Purpleheart, Mata mata FRC
3	For wood poles: >3000-4000 lbs Janka Hardness For non-wood poles: Pole hardness and/or construction may require special drilling equipment (higher power drills, e.g., rotabroach type of drill) and procedures (post-drilling hole preservation, e.g., cold galvanization); require installation of climbing steps	Brazilian Ebony, Brazilian Teak Galvanized Steel
1	For wood poles: >4000 lbs Janka Hardness. For non-wood poles: Pole hardness, density and/or construction require special drilling equipment (rotary hammer drill) and procedures (post-drilling hole preservation); require installation of climbing steps	Lignum vitae Concrete (especially round concrete to avoid reinforcing tendons)
*	Insufficient Information	

References

Electric Power Research Institute (EPRI). 2003. *Which Distribution Pole has the Lowest Life-cycle Cost?* Draft Technical Update. EPRI, Palo Alto, CA.

Electric Power Research Institute (EPRI). 2005. *Assessment of Treated Wood and Alternate Materials for Utility Poles.* Technical Report 1010144. EPRI, Palo Alto, CA.

Electric Power Research Institute (EPRI). 2006. *Demonstration of Decision Tool for Selection of Distribution Poles*, Technical Report 1012598. EPRI, Palo Alto, CA.

Life Cycle Cost/Economic Criteria

The nine life cycle cost/economic criteria included in the CST evaluation are discussed in the subsections below, including a discussion of the issue, a definition and rationale for evaluating the criterion, a description of the criterion information requirements and scoring calculation procedures and modifiers, definition of the five scoring ranges, and description of sources of supplementary information useful for determining the appropriate scoring range. The scoring procedures for each of the nine life cycle cost/economic criteria are relatively simple, because they only require selecting one of the scoring ranges, but do not require the mass-based approach for individual pole components that is required for the environmental criteria. To determine the appropriate scoring range for some life cycle cost criteria (e.g., installation, maintenance, removal, disposal, and recycle/reuse costs), it may be necessary for utilitiy engineers familiar with designing new distribution lines in the company's service area to make "best estimates" or "most likely" values, based on experience with similar transmission or distribution poles assuming the comparison is made between poles of the same class and height.

Issue for Criteria Group

To what extent does the choice of pole material affect life cycle costs and resource economics, assuming the comparison is made between transmission or distribution poles of the same class and height?

Definition/Rationale for Criteria Group

Life cycle costs highlight the trade offs between capital or purchase costs and generally recurring costs during use, maintenance, or disposal. It is not uncommon for durable goods to have a greater portion of the life cycle costs associated with the use phase rather than with purchase, a fact which is often unknown to consumers. Two examples of greater cost during the use phase are a refrigerator, where the cost of electricity can far exceed the cost of the refrigerator; and tires, where the fuel costs over the life of a tire can exceed the cost of that tire. Additionally, one of the concerns with the non-treated poles is the availability of both pole materials and pole manufacturing infrastructure to assure a continued supply of replacement poles. This category includes criteria used to assess the long term viability of pole materials.

Scoring for Criteria Group

The scoring ranges for the first six of the Life Cycle Cost/Economics Criterion Group are based on increased or decreased cost relative to a utility-defined baseline pole (for this demonstration of 80-foot, Class 2 transmission poles, the baseline was chosen as Penta-SYP). Increased costs receive lower scores, while decreased costs relative to the baseline receive a higher score. The baseline score is fixed at 5. An individual utility can choose their current preferred pole as the baseline, or the baseline pole can be the one currently purchased in the greatest quantities throughout the U.S.

Acquisition Costs at Pole Yard (pole, liner, sleeve, cross arms, hardware, and transport to yard)

Issue

To what extent does the choice of pole material affect the purchased cost of a pole and its associated hardware?

Definition/Rationale

The purchased cost of a pole and the associated materials necessary for deployment is a concern to utilities. Costs for poles using any of the alternative treatments, or for the non-treated wood or non-wood poles tend to vary both higher and lower than the treated wood poles, historically ranging from slightly higher to much higher (EPRI, 2003; EPRI, 2005, NYSEG, 1997; EDM, 1997). In addition, some of the alternative poles require special hardware to maintain compatibility with the treatment. This criterion is used to assess the ready-to-install cost (pole, hardware, special treatments or preservatives, and cross arms, if different) of an alternative pole relative to a utility-defined baseline pole. The acquisition cost is assumed to include the cost of transport from the manufacturer to the utility's pole storage yard. Note that transport for poles or pole sections in excess of 60 feet may require special permits for overweight or over length loads, at additional costs.

Scoring Procedures and Modifiers

The scoring system for the criterion Acquisition Costs at Pole Yard (pole, liner, sleeve, cross arms, hardware, and transport to yard) (Table A-13) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case Penta-SYP). Increased costs receive lower scores, while decreased costs relative to a baseline receive a higher score. The baseline score is fixed at 5. The scoring procedure involves selecting the appropriate scoring range based on acquisition cost at the pole yard relative to the baseline pole.

Table A-13
Scoring Ranges for the Criterion Acquisition Costs at Pole Yard (pole, liner, sleeve, cross arms, hardware, and transport to yard)

Score	Scoring Range Qualifications	80-foot, Class 2, Transmission Pole Examples
9	≥ 25 percent less than baseline cost	
7	> 10 percent to < 25 percent less than baseline	CuNap-DF, Galvanized Steel
5	±10 percent of baseline cost for Penta-SYP	Penta-SYP
3	> 10 percent to < 25 percent greater than baseline	Penta-WRC
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

References

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Electric Power Research Institute (EPRI). 2003. Which Distribution Pole has the Lowest Life-cycle Cost? Draft Technical Update. EPRI, Palo Alto, CA.

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Passadore, J. 2007. Manager, Pole & Piling Dept., North Pacific Group, Personal communication with D.P. Evers, Battelle. May 8, 2007.

Storage and Transportation Costs from Pole Yard to Installation Site

Issue

To what extent does choice of pole material affect the costs of pole storage and transport?

Definition/Rationale

As with the installation criterion described below, each utility has developed a series of pole storage and transport procedures and supporting equipment. Due to the materials of construction of some of the alternative poles, these procedures and the supporting equipment may require changes due to a change in pole weight, the potential to damage the pole during transit, or potential interactions that may occur between pole treatment compounds and transportation or storage equipment or as a result of storage (environmental exposure). Also included are any costs associated with clean up or remediation of pole storage facilities due to contamination with pole treatment compounds. This criterion is used to assess the costs for storage and transport of an alternative pole relative to a utility-defined baseline pole.

Scoring Procedures and Modifiers

The scoring system for the criterion Storage and Transportation Costs from Pole Yard to Installation Site (Table A-14) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case Penta-SYP). Increased costs receive lower scores, while decreased costs relative to a baseline receive a higher score. The baseline score is fixed at 5. The scoring procedure involves selecting the appropriate scoring range based on storage and transportation costs from pole yard to installation site relative to the baseline pole.

Table A-14
Scoring Ranges for the Criterion Storage and Transportation Costs from Pole Yard to Installation Site

Score	**Scoring Range Qualifications**	**80-foot, Class 2, Transmission Pole Examples**
9	≥ 25 percent less than baseline cost	
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for Penta-SYP	CuNap-DF, Penta, WRC, Galvanized Steel, Penta-SYP
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

References

Gentile, T. 2006. Bates Equipment Company, Personal Communication with Duane Tolle, Battelle, May 25, 2006.

Schwenger, M. 2006. StressCrete. Personal communication with D. P. Evers, Battelle. May 23, 2006.

Swanson, D. 2007. Bonneville Power Administration, Pole Installation Foreman, Personal Communication with D.A. Tolle, Battelle, May 7 and 17, 2007.

Installation Costs

Issue

To what extent does choice of pole material affect the costs of pole installation?

Definition/Rationale

Each utility has developed a pole installation "kit" consisting of the procedures, equipment, and personnel required to install poles. Since the alternative poles may have different properties, the procedures, equipment or personnel (number or skill set) may require changes to accommodate the alternative pole materials. These changes could increase or decrease the cost to install a pole and prepare it for service (installation of cross arms and hardware, grounding, etc.). This criterion is used to assess the cost to install an alternative pole and prepare it for service relative to a utility-defined baseline pole.

Scoring Procedures and Modifiers

The scoring system for the criterion Installation Costs (Table A-15) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case Penta-SYP). Increased costs receive lower scores, while decreased costs relative to a baseline receive a higher score. The baseline score is fixed at 5. The scoring procedure involves selecting the appropriate scoring range based on installation costs relative to the baseline pole.

Table A-15
Scoring Ranges for the Criterion Installation Costs

Score	Scoring Range Qualifications	80-foot, Class 2, Transmission Pole Examples
9	≥ 25 percent less than baseline cost	
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for Penta-SYP	CuNap-DF, Penta, WRC, Galvanized Steel, Penta-SYP
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

References

Gentile, T. 2006. Bates Equipment Company, Personal Communication with Duane Tolle, Battelle, May 25, 2006.

Schwenger, M. 2006. StressCrete. Personal Communication with D. P. Evers, Battelle. May 23, 2006.

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Maintenance Costs During Pole Use (retreatment, inspection)

Issue

To what extent does choice of pole material affect the costs of pole maintenance while in use?

Definition/Rationale

After installation poles need periodic inspection to assess whether additional treatment, replacement, or other maintenance may be required. For some treatment types, in service poles can be effectively retreated in the field, or the treatment from the manufacturer can be supplemented with a different, but compatible material. This is true for treated wood, non-treated wood, and the non-wood poles. This criterion is used to assess the cost for field maintenance, including inspection, on an alternative pole relative to a utility-defined baseline pole.

Scoring Procedures and Modifiers

The scoring system for the criterion Maintenance Costs During Pole Use (retreatment, inspection) (Table A-16) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case Penta-SYP). Maintenance costs are based on the expected service life of the pole and are not calculated on an annualized basis. Increased costs receive lower scores, while decreased costs relative to a baseline receive a higher score. The baseline score is fixed at 5. The scoring procedure involves selecting the appropriate scoring range based on maintenance costs relative to the baseline pole.

Table A-16
Scoring Ranges for the Criterion Maintenance Costs During Pole Use (retreatment, inspection)

Score	Scoring Range Qualifications	80-foot, Class 2, Transmission Pole Examples
9	≥ 25 percent less than baseline cost	
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for CCA-treated wood	CuNap-DF, Galvanized Steel, Penta-SYP
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	Penta-WRC
*	Insufficient Information	

References

Electric Power Research Institute (EPRI). 2003. Which Distribution Pole has the Lowest Life-cycle Cost? Draft Technical Update. EPRI, Palo Alto, CA.

Electric Power Research Institute (EPRI). 2005. *Assessment of Treated Wood and Alternate Materials for Utility Poles.* Technical Report 1010144. EPRI, Palo Alto, CA.

New York State Electric and Gas Corporation (NYSEG). 1997. Wood Concrete & Steel Comparison Research and Development Test Project. New York State Electric and Gas Corporation, Ithaca, NY.

Disposal Costs

Issue

To what extent does choice of pole material affect the cost to dispose of a pole at the end of its useful life?

Definition/Rationale

This criterion includes disposal costs for hazardous and non-hazardous waste for pole disposal by landfill and/or incineration. The materials of construction, particularly the choice of preservative, may have a significant influence on the cost to dispose of a pole. Those materials–and the wood poles treated with those materials–which are now, or may in the future be, considered hazardous wastes will likely cost considerably more for disposal than a material (in a treated-wood pole) considered benign. However, state environmental regulations, landfill or incinerator operator guidelines, and utility choice of disposal option may influence the disposal cost as much as the pole type.

This criterion also assesses the costs for any potential remediation or site clean up that might occur with removal of the pole. For some pole types, penta-treated wood poles as an example, there is a small probability that the removal of the pole will require the pole site to be treated as a hazardous waste site, thus requiring remediation (most likely removal of the surrounding soil to the depth of the hole) (EPRI, 2003).

Examples of hazardous materials used on pole construction or treatment under the current (2007) regulatory climate include creosote and penta. [Note however, that EPRI (1992 and 1990) TCLP testing at end-of-life has never shown creosote- or penta-treated poles to be classified as hazardous wastes under RCRA. Thus, disposal *may* be allowed at sanitary or construction debris landfills, or in non-hazardous waste incinerators, e.g. lower costs options.] A third popular pole treatment, CCA, is currently exempt from regulation as a hazardous waste. For many or most of the non-wood and non-treated wood poles, disposal costs can only be forecast, as in most cases few or none have been discarded, therefore market demand for disposal options and regulatory restrictions have not been determined.

Scoring Procedures and Modifiers

The scoring system for the criterion Disposal Costs (Table A-17) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case Penta-SYP) and includes the potential that at some point in the future soil remediation may be required at a pole removal site. Increased costs receive lower scores, while decreased costs relative to a baseline receive a higher score. The baseline score is fixed at 5. The scoring procedure involves selecting the appropriate scoring range based on disposal costs relative to the baseline pole.

Table A-17
Scoring Ranges for the Criterion Disposal Costs

Score	**Scoring Range Qualifications**	**80-foot, Class 2, Transmission Pole Examples**
9	≥ 25 percent less than baseline cost	CuNap-DF, Galvanized Steel
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for CCA-treated wood	Penta-WRC, Penta-SYP
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

References

Electric Power Research Institute (EPRI). 1992. *Creosote-Treated Wood Poles and Crossarms: TCLP Results.* TR-100870. EPRI, Palo Alto, CA.

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Electric Power Research Institute (EPRI). 2005. *Assessment of Treated Wood and Alternate Materials for Utility Poles.* Technical Report 1010144. EPRI, Palo Alto, CA.

Recycle or Reuse Costs

Issue

To what extent does choice of pole material affect the cost to prepare a pole for recycle or reuse at the end of its useful life?

Definition/Rationale

As with the criterion for Disposal Costs, the materials of construction, particularly the choice of preservative, may have a significant influence on the cost to prepare a pole for recycling or reuse. Those materials–and the wood poles treated with those materials–which are now, or may in the future be, considered hazardous wastes may require certification, stabilization, or treatment of the pole prior to release outside the utility. Poles not containing hazardous materials may only require removal of hardware. EPRI is currently studying options for pole reuse and recycle including resawing of both treated and non-treated wood poles. Any recycling company selling the used poles to a mill for resawing into lumber will likely have to certify that all metal, stones, and other hard materials have been removed from the pole prior to acceptance. Concrete and FRC poles will likely require some inspection to establish worthiness for non-utility uses.

Scoring Procedures and Modifiers

The scoring system for the criterion Recycle or Reuse Costs (Table A-18) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case Penta-SYP). Increased costs receive lower scores, while decreased costs relative to a baseline receive a higher score. The baseline score is fixed at 5. The scoring procedure involves selecting the appropriate scoring range based on recycle or reuse costs relative to the baseline pole.

Table A-18
Scoring Ranges for the Criterion Recycle or Reuse Costs

Score	Scoring Range Qualifications	80-foot, Class 2, Transmission Pole Examples
9	≥ 25 percent less than baseline cost	Galvanized Steel
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for CCA-treated wood	CuNap-DF, Penta-WRC, Penta-SYP
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

References

Electric Power Research Institute (EPRI). 2003. Which Distribution Pole has the Lowest Life-cycle Cost? Draft Technical Update. EPRI, Palo Alto, CA.

Electric Power Research Institute (EPRI). 2005. *Assessment of Treated Wood and Alternate Materials for Utility Poles.* Technical Report 1010144. EPRI, Palo Alto, CA.

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Resource Renewability/Sustainability (including future raw material availability)

Issue

Can utility transmission or distribution poles use a greater percentage of raw materials/energy sources produced from renewable resources?

Definition/Rationale

Resource renewability is the capability of a particular material to be replaced in a time frame of relevance to human society. For nonrenewable materials, resource sustainability is a measure of the supply compared to current demand. In general, renewable resources are preferred to non-renewable resources, as each generation can see to it that natural capital is replaced or replenished for succeeding generations. For non-renewable resources, those which have long depletion times are preferred, allowing adequate time for development of alternatives, replacements, or recovery procedures. Renewability and sustainability are measures of the ability to conserve natural capital and should not be confused with the availability of supply. Supply is covered under the criterion Manufacturing Capability, which is a measure of the ability to supply and convert natural capital into economic goods.

Scoring Procedures and Modifiers

Table A-19 shows the Resource Renewability/Sustainability scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). Scoring is based on recovery or replacement times for renewable resources, or on depletion times for non-renewable resources. Renewable materials with short replacement times receive the highest scores, while non-renewable resources with the shortest depletion times (run out in the fewest years) receive the lowest scores. The scoring procedure involves selecting the appropriate scoring range based on resource renewability/sustainability. The estimated years for global depletion of minerals is based on the global reserve base divided by the global annual production reported by the USGS (2007). The scoring ranges used for this criterion were developed as part of a pollution prevention methodology based on life cycle assessment for the U.S. EPA (Tolle et al, 1994).

Table A-19
Scoring Ranges for the Criterion on Resource Renewability/Sustainability

Score	Criteria Ranges for Resource Renewability	Examples
9	Renewability < 1 year	Agricultural or Food Crops
7	Renewability 1 - 10 years	
5	Renewability >10 years, or Nonrenewable, sustainability > 500 years	Wood, Gravel or Stone
3	Nonrenewable, sustainability 50 - 500 years	Steel
1	Nonrenewable, sustainability < 50 years	Zinc
*	Insufficient data	

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Tolle, D.A., B.W. Vigon, J.R. Becker, and M.A. Salem. 1994. *Development of a Pollution Prevention Factors Methodology Based on Life-cycle Assessment: Lithographic Printing Case Study*. EPA/600/R-94/157. Risk Reduction Engineering laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. 27 pp.

U. S. Geological Survey (USGS). 2007. Minerals Yearbook. http://minerals.usgs.gov/minerals/pubs/myb.html.

Raw Materials Delivery Infrastructure

Issue

To what extent is continued, unrestricted access to raw materials assured?

Definition/Rationale

Even with adequate supplies of raw materials available, geopolitical concerns may limit availability of the materials or restrict access. One example of a material with large supply but unstable access is diamonds. Much of the world’s supply is concentrated in sub-Saharan or Equatorial Africa, a region in which many of the nations are currently experiencing periods of unstable government or civil uprisings. Likewise, supplies of many of the alloying agents most frequently used to make steel and aluminum are also concentrated in the same region of Africa. Access to crude oil, both in the Middle East and in a number of South and Central American countries, could also be considered tenuous, with political and/or religious uprisings happening seemingly almost daily.

Another aspect of delivery infrastructure is the ability to move supplies to consumers. In many cases the facilities to process or deliver raw materials is limited, or transport is through unstable regions. With many of the tropical hardwoods, the combination of limited areas of sustainable forestry and lack of mill facilities may limit the number of poles which could be delivered.

Scoring Procedures and Modifiers

Table A-20 shows the scoring ranges for the Raw Materials Delivery Infrastructure criterion. Higher scores are assigned to raw materials which are judged to have an adequate conversion and delivery infrastructure, and that infrastructure exists within stable geopolitical regions, thus purchase plans can be made and executed with a high probability of completion according to plan. Lower scores are assigned to raw materials for which adequate replacements cannot be brought to market within the desired timeframe, or for materials in which major supplies exist only in geopolitically unstable regions. The scoring procedure involves evaluating the potential data, and selecting the appropriate scoring range based on the raw materials delivery infrastructure. Potential data sources include the CIA World Factbook (CIA, 2006) and the USGS Minerals Yearbook (USGS, 2007).

Table A-20
Scoring Ranges for the Criterion on Raw Materials Delivery Infrastructure

Score	Conditions
9	Stable or favorable political climate, conversion capacity meets or exceeds current demands, and transportation or delivery infrastructure is capable of meeting or exceeding current demands
7	Stable or favorable political climate, conversion capacity that can be expanded to meet or exceed current or forecast demands within one generation, and transportation or delivery infrastructure that can be expanded to meet or exceed current or forecast demands within one generation (Low risk, short term positive ROI)
5	Stable or favorable political climate, conversion capacity that cannot be expanded to meet current or forecast needs within one generation, and transportation or delivery infrastructure that cannot be expanded to meet current or forecast needs within one generation (Low risk, longer term positive ROI)
3	Unstable or unfavorable political climate, conversion capacity that can be expanded to meet or exceed current or forecast demands within one generation, and transportation or delivery infrastructure that can be expanded to meet or exceed current or forecast demands within one generation. (High risk, short term positive ROI)
1	Unstable or unfavorable political climate, conversion capacity cannot be expanded to meet current or forecast needs within one generation, and transportation or delivery infrastructure cannot be expanded to meet current or forecast needs within one generation (High risk, longer term ROI)
*	Inadequate data

References

Central Intelligence Agency (CIA). 2006. World Factbook
http://www.cia.gov/cia/publications/factbook/.

United States Geological Survey (USGS). 2007 Minerals Yearbook.
http://minerals.usgs.gov/minerals/pubs/myb.html.

Manufacturing Capability (pole supply and available facility output)

Issue

To what extent is supply and demand of transmission or distribution poles consistent?

Definition/Rationale

Provided raw or processed materials can be delivered to manufacturing facilities, facility output or availability of product may be limited due to a lack of adequate production facilities, restrictions on supplies of critical raw materials, or inadequate access to supporting materials of infrastructure. One commodity for which many industrialized nations are currently experiencing a shortage is electricity. There is a lack of electric generating facilities which are capable of using the most economic fuels currently available. For many of the alternative material poles, there is a large gap in the potential market demand and the ability to supply poles. For example, current (2005) estimates are that the supply of steel, concrete and FRC poles combined is only on the order of 100,000 poles per year versus a potential demand of millions of poles per year.

Scoring Procedures and Modifiers

Table A-21 shows the scoring ranges for the Manufacturing Capability (pole supply and available facility output) criterion. Materials or products for which current supply and demand are matched near term, or for which supply exceeds demand receive the highest scores. Moderate scores are given to products or materials where supply can be matched to demand within a generation. Lower scores are given to products or materials in which demand is judged to outpace supply for more than a generation. The scoring procedure involves selecting the appropriate scoring range based on manufacturing capability, including pole supply and avialable facilty output.

Table A-21
Scoring Ranges for the Criterion on Manufacturing Capability (pole supply and available facility output)

Score	Conditions	80-foot, Class 2, Transmission Pole Examples
9	Current manufacturing capacity exceeds current and forecast market demand. Price sensitivity to increasing demand is essentially zero.	Penta-WRC
7	Current manufacturing capacity meets current and forecast demand. Prices may rise in response to increasing demand as market reaches a new equilibrium.	
5	Current manufacturing capacity does not meet current or forecast demand, but manufacturing capacity shortfall can be met by expansion in short time frames (less than 10 years). Prices may rise dramatically in response to increasing demand as market reaches a new equilibrium.	CuNap-DF
3	Current manufacturing capacity falls well below current or forecast demand, and manufacturing capacity expansion will take on the order of a generation to meet current and forecast demand. Prices may be volatile and rise dramatically in response to increasing demand as market reaches a new equilibrium.	Galvanized Steel, Penta-SYP
1	Current manufacturing capacity falls well below current or forecast demand, and manufacturing capacity expansion will take more than a generation to meet current and forecast demand. Prices may be volatile and rise dramatically in response to increasing demand as market reaches a new equilibrium.	
*	Inadequate data	

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Schwenger, M. 2006. StressCrete. Personal communication with D. P. Evers, Battelle. May 23, 2006.

Environmental Criteria

The nine environmental criteria included in the CST evaluation are discussed in the subsections below, including a discussion of the issue, a definition and rationale for evaluating the criterion, a description of the criterion information requirements and scoring calculation procedures and modifiers, definition of the five scoring ranges, and description of sources of supplementary information useful for determining the appropriate scoring range. Descriptions of the environmental criteria are based on the environmental profile approach published by EPRI (2005) as Technical Report 1010143.

Issue for Criteria Group

What are the most important environmental criteria that need to be evaluated in order to choose between different types of transmission or distribution poles assuming the comparison is made between poles of the same class and height?

Definition/Rationale for Criteria Group

Environmental criteria include those with a potential for global, regional, and/or local impacts due to material use or emissions associated with one or more stages during the full life cycle of a distribution pole. The nine environmental criteria selected for distribution pole screening are Acidification Potential, Carcinogenicity, Ecological Habitat Alteration, Energy Use, Global Warming Potential, Inhalation Toxicity, Smog Creation Potential, Recyclability Potential (Post-consumer), and Toxic Material Mobility upon Landfilling or Incineration. These nine criteria were selected because they cover a wide variety of environmental issues without significant overlap in impacts between criteria. Each of the toxicity and fate scores is an indication of the hazard potential and does not imply a detailed risk assessment that considers pollutant pathways and exposure under site-specific conditions.

Scoring for Criteria Group

As indicated in the EPRI (2005) Technical Report 1010143, air and water emission data from manufacturing were used to evaluate the three criteria Acidification Potential, Carcinogenicity, and Smog Creation Potential. Emission data from the U.S. Environmental Protection Agency (EPA) databases TRI and AIRS Executive for Windows were obtained for the year 2002. Searches for manufacturing emissions were made using the appropriate Standard Industrial Codes (SIC) for a given pole type. The SIC for wood preserving (2491) was used to determine emissions for treated wood manufacturing, but emissions were separated according to the type of treatment. The SICs for hydraulic cement (3241) and concrete products (3272) were used to determine emissions for concrete pole manufacturing. The SIC for blast furnaces and steel mills (3312) was used to determine emissions for steel pole manufacturing. Average emissions and number of reporting facilities were obtained for each SIC using the “Customized Query” feature in the TRI database. This detail permitted exclusion of outliers by restricting the evaluation to chemical emissions reported for at least 90% of the facilities and emissions that comprised at least 99% of total emissions for a given SIC. However, total dioxin was also included due to its high toxicity and carcinogenicity even if it was less than 1% of total emissions. Total dioxin reported by TRI includes 17 congeners of dioxin and furan that must be reported by each facility that exceeds 0.1 gram per year in emissions (Web site for TRIfacts, 2005).

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

TRIfacts.org. 2005. TRI putting TRI dioxin data in perspective. http://www.trifacts.org/teq_tm17/index.php. Prepared by The Chlorine Chemistry Council.

Acidification Potential

Issue

How can the manufacturing life cycle stage of the utility transmission or distribution pole be modified to minimize release of acidifying substances to the air that can result in acid deposition on sensitive vegetation, soil, or surface waters?

Definition/Rationale

Acid deposition is primarily created by the emission of sulfur and nitrogen compounds (Nordic Council, 1992). Acid deposition includes both wet deposition (acid rain) by chemical scavenging and deposit via precipitation (rain, snow, fog) and dry deposition by absorption of gases or by particle collection at surfaces (Longcore et al., 1993). Acid deposition is a large-scale regional phenomenon that can involve long-distance transport of sulfur- and nitrogen-containing air pollutants. Potential ecological consequences of acid deposition include: changes in surface water chemistry, decline in fish populations, leaching of toxic metals from soils into surface waters, decreased forest growth, increased plant diseases, and accelerated damage to materials. Much of the bedrock in the northeastern U.S. and Canada contains total alkalinity of less than 200 µeq/L, and, thus, lacks acid-neutralizing capacity, making the soil particularly sensitive to acidic deposition. The Adirondack region of New York has the most acidic lakes of any area in the U.S. (Driscoll et al., 1994). One specific concern in this area is the presence of mercury in fish at levels of concern to humans and fish eating wildlife. The increased availability of mercury, including highly toxic methylmercury, to fish may be the result of acid deposition. Acidification potentials (APs) have been calculated for chemical air emissions contributing to acid rain based on the potential amount of H^+ per mass unit relative to the same parameter for SO_2 (Heijungs et al., 1992a and 1992b; Wenzel et al., 1998). The scoring ranges and the score modifier for acid sensitive regions used for this criterion are described by Jensen and Walker (1995) and Tolle et al (1994).

Scoring Procedures and Modifiers

1. Determine which substances containing acid precursors (e.g., SO_2, SO_X, SO_3, NO, NO_X, NO_2, HCl, HF, NH_3, H_2SO_4, HNO_3) are released as typical air or water emissions during the manufacturing life cycle stage of the utility distribution pole. Sources can include two of the U.S. EPA's databases: TRI (http://www.epa.gov/enviro/html/tris/tris_query.html) and AIRS Executive (http://www.epa.gov/airs/aexec.html).

2. Determine the raw AP score for each individual substance relative to sulfur dioxide (SO_2) by using the values listed below Wenzel et al. (1998) [updated from Heijungs et al. (1992b)]. The AP is defined as the ratio between the number of potential H^+ equivalents per emitted quantity of SO_2, expressed as the formula:

$$AP_i = \frac{v_i|M_i}{v_{SO2}|M_{SO2}}$$

3. Apply score modifiers as appropriate (**Final Score = Raw Score - Modifier Score;** but final score is never less than 1) to determine the final AP score for each chemical.

4. Calculate the average final AP score for all acid precursor emissions released into air and water. Table A-22 shows the Acidification Potential criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005).

Major Criteria Air Emission Modifier - Due to the substantially greater quantity (typically ≥100 TPY) of chemicals considered major criteria pollutants reported in AIRS Executive, a score modifier was given to these major source emissions. Thus, the raw AP score determined for a major source chemical should be subtracted by 2 to get the final AP score for that chemical.

Acid Sensitive Ecosystem Modifier - Increase the score by 4 points (maximum score of 9), if all areas likely to receive acid deposition due to air emissions from the process or life-cycle stage under consideration (i.e., areas downwind of emissions) are known to be relatively insensitive to acid deposition. Areas sensitive to acid deposition are those where the underlying bedrock has a total alkalinity of less than 200 μeq/L. Most of the eastern U.S. and eastern Canada qualify as sensitive to acid deposition using this threshold and the presence of lakes with a pH of <5.0 (Longcore et al., 1993). Most of the general effects of acid deposition have been observed to date in the northeastern U.S. (especially the Adirondack region of northern New York) and eastern Canada (e.g., Sudbury Ontario).

Table A-22
Scoring Ranges for the Criterion on Acidification Potential

Raw Score	Criterion Ranges for Acidification Potential (AP) Relative to Sulphate
9	<0.09
7	0.10-0.49
5	0.50-0.99 (NO2, NOx, HCl, HNO3, SO3, H2SO4, H3PO4)
3	1.00-1.49 (SO2, NO, SOX)
1	≥1.50 (HF, NH3, H2S)
*	Insufficient Information

References

Driscoll, C.T., C. Yan, C.L. Schofield, R.K. Munson, and J.G. Holsapple. 1994. The Mercury Cycle in Fish in the Adirondack Lakes. *Environ. Sci. Technol.* 28(3):136A-143A.

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Heijungs, R. (Final Editor). 1992a. *Environmental Life-Cycle Assessment of Products: Backgrounds - October 1992*. Report 9267. CML (Centre of Environmental Science) in Leiden, TNO (Netherlands Organisation for Applied Scientific Research) in Apeldoorn, and B&G (Fuels and Raw Materials Bureau) in Rotterdam, The Netherlands. 130 pp.

Heijungs, R. (Final Editor). 1992b. *Environmental Life-Cycle Assessment of Products: Guide - October 1992*. Report 9266. CML (Centre of Environmental Science) in Leiden, TNO (Netherlands Organisation for Applied Scientific Research) in Apeldoorn, and B&G (Fuels and Raw Materials Bureau) in Rotterdam, The Netherlands. 96 pp.

Jensen, A.A. and J.D. Walker (Eds.) 1995. Chapter 5: Other Chemical Characteristics pp. 113-129, In M.B. Swanson and A.C. Socha (Eds.) *Chemical Ranking and Scoring: Guidelines for Relative Assessments of Chemicals*. Proceedings of the Pellston Workshop on Chemical Ranking and Scoring, 12-16 February 1995, Sandestin, Florida. SETAC Press, Pensacola, Florida. 154 pp.

Longcore, J.R. et al. 1993. *Acidic Depositions: Effects on Wildlife and Habitats*. Wildl. Soc. Tech. Rev. 93-1, The Wildlife Society, Bethesda, MD. 42 pp.

Nordic Council. 1992. *Product Life Cycle Assessment - Principles and Methodology*. The Nordic Council, Stockholm, Sweden.

Tolle, D.A., B.W. Vigon, J.R. Becker, and M.A. Salem. 1994. *Development of a Pollution Prevention Factors Methodology Based on Life-cycle Assessment: Lithographic Printing Case Study*. EPA/600/R-94/157. Risk Reduction Engineering laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. 27 pp.

Wenzel, H., M. Hauschild, and L. Alting. 1998. *Environmental Assessment of Products. Methodology, Tool and Techniques, and Case Studies in Product Development*. Chapman and Hall, London, GB. Table 3-1. In: H.A. Udo de Haes (Ed.) 2002. Life Cycle Impact Assessment: Striving Toward Best Practice. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL.

Carcinogenicity

Issue

How can the manufacturing or use/reuse/maintenance life cycle stages of the utility distribution pole be modified to minimize release of carcinogenic substances to the environment that can result in suffering and death of humans?

Definition/Rationale

Release of carcinogenic emissions (including leachate) into the environment can result in suffering and death of humans. Materials and processes associated with manufacturing of utility distribution poles or with treatments or coatings associated with the use/reuse/maintenance of the finished pole should be utilized which eliminate or produce only very minimal quantities of carcinogenic emissions.

Scoring Procedures and Modifiers

Table A-22 shows the Carcinogenicity criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). These scores are based on evaluating the potential carcinogenic risk of a chemical to humans by using peer-reviewed conclusions based on laboratory animal testing and epidemiological or case studies in humans. Obtain peer-reviewed conclusions on the weight-of-evidence (WOE) for carcinogenicity from the International Agency for Research on Cancer (IARC) and the U.S. Environmental Protection Agency (EPA). The EPA has ranked selected chemicals based on the WOE of carcinogenicity from greatest to least evidence as follows: Group A (greatest), Group B1, Group B2, Group C, Group D, and Group E. Similarly, IARC has provided summary ratings for selected chemicals from greatest to least evidence of carcinogenicity as follows: Group 1 (greatest), Group 2A, Group 2B, and Group 3. Possible conclusions for the WOE for carcinogenicity for each test can be sufficient, limited, inadequate, or no evidence. The WOE of carcinogenicity from the IARC and/or EPA conclusions is used to determine a raw score, which is converted to a final score by adding a number based on the oral slope factor. The oral slope factor (TD_{50} in mg/kg/day) is an indication of cancer potency determined by extrapolation modeling.

The following steps are used to determine the score for this criterion:

1. Tabulate the chemical emissions for each process in the life cycle of the utility pole associated with manufacturing of the pole or with treatments or coatings on the pole during use/reuse/maintenance of the finished pole.
2. Obtain IARC and/or EPA WOE conclusions (group rank) for the chemicals of interest from one of the following databases available online from the National Library of Medicine: RTECS, HSDB, or IRIS. IRIS is also available on the World Wide Web at http://www.epa.gov/iris/. Carcinogenicity group ranks are also available for many of the common chemicals in a guidebook compiled by ACGIH (2003).

3. Use the WOE group to determine the raw score as indicated below (Table A-23). When IARC and EPA conclusions are different use the one that results in the lowest raw score (greatest WOE for carcinogenicity).

4. For chemicals receiving a raw score of 3 or 5 in Step 2, determine a modifier score by obtaining the oral slope factor and comparing this number to the modifier definition list in Table A-24. Obtain the oral slope factor from IRIS or the Carcinogenic Potency Database (CPDB) available through Lawrence Livermore Laboratory’s web site at http://potency.berkeley.edu/pdfs/ChemicalTable.pdf. In the CPDB, use the largest oral slope factor (TD_{50}) for rats or mice. If there is no oral slope factor use a modifier score of zero. Use of the oral slope factor to modify the IARC or EPA WOE is recommended in Chapter 3 of the SETAC document on chemical ranking and scoring (Hurlburt, 1995).

5. Calculate the final score for a given chemical emission by subtracting the modifier score (step 4) from the raw score (step 3). (i.e., **Raw Score – Modifier Score = Final Score**; but final score is never less than 1).

6. Determine the average final score for all chemicals released in air and water, but use only one score for individual chemicals that are emitted in both media.

Table A-23
Scoring Ranges for the Criterion on Carcinogenicity

Raw Score	**Criterion Ranges for Carcinogenicity: EPA or IARC Weight of Evidence (WOE)**
9	IARC Group 4 (Animal or Human Negative Evidence) or EPA Group E
7	IARC Group 3 or EPA Group D
5	IARC Group 2B or EPA Group C
3	IARC Group 2A or EPA Group B1 or B2
1	IARC Group 1 or EPA Group A or IARC Human Sufficient
*	No data; or no IARC or EPA conclusion on the evidence

Table A-24
Modifier Scores for the Criterion on Carcinogenicity

Modifier Score	Modifier Score Definition
2	Oral slope factor ≥1 x 10-1 mg/kg/day
0	Oral slope factor <1 x 10-1 mg/kg/day or no oral slope factor available.

References

American Conference of Governmental Industrial Hygienists (ACGIH). 2003. *2003 Guide to Occupational Exposure Values*. American Conference of Governmental Industrial Hygienists, Inc., Cincinnati, OH.

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Lawrence Livermore National Laboratory (LLNL). 2005. Carcinogenic Potency Database (CPDB) http://potency.berkeley.edu/pdfs/ChemicalTable.pdf

Hurlburt, G.K. (Ed.). 1995. Chapter 3: Human Health Effects pp. 61-88, In M.B. Swanson and A.C. Socha (Eds.) *Chemical Ranking and Scoring: Guidelines for Relative Assessments of Chemicals*. Proceedings of the Pellston Workshop on Chemical Ranking and Scoring, 12-16 February 1995, Sandestin, Florida. SETAC Press, Pensacola, Florida. 154 pp.

Ecological Habitat Alteration

Issue

To what extent can material/energy supply selections be made which minimize the area of ecological habitat alteration and the amount of recovery time before the habitat can be returned to the original stage of habitat succession prior to raw material acquisition for a utility transmission or distribution pole (includes tree farming and harvesting)?

Definition/Rationale

Many activities associated with the acquisition of raw materials cause environmental damages. Habitat alteration is indicated by two measures - the area damaged by the activity on average per event and the recovery time to restore the ecosystem to its original stage of habitat succession before the activity was started. An event is defined as an average occurrence of the activity. Thus, for acquisition of oil an event might be the size of the area affected by a typical spill. Recovery times cited in the table below represent the best judgment of the *minimum* periods over which the function or integrity of the system may be impaired. There may be specific situations that will require much longer habitat recovery times than the times in the table below. One example is for strip mining in heavily forested areas, where it may take many decades after the mining has been completed before the forest ecosystem re-establishes itself. The analyst should use their best judgment where specific knowledge is not available.

Each raw material has different acquisition requirements that must be met. Specification of materials/energy types that cause the least alteration to ecological habitats and allow the most rapid recovery to the original stage of habitat succession before acquisition is preferred. While many companies are not directly in control of this stage of the life cycle of their products, good product stewardship would entail an examination of habitat effects attributable to raw materials.

Scoring Procedures and Modifiers

Table A-25 shows the Ecological Habitat Alteration criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). The scoring ranges used for this criterion were developed as part of a pollution prevention methodology based on life cycle assessment for the U.S. EPA (Tolle et al, 1994). To apply this criterion the following information is needed:

1. Determine the principal components (raw material/energy requirements) for each module of raw material acquisition.
2. Select an initial component score using the list of examples provided in Table A-27.
3. For the wood component (step 2), determine if the pole manufacturer obtains their poles from forests that are sustainably managed for biodiversity.
4. Calculate the score for the wood component of a given pole type by adding the modifier score (Table A-26) to the raw score (i.e., **Raw Score + Modifier Score = Final Score**).
5. Determine each individual component score for a given module based on weight ratios of the module input per unit of product times the initial component score, ignoring materials present in less than one percent by weight.

Table A-25
Scoring Ranges for the Criterion on Ecological Habitat Alteration

Score	Criterion Ranges for Habitat Alteration
9	Few acres altered; habitat recovery <5 years
7	Moderate number (dozens) of acres altered; recovery 5-25 years
5	Moderate number of acres altered; recovery 25-100 years
3	Many acres (hundreds) altered; recovery 25-100 years
1	Many acres altered; recovery 100+ years
*	Insufficient information

Table A-26
Score Modifier for Sustainable Forestry

Modifier Score	Modifier Score Definition
2	Source of wood poles is from a forest sustainably managed for biodiversity
0	Source of wood poles is unknown or from a forest that is not sustainably managed for biodiversity

The score modifier is based on the premise that if the forest can be returned to the ecological condition and biodiversity that existed before harvesting in a significantly reduced recovery period, then poles taken from this type of forest should be given a better score than those that do not come from forests sustainably managed for biodiversity. A description of the approach that foresters would need to take to manage a forest for biodiversity is discussed by Carey and Curtis (1996). Only about 25% of private forestland in the United States has been certified for sustainability by one of three organizations (Alverez, 2007).

Table A-27
Examples of Habitat Alteration Factors

Type of Activity	Typical Area Affected (acres)	Approximate Recovery Time (yrs)
Forestry, temperate hardwoods	100 - 1000	75-80
Forestry, temperate softwoods	100 - 1000	distrib. pole (25 - 35); trans. pole (55-90)
Forestry, tropical	10 - 50	>100
Mining, strip (semi-arid grassland)	100 - 1000	2 - 5
Mining, strip (temperate hardwoods)	100 -1000	75-100
Mining, strip (temperate softwoods)	100 -1000	25 - 50
Mining, underground	2 - 10	5 - 25
Natural gas extraction	<1	<5
Oil extraction	1 - 3	4 - 10

References

Alvarez, M. 2007. The State of America’s Forests. Society of American Foresters. Bethesda, MD.

Cary, A.B. and R.O. Curtis. 1996. *Conservation of Biodiversity: a Useful Paradigm for Forest Ecosystem Management*. Wildl. Soc. Bull. 24(4):610-620.

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Energy Use

Issue

How much energy is used for manufacture and/or assembly of the components of the utility transmission or distribution pole, and the raw materials used in the components?

Definition/Rationale

Energy usage is a measure of the amount of energy in the form of electricity or primary fuel required from sources outside the process in the manufacture of the pole and its constituent materials. The lower the energy requirements the lower the demand on energy resources and the lower the environmental releases from energy generation. Since many of the raw/intermediate materials are purchased by the manufacturer, the primary raw materials may have been evaluated from generic industry data. The scoring ranges used for this criterion were developed as part of a pollution prevention methodology based on life cycle assessment for the U.S. EPA (Tolle et al, 1994).

Scoring Procedures and Modifiers

Table A-28 shows the Energy Use criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). To apply this criterion, the following information is needed:

1. Determine the energy requirements for each component of the utility pole, including the pole structure and any treatments, as well as the energy requirement for raw materials processing and preparation (Table A-29). Energy requirements of pole treatments comprising less than 1 percent of the weight of a unit of module output, and their precursors, may be ignored.
2. Reference each component against its unit energy use.
3. Aggregate each individual component score to the entire utility pole based on weight ratios of the component to the total, ignoring materials present in less than one percent by weight.

Table A-28
Scoring Ranges for the Criterion on Energy Use

Score	Criteria Ranges for Energy Usage Per Unit Output
9	<500 BTU/lb (includes materials with no energy usage)
7	500 - <1,000 BTU/lb
5	1,000 - <2,500 BTU/lb
3	2,500 - <5,000 BTU/lb
1	≥5,000 BTU/lb
*	Insufficient data

Table A-29
Energy Usage Factors for Examples of Common Industrial Processes

Process	Net Process Energy, BTU/lb[b]
Natural Gas Production	1,224
Crude Oil Production / Distillation / Hydrotreating	591
Salt Mining	592
Sodium Hydroxide Production / (Diaphragm Cell)[c]	11,275
Soda Ash Production (Trona)	14,045
Chlorine Production / (Diaphragm Cell)[c]	4,739
Sulfuric Acid Production / (Contact Process)[d]	4,367
Wood and Raw Wood Products	109
Sulfur Mining	3,089
Wood Treating	114
Steel Production	750
Electrical Power (National Grid)[e]	10,750[f]
CCA-treated wood utility pole[g]	330
Steel utility pole[g]	10,500
Concrete utility pole[g]	600

(a) Exclusive of Energy of Material Resource, i.e. energy inherent in product; inclusive of precombustion energy, if any.
(b) References: Franklin Associates Ltd., 1991; Brown, et al., 1985; EPA, 1991; values in BTU/lb except as noted.
(c) Module input is salt delivered to production facility; NaOH = 80.3% of cell output on mass allocation basis; Cl2 = 16.6% of output.
(d) Module input is sulfur delivered to production facility.
(e) Includes generation, transmission, and distribution losses.
(f) Units are BTU/KWh.
(g) Reference: Erlandsson, et al. 1992.

References

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Global Warming Potential

Issue

How can the raw material acquisition and manufacturing stages of the life cycle of utility transmission or distribution poles be modified to minimize release of air emissions that can result in an increased potential for global warming?

Definition/Rationale

The temperature of the earth is determined by the balance of the incoming solar radiation and the outgoing infrared radiation from the earth (Wuebbles and Edmonds, 1991; Heijungs et al., 1992a and 1992b; Nordic Council, 1992). Atmospheric gases, called greenhouse gases, that absorb infrared radiation are increasing, and there is concern that this could result in global warming. Global warming potentials (GWPs) relative to CO_2 have been developed for all important greenhouse gases by the Intergovernmental Panel on Climate Change (IPCC) for different time scales (e.g., 100 years) that can be used to evaluate the relative GWP when more than one gas is involved in the evaluation. The GWPs for CO_2, CH_4, and N_2O are, respectively, 1, 23, and 296 over a 100-year time horizon. These values are the most recent estimate of GWPs by the IPCC in its Third Assessment Report (TAR) (IPCC, 2001) and 40 CFR Part 82 required by Title VI of the Clean Air Act Amendments. The scoring ranges used for this criterion are reported by Jensen and Walker (1995) and Tolle et al (1994).

Scoring Procedures and Modifiers

Table A-30 shows the Global Warming Potential criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). To apply this criterion, the following information is needed:

1. Tabulate the chemical emissions that are considered global warming gases for each process in the raw material acquisition and manufacturing stages of the life cycle of utility distribution poles.
2. Determine the GWP (100 year) from the most recent estimate by the IPCC in its TAR (IPCC, 2001). This information is available in Tables 3 and 4 of an EPA report at the web site http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BUM9T/$File/ghg_gwp.pdf or from the column in Table 6.7 for the 100-year time horizon in the IPCC TAR at http://www.grida.no/climate/ipcc_tar/wg1/248.htm.
3. Determine the raw score using the GWP from the TAR and scoring ranges listed below. Apply score modifiers as appropriate (**Final Score = Raw Score - Modifier Score;** but final score is never less than 1).

4. Calculate the average final score for all global warming gases in both the raw material acquisition and manufacturing stages.

Table A-30
Scoring Ranges for the Criterion on Global Warming Potential

Raw Score	Criterion Ranges for Global Warming Potential (GWP) (Equal Mass Relative to CO2 over 100 Year)
9	<1 (H-2401, H-2311)
7	1-99 (CO2, HCFC-123, H-1211, H-1202, H-2402, H-1201, Methane (CH4), Chloroform, Methylene Chloride)
5	100-499 (Nitrous Oxide, HCFC-124, HFC-152a, Methyl Chloroform)
3	500-5000 (CFC-11, Carbon Tetrachloride, HCFC-22, HFC-125, HFC-134a, HCFC-141b, HCFC-142b, HFC-143a)
1	>5000 (CFC-12, CFC-113, CFC-114, CFC-115, HFC-23, Perfluoromethane)
*	Insufficient information

Major Criteria Air Emission Modifier - Due to the substantially greater quantity (typically ≥100 TPY) of chemicals considered major criteria pollutants reported in AIRS Executive, a score modifier was given to these major source emissions. Thus, the raw GWP score determined for a major source chemical should be subtracted by 2 to get the final GWP score for that chemical.

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Heijungs, R. et al. 1992a. *Environmental Life Cycle Assessment of Products: Backgrounds - October 1992*. Report No. 9267. Center of Environmental Science, Leiden, The Netherlands.

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Inhalation Toxicity

Issue

How can the life cycle of utility transmission or distribution poles be modified to minimize release of air emissions that have the potential for inhalation toxicity to humans located near air emission sources associated with manufacturing facilities?

Definition/Rationale

Materials in the manufacturing processes, product, and packaging should be utilized which minimize or eliminate toxic emissions. Likewise, the elimination or minimization of metabolites (e.g., dioxins/by-products from combusted materials) is important. The potential to create toxic chemicals during incineration of manufacturing wastes should be minimized or eliminated.

Scoring Procedures and Modifiers

Table A-31 shows the Inhalation Toxicity criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). The scoring ranges used for this criterion were developed as part of a pollution prevention methodology based on life cycle assessment for the U.S. EPA (Tolle et al, 1994). To apply this criterion, the following information is needed:

1. Tabulate the chemical air emissions (post controls) for each manufacturing process.
2. Look up the no-observed-adverse-effect-level (NOAEL) for human inhalation toxicity for the compounds in the online IRIS database available from the National Library of Medicine or at the EPA web site http://www.epa.gov/iris/. If the NOAEL is not available, use the permissible exposure limit (PEL) or the 8-hour, time-weighted average (TWA) specified by the Occupational Safety and Health Administration (OSHA, 1997) standards and listed in 29 CFR, Part 1910.1000. The guide by the American Conference of Governmental Industrial Hygienists (ACGIH, 2003) contains the OSHA TWA and Short Term Exposure Limit/Ceiling (STEL/CEIL), as well as the ACGIH TWA and STEL/CEIL.
3. For criteria air pollutants, use the National Ambient Air Quality Standards (NAAQS) as an indicator of the NOAEL. NAAQS values are listed at http://epa.gov/air/criteria.html.

4. Calculate the average inhalation toxicity score for all air emissions during the manufacturing life cycle stage.

Table A-31
Scoring Ranges for the Criterion on Inhalation Toxicity

Raw Score	Air Concentration Criterion Ranges for Major Component, Additives, or Degradation Products; NOAEL or OSHA Standard
9	NOAEL >1,000 mg/m3 in air (includes materials with no toxicity)
7	NOAEL 10-1,000 mg/m3 in air
5	NOAEL 0.1-10 mg/m3 in air
3	NOAEL 0.01-0.1 mg/m3 in air
1	NOAEL <0.01 mg/m3 in air
*	Insufficient information

References

American Conference of Governmental Industrial Hygienists (ACGIH). 2003. *Guide to Occupational Exposure Limits*. ACGIH, Cincinnati, OH.

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

OSHA. 1997. Part 1910 - Occupational Safety and Health Standards, §1910.1000: Air contaminants. 29 CFR, Part 1910. Updated Sept. 30, 1997.

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Smog Creation Potential

Issue

How can the manufacturing stage of the life cycle of utility transmission or distribution poles be modified to minimize release of air emissions that have the potential for ground-level ozone (smog) formation?

Definition/Rationale

The Photochemical Oxidant Creation Potential (POCP) of an emission is based on the ratio between the change in the ozone concentration due to a change in the emission of that VOC and the change in the ozone concentration due to a change in ethylene emissions.

Scoring Procedures and Modifiers

Photochemical oxidant formation, which is typically associated with the formation of summer smog, is the result of reactions between NO_x and volatile organic compounds (VOCs) or other hydrocarbons (HCs) under the influence of UV light (Heijungs et al., 1992a; Nordic Council, 1992). The most well known impacts of smog are visibility problems, eye irritation, respiratory tract problems, and crop damage. The most studied oxidant is ozone, but peroxyl acetyl nitrate (PAN) has also been studied and is about ten times worse than ozone in causing environmental damage. The more reactive substances will form smog within a few hours after environmental release, causing a local or regional problem. This is a particularly acute problem in southern California, where air stagnation and auto exhaust aggravate the problem.

In order to evaluate the POCP for emissions of different VOCs and other HCs, POCPs have been calculated for over 78 HCs. The POCP can be defined as the ratio between the change in ozone concentration due to a change in the emission of that HC and the change in the ozone concentration due to a change in the emission of ethylene. The POCP for individual VOCs known to be released from refining can be orders of magnitude different. For example, the POCPs for methane, ethane, and m-xylene are, respectively, 0.034, 0.14, and 1.09 (Klöppfer and Potting, 2002 [updates data in Heijungs et al. (1992b)]).

Table A-32 shows the Smog Creation Potential criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). The scoring ranges used for this criterion are reported by Jensen and Walker (1995) and Tolle et al (1994). To apply this criterion, the following information is needed:

1. Tabulate the chemical air emissions considered to be photochemical oxidants for each process in the manufacturing stage of the life cycle of utility distribution poles.
2. Determine the raw POCP score for a chemical based on information in Klöppfer and Potting (2002) or use the examples listed below. Apply score modifiers as appropriate (**Final Score = Raw Score - Modifier Score**; but final score is never less than one**).**
3. Calculate the average final score for all photochemical oxidant air emissions released during the manufacturing life cycle stage.

Major Criteria Air Emission Modifier - Due to the substantially greater quantity (typically ≥100 TPY) of chemicals considered major criteria pollutants reported in AIRS Executive, a score modifier was given to these major source emissions. Thus, the raw GWP score determined for a major source chemical should be subtracted by 2 to get the final GWP score for that chemical.

Non-Attainment Area Modifier - The score should be modified if all emission sources are located in an air quality non-attainment area for ozone. Decrease the calculated score by two or four points for areas with ozone non-attainment classifications considered, respectively, "marginal-to-serious" or "severe-to-extreme". The 1-Hour Ozone Non-attainment Area Map can be found in the U.S. EPA Green Book (Web site for U.S. EPA, 2006).

Table A-32
Scoring Ranges for the Criterion on Smog Creation Potential

Raw Score	Criterion Ranges For Ground-Level Ozone (Smog) Formation Potential Relative To Ethylene
9	<0.005
7	0.050-0.006 (e.g., NO2, CO, SO2, tetrachloroethylene, methane, average halogenated hydrocarbons, methylene chloride)
5	0.500-0.051 (e.g., average alcohols, methanol, acetone, methyl ethyl ketone, average non-methane hydrocarbons, ethanol, styrene, ethylene glycol, average VOCs, benzene, average esters, average ketones,)
3	0.999-0.501 (e.g., average aromatic hydrocarbons, average alkanes, toluene, pentachlorophenol, naphthalene, ethyl benzene, 1,2,4-trimethylbenzene, average xylenes, o-xylene, p-xylene, average olefins)
1	≥1.000 (e.g., ethylene, propylene, m-xylene)
*	Insufficient information [see Klöppfer and Potting (2002) for POCP of additional chemicals]

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Heijungs, R. et al. 1992a. Environmental Life Cycle Assessment of Products: Backgrounds - October 1992. Report No. 9267. Center of Environmental Science, Leiden, The Netherlands.

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U.S. Environmental Protection Agency (EPA). 2006. Green Book Nonattainment Areas for Criteria Pollutants http://www.epa.gov./oar/oaqps/greenbk/map8hrnm.html

Recyclability Potential (Post-consumer)

Issue

What portion of the utility transmission or distribution pole is or could be recycled at the end of its useful life-time?

Definition/Rationale

Recyclability potential is the proportion of the utility transmission or distribution pole that can be recycled into the same or other similar products given current or near-commercial technology, market and infrastructure conditions. Recycling by definition does not include reuse of the pole, such as in give-away programs. Nor does it include down-valued uses such as reducing concrete poles to rubble for use as rip rap, or reduction of wood poles to chips for use as a bulking agent in composting.

Assessment of this criterion entails a judgment on the part of the evaluator that there is a current demand/use for the material in recycle applications, and that there is a mechanism for the user to collect and send the material to a recycler, or that a market and infrastructure are developing in the near term.

Recycling reduces environmental costs in such life-cycle stages as raw material extraction and manufacturing. Recycling may entail some environmental energy and emission burdens. Typically, these are lower than the burdens associated with the use of virgin materials.

Scoring Procedures and Modifiers

Table A-33 shows the Recyclability Potential (Post-consumer) criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). To apply this criterion the following information should be supplied:

1. Assess whether the pole components can be separated at the end of life to allow recycling. If so assess each component using the procedure below, otherwise assign a a score based on the entire pole.

2. What is the percentage of utility pole material that can be currently recycled or could be recycled with near-term (12 to 18 month time horizon) technology and infrastructure? Manufacturing, use, and disposal processes that may degrade or contaminate the material and reduce further usefulness, such as applied treatments and their depth of penetration, should be considered in the evaluation.
3. Select unit recyclability potential scores for each material of construction (Table A-34). However, for poles, or other products, in which the construction does not prevent the materials being separated at the end of life, such as is the case for a preservative-treated wood pole, select a score for the composite pole or product and not for the individual materials.
4. Aggregate each individual component score to the entire utility pole based on weight ratios of the components to the total.

Table A-33
Scoring Ranges for the Criterion on Recyclability Potential (Post-consumer)

Score	Criterion Ranges for Post-consumer Recyclability Potential
9	Well established, convenient mechanism and >100 million lb annual market.
7	Good mechanism and 10-100 million lb annual market.
5	Established, convenient mechanism for recycle, but less than 10 million lb annual market.
3	Recycling mechanism only fair and/or less than 10 million lb annual market.
1	Mechanism and/or market totally lacking
*	Insufficient data

Table A-34
Examples of Recyclability Data

Material	Mechanism Availability	Market Volume (million lbs.)
Aluminum	Well established, or widespread	1,600
Steel	Well established, or widespread	9,200
Glass	Well established, or widespread	4,800
Paper and Paperboard	Well established, or widespread	73,400
Wood, untreated	Good, regionally available	2,600(a)
PET (milk and juice bottles)	Fair, regionally available, economically marginal	940
HDPE	Fair, regionally available, economically marginal	860
PVC	Poor, very patchy, economically unfavorable	Not reported
LDPE (plastic bags)	Fair, regionally available, economically marginal	300
PP (reusable plastic containers)	Poor, extremely patchy	20
PS	Poor, extremely patchy	Not reported
Other plastics or polymers	Poor, extremely patchy	660

(a) Includes wood recovered for composting, compounding, or incineration (U.S. EPA, 2003).

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

Steel Recycling Institute (SRI). 2006. Steel Recycling Rates (construction steel scrap includes steel utility poles). http://www.recycle-steel.org/PDFs/ratesheet.pdf, http://www.recycle-steel.org/buyrecycled.html, http://www.recycle-steel.org/construction.html.

United States Environmental Protection Agency. 2003. *Municipal Solid Waste in the United States: 2001 Facts and Figures*. U.S. EPA, Washington, DC.

Toxic Material Mobility upon Landfilling or Incineration

Issue

How mobile are the toxic additives or degradates of the preservatives or coatings applied to a utility transmission or distribution pole upon landfilling or incineration?

Definition/Rationale

Toxic material mobility in the landfill environment is a measure of the speed with which these compounds are leached from the pole and the rate at which they might move from the original point of pole placement into the liquid leachate or landfill gas stream and thus potentially escape the landfill, or the extent to which components are expected to migrate from a point of incineration. Mobility of residual components from the landfilling of incinerator ash is also a consideration. This criterion is used in conjunction with the toxicity criterion to estimate overall hazard potential from toxic constituents or by-products. It is environmentally desirable that potentially toxic emissions be minimized. To ensure that this is the case, volatility and aqueous solubility are used to estimate mobility potential.

Scoring Procedures and Modifiers

Table A-35 shows the Toxic Material Mobility upon Landfilling or Incineration criterion scoring ranges used in the environmental profile screening system for utility distribution poles (EPRI, 2005). To apply this criterion the following information is needed:

1. Tabulate the principal component materials of the preservatives or coatings applied to a utility pole and calculate the weight fractions of each of these components.
2. Tabulate the fractions of each pole that are disposed into landfills and via incineration.
3. Reference each component against its volatility (or Henry's Law constant) and water solubility as listed in chemical property reference listings or on Material Safety sheets. Materials with lower Henry's Law constants or water solubilities are expected to take longer to dissipate from the utility pole and migrate from the landfill. Sample scores are given for a select group of materials in Table A-36. Chemical properties, such as volatility or aqueous solubility may be available from the following databases:
   - HSDB (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB) and
   - ChemIDPlus Advanced (http://chem2.sis.nlm.nih.gov/chemidplus/)
   - ChemFinder.com (http://chemfinder.cambridgesoft.com/)
   - CHEMFATE Chemical Search (http://www.syrres.com/esc/chemfate.htm).
4. Aggregate individual component scores for landfilling and incineration, separately, to the entire utility pole based on weight ratios to the total using the weight fractions from Step 1.
5. Tabulate the overall Toxic Material Mobility score as the sum of weight fractions calculated in Step 2 multiplied by the respective scores from Step 4.

Table A-35
Scoring Ranges for the Criterion on Toxic Material Mobility upon Landfilling or Incineration

Score	Criteria Ranges of Years for Significant Movement
9	>100 years for significant movement (includes materials that are 100% recyclable and would not be sent to a landfill)
7	25 - 100 years
5	5 - 25 years
3	1 - 5 years
1	<1 year
*	Insufficient data

Table A-36
Examples of Scores for Selected Materials

Material	Score
Sodium chloride	3 (Moderately high aqueous solubility)
Acetone	1 (High Henry's Law constant)
Wood	9 (Low aqueous solubility)
HDPE	9 (Low aqueous solubility)
Pentachlorophenol	7 (Moderately low Henry's Law constant)
Naphthalene	3 (Moderately high Henry's Law constant)
CCA	1 (High aqueous solubility of arsenic salts)

References

Electric Power Research Institute (EPRI). 2005. *Environmental Profile of Utility Distribution Poles*, Technical Report 1010143. EPRI, Palo Alto, California.

B
CRITERIA SCORES FOR FOUR TYPES OF ELECTRIC TRANSMISSION POLES

Raw, Unweighted Criteria Scores for Four Pole Types

Four transmission pole types were evaluated to demonstrate the CST approach using the procedures and semi-quantitative scoring ranges described in Appendix A. The decision tool demonstration included three treated-wood poles (CuNap-DF, Penta-WRC, and Penta-SYP) and one non-wood pole alternative (galvanized steel). The tables in this appendix show the individual raw (unweighted) scores for pole components and mass-based average or pole-based score for the total pole for each of the 26 impact criteria. For each pole type there are three tables that include the criteria scores associated with each of the three major evaluation groups. Thus, the scores for the CuNap-DF wood pole are in Tables B-1, B-2, and B-3, respectively, for the engineering/technical performance, life cycle cost/economics, and environmental profile groups of criteria. The scores for the Penta-WRC wood pole are in Tables B-4, B-5, and B-6, respectively, for the engineering/technical performance, life cycle cost/economics, and environmental profile groups of criteria. The scores for the galvanized steel pole are in Tables B-7, B-8, and B-9, respectively, for the engineering/technical performance, life cycle cost/economics, and environmental profile groups of criteria. The scores for the Penta-SYP wood pole are in Tables B-10, B-11, and B-12, respectively, for the engineering/technical performance, life cycle cost/economics, and environmental profile groups of criteria.

Table B-1
Individual Constituent Criteria Scores for CuNap-DF Pole: Engineering/Technical Performance Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Engineering/Technical Performance Criteria							
				Service Life with Maintenance	Regulatory Status	Emergency Field Procedures	Equipment Requirements for Transport to Job Site/Install/Removal	Handling Protection	Grounding	Weight/Number for Bulk Transport from Manufacturer	Hardness
			Overall Score	5.0	7.0	9.0	7.0	9.0	9.0	7.0	9.0
			Pole-based Scores	5.0	7.0	9.0	7.0	9.0	9.0	7.0	9.0
Wood, DF	4022.15	0.997	Mass-based Scores								
Copper naphthenate	10.28	0.003									
Fuel oil, No. 2	12.57	0.003									

Table B-2
Individual Constituent Criteria Scores for CuNap-DF Pole: Life Cycle Cost/Economic Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Life Cycle Cost\Economics Criteria: Acquisition Cost	Transportation Cost	Installation Cost	Maintenance Cost	Disposal Cost	Reuse or Recycle Cost	Resource Renewability or Sustainability	Raw Materials Infrastructure	Manufacturing Capacity
			Overall Score	7.0	5.0	5.0	5.0	9.0	5.0	5.0	9.0	5.0
			Pole-based Scores	7.0	5.0	5.0	5.0	9.0	5.0			5.0
Wood, DF	4022.15	0.997	**Mass-based Scores**							5	9	
Copper naphthenate	10.28	0.003								1	9	
Fuel oil, No. 2	12.57	0.003								1	9	
Copper	**Reserves**	**Reserve Fraction**									**Country Score**	
US	70000	0.075									9	
Australia	43000	0.046									9	
Canada	20000	0.021									9	
Chile	360000	0.384									7	
China	63000	0.067									7	
Indonesia	38000	0.041									1	
Kazakhstan	20000	0.021									3	
Mexico	40000	0.043									5	
Peru	60000	0.064									1	
Poland	48000	0.051									5	
Russia	30000	0.032									7	
Zambia	35000	0.037									5	
Other	110000	0.117									3	

Table B-3
Individual Constituent Criteria Scores for CuNap-DF Pole: Environmental Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Environmental Criteria								
				Acidification Potential	**Carcinogenicity**	**Ecological Habitat Alteration**	**Energy Use**	**Global Warming Potential**	**Inhalation Toxicity**	**Smog Creation Potential**	**Recyclability Potential**	**Toxic Material Mobility**
			Overall Score	9.0	6.0	3.0	9.0	9.0	5.0	3.0	3.0	3.2
			Pole-based Scores	9.0				9.0			3.0	
Wood, DF	4022.15	0.997	**Mass-based Scores**			3	9					
Copper naphthenate	10.28	0.003			7	6.4	7					1
Fuel oil, No. 2	12.57	0.003			7	7	7					5
CuNap Wood Treating Facilities:												
Air Emissions												
Naphthalene				NA	3			NA	5	3		
Water Emissions												
Naphthalene				NA	LIA							
No. 2 Fuel oil [(1)]				NA	7							

(1) PCS lists as oil and grease
NA = Not Applicable; LIA = Listed in Air

Table B-4
Individual Constituent Criteria Scores for Penta-WRC Pole: Engineering/Technical Performance Criteria

				Engineering/Technical Performance Criteria							
Material	**Weight in Pole (lbs.)**	**Weight Fraction**	**Criterion**	**Service Life with Maintenance**	**Regulatory Status**	**Emergency Field Procedures**	**Equipment Requirements for Transport to Job Site/Install/Removal**	**Handling Protection**	**Grounding**	**Weight/Number for Bulk Transport from Manufacturer**	**Hardness**
			Overall Score	7.0	5.0	9.0	7.0	9.0	9.0	7.0	9.0
			Pole-based Scores	7.0	5.0	9.0	7.0	9.0	9.0	7.0	9.0
Wood, WRC	3005.73	0.970	**Mass-based Scores**								
Penta	7.86	0.003									
Diesel oil, No. 2	86.41	0.028									

Table B-5
Individual Constituent Criteria Scores for Penta-WRC Pole: Life Cycle Cost/Economics Criteria

				Life Cycle Cost\Economics Criteria								
Material	**Weight in Pole (lbs.)**	**Weight Fraction**	**Criterion**	**Acquisition Cost**	**Transportation Cost**	**Installation Cost**	**Maintenance Cost**	**Disposal Cost**	**Reuse or Recycle Cost**	**Resource Renewability or Sustainability**	**Raw Materials Infrastructure**	**Manufacturing Capacity**
			Overall Score	3.0	5.0	5.0	1.0	5.0	5.0	4.9	9.0	9.0
			Pole-based Scores	3.0	5.0	5.0	1.0	5.0	5.0			9.0
Wood, WRC	3005.73	0.970	**Mass-based Scores**							5	9	
Penta	7.86	0.003								1	9	
Diesel oil, No. 2	86.41	0.028								1	9	

Table B-6
Individual Constituent Criteria Scores for Penta-WRC Pole: Environmental Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Environmental Criteria								
				Acidification Potential	Carcinogenicity	Ecological Habitat Alteration	Energy Use	Global Warming Potential	Inhalation Toxicity	Smog Creation Potential	Recyclability Potential	Toxic Material Mobility
			Overall Score	9.0	5.8	3.1	8.9	9.0	3.0	3.0	3.0	5.0
			Pole-based Scores	9.0				9.0			3.0	
Wood, WRC	3005.73	0.970	**Mass-based Scores**			3	9					
Penta	7.86	0.003			1	7	7					5
Diesel oil, No. 2	86.41	0.028			7	7	7					5
Penta Wood Treating Facilities:												
Air Emissions												
Pentachlorophenol				NA	1			NA	5	3		
Dioxin and dioxin-like compounds[(1)]				NA	7			NA	1	NA		
Water Emissions												
Pentachlorophenol				NA	LIA							
Dioxin and dioxin-like compounds[(1)]				NA	LIA							
Fuel oil, (P-9)[(2)]				NA	7							

(1) The dioxin congeners released include several that are IARC Group-3
(2) PCS lists as oil and grease
NA = Not Applicable, LIA = Listed in Air

Table B-7
Individual Constituent Criteria Scores for Galvanized Steel Pole: Engineering/Technical Performance Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Engineering/Technical Performance Criteria: Service Life with Maintenance	Regulatory Status	Emergency Field Procedures	Equipment Requirements for Transport to Job Site/Install/Removal	Handling Protection	Grounding	Weight/Number for Bulk Transport from Manufacturer	Hardness
			Overall Score	7.0	7.0	7.0	9.0	7.0	1.0	9.0	3.0
			Pole-based Scores	7.0	7.0	7.0	9.0	7.0	1.0	9.0	3.0
Steel	1599.00	0.935	**Mass-based Scores**								
Zinc (as Galvanizing)	105.00	0.061									
Corrocoat (polyurethane)	7.00	0.004									

Table B-8
Individual Constituent Criteria Scores for Galvanized Steel Pole: Life Cycle Cost/Economics Criteria

				Life Cycle Cost/Economics Criteria								
Material	**Weight in Pole (lbs.)**	**Weight Fraction**	**Criterion**	**Acquisition Cost**	**Transportation Cost**	**Installation Cost**	**Maintenance Cost**	**Disposal Cost**	**Reuse or Recycle Cost**	**Resource Renewability or Sustainability**	**Raw Materials Infrastructure**	**Manufacturing Capacity**
			Overall Score	7.0	5.0	5.0	5.0	9.0	9.0	2.9	8.9	3.0
			Pole-based Scores	7.0	5.0	5.0	5.0	9.0	9.0			3.0
Steel	1599.00	0.935	**Mass-based Scores**							3	9	
Zinc (as Galvanizing)	105.00	0.061								1	7.95	
Corrocoat (polyurethane)	7.00	0.004								1	9	
Zinc	**Reserves**	**Reserve Fraction**									**Country Score**	
US	90000	0.24									9	
Australia	80000	0.21									9	
Canada	31000	0.08									9	
China	92000	0.25									7	
Kazakhstan	35000	0.09									3	
Mexico	25000	0.07									5	
Peru	20000	0.05									1	
Other	87000	0.23									3	

Table B-9
Individual Constituent Criteria Scores for Galvanized Steel Pole: Environmental Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Environment Criteria								
				Acidification Potential	Carcinogenicity	Ecological Habitat Alteration	Energy Use	Global Warming Potential	Inhalation Toxicity	Smog Creation Potential	Recyclability Potential	Toxic Material Mobility
			Overall Score	2.2	6.1	3.0	6.6	5.0	5.0	3.8	8.6	9.0
			Pole-based Scores									
Steel	1599.00	0.935	**Mass-based Scores**			3	7				9	
Zinc (as Galvanizing)	105.00	0.061			7	3	1				3	9
Corrocoat (polyurethane)	7.00	0.004			7	7	7				1	9
Steel Mills (incl. galvanizing) Mfg.:												
Major Criteria Air Emissions												
SO2 (≥ 100 TPY)				1	7			NA	5	5		
CO2 (per Erlandsson et al., 1992)				NA	NC			5	9	NA		
NO2 (≥ 100 TPY)				3	7			NA	5	5		
CO (≥ 1000 TPY)				NA	NC			NA	7	5		
Pb (≥ 5 TPY)				NA	3			NA	1	NA		
VOC (≥ 100 TPY)				NA	CD			NA	CD	3		
TRI Air Emissions												
Hydrochloric Acid				5	7			NA	5	NA		
Ethylene				NA	7			NA	7	1		

Benzene				NA	1			NA	5	5		
Zinc Compounds				NA	7			NA	ND	NA		
Ammonia				1	NC			NA	5	NA		
Zinc (Fume Or Dust)				NA	7			NA	5	NA		
Naphthalene				NA	3			NA	5	3		
Nitric Acid				NA	NC			NA	5	NA		
Manganese Compounds				NA	7			NA	3	NA		
Toluene				NA	5			NA	7	3		
Dioxin And Dioxin-Like Compounds				NA	1			NA	1	NA		
Water Emissions												
Nitrate Compounds				NA	NC							
Ammonia				1	NC							
Manganese Compounds				NA	LIA							
Zinc Compounds				NA	LIA							
Dioxin and dioxin-like compounds				NA	LIA							

NA = Not Applicable; NC = No Conclusion on carcinogenicity; ND = No Data; CD = Chemical Dependant; LIA = Listed in Air

Table B-10
Individual Constituent Criteria Scores for Penta-SYP Pole: Engineering/Technical Performance Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Engineering/Technical Performance Criteria							
				Service Life with Maintenance	Regulatory Status	Emergency Field Procedures	Equipment Requirements for Transport to Job Site/Install/Removal	Handling Protection	Grounding	Weight/Number for Bulk Transport from Manufacturer	Hardness
			Overall Score	5.0	5.0	9.0	7.0	9.0	9.0	7.0	9.0
			Pole-based Scores	5.0	5.0	9.0	7.0	9.0	9.0	7.0	9.0
Wood, SYP	5234	0.981	Mass-based Scores								
Diesel oil, No. 2	95.23	0.018									
Penta	8.66	0.002									

Table B-11
Individual Constituent Criteria Scores for Penta-SYP Pole: Life Cycle Cost/Economic Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Life Cycle Cost\Economics Criteria								
				Acquisition Cost	Transportation Cost	Installation Cost	Maintenance Cost	Disposal Cost	Reuse or Recycle Cost	Resource Renewability or Sustainability	Raw Materials Infrastructure	Manufacturing Capacity
			Overall Score	5.0	5.0	5.0	5.0	5.0	5.0	4.9	9.0	3.0
			Pole-based Scores	5.0	5.0	5.0	5.0	5.0	5.0			3.0
Wood, SYP	5234	0.981	**Mass-based Scores**							5	9	
Diesel oil, No. 2	95.23	0.018								1	9	
Penta	8.66	0.002								1	9	

Table B-12
Individual Constituent Criteria Scores for Penta-SYP Pole: Environmental Criteria

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Environmental Criteria								
				Acidification Potential	**Carcinogenicity**	**Ecological Habitat Alteration**	**Energy Use**	**Global Warming Potential**	**Inhalation Toxicity**	**Smog Creation Potential**	**Recyclability Potential**	**Toxic Material Mobility**
			Overall Score	9.0	5.8	3.1	9.0	9.0	3.0	3.0	3.0	5.0
			Pole-based Scores	9.0				9.0			3.0	
Wood, SYP	5234	0.981	**Mass-based Scores**			3	9					
Diesel oil, No. 2	95.23	0.018			7	7	7					5
Penta	8.66	0.002			1	7	7					5
Penta Wood Treating Facilities:												
Air Emissions												
Pentachlorophenol				NA	1			NA	5	3		
Dioxin and dioxin-like compounds[(1)]				NA	7			NA	1	NA		
Water Emissions												
Pentachlorophenol				NA	LIA							
Dioxin and dioxin-like compounds[(1)]				NA	LIA							
Fuel oil, (P-9)[(2)]				NA	7							

(1) The dioxin congeners released include several that are IARC Group-3
(2) PCS lists as oil and grease
NA = Not Applicable, LIA = Listed in Air

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