

# Demonstration of Decision Tool for Selection of Distribution Poles

*Technical Report*

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# **Demonstration of Decision Tool for Selection of Distribution Poles**

**1012598**

Final Report, October 2006

EPRI Project Manager  
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This report describes research sponsored by the Electric Power Research Institute (EPRI).

The report is a corporate document that should be cited in the literature in the following manner:

*Demonstration of Decision Tool for Selection of Distribution Poles*. EPRI, Palo Alto, CA: 2006.  
1012598.



# PRODUCT DESCRIPTION

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This report describes a Comprehensive Screening Tool (CST) for comparing different types of utility distribution poles. The completed tool permits utilities to evaluate distribution pole options using 26 criteria divided into engineering/technical performance, life cycle cost/economics, and environmental profile groups. The decision tool allows utilities to make a comprehensive evaluation of distribution 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. In a demonstration, the CST procedures scored two treated-wood poles (CCA and ACQ) and two non-wood pole alternatives (galvanized steel and concrete). The 26 criteria were priority weighted based on relative importance by using a 12-member expert panel, the Analytic Hierarchy Process (AHP), and Expert Choice® software. To insure acceptance by a broader range of stakeholders, the weighting process incorporated two perspectives, the Electric Utility Perspective and the Public Policy Perspective.

## Results & Findings

The demonstration showed that the customized decision tool is ready 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, particularly when the various criteria do not favor a single pole type. For the four pole types used in this demonstration, the overall weighted scores only differed among pole types using criteria weights under the Electric Utility Perspective. The overall weighted scores for the Public Policy Perspective were not significantly different among any of the four pole types evaluated.

The CST is easy to use—the application procedures are detailed in the appendix—and can be tailored to the specific regional economic and environmental conditions of an individual utility. A utility can tailor the criteria weighting factors to emphasize engineering performance, life cycle cost, or environmental priorities by using the same weighting procedures described for the demonstration.

## Challenges & Objectives

The current project expanded on an initial concept design completed in December 2005 by incorporating look-up tables or references for scoring criteria, by defining procedures for priority weighting, and by conducting a demonstration of the tool for scoring and comparing two treated wood and two non-wood pole types. This report should be extremely useful to utilities, because it permits evaluation of different distribution pole types from a life cycle perspective across three major groups of criteria using a single, semi-quantitative approach with 26 criteria. The next logical step is a demonstration of the CST with additional types of treated-wood, non-treated wood, and non-wood distribution poles.

## **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 three earlier EPRI projects into a single coordinated approach for comparing distribution pole options. The three earlier EPRI studies separately evaluated engineering/technical performance (EPRI report 1010144, 2005, *Assessment of Treated Wood and Alternate Materials for Utility Poles*), life cycle cost/economics (EPRI Draft Technical Update, 2003, *Which Distribution Pole has the Lowest Life-cycle Cost?*), and environmental profile (EPRI report 1010143, 2005, *Environmental Profile of Utility Distribution Poles*). No other published methodology is available as a single approach that can be used by utilities to semi-quantitatively select between distribution pole options.

## **Approach**

The goal of this study was to finalize and demonstrate a previous CST concept design for comparing different types of utility distribution poles. The project team demonstrated the decision tool by scoring two treated-wood poles (CCA and ACQ) and two non-wood pole alternatives (galvanized steel and concrete), using 26 criteria priority weighted by using an expert panel, a scientific process, and calculation software.

## **Keywords**

Comprehensive screening tool  
Life cycle analysis  
Engineering/technical performance criteria  
Life cycle cost/economic criteria  
Environmental criteria  
Non-wood poles  
Treated wood poles  
Utility distribution poles

## ABSTRACT

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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 poles. The completed decision tool permits utilities to evaluate distribution pole options using 26 criteria divided between three evaluation groups for engineering/technical performance, life cycle cost/economics, and environmental profile. The decision tool allows utilities to make a comprehensive evaluation of distribution 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. The CST procedures were demonstrated by scoring two treated-wood poles (CCA and ACQ) and two non-wood pole alternatives (galvanized steel and concrete). The 26 criteria were priority weighted based on relative importance by using an expert panel, the Analytic Hierarchy Process (AHP), and Expert Choice® software. The weighting process was based on two different perspectives—Electric Utility and National Policy—to insure acceptance by a broader range of stakeholders.



# ACRONYMS

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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 distribution poles)
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.

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LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
MSDS	Material Safety Data Sheet
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	Peroxy acetyl nitrate
PEL	Permissible exposure limit
Penta	Pentachlorophenol
POCP	Photochemical Oxidant Creation Potential
RCRA	Resource Conservation and Recovery Act
ROI	Return on investment
RTECS	Registry of Toxic Effects on Chemical Substances, NIOSH database
RUP	Registered Use Pesticide
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
WWPI	Western Wood Preservers Institute

## **ACKNOWLEDGEMENTS**

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Special thanks are due to Jerry Zak at GEI Consultants, Inc. for his suggestions on the initial set of evaluation criteria for the Comprehensive Screening Tool (CST). The advice, suggestions, encouragement, and review comments of the EPRI Program Manager, Dr. Mary McLearn, on this final report are greatly appreciated.



# CONTENTS

---

- 1 INTRODUCTION ..... 1-1**
  - CST Concept Design..... 1-1
  - Life Cycle Approach ..... 1-1
  - Screening Criteria Selected for Three Major Evaluation Groups ..... 1-2
  - Instructions for Scoring Distribution Poles..... 1-2
  
- 2 BASIS FOR SCORING 26 POLE SELECTION CRITERIA ..... 2-1**
  - Engineering/Technical Performance Criteria..... 2-1
    - Expected Service Life with Maintenance ..... 2-1
    - Regulatory and Treated-Wood Registration Status ..... 2-1
    - Adaptability of Field Procedures and Hardware for Emergencies ..... 2-2
    - Equipment Requirements for Transport/Install/Removal ..... 2-2
    - Handling Protection to Avoid Damage..... 2-2
    - Grounding..... 2-3
    - Weight ..... 2-3
    - Hardness ..... 2-3
  - Life Cycle Cost/Economic Criteria..... 2-3
    - Acquisition Costs at Pole Yard (Pole, Liner, Sleeve, Cross Arms, Hardware, and Transport to Yard) ..... 2-4
    - Storage and Transportation Costs from Pole Yard to Installation Site ..... 2-4
    - Installation Costs ..... 2-4
    - Maintenance Costs During Pole Use (Retreatment, Inspection) ..... 2-4
    - Disposal Costs..... 2-4
    - Recycle or Reuse Costs ..... 2-5
    - Resource Renewability/Sustainability (Including Future Raw Material Availability)..... 2-5
    - Raw Materials Delivery Infrastructure..... 2-5
    - Manufacturing Capability (Pole Supply and Available Facility Output) ..... 2-5
  - Environmental Criteria..... 2-6

Acidification Potential .....	2-6
Carcinogenicity .....	2-6
Ecological Habitat Alteration.....	2-7
Energy Use.....	2-7
Global Warming Potential.....	2-7
Inhalation Toxicity.....	2-7
Smog Creation Potential.....	2-8
Recyclability Potential (Post-Consumer) .....	2-8
Toxic Material Mobility Upon Landfilling or Incineration .....	2-9
<b>3 FOUR POLE TYPES COMPARED FOR DEMONSTRATION .....</b>	<b>3-1</b>
CCA- and ACQ-Treated Wood Poles.....	3-1
Concrete and Galvanized Steel Alternatives.....	3-2
<b>4 UNWEIGHTED INDIVIDUAL CRITERIA SCORES COMPARED AMONG POLE TYPES .....</b>	<b>4-1</b>
Engineering/Technical Performance Criteria.....	4-1
Expected Service Life with Maintenance.....	4-2
Regulatory and Treated-Wood Registration Status.....	4-2
Adaptability of Field Procedures and Hardware for Emergencies .....	4-2
Equipment Requirements for Transport/Install/Removal .....	4-2
Handling Protection to Avoid Damage.....	4-3
Grounding.....	4-3
Weight .....	4-3
Hardness .....	4-3
Life Cycle Cost/Economics Criteria .....	4-3
Acquisition Costs at Pole Yard (Pole, Liner, Sleeve, Cross Arms, Hardware, and Transport to Yard) .....	4-4
Storage and Transportation Costs from Pole Yard to Installation Site .....	4-4
Installation Costs .....	4-4
Maintenance Costs During Pole Use (Retreatment, Inspection) .....	4-4
Disposal Costs.....	4-5
Recycle or Reuse Costs .....	4-5
Resource Renewability/Sustainability (Including Future Raw Material Availability).....	4-5
Raw Materials Delivery Infrastructure.....	4-5
Manufacturing Capability (Pole Supply and Available Facility Output) .....	4-6

---

Environmental Criteria.....	4-6
Acidification Potential .....	4-6
Carcinogenicity .....	4-6
Ecological Habitat Alteration.....	4-6
Energy Use.....	4-7
Global Warming Potential.....	4-7
Inhalation Toxicity.....	4-7
Smog Creation Potential.....	4-7
Recyclability Potential (Post-Consumer) .....	4-7
Toxic Material Mobility Upon Landfilling or Incineration .....	4-8
<b>5 PRIORITY WEIGHTING OF DECISION CRITERIA.....</b>	<b>5-1</b>
Expert Panel.....	5-1
Use of AHP and Expert Choice® Software .....	5-1
Results of Weighting for Two Hierarchy/Perspective Combinations .....	5-2
<b>6 OVERALL WEIGHTED, TOTAL SCORES COMPARED AMONG POLE TYPES .....</b>	<b>6-1</b>
Overall Weighted, Total Score Calculation and Limitations .....	6-1
Electric Utility Perspective .....	6-2
National Policy Perspective.....	6-2
Sensitivity Analysis.....	6-2
<b>7 DISCUSSION ON POTENTIAL USEFULNESS OF APPROACH TO UTILITIES .....</b>	<b>7-1</b>
Ability to Differentiate Scores Among Pole Types.....	7-1
Usefulness as a Decision Tool .....	7-1
Instructions for Scoring Pole Types.....	7-2
<b>8 SOURCES .....</b>	<b>8-1</b>
Literature References.....	8-1
Websites .....	8-3
<b>A DEFINITION AND SCORING OF DECISION CRITERIA .....</b>	<b>A-1</b>
Engineering/Technical Performance Criteria.....	A-1
Issue for Criteria Group .....	A-1
Definition/Rationale for Criteria Group.....	A-1
Scoring for Criteria Group.....	A-1

---

Expected Service Life with Maintenance.....	A-2
Issue .....	A-2
Definition/Rationale .....	A-2
Scoring Procedures and Modifiers .....	A-2
References .....	A-3
Regulatory and Treated-Wood Registration Status.....	A-4
Issue .....	A-4
Definition/Rationale .....	A-4
Scoring Procedures and Modifiers .....	A-4
References .....	A-5
Adaptability of Field Procedures and Hardware for Emergencies.....	A-6
Issue .....	A-6
Definition/Rationale .....	A-6
Scoring Procedures and Modifiers .....	A-7
References .....	A-8
Equipment Requirements for Transport/Install/Removal.....	A-8
Issue .....	A-8
Definition/Rationale .....	A-8
Scoring Procedures and Modifiers .....	A-9
References .....	A-10
Handling Protection to Avoid Damage .....	A-10
Issue .....	A-10
Definition/Rationale .....	A-10
Scoring Procedures and Modifiers .....	A-11
References .....	A-11
Grounding .....	A-11
Issue .....	A-11
Definition/Rationale .....	A-12
Scoring Procedures and Modifiers .....	A-12
References .....	A-13
Weight .....	A-13
Issue .....	A-13
Definition/Rationale .....	A-13
Scoring Procedures and Modifiers .....	A-13

---

References .....	A-14
Hardness .....	A-14
Issue .....	A-14
Definition/Rationale .....	A-14
Scoring Procedures and Modifiers .....	A-15
References .....	A-15
Life Cycle Cost/Economic Criteria.....	A-16
Issue for Criteria Group .....	A-16
Definition/Rationale for Criteria Group.....	A-16
Scoring for Criteria Group.....	A-16
Acquisition Costs at Pole Yard (Pole, Liner, Sleeve, Cross Arms, Hardware, and Transport to Yard) .....	A-17
Issue .....	A-17
Definition/Rationale .....	A-17
Scoring Procedures and Modifiers .....	A-17
References .....	A-18
Storage and Transportation Costs from Pole Yard to Installation Site.....	A-18
Issue .....	A-18
Definition/Rationale .....	A-18
Scoring Procedures and Modifiers .....	A-18
References .....	A-19
Installation Costs .....	A-19
Issue .....	A-19
Definition/Rationale .....	A-19
Scoring Procedures and Modifiers .....	A-20
References .....	A-20
Maintenance Costs During Pole Use (Retreatment, Inspection).....	A-20
Issue .....	A-20
Definition/Rationale .....	A-20
Scoring Procedures and Modifiers .....	A-21
References .....	A-21
Disposal Costs .....	A-21
Issue .....	A-21
Definition/Rationale .....	A-22
Scoring Procedures and Modifiers .....	A-22

---

References .....	A-23
Recycle or Reuse Costs.....	A-23
Issue .....	A-23
Definition/Rationale .....	A-23
Scoring Procedures and Modifiers .....	A-23
References .....	A-24
Resource Renewability/Sustainability (Including Future Raw Material Availability) .....	A-24
Issue .....	A-24
Definition/Rationale .....	A-24
Scoring Procedures and Modifiers .....	A-25
References .....	A-25
Raw Materials Delivery Infrastructure .....	A-25
Issue .....	A-25
Definition/Rationale .....	A-25
Scoring Procedures and Modifiers .....	A-26
References .....	A-27
Manufacturing Capability (Pole Supply and Available Facility Output).....	A-27
Issue .....	A-27
Definition/Rationale .....	A-27
Scoring Procedures and Modifiers .....	A-27
References .....	A-27
Environmental Criteria.....	A-28
Issue for Criteria Group .....	A-28
Definition/Rationale for Criteria Group.....	A-29
Scoring for Criteria Group.....	A-29
References .....	A-29
Acidification Potential .....	A-30
Issue .....	A-30
Definition/Rationale .....	A-30
Scoring Procedures and Modifiers .....	A-30
References .....	A-31
Carcinogenicity.....	A-32
Issue .....	A-32
Definition/Rationale .....	A-32

---

Scoring Procedures and Modifiers .....	A-32
References .....	A-33
Ecological Habitat Alteration .....	A-34
Issue .....	A-34
Definition/Rationale .....	A-34
Scoring Procedures and Modifiers .....	A-35
References .....	A-36
Energy Use .....	A-36
Issue .....	A-36
Definition/Rationale .....	A-36
Scoring Procedures and Modifiers .....	A-36
References .....	A-37
Global Warming Potential.....	A-38
Issue .....	A-38
Definition/Rationale .....	A-38
Scoring Procedures and Modifiers .....	A-38
References .....	A-39
Inhalation Toxicity.....	A-40
Issue .....	A-40
Definition/Rationale .....	A-40
Scoring Procedures and Modifiers .....	A-40
References .....	A-41
Smog Creation Potential .....	A-41
Issue .....	A-41
Definition/Rationale .....	A-41
Scoring Procedures and Modifiers .....	A-41
References .....	A-43
Recyclability Potential (Post-Consumer).....	A-43
Issue .....	A-43
Definition/Rationale .....	A-43
Scoring Procedures and Modifiers .....	A-44
References .....	A-45
Toxic Material Mobility Upon Landfilling or Incineration .....	A-45
Issue .....	A-45



Definition/Rationale ..... A-46  
Scoring Procedures and Modifiers ..... A-46  
References ..... A-47

**B CRITERIA SCORES FOR FOUR TYPES OF ELECTRIC DISTRIBUTION POLES ..... B-1**  
Raw, Unweighted Criteria Scores for Four Pole Types..... B-1

# LIST OF FIGURES

---

Figure 1-1 Life Cycle Stages of Utility Poles Considered in Evaluation .....	1-2
Figure 5-1 Policy Perspective Weighting .....	5-2
Figure 5-2 Utility Perspective Weighting .....	5-3



# LIST OF TABLES

---

Table 1-1 Decision Tool Criteria Organized by Three Evaluation Groups .....	1-3
Table 3-1 Description of Four Distribution Pole Types (40-Foot, Class 4) Compared for CST Demonstration.....	3-1
Table 4-1 Matrix of Unweighted, Individual Scores for 26 Criteria by Four Pole Types.....	4-1
Table 5-1 Matrix of AHP Priority Weighting for 26 Criteria by Two Perspectives.....	5-3
Table 6-1 Overall Weighted, Total Scores for Four Pole Types Evaluated.....	6-1
Table A-1 Scoring Ranges for the Criterion on Expected Service Life with Maintenance .....	A-3
Table A-2 Modifier Score for the Criterion on Expected Service Life with Maintenance.....	A-3
Table A-3 Scoring Ranges for the Criterion on Regulatory and Treated-Wood Registration Status.....	A-5
Table A-4 Scoring Ranges for the Criterion on Adaptability of Field Procedures and Hardware for Emergencies .....	A-7
Table A-5 Scoring Ranges for the Criterion on Equipment Requirements for Transport/Install/Removal .....	A-9
Table A-6 Scoring Ranges for the Criterion on Handling Protection to Avoid Damage .....	A-11
Table A-7 Scoring Ranges for the Criterion on Grounding .....	A-12
Table A-8 Scoring Ranges for the Criterion on Weight.....	A-14
Table A-9 Scoring Ranges for the Criterion on Hardness.....	A-15
Table A-10 Scoring Ranges for the Criterion Acquisition Costs at Pole Yard (Pole, Liner, Sleeve, Cross Arms, Hardware, and Transport to Yard).....	A-17
Table A-11 Scoring Ranges for the Criterion Storage and Transportation Costs from Pole Yard to Installation Site .....	A-19
Table A-12 Scoring Ranges for the Criterion Installation Costs.....	A-20
Table A-13 Scoring Ranges for the Criterion Maintenance Costs During Pole Use (Retreatment, Inspection).....	A-21
Table A-14 Scoring Ranges for the Criterion Disposal Costs .....	A-22
Table A-15 Scoring Ranges for the Criterion Recycle or Reuse Costs .....	A-24
Table A-16 Scoring Ranges for the Criterion on Resource Renewability/Sustainability .....	A-25
Table A-17 Scoring Ranges for the Criterion on Raw Materials Delivery Infrastructure .....	A-26
Table A-18 Scoring Ranges for the Criterion on Manufacturing Capability (Pole Supply and Available Facility Output) .....	A-28
Table A-19 Scoring Ranges for the Criterion on Acidification Potential.....	A-31
Table A-20 Scoring Ranges for the Criterion on Carcinogenicity .....	A-34

---

Table A-21 Modifier Scores for the Criterion on Carcinogenicity .....	A-34
Table A-22 Scoring Ranges for the Criterion on Ecological Habitat Alteration .....	A-35
Table A-23 Examples of Habitat Alteration Factors .....	A-35
Table A-24 Scoring Ranges for the Criterion on Energy Use .....	A-36
Table A-25 Energy Usage Factors for Examples of Common Industrial Processes.....	A-37
Table A-26 Scoring Ranges for the Criterion on Global Warming Potential .....	A-39
Table A-27 Scoring Ranges for the Criterion on Inhalation Toxicity .....	A-40
Table A-28 Scoring Ranges for the Criterion on Smog Creation Potential .....	A-42
Table A-29 Scoring Ranges for the Criterion on Recyclability Potential (Post-Consumer).....	A-44
Table A-30 Examples of Recyclability Data .....	A-45
Table A-31 Scoring Ranges for the Criterion on Toxic Material Mobility Upon Landfilling or Incineration .....	A-47
Table A-32 Examples of Scores for Selected Materials.....	A-47
Table B-1 Individual Constituent Criteria Scores for CCA-Treated Wood Pole: Engineering/Technical Performance Criteria .....	B-2
Table B-2 Individual Constituent Criteria Scores for CCA-Treated Wood Pole: Life Cycle Cost/Economic Criteria .....	B-3
Table B-3 Individual Constituent Criteria Scores for CCA-Treated Wood Pole: Environmental Criteria.....	B-5
Table B-4 Individual Constituent Criteria Scores for ACQ-Treated Wood Pole: Engineering/Technical Performance Criteria .....	B-7
Table B-5 Individual Constituent Criteria Scores for ACQ-Treated Wood Pole: Life Cycle Cost/Economics Criteria.....	B-8
Table B-6 Individual Constituent Criteria Scores for ACQ-Treated Wood Pole: Environmental Criteria.....	B-9
Table B-7 Individual Constituent Criteria Scores for Galvanized Steel Pole: Engineering/Technical Performance Criteria .....	B-10
Table B-8 Individual Constituent Criteria Scores for Galvanized Steel Pole: Life Cycle Cost/Economics Criteria.....	B-11
Table B-9 Individual Constituent Criteria Scores for Galvanized Steel Pole: Environmental Criteria.....	B-12
Table B-10 Individual Constituent Criteria Scores for Concrete Pole: Engineering/Technical Performance Criteria .....	B-14
Table B-11 Individual Constituent Criteria Scores for Concrete Pole: Life Cycle Cost/Economic Criteria .....	B-15
Table B-12 Individual Constituent Criteria Scores for Concrete Pole: Environmental Criteria.....	B-16

# 1

## INTRODUCTION

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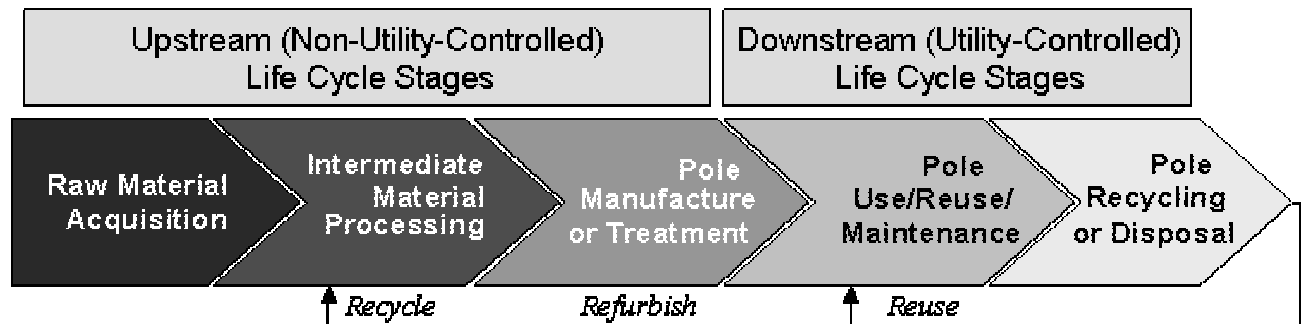
### **CST Concept Design**

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 poles. The initial concept design for this decision tool was completed in December 2005 (EPRI, 2005c) 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 current project involved development of look-up tables or references for scoring criteria, priority weighting, and demonstration of the tool for scoring and comparing two treated wood and two non-wood pole types. The completed decision tool permits utilities to evaluate distribution pole options using 26 criteria divided between three evaluation groups.

The criteria for the CST are designed for screening different types of 40-foot, Class 4, distribution 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 2002 National Electric Safety Code (NESC) (IEEE, 2002) and the American National Standards Institute (ANSI, 2002) specifications for pole strength and wood pole class dimensions for particular tree species. The ANSI specifications were expected to be updated in 2005, but the update has still not been finalized by July 2006. Updated NESC criteria are anticipated in 2007, when they are expected to 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, 2005) specifications according to the Use Category System. The AWPA normally publishes updated specifications each year. Steel distribution poles are assumed to be manufactured from steel sheets (typically gauge 11) that meet American Society of Testing and Materials (ASTM) standards.

### **Life Cycle Approach**

The CST criteria consider the full life cycle of utility distribution 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.



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

## 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 an expert team, the Analytic Hierarchy Process (AHP), and Expert Choice® software.

## Instructions for Scoring Distribution 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 distribution 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 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 panel of utility experts, a scientific process, and calculation software. The weighting process described in Section 5 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.

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

<b>Engineering/Technical Performance Criteria</b>	<b>Life Cycle Cost/Economic Criteria</b>	<b>Environmental Criteria</b>
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/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	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



# 2

## BASIS FOR SCORING 26 POLE SELECTION CRITERIA

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### **Engineering/Technical Performance Criteria**

The basis for scoring each of the eight engineering/technical performance criteria included in the CST evaluation is discussed briefly below and in more detail in Appendix A.

#### ***Expected Service Life with Maintenance***

One of the most highly desirable performance requirements for a utility distribution pole is a long service life before replacement. This criterion discusses the typical (average) number of years that a distribution 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. To meet AWWPA guidelines, retreatment of wood poles should begin at 15 years and continue on a 10-year cycle. 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 by a 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 FY07 (EPA, 2006a). 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 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. 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/Install/Removal***

The type of equipment for transportation, installation, and removal of treated-wood utility 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. The scoring system for this criterion gives higher scores for lighter pole types that permit transportation of greater numbers on a pole truck or flatbed trailer and 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 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. Heavy poles 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 will get the lowest score.

### ***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**

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. 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**

The weight of a 40-foot, Class 4 utility pole 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. The scoring system for this criterion gives 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.

## **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 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 a rotary hammer drill and potential damage to structural integrity (e.g., exposure of tendons).

## **Life Cycle Cost/Economic Criteria**

The basis for scoring each of the nine life cycle cost/economic criteria included in the CST evaluation is discussed briefly below and in more detail in Appendix A. 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 pole. For each 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 CCA-treated Southern Yellow Pine (SYP).

### ***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, Douglas Fir, steel, or concrete) in combination with different preservatives (CCA or ACQ) 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. Higher scores were given to poles which were less expensive than CCA-treated SYP, while most of the non-wood poles received scores lower than that of CCA-treated SYP due to higher costs.

### ***Storage and Transportation Costs from Pole Yard to Installation Site***

Because of handling requirement to prevent damage and weight issues, the steel and concrete poles may require special procedures during transport from pole yard or storage point to point of use. This criterion assesses 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 CCA-treated SYP, and lower scores to pole types that were more expensive to store and transport than CCA-treated SYP.

### ***Installation Costs***

As with transport, the special handling requirements and weight of the alternative pole materials 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 CCA-treated SYP, and lower scores to pole types that were more expensive than CCA-treated 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 and concrete poles need only periodic inspection. These lesser requirements may lead to relative cost advantages which this criterion attempts to assess. Higher scores were given to poles which were expected to have lower maintenance costs than CCA-treated SYP, and lower scores to pole types that were more expensive to maintain than CCA-treated SYP.

### ***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. Materials which are subject to the least disposal restrictions, such as steel and concrete, 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 CCA, 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, reserves and demand or consumption. 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 convert the raw materials into poles. This criterion assesses the pole supply by evaluating the current and future manufacturing capability for each pole type. Poles with current adequate manufacturing supply received the highest scores. Treated wood poles are one example. 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 is discussed briefly below and in more detail in Appendix A. Descriptions of the environmental criteria are based on the environmental profile approach published by EPRI (2005a) as Technical Report 1010143.

### ***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<sub>2</sub> 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<sup>+</sup> per mass unit relative to the same parameter for SO<sub>2</sub> (Wenzel et al., 1998). The raw AP scores determined for the criteria pollutants SO<sub>2</sub> and NO<sub>2</sub> (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. Since a concrete utility pole does not have an applied preservative treatment or coating it was given a Carcinogenicity score of 9, because it is not expected to have any carcinogenic impact during the pole use life cycle stage. 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, 2005a).

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 WOE raw scores are 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 in the process of collecting a resource, and the amount of time required for the ecosystem to return to its natural state 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.

### ***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. Energy use data were taken from the Swiss life cycle inventory (LCI) of poles (Erlandsson et al., 1992) for all types of poles.

### ***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 gasses, called greenhouse gasses, 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<sub>2</sub> by air emissions from material acquisition and manufacturing. Emissions of greenhouse gasses were determined from the EPA databases TRI and AIRS Executive. GWP equivalency factors have been developed for all important greenhouse gasses 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<sub>2</sub> (identified by AIRS Executive) was subtracted by a score modifier of 2 to get the final GWP score for CO<sub>2</sub>.

### ***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 (2006b) IRIS database. When the NOAEL was not available, the OSHA (1997) or American Conference of Governmental Industrial Hygienists (ACGIH) standards in the ACGIH (2003) guide was 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<sub>x</sub> 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 gasses 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<sub>2</sub>, NO<sub>2</sub>, 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 non-wood poles, recyclability was assessed by scoring each pole material individually, as these materials were considered separable.

Recycling has been defined, in accordance with the U.S. 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 U.S. 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.

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 U.S. EPA.

### ***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

In this section the composition of each of the poles evaluated will be discussed, 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, and that its contribution to the potential effects, costs, or impacts of a product is proportional to the mass of material consumed. As described in Table 3-1, Battelle evaluated four different 40-foot tall, Class 4 pole types that are commercially available: two preservative-treated wood and two non-wood materials (EPRI, 2005a). Weights for each pole type listed in Table 3-1 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 Distribution Pole Types (40-Foot, Class 4) Compared for CST Demonstration**

Pole Material	Example Manufacturers	Treatment or Coating
Treated Wood (Southern Yellow Pine)	McFarland Cascade <sup>(1)</sup>	Chromated Copper Arsenate (CCA) (0.60 pcf)
Steel (0.12-inch thick)	International Utility Structures Inc. (IUSI) <sup>(2)</sup>	Hot-Dip Galvanizing with polyurethane-coated butt
Prestressed Concrete (with internal steel strands)	Lonestar Prestress Mfg., Inc. <sup>(3)</sup>	none
Treated Wood (Douglas fir)	JH Baxter <sup>(4)</sup>	Ammoniacal Copper Quat (ACQ) Preserve® Type B (0.60 pcf)

(1) <http://www.ldm.com/products.htm>

(2) Now owned by Valmont-Newmark <http://www.valmont.com/asp/poles/poles4c.shtml>

(3) [http://www.lonestarprestress.com/Catalog-Specs/Pole%20Catalog/lonestar\\_utility.pdf](http://www.lonestarprestress.com/Catalog-Specs/Pole%20Catalog/lonestar_utility.pdf)

(4) <http://www.jhbaxter.com/utility.html>

### CCA- and ACQ-Treated Wood Poles

The CCA-treated pole was comprised of four materials: southern yellow pine (1,218 lbs.), trivalent chromium (4.8 lbs.), copper (2.4 lbs.), and arsenic (3.6 lbs.) (derived from MSDS by Chemical Specialties, Inc., 2003). The total weight of the pole was 1,229 lbs. (Web site for McFarland Cascade, 2006), yielding a percentage composition as follows: southern yellow pine, 99 percent; trivalent chromium, 0.4 percent; copper, 0.2 percent; and arsenic, 0.3 percent.

Note that the chromium as applied is hexavalent chromium, the more toxic form, but this form is quickly reduced upon exposure to ambient conditions during storage and use to the trivalent form (Lebow et al., 2003). This transformation significantly alters the score for chromium for a number of criteria. 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 upon available estimates, industry knowledge and limited data, a further assumption was that the poles would have a service life of 40-60 years with retreatment (WWPI, 1997; EPRI, 2003).

The ACQ-treated pole was comprised of three materials: Douglas fir (972 lbs.), copper salts (22 lbs.), and quaternary ammonium compounds (11 lbs.) (Derived from MSDS by Chemical Specialties, Inc., 2000). The total pole weight was 1,004 lbs. (Web site for J. H. Baxter, 2006), yielding a percentage composition as follows: Douglas fir, 97 percent; copper salts, 2.2 percent; and quaternary ammonium compounds, 1.0 percent. As with the other treated-wood poles, Battelle assumed that upon disposal the materials of construction of the pole could not be separated (affecting the potential recyclability of the pole) and that the poles would have a service life of 40-60 years with retreatment (WWPI, 1997; EPRI, 2003). Reuse may be an option for treated-wood poles, including ACQ. Since ACQ is not recognized as toxic or hazardous, recycling of the poles at the end of life into a similar or different product may be possible. However, as of yet there does not appear to be a sufficient demand for recycling, because a large number of poles are not currently coming out of service. Further explanation of the definition of reuse versus recycling can be found in Appendix A under the criterion Recyclability Potential (Post-consumer). It is also noteworthy that ACQ may not be compatible with many common types of pole hardware. Anecdotal evidence suggests this is due to the corrosivity of ACQ, but it might be more correctly attributed to galvanic effects. Stainless steel hardware does appear to be compatible with ACQ at considerable additional cost. The corrosivity is not factored into the current analysis, but the cost implications of the hardware are included.

## **Concrete and Galvanized Steel Alternatives**

The steel-reinforced, prestressed concrete pole is comprised of two materials: concrete (including the aggregate) (3,507 lbs.), and steel (94 lbs.). The total pole weight is 3,601 lbs. (L. Rowe, 2003, Personal Communication; Web site for Lonestar Prestress Mfg., Inc., 2006), yielding a percentage composition as follows: concrete, 97 percent; and steel, 2.6 percent. Note that the weight of concrete poles tends to vary considerably depending upon whether a manufacturer creates a partially hollow or a solid pole. A partially hollow pole will weigh less but require a greater proportion of reinforcing steel to maintain the same strength. None of the manufacturers contacted in the course of this effort specified any type of surface treatment or preservative. Based upon previous life cycle cost estimates (WWPI, 1997), the pole life was estimated at greater than 80 years.

The galvanized steel pole is comprised of three materials: steel (415 lbs.), zinc (the galvanizing) (15 lbs.), and polyurethane (additional protection for the buried portion of the pole) (1.1 lbs.) (D. Winklejohn, 2003, Personal Communication). The total pole weight is 431 lbs. (IUSI, 2002), yielding a percentage composition as follows: steel, 96 percent; zinc, 3.3 percent; and polyurethane, 0.2 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. Based upon previous life cycle cost estimates (WWPI, 1997) and the manufacturer of the galvanized steel pole selected for this study (Web site for IUSI, 2003), the pole life was estimated at greater than 80 years. As with concrete poles, weights varied greatly by manufacturer, as a result of design choices made such as steel type, pole shape and thickness. The pole used for the scoring appears to be on the lighter end of the weight scale for a 40-foot, Class 4 pole.



# 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 pole types evaluated using the CST. The unweighted, individual scores for all 26 CST criteria are shown in Table 4-1.

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

Criterion	CCA-SYP	ACQ-DF	Gal. Steel	Concrete
Service Life	5.0	5.0	9.0	9.0
Regulatory Status	3.0	5.0	7.0	9.0
Emergency Field Procedures	9.0	5.0	7.0	3.0
Equip. Requirements Transport/Install/Removal	7.0	7.0	9.0	1.0
Handling Protection	9.0	9.0	7.0	5.0
Grounding	9.0	9.0	1.0	3.0
Weight	7.0	7.0	9.0	1.0
Hardness	7.0	9.0	3.0	1.0
Acquisition Cost	5.0	1.0	1.0	1.0
Transportation Cost	5.0	5.0	5.0	3.0
Installation Cost	5.0	5.0	5.0	5.0
Maintenance Cost	5.0	3.0	9.0	9.0
Disposal Cost	5.0	9.0	9.0	9.0
Reuse or Recycle Cost	5.0	5.0	7.0	5.0
Resource Renewability or Sustainability	5.0	4.9	2.9	4.9
Raw Materials Infrastructure	9.0	8.9	9.0	9.0
Manufacturing Capacity	9.0	5.0	3.0	3.0
Acidification Potential	9.0	1.0	2.2	3.5
Carcinogenicity	4.7	7.0	6.1	6.7
Ecological Habitat Alteration	3.0	3.0	3.0	3.0
Energy Use	9.0	9.0	1.0	7.0
Global Warming Potential	9.0	9.0	5.0	5.0
Inhalation Toxicity	3.7	5.0	5.0	5.3
Smog Creation Potential	9.0	9.0	3.8	4.1
Recyclability Potential	1.0	1.0	8.8	3.2
Toxic Material Mobility	1.0	1.7	9.0	9.0

### ***Expected Service Life with Maintenance***

Assuming regular maintenance, the two non-wood pole types (galvanized steel with polyurethane butt treatment and concrete) both receive the highest score for the criterion Expected Service Life with Maintenance, since their average service life is estimated at >80 years. Although galvanized steel and concrete utility poles have only been in use for >50 years, there is sufficient historical basis for related structures like buildings and bridges, which have survived in similar environments for well over 100 years. At least two other studies comparing different pole types made the assumption that the average service life of galvanized steel and concrete utility poles is more than 80 years (NYSEG, 1997; EDM, 1997). This is considerably better than the average service life with maintenance for the two treated-wood poles (CCA and ACQ), since their average service life is estimated at 41-60 years. The rank order of scores for the four pole types from lowest to highest is: CCA = ACQ << galvanized steel = concrete.

### ***Regulatory and Treated-Wood Registration Status***

For the criterion Regulatory and Treated-Wood Registration Status, the rank order of scores for the four pole types from lowest to highest is: CCA < ACQ < galvanized steel < concrete. CCA-treated wood was given the lowest score, since CCA has a Toxic Characteristic Leaching Procedure (TCLP) concentration limit exemption from classification as a federal hazardous waste, it is a restricted use pesticide (RUP), and CCA has recently been banned from residential use due to leaching of arsenic from treated wood.

### ***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 pole types from lowest to highest is: concrete < ACQ < galvanized steel < CCA. The highest score is given to CCA-treated wood, because standard galvanized fasteners, drill, bit, and wrenches can be used. Concrete was given the lowest score, because a rotary hammer drill is required to drill holes in the field and care must be taken to avoid hitting the internal steel reinforcing tendon.

### ***Equipment Requirements for Transport/Install/Removal***

For the criterion Equipment Requirements for Transport/Install/Removal, the rank order of scores for the four pole types from lowest to highest is: concrete < CCA = ACQ < galvanized steel. The highest score is given to galvanized steel, because more poles can be transported on a pole truck to the pole yard, installation equipment requires very little adaptation except use of webbed straps, and poles are light enough to permit hand carrying short distances to tight or difficult spots (Oliver, 2006a and 2006b). Concrete poles are given the lowest score, because the very heavy poles can only be transported to the pole yard in very limited numbers without exceeding axle load limits, and 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.

### **Handling Protection to Avoid Damage**

For the criterion Handling Protection to Avoid Damage, the rank order of scores for the four pole types from lowest to highest is: concrete < galvanized steel < CCA = ACQ. The highest score is given to the two 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 of the four pole types is given to concrete, because it requires intermediate protection, including blocking during transport and careful handling with manufacturer-installed lift points and/or webbed straps during installation to avoid cracking.

### **Grounding**

For the criterion on Grounding, the rank order of scores for the four pole types from lowest to highest is: galvanized steel < concrete << CCA = ACQ. The highest score is given to the two 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, 2005b).

### **Weight**

For the criterion on Weight, the rank order of scores for the four pole types from lowest to highest is: concrete << CCA = ACQ < galvanized steel. The highest score is given to galvanized steel, since the weight of these poles is low enough that a very high number of poles can be hauled in a standard pole truck. The lowest score is given to concrete, since the high weight of these poles means that a very low number of poles can be hauled in a standard pole truck.

### **Hardness**

For the criterion on Hardness, the rank order of scores for the four pole types from lowest to highest is: concrete < galvanized steel < CCA < ACQ. The highest score is given to ACQ-treated wood poles, because they have a low Janka hardness and are easy to climb and drill. The lowest score is given to concrete, because pole hardness requires 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/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 pole types evaluated using the CST. Note that most of the economic criteria are relative cost criteria with the baseline pole, in this case CCA-treated 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. However, due to the age of the data these reports were only able to provide trends and historical information, as opposed to current or recent cost data.

### ***Acquisition Costs at Pole Yard (Pole, Liner, Sleeve, Cross Arms, Hardware, and Transport to Yard)***

Both of the non-wood poles and the ACQ-treated wood pole are much more expensive than the CCA-treated wood pole baseline (EPRI, 2005b). For the ACQ-treated pole this is due to both the stainless steel hardware required, as well as the additional costs for the treatment (EPRI, 2005b). The rank ordering of poles from lowest to highest is: ACQ = Steel = Concrete << CCA.

### ***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. Concrete pole manufacturers (M. Schwenger, 2006, Personal Communication) acknowledge the fact that concrete poles may require special storage and transportation due to pole weight and to prevent sagging of the pole which would cause cracking, but no one seems to have tried to monetize the potential cost change. Steel poles require cradles lined with webbing for support during transportation, but do not require a tandem-wheeled, flatbed pole trailer that would be required for transporting multiple concrete poles behind a digger derrick (T. Gentile, 2006, Personal Communication; Oliver, 2006a). Battelle made a judgment on the magnitude of the costs, but cautions the user to closely look at their particular situation. The rank ordering of the poles from lowest to highest score is: Concrete < CCA = ACQ = Steel.

### ***Installation Costs***

As with storage and transportation costs, there is very little information available on differences in installation costs due to pole type and the installation costs for non-wood poles have not been monetized. The typical digger derrick used for 40-foot wood distribution poles is also adequate for installing 40-foot concrete distribution poles, despite the increase in weight (T. Gentile, 2006, Personal Communication). Steel and concrete 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). The rank ordering of poles from lowest to highest score is: CCA = ACQ = Steel = Concrete.

### ***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. The wood poles required more frequent inspection than the non-wood poles (EPRI, 2003). In addition, the wood poles required a periodic retreatment, approximately every 10 years, beginning at 20 years of service life, in order to maintain optimum performance. In the study by NYSEG (1997), concrete poles were assumed to require almost no maintenance and galvanized steel was assumed to require 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. The retreatment for the ACQ-treated pole was estimated to be about 20 percent higher cost (2006 cost) (EPRI, 2005b), due to the higher cost of ACQ treatment chemicals (EPRI, 2005b). The rank ordering from lowest to highest scoring poles is: ACQ < CCA << Steel = Concrete.

### ***Disposal Costs***

Disposal costs are also comprised of two primary components: physical removal and restoration or remediation of the pole (hole) area. For CCA-treated poles, there is a small probability that the removal of the pole will require the pole site (the hole and surrounding soil) 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). A similar probability exists for ACQ-treated poles (EPRI, 2003). In either case the remediation is very costly. For either steel or concrete poles, there are no expected remediation costs, which accounts for much of the disposal cost differential. In fact, if remediation of the hole is required, the cost will far exceed the other pole costs. The rank ordering from lowest to highest scoring poles is: CCA << ACQ = Steel = Concrete. (Note that the difference in expected disposal cost between ACQ and Steel or Concrete is two orders of magnitude, but due to the structure of the scoring system in the criteria they all score the same because the expected cost for ACQ-treated pole disposal is also about three-quarters of an order of magnitude less than the expected disposal cost for a CCA-treated pole. Overall, disposal costs are very difficult to rank order in any meaningful way due to the vast spread in expected costs.)

### ***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, 2005b; 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 poles from lowest to highest scoring is: CCA = ACQ = Concrete < 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, 2006). 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 pole types from lowest to highest scores is: Steel << CCA = ACQ = Concrete.

### ***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, steel, and aggregate). The scores for many of the minor constituents (or active ingredient in the case of the treated wood poles), tends to be much lower, but since these materials are used in such small weight fractions the scores tend not to have much influence on the score for the 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. The rank ordering of poles from lowest to highest is: CCA = ACQ = Steel = Concrete.

### ***Manufacturing Capability (Pole Supply and Available Facility Output)***

Scores for the Manufacturing Capability criterion were at opposite extremes for the wood and non-wood pole types. The CCA-treated wood pole scored highest due to the infrastructure that has developed over time to supply. Because ACQ-treated wood poles are currently not available in large supply (EPRI, 2005b) Battelle judged the infrastructure to be less than the near term potential demand, resulting in a lower score. The non-wood poles tend to be newer and used less frequently or in special situations, compared to treated-wood poles. Thus, non-wood poles scored much lower because the ability to ramp up production is limited by the time required to construct plants (including siting, financing, design and construction), which will require more than 15 years to reach the equivalent capacity of the wood pole production industry (M. Schwenger, 2006, Personal Communication). The rank order of the pole types from lowest to highest is: Steel = Concrete < ACQ << CCA.

## **Environmental Criteria**

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

### ***Acidification Potential***

For the criterion on Acidification Potential (AP), the rank order of scores for the four pole types from lowest to highest is: ACQ < galvanized steel < concrete < CCA. The highest score is given to CCA, since there are no emissions during the life cycle that contribute to AP. The lowest score is given to ACQ, due to the ammonia released in air from the ACQ wood treating facilities, which has an AP score of 1. Manufacturing of galvanized steel and concrete poles result in the release of several chemicals, respectively, that have average AP scores of 2.2 and 3.5.

### ***Carcinogenicity***

For the criterion on Carcinogenicity, the rank order of scores for the four pole types from lowest to highest is: CCA < galvanized steel = concrete = ACQ. The lowest score is given to CCA, since the metals emitted during manufacture have an average carcinogenicity score of 4.7. The carcinogens released during manufacture of the other three types of poles have average carcinogenicity scores that are not significantly different between these three pole types.

### ***Ecological Habitat Alteration***

The criterion score for Ecological Habitat Alteration is the same for all four pole types: CCA = galvanized steel = concrete = ACQ. The acquisition of raw materials for each of these pole types, including mining of metals for treatment chemicals, result in Ecological Habitat Alteration scores of 3.

### ***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 exceptionally poorly due to the high content of highly refined materials (i.e., steel and zinc for galvanizing), which tend to be energy intensive. The concrete pole scored almost as well as the wood poles, primarily from use of aggregate that receives very little processing. Portland cement, which is the binder, has a very high energy density, but it is only a small fraction of the overall concrete mass in a pole. The rank ordering of the pole types from lowest to highest score is: Steel << Concrete < CCA = ACQ.

### ***Global Warming Potential***

For the criterion on Global Warming Potential (GWP), the rank order of scores for the four pole types from lowest to highest is: galvanized steel = concrete << ACQ = CCA. The two treated-wood poles score much better than the two non-wood poles, since they release almost no global warming gasses during manufacture, and carbon is actually sequestered in the trees during growth and in the wood pole during use. During manufacturing, the two non-wood poles release the major criteria pollutant CO<sub>2</sub>, 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 pole types from lowest to highest is: CCA < ACQ = galvanized steel = concrete. The lowest score is given to CCA, since the metal compounds (i.e., Cr, Cu, and As) emitted in air during manufacture of CCA-treated poles have high inhalation toxicity (low scores).

### ***Smog Creation Potential***

For the criterion on Smog Creation Potential, the rank order of scores for the four pole types from lowest to highest is: galvanized steel = concrete < CCA = ACQ. The lowest scores are given to the two non-wood pole types, because the pollutants SO<sub>2</sub>, NO<sub>2</sub>, CO, and VOC emitted during manufacturing of non-wood poles have moderately low Smog Creation Potential scores 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. 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 CCA and many other 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 the preservative, which tends to limit the commercial recycling market. For ACQ, the conclusion in the current study is that this preservative is so new that the market and infrastructure are presently very limited. 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 pole types had increasing scores in the following order: CCA = ACQ < Concrete << 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. The two water-based wood preservatives (CCA and ACQ) included materials with higher water solubilities; so they scored low. The non-wood pole types scored much higher than any of the treated-wood poles. The concrete and steel poles do not have any toxic materials expected to migrate, so they were given a score of 9. The rank ordering of the pole types from lowest to highest is: CCA < ACQ << Concrete = Steel.

# 5

## PRIORITY WEIGHTING OF DECISION CRITERIA

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### Expert Panel

Battelle used a team of 12 experts that have a combined familiarity with the categories of interest and the poles being evaluated. The team was composed of experts from utilities (Department of Energy, private utilities, and rural or member cooperatives), EPRI contractors, and utility advisory groups, 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.

### 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 team. 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:

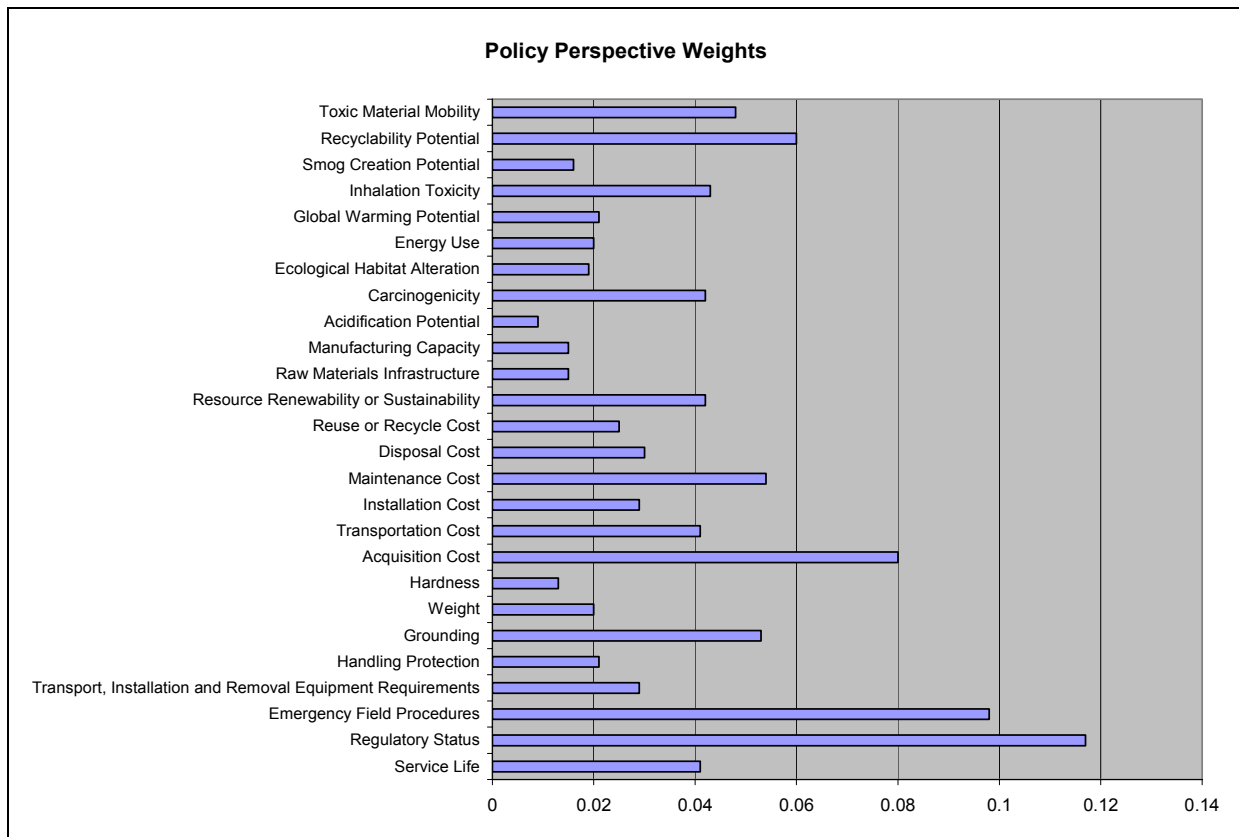
- Better, faster, more justifiable decisions,
- Organizational and strategic alignment,
- A structured decision-making approach,
- Consensus and improved communication,
- An improved bottom line.

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

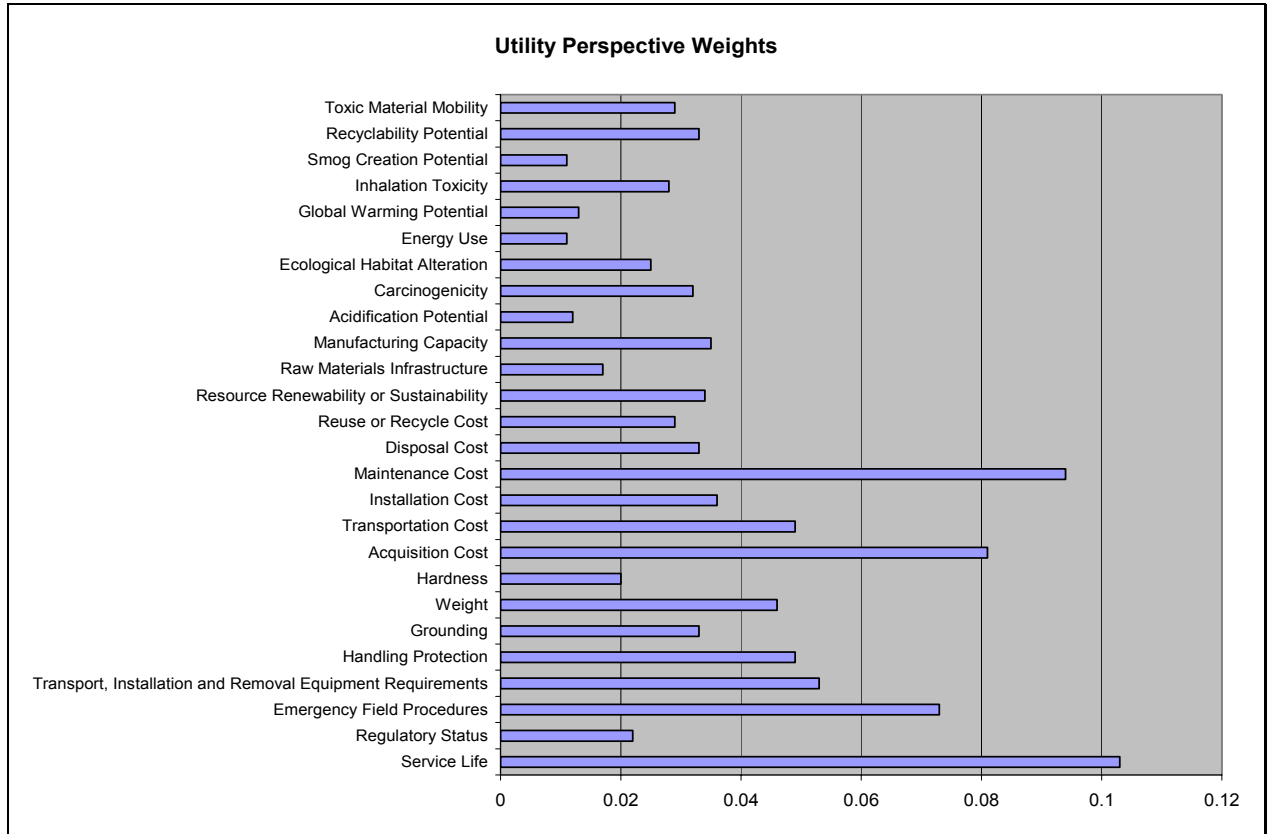
- Structuring your decision into objectives and alternatives,
- Measuring your objectives and alternatives using pair-wise comparisons,
- Synthesizing objective and subjective inputs to arrive at a prioritized list of alternatives, taking care of all the heavy mathematical lifting.”

## Results of Weighting for Two Hierarchy/Perspective Combinations

As with an earlier study for EPRI (2005a), a set of priority weights (based on relative importance determined by the expert 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**  
**Policy Perspective Weighting**



**Figure 5-2**  
Utility Perspective Weighting

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

Criterion	Policy Perspective	Utility Perspective
<b>Engineering and Technical Performance</b>	<b>0.392</b>	<b>0.399</b>
Service Life	0.041	0.103
Regulatory Status	0.117	0.022
Emergency Field Procedures	0.098	0.073
Transport, Installation and Removal Equipment Requirements	0.029	0.053
Handling Protection	0.021	0.049
Grounding	0.053	0.033
Weight	0.02	0.046
Hardness	0.013	0.02

**Table 5-1**  
**Matrix of AHP Priority Weighting for 26 Criteria by Two Perspectives (Continued)**

Criterion	Policy Perspective	Utility Perspective
<b>Life Cycle Cost and Economics</b>	<b>0.331</b>	<b>0.408</b>
Acquisition Cost	0.08	0.081
Transportation Cost	0.041	0.049
Installation Cost	0.029	0.036
Maintenance Cost	0.054	0.094
Disposal Cost	0.03	0.033
Reuse or Recycle Cost	0.025	0.029
Resource Renewability or Sustainability	0.042	0.034
Raw Materials Infrastructure	0.015	0.017
Manufacturing Capacity	0.015	0.035
<b>Environmental</b>	<b>0.278</b>	<b>0.194</b>
Acidification Potential	0.009	0.012
Carcinogenicity	0.042	0.032
Ecological Habitat Alteration	0.019	0.025
Energy Use	0.02	0.011
Global Warming Potential	0.021	0.013
Inhalation Toxicity	0.043	0.028
Smog Creation Potential	0.016	0.011
Recyclability Potential	0.06	0.033
Toxic Material Mobility	0.048	0.029

# 6

## OVERALL WEIGHTED, TOTAL SCORES COMPARED AMONG POLE TYPES

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### 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**

<b>Perspective</b>	<b>CCA/SYP</b>	<b>ACQ/DF</b>	<b>Gal. Steel</b>	<b>Concrete</b>
<b>Electric Utility</b>	5.9	5.2	6.2	5.0
<b>National Policy</b>	5.4	5.0	5.9	5.2

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 expert team who may not offer a valid statistical sample of the population. 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 costs (EPRI, 2003 and 2005b), other life cycle costs were estimated based on expert opinion (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**

The five criteria given the highest priority weighting in the Electric Utility Perspective (see Figure 5-2 and Table 5-1) were Service Life, Maintenance Cost, Acquisition Cost, Emergency Field Procedures, and Transport/Installation/Removal Equipment Requirements. These five criteria represent 40% of the priority weighting. Based on the available data for scoring the criteria, the galvanized steel poles had a better overall weighted score than the concrete poles or the ACQ-treated wood poles for the Electric Utility Perspective. However, the overall weighted total score for galvanized steel poles was not significantly better than the CCA-treated wood poles, and the CCA-treated wood poles were not significantly better than the concrete poles or the ACQ-treated wood poles. The only potentially significant differences (a score difference of 1.0 or more) were the galvanized steel poles compared to the concrete poles or the ACQ-treated wood poles.

## **National Policy Perspective**

The five criteria given the highest priority weighting in the National Policy Perspective (see Figure 5-1 and Table 5-1) were Regulatory Status, Emergency Field Procedures, Acquisition Cost, Recyclability Potential, and Maintenance Cost. These five criteria represent 41% 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., CCA = ACQ = Concrete = Galvanized Steel.

## **Sensitivity Analysis**

Battelle examined 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 Reuse or Recycle Cost. By allowing the scores for one or more of these criteria to increase to the maximum (9) or decrease to the minimum (1), we could calculate the potential change in the overall score. In the cases where just one or two of the criteria scores were changed, there were no significant changes in the overall scores (total value changed less than 0.3). Only when all of the above criteria were allowed to change at the same time did we see what might be a significant change, and this change was only on the order of 0.5 in the total score. So in order to change the rank order preference of the pole types, the scores for one pole would need to increase to the maximum for each of these criteria, while the scores for another pole type would need to decrease to the minimum at the same time. While data for the above four life cycle cost criteria are somewhat qualitative rather than confirmed hard dollar values, the judgments made based upon this information does not appear to introduce a significant error in the total score for all criteria.

# 7

## DISCUSSION ON POTENTIAL USEFULNESS OF APPROACH TO UTILITIES

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### Ability to Differentiate Scores Among Pole Types

Overall the CST is very good at differentiation of the four pole types evaluated when comparing selected raw (unweighted) individual scores. When comparing the individual raw scores within any one of the 26 criteria, 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. Also, any pair of the four pole types has at least 10 criteria where the raw individual scores are significantly different.

The CST has limited ability to differentiate between the four pole types for the following four life cycle cost/economic criteria: Transportation Cost, Installation Cost, Disposal 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 four life cycle cost criteria.

For the four pole types used in this demonstration, the overall weighted scores were only different among pole types using criteria weights under the Electric Utility Perspective. The overall weighted scores for the Public Policy Perspective were not significantly different among any of the four pole types. It is possible that the Public Policy Perspective could show significant differences in the overall weighted scores if other pole types (e.g., untreated wood or FRC) 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 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 panel of 12 utility experts involved in weighting procedures for this demonstration (see Section 5), 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 poles. No other published methodology is available as a single approach that can be used by utilities to semi-quantitatively select between distribution 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 pole options in an organized and semi-quantitative fashion across the full life cycle of the poles.

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 poles in this report, but it can be used to score and evaluate a wide variety of existing and proposed distribution 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 scores are multiplied times priority weighting factors, which were developed based on relative importance by the expert panel using the AHP and Expert Choice® software (or by the individual company). These 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 pole types.

# 8

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# A

## DEFINITION AND SCORING OF DECISION CRITERIA

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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 Class 4, 40-foot, distribution poles?

#### ***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 AWPAs 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 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 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 AWWPA 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.

### ***Scoring Procedures and Modifiers***

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. As indicated below, utilities without a pole inspection and maintenance program should modify the final score by subtracting two points (Table A-2). Thus, the final score is determined by the formula: Final Score = Raw Score - Modifier Score. 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). The scoring procedure involves selecting the appropriate scoring range and, if appropriate, applying the score modifier.

**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, Gal. Steel (polyurethane coated butt)
7	61-80 years of expected service life	FRC, Greenheart
5	41-60 years of expected service life	All 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 the Criterion on Expected Service Life with Maintenance**

Modifier Score	Modifier Score Definition
2	Deduction for utilities without pole inspection/maintenance program

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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 FY07 (EPA, 2006a). 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. For example, there were difficulties in getting creosote-treated wood poles re-registered during 2005.

### ***Scoring Procedures and Modifiers***

The scoring system in Table A-3 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-3**  
**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, <i>or</i> 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, PCP, ACQ
3	Pole types that have two of the following: RCRA regulations or TCLP exemptions, Clean Air Act emission restrictions, MCL standards, <i>or</i> 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, <i>or</i> 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 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 hot-dipped 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 the galvanizing.

**Scoring Procedures and Modifiers**

The scoring system in Table A-4 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 adaptability of field procedures and hardware required for emergencies.

**Table A-4  
Scoring Ranges for the Criterion on Adaptability of Field Procedures and Hardware for Emergencies**

Score	Scoring Range Qualifications	Examples
9	Pole types that use <i>standard</i> 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, <i>extreme</i> 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/Install/Removal**

### ***Issue***

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

### ***Definition/Rationale***

The type of equipment for transportation, installation, and removal of treated-wood utility 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, removal, and reuse by the public. 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 poles are light enough to permit hand carrying short distances to tight or difficult spots, and lighter helicopters may be used when remote or difficult installations are required.

**Scoring Procedures and Modifiers**

The scoring system in Table A-5 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 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-5  
Scoring Ranges for the Criterion on Equipment Requirements for  
Transport/Install/Removal**

<b>Score</b>	<b>Scoring Range Qualifications</b>	<b>Examples</b>
9	<i>Poles &lt;750 lbs.</i> 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	<i>Poles 750-1500 lbs.</i> 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 & Nontreated Wood
5	<i>Poles &gt;1500-2250 lbs.</i> 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.	
3	<i>Poles &gt;2250-3000 lbs.</i> 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.	Concrete (StressCrete)
1	<i>Poles &gt;3000 lbs.</i> 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.	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-6 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-6**  
**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	

## References

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

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Shakespeare Composite Structures. 2006. <http://www.skp-cs.com/poleproducts/td/tdreport.asp>.

StressCrete Group. 2006. [http://www.stresscrete.com/products/UP\\_dp.asp](http://www.stresscrete.com/products/UP_dp.asp).

## Grounding

### Issue

Does the selected utility 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. Thus, 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 (2002) 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-7 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-7**  
**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 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	

## **References**

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

National Rural Electric Cooperative Association (NRECA). 1999. *Non-Wood Distribution Poles, Design, Procurement, and Installation Guide*. Cooperative Research Network, Project 97-24. National Rural Electric Cooperative Association, Arlington, Virginia.

Institute of Electrical and Electronics Engineers (IEEE). 2002. Document Number ANSI/IEEE C2-2002, National Electric Safety Code (NESC). Institute of Electrical and Electronics Engineers, New York, New York.

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## **Weight**

### **Issue**

For a 40-foot, Class 4 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?

### **Definition/Rationale**

The weight of a 40-foot, Class 4 utility pole 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 Table A-8 gives 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 weight.

**Table A-8**  
**Scoring Ranges for the Criterion on Weight**

Score	Scoring Range Qualifications	Examples
9	Poles <750 lbs. Very high number of poles can be hauled in a standard pole truck	Gal. Steel (polyurethane coated butt), FRC
7	Poles 750-1500 lbs. High number of poles can be hauled in a standard pole truck	Most Treated-Wood & Nontreated Wood
5	Poles >1500-2250 lbs. Intermediate number of poles can be hauled in a standard pole truck	
3	Poles >2250-3000 lbs. Low number of poles can be hauled in a standard pole truck	Concrete (StressCrete)
1	Poles >3000 lbs. Very low number of poles can be hauled in a standard pole truck	Concrete (Lonestar Prestress)
*	Insufficient Information	

## References

American Iron and Steel Institute (AISI). 2004. *What Every Lineman Should Know I*. From <http://www.steel.org/AM/Template.cfm?Section=construction&CONTENTFILEID=1507&TEMPLATE=/CM/ContentDisplay.cfm>.

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

## 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 linemen 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-9 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-9**  
**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, ACQ-treated Douglas Fir
7	For wood poles: >1000-2000 lbs Janka Hardness or pole types harder to climb with gaffs and drill	Wallaba, CCA-treated 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  Gal. 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

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

## **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 utility engineers familiar with designing new distribution lines in the companies service area to make “best estimates” or “most likely” values, based on experience with similar 40-foot, Class 4 distribution pole types.

### ***Issue for Criteria Group***

To what extent does the choice of pole material affect life cycle costs and resource economics?

### ***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 the baseline was chosen as CCA-treated wood). 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 the commonly used treated wood poles (CCA and Penta) have been relatively stable in the range of \$200 per pole (40-foot, Class 4) range (2005 costs) (EPRI, 2003; EPRI, 2005). Costs for poles using any of the alternative treatments, or for the non-treated wood or non-wood poles tend to range 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 utilities pole storage yard.

### 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-10) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case CCA-treated wood). 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-10**  
**Scoring Ranges for the Criterion Acquisition Costs at Pole Yard (Pole, Liner, Sleeve, Cross Arms, Hardware, and Transport to Yard)**

Score	Scoring Range Qualifications	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	CCA-Treated Wood
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	ACQ-treated Wood, Concrete, Gal. Steel
*	Insufficient Information	

## **References**

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

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

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.

## **Storage and Transportation Costs from Pole Yard to Installation Site**

### ***Issue***

To what extent does choice of pole material affect the costs of pole 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). 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-11) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case CCA-treated wood). 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-11**  
**Scoring Ranges for the Criterion Storage and Transportation Costs from Pole Yard to Installation Site**

Score	Scoring Range Qualifications	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	CCA-Treated Wood, ACQ-Treated Wood <sup>(1)</sup> , Gal. Steel <sup>(1)</sup>
3	> 10 percent to < 25 percent greater than baseline	Concrete <sup>(1)</sup>
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

<sup>(1)</sup> Best qualitative estimate of cost differences based on personal communication.

### **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.

### **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-12) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case CCA-treated wood). 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-12**  
**Scoring Ranges for the Criterion Installation Costs**

Score	Scoring Range Qualifications	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	CCA-Treated Wood, ACQ-Treated Wood <sup>(1)</sup> , Gal. Steel <sup>(1)</sup> , Concrete <sup>(1)</sup>
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

<sup>(1)</sup> Best qualitative estimate of cost differences based on personal communication.

## 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.

Valmont-Newmark. 2006. Personal Communication with D. P. Evers, Battelle. May 23, 2006.

## 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-13) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case CCA-treated wood). 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-13**  
**Scoring Ranges for the Criterion Maintenance Costs During Pole Use (Retreatment, Inspection)**

Score	Scoring Range Qualifications	Examples
9	≥ 25 percent less than baseline cost	Concrete, Gal. Steel
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for CCA-treated wood	CCA-Treated Wood
3	> 10 percent to < 25 percent greater than baseline	ACQ-treated Wood
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

**References**

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

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

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.

Examples of hazardous materials used on pole construction or treatment under the current (2006) 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-14) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case CCA-treated wood). 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-14**  
**Scoring Ranges for the Criterion Disposal Costs**

Score	Scoring Range Qualifications	Examples
9	≥ 25 percent less than baseline cost	ACQ-treated Wood, Concrete, Gal. Steel
7	> 10 percent to < 25 percent less than baseline	
5	±10 percent of baseline cost for CCA-treated wood	CCA-Treated Wood
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

## **References**

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

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

## **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. These poles will likely require certification by the utility that all metal, stones, and other hard materials have been removed from the pole prior to acceptance by any mill for resawing into lumber. 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-15) is based on increased or decreased cost relative to a utility-defined baseline pole (in this case CCA-treated wood). 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-15**  
**Scoring Ranges for the Criterion Recycle or Reuse Costs**

Score	Scoring Range Qualifications	Examples
9	≥ 25 percent less than baseline cost	
7	> 10 percent to < 25 percent less than baseline	Gal. Steel <sup>(1)</sup>
5	±10 percent of baseline cost for CCA-treated wood	CCA-Treated Wood, ACQ-Treated Wood <sup>(1)</sup> , Concrete <sup>(1)</sup>
3	> 10 percent to < 25 percent greater than baseline	
1	≥ 25 percent greater than baseline cost	
*	Insufficient Information	

<sup>(1)</sup> Best qualitative estimate of cost differences based on personal communication.

## References

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

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

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

Valmont-Newmark. 2006. Personal Communication with D. P. Evers, Battelle. May 23, 2006.

## Resource Renewability/Sustainability (Including Future Raw Material Availability)

### Issue

Can the utility distribution pole 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.

**Scoring Procedures and Modifiers**

Table A-16 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 (2006).

**Table A-16**  
**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**

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

U. S. Geological Survey (USGS). 2006. 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-17 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 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, 2006).

**Table A-17**  
**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). 2006 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 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.

### **Scoring Procedures and Modifiers**

Table A-18 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 available facility output.

### **References**

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

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

**Table A-18**  
**Scoring Ranges for the Criterion on Manufacturing Capability (Pole Supply and Available Facility Output)**

Score	Conditions	Examples
9	Current manufacturing capacity exceeds current and forecast market demand. Price sensitivity to increasing demand is essentially zero.	CCA-treated Wood
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.	ACQ-treated Wood
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.	Concrete, Gal. Steel
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	

## 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 Class 4, 40-foot, distribution poles?

### **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**

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

TRIfacts.org. 2005. TRI putting TRI dioxin data in perspective.  
[http://www.trifacts.org/teq\\_tm17/index.php](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 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  $\mu\text{eq/L}$ , 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  $\text{H}^+$  per mass unit relative to the same parameter for  $\text{SO}_2$  (Heijungs et al., 1992a and 1992b; Wenzel et al., 1998).

### Scoring Procedures and Modifiers

1. Determine which substances containing acid precursors (e.g.,  $\text{SO}_2$ ,  $\text{SO}_x$ ,  $\text{SO}_3$ ,  $\text{NO}$ ,  $\text{NO}_x$ ,  $\text{NO}_2$ ,  $\text{HCl}$ ,  $\text{HF}$ ,  $\text{NH}_3$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{HNO}_3$ ) 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](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 ( $\text{SO}_2$ ) 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  $\text{H}^+$  equivalents per emitted quantity of  $\text{SO}_2$ , expressed as the formula:

$$\text{AP}_i = \frac{v_i/M_i}{v_{\text{SO}_2}/M_{\text{SO}_2}}$$

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-19 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  $\geq 100$  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  $\mu\text{eq/L}$ . 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-19**  
**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 ( $\text{NO}_2$ , $\text{NO}_x$ , HCl, $\text{HNO}_3$ , $\text{SO}_3$ , $\text{H}_2\text{SO}_4$ , $\text{H}_3\text{PO}_4$ )
3	1.00-1.49 ( $\text{SO}_2$ , NO, $\text{SO}_x$ )
1	$\geq 1.50$ (HF, $\text{NH}_3$ , $\text{H}_2\text{S}$ )
*	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.

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

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.

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.

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-20 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. When IARC and EPA conclusions are different use the one that results in the highest raw score.
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-21. 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.
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.

## References

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

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

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

**Table A-20**  
**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-21**  
**Modifier Scores for the Criterion on Carcinogenicity**

Modifier Score	Modifier Score Definition
2	Oral slope factor $\geq 1 \times 10^{-1}$ mg/kg/day
0	Oral slope factor $< 1 \times 10^{-1}$ mg/kg/day or no oral slope factor available.

## Ecological Habitat Alteration

### *Issue*

To what extent can material/energy supply selections be made which minimize collateral damages to ecosystems during the raw material acquisition life cycle stage (includes tree farming and harvesting) of a utility distribution pole?

### *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 quality of the system. 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 available.

Each raw material has different acquisition requirements that must be met. Specification of materials/energy types that cause the least damage to ecosystems and allow the most rapid recovery from such damages that are unavoidable 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-22 shows the Ecological Habitat Alteration 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 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-23.
3. 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-22**  
**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-23**  
**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	25 - 35
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

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

## Energy Use

### Issue

How much energy is used for manufacture and/or assembly of the components of the utility 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.

### Scoring Procedures and Modifiers

Table A-24 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-25). 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-24**  
**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-25**  
**Energy Usage Factors for Examples of Common Industrial Processes**

Process	Net Process Energy, BTU/lb <sup>(b)</sup>
Natural Gas Production	1,224
Crude Oil Production/Distillation/Hydrotreating	591
Salt Mining	592
Sodium Hydroxide Production/(Diaphragm Cell) <sup>(c)</sup>	11,275
Soda Ash Production (Trona)	14,045
Chlorine Production/(Diaphragm Cell) <sup>(c)</sup>	4,739
Sulfuric Acid Production/(Contact Process) <sup>(d)</sup>	4,367
Wood and Raw Wood Products	109
Sulfur Mining	3,089
Wood Treating	114
Steel Production	750
Electrical Power (National Grid) <sup>(e)</sup>	10,750 <sup>(f)</sup>
CCA-treated wood utility pole <sup>(g)</sup>	330
Steel utility pole <sup>(g)</sup>	10,500
Concrete utility pole <sup>(g)</sup>	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; Cl<sub>2</sub> = 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

Brown, H. et al. 1985. Energy Analysis of 108 Industrial Processes. U.S. Department of Energy, Fairmont Press.

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

Erlandsson, Martin, Kai Ödeen, and Marie-Louise Edlund. 1992. Environmental consequences of various materials in utility poles – A life cycle analysis. Presented at International Research Group on Wood Preservation, 23d Annual Meeting, May 10-15. IRG/WP/3726-92.

## **Global Warming Potential**

### ***Issue***

How can the raw material acquisition and manufacturing stages of the life cycle of utility 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<sub>2</sub> 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<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O 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.

### ***Scoring Procedures and Modifiers***

Table A-26 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 gasses 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](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](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 gasses in both the raw material acquisition and manufacturing stages.

**Table A-26**  
**Scoring Ranges for the Criterion on Global Warming Potential**

Raw Score	Criterion Ranges for Global Warming Potential (GWP) (Equal Mass Relative to CO <sub>2</sub> over 100 Year)
9	<1 (H-2401, H-2311)
7	1-99 (CO <sub>2</sub> , HCFC-123, H-1211, H-1202, H-2402, H-1201, Methane (CH <sub>4</sub> ), 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  $\geq 100$  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

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

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

Heijungs, R. et al. 1992b. *Environmental Life Cycle Assessment of Products: Guide – October 1992*. Report No. 9266. Center of Environmental Science, Leiden, The Netherlands.

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Wuebbles, D.J. and J. Edmonds. 1991. *Primer on Greenhouse Gases*. Lewis Publishers, Inc., Chelsea, MI.

## Inhalation Toxicity

### Issue

How can the life cycle of utility 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-27 shows the Inhalation Toxicity 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 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-27**  
**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/m <sup>3</sup> in air (includes materials with no toxicity)
7	NOAEL 10-1,000 mg/m <sup>3</sup> in air
5	NOAEL 0.1-10 mg/m <sup>3</sup> in air
3	NOAEL 0.01-0.1 mg/m <sup>3</sup> in air
1	NOAEL <0.01 mg/m <sup>3</sup> in air
*	Insufficient information

## References

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

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

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

## Smog Creation Potential

### Issue

How can the manufacturing stage of the life cycle of utility 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  $\text{NO}_x$  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 peroxy 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 (Klöpffer and Potting, 2002 [updates data in Heijungs et al. (1992b)]).

Table A-28 shows the Smog Creation 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 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  $\geq 100$  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-28**  
**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., NO <sub>2</sub> , CO, SO <sub>2</sub> , 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	$\geq 1.000$ (e.g., ethylene, propylene, m-xylene)
*	Insufficient information [see Klöppfer and Potting (2002) for POCP of additional chemicals]

## References

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

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

Heijungs, R. et al. 1992b. Environmental Life Cycle Assessment of Products: Guide - October 1992. Report No. 9266. Center of Environmental Science, Leiden, The Netherlands.

Klöpffer, W. and J. Potting (Eds.). 2002. Best Available Practice in Life Cycle Impact Assessment of Climate Change, Stratospheric Ozone Depletion, Acidification, Eutrophication, and Tropospheric Ozone Formation. Backgrounds on Impact Categories. Bilthoven, NL: National Institute of Public Health and the Environment (RIVM). RIVM Report 408660 002. Report by SETAC Europe Scientific Task Group on Global and Regional Impact Categories (STG-GARLIC).

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

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 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 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-29 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. 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.
2. Select unit recyclability potential scores for each material of construction (Table A-30). 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.
3. Aggregate each individual component score to the entire utility pole based on weight ratios of the components to the total.

**Table A-29**  
**Scoring Ranges for the Criterion on Recyclability Potential (Post-Consumer)**

<b>Score</b>	<b>Criterion Ranges for Post-consumer Recyclability Potential</b>
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-30**  
**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 <sup>(a)</sup>
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

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

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 utility 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-31 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-32. 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-31**  
**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-32**  
**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**

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



# **B**

## **CRITERIA SCORES FOR FOUR TYPES OF ELECTRIC DISTRIBUTION POLES**

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### **Raw, Unweighted Criteria Scores for Four Pole Types**

Four 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 two treated-wood poles (CCA and ACQ) and two non-wood pole alternatives (galvanized steel and concrete). 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 CCA-treated 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 ACQ-treated 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 concrete 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 CCA-Treated Wood Pole: Engineering/Technical Performance Criteria**

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Engineering/Technical Performance Criteria							
				Service Life	Regulatory Status	Emergency Field Procedures	Transport, Installation and Removal Equipment Requirements	Handling Protection	Grounding	Weight	Hardness
				Overall Score	5.0	3.0	9.0	7.0	9.0	9.0	7.0
			Pole-Based Scores	5.0	3.0	9.0	7.0	9.0	9.0	7.0	7.0
Wood, SYP	1218.20	0.991	Mass-based Scores								
Chromium, Trivalent	4.83	0.004									
Copper	2.39	0.002									
Arsenic	3.58	0.003									
Water (In CCA Soln) [Ignored]		0.000									

**Table B-2**  
**Individual Constituent Criteria Scores for CCA-Treated Wood 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	5.0	9.0
			Pole-Based Scores	5.0	5.0	5.0	5.0	5.0	5.0			9.0
Wood, SYP	1218.20	0.991	Mass-Based Scores							5	9	
Chromium, Trivalent	4.83	0.004								3	4.12	
Copper	2.39	0.002								1	5.84	
Arsenic	3.58	0.003								5	8.14	
Water (In CCA Soln) [Ignored]		0.000										
<b>Chromium</b>	<b>Reserves</b>	<b>Reserve Fraction</b>									<b>Country Score</b>	
India	57000	0.045									9	
Kazakhstan	470000	0.371									3	
South Africa	270000	0.213									7	
Others	470000	0.371									3	
<b>Copper</b>												
U.S.	70000	0.075									9	
Australia	43000	0.046									9	
Canada	20000	0.021									9	
Chile	360000	0.384									7	

**Table B-2**  
**Individual Constituent Criteria Scores for CCA-Treated Wood Pole: Life Cycle Cost/Economic Criteria (Continued)**

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	5.0	9.0
Pole-Based Scores	5.0	5.0	5.0	5.0	5.0	5.0				9.0		
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	
<b>Arsenic</b>												
Belgium	1000	0.019									9	
Chile	13000	0.243									9	
France	30000	0.562									9	
Kazakhstan	1000	0.019									3	
Mexico	1000	0.019									5	
Peru	2500	0.047									1	
Russia	3400	0.064									7	
Other	1500	0.028									3	

**Table B-3  
Individual Constituent Criteria Scores for CCA-Treated Wood 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	4.7	3.0	9.0	9.0	3.7	9.0	1.0
			Pole-Based Scores	9.0			9.0	9.0		9.0	1.0	
Wood, SYP	1218.20	0.991	Mass-Based Scores			3						
Chromium, Trivalent	4.83	0.004			7	3					1	
Copper	2.39	0.002			7	3					1	
Arsenic	3.58	0.003			1	3					1	
Water (In CCA Soln) [Ignored]		0.000										
<b>CCA Wood Treating Facilities</b>												
<b>Air Emissions</b>												
Arsenic (7440382)				NA	1			NA	3	NA		
Chromium (7440473)				NA	7			NA	5	NA		
Copper (7440508)				NA	7			NA	3	NA		
Arsenic Compounds				NA	1			NA	3	NA		
Chromium Compounds				NA	7			NA	5	NA		
Copper Compounds				NA	7			NA	3	NA		

**Table B-3**  
**Individual Constituent Criteria Scores for CCA-Treated Wood Pole: Environmental Criteria (Continued)**

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	4.7	3.0	9.0	9.0	3.7	9.0	1.0
Pole-Based Scores	9.0			9.0	9.0		9.0	1.0				
<b>Water Emissions</b>												
Arsenic (7440382)				NA	LIA							
Chromium III (16065831)				NA	LIA							
Chromium VI (18540299)				NA	1							
Copper (7440508)				NA	LIA							
Arsenic Compounds				NA	LIA							
Chromium Compounds				NA	LIA							
Copper Compounds				NA	LIA							

NA = Not Applicable; LIA = Listed in Air

**Table B-4**  
**Individual Constituent Criteria Scores for ACQ-Treated Wood Pole: Engineering/Technical Performance Criteria**

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Engineering/Technical Performance Criteria							
				Service Life	Regulatory Status	Emergency Field Procedures	Transport, Installation and Removal Equipment Requirements	Handling Protection	Grounding	Weight	Hardness
				Overall Score	5.0	5.0	5.0	7.0	9.0	9.0	7.0
			Pole-Based Scores	5.0	5.0	5.0	7.0	9.0	9.0	7.0	9.0
Wood, Douglas Fir	971.60	0.97	Mass-Based Scores								
Quaternary ammonium compounds	10.80	0.01									
Copper	21.60	0.02									

**Table B-5**  
**Individual Constituent Criteria Scores for ACQ-Treated Wood Pole: Life Cycle Cost/Economics 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	1.0	5.0	5.0	3.0	9.0	5.0	4.9	8.9
			<b>Pole-Based Scores</b>	1.0	5.0	5.0	3.0	9.0	5.0			5.0
Wood, Douglas Fir	971.60	0.97	<b>Mass-Based Scores</b>							5	9	
Quaternary ammonium compounds	10.80	0.01								1.64	9	
Copper	21.60	0.02								1	5.84	
<b>Copper</b>	<b>Reserves</b>	<b>Reserve Fraction</b>									<b>Country Score</b>	
U.S.	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-6**  
**Individual Constituent Criteria Scores for ACQ-Treated Wood 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	1.0	7.0	3.0	9.0	9.0	5.0	9.0	1.0
			<b>Pole-Based Scores</b>	1.0			9.0	9.0	5.0	9.0	1.0	
Wood, Douglas Fir	971.60	0.97	<b>Mass-Based Scores</b>			3						
Quaternary ammonium compounds	10.80	0.01				7.24						3
Copper	21.60	0.02			7	3						1
<b>ACQ Wood Treating Facilities</b>												
<b>Air Emissions</b>												
Ammonia (7664417)				1	NC			NA	5	NA		
<b>Water Emissions</b>												
Ammonia (7664417)				1	LIA							

NA = Not Applicable; NC = No Conclusion on carcinogenicity; 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	Regulatory Status	Emergency Field Procedures	Transport, Installation and Removal Equipment Requirements	Handling Protection	Grounding	Weight	Hardness	
				Overall Score	9.0	7.0	7.0	9.0	7.0	1.0	9.0	3.0
				Pole-Based Scores	9.0	7.0	7.0	9.0	7.0	1.0	9.0	3.0
Steel	405.74	0.96	Mass-Based Scores									
Zinc (as Galvanizing)	14.23	0.03										
Corrocoat (polyurethane)	1.03	0.00										

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

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Life Cycle Cost/Economics Criteria							Raw Materials Infrastructure	Manufacturing Capacity
				Acquisition Cost	Transportation Cost	Installation Cost	Maintenance Cost	Disposal Cost	Reuse or Recycle Cost	Resource Renewability or Sustainability		
				Overall Score	1.0	5.0	5.0	9.0	9.0	7.0		
			Pole-Based Scores	1.0	5.0	5.0	9.0	9.0	7.0			3.0
Steel	405.74	0.96	Mass-Based Scores							3	9	
Zinc (as Galvanizing)	14.23	0.03								1	7.95	
Corrocoat (polyurethane)	1.03	0.00								1	9	
<b>Zinc</b>	<b>Reserves</b>	<b>Reserve Fraction</b>									<b>Country Score</b>	
U.S.	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
			<b>Overall Score</b>	2.2	6.1	3.0	1.0	5.0	5.0	3.8	8.8	9.0
			<b>Pole-Based Scores</b>				1.0	5.0				
Steel	405.74	0.96	<b>Mass-Based Scores</b>			3					9	
Zinc (as Galvanizing)	14.23	0.03			7	3					3	9
Corrocoat (polyurethane)	1.03	0.00			7	7					1	9
<b>Steel Mills (incl. galvanizing) Mfg.</b>												
<b>Major Criteria Air Emissions</b>												
SO <sub>2</sub> (≥ 100 TPY)				1	7			NA	5	5		
CO <sub>2</sub> (per Erlandsson et al., 1992)				NA	NC			5	9	NA		
NO <sub>2</sub> (≥ 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		
<b>TRI Air Emissions</b>												
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		

**Table B-9**  
**Individual Constituent Criteria Scores for Galvanized Steel Pole: Environmental Criteria (Continued)**

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	1.0	5.0	5.0	3.8	8.8
Pole-Based Scores				1.0	5.0							
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		
<b>Water Emissions</b>												
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 Concrete Pole: Engineering/Technical Performance Criteria**

	Weight in Pole (lbs.)	Weight Fraction	Criterion	Engineering/Technical Performance Criteria							
				Service Life	Regulatory Status	Emergency Field Procedures	Transport, Installation and Removal Equipment Requirements	Handling Protection	Grounding	Weight	Hardness
<b>Material</b>			<b>Overall Score</b>	9.0	9.0	3.0	1.0	5.0	3.0	1.0	1.0
			<b>Pole-Based Score</b>	9.0	9.0	3.0	1.0	5.0	3.0	1.0	1.0
Concrete, including Aggregate	3507.10	0.97	<b>Mass-Based Score</b>								
Steel, reinforcing	93.90	0.03									

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

Material	Weight in Pole (lbs.)	Weight Fraction	Criterion	Life Cycle Costs/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
				<b>Overall Score</b>	1.0	3.0	5.0	9.0	9.0	5.0	4.9	9.0
<b>Pole-Based Score</b>	1.0	3.0	5.0	9.0	9.0	5.0			3.0			
Concrete, including Aggregate	3507.10	0.97	<b>Mass-Based Score</b>						5	9		
Steel, reinforcing	93.90	0.03							3	9		

**Table B-12**  
**Individual Constituent Criteria Scores for Concrete 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
			<b>Overall Score</b>	3.5	6.7	3.0	7.0	5.0	5.3	4.1	3.2	9.0
			<b>Pole-Based Score</b>				7.0					9.0
			<b>Mass-Based Score</b>			3					3	
Concrete, including Aggregate	3507.10	0.97				3					9	
Steel, reinforcing	93.90	0.03										
<b>Major Criteria Air Emissions</b>												
S <sub>O</sub> <sub>2</sub> (≥ 100 TPY)				1	7			NA	5	5		
CO <sub>2</sub> (per Erlandsson et al., 1992)				NA	NC			5	9	NA		
NO <sub>2</sub> (≥ 100 TPY)				3	7			NA	5	5		
CO (≥ 1000 TPY)				NA	NC			NA	7	5		
VOC (≥ 100 TPY)				NA	CD			NA	CD	3		
<b>TRI Air Emissions</b>												
Sulfuric Acid				5	1			NA	5	NA		
Hydrochloric Acid				5	7			NA	5	NA		
Benzene				NA	1			NA	5	5		
Toluene				NA	5			NA	7	3		
Ethylene Glycol				NA	7			NA	7	5		
Naphthalene				NA	3			NA	5	3		
Xylene (Mixed Isomers)				NA	5			NA	7	3		
Lead				NA	3			NA	1	NA		
Dioxin And Dioxin-Like Compounds				NA	1			NA	1	NA		

**Table B-12**  
**Individual Constituent Criteria Scores for Concrete Pole: Environmental Criteria (Continued)**

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	3.5	6.7	3.0	7.0	5.0	5.3	4.1	3.2
<b>Pole-Based Score</b>				7.0						9.0		
<b>Water Emissions</b>												
Nickel Compounds				NA	1							
Zinc Compounds				NA	7							
Chromium Compounds				NA	7							
Lead				NA	LIA							
Lead Compounds				NA	3							
Dioxin and dioxin-like compounds				NA	LIA							
<b>Downstream Score (NI=9)</b>					9							

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






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