

A LIFE CYCLE ASSESSMENT OF UTILITY POLES: A COMPARATIVE
ANALYSIS OF WESTERN RED CEDAR TREATED WITH COPPER
CHROMATED ARSENATE (CCA), UNTREATED WESTERN RED CEDAR,
AND CONCRETE

by

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A thesis submitted in partial fulfilment of
the requirements for the degree of

MASTER OF ARTS
in
ENVIRONMENT AND MANAGEMENT

ROYAL ROADS UNIVERSITY

February 2001

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0-612-62021-2

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Acknowledgements

To the memory of Jim Todgham, who enabled me to grow, and to understand and appreciate the value of the natural world, protected spaces, and above all, environmental protection.

To my wife, Susan, for being always supportive and for being my very best friend. To my family, for being supportive and patient while we were absent from many family events.

For Wayne Poole and Frank Brooks at ENMAX Power Corporation, who saw in me the potential to make a difference for an emerging power utility as it moves to embrace change in the 21st Century.

To Phil Lulman, a private consultant who has been a rock of support, kindness, and advice; a true mentor in the field of environmental management and a man whose wealth of knowledge, perspective and abilities has been an inspiration.

For the people who were interviewed and peppered with countless questions to gather data for this thesis including: Bell Pole Company in Carseland, Alberta and Salmon Arm, B.C.; Chris Day at Stress Crete Ltd.; Craig Wilson of Timber Specialities Ltd. and Wayne Trusty of the Athena Sustainable Building Project.

Special thanks the faculty of Royal Roads University, in particular to Dr. Robert Gale, my thesis advisor, for his assistance and guidance from concept to the preparation of this thesis. My sincere thanks to Dr. Tony Boydell for his direction and inspiration during the concept and development of my research.

My thanks and continued success to Dr. Stephen Grundy and Dr. Tony Boydell architects of the Masters of Environment and Management Program, my thanks for developing this unique and rewarding learning experience. To the entire faculty of the Environment and Management Program for the inspiration and discovery that this program so special.

Special thanks for those whose work assisted me and supports us as students throughout the entire program: Dana McFarland, University Librarian, for providing a solid basis from which to gather information. Thanks to Stephanie Rault, major projects support, to Matthew Ellis for keeping everyone on track and always considering the very best for the program.

Contents

Acknowledgements	i
Glossary of Terms	ix
Acronyms	xvii
1.0 INTRODUCTION: STUDY BACKGROUND	1
1.1 Problem/Opportunity	1
1.2 Objectives of Study	3
1.3 Methodology	4
1.3.1 Literature Review	4
1.3.2 Surveys	5
1.3.3 Data Collection	5
1.3.4 Personal Interviews	6
1.3.5 Analysis	6
1.4 Thesis Outline	6
2.0 LIFE CYCLE ASSESSMENT METHODOLOGIES	9
2.1 Life Cycle Assessment: the basic framework	11
2.2 ISO Standards	12
2.3 Computer Based Life Cycle Assessment	17
2.4 Pembina Institute Life Cycle Value Assessment	22
2.5 Streamlined Life Cycle Assessment	23
2.6 Risk and Hazard	27
2.7 Life Cycle Assessment and Public Policy	28
2.8 Summary	28
3.0 LIFE CYCLE ASSESSMENT GOALS AND SCOPE DEFINITION	31
3.1 Goal of the Life Cycle Assessment Study	31
3.2 Definition of Scope	33
3.2.1 Systems	33
3.2.2 Functional units	34
3.2.3 System boundaries	35

3.2.4	Data quality and limitations	37
3.2.5	Time related coverage	38
3.2.6	Geographical coverage	38
3.2.7	Technology coverage	39
3.2.8	Precision, completeness and representativeness of the data	39
3.2.9	Consistency and reproducibility of the methods throughout the LCA	40
3.2.10	Sources of data and their representativeness	40
3.2.11	Uncertainty of the information	41
3.3	Data Quality Quantification	41
3.4	Processes not included in this LCA	44
3.5	Summary	45
4.0	LIFE CYCLE PROCESS ASSESSMENT	47
4.1	Process diagrams	47
4.1.1	Non treated wood pole life cycle	48
4.1.2	Western red cedar CCA treated utility pole life cycle	52
4.1.3	Concrete utility pole life cycle	57
4.2	Summary	62
5.0	IMPACT ASSESSMENT	63
5.1	The factors of environmental impact	63
5.2	Utility pole longevity	65
5.3	Environmental Impact - Non Treated Western Red Cedar	66
5.4	Environmental Impact – CCA Treated Western Red Cedar	68
5.5	Environmental Impact – Prestressed Concrete Utility Pole	70
5.6	Utility Pole Manufacturing Improvements	72
5.6.1	Life enhancement measures	72
5.6.2	Pole uses and options after utility use	74
5.6.3	Process improvements for concrete and wood utility poles based on this study	76
5.7	Summary	77

6.0	TOTAL COST ASSESSMENT	79
6.1	Total Cost Assessment	79
6.1.1	Total cost assessment: decisions to be made	80
6.1.2	Total cost assessment inventory	80
6.1.3	Financial analysis	81
6.2	Factors that affect decision making	83
6.2.1	Product quality – wood poles	84
6.2.2	Pole quality – concrete	86
6.2.3	Electrical safety	89
6.2.4	Operational flexibility	89
6.3	Summary	90
7.0	EVALUATION	91
7.1	Identification of significant environmental issues	91
7.1.1	Comparative environmental impacts	91
7.1.2	Qualitative impacts	97
7.2	Cost considerations	100
8.0	CONCLUSIONS	104
8.1	Recommendations	106
8.1.1	General recommendations	107
8.1.2	Recommendations for electrical utilities	108
8.1.3	Recommendations for life cycle studies	109
REFERENCES		
Annex A – References		111
Annex B – Interviews		119

APPENDICES

Appendix A – Impact Assessment – Detailed Calculations and Assumptions	A-1
Appendix B – Leaching of CCA Treated Wood	B-1
Appendix C – Total Cost Assessment :Detailed Calculations & Assumptions	C-1
Appendix D - Field Notes: Concrete Pole Quality Assessment	D-1

List of Tables

2.1 Life Cycle Software Tools Evaluated by Environment Canada	19
2.2 Streamlining LCA approaches	25
3.1 Data Quality Evaluation Index	43
3.2 Processes not quantified in this life cycle assessment	44
5.1 Non treated utility pole – life cycle resource use and emissions	61
5.2 Other Environmental impacts – Non Treated Utility Pole	67
5.3 CCA treated utility pole – life cycle resource use and emissions	69
5.4 Other Environmental impacts – CCA treated utility poles	69
5.5 Concrete utility pole – life cycle resource use and emissions	71
5.6 Other Environmental impacts – Concrete utility poles	71
5.7 CCA treated utility pole with life enhancement - life cycle resource use and emissions	73
5.8 Other Environmental impacts – CCA treated wood with life enhancement	74
6.1 Total operating costs per pole	81
6.2 Total Cost Assessment – Net Present Value	82
6.4 Qualitative survey of concrete poles in the field	88
7.1 Total life cycle cost – utility pole options from best to worst	101

List of Figures

2.1 The LCA Concept Model	11
2.2 Phases of an LCA	14
2.3 The Life Cycle System Concept	14
2.4 Pembina Institute Life Cycle Value Assessment Model	22

3.1 Non treated wood utility pole – system	36
3.2 CCA treated wood utility pole – system	36
3.3 Concrete utility pole – system	37
 <u>Non treated western red cedar utility pole life cycle</u>	
4.1 Forestry operation	49
4.2 Non treated utility pole – regional distribution centre	50
4.3 Non treated utility pole – consumer use (utility)	51
 <u>Western red cedar CCA treated utility pole life cycle</u>	
4.4 Forestry operation	53
4.5 CCA manufacturing process	54
4.6 Wood pole processing and treatment	55
4.7 Consumer use (utility)	56
 <u>Concrete utility pole life cycle</u>	
4.8 Concrete utility pole component production – Cement	58
4.9 Concrete utility pole component production – Steel re-enforcement Rod	59
4.10 Concrete utility pole – Manufacturing	60
4.11 Concrete utility pole – Consumer use (Utility)	61
 7.1 Life cycle primary energy consumption	
7.2 Life cycle solid waste	92
7.3 Life cycle air emissions not including Carbon Dioxide	93
7.4 Life cycle global warming potential	93
7.5 Life cycle acid rain formation precursors	94
7.6 Life cycle smog formation precursors	94

Glossary of Terms

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Accidental Emissions	An unintended environmental release. Example: Crude oil spills resulting from tanker accidents, venting of reactors due to mechanical failure or human error.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Allocation	Partitioning the input or output flows of a process to the product system under study.	dk-TEKNIK Energy & Environment - European Environment Agency - Copenhagen, Denmark (1997)
BTU (British Thermal Unit)	The quantity of heat energy required to raise the temperature of 1 pound of water (air-free) from 60 to 61 degrees Fahrenheit at a constant pressure of 1 standard atmosphere. Experimentally equal to 1,054.5 joules.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Characterization	Second element within impact assessment succeeding the classification element and proceeding valuation, in which analysis/quantification and aggregation of the impacts within the chosen impact categories take place.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Characterization Factor (exposure factor, effect factor, exposure-effect factor, equivalence factor)	A factor which expresses the contribution of a unit environmental intervention (such as the atmospheric emission of 1 kg CFC - 11) to the chosen impact categories (such as global warming and ozone depletion).	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Classification	The first element within the impact assessment, which attributes the environmental interventions listed in the inventory table to a number of selected impact categories.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Closed Loop Recycling	A recycling system in which a particular mass of material is remanufactured into the same product (e.g., glass bottle into glass bottle).	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Conclusions and Recommendations	Conclusions summarize the identification and evaluation of significant environmental issues. Recommendations are those features that arise directly from conclusions, given to the goal of the study.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Design for Environment (DfE)	A general term for a number of methods for incorporating environmental factors into the design process. The concept of DfE has been developed without formal links to LCA, but in more recent years are developing an association through "Life Cycle Thinking".	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Distribution utility poles	Poles that transmit stepped-down electricity from substations to residential and commercial customers; the ranging from 25 to 55 feet.	The Western Red Cedar Association
Effect	A specific change in human health, in eco-system or global resource situation as a consequence of a specific impact.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Embodied Energy	Energy contained in a material that can be removed for useful purposes through combustion or other means.	US EPA - Life Cycle Design Manual (1993)
Environment	Entire surroundings and conditions in which individuals, populations and organizations operate and interrelate. The surroundings include air, water, land, natural resources, flora, fauna and humans and extend within an organization's location to the global system.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Environmental Aspect	Element of an organization's activities, products, or services which can interact with the environment.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Environmental Intervention (Environmental flow, environmental burden, stressor, elementary flow)	Exchange between the atmosphere (the "economy") and the environment including resource use, emissions to air water or soil.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Evaluation	It is the second step within the life cycle interpretation including completeness check, sensitivity check, consistency check, and other checks.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Externalities	Costs borne by society rather than those involved in a transaction.	US EPA - Life Cycle Design Manual (1993)

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Final Product	Product which requires no additional transformation prior to its use.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Fuel Unit	Weight or Volume of fuel such as liters or gallons of fuel oil, kilograms or pounds of coal or Gigajoules or cubic feet of natural gas.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Functional Unit	The quantity of product that is used to base calculations of material and energy flows across a system.	SETAC(1999) Streamline LCA
Gigajoules (Gj)	1,000,000,000 or 10^9 joules	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Global Warming	The theory that elevated concentrations of certain atmospheric constituents is causing an increase in the earth's average temperature.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Goal and Scope Definition	Activities that initiates an LCA, defining its purpose, boundaries, limitations, main lines and procedures.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Greenhouse Effect	The theory that certain atmospheric conditions trap heat in the earth's atmosphere leading to global warming.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Greenhouse Gas	An atmospheric constituent, such as carbon dioxide, that is thought to contribute to global warming.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Impact Analysis	The assessment of the environmental consequences of energy and natural resource consumption and waste releases associated with actual or proposed action.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Impact Category (problem type, environmental problem, and environmental theme).	Chosen level in the cause-effect chain of the considered environmental effect type, relating somehow to the areas of protection. The impact score profiles gives the scores for the impact categories.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Impact vs. Effect	Most of the environmental problems treated in present characterization methods are quantified at the level of environmental impacts (e.g.: ozone formation, H ⁺ deposition, ozone depletion, rise of radiate forcing). Environmental effects are the chosen endpoints within these impact chains (e.g.: reduced human health, reduced growth of crop, dying of plants, reduced biodiversity, etc.). This means that all steps in the cause-effect chain are impacts while effects are the chosen endpoints.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Indicator	A simplification and distillation of complex information intended as a summary description of conditions or trends to assist decisions.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Input	Material or energy, which enters a unit process - material may include raw materials and products.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Inventory Table	List of environmental entities added to and taken from the environment (environmental interventions) through economic actions which are directly caused by processes within a product system. It is the main result of the inventory analysis.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Joule	Metric unit of energy, equal to 9.48×10^{-4} Btu	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Leachate	The solution that is produced by the action of percolating water through a permeable solid, as in a landfill.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Life Cycle	Consecutive and interlinked stages of a production system, from raw material acquisition, through manufacturing, use and final disposal.	SETAC(1999) Streamline LCA
Life Cycle Accounting	A system for assigning specific costs to product systems within a physical life cycle framework. Based on total cost assessment.	US EPA - Life Cycle Design Manual (1993)

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Life Cycle Assessment (LCA)	Compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product or process system throughout its life cycle.	SETAC(1999) Streamline LCA
Life Cycle Design	A system oriented approach for designing more ecological and economically sustainable product systems. Life cycle design integrates environmental requirements into the earliest stages of design so total impacts caused by product systems can be reduced. In LCD, environmental, performance, cost, cultural and legal requirements are balanced.	US EPA - Life Cycle Design Manual (1993)
Life Cycle Impact Assessment (LCIA)	A phase of LCA aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of the product or process system.	SETAC(1999) Streamline LCA
Life Cycle Inventory (LCI)	A phase of LCA involving the accounting of inputs and outputs across a given product or process life cycle.	SETAC(1999) Streamline LCA
Life Cycle System	The boundaries of interconnected activities associated with a product or process including all mass and energy inputs and outputs. A system is defined by the function of a product, process, or activity being evaluated.	SETAC(1999) Streamline LCA
Life Cycle Thinking	Using the life-cycle concept to evaluate environmental issues in a holistic system-wide perspective.	SETAC(1999) Streamline LCA
Megajoule (Mj)	One megajoule is equivalent to 0.2878 kilowatt hours. 1,000 megajoules = 1 gigajoule.	Australian Gas Light Company (AGL)
Open Looped Recycling	A recycling system in which a product made from one type of material is recycled into a different type of product. The product receiving recycled material itself may or may not be recycled.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Pollution	Any by-products or unwanted residual produced by human activity. Residuals include all residual all hazardous and non-hazardous substances generated and releases to the air water, or land.	US EPA - Life Cycle Design Manual (1993)

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Pollution Prevention	Any practice that reduces the amount or environmental and health impacts of any pollutant released into the environment prior to recycling, treatment and disposal. Pollution prevention includes modifications of equipment and processes; reformulation or redesign of products and processes; substitution of raw materials; and improvement in housekeeping; maintenance, training, or inventory control.	US EPA - Life Cycle Design Manual (1993)
Process	The operations that make up a sub-system.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Process Emissions	Waste materials generated or produced from raw materials, reactions, and processes or related equipment inherent to the process.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Process Energy	The energy required for each sub system for process requirements. These are qualified in terms of fuel or power units such as litres or gallons of distillate oil, gigajoules or cubic feet of natural gas or kilowatt-hours (kWh) of electricity.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Process Flow Diagram	Chart containing labeled boxes connected by lines with directional arrows to illustrate the unit process or sub-system included in the product system and the interrelationships between those unit processes.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Raw Materials	The total inputs for a subsystem including all material present in the product and material found in losses due to emission, scrap and off-spec products and no-emission losses (such as moisture due to evaporation). Water is not always a raw material input because it is often removed during the drying step.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)
Renewable	Capable of being replenished quickly enough to meet present or near term demand. Time and quantity are critical elements in measures of renewably.	US EPA - Life Cycle Design Manual (1993)
Residual	The remainder. In the life cycle framework, those wastes remaining after all usable materials have been recovered.	US EPA - Life Cycle Design Manual (1993)

Term	Definition	Source
Reuse	The additional use of a component, part, or product after it has been removed from a clearly defined service cycle. Reuse does not include reformation.	US EPA - Life Cycle Design Manual (1993)
Screening LCA	An application of LCA used primarily to determine whether additional study is needed and where that study should focus.	SETAC(1999) Streamline LCA
Streamlined LCA	Identification of elements of an LCA that can be omitted or where surrogate or generic data can be used without significantly affecting the accuracy of the results.	SETAC(1999) Streamline LCA
Sustainable	Able to be maintained through time. Over use of resources may decrease future productivity, thereby lowering sustainable yields. An additional factor defining natural resource sustainability is the amount and kind caused by their use. Systems that rely on abundant resources may not be sustainable if this resource results in major impacts.	US EPA - Life Cycle Design Manual (1993)
System Boundaries	Define the extent of systems and activities. Boundaries delineate areas for design or analysis.	US EPA - Life Cycle Design Manual (1993)
Total Cost Assessment (TCA)	A comprehensive method of analyzing costs and benefits of a pollution prevention or design project. TCA includes: - <i>Full cost accounting</i> , a managerial accounting method that assigns both direct and indirect costs to specific products, - estimates of both short and long term direct, indirect or hidden, liability and less tangible costs; - costs projected over a long horizon, such as 10 - 15 years	US EPA - Life Cycle Design Manual (1993)
Transparency	Open, comprehensive and understandable presentation of information.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Transportation Energy	The energy required transporting materials and products throughout the process and to final distribution to the consumer. This is converted from the conventional units of "ton-miles"(metric - kilogram-kilometers) by each transportation mode (e.g., truck, rail, barge, airfreight, pipeline, etc.) using the average efficiency of each mode.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)

<i>Term</i>	<i>Definition</i>	<i>Source</i>
Valuation/ weighing	Last element within the impact assessment following the characterization/normalization element, in which the results of the characterized/normalization, in particular the (normalized) impact scores, are weighted against each other in a quantitative and/or qualitative way in order to be able to make the impact information more decision-friendly. This element which is necessary involves qualitative or quantitative valuations which are not only based on natural sciences. For instance, political and/or ethical values can be used in this element. The valuation can result in an environmental index.	dk-TEKNIK Energy & Environment - European Environmental Agency (1997)
Waterborne Waste	Discharges to water of regulated pollutants (usually expressed in kilograms per unit of output after existing treatment processes.	US EPA - Life Cycle Assessment: Inventory Guidelines and Principles (1993)

ACRONYMS

CCA	Copper Chromated Arsenate
CCME	Canadian Council of Ministers of Environment
CEA	Canadian Electricity Association
CEPA	Canadian Environmental Protection Act
CO₂	Carbon Dioxide
CSA	Canadian Standards Association
DfE	Design for Environment
EEC	European Economic Community
EPA	Environmental Protection Agency (United States)
g	Gram
ISO	International Organization for Standardization
Kg	Kilogram
Km	Kilometres
kV	Kilovolt
LCA	Life Cycle Assessment
LCVA	Life Cycle Value Assessment
Mj	Mega Joule
NAFTA	North American Free Trade Agreement
NO_x	Nitrous Oxide
NPV	Net Present Value
PM	Particulate Matter
SETAC	Society of Environmental Toxicology and Chemistry
SO₂	Sulphur Dioxide
SOP	Strategic Options Process
TCA	Total Cost Assessment
UNEP	United Nations Environmental Program
VOC	Volatile Organic Compound

1.0 INTRODUCTION: STUDY BACKGROUND

Life Cycle Assessment, Analysis, Evaluation or Value Assessment are terms used interchangeably in the literature. No matter the term used, the meaning is to assess the environmental impact of a product or service from its formation (creation) to final disposition.

The concept of Life Cycle Assessment has evolved from modest beginnings in the late 1960s to highly sophisticated and complex assessments that are being conducted today. Over that period, Life Cycle Assessment has become a valuable tool dealing with common products that affect people in their day-to-day lives. Two of the most cited examples are the cloth versus disposal diaper (Wall Street Journal Marketplace, 1994) and the McDonald's Corporation paper versus polystyrene packaging (National Pollution Prevention Centre for Higher Education, 1995).

Life Cycle Assessment has evolved into a tool to assess pollution prevention possibilities from design to final product through its examination of raw material and energy use as well as waste outputs. It has been used as a tool to educate both consumers and designers to think of the potential environmental impacts due to its total lifespan perspective. Governments and companies are utilizing life cycle assessment as a policy evaluation tool to determine the management strategies for controlling the use of hazardous or toxic materials.

1.1 Problem/Opportunity

The objective of this research will be to provide an assessment of Western Red Cedar (*Thuja plicata*) pressure treated with Copper Chromated Arsenate (CCA),

non-treated Western Red Cedar, and pre-stressed concrete utility poles utilizing Life Cycle Value Assessment (LCA).

This research is driven by the specific needs of two organizations, ENMAX Power Corporation and the Canadian Electricity Association:

- 1) ENMAX Power Corporation has a need to determine, from 6 popular utility pole treatments and alternative types, the most viable options from an environmental, total cost, and quality perspective for future purchasing consideration.
- 2) Canadian Electricity Association is working in co-operation with Environment Canada and Health Canada to develop a life cycle methodology in the use of treated wood and alternatives. The Association's hope is to develop a comprehensive life cycle evaluation tool for industry to use when making purchasing decisions concerning the use of wood treatment products.

The life cycle assessment work is only one aspect of a much broader policy mandate currently being developed by Environment Canada. Its objective is to develop a comprehensive management framework of treated wood products. The management system may include everything from sustainable forestry, waste management from wood stripping, pollution prevention measures for each type of chemical treatment, storage measures, installation guidelines, and reuse and disposal options. The program will include extensive tracking and reporting, and an education program for industry as well as for consumers.

The development of a management framework will have significant and far-reaching implications. Treated wood products are utilized in almost all aspects of industry, from the construction of homes, utility poles, docks, and railway ties to boardwalks located in National Parks. It is estimated that the current in-service volume of treated wood in Canada is 1,134 million cubic feet with a value of \$10 billion (Environment Canada, 1999a).

1.2 Objectives of Study

Life cycle assessment is very dependent upon the goals and objectives of this study. The perspective of the practitioner utilizing LCA tools and the available data all contribute to how the assessment will be conducted. For example, the assessment methodology may simply include and assess the environmental impacts alone. Those interested in costs may include a total cost assessment to compare and contrast costs in concert with the environmental impact. Recent work in the procurement area has begun to include aspects of quality into the life cycle assessment. This further expands the assessment to cover environment, cost and quality, which can affect both the environmental and cost implications.

This study will first assess the current methodologies used for life cycle assessment, including some of the rapidly developing computer-based tools.

The second part of this study will be to conduct a Life Cycle Assessment, a total cost assessment, and a quality assessment for Western Red Cedar (*Thuja plicata*) pressure treated with Copper Chromated Arsenate (CCA), non-treated Western Red Cedar, and pre-stressed concrete utility poles.

The Life Cycle Assessment will develop a valuation under each category so that the product impacts can be assessed on their own as well as being compared and contrasted for each product. Inevitably there will be difficulties in gathering data to use in each of the methods identified above. The study will thus identify shortcomings in the availability of data. This means that the valuation under each category will be indicative of the range of environmental impacts and costs and not a precise measurement. In this regard, the findings presented in this report will identify the work that still has to take place in order to strengthen both the collection of data and the application of specific methodologies.

It is important to note that the credibility of Life Cycle Assessment is based upon the accuracy of data collected and the impartial application of that data. The fact that full life cycle impacts, energy use, costs, and end-of-use scenarios are still in the early stages for this topic area will make this a considerable challenge.

1.3 Methodology

The research for this study is made up of five parts:

- Literature Review
- Surveys
- Data Collection
- Personal Interviews
- Analysis

1.3.1 Literature Review

The literature review is conducted to determine the present “state of the art” of the life cycle methodologies and approaches. An overview of the LCA tools or computer-based LCA packages will be included. The review will identify the historical development, trends, and issues in conducting a life cycle assessment. Methods that are employed to gather information include:

- On-line catalogue searches: at Royal Roads University, the University of Calgary, and Calgary Public Library.
- Searches on the World Wide Web utilizing a variety of search engines.
- Searches of key document databases, notably those at the United States Environmental Protection Agency and Environment Canada.
- Searches through various Life Cycle Assessment, Environmental Management, and Environmental Protection journals.

1.3.2 Surveys

While the writer was in the process of developing the objectives of this thesis the Canadian Electricity Association conducted a comprehensive industry survey of member utilities that determined the current state of treated wood utility poles and alternatives. This survey was the first to identify the number and types of treated wood poles in service, and the estimated longevity of these poles. The survey identified what other alternatives were being considered for use and the issues around the use of these alternatives. The survey also gathered information on the quantity of treated wood being disposed, reused and recycled.

For this study e-mail and phone surveys of the inputs/outputs of the treatment process of local wood treating facilities, chemical manufacturers and forestry operations were conducted to ensure data integrity and to acknowledge individual company sensitivity to the disclosure of data (Appendix B).

Information from the concrete, steel and concrete pole manufactures was collected by e-mail and telephone interviews (Appendix B).

1.3.3 Data Collection

To complete the analytical part of the life cycle assessment, environmental impact data was collected first from primary sources, then from previous studies and finally from industry data bases (as available). Cost data was collected from primary sources that were supplying ENMAX Power Corporation at the time of this study. Quality assessments were made on-site in Toronto, Ontario. The assessment is based upon a non-biased field sample of visual observations of concrete utility poles located in four areas. The poles sampled represent concrete utility pole in use for a period in excess of 15 years. This assessment is of pole condition, which may give rise to concerns over structural integrity and overall quality.

1.3.4 Personal Interviews

Interviews were conducted with representatives of companies that treat wood, supply the CCA chemical, and manufacture the concrete utility pole. These interviews were conducted at the suppliers' sites, allowing the opportunity to check records and make visual observations. All other interviews, such as those conducted with the forestry operation and cement and steel manufacturers, were conducted by phone and e-mail (Annex B).

Discussions were conducted directly with utilities utilizing the products in the study to determine how decisions such as cost comparisons were made, or if LCAs were conducted. Individual utilities were contacted to determine if quality checks and/or preventive maintenance are conducted and if so, the timeframe used.

1.3.5 Analysis

All analytical information was collected and manipulated to meet the reporting requirements and unit quantification utilizing Microsoft Excel Office 98 edition. Raw material data was determined using the Athena Sustainable Materials beta version software program, and database.

1.4 Thesis Outline

Chapter 1: Introduction - Study Background

The first chapter explains the contextual background, and the purpose and objective of the thesis. An overview of the methodology used for the research is provided.

Chapter 2: Life Cycle Assessment Methodology

The purpose of this chapter is to:

1. Review current Life Cycle Assessment approaches including ISO standards, from establishing the goal, scope and objectives through to the final results;
2. Determine if particular industries are using a common or a divergent approach; and
3. Review commercial Life Cycle Assessment computer systems that are available and determine the relative advantages and disadvantages of using such systems.

Chapter 3: Life Cycle Assessment Goals and Scope Definition

Life Cycle Assessments are an intuitive process. One of the most important steps is to define goals and set the boundaries for the study. This is often difficult as these are quite commonly set by the availability of time, resources and raw materials data. The establishment of system boundaries for the Life Cycle Assessment and the rationale for these boundaries will be determined. The functional units and data quality parameters will also be discussed.

Chapter 4: Life Cycle Process Assessment

A detailed determination of each of the processes in the life cycle of each product under study will be displayed in process flow diagrams. The identification of the raw material inputs, energy inputs and waste outputs will be determined from these process diagrams.

Chapter 5: Impact Assessment

This section will focus on evaluating the significance of potential environmental impacts utilizing the results of the Life Cycle Process Assessment. This work is aimed at understanding the significant environmental impacts and quantifying these impacts with data. The level of detail varies according to data availability.

Chapter 6: Total Cost Assessment

This chapter will estimate the total costs associated with the entire life cycle for each of the three products and life-enhancement treatments used for CCA-treated cedar poles. It is important to understand the environmental impacts of a product throughout its life cycle. It is equally important to understand all of the costs, including some of those external costs often not included in the direct costs, that have the potential to affect the decision making around choice. Other factors that affect decision making such as product quality, safety considerations and longevity are discussed. This section will evaluate total cost from the decision maker's perspective.

Chapter 7: Evaluation and Conclusions

This chapter is a synthesis of the environmental, cost, and quality factors and data to assess the life cycle value of each of the three products and the life enhancement measures for CCA-treated cedar poles.

Chapter 8: Recommendations

This chapter will address the thesis question, provide recommendations for policy decision making and areas of future research. The recommendations are divided into three areas: general recommendations, recommendations for electrical utilities and recommendations related to the LCA process.

2.0 LIFE CYCLE ASSESSMENT METHODOLOGIES

In Life Cycle Assessment (LCA) attempts have been made to standardize the methods used to assist practitioners and users of the technique so that there is a standard approach, consistency in analysis and, if possible, consistency in the data sources used. However, since LCA is still relatively new, acceptance of a scientifically accepted standard for all LCA's through all facets of the assessment has not been agreed upon at this point. In fact it could be argued that there is incongruent use of the terminology between practitioners.

The phrase "life cycle assessment" has been used interchangeably with terms including: life cycle analysis; life cycle thinking; design for environment; life cycle management; and life cycle assessment. Even the word "methodology" has been used through this process to explain everything from the basic steps of a LCA, to how best to value data from a particular raw material input or output of a product. This interchangeable use of terminology does create confusion for new practitioners and inexperienced users of the LCA technique. This confusion is unfortunate because it can detract from the credibility of the analysis, despite the effort and resources applied to determining the environmental impacts of a product throughout its life cycle.

For the above reason, a common list of terms has been defined in the glossary. The use of these terms will ensure consistent meaning throughout this report and contribute towards the effort to standardize the use of technical language in life cycle assessment.

Attempts to standardize the life cycle assessment framework methodology have been successful at the highest level. It is generally accepted and now captured in the International Organization for Standardization – ISO Standard 14040-97 *Environmental Management – Life Cycle Assessment – principles and framework*.

A number of organizations have been instrumental since the 1960s in developing the overall life cycle assessment methodology and the subsequent methods for developing models for assessing environmental impact. Arthur D. Little and Midwest Research Institute which later became Franklin Associates (both private consulting firms in the United States), undertook early life cycle assessment studies in the mid 1970s. In the 1980s interest in the environment saw an increase in LCAs in Europe largely in the area of packaging systems (Curran, 1996).

In the 1990s extensive work on LCA has been undertaken in a co-operative framework between the United States Environmental Protection Agency (EPA) and the Society of Environmental Toxicology and Chemistry (SETAC). In 1994 the Canadian Standards Association (CSA) developed the first comprehensive LCA framework (*PLUS 1107 – User's Guide to Life Cycle Assessment: Conceptual LCA in Practice*) document while recognizing the work being performed by SETAC and the EPA. The CSA work would form the comprehensive basis of the ISO standard developed three years later.

The ISA standard is derived from the US-EPA/SETAC model and the CSA model, and countless variations including the SETAC Simplified LCA Approach, various computer-based software life cycle assessment programs, and the Pembina Institute's life cycle value assessment.

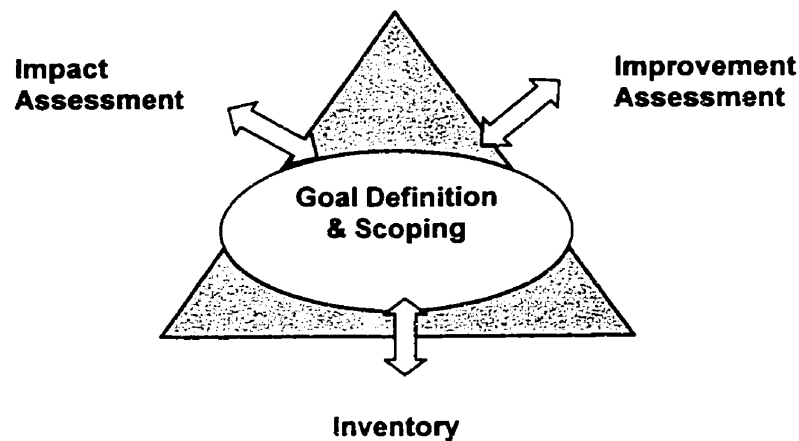
What follows in this chapter is an overview of the basic LCA framework as defined by SETAC and the ISO LCA standard. Since much of the advancement in LCA has been through the use of tools such as computer software and inventory databases, it is very important to discuss the availability and application, and to note how it is affecting the LCA methodologies. This chapter will include a discussion on the Pembina Institute's life cycle value assessment as a new and innovative approach to integrate costs with LCA. SETAC's development of a streamlined LCA is an attempt to compromise resource requirements for use of the tool. It offers interesting possibilities as well as

concerns about the practice of LCA. A summary of the state of methodologies will complete this chapter.

2.1 Life Cycle Assessment: The Basic Framework

The basic framework or high level methodology to conduct a life cycle assessment has been very consistent from the work started in the 1970s and through to today. The work of Arthur D. Little, Franklin Associates, SETAC, the CSA, and the United States EPA, has been very consistent.

Figure 2.1 The LCA Concept Model (Source: SETAC 1993).



The standard Life Cycle Assessment framework consists of the following four themes:

Inventory: An objective, data-based process of quantifying energy and raw material requirements, air emissions, waterborne effluents, solid waste, and other environmental releases throughout the life cycle of a product, process, or activity (Curran, 1996).

Impact Assessment: A technical, quantitative, and/or qualitative process of characterizing and assessing the effects of resource requirements and environmental loading identified in the inventory component (US-EPA, 1994).

The assessment should address both ecological and human health considerations, as well as other effects such as habitat modification and noise pollution (Curran, 1996).

Improvement Assessment: A systematic evaluation of needs and opportunities to reduce the environmental burden associated with energy and raw materials use and waste emissions throughout the life cycle of the product, process or activity (US-EPA, 1993). This assessment may include both quantitative and qualitative measures of improvement, such as changes in product, process and activity design. Considerations for raw material use, industrial processing, consumer use, and waste management can be incorporated (Curran, 1996).

Goal Definition and Scoping: In recent years this phase has become integrated into the overall framework. This is described in the ISO standard below and is considered as the most important aspect of a LCA according to SETAC in its 1999 paper on streamlined Life Cycle Assessment.

2.2 ISO Standards

Life cycle assessment is one aspect of a set of voluntary measures that are being adopted around the world as part of an Environmental Management System (EMS). After various standards were developed in various countries the International Organization for Standardization (ISO), developed a series of environmental management standards to help companies address their environmental issues using a rigorous and systematic approach. Reasons for developing and implementing an EMS are varied ranging from international trade, corporate image, or reduction of insurance premiums because of a heightened level of due diligence. Registration through ISO or self-declaration of adherence to the standard is a business decision; however, the rigour of third-party verification associated with formal ISO registration is more credible.

ISO adopted the life cycle assessment model that had been developed by the Society for Environmental Toxicology and Chemistry (SETAC) and the United

States Environmental Protection Agency (US-EPA). The standards include work undertaken by SETAC's European Organization as well as work by the Canadian Standards Association (CSA). Following out of the 14000 series, which includes Environmental Management, the ISO standards cover a number of aspects covering Life Cycle Assessment.

ISO Standards covering Life Cycle Assessment (IISD 1996:67):

14040 – Environmental Management – Life Cycle Assessment – *Principles and framework*

14041 – Environmental Management – Life Cycle Assessment – *Inventory Analysis*

14042 – Environmental Management – Life Cycle Assessment – *Impact Analysis*

14043 – Environmental Management – Life Cycle Assessment – *Interpretation*

The ISO methodological framework as covered under the ISO 14040 standard is described in Figure 2.2 for the major categories covered while conducting the assessment and Figure 2.3 for the conceptual model of energy, raw material inputs and waste product out puts. The concept of improvement as illustrated in Figure 2.1 is intuitive during the process as an outcome in the conclusions and recommendations. The subsequent standards to 14040 offer detailed direction covering the major phases of the LCA.

Figure 2.2 Phases of an LCA (ISO 14040-97)

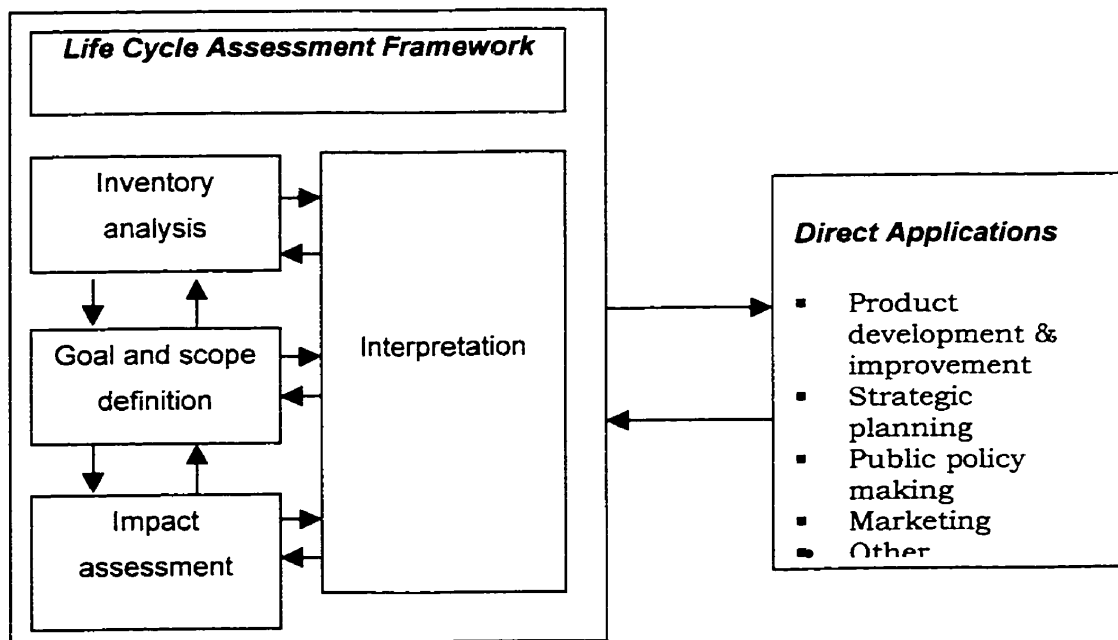
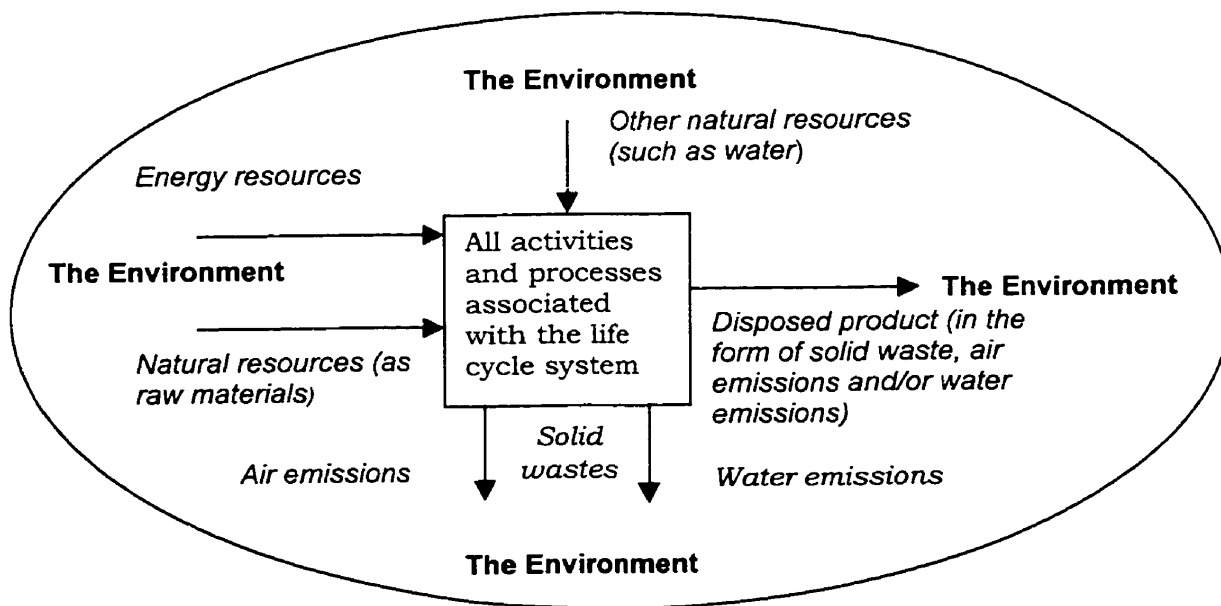


Figure 2.3 The Life Cycle System Concept (ISO 14040-97)



The components of a life cycle assessment according to the ISO standard follow a detailed methodology in an attempt to capture the energy, raw materials, and wastes of each process, from raw material acquisition to final disposal. The detailed framework follows (ISO 14040):

A. Goal Definition and Scope

- i. Goal of the study: the reason(s) for the study and the intended audience
- ii. Scope of the study
 - function of the products or systems
 - functional units
 - product system boundaries
 - allocation procedures
 - methodology of impact assessment and interpretation to be used
 - data requirements
 - assumptions
 - limitations
 - data quality requirements
 - type of critical review (if required)
 - type and format of report required

B. Life Cycle Inventory Analysis

- i. General description of life cycle inventory
- ii. Data collection and calculation procedures
 - allocation procedures
 - calculation of energy flows

C. Life Cycle Impact Assessment

- evaluation of the significance of potential environmental impacts using the results of the inventory analysis
- level of detail, choice of impacts evaluated and methodologies used depend upon the goals and scope of the study

D. Life Cycle Interpretation

- the analysis of the Life Cycle Inventory and the Impact Assessment taking the goal and scope into account to determine the conclusions and recommendations

E. Reporting

- the results of the LCA are presented to the commissioner of the study in a way that is fair, transparent, and accurate according to the goals and scope defined
- a third-party report shall be prepared for all or any interested third parties

F. Critical Review

The critical review shall consider the following points:

- methods used to conduct the LCA are consistent with the international standard
- methods used to conduct the LCA are technically and scientifically valid.
- data used is appropriate and reasonable in relation to the goal of the study
- interpretations made reflect the limitations identified in relation to the goal of the study
- the report is transparent and consistent

Based on the above standard it is clear that throughout the development of a LCA, consistent communication is occurring between the practitioner and the party commissioning the study. While it is good to define such aspects as the goal and scope up front, there is a considerable amount of “adaptive management” that takes place for a variety of reasons. Insufficient data or poor quality data is one of the key reasons cited in the literature for reassessing the goals and scope of a LCA study (European Environmental Agency, 1997).

One area where the LCA process may break down is communication between the practitioner and the client around expectations of the study. This is why up-front, clear, understanding of the goals and expectations of the various aspects and deliverables of the study are very important. Regular written and verbal communications against deliverables should minimize problems in this area.

2.3 Computer Based Life Cycle Assessment

In recent years the development of software systems to assist in performing Life Cycle Assessments has advanced the bridge between the theory of Life Cycle Assessment and practice of performing the study. The software has enabled practitioners to follow a standard form, simplify the repetitive calculations and various mathematical equations that are required. In addition considerable advancement has occurred in establishing standardized databases for various applications, processes, and materials.

LCA software can be classed into three generic categories (Curran, 1996):

1. Strict LCA tools: Designed to supply information to support LCA as a stand-alone activity. The tool helps to perform the inventory analysis and in some cases the impact assessment or the determination of the level of environmental impact.
2. Product design tools: Designed for LCA users with little or no knowledge or technical expertise in environmental issues. Most of the detailed calculations are contained within embedded shells within the program software. This software has been designed for equipment and packaging in which there are considerable options available for both cost considerations and environmental impacts. Manufactured food products in Canada have utilized this approach for prepared food packaging.

3. **Engineering tools:** This class of software represents engineering analysis tools that have been adapted into LCA. Two sub categories of software include activity-based models and process simulations.

Although the sophistication of the various software packages has grown and continues to evolve exponentially every year, there are simple facts that must be considered when using any LCA software. Although they are very useful in processing the data, ensuring capture and allocation (often at the direction of the user), they still must be properly defined within the context of LCA goal and scope. All literature indicates that this stage, to which the least attention is often paid, is the critical foundation of any LCA study (Joel Ann Todd and Mary Ann Curran (Edited), 1999). Poorly defined data from the goal and scope exercise will jeopardize the credibility of the LCA study no matter how sophisticated the computer software.

In 1996, the Hazardous Materials Branch of Environment Canada conducted a detailed evaluation of Life Cycle Assessment tools (Menke, D., Davis, G., and Vigon, B. 1996). It represents one of the first attempts to critically evaluate the various tools from a practical user's perspective, including cost, depth of inventory data, and ease of use. The report did not, however, receive the benefit of an in-depth technical evaluation. Given the timing of the report it corresponds with one of the largest budgetary cuts to Environment Canada. Just the same it provided an exceptional review of the software and database systems designed to support LCA.

In the Environment Canada report 37 software tools were identified, of which 4 were under development while this review was being conducted (Menke et al, 1996). Fourteen demo disks and user manuals were acquired from vendors for an initial evaluation. The initial selection criteria of 14 software tools included the collection of basic information within five functional categories: software name, vendor information, system features, computing (user support, operating system and hardware requirements), commercial specifications (including price), and finally, customers and reviews (from published reports).

A second selection criterion was defined for further review: tools that have highly detailed and representative life cycle inventory, tools with impact assessment capabilities and flexibility, and extensive use within the industry.

The detailed evaluation included five software tools as reported in Table 2.1. Information from this table shows that European companies have led the way in software development for LCA and the development of comprehensive databases. Given the cost for these programs, companies must be prepared to commit to the LCA process to realize the value they provide. Equally, starting at scratch to gather data, and set up systems to perform the LCA will most likely cost much more than these programs. Therefore there is a considerable trade-off. These programs are not for the casual user of a small to mid size firm.

Table 2.1 Life cycle software tools evaluated by Environment Canada (Menke et al, 1996) Costs are current versions (Year 2000) with foreign prices converted to United States Dollars on October 18, 2000.

LCA Software Tool	Description
KCL-ECO (Finland) Cost \$6,127 USD	A highly effective graphical interface makes this package very user friendly. The capability to edit variables from anywhere in the program makes this very flexible for building processes "on the go". A descriptive field associated with a process block can be attached to the graphical interface and included in the table of results allowing for enhanced clarity of presentation. There is no indication of data quality and sources of inventory data referenced in the literature.
Team TM (United States) Cost: \$3,000 USD	This tool is described as a life cycle inventory and costing module. The software is divided into two levels, a database level and a calculation level. The system contains 216 individual data files for product and material production, energy generated, and transportation. The user can define closed loop and recycling inputs/outputs. There is no indication of data quality and sources; however, LCA associations and journals regularly reference the program with a long history in the field.
LCAit (Sweden) Cost: \$3,511 USD	This program is described as a Life Cycle Inventory package with an internal database. The package has limited capability to apply valuation index factors to the raw material inventory data. The program as reviewed could handle 16 material inflows for each process. The ability to deal with co-mingled material for waste management is problematic. The 1995 package made no attempt to provide any data quality assessment.

LCA Software Tool	Description
PEMS (United Kingdom) Cost: \$ N/A	This package is a life cycle inventory tool covering materials, transportation, energy and waste management, as well as life cycle assessment capabilities (both problem and medium oriented). All data is calculated back to defined functional units. Various tools such as mass balance calculations and distributed blocks to split multiple streams are available. Allocations can be made by weight, energy content, chemistry, and economics. There is no indication of data source quality and references.
SimaPro (Netherlands) Cost: \$2,400 USD	This tool is recognized as one of the most comprehensive of all the LCA software tools. It is a package capable of conducting all aspects of a LCA, including multiple methods for impact analysis. All data is fully referenced. The program has followed many of the conventions set by SETAC for Life Cycle Impact Assessment.

The in-depth review criteria included the following:

1. Computer requirements and interface (hardware and software requirements)
2. System definition (system development and editing, archiving)
3. Data and data management (embedded data, data quality indicators, data protection and editing, user defined data)
4. Flexibility (unit flexibility, use of formulas and allocation)
5. Calculations and comparisons (sensitivity analysis, impact assessment, comparison of results)
6. Outputs and exports (system, table and graphs, export options)

The evaluation of software tools led to the following findings:

- All software tools have many common capabilities.
- Many of the unique features/capabilities were found in some but not all tools.
- Of the five tools evaluated, Team TM met all but the graphical display of results criteria (this has since been addressed in Version 3 software).
- LCAit met only three of the eight criteria.
- SimaPro has addressed most of the criteria evaluated in its 1999 Version 4 software.

In an effort to bring Life Cycle Assessment to a broader base of users a number of free software tools have emerged and are in development. The United States National Institute of Standards and Technology – Green Building Program has developed BEES 2.0 (Building for Environmental and Economic Sustainability). The focus of this software is to measure the environmental performance of building materials. A similar Canadian version to BEES, the ATHENA Sustainable Materials Institute¹ has developed a free software package related to building materials to assist in environmentally responsible decision making.

Carnegie Mellon University has developed a free life cycle assessment tool² as part of its Green Design Initiative. It is described as an economic input-output life cycle assessment. The site allows the user to estimate the overall environmental impacts from producing a certain dollar amount of any one of 500 commodities or services in the United States.

BC Lands and Parks has developed, in conjunction with the Tellus Institute, a free total cost assessment software package³. This powerful tool allows for calculation of total costs associated with the purchasing of various products. It takes into consideration all internal and external costs associated with products, providing a true total cost evaluation and comparison between products.

The United States Environmental Protection Agency is developing a new life cycle assessment web site (LCAccess)⁴ initially proposed for release in fall 2000 and still under development. The purpose of the web site is to fill a critical need in the life cycle community – where and how to locate existing life cycle inventory (LCI) data (Curran, personal communication, 2000). The web site will include modules which cover the following six considerations: the role of LCA,

¹ URL: <http://www.athenasmi.ca>

² URL: <http://www.eiolca.net>

³ URL: <http://www.elp.gov.bc.ca/epd/epdpa/embi/tcabc/index.html>

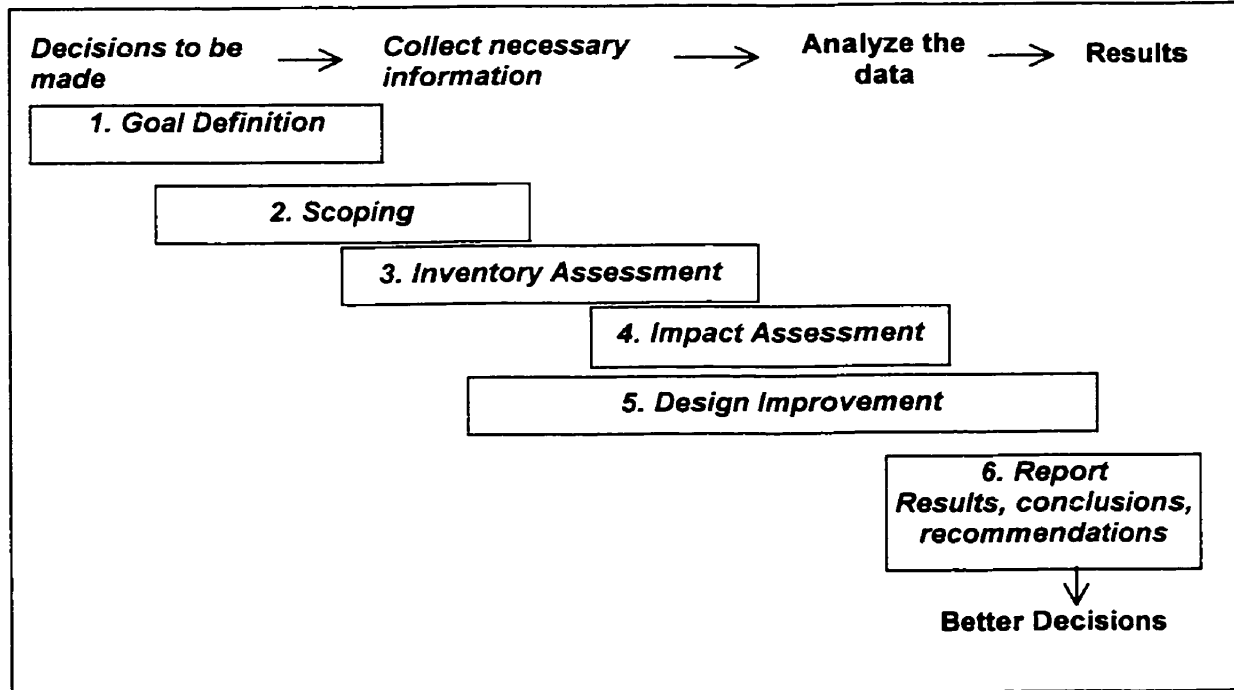
⁴ URL: http://www.epa.gov/ordntrnt/ORD/NRMRL/std/sab/lca_access.htm

what LCA is, data sources, LCA resources (documents, software, and links), ongoing efforts (to link the LCA community), and upcoming events (conferences, meetings and activities). It promises to offer the first comprehensive and integrated source for LCA. It will also aid in allowing a broader base of users to access the life cycle assessment tools.

2.4 Pembina Institute Life Cycle Value Assessment

The Pembina Institute based in Drayton Valley, Alberta has developed an analysis tool that integrates environmental and economic considerations. They term this approach Life Cycle Value Assessment (LCVA). According to the Pembina Institute the value to business of LCVA comes from its ability to develop better financial and environmental information and to bring these together for designers and decision-makers (Pembina Institute, 2000).

Figure 2.4 Pembina Institute life cycle value assessment model



A key difference between the Pembina LCVA model and conventional life cycle assessment models is the incorporation of financial and socio-economic inventory and analysis into the procedure. It simplifies and streamlines key aspects of the data collection steps in a defensible and transparent manner.

The premise that Pembina makes, and which makes practical and realistic sense, is that a business decision will be made whether or not an LCA technique is utilized. This integrated approach will provide the decision-maker with the best and most complete environmental and financial information possible, within time and resource constraints for business decision making.

The LCVA model was developed in the early 1990s and has been used by a variety of companies. Recently a number of life cycle assessments have been made public, including:

- Life Cycle Value Assessment of a Wind Turbine, February 2000
- Climate-Friendly Hydrogen Fuel: A comparison of Life-cycle greenhouse gas emissions for selected fuel cell vehicle hydrogen production systems, March 2000

2.5 Streamlined Life Cycle Assessment

Completion of a comprehensive Life Cycle Assessment is not an easy straightforward exercise. The Society of Toxicology and Chemistry (SETAC) and the United States Environmental Protection Agency (EPA) have become sensitive to and concerned about the costs and time required to complete Life Cycle Assessments. Some have questioned whether the LCA community has established a methodology that is, in fact, beyond the reach of most potential users (Todd and Curran, 1999).

In an effort to make the life cycle assessment tool more accessible to a broader base of business so that sustainable business decisions can be made, SETAC and the US-EPA have studied various means to streamline life cycle assessment.

The objective for streamlining LCA is to maintain the comprehensive nature of the technique without sacrificing accuracy or credibility. In a keynote address at the *InLCA* conference in April 2000, Mr. Bas de Leeuw, senior advisor of the United Nations Environment Programme (UNEP), commented that “The level of sophistication of life cycle assessment was very high, but users and decision makers were asking for simplicity and a realistic context. The information of course must also be well grounded and credible” (Bas de Leeuw, 2000). Despite the value of LCA, the following have created a tension for LCA practitioners and users: detail, lack of impact information, the time it takes to complete a comprehensive information, and a lack of simplicity of the analysis or bottom line.

Streamline life cycle assessment attempts to address some of the concerns raised above through:

- omitting one or more stages in the life cycle
- focusing on only a specific set of environmental issues
- limiting analysis to a shortened list of inventory categories
- omitting impact assessment
- using qualitative information
- using surrogate data from previous studies
- applying threshold levels to stop analysis at specific points (Young, 1995)

SETAC and the Research Triangle Institute working in conjunction with the US EPA have assessed various means of streamlining the basic life cycle assessment process. Table 2.2 summarizes each of the means tested and the advantages and drawbacks that they have observed.

Table 2.2 Streamlining LCA approaches (SETAC 1999)

Streamlining Approach	Application	Advantages	Disadvantages
Removing upstream components	Includes fabrication into finished product, consumer use and post consumer waste management.	Focus with internal operations and post consumer. Good for product stewardship programs. Eliminates issue of proprietary vendor data.	Important consequences of raw material extraction are missed. May cause a skewing of the overall LCA. Questionable validity.
Partially removing upstream components	Includes raw material extraction and pre-combustion processes for fuels used to extract raw materials. All steps identified above.	Provides a "reasonableness" to the study. Saves some time and resources. Enhances the validity of the study.	Selection of only some raw material components with the exclusion of others may still miss key impact areas.
Removing downstream components	All processes after final material manufacturing are excluded.	Captures some important environmental concerns within the LCA that can be used for product improvement. Encourages suppliers and vendors to provide materials with improved environmental profiles.	Ignores important stages in the life cycle. The use stage of many products has critical environmental impacts. Buildings and building materials have particularly long life spans, and final disposal is an important issue.
Removing up and downstream components	Only primary material manufacturing is included, as well as any pre-combustion processes for fuels used in manufacturing.	Focuses the LCA solely within the confines of the plant or facility. Data is easily collected and all processes are under the control of the facility being studied.	All benefits of the total life cycle approach are lost. This study is more viewed as an environmental assessment than LCA.
Using specific entries to represent impacts	Selected entries are used to approximate results in each of 24 impact categories, based on mass and subjective decisions; other entries within each category are excluded.	Focuses the study on what is important to the user and is likely to produce information that will be helpful to the user. Defined parameters are helpful to facilitate decision-making.	Important environmental considerations may be omitted. Decisions that support inclusion of environmental factors may be at the sacrifice of human health factors.

Streamlining Approach	Application	Advantages	Disadvantages
Using specific entries to represent Life Cycle Inventory	Specific entries from the individual processes comprising the LCI that correlate highly with full Life Cycle Inventory results are searched for; other entries are excluded.	Keys in on areas of the life cycle for which data is available. Increases credibility due to the high level of quantifiable data. Key advantages are feasibility and data quality.	Important environmental considerations will not be included. Even acknowledgement of such areas as habitat diversity add significant value even though they are hard to quantify.
Using "showstopper" or "knockout" criteria	Criteria are established that, if encountered during the study, can result in an immediate decision.	Highlights those factors that really affect the environment and excludes all others.	Although the process "cuts to the chase" of impacts, it considers environmental impacts or benefits as all or nothing. Often they are not, and it is the cumulative effects that have as much importance as the high impact factors considered.
Using qualitative or less accurate data	Only dominate values within each of 6 process groups (raw materials acquisition, intermediate material manufacture, primary material and product manufacture, consumer use, waste management and ancillary materials) are used; other values are excluded, as are areas where data can be qualitative or otherwise of high uncertainty.	All potential environmental issues are detected at each stage of the life cycle. Includes items such as biodiversity and habit issues which are important considerations but hard to quantify.	The difficulty in assessing the importance of each environmental concern in the overall life cycle and in comparison to other products.
Using surrogate process data	Selected processes are replaced with apparently similar processes based upon physical, chemical, or functional similarity to the datasets being replaced.	Estimates can be developed for data that would otherwise be unavailable.	In using surrogate, caution should be exercised to ensure the data is a realistic representation of the product, material or process being reviewed.

Streamlining Approach	Application	Advantages	Disadvantages
Limiting raw materials	Raw materials comprising less than 10% by mass of the LCI totals are excluded. This approach was repeated using a 30% limit.	Limits the number of items that must be studied, and focuses on those that are likely to be the most important for the product under study. It is easy to define and does not have an inherent bias.	By focusing only on volume and disregarding hazard or toxicity, important environmental effects may be overlooked.

2.6 Risk and Hazard

Although not discussed in the literature at length, the effects of a poor LCA could be considerable. Decisions made in either the private sector or the public sector could be far reaching. Private sector decisions made based upon a poor LCA may cause a company to invest millions in a product and find out later that environmental or even consumer demand will doom the product to failure. Urea formaldehyde insulation, for example, was installed in houses in the 1970s and 1980s. The product created significant health concerns and its use was discontinued. There was most likely no life cycle assessment conducted on this product, but if one had been conducted it is conceivable that it would never have been developed.

Risk and consequences are integral parts of the life cycle assessment process. The impact analysis of the LCA should consider the full range of risks associated with activities. In retrospect it would be interesting to consider what products would be in use now if a full LCA was conducted when they were being conceived, for example, nuclear reactors and automobiles.

On the public policy side the consequences of poor or non-existent life cycle assessment might be that regulatory action is not taken where it should be. The resulting consequences may affect taxpayers for many years. Given that government policy is focusing on environmental labelling, the certification of products and services must be extremely accurate. The failure to do so will

discredit the labelling program, provide competitive advantages that should not exist, and may result in health, environmental or social consequences.

2.7 Life Cycle Assessment and Public Policy

Excellent applications of life cycle assessment in the private sector include areas such as pollution prevention, energy conservation, and waste management. In some cases LCA provides excellent product design and efficiency awareness to planners and designers. Comparative LCA studies have also been conducted by companies, at first for product marketing, but more recently for product line intelligence and strategy internal to the company. One of the most referenced examples of comparative LCA centred on the debate between cloth and disposable diapers.

The use of LCA in the public sector is used for quite different applications. These include decision making around the need for and where to apply certain regulations. In Alberta LCA has been a useful tool in developing beverage container regulations, in particular what products should be returned to the depot system for recycling. In the United States, the EPA, in association with various related companies, conducted life cycle design of milk and juice packaging. The result of this work influenced public policy to direct regulations towards more environmentally preferable packaging and waste minimization strategies (Spitzley, D., Keoleian, G., and McDaniel, J. 1997).

2.8 Summary

Based on this review of methodologies it would appear there is no perfect life cycle assessment. Reality is there are many good ways to do a LCA. Just as Environmental Science and management are relatively recent phenomenon, so also is the development and use of the life cycle process. Similar to all scientific enquiry the information grows with testing, in controlled and well understood

circumstances. It is important to appreciate the discovery that takes place while conducting a life cycle assessment that builds continuous improvement and further enhances the over process.

What is important is that there must be a genuine effort to gather accurate data, to ensure non-bias in the process and to deliver transparency in analysis and evaluation. Credibility to the process and potential errors in life cycle assessments may have profound consequences in policy decisions such as not regulating a product or failing to certify a product as environmentally superior when it really is. In the end the adverse effects will prove consequential to everyone, governments, taxpayers, and communities. In true ecological context the commutative effects of environmental consequences will effect everyone.

Based on the literature and recent discussions at the U.S. EPA's International Life Cycle Assessment Conference held in April 2000, the value of LCA is defined by the user. The amount of detail and the credibility of data are determined on the final use of the LCA. For product labelling, considerable credibility rests on the assessment. However, even that assessment is subject to periodic review as new data becomes available. The real value for life cycle assessment is the education it provides, life cycle thinking. Considerations for environmental design, pollution prevention, total cost assessment and recycle/reuse opportunities are generated from the assessment. It is clear there is a desire among life cycle practitioners to develop databases and share impact, which will certainly make future assessments, even simple ones, much easier.

The research that follows has adapted the use of many of the methodologies discussed, not by design but due to adaptive innovation and resourcefulness. If specific and detailed information was not available, surrogate data was sought and used. This is the case for most researchers when time and resources to gather data are limited. It is important in the process to identify where data originated from and the relative degree of certainty there is in the data.

The research that follows has adopted the Pembina Institutes model of Life Cycle Value Assessment and attempted to take it a step further. This work will incorporate the financial and socio-economic aspects that Pembina uses, but also to consider the quality aspects of products and the non-quantified factors of decision making. The objective of this methodology is to present as much environmental, social, quality and business information as possible to the decision maker in a framework that is easily understood, so that an effective decision can be arrived at.

The future success of LCA will depend on access to computer-based systems to perform the tasks, and on accurate, defensible inventories and impact analysis information. Some large firms, but even more medium and small business operations, will never embrace widespread day-to-day use of life cycle assessment unless the analysis can be performed relatively inexpensively both in terms of cost and of resources, particularly time. Business decision making is occurring at a rapid pace, and although there is a heightened awareness for the environment in most developed and emerging countries, buy-in to the LCA concept will not occur if the process and the data remain as closed and inaccessible as they are today.

3.0 LIFE CYCLE ASSESSMENT GOALS AND SCOPE DEFINITION

3.1 Goal of the Life Cycle Assessment Study

The goal of this research is to assess western red cedar treated with chromated copper arsenate, non-treated western red cedar, and concrete distribution utility poles, utilizing Life Cycle Assessment (LCA).

This study is intended to assist ENMAX Corporation in the selection of utility poles from an environmental, quality- and total cost perspective. Although this study does not cover the full range of possible options, previous studies on other alternatives are available to cover most of the major alternatives.

This study is also intended to assist the Canadian Electricity Association in working with Environment Canada as part of the Strategic Options Process in addressing policy decisions surrounding the use of some heavy duty wood preservative products. The use of life cycle assessment was identified in the Strategic Options Process for the Management of Canadian Environmental and Protection Act (CEPA) toxic substances from the Wood Preservation Sector. Through the life cycle approach it is determined that the releases are significant, development of management control measures would be undertaken (Environment Canada, 1999a).

This study considers the raw material acquisition, product formulation, and product use stages equally. The recycle/reuse options are considered from a qualitative point of view; however, there are so few options and very little quantitative data in this area at this time. Each stage of the process has the potential to impact the environment and needs to be considered within the context of this assessment. There must also be consideration for economic costs, quality factors, and operational aspects of various utility pole options.

Data in this research is believed to be the most recent available. The majority of data is from industry sources directly, including - forestry operations, pole mills, utility pole treating facilities, chemical suppliers and cement pole manufacturers. There was no data available for the source formation of the CCA chemical components. Data for the cement manufacturing and rebar manufacturing were acquired from the Athena Sustainable Building Products database. Their figures were cross-referenced with cement plant emission levels from the United Kingdom.

In interviews for data collection it was discovered that companies do not collect or have data readily available on a consumption basis. Most of the information was available on a cost basis, which required extensive extrapolation to determine consumption.

It should be acknowledged and it is noted later in the study that most utilities attempt to reuse/recycle used poles by giving them to other organizations. Because the poles are given to others the reclamation benefits do not accrue directly to the utility but to society in a broader sense. Also, this practise offsets the acquisition of new wood by others but not by the utility. This creates a methodological issue for the life cycle assessment as to who acquires the benefit of such activity. Reuse is a highly beneficial and sustainable practice; however, both title and benefit is passed to the new owner. The original owner offers the pole as an alternative to landfilling; this is usually cheaper since there is no landfill cost, possibly a small revenue stream, and the new owner assumes the hauling cost. This issue is important not just to this study but to the entire area of greenhouse gas emission credits and emissions ownership. This is due to the fact that there currently is no officially sanctioned body that has established formal guidelines for emission ownership. Despite this some emission credits have been traded based some pilot emission trading exchanges such as KEFI in Alberta.

The process diagrams included in Chapter 4 were reviewed and verified by the companies involved. In each case the diagrams provided a generally accepted

representation of the processes. In the case of steel and concrete manufacturing the diagrams represent generally accepted manufacturing processes from various sources. In the case of the forestry operation, although not included in the flow diagram, there is a considerable amount of administrative, public consultation, and preparatory work involved in the forest harvesting and renewal process.

3.2 Definition of Scope

It is very important when undertaking a LCA to map out the various considerations that must be included in the study. These considerations include:

- defining the system or process that is to be evaluated,
- the standard unit of measurement that will be used,
- what is excluded from systems or processes,
- define the limitations of the data,
- the period of time covered in the context of the study,
- the geographical coverage of the LCA,
- define the technology that is covered in the systems under study,
- the reproducibility of methods utilized in the LCA,
- the sources of data and representativeness, and
- an understanding of the level of uncertainty related to the information.

By addressing each of these considerations, the issue credibility surrounding the study will have a considerable foundation. The following addresses each of these considerations within the context of the research topic.

3.2.1 Systems

The systems being considered include:

- a) Western red cedar from harvesting in the forest, processing for use as a utility pole, installation and use as a utility distribution pole, removal, reuse, and final disposal.

- b) Western red cedar from harvesting in the forest, processing for use as a utility pole, treatment with chromated copper arsenate (CCA), installation and use as a utility distribution pole, maintenance, removal, reuse, and final disposal.
- c) Raw material extraction (mining) for constituents to produce cement, raw material extraction (mining) for constituents to produce steel re-enforcement bar, production into a distribution pole, installation, maintenance, removal, recycle, and disposal.

3.2.2 Functional Units

A functional unit is the standard size that will be considered within the context of the LCA. The size of utility pole being considered is a 40-foot Class #3 distribution pole constructed to the following standards:

- Wood pole not chemically treated AWPI Standard 40 feet Class #3.
- Wood pole chemically and pressure treated with chromated copper arsenate (CCA) to the following standards: CAN/CSA Standard #080.4-97 *Preservative Treatment of poles by pressure process* and #080.8-97 *Preservative treatment of Western Red Cedar and Alaska Yellow Cedar Poles by the full-length thermal process*. American National Standards Institute ANSI 05.1. American Wood Preservers Association A3, C4, P5. The pole is treated over its full length. (ENMAX, Wood Utility Pole Technical Reference: P860-01 Dec. 1995)
- Concrete poles specified in the Stress Crete Distribution Pole Guide⁵
- The unit of measure will be one single pole. No additional materials or equipment are included such as cross arms, transformers or wires.

⁵ URL: <http://www.stresscrete.com/html/design.html>

All data was adjusted to the functional unit of a single 40-foot utility pole. In the terms of dimensional measurements the average measurement used was 0.75 cubic metres (G. Sluggett, personal communication, 2000). Product measurements are based on actual weights provided by all suppliers. In many cases U.S. data was provided in gallons, pounds and BTUs. These were all converted to metric as the standard of this report.

3.2.3 System Boundaries

The system boundary for this study includes all of the direct input and output in the life cycle of wood poles and concrete poles as indicated in the flow diagrams in Figures 3.1, 3.2 and 3.3. Inputs in the life cycle include energy consumption, raw material, ancillary materials, and water. Outputs include all products, by-products, solid wastes, air emissions and aqueous wastes. No data has been included about life cycle items considered indirect to the life cycle of the utility poles under study. Such items may include energy to transport employees to the workplace, energy/raw materials for employee clothing, or permanently placed capital equipment such as the pressure tank for treating wooden poles, and concrete utility pole fabricating equipment. A full mapping of all data considerations to this life cycle assessment is included in Chapter 4.

Included in this study is consideration of costs and quality, as the life cycle review must account for on-going maintenance, life extending measures, and the environmental/cost implications for the process. The total cost assessment will be applied to the options being considered from the purchaser's perspective. Quality measures will be identified and survey data will illustrate life expectancy. Operational considerations such as storage and safety considerations will also be noted.

Given the renewable nature of forest products, there is no defined methodology to incorporate the renewability aspect into LCA studies. Qualitative consideration will be made to this fact in the analysis as well as consideration

for both carbon sink and loss of carbon sink in the extraction of trees from the forest.

Figure 3.1 Non-treated wood utility pole

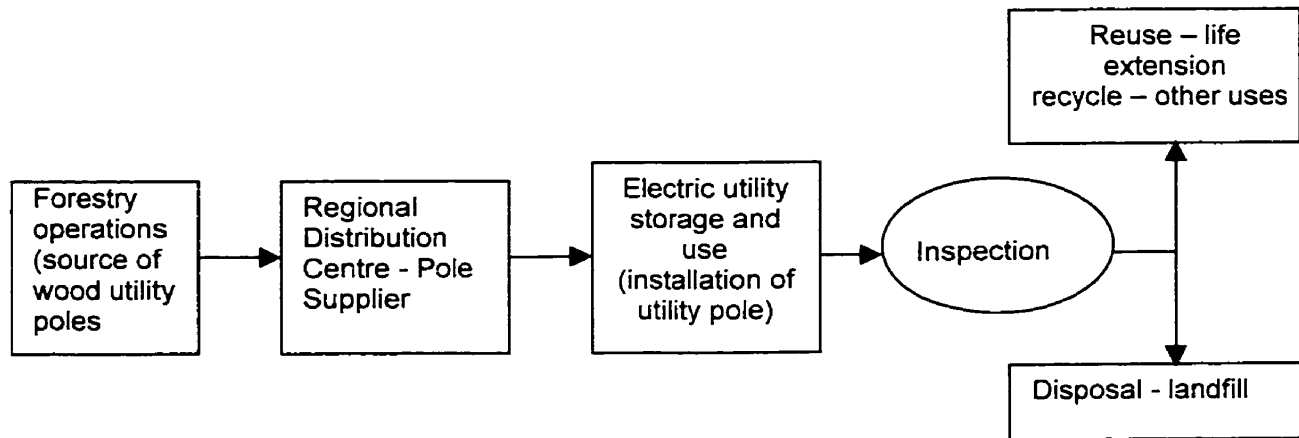


Figure 3.2 CCA Treated wood utility pole

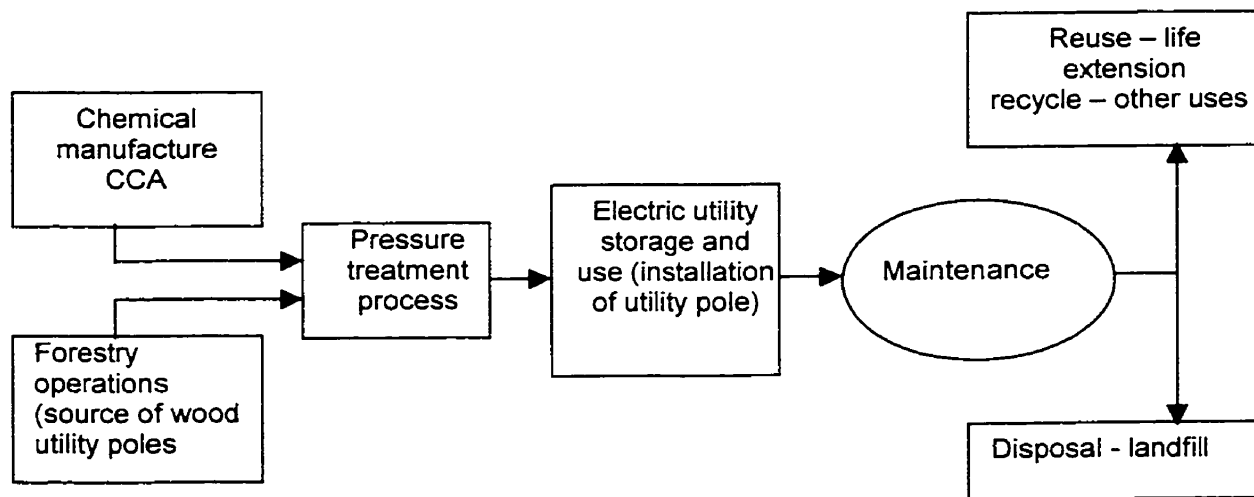
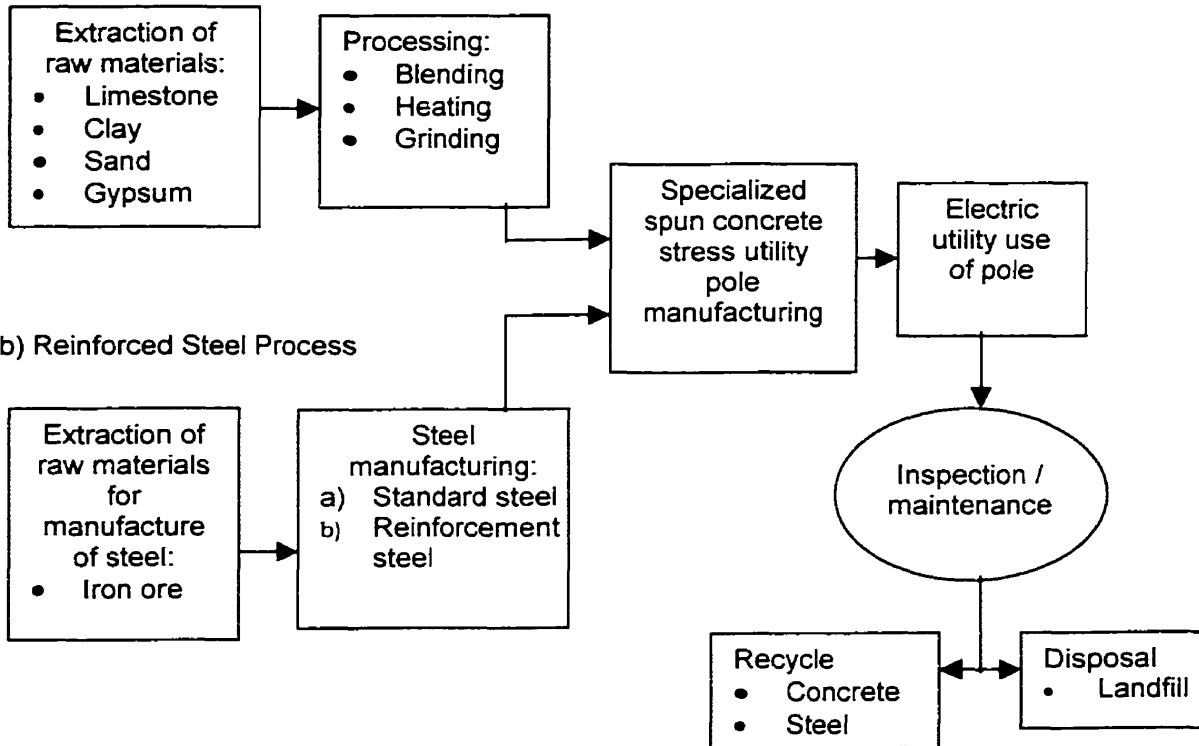


Figure 3.3 Concrete utility pole**a) Cement Process****3.2.4 Data Quality and Limitations**

Limitations to this study are the availability of data. Primary sources of data have been identified and used where possible. Where primary data was not available or companies were unwilling to provide data, similar research data was sought. In the absence of primary research, industry-based data sources were sought. Where no data was available consideration for further research was noted. All data sources will be noted through the data inventory process.

This study is limited to the life cycle of products identified. It is acknowledged that other processes and materials are available that may serve particular applications and environmental settings a utility may have within its

jurisdiction. This study is intended to supplement existing data of some of these other products and to suggest further research considerations.

3.2.5 Time Related Coverage

This study is based on currently available data. However, given the overall time horizon of the life of wood and concrete utility poles, considerations for well into the future and for the past are included. While the total life span for a wood pole can be as great as 80 years in some soil and climatic conditions, ENMAX Corporation considers the average lifespan for a wood pole to be 35 years (D. Hanna, personal communication, 2000). Concrete poles have not been in use for as long as wood, but are showing potential of a minimum of 100 years service life.

3.2.6 Geographical Coverage

Wood pole experience and data is based on the Calgary, Alberta area. Wood suppliers are located in the central interior of British Columbia. The wood treating facility is located 50km south-east of Calgary. The data would generally apply to the use of poles throughout Western Canada. The differentiating factors that could affect the amount of environmental impact are the soil type and moisture level, which vary even in the Calgary area. Distance from wood supply and wood preserver facilities will also affect the final LCA outcomes.

Concrete utility pole data and quality studies are based upon use of poles in the greater Toronto, Ontario area. Concrete poles are less affected by local conditions such as soil conditions, but are more susceptible to environmental considerations such as the presence of salt from natural conditions (ocean areas) and the use of road salt (Ontario, Quebec and Atlantic Canada). Cost and environmental considerations for concrete poles are from place of manufacture to Calgary, Alberta.

3.2.7 Technology Coverage

This study considers current technology for the removal of wood fibre, manufacture of the wood preservation chemicals used, and the technology to treat wood poles with the preservative. No consideration is made for future advancement in the process. There is also no consideration included in this study for technological innovation in the installation of poles. Measures such as containment wrapping may have a profound impact on the overall life cycle impact; however, this area is best considered independently.

The same considerations apply to concrete utility poles. Future uses of reinforcement materials made from other metallurgical compounds, the use of polymer products, or innovations in concrete process will not be considered in this study.

Since technological innovation offers advancement in efficiency and resource use, this study should be considered as a worst case scenario.

3.2.8 Precision, Completeness and Representativeness of the Data

Since the primary source of the data is based upon the various manufacturers and their primary suppliers, data quality is reliant upon the information these companies are prepared to share. Impact data for some products was obtained from the Voluntary Challenge and Registry (VCR) and the National Pollution Reporting Initiative (NPRI) maintained by Environment Canada. The Athena Sustainable database represents extensive and detailed determination of all the impact areas involved in the lifecycle formation of concrete and steel reinforcement bar.

3.2.9 Consistency and Reproducibility of the Methods Used Throughout the LCA

The methods of data collection contained in this study are detailed, and the sources of primary data are noted. The detailed calculations are contained in the appropriate appendices. Where judgements or assumptions have been made they have been annotated in the data calculation appendixes. Where no acceptable data is available or appropriate it will be noted that further research is required. This study is intended to be as transparent as possible.

3.2.10 Sources of Data and Their Representativeness

Data collected is from primary sources such as utility pole pressure treating companies and concrete utility pole manufacturers. In this study only one company provided detailed data for the wood pole data set. Similarly only one supplier provided data on the manufacturing of concrete poles. Two additional companies were approached for both options, but failed to respond.

Attempts were made to contact companies related to raw material acquisition of each of the three constituents of the CCA chemical. Unfortunately none of these companies would respond with detailed data.

It is possible that slight differences may occur in resource use between each of the suppliers. These companies may choose slightly different processes, possibly higher levels of environmental protection and in the case of wood preservatives, longer and contained fixation times which may require higher energy inputs. It is not expected that at the functional level of the pole these difference between companies would be significant.

This study has based data collection on the basis of a real life situation that would exist for ENMAX Corporation. Data is therefore based upon suppliers providing services to ENMAX in Calgary, Alberta with travel distances

incorporated into the determination of energy and raw material inputs and related emission levels.

3.2.11 Uncertainty of the Information

The determination of emission levels is based on conversion factors developed by Environment Canada, the United States Environmental Protection Agency, United States Department of Energy, various energy and environment departments in Europe, and specific company information. These conversion factors are based on considerable research, but like most scientific data are periodically subject to change as better information becomes available.

The depth of information that the Athena Sustainable Building Products database provided was very detailed. This data reflects considerable time and resources. Given the available time and resources for this study this depth of data would not have been achieved without the use of this database. Given discussions with the organization this data represents some of the best and most current available in Canada today.

Some of the areas of uncertainty are related to emission levels for rail transportation. Although care was taken to research a conversion factor related to the weight of a single car load per travelled distance, there are wait times and minor yard movements that may increase or decrease actual values.

3.3 Data Quality Quantification

Based on the life cycle assessment conceptual framework established by the Society of Environmental Toxicology and Chemistry (Fava, J., Consoli, F., Denison, R., Dickson, K., Mohin, T., and Vigon, B. (Edited) 1992.), it is important to illustrate to the audience reviewing the life cycle assessment the sources and quality of data that went into the research. The importance of data quality, credibility, and integrity cannot be understated. Table 3.1 represents

for this research the various sources by data set category and an applied index of quality related to the data source. This is based upon the criteria presented below.

Data Quality Evaluation Index Criteria:

The numbers indicated represent the level of confidence for each specific criteria. These are averaged between the four criteria considerations to arrive at the index level.

A. Source data/reliability:

Primary (5); Surrogate high confidence (4); Industry standards, surrogate low confidence (3); Qualified estimates (2); Non qualified estimates (1).

B. Age of Data

2000 - 1999 (5); 1997 - 1999 (4); 1993 - 1997 (3); 1989 - 1993 (2);
Prior to 1988 (1).

C. Geographic Association

Relevance of data from origin site produced or service provided.

Site specific (5); Same city or county (4); Same province or state (3); Same country or trading block (i.e., EEC or NAFTA) (2); Different country or trading block (1).

D. Technological co-relation (Li, 1997)

Data from businesses directly involved in the process or services under study (5); Data from processes and services under study but from different suppliers (4); Data from processes and materials under study but different technology (3); Data on related processes or materials but same technology (2); Data related to processes or materials but different technology (1).

Table 3.1 Data quality evaluation index

LCA Data Set	Primary Information	Secondary Information	Validation Index
Harvesting lumber	Bell Pole, Athena Sustainable Products Database	US – EPA Sector Notebook, BC Forest Industries Greenhouse Gas Emission Trends 1978-1999	4.5
CCA production	Timber Specialties Ltd., Occidental Chemical	BPH Copper Ltd.	3.4
CCA treating	Bell Pole – Carseland, Alberta	CSA Standard 80, Canadian Treated Wood Association, US EPA Emission Factor (AP-42) Wood Preserving	4.5
Steel reinforcement bar fabrication	Athena Sustainable Products Database, Pembina Institute, National Pollution Release Inventory – Stelco Halton Works	Environment Canada – Strategic Options for the management of toxic substances – Steel Manufacturing Sector. EPA Sector Notebook – Steel	4.3
Cement manufacturing	Athena Sustainable Products Database, Pembina Institute	Castle Cement (UK) Ltd.	4.3
Cement pole manufacturing	Stress Crete	Utility Structures Ltd., Environment Canada – Ready Mix Concrete, Environmental Code of Practice, 1993	5.0
Install cement pole	ENMAX Power	Stress Crete	4.5
Install wood pole	ENMAX Power		4.8
Inspection/ life enhancement wood	ENMAX Power	Genics Inc.	4.8
Inspection / life enhancement cement	Estimations based upon discussions with Toronto Hydro	ENMAX Power	3.6
Removal wood / landfill	ENMAX Power, Supply Management Services – City of Calgary	City of Calgary – Solid Waste Services	4.8
Removal Wood Secondary Use	ENMAX Power Corp, Supply Management Services – City of Calgary	B.C. Hydro and EPCOR Electric Utilities	4.8
Removal cement / landfill	Estimations based on discussions with Toronto Hydro	ENMAX Power	3.3

LCA Data Set	Primary Information	Secondary Information	Validation Index
Removal / recycle cement	Estimations based on discussions with Toronto Hydro	ENMAX Power	3.3
Removal / secondary energy wood	ENMAX Power		3.3

In the table above, the maximum score of 5 would represent the maximum score in each of the four criteria areas. Based upon the data collected the general data quality is very good. The best data is from the cement pole manufacture that provided current direct data for utility consumption. Data sets that are in the range of 4 may have been current and specific to the area of study, the source data reliability was not as strong. Data in the 3 range lacked the reliability criteria and the technology co-relation.

3.4 Processes Not Included in This LCA

Just as it is important to provide details on what has been included in the LCA, it is important to be clear as to what has not been included with the research. This will ensure that there are no surprises or misunderstanding related to the goals and scope of the study.

Table 3.2 Processes not quantified in this life cycle assessment

Unit Process	Reason for Exclusion
Raw material gathering impacts for copper oxide, chromic acid, and arsenic acid.	No data available. Arsenic is a by-product of gold mining, but the correlation between waste production and reuse could not be found. There is currently no quantification of chemical production energy and outputs.
Quantification of electrical and natural gas inputs related to CCA and cement production.	Unable to locate quantification factors. Expected volumes less than 1% of raw material inputs at the functional unit level.
Quantification of energy for recycling of waste to energy – wood; recycling cement & steel rebar.	Data unavailable. There is currently no waste recovery from wood in Alberta. There was no data available for energy and waste by products from primary cement recycling, and steel recycling was incorporated into the original data for processing; therefore, inclusion would be duplication.

3.5 Summary

The process of life cycle assessment has been evolving substantially since its modest beginnings in the early 1970s. Some of the highest profile uses of LCA have included comparisons of everyday consumer products such as cloth and paper diapers, beverage container packaging, and fast food packaging (e.g., McDonald's Corporation polystyrene clam shell container versus paper wrap for hamburgers).

LCA studies have benefited the manufacturing process through identification of potential areas of waste and redundancy. One of the most positive results of the LCA process has been its support of the pollution prevention process. By identifying all of the process inputs and outputs, elimination or reduction of polluting materials can be integrated into the process. In addition, engineered technologies and even employee training requirements can be integrated into the manufacturing process improvements.

This assessment process, to evaluate non-treated, CCA treated, and concrete utility poles utilizing life cycle assessment as well as total cost assessment and factors of decision making, is unique. No other study was found that incorporated these aspects for these products. The approach taken through this study was to utilize a fully integrated supplier for the wood pole. Bell Pole Company was selected because they operate forestry operations, sawmills and treating facilities.

With an LCA study, information and analysis could have been more extensive with more time and resources. This is the fundamental trade-off that occurs in studies such as this. In most cases, the researcher is dependent on companies for information. They may provide all or none of the required data. They may not have the information in the format or the detail that is requested. Given these challenges, surrogate data must be used or some assumptions made to complete the study.

The information collected for this study represents the best available at the time. Data was collected from the source for actual inputs and outputs. Data related to emissions represents the most current from government sources. Where time and data allowed, corresponding reference data was compared with field data for consistency and relevance.

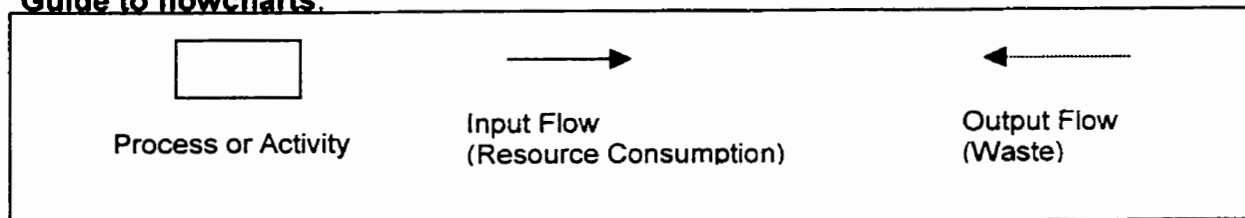
4.0 LIFE CYCLE PROCESS ASSESSMENT

The concept of life cycle assessment is to evaluate the environmental effects associated with any given activity from the initial gathering of raw material from the earth until the point at which all residuals are returned to the earth (Vigon, B.W., Tolle D.A., Cornaby, B.W.; and Latham, H. C. 1993). Before quantifying the environmental effects it is important to determine the scope of the process that is involved. In this case we are examining the life cycle processes for three utility pole options: non-treated western red cedar, CCA treated western red cedar, and stressed concrete.

4.1 Process Diagrams

The flow diagrams that follow are representations of the life cycle of a western red cedar utility pole from the raw material stage through to disposal. In setting the context for the data that follows it is important to note that although the consumer (the utility) does recycle and utilize life enhancement processes in their current operation, the purpose of this research is to evaluate the three options equally. These process enhancements will be discussed and analyzed in detail as part of the next chapter.

Guide to flowcharts:



4.1.1 Non Treated Western Red Cedar Utility Pole Life Cycle

The three flow charts that follow (Figures 4.1, 4.2 and 4.3) describe in detail the life cycle of a non-treated utility pole. A process starting as a tree in the forest, designation of land through a Timber Forest Licence (TFL) for the harvesting of wood. This is a complex and detailed process covered under the provincial forestry legislation. In this case it falls under the B.C. Forest Act. The process continues from the removal a pole quality tree from the forest, hauling it to a mill for processing, sending it to a distribution centre where it is sold to the utility. The utility in turn uses the pole, then removes it after years of use and discards in landfill. (If the pole is of reasonable quality, it is given or sold for reuse.)

The importance of the flow charts is to illustrate where the inputs of raw materials, in this case largely fuel, to move the poles, or electricity to peel and process the wood.

Figure 4.1 Forestry operation

(Generalized) Bell Pole Company Mill Sites – Lumby and Revelstoke, B.C. (Sluggett, personal communication, 2000)

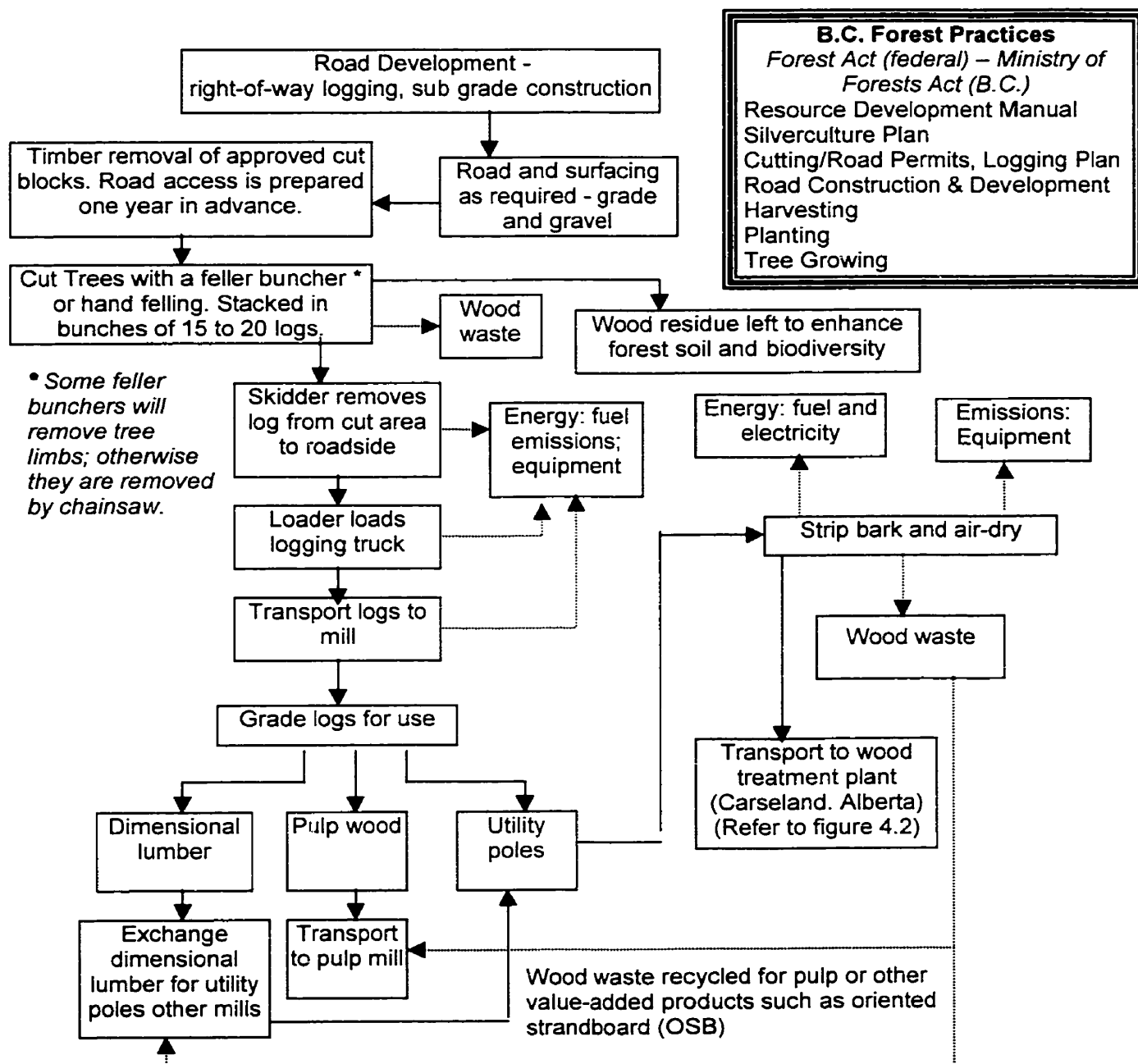


Figure 4.2 Non treated pole – regional distribution centre (Bell Pole, Carseland, Alberta)

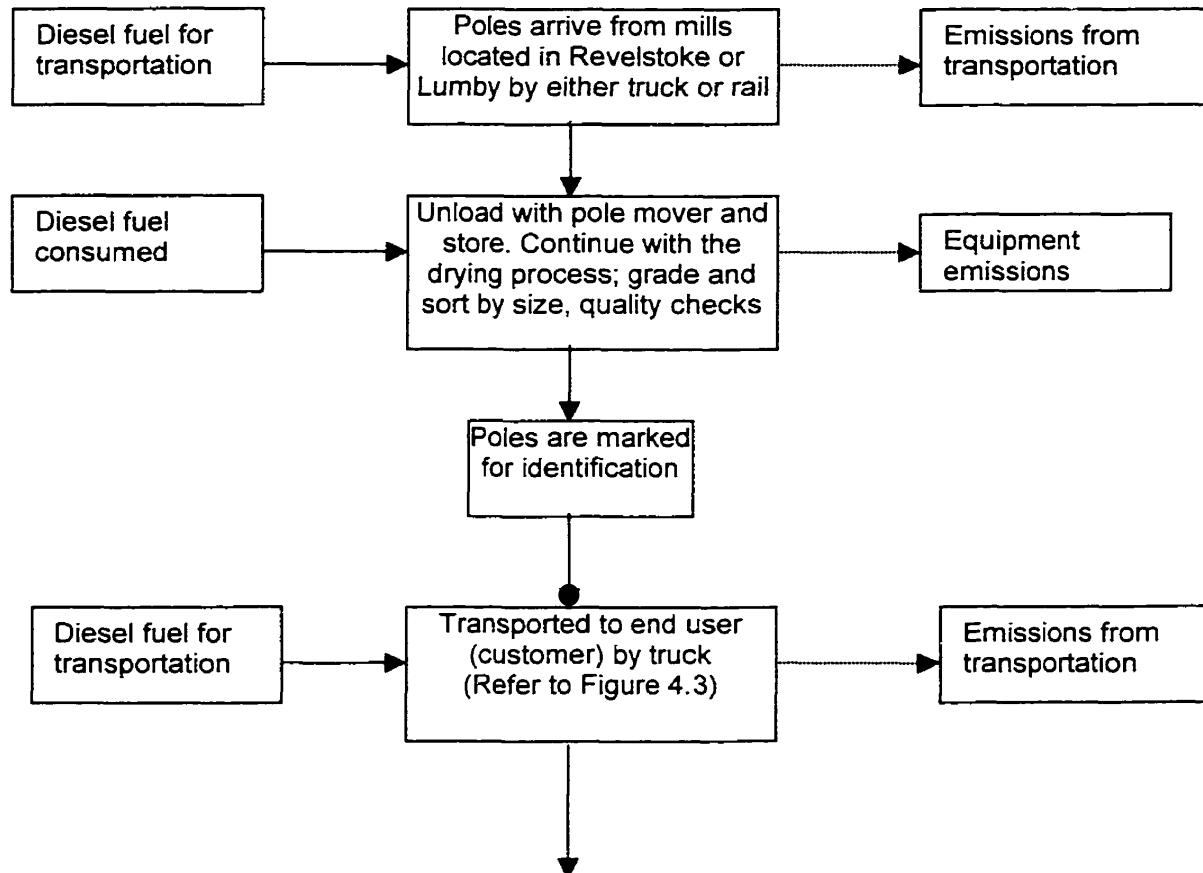
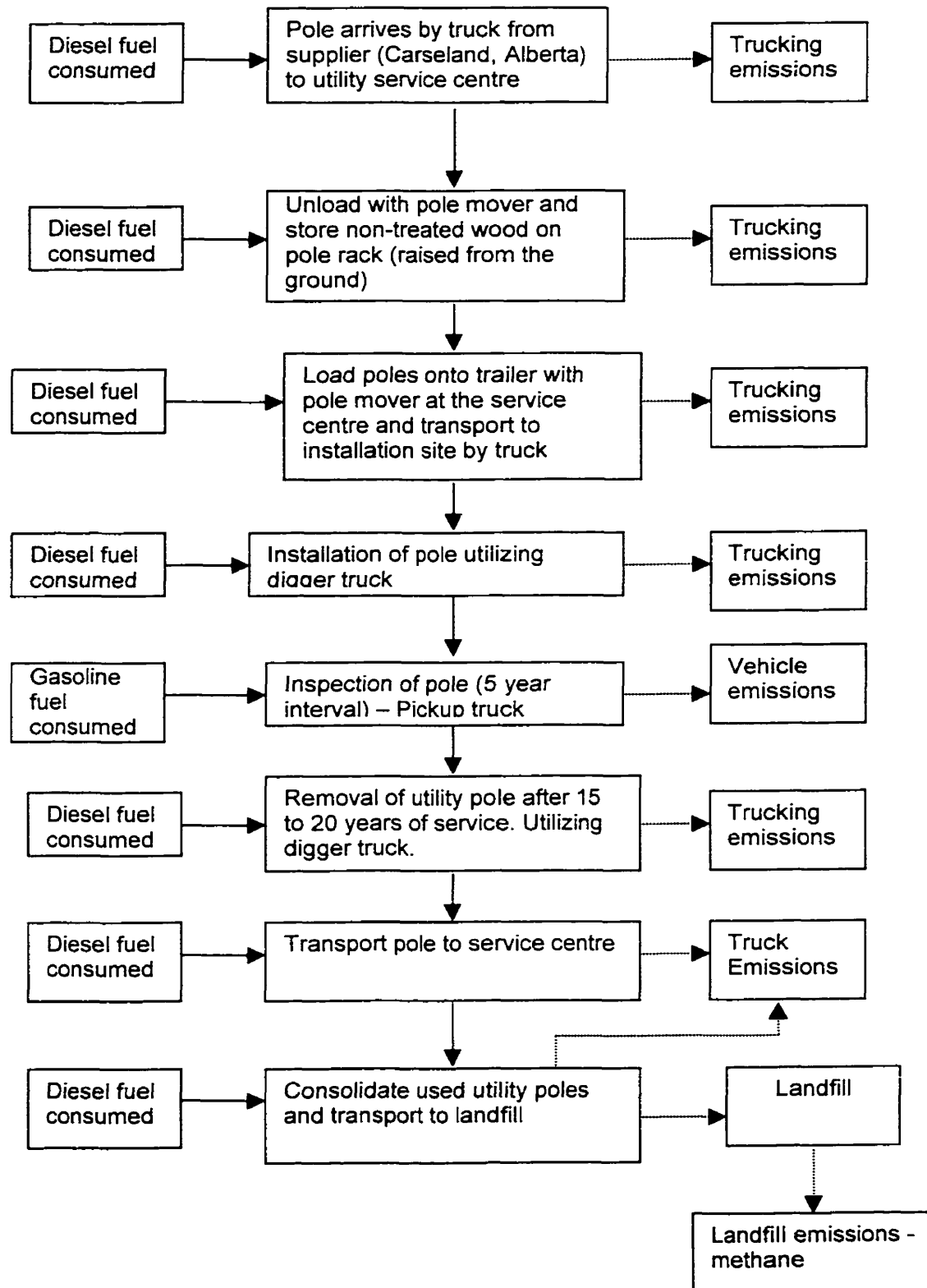


Figure 4.3 Non treated utility pole – consumer use (utility)



4.1.2 Western Red Cedar CCA Treated Utility Pole Life Cycle

The following four flowcharts (Figures 4.4 to 4.7) describe the lifecycle of the CCA treated wood pole from, harvesting in the forest, through processing, pressure treating, and final utility use to disposal. An additional chart describes the process of chemical formulation from raw material to the formulation of CCA and shipping to the local wood pole treater. The forestry and milling process of the utility pole is exactly the same as the process described in the non-treated process (figure 4.1).

All of the processes have indicated the raw material, generally energy inputs and waste by-products of each stage of the process while progressing through the lifecycle.

Figure 4.4 Forestry operation

(Generalized) Bell Pole Company Mill Sites – Lumby and Revelstoke, B.C. (G. Sluggett, Personal Communication, 2000)

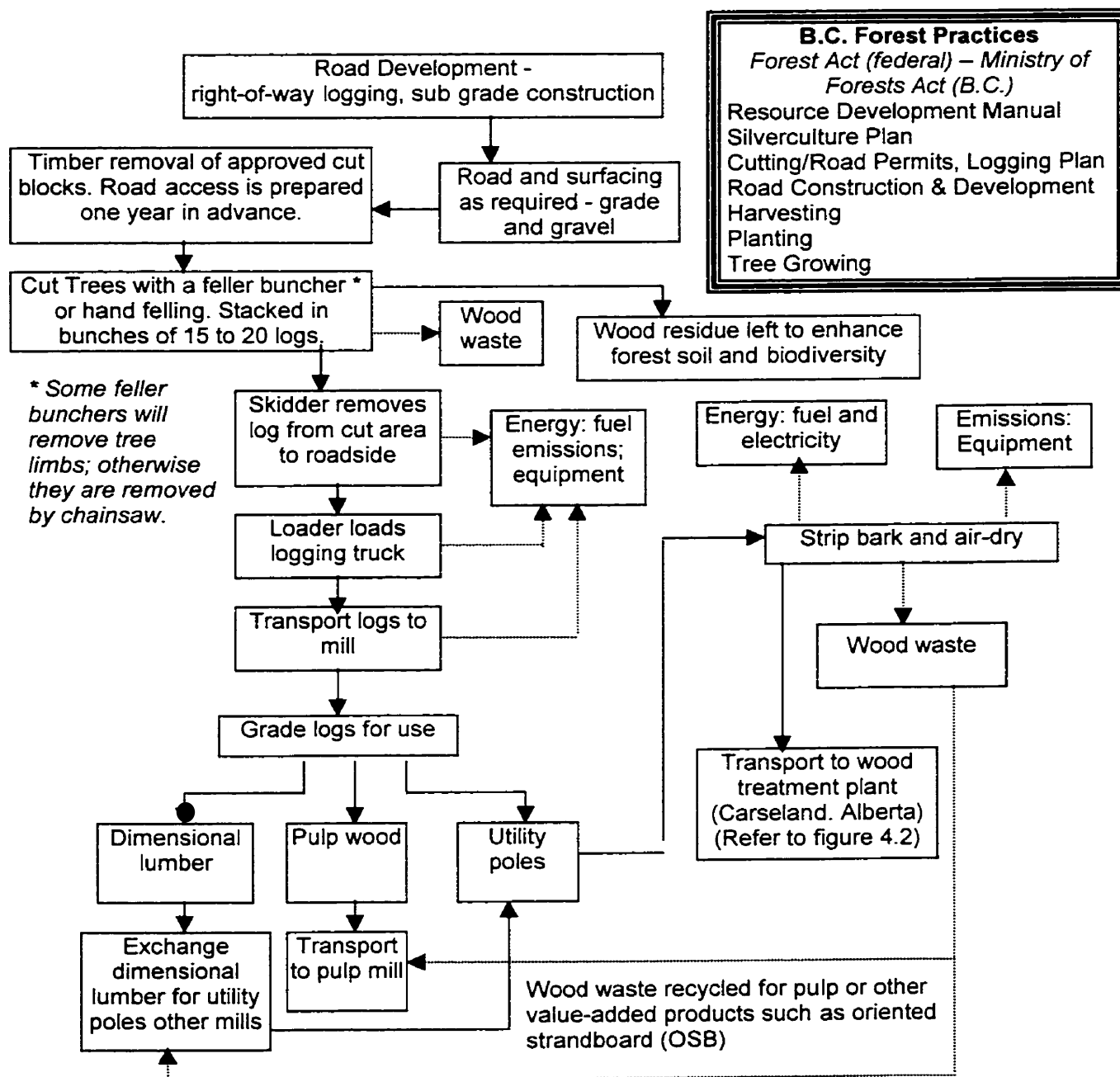


Figure 4.5 CCA manufacturing process (Rayes, 1998) (Wilson, Personal communication, 2000)
 (Timber Specialities Limited Campbellville, Ontario; Tangent, Oregon; Memphis, Tennessee)

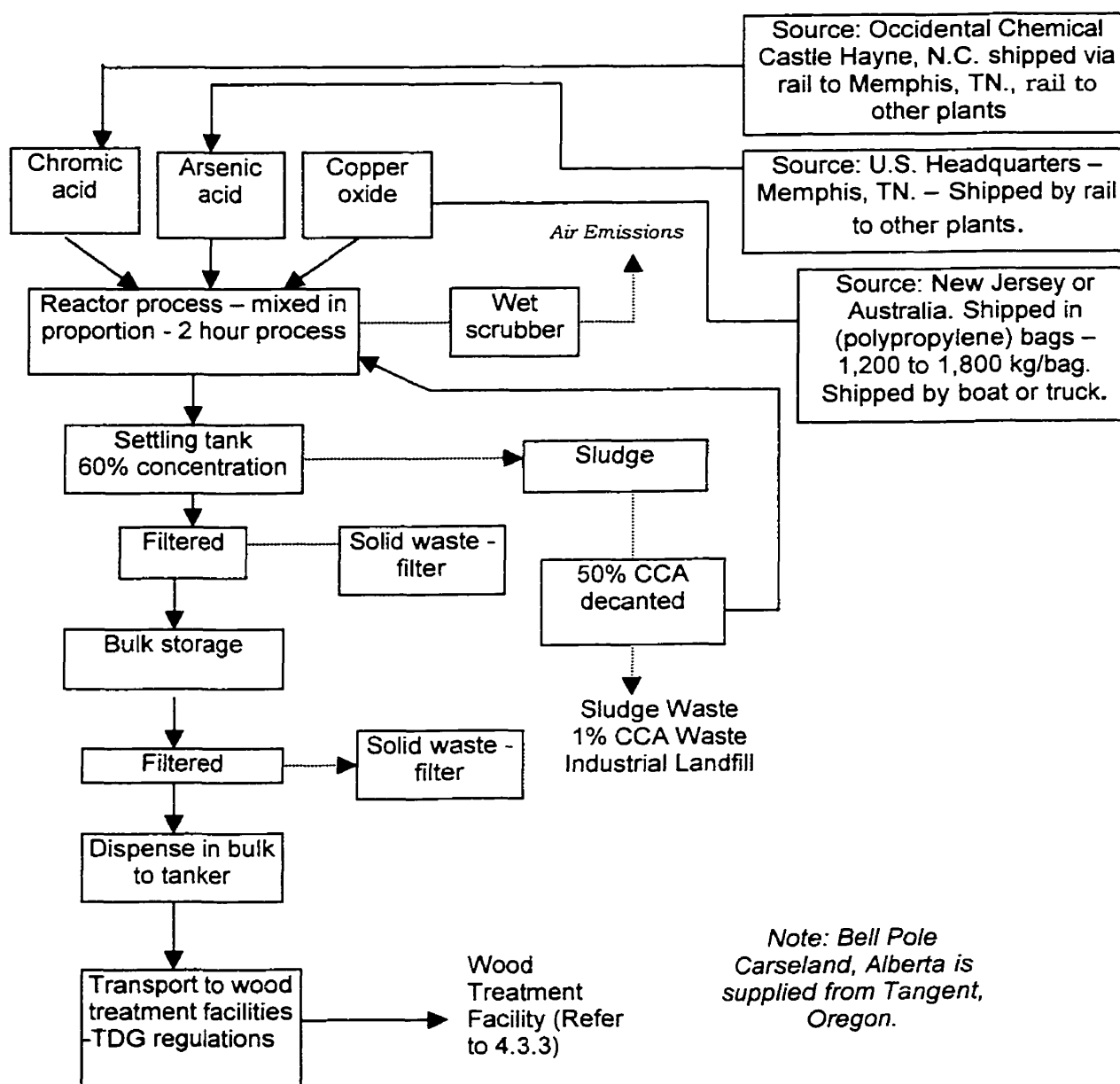


Figure 4.6 Wood pole processing and treatment (Rayes, 1998) (Garay, Personal Communication, 2000) (Bell Pole Company)

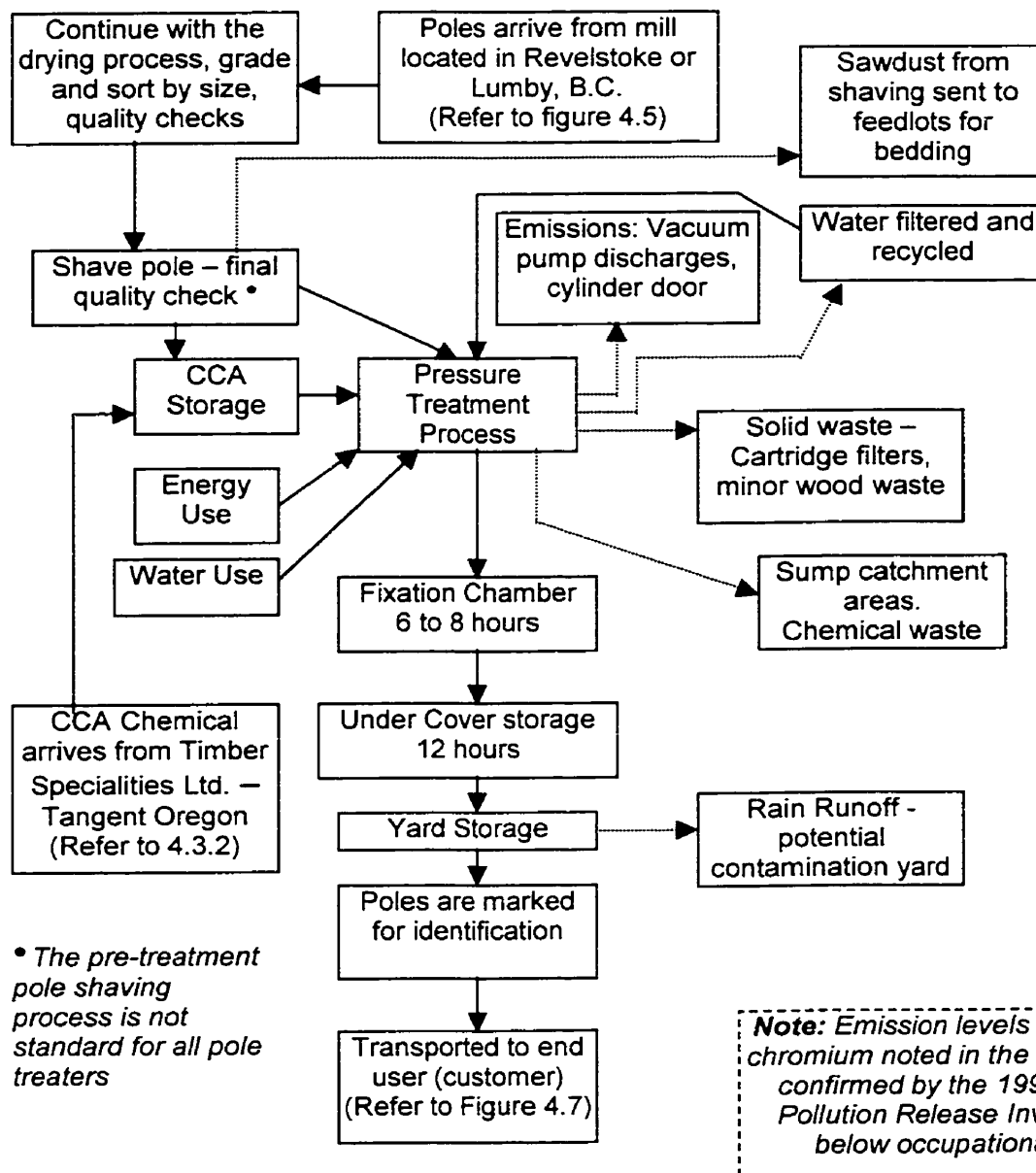
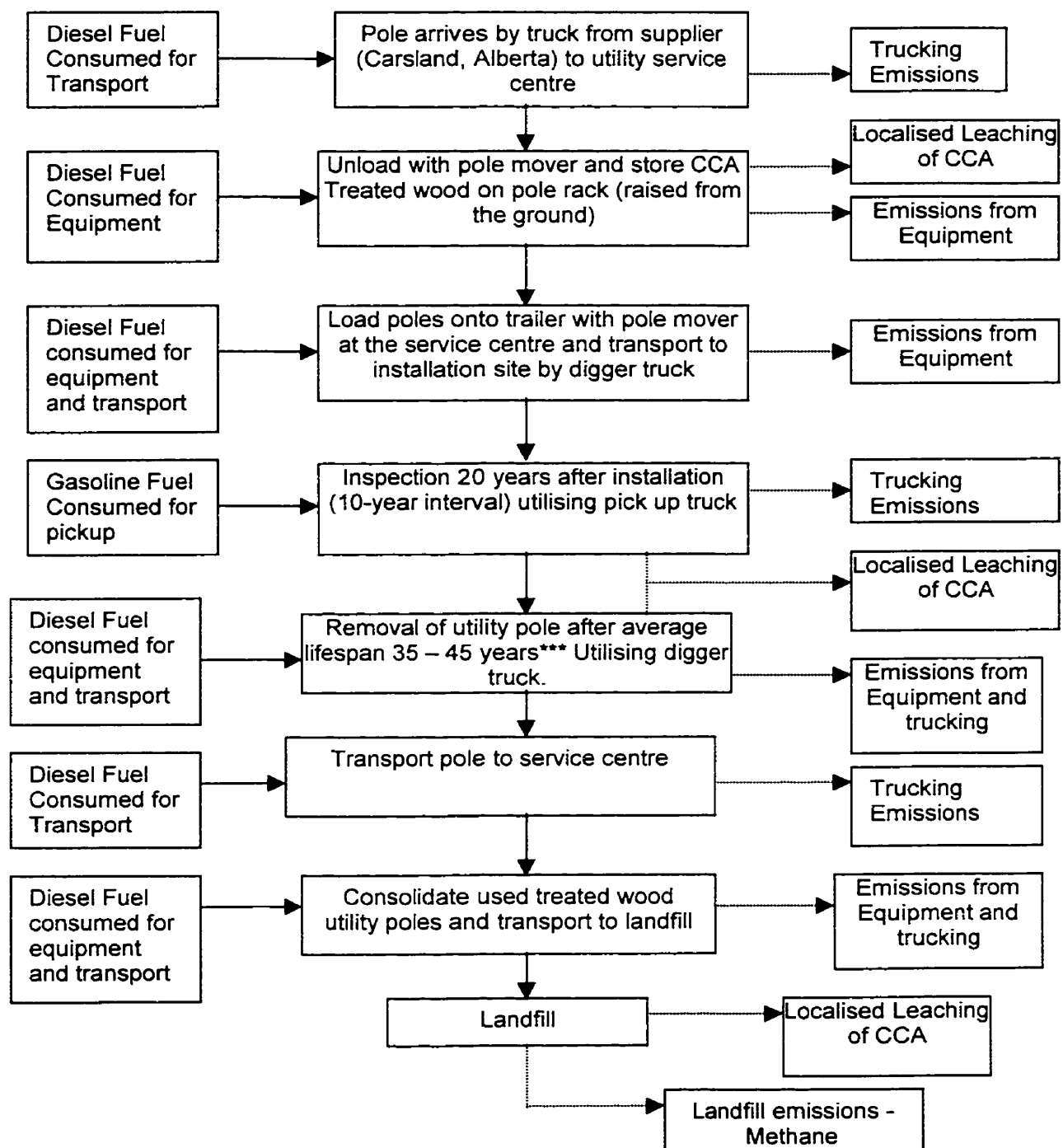


Figure 4.7 Consumer use (utility) (Hanna, personal communication, 2000)



4.1.3 Concrete Utility Pole Life Cycle

The following four flowcharts (Figures 4.8 to 4.11) describe the lifecycle of the spun concrete utility pole. The lifecycle starts with the formation of the key ingredient cement, then the re-enforced steel rod (re-bar) formation. The next flowchart describes the manufacturing process that takes these ingredients and produces the 40-foot concrete utility pole. The remaining flow chart describes the utility use and eventual disposal after use.

Given the complexity of the base materials – cement and steel re-bar, not all of the various waste products and emissions have been noted on the flowcharts. It is important to note the extent and complexity of the process, emission and waste by-products are noted in detail in Chapter 5 and Appendix A.

Figure 4.8 Concrete utility pole component production - cement (Portland Cement Association, 2000)

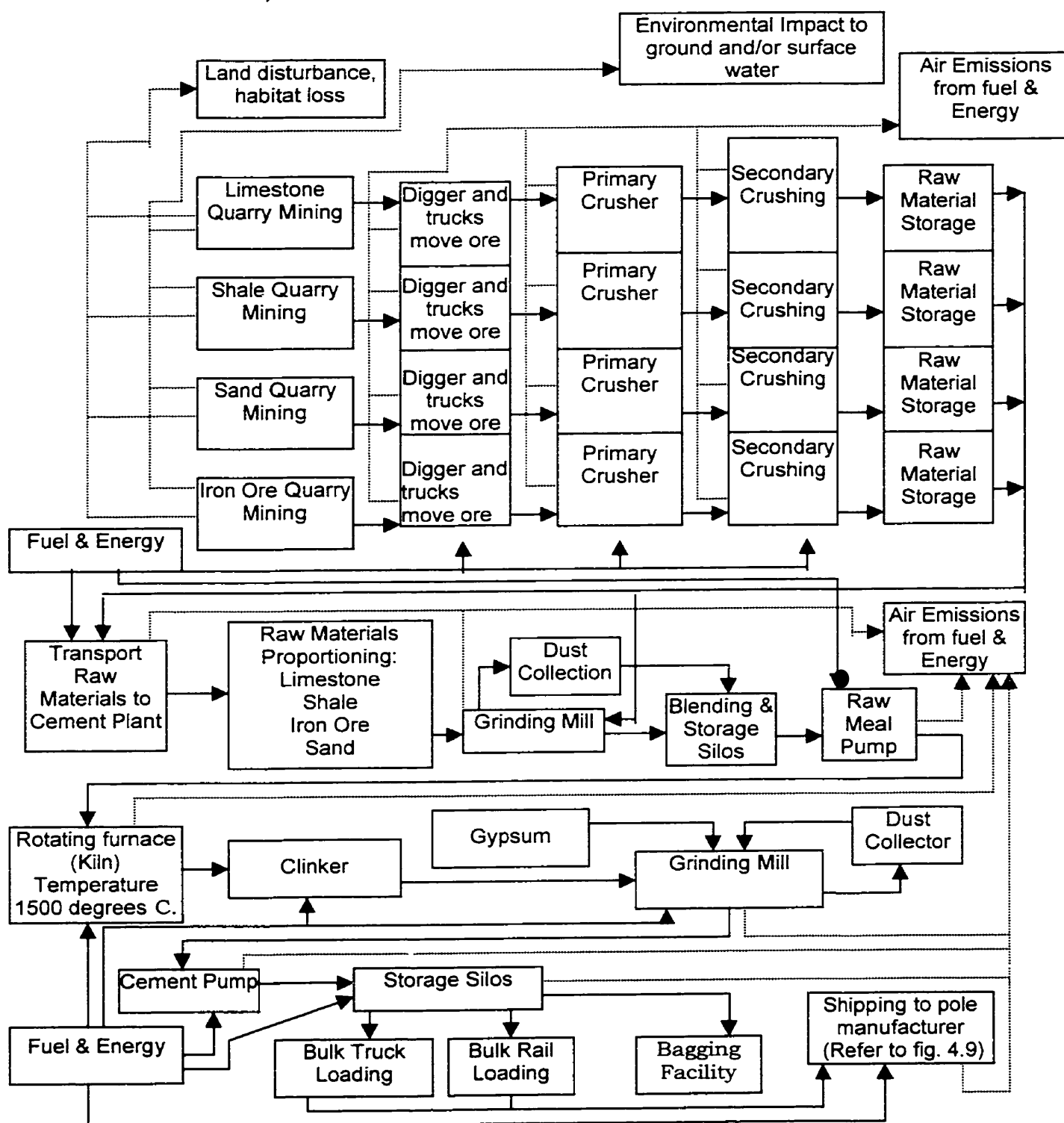


Figure 4.9 Concrete utility pole component production – steel reinforcing rod (US EPA, 1995)

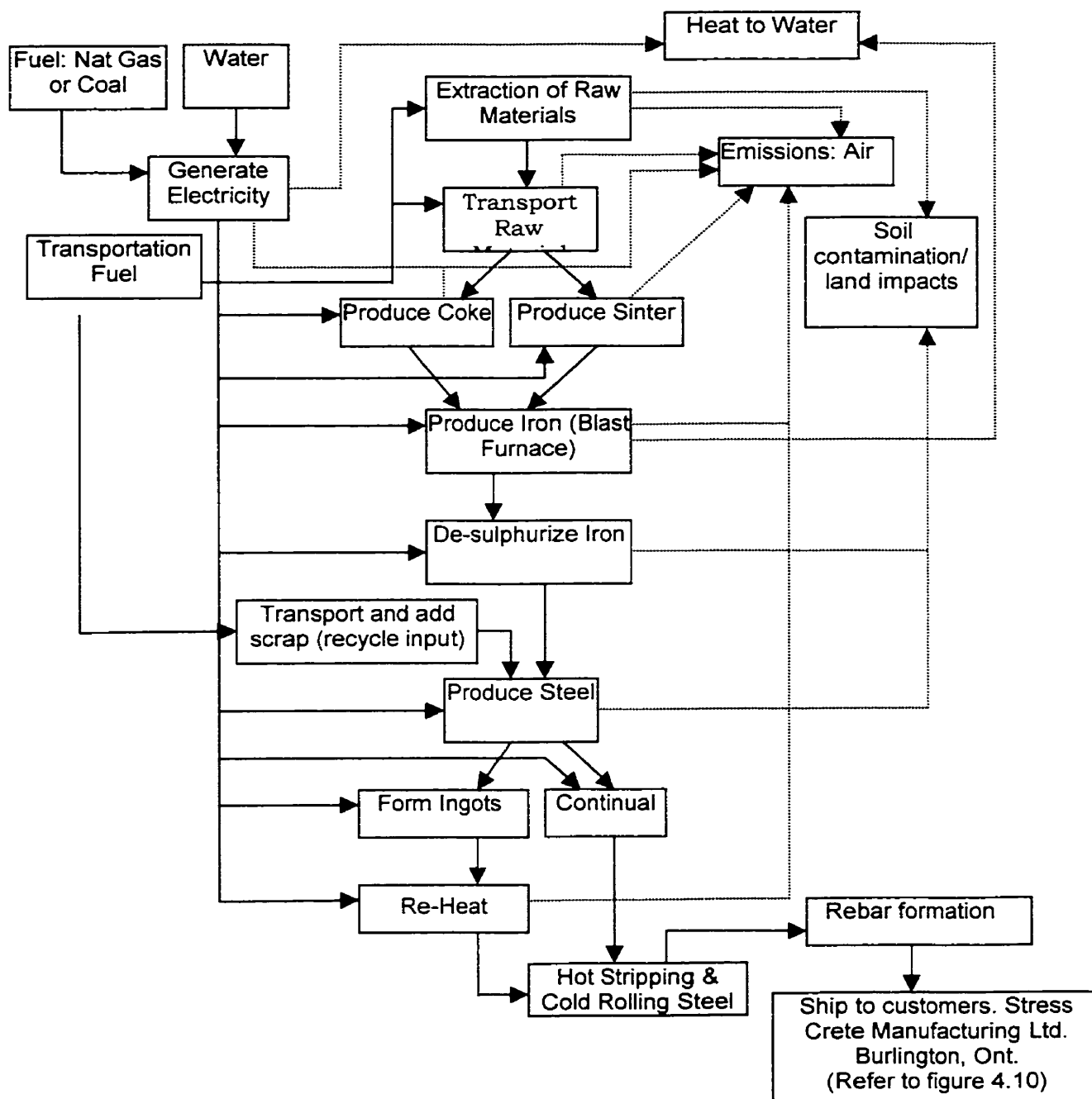


Figure 4.10 Concrete utility pole manufacturing (Rosati, personal communication, 2000) (Newmarket International, 2000)

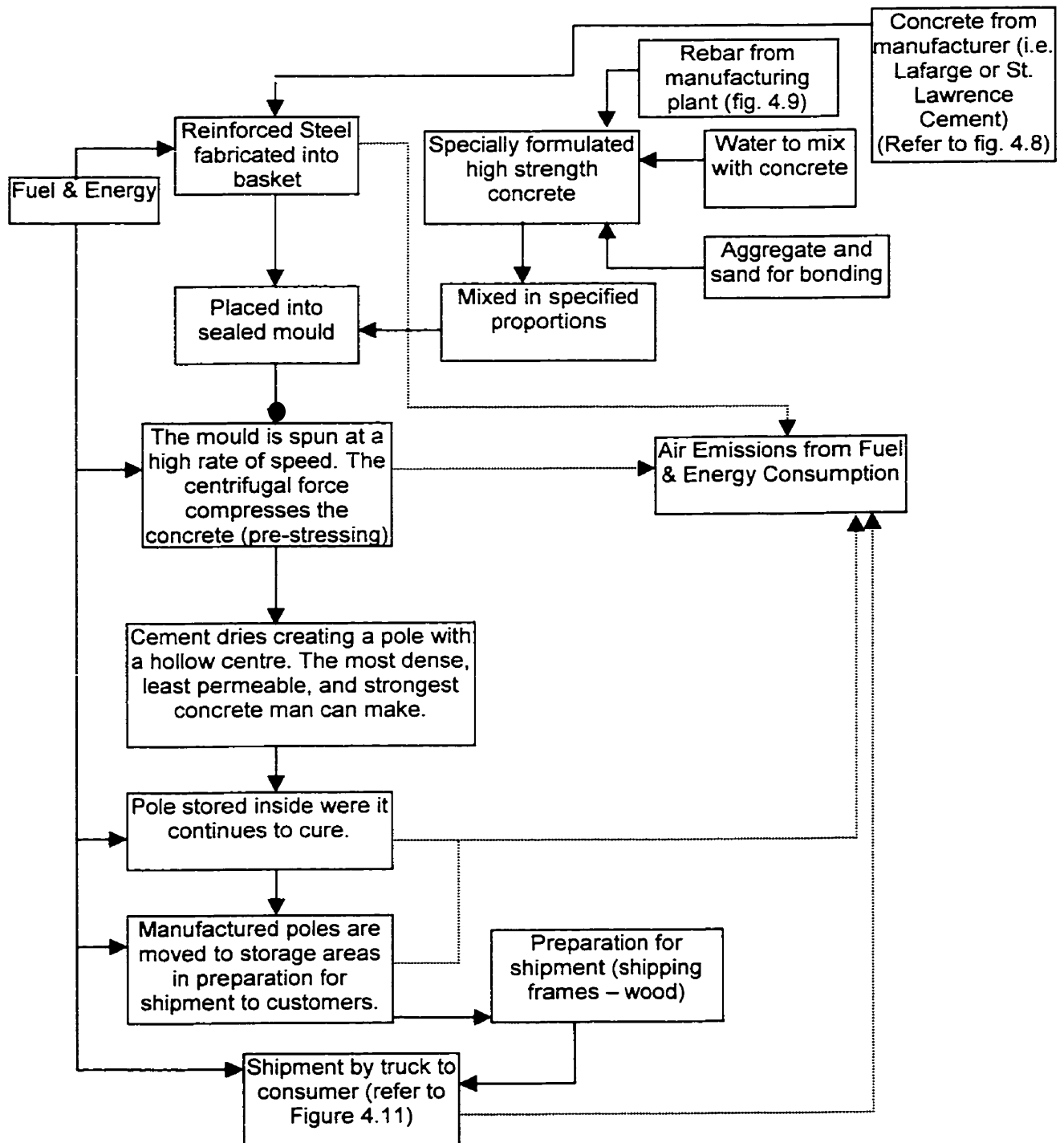
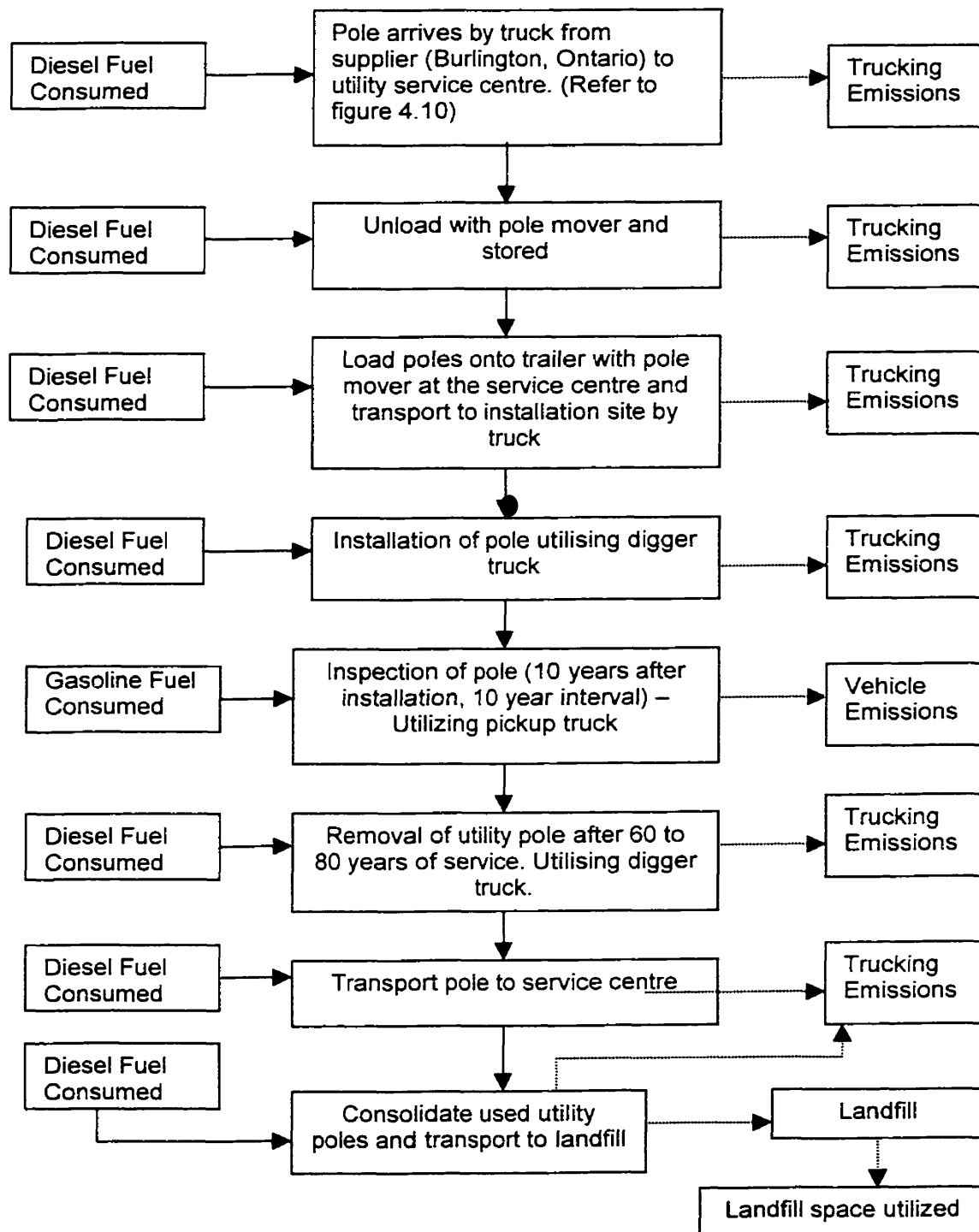


Figure 4.11 Concrete utility pole - consumer use (utility)



4.2 Summary

This chapter has identified in detail the energy inputs, waste outputs and processes that go into the three utility pole options: non-treated western red cedar, CCA treated western red cedar, and stressed concrete. It is clear that the most complex process is the creation of the concrete poles and the simplest is the non-treated western red cedar.

What the process diagrams provide is the opportunity to determine where the raw material, energy inputs and waste outputs occur. If it was possible to eliminate processes, recycle or reduce, it would have an effect on the bottom line impacts in the life cycle assessment. If the process method adds too much energy compared to the benefit derived from it, then it may not be an advantage. Clearly the process flow chart is part of the toolbox, to assist in quantification and decision making of process improvements that will lower environmental impact as well as costs.

This is why this process is so important from the perspective of pollution prevention. The process clearly identifies possible process improvements such as design or engineering enhancements, and even may suggest the question, “Why is this step needed?” This will be examined in detail in the next chapter as we quantify the raw material uses and energy consumption, and start to apply improvement options to each of the options being presented.

The simple fact that the flow diagram process illustrates the breadth and extent of the entire life of these poles illustrates the value of life cycle assessment in educating users to the steps, potential consequences and opportunities for improvement.

5.0 IMPACT ASSESSMENT

This aspect of the Life Cycle Assessment will assess the inventory data in terms of the environmental impacts and significance both quantitatively and qualitatively. The chapter will present all of the impact data relative to each of the three options: non-treated western red cedar, CCA treated western red cedar, and stressed concrete utility poles. There will be an examination of utility pole longevity, factors of quality, and safety considerations that affect decision-making.

5.1 The Factors of Environmental Impact

Environmental impacts occur at every stage of the life cycle and with every movement of raw materials and transportation. Depending on the nature of the activity they affect land, water and air to varying degrees. The Society of Environmental Toxicology and Chemistry (SETAC) has been one of the foremost leaders in defining the life cycle process and advancing the use and understanding of the life cycle evaluation tools. They have proposed a standard listing of environmental impact areas (Fava, J., Consoli, F., Denison, R., Dickson, K., Mohin, T., and Vigon, B. (Edited) 1992).

For the purpose of this study the following impact areas have been evaluated:

Resource Depletion

- Flow resources – renewable resources (forestry)
- Stock resources – non-renewable resources (oil and natural gas)

Ecological Health – Chemical Stressors

- Climate change gases
- Toxicants
- Acidification precursors
- Smog formation

Ecological Health – Non Chemical Stressors

- Habitat alteration
- Noise
- Solid Waste

Social Health

- Environmental quality
- Natural resource depletion
- Recreation
- Aesthetics

Corporate Health

- Liability potential
- Corporate Image
- Worker safety

Just as the study of ecology illustrates the interconnection of cause and effect, environmental risk assessment studies begin to illustrate the interconnection of an environmental stress on each of the aspects that affect ecosystems and human health. For example, sulphur dioxide is emitted into the atmosphere, and the initial impact is acid rain. A secondary impact is an acidified lake. Subsequent effects could be fish kill (tertiary) and loss of biodiversity (quaternary).

The assessment that follows will not show a quantitative cause and effect relationship between the quantity of electricity consumed and the loss of biodiversity. For example, the amount of electricity consumed at a mill to strip bark for poles cannot be equated with fish loss at the source of electrical energy. Obviously the notion of both collective and cumulative effects of electricity use becomes a big factor in assessing actual environmental impact; the environmental effects can and do occur over varying degrees of geographical size and over time.

Therefore the analysis of effects that follows is a determination of the relative environmental impacts based on the life cycle of the product and not the absolute impacts. These would be undertaken as separate and focused studies of each aspect of the process.

5.2 Utility Pole Longevity

It is important to recognize that of the three different types of utility poles being evaluated – non-treated western red cedar, CCA treated western red cedar, and stressed concrete — each has different life expectancy and quality characteristics which will affect the time frame in terms of analyzing each option's environmental impact. These time factors will be identified separately for the impact analysis and will be applied to produce a final impact value.

There are many factors that will affect lifespan and performance quality of each of the utility pole options considered. Some of the factors relate to the quality of application of wood preservative, while many others are site specific environmental factors such as soil type, drainage, rain quantity, average relative humidity, dry to humidity changes, and freeze/thaw cycles. Factors such as handling, number of times the wood pole has been climbed, location relative to road spray (particularly where high quantities of salt are used) will all affect pole life, and each is unique to each area.

Two additional concepts are important in analysis of utility pole longevity. There is a difference between physical life and service life. "The service life of a utility pole is the period in which the pole is in service for carrying electrical energy. Factors that cause changes in service life include line relocation, accidental breakage or line upgrading" (R.W. Stephens, G.E. Brudermann and J.D. Chalmers, 1996. p38). Physical estimates of pole integrity and strength have only recently been developed and fully quantified, giving utilities a more informed indication of remaining service life. Physical life can be considerable beyond the service life, depending on environmental effects.

The estimations of life expectancy have been very well documented for treated wood, and manufacturers have provided estimates for concrete utility poles. However, other than utility experience, there are very few documented studies for non-treated poles.

The estimated life expectancy of poles in this study is as follows:

1. ***Non-Treated western red cedar*** – 12 to 18 years (based on utility experience). Fifteen years will be the standard life expectancy used for this study.
2. ***CCA treated western red cedar*** – 35 to 40 years (D. Hanna, personal communication, 2000); 30 years (CCME, 2000); 37 years (Stewart, 1996). Thirty-five years will be the standard life expectancy used for this study.
3. ***Prestressed concrete*** - Warranted for 10 years (Stress Crete, 2000); 50 years life expectancy (Canadian Precast/Prestressed Concrete Institute, 2000). Fifty years will be the standard life expectancy used for this study.

Additional sensitivity analysis is required to test the longevity of these products. There was considerable literature that suggested that non-treated cedar poles located in some areas have been in use for as long as 40 years.

5.3 Environmental Impact - Non-treated Western Red Cedar Utility Pole

Western red cedar is only one of a number of species of trees used for utility poles in North America. It is, however, regarded as one of the more durable species due to its strength and low propensity to decay in moisture-rich environments. Based on a recent Canadian utility survey, wood utility poles represent 99% of those in service, of which only 0.02% are non-treated based on a population of 10,924,080 poles (CEA, 2000).

The table that follows (Table 5.1) lists the major life cycle stages of the non-treated western red cedar utility pole. At each stage of the life cycle energy

consumption and various environmental impacts are listed. These impacts have been totalled representing the total emissions. The applied life expectancy is noted and the total annual emissions have been calculated. By developing an annual emission indicator the relative impact according to the life of the product can be estimated. Details of the impact assessment are located in Appendix A. Based upon the information presented, emission levels are highest when the individual pole is installed and removed. This contrast the early stages in which the poles are generally handled in large quantities so the emission levels per pole are low.

Table 5.1 Non treated utility pole - life cycle resource use and emissions

	Harvest and Mill	Regional Distribution Centre	Install Pole	Remove Pole / Landfill	Total	Life Expectancy	Annual
Primary Energy Consumption (Mj)	29.3	281.9	2,267.1	1,395.2	3,973.5	15	264.9
Solid Waste (Kg)	5.8	1.5	-	440.0	447.3	15	29.8
Water Emissions	-	-	-	-	-	15	0
Air Emissions (g) (not including CO ₂)	56.2	8.8	330.5	215.1	610.6	15	40.7
Carbon Dioxide (CO ₂) (kg)	2.4	1.2	19.5	12.7	35.8	15	2.4
Global Warming Potential (kg)	6.0	1.2	19.7	12.9	39.8	15	2.7
Acidification (SO ₂ + NO _x)	22.1	0	3.7	12.1	37.9	15	2.5
Ground Level Ozone (Smog) (VOC + NO _x)	27.6	0	2.0	7.1	36.7	15	2.5
Particulate Matter	0	0	0	0	0	15	0

The table that follows (Table 5.2) is a quantitative assessment of some of the other environmental impacts associated with non-treated western red cedar utility poles throughout the lifecycle.

Table 5.2 Other environmental impacts – non treated utility pole

Resource Depletion	Other than wood fibre that is extracted for the utility pole, resource use includes the primary energy as indicated in the previous table, coal, natural gas or hydro for power production in the province of impact. It should be noted that due to the rigorous engineering requirements for utility poles the harvested and processed trees are considered prime timber.
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Particulate Matter – Airborne (PM)	Other than the emissions related to transport and dust from the forestry operations, particulate matter is minimal at the function unit level – a single pole.
Toxic Effects	None noted from direct use.
Habitat Alteration	The harvesting of trees, particularly western red cedar, does affect habitat in the areas from which they are harvested. The original trees range in age from 80 to 130 years. Although there are strict guidelines on harvest, forest management, and reforestation, some erosion and species displacement does occur. From an ecological health perspective the rapid removal of forests based on the longevity of the pole will be to reduce the greenhouse gas sink, and increase carbon release from landfilling of wood.
Recreation	This has a social / environmental impact, and is highly subjective. On one side, the installation of logging roads and the provision of such areas for recreational activities such as hiking, skiing, and camping enhance recreational access. On the other side, it affects the aesthetics of recreation with visual impacts, noise and odours from motorized equipment.

5.4 Environmental Impact - CCA Treated Western Red Cedar Utility Pole

Although CCA-treated utility poles represents only 8.6% of today's in-service poles, the process is gaining popularity over other treatments with the highest replacement rate among utility pole preserving processes and products (CEA, 2000).

In table 5.3 the major life cycle stages of the CCA treated utility pole are presented. Corresponding with each of these stages is the energy inputs and emission levels associated with each stage. Details of the impact assessment are located in Appendix A.

The total life cycle emissions have been annualized based upon the life expectancy of the product. Based upon the data, the highest energy inputs and emission levels are at the consumer (utility) end of the life cycle, where more equipment is being utilized for longer per pole than in the front end of the life cycle. The addition of CCA to the process only adds a relatively small increase in energy and emissions.

Table 5.3 CCA treated utility pole - life cycle resource use and emissions

	Harvest and Mill	CCA Manufac - ture	CCA Treating	Install Pole	Remove Pole / Landfill	Total	Life Expectan - cy	Annual Emission
Primary Energy Consumption (Mj)	29.3	115.8	434.7	2,267.1	1,395.2	4,242.1	35	282.8
Solid Waste (kg)	5.8	29.6	1.6	-	451.6	488.6	35	14.0
Water Emissions	-	-	-	-	-	-	35	0
Air Emissions (g) (not including CO ₂)	56.2	27.9	27.9	543.0	215.1	870.0	35	24.9
Carbon Dioxide (CO ₂) (kg)	2.4	1.1	1.4	19.5	12.7	37.0	35	1.1
Global Warming Potential (kg)	6.0	1.2	1.4	19.7	12.9	41.2	35	1.2
Acidification (SO ₂ + NO _x)	22.1	2.1	3.7	12.1	17.5	57.5	35	1.6
Ground Level Ozone (Smog) (VOC + NO _x)	27.6	4.2	2.1	7.1	4.7	45.7	35	1.3
Particulate Matter	0	0	0	0	0	0	35	0

In Table 5.4 a quantitative assessment of some of the other environmental impacts associated with CCA treated utility poles are presented. Additional detail surrounding the issue of CCA leaching in soil is presented in Appendix B.

Table 5.4 Other environmental impacts – CCA treated utility pole

Resource Use	Other than wood fibre that is extracted for the utility pole, resource use includes the primary energy as indicated in the previous table, coal or natural gas for power production in the province of impact.
Particulate Matter - Airborne (PM)	Other than the emissions related to transport and dust from the forestry operations, particulate matter is minimal at the functional unit level – a single pole.
Toxic Effects	The leaching of CCA does occur. However, research conducted by Dr. Paul Cooper indicates that leaching of each of the three components does not exceed CCME (1999) or Alberta Tier 1 (1994) remediation criteria. Papers by Dr. Cooper and others do acknowledge instances where national and provincial guidelines are exceeded; however, the area of impact does not generally exceed a 120-cm radius of the pole.
Habitat Alteration	The harvesting of trees, particularly western red cedar, does affect habitat in the areas from which they are harvested. The original trees range in age from 80 to 130 years. Although there are strict guidelines on harvest, forest management, and reforestation, some erosion and species displacement does occur.

Recreation	This has a social/environmental impact, and highly subjective. On one side, the installation of logging roads and the provision of such areas for recreational activities such as hiking, skiing, and camping enhance recreational access. On the other side, it affects the aesthetics of recreation with visual impacts, noise and odours from motorized equipment.
Company Liability	If the remediation guidelines change or it is determined that soil or groundwater is adversely impacted by CCA leaching, companies may be required to clean up impacted areas. This impact will have an impact on the LCA calculations, increasing emission levels and soil waste.

5.5 Environmental Impact - Prestressed Concrete Utility Pole

Prestressed concrete poles are relatively new to Canada. They have been used for a number of years in Europe; France in particular. In Canada use as streetlight poles has been most extensive in Ontario. More recently, Toronto Hydro and Hydro Mississauga have moved to concrete distribution poles as replacements for wood. Nationwide, concrete poles represent 0.59% of the almost 11 million poles in service (CEA, 2000).

In Table 5.5, which follows, the life cycle of the concrete utility pole is presented. The two key ingredients – cement and steel together with the manufacturing of the concrete utility pole have been listed individually on this table. The energy and emissions related to each of the stages is presented. Details of the energy and environmental impacts are detailed in Appendix A.

The energy and emission levels present are annualized based upon the life expectancy of a concrete pole. In this analysis emission to water becomes a significant issue in contrast to the previous utility pole options. Total energy is in excess of 100% higher than other options. Energy and emissions are highest at the user end of the life cycle similar to previous options.

Table 5.5 Concrete utility pole - life cycle resource use and emissions

	Cement	Rebar	Cement Pole	Install Pole	Remove Pole / Landfill	Total	Life Expect	Annual Emissions
	Manufacture							
Primary Energy Consumption (Mj)	1543.25	1,085.7	2,722.7	3,504.2	2,890.8	11,746.7	50	234.9
Solid Waste (kg)	51.8	34.5	n/a	-	1,245.1	1,331.4	50	26.6
Water Emissions (mg)	1,388,972	107,139.5	-	-	-	1,496,111	50	29,922.2
Air Emissions not including CO ₂ (g)	2,769.93	2,791.4	421.9	543.0	215.1	6,741.3	50	134.8
Carbon Dioxide CO ₂ (kg)	484.2	163.4	24.9	32.0	26.1	730.6	50	14.6
Global Warming Potential (kg)	656.5	262.8	25.2	32.4	12.9	989.9	50	19.8
Acidification SO ₂ + NO _x (g)	1,266.4	1,234.5	15.5	19.9	34.5	2,570.8	50	51.4
Ground Level Ozone (Smog) (VOC + No _x) (g)	1,095.7	612.0	9.1	11.7	9.5	1,738.0	50	34.8
Particulate Matter PM (g)	692.7	289.1	27.34			1,009.1	50	20.2

In Table 5.6 that follows, some of the quantitative environmental effects related to concrete utility poles are presented. Some of the impacts related to the life cycle of the concrete utility pole are significant and long lasting impacts to land and water. Although reclamation may tidy quarry areas, their impact usually is permanent.

Table 5.6 Other environmental effects – concrete utility poles

Resource Use	In addition to the primary energy consumed throughout the lifecycle, concrete poles utilize an extensive list of raw material resources mined from limestone formations, sand and gravel quarries. It should also be noted that cement production facilities also utilize fly ash from coal burning hydro facilities, which helps to utilize by-products of the energy production cycle.
Particulate Matter - Airborne (PM)	There is quantified particulate matter for the production of cement, rebar and the manufacturing of the pole.
Toxic Effects	There is a possible increase in soil pH from manufactured concrete pole. Most of the human health and environmental effects occur during the production and manufacturing.

Habitat Loss	Production of cement and rebar produces high levels of suspended solids in water, which can affect fish habitat. Cement production and the high level of fossil fuel consumption directly produce high levels of chemical oxygen demand, which will affect water quality, also affecting fish habitat and possibly overall water drinking quality. The nature of raw materials extraction does affect mammal, reptile and possibly avian wildlife.
Recreation	The generally accepted methods for gathering raw materials for the production of cement and steel rebar is open pit mining. Although provincial regulations require reclamation of such disturbed areas, the land available is usually excluded from recreation. There are many aesthetic effects that reduce recreational quality. These include visual aesthetics, noise impacts, and dust.
Company Liability	The use of concrete utility poles is unlikely to pose a liability to companies that utilize them. The environmental impacts of raw materials collection and manufacturing may affect costs if greenhouse gas levies or costs are allowed to flow through to the end user.

5.6 Utility Pole Manufacturing Improvements

The life cycle assessment process highlights by careful examination, where improvements can be made to streamline the process, reduce energy, eliminate toxic materials and consequently reduce costs. This is why LCA is often referred to as a tool for pollution prevention.

5.6.1 Life Enhancement Measures

The life cycle data presented in this chapter is based on a standard lifecycle of each type of utility pole. It projects the emissions on an annual basis based on the predicted life expectancy for each of the options presented.

Some utilities have taken steps to extend the life expectancy of CCA wood utility poles by accurately testing poles for integrity and determining the expected remaining life of the pole. In some cases adding a steel brace at the groundline will extend the original pole's life by as much as another 10 years (D. Hanna, personal communication, 2000).

In Alberta some electrical utilities (ATCO and ENMAX) have for the last 5 years been applying a copper naphthinate wrap (CobraWrap™) and boron rods (CobraRod™) to enhance the life of the pole. According to the process manufacturer, Genics Incorporated, this process may extend the life of a treated pole up to 10 years per application, extending the pole life an additional 20 to 40 years, giving it an extended lifespan of up to 80 years.

Assuming that application of this product will enhance a CCA utility pole 20 additional years, the implications for the environmental impacts for CCA treated wood change considerably. Table 5.7 presents the life cycle energy and emission levels associated with the originally presented CCA treated utility pole and the additional energy and emissions for the life enhancement treatment over a 30-year period. The energy and emissions have been annualized based upon the extended lifespan. The additional life enhancement measures do not significantly increase energy and emission levels, in exchange to the benefit of extended life that the system provides.

Table 5.7 CCA treated utility pole life enhancement - life cycle resource use and emissions

	Total CCA Base Life Cycle	Inspection and Life Enhancement			Revised Total	Life Expect	Annual
		@ 35 years	@ 45 years	@ 55 years			
Primary Energy Consumption (Mj)	4,242.1	82.5	82.5	82.5	4,489.6	65	69.1
Solid Waste (kg)	488.6	0	0	0	488.6	65	7.5
Water Emissions	-	0	0	0	0	65	0
Air Emissions not including CO ₂ (g)	870.0	1.4	1.4	1.4	874.2	65	13.4
Carbon Dioxide CO ₂ (kg)	37.0	.7	.7	.7	39.1	65	0.6
Global Warming Potential (kg)	41.2	.8	.8	.8	43.2	65	0.7
Acidification SO ₂ + NO _x (g)	57.5	.8	.8	.8	59.9	65	0.9
Ground Level Ozone (Smog) VOC + NO _x (g)	45.7	.6	.6	.6	47.5	65	0.7
Particulate Matter PM (g)	0	0	0	0	0	65	0

Similar to previous pole options, Table 5.8 presents some of the qualitative environmental impacts associated with the life extension method. There has not

been significant research on the full range of potential impacts, however at this point they appear to be minimal at the individual pole level.

Table 5.8 Other environmental impacts –life enhancement

Resource Use	Additional fuel is consumed for the inspection and installation of the life enhancement system.
Particulate Matter - Airborne (PM)	Other than the emissions related to transport and dust from the forestry operations, particulate matter is minimal at the functional unit level – a single pole.
Toxic Effects	At the 35-year stage there is no longer leaching of CCA products. Based on the system developed by Genics Inc., leaching of copper naphthinate should be minimal. More research in this area is required.
Habitat Alteration	There is no known habitat alteration due to the life enhancement process. As previously mentioned the harvesting of trees, particularly western red cedar, does affect habitat in the areas where they are harvested. The original trees range in age from 80 to 130 years. Although there are strict guidelines on harvest, forest management, and reforestation, some erosion and species displacement does occur.
Recreation	There is no known impact on recreation caused by installing the life enhancement process. As previously mentioned this has a social /environmental impact and is highly subjective. On one side, the installation of logging roads and the provision of such areas for recreational activities such as hiking, skiing, and camping enhance recreational access. On the other side it affects the aesthetics of recreation with visual impacts, noise and odours from motorized equipment.
Company Liability	Future research may indicate that there is an impact on the environment. This is highly unlikely given the amount of research that goes into the approval process for the product.

5.6.2 Pole Uses and Options After Utility Use

There are a variety of end-of-life options for non-treated wood; CCA treated wood and concrete. Based on survey data from the Environment Canada and the Canadian Electricity Association treated wood utility survey, the majority of utilities either give away or sell removed poles for other non-utility uses, generally for landscaping and most often to rural/agricultural users (Rayes,

1998 and CEA, 2000). Utilities often make a determination on quality and either send them for extended use outside the utility or send to landfill. The wood sent to landfill is generally either too poor in quality, or has extensive hardware which is not cost-effective to remove and sell.

It could be expected that non-treated wood would hold higher value and have more secondary uses than treated wood. This is particularly the case as wood treatments have been highly variable over the years. At EPCOR, an electric utility located in Edmonton, Alberta, the wood is generally only butt-treated with petachlophenol. This allows removal and discarding of the lower level below ground-line, and subsequent secondary use of untreated wood above ground-line. The utility has made an arrangement with a local lumber mill that mills the wood into dimensional lumber for sale (EPCOR, 2000). BC Hydro and TELUS Corporation have a similar program with a manufacturer that produces Adirondack outdoor chairs (B.C. Hydro, 2000).

A post-use option that is utilized in the United States but has not been embraced in Canada is the waste-to-energy option. The burning of wood as well as other waste items, largely in cement kilns, has been viewed as an advantage to reduce energy cost and greenhouse gas emissions, but can also be seen as problematic. Without the properly engineered filtering systems, known carcinogenic by-products such as emissions of metals and possibly dioxins and furans may be possible.

Concrete utility poles maybe recycled for their original components. However, there is very little evidence of this occurring. Both Toronto Hydro and Mississauga Hydro were contacted (given their long historical use of concrete poles), but failed to provide any data on recycling activity. Stress Crete, a pole manufacturer in Burlington Ontario, indicated in an interview that removal of the concrete from the steel reinforcement was so difficult that recycling would be practically impossible. "They are engineered to last a long time. They are not to be broken down and recycled" (Day, 2000).

In other locations where concrete poles have been used, the primary use after the utility has ended its service life has been as engineering fill or marine structures such as break-walls for shore protection. Florida Power Corporation developed a program with Pinellas County to utilize 900,000 pounds of discarded cement utility poles to develop an artificial reef (US – EPA, 1997b).

Each of the end-of-life utility pole options has important resource and environmental considerations. The extended use of treated wood poles for landscaping or agricultural uses may save new wood from being extracted from the forest. The creation of new dimensional wood or value added products are an excellent use of resources.

5.6.3 Process Improvements for Concrete and Wood Utility Poles Based on This Study

While examining the life cycle of utility poles, both wood and concrete, it became apparent that the method of transportation which was used contributed significantly to the environmental impact of each product. Using rail transport to move both cement poles and wood poles will save resources, cut emissions and potentially - save money.

Transportation of wood poles by rail from Bell Pole's facilities in B.C. would save 1.4 litres of fuel per pole. This saving is due to the efficiency of transport to haul large and bulky items such as the 40-foot utility poles.

Transportation of concrete poles from Burlington to Calgary by rail rather than truck, on a per-pole basis, would decrease energy consumption from 2,722 (Mj) to 1,133 (Mj). Air emissions reductions would be cut from 397.01 to 220.96 grams not including carbon dioxide. Utilizing rail service would reduce the global warming potential from 25.2 to 10.5 (Kg).

These estimations are made without fully understanding the issues for the company of moving these products to markets. There may be logistic issues or

issues with damage to product, particularly for cement poles, from rail car jarring.

It may also be possible to transport CCA product from Tangent, Oregon to Calgary. This would depend on the installation of loading infrastructure and the availability of the appropriate type of car for shipping of the CCA chemical.

The approach of treating only the ground-line portion of the pole offers considerable waste reduction potential at the end of the pole's life with the utility. However, the process for butt treating is limited to oil-based treatments such as pentachlorophenol. However, new research on the use of copper naphthenate as a total wood pole treatment may offer an alternative to CCA.

Other technologies such as peeling the treated portion of a full-length treated pole may be more cost effective and meet the same objective as a butt-treated pole. This in fact may be a value-added process that wood treatment companies might consider.

5.7 Summary

The environmental impacts related to raw material acquisition, chemical production, manufacturing of both treated wood and concrete poles, installation, life enhancement and the final removal and disposal, have impacts or stresses that affect ecosystem health, human health, resource depletion, social health and corporate health. The absolute impact is currently variable and subjective. However, there are considerable impacts that have been quantified through the life cycle assessment.

The environmental impacts have been quantified Based on the raw material collection, transportation, manufacturing, installation, and removal. These figures were adjusted according to the estimated life expectancies of each option, which is an additional dimension that affects the accuracy of this analysis.

It is important to recognize that efforts are being made by most electric utilities to extend the life of poles in use and to find alternatives to landfilling of poles at the end of their useful life.

One of the most contentious issues of treated wood poles is the amount and extent of chemical leaching that occurs over the useful life of the pole. Dr. Kenneth Brooks, an American specialist in treated woods, has equated the amount of copper loss to less than the weight of a penny over the entire life of a utility pole. The loss of other chemicals is subject to the location and the quality of the fixation process that follows CCA treating.

6.0 TOTAL COST ASSESSMENT

This chapter will examine the cost component of the life cycle assessment. The cost structure presented represents both capital and operational direct expenditures, indirect costs (often missed in standard cost analysis), and external or social costs (which are seldom considered). The costs included reflect the cost to the purchaser for the three utility pole options plus the CCA treated wood life enhancement option and the respective lifespan as defined in the previous section.

This assessment will also include some of the qualitative factors of decision making such as quality, safety and operational flexibility.

6.1 Total Cost Assessment

Costing of life cycle impacts is integral to realizing the full potential of life cycle assessment (LCA) as a decision support tool (White, A., Savage, D., and Shapiro, K. 1996). This is because our society tends to use financial criteria as a sole determiner of product worth.

Just as life cycle assessment has various definitions and terms to describe it, so does the concept that describes Total Cost Assessment (TCA). Terms such as full cost accounting, life cycle costing, and total cost accounting are used frequently and interchangeably. As in the case of LCA, use of terminology and concepts must be established early and used consistently throughout the analysis.

A total cost assessment follows a four-step process:

- 1) Define the decisions that need to be made (the environmental options);
- 2) Identify and understand costs;
- 3) Analyze financial performance; and
- 4) Make the decision.

6.1.1 Total Cost Assessment: Decisions to be Made

In the research reported here, the decision of which utility pole to use requires a comparative analysis of one option, called the base case, with one or more other options. In this study the base case is the non-treated western red cedar utility pole. The three options considered are: the CCA-treated western red cedar utility pole, the concrete utility pole, and the life-enhanced CCA-treated utility pole.

What follows is an assessment of the major cost categories and costs for non-treated, CCA treated and concrete utility poles. Since the life expectancies of each of the options is so variable the financial analysis examines the costs over a 100-year horizon, expensing the costs as they would occur over this period. Refer to Appendix C for details of calculations and assumptions.

6.1.2 Total Cost Assessment Inventory

Table 6.1 presents an inventory of all of the costs including the external costs associated with the potential liabilities, contamination remediation costs and social costs associated with the emissions. Capital cost recovery is included in the costs presented. There is no provision in this analysis for capital cost allowances and taxation.

Table 6.1 Total operating costs per pole (Day, 2000); (ENMAX, 2000a); (Zeegers, 2000)

	Non-Treated Wood Pole	CCA Treated Wood Pole	Concrete Utility Pole
Direct Materials incl. Shipping	\$ 305.00	\$ 390.00	\$ 1,183.33
Storage	\$ 167.75	\$ 216.01	\$ 650.83
Operations – Installation	\$ 153.89	\$ 153.89	\$ 307.77
Equipment Costs – Installation	\$ 101.63	\$ 101.63	\$ 203.19
Operations Removal	\$ 153.00	\$ 153.00	\$ 307.77
Equipment Costs - Removal	\$ 74.00	\$ 74.00	\$ 203.19
Administration & Overhead	\$ 310.00	\$ 310.00	\$ 380.00
Supervision	\$ 66.00	\$ 66.00	\$ 66.00
Life Enhancement Cost (CCA only) Every 10 years of program assuming three treatments (includes pole quality testing)		\$ 150.00	
Waste Management & Environmental			
Regulatory	\$ 10.00	\$ 25.00	\$ 10.00
Disposal Fees	\$ 14.29	\$ 14.29	\$ 30.00
Hauling Costs	\$ 10.00	\$ 10.00	\$ 20.00
Testing/Lab Fees	\$ 0.00	\$ 350.00	\$ 60.00
Record Keeping	\$ 25.00	\$ 150.00	\$ 50.00
External Costs			
Storage yard liabilities *	\$ 0.00	\$ 200.00	\$ 0.00
Site specific clean-up *	\$ 0.00	\$ 350.24	\$ 268.32
Life Cycle Costs *	\$ 5.60	\$ 5.86	\$ 194.02

*Refer to Appendix 3 for detail and assumptions

6.1.3 Financial Analysis

Simply defining the various costs involved in the purchase, installation, removal and disposal of utility poles illustrates just part of the financial story. Since each of these products has a different lifespan, the only way to understand the costs related to each product is to evaluate it over a long time frame and equate each option to the same time frame.

To do this, the above costs have been placed on a time continuum estimating a 100 year lifespan, where a company may expect to incur costs related to each of the options, including the life enhancement option for CCA poles. Each of these costs is then discounted to a present value and summed to determine the net present value. Since the capital costs, particularly for equipment, have been included in the cost estimates there has been no reconciliation for capital costs and equally no adjustments for capital depreciation or taxes.

Based on this method and since there is revenue associated with the analysis (because the installation of a single power pole is an expense related to providing distributed power), the lowest net present value would be the most acceptable financial option.

Calculations in Table 6.2, which follows, is based on the present value formula $(NPV) = (Rate, Nper, Pmt, Fv, Type)$, where:

Rate = interest rate per period = 9% (ENMAX standard)

Nper = payment periods = years from 0 in which expenditures are made.

Pmt = payments made at each period and does not change over the period = 0

Fv = Future Value which is the estimated expenditure at the indicated point in the future.

Type = payment at the start or end of the period. The end of the period is used for this analysis.

Table 6.2 Total cost assessment – net present value

a) Years 1 to 45

	Year in which costs are expected (in Cdn. Dollars)				
	Year 1	Year 15	Year 30		Year 45
Non Treated Cedar Utility Pole	-1109.87	-1395.41	-1395.41		-1395.41
Present Value	1109.87	383.09	\$105.17		28.87
	Year 1			Year 35	
CCA Treated Cedar Pole (no life Enhancement)	-1243.38			-2369.91	
Present Value	1243.38			116.09	
	Year 1			Year 35	Year 45
CCA Treated Cedar Pole (Life Enhancement)	-1243.38			-255.11	-50.11
Present Value	1243.38			11.03	1.04
	Year 1				
Concrete Utility Pole	-2985.14				
Present Value	2985.14				

Table 6.2 Total cost assessment – net present value (cont'd)**b. Years 50 to 100**

	Year in which costs are expected (in Cdn. dollars)					
		Year 60	Year 75	Year 90	Year 100	NPV
Non Treated Cedar Utility Pole		-1395.41	-1395.41	-1395.41	-930.18	
Present Value		7.93	2.18	0.60	0.17	1637.88
			Year 70		Year 100	NPV
CCA Treated Cedar Pole (Life Enhancement)			-2369.91		-2231.01	
Present Value			5.69		0.40	1365.56
	Year 55	Year 65			Year 100	NPV
CCA Treated Cedar Pole (Life Enhancement)	-50.11	-2369.91			2052.14	
Present Value	1.04	8.75			0.37	1,265.00
	Year 50				Year 100	NPV
Concrete Utility Pole	-3,934.42				-3934.42	
Present Value	52.91				0.71	3038.76

Based on the above analysis as expenses are projected into the future, the value of those expenses decreases in current terms. This examination illustrates the value of money over time. Given each of the options, the base case of non-treated wood, CCA treated wood, CCA treated with life enhancement and concrete pole, the lowest net present value is the CCA treated wood pole with life enhancement. The highest net present value is the concrete pole.

6.2 Factors that Affect Decision Making

When decisions are made to purchase any product in a company, the standard decision-making tools usually include price, product quality, warranty, after sales service, and residual value. Environmental considerations are usually considered for products and services that may have a direct impact, or due to regulatory requirements. In this study the examination has first centred on the environmental impact throughout the life cycle of the product; in this case the three options of utility poles. In this chapter the financial cost, including environmental impacts, has been factored into the decision making. It is

important to consider some of the other more qualitative factors that go into the purchase decision making: product quality, safety considerations, operational flexibility, and even highly subjective opinion.

6.2.1 Product Quality – Wood Poles

Wood poles have been used for carrying wire for communications since the late 1800s. With the advancement of electricity after Thomas Edison's development of the incandescent light in 1882, electricity generation advanced the need for lighting communities and powering industry across Canada (Canadian Electricity Association, 2000). To distribute power for residential, commercial and industrial uses, the wood pole has been the standard. In a recent Canadian Electricity Association survey, wood poles account for 99% of the total used in the industry (Canadian Electricity Association, 2000).

The wood pole offers the following advantages:

- It is available in the majority of sizes to meet the needs of utilities.
- It is traditionally cheaper than most alternatives.
- It offers flexibility of installation of apparatus and supporting equipment, such as transformers and crossarms.
- Its lifespan is well documented
- Deterioration and weakness in the pole is visible and generally easy to determine.
- Wood poles can be climbed by electrical personnel, making repairs or maintenance easier and possibly more efficient.
- Its behaviour around energized power lines is predictable and well understood.

The wood pole also has some disadvantages:

- The pole can burn in a flash-over fault from a pole-mounted transformer.
- The use of preservative chemicals is a matter of health and environmental concern to the general public.
- Its normal life expectancy is less than alternatives such as steel, and possibly fibreglass or concrete.
- There is increased public concern over the harvesting of prime (original) forest cover for wood poles.
- The wood pole is susceptible to damage from boring insects such as carpenter ants (*Hymenoptera formicidae*) and termites (*Termitidae*), and tree clinging birds such as woodpeckers (*Picidae*) and common flickers (*Colaptes auratus*) in search of these insects.
- Deterioration from moisture at the top and below ground-line.

6.2.1.1 Discussion

Standards for utility poles have been well established both within the provincial electrical codes and by the Canadian Standards Association. These standards attest to the lengthy and continued use of the product.

There are also various standards for testing and determining wood pole quality and life expectancy. Many of these standards have emerged from the treated wood industry as well as from the utilities. Most companies including ENMAX utilize third-party contractors specifically trained to test the quality of poles.

A key aspect of the inspection is the record keeping associated with it. Metal tags are installed on all poles to identify the date of inspection and a registration number. A field report corresponding to the registration number tracks baseline information about the pole as well as 17 different inspection areas such as pole top condition, body condition, and an evaluation of pole treatment condition. The process also allows for preventive maintenance action such as life enhancement treatments or recommendations for

removal/replacement of such items as crossarms or the entire structure (ENMAX, 2000b).

In the 1998 ice storm, which was classified as the worst ice episode in history (Environment Canada), Quebec Hydro lost more than 26,000 utility poles under the weight of as much as 90 mm of built up ice on lines, poles, and transformers. Some of the post ice storm recommendations include increasing the amount of buried distribution lines, and developing plans for more pre-emptive ice removal, possibly from the application of ice retardant (Quebec Hydro, 1998). Since the ice storm there has been no question of wood pole quality, but additional research has been undertaken by Quebec Hydro to study transmission tower design and alternatives such as concrete.

6.2.2 Pole Quality – Concrete

Concrete poles have been used longer and more extensively in Europe and in Japan than in North America. A number of American utilities are utilizing concrete in areas prone to high winds, such as hurricane zones. Most of these applications have been for transmission lines (lines over 230 kV). A number of utilities throughout North America have also moved to concrete distribution poles, at least for main trunk routes. In Canada urban areas such as Halifax, St. John's (Newfoundland), the City of Toronto and Mississauga have begun using concrete almost exclusively for street lighting and are moving towards using them for distribution poles (Day, 2000).

Concrete poles offer many advantages including:

- Long lifespan
- Engineered strength and consistency
- Consistent colour and aesthetic quality (claimed by the manufacturer)
- No safety issues with respect to handling (no protective equipment is required while working on or with the pole)
- There is no odour from concrete poles
- Can be stored anywhere

Some of the disadvantages include:

- Their overall weight is very high. In sizes over 45 feet additional equipment is required to move the pole into place.
- Longer poles are subject to damage due to their weight in moving and transporting (additional care is required to brace the entire length of the pole)
- Damage from corrosion by products such as road salt is hidden from view. Quality/longevity tests are not developed to the same extent as wood.
- Improper handling while transporting and putting in place may cause severe damage due to the excessive weight.

6.2.2.1 Discussion

In conducting this research attempts were made to determine if there was a monitoring/maintenance program in place for concrete poles. No information was available. Given that there was no information, a sample of these poles were examined and conditions were noted; with so little information about the poles it was difficult to conclude if they were spun concrete poles or formed concrete poles. The details of this examination are in Appendix D.

A survey of 48 concrete poles found in four different locations of the former borough of Scarborough in the City of Toronto indicated that poles manufactured in the mid 1980s (15 years old) are subject to surface breakdown and rust due to exposure to salt, and vandalism. In new poles, placement away from direct road contact has reduced the impact on concrete. Details are provided in Table 6.4.

Table 6.3 Qualitative survey of concrete poles in the field

Location	Date of Manufacture	Surveyed Distance	Comments
Kingston Rd. from Brimley Rd. to Markham Rd. East side of street. (Electrical distribution poles)	1971 and 1972	3.0 km	Sample size is 30% of the total distance with concrete poles. 79% had notable cracking, 33% had visible rust, 54% were missing an access plate, and 12% had visible maintenance (i.e., painting and filling)
Brimley Rd. from Ellesmere Rd. to Progress Ave. West side of street. (Electrical distribution poles).	1972	0.6 km	Sample size is 75% of the total distance with concrete poles. 36% had notable cracking, 18% had visible rust, and 18% had damaged access plates. None of the poles visible maintenance. One pole was replaced in 1996.
Brimley Rd. from Ellesmere Rd. to Omni Dr. East side of street. (Street light poles).	10% – 1984 90% – 1993 & 1994	0.2.5 km	Sample size is 20% of the street distance with concrete poles. 50% had notable cracking, 0 had visible rust, and 0 had damaged access plates.
Ellesmere Rd. from Brimley to Borough Dr. approach West. North Side of street. (Street light poles)	50% - 1972 25% - 1996 12% - 1994 12% - 1979	0.25 km	Sample size is 4% of the street distance with concrete poles. 75% had notable cracking, 25% had visible rust, and 12% had damaged access plates.

The follow observations were made about the poles surveyed:

- Proximity to the street influenced damage. The poles located on Kingston Rd. were within 0.25 metres of the roadway where winter snow combined with road salt generally are mounded at the base of the pole. All others ranged from 1.5 to 3 metres.
- Damaged or removed access plates affected cracking. 100% of those missing and access plate or having a damaged access plate showed cracking and some rusting.
- Most of the cracking occurred in the lower third of the pole.
- Poles with transformers tended to have more cracking (possibly due to the top weight combined with wind stress).

Casual observations of concrete poles located in Mississauga and Burlington, Ontario did not show any of the characteristics demonstrated by the poles surveyed. For the most part they were, however, newer and in most cases were located far from active roadways (in excess of 3 metres).

It should be noted that cracks, spawling and rust stains are not indicators of poor quality manufacturing but rather indicators of use. One of the recurring comments in discussion about concrete poles is that structural integrity is an unknown factor. Cement will break down, steel will rust and deteriorate. Will the pole fall down one day? This is not known but comparisons to deterioration of high corrosion sites such as parking lots and highways support some concerns about the long-term integrity of the product.

6.2.3 Electrical Safety

There is no literature attesting to the relative safety of wood versus concrete utility poles. Since many more alternatives to wood poles are being utilized, specific research will emerge in this area over time. Based on very informal interviews with ENMAX employees there were no specific concerns about the safety of concrete poles. It was noted, however, that with steel being used for pole reinforcement, if there was any inconsistency of the distance of the rebar to the surface there would be a potential for electrical shock. This aspect is enhanced as more utility work is performed around energized wires.

6.2.4 Operational Flexibility

In formal and informal discussions about the use of concrete poles at ENMAX Power, there was considerable discussion about the lack of flexibility associated with concrete poles. Of note was the inability to climb concrete poles and the fact that a bucket truck is required for all work around these poles. In some cases even a second truck may be required, increasing costs and associated

environmental emissions. The other operational concern raised was that additional planning and associated costs would be incurred to define poles that were to hold transformers and the variety of hardware that is used on a pole to make them functional. The wood pole is absolutely flexible since every pole is the same but can be fully adapted for crossarms and transformers (either single or three units). It is possible that some specialised drills and equipment may increase the flexibility of use of concrete poles, but for a utility that has not used these poles these are some of the concerns that have been noted.

The incorporation of concrete distribution poles into any electric utility's system would require additional investigation and the development of detailed operational standards and protocols. None of these costs were included in previous cost estimates, but it is speculated that they would be considerable, as would using any alternate to the standard wood pole.

6.3 Summary

The total costs involved with each of the alternatives have been presented in this chapter. They represent all of the direct and indirect costs. They have also included the external costs that society bears with respect to the life cycle costs.

This chapter has also covered a wide range of qualitative factors that play an important part in the decision making process. It is generally accepted that a decision is made on the basis of the best information available including costs, product longevity, warranty, and after-sales service; however, factors such as product quality, safety, operational flexibility, and even the decision maker's personal bias all contribute to the final selection. Simply understanding what contributes to the decision making process will assist future decision making.

In this study the various qualitative factors are illustrated for decisions that would need to be made when deciding which of the three options would be chosen; non-treated western red cedar poles, CCA-treated poles, or concrete poles. The chapter that follows will summarize all of the analysis that has been conducted, and will make conclusions and recommendations.

7.0 EVALUATION

This chapter will summarize and evaluate all the information that has been collected and analyzed as part of this study. This chapter is set up under two main topic areas, identification of significant environmental issues, and cost considerations

7.1 Identification of Significant Environmental Issues

The identification of significant environmental issues is based on an assessment of comparative environmental impacts and quantitative impacts. Additional qualitative considerations are presented as part of the overall evaluation.

7.1.1 Comparative Environmental Impacts

To appreciate the environmental impacts of each of the options presented, the key indicators must reflect the options' expected lifespan. Data for environmental stressors, calculated on an annualized basis, is presented graphically in Figures 7.1 to 7.6 for each of the three options (non-treated western red cedar, copper chromated arsenate (CCA) treated western red cedar, and spun concrete utility poles). Each figure also includes the option for enhanced CCA treated wood.

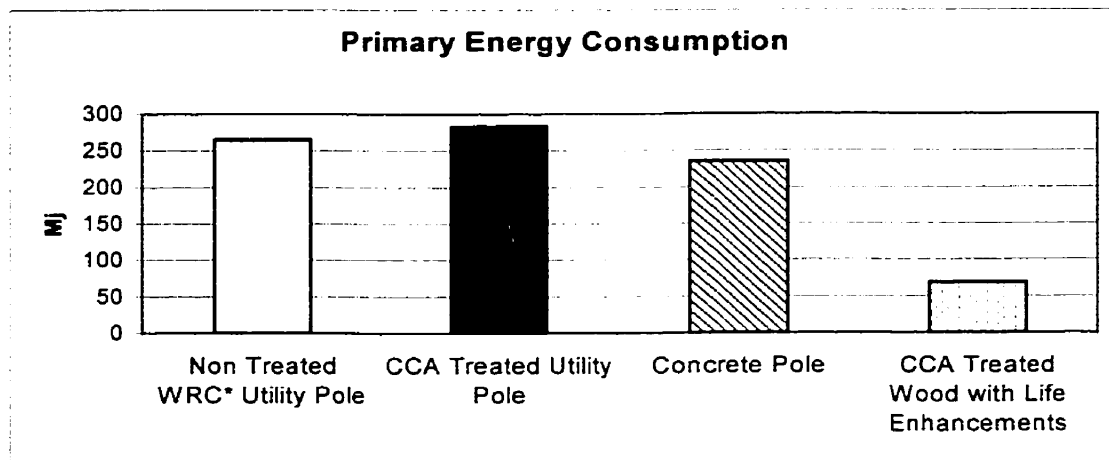
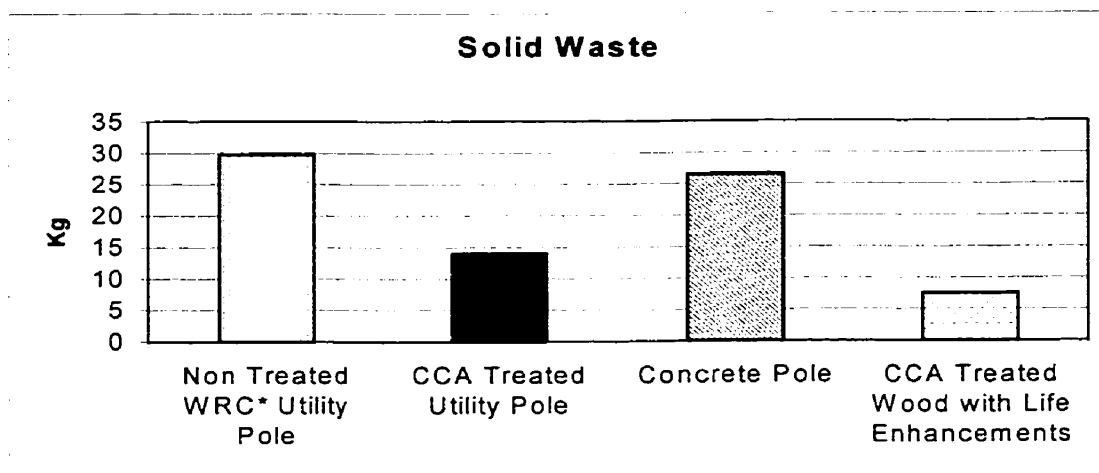
Figure 7.1 Life cycle primary energy consumption (annualized)**Figure 7.2 Life cycle solid waste (annualized)**

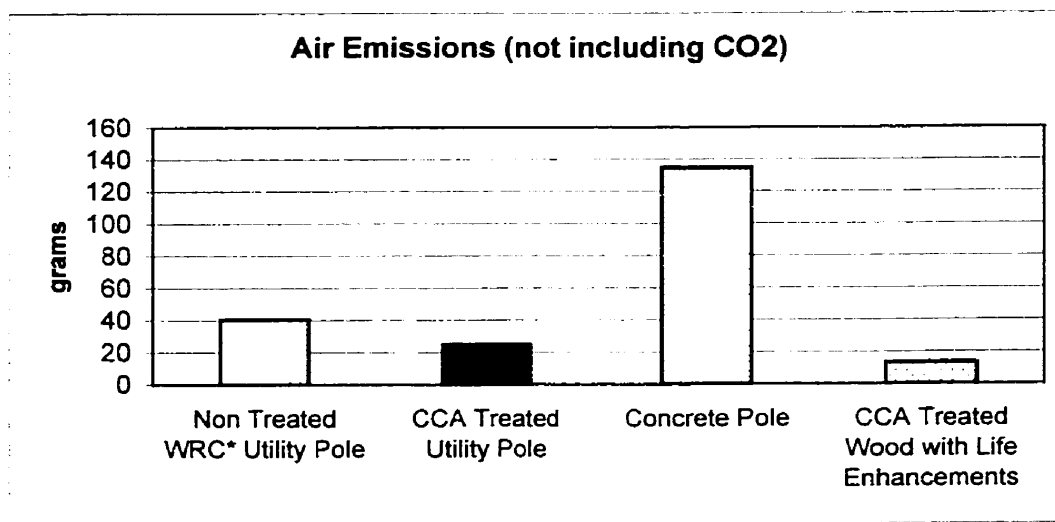
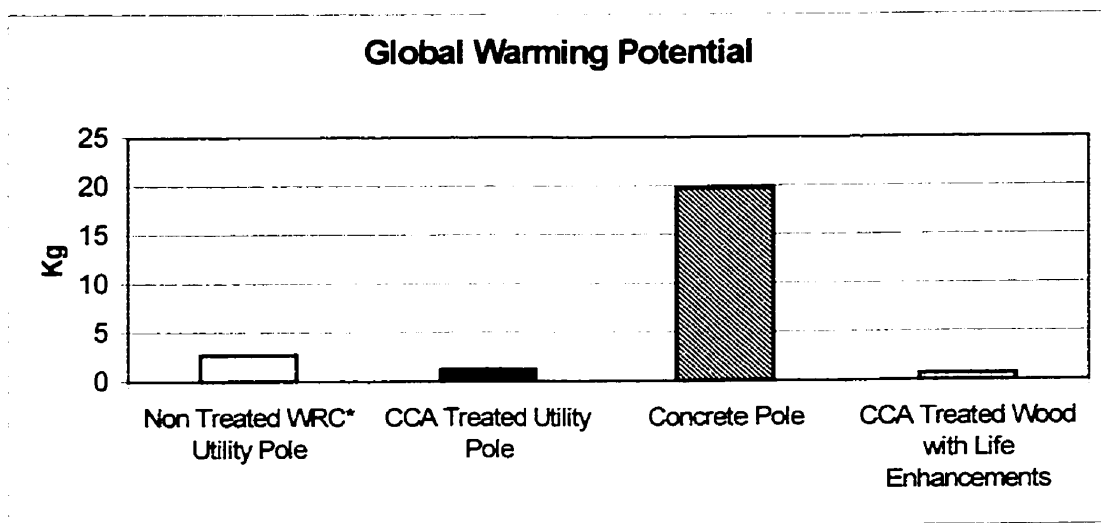
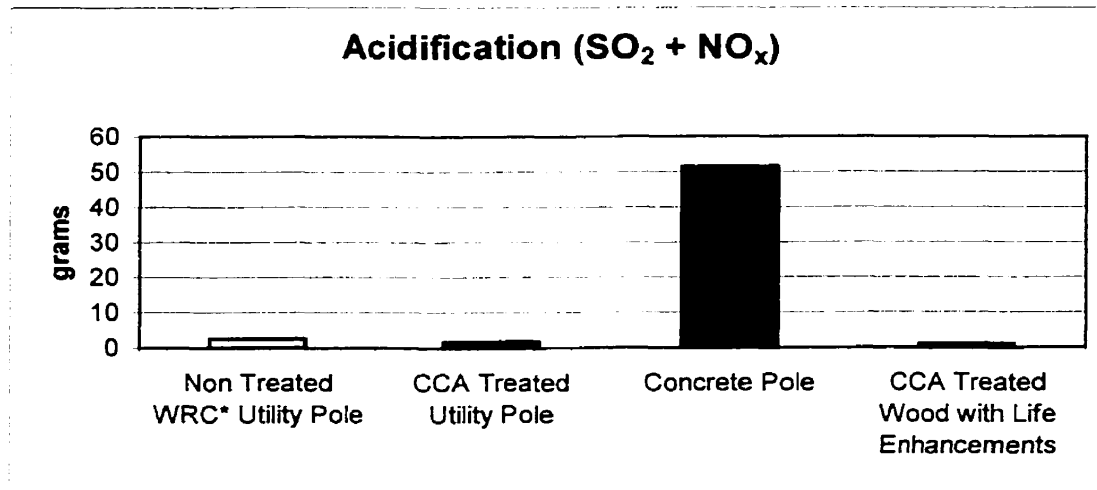
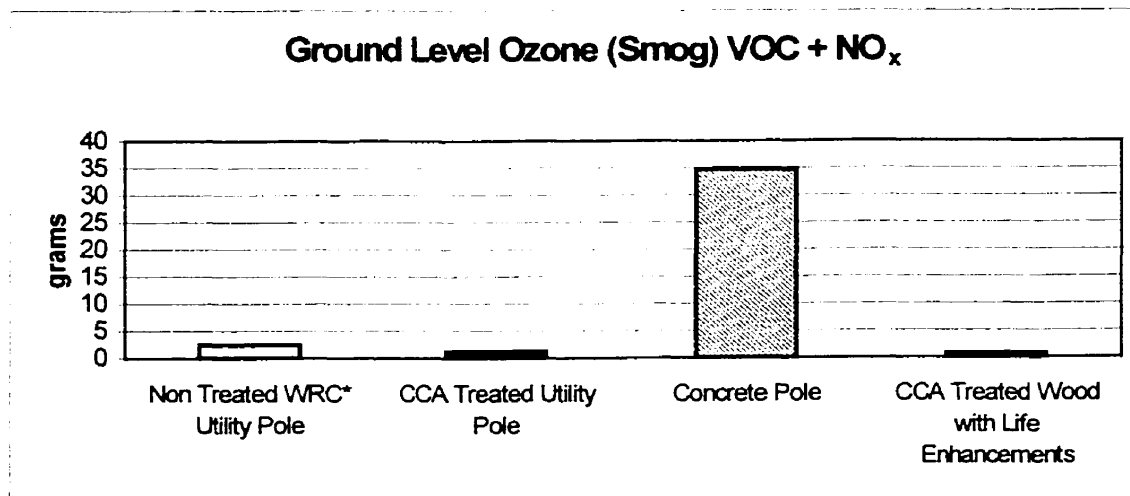
Figure 7.3 Life cycle air emissions not including carbon dioxide (CO₂) (annualized)**Figure 7.4 Life cycle global warming potential (annualized)**

Figure 7.5 Life cycle acid rain formation precursors (annualized)**Figure 7.6 Life cycle smog formation precursors (annualized)**

Based on the available data and the primary environmental indicators developed in this life cycle assessment for the three utility pole options and the optional life-enhanced process to CCA treated wood, the following observations can be made:

- Primary energy consumption for all three options (non-treated western red cedar, CCA treated western red cedar, and concrete utility poles) is almost the same. Of the three options, concrete poles have the lowest consumption. If the concrete pole manufacturer were located in Calgary or within Alberta the energy consumption would be reduced marginally. It was also found that if rail transportation were utilized to transport poles, energy consumption would be reduced by 45% for concrete poles. The wood pole treater transporting poles from the mills to their facility could achieve similar levels if they used rail exclusively.
- Solid waste production throughout the life cycle was highest for the non-treated utility pole and the concrete pole. This determination accounts only for the useful life within the utility. The CCA treated cedar pole was found to have the lowest solid waste production through its life cycle. It should be noted that most utilities are attempting to offer extended use of all poles once they reach the end of their useful life for the utility. Recycling of concrete poles has not been fully developed but appears possible. Some American are utilizing used concrete poles for artificial reefs for shoreline protection. More research is required to develop waste disposal options in Alberta and elsewhere in Canada.
- Total air emissions not including carbon dioxide (CO₂) was 5 times higher for concrete utility poles than for CCA treated cedar poles. This is due to the high level of emissions that are created in the manufacture of steel reinforcing rods and concrete, which consumes large quantities of energy. It should be noted that cement production facilities are utilizing new technology to recover heat and co-generate

electricity, making the process much more efficient and emission levels lower per unit of production. Non treated utility poles had higher emission levels than treated wood; this is reflective of the short life span of non-treated wood.

- The global warming potential is an indicator of the total greenhouse gases that are produced, factored to the representative global warming potential for each gas. For this study this indicator includes carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (NO_x). Based on the life cycle the concrete pole has the highest global warming potential: 17 times higher than the CCA treated wood pole. The non-treated wood pole had a slightly higher global warming potential than the CCA treated pole. This reflects the short lifespan of the non-treated pole. Most of these emissions are related to transportation.
- Acidification, or the release of gases that form acid rain when combined with water, is one of the life cycle indicators. Based on this study the wood options generate minimal impacts. The concrete pole, in contrast, had a level 20 times higher than non-treated cedar poles and over 30 times higher than CCA treated cedar poles. High temperature combustion that occurs during the production of concrete and steel contributes to the formation of these gases. It should be noted that acid rain is a regional air pollutant.
- The concrete pole option was 13 times higher than the non-treated pole option and over 26 times higher than the CCA treated wood option. A similar life cycle indicator is the gases that combine to form ground level ozone, or smog. These gases affect the elderly and anyone suffering from respiratory diseases such as asthma. It contributes to lung disease, makes eyes red and watery, and decreases visibility. This study found that the wood options were all very low.

- The life cycle emissions related to CCA treated wood with life enhancement (copper naphthinate and boron) dramatically reduces all of the indicator areas to the lowest of all the options presented. Primary energy drops by 75% over the highest option (CCA treated wood). In all other categories the life-enhanced treatment reduces the annualized indicators to the lowest level of all options.

7.1.2 Qualitative Impacts

7.1.2.1 Leaching of CCA Chemicals - Chromium, Copper, Arsenic

The data indicates that the life-enhanced CCA cedar utility pole has the lowest quantified impact on the environment. CCA treated wood does leach into soil in varying levels, some of which are well below national environmental standards. Other sites exceed both national and Alberta Tier 1 remediation criteria. There is still enough uncertainty in this area, both for experts and for the public, for this to remain a significant concern. Dr. Paul Cooper's research is significant; however, it has largely focused on central and eastern North American wood species such as jack pine, red pine and yellow pine. This research is also conducted largely in central Canada where the ambient humidity and precipitation levels tend to be higher, which should make for worst case conditions.

It is very clear from research of Dr. Paul Cooper and Dr. Kenneth Brooks that the quality of fixation associated with the CCA treatment has a direct correlation the quantity of leaching. Ensuring that utility pole treaters properly fixate poles, or provide test results to confirm complete fixation, must be a part of the consumer's quality assurance.

There was no data found on the effects of copper naphthenate and boron used in the life enhancement process. Genics Inc. is currently undertaking some life expectancy tests and may be testing for leaching as well; this was not uncovered during this research. Based on the system developed by Genics Inc.,

if properly applied there should be minimal leaching of these products to the surrounding soils. Any leaching that may occur would be located at the base of the installation with minimal lateral dispersion.

7.1.2.2 Resource Use

In one interview undertaken for this research the concept of sustainable utility poles was described. It was suggested that with CCA treated wood and the application of life enhancement measures, it might be possible that a wood pole could last up to 100 years or more. If a western red cedar pole takes between 100 and 140 years to grow to a 40-foot pole size, the pole would be almost fully sustainable.

Even if this concept is in reality not fully attainable, the renewable nature of forests and wood is a distinct advantage. This consideration, however, must be tempered in relation to how the wood has been harvested. The development of a sustainable forest practices standard through the International Organization for Standardization (ISO), as well as sustainable forestry initiatives that are being developed by various provincial governments and forestry associations will minimise the negative and cumulative effects of forestry. It is in the best interests of the forest industry and provincial governments to ensure forest stocks remain sustainable and to fully address the environmental impacts of removal and restocking to maintain credibility in international markets.

In contrast, the raw materials for spun concrete poles include limestone, shale, sand, and iron, which are mined stock resources; although generally plentiful, they are not renewable. The manufacturing processes for concrete and steel for reinforcement rod consume large quantities of water and energy resources. The extraction and movement of raw materials requires the use of heavy equipment that requires large amounts of energy to produce and run. The quantity of raw materials extracted relative to finished products is very high. It should, however, be noted that steel production is now incorporating more recycled steel into the process, which is significant from a waste management

perspective. The quantity of recycled to new steel in the manufacture of steel rebar could not be determined.

7.1.2.3 Habitat Alteration

There is no question that both wood poles and spun concrete poles will modify the landscape during the raw material collection stage. In both cases tracts of land are altered from their natural processes and the raw materials are taken from the land. In the case of concrete the spatial area of disturbance may be relatively small in comparison to active forestry operations, but for a longer period of time and causing more extensive damage. In contrast forestry may represent harvesting of virgin forests or harvesting of a plantation forest (one that was originally virgin, but has grown up based on re-forestation techniques) instead.

The removal of trees from the forest does have an impact on wildlife at all levels; however, this impact is generally over a shorter duration. In both cases, the impact is not aesthetically pleasing. The visual damage creates complimentary nuisance impacts such as noise and odour. In forestry opening up areas for harvesting, despite the issues of habitat alteration, creates complimentary benefits, in particular that of accessible land for human recreation. In some cases it can enhance opportunities for camping, wildlife viewing, and hunting, to name a few. Mined areas that supply raw materials for cement and steel production tend to restrict access to these sites, as they are essentially dangerous places for public recreation.

Both activities do affect ecosystems. When vegetation is disturbed for access roads and tree removal, erosion occurs. The build up of particulate matter in streams and rivers will affect fish habitat, which decreases the food supply for animals higher in the food chain such as bear and raptors. However, in the forest renewal stage these habitats have a tendency to recover, in a similar way as a natural fire renews the ecosystem. It is acknowledged that the level of nutrient regeneration that occurs in a fire is vastly more extensive and efficient than the regeneration that occurs during forest renewal after harvesting. Open

pit mining, in contrast, is not reclaimed until and only if extensive reclamation is required. Open pit or mountain-side operations are seldom reclaimed to a stage close to the original state. Depending on the nature of the activity, reclamation may take place for 40 to 100 years and often physical alteration to the landscape is permanent.

7.2 Cost Considerations

To consider the best of the options from a cost perspective it was important to consider the longevity of each of the pole options and then determine when costs will occur. A 100-year time horizon was used as a benchmark date because it covered the full cycle of replacement of all options, including life-enhanced CCA treated western red cedar.

In the financial analysis the life cycle environmental impacts were quantified and values were attached to the impacts and added to the total costs. Despite the fact that the leaching of chromium, copper and arsenic is an area of considerable uncertainty, costs to clean up storage facilities and actual pole locations were determined and added to the overall costs on a per pole basis. The costs that were derived are considered to be an environmental total cost assessment.

Based on the total costs over the life cycle for each option and accounting for the time value of money (net present value), the total cost of the options from best to worst are given in Table 7.1.

Table 7.1 Total life cycle cost – utility pole options from best to worst

Options	Total Life Cycle Cost
CCA Treated Western Red Cedar Utility Pole with life enhancement	\$1,265
CCA Treated Western Red Cedar Utility Pole	\$1,366
Non-Treated Western Red Cedar Utility Pole	\$1,638
Pre Stressed Concrete Utility Pole	\$3,039

Based upon the financial analysis and the total cost assessment over the 100-year timeframe, the lowest cost option was the CCA treated western red cedar pole with life enhancement measures. The other wood pole options were marginally higher. The concrete pole option was over 2.5 times higher.

In addition to the total life cycle costs, there are many other considerations that contribute to the decision-making process. Each of these may affect the final decision to the point of selecting the most expensive option or the option that has the highest environmental impact. Those considerations include:

a) *Quality*

Each of the utility poles examined in this study has distinct advantages and disadvantages. Wood poles can burn in a flash-over fault, where a concrete pole will not. A wood pole shows its deterioration but the concrete pole may not demonstrate deterioration in an obvious way. In severe weather situations such as a severe ice storm it is possible a concrete distribution pole is a better option. The wholesale replacement of over 26,000 wood utility poles at one time (1998 ice storm – Quebec Hydro) is a considerable expense and possibly the weather risk needs to be incorporated into the financial analysis if it is significant.

It should be noted that use of concrete streetlight poles is growing across Canada. Their use in distribution systems may be hindered and the quality of the pole questioned due to the effect that electrical hardware (wires and transformers) may have on the structural integrity of the pole over its life. There

are concerns that a concrete pole does not show its age, and possibly one day may simply fall down. There were no studies that assessed concrete pole quality over time, with significant top weight and against the effects of salt.

b) Utility worker safety

In terms of electrical safety, there was no direct reference that indicated that stressed concrete utility poles are a concern to safety. Informal comments from utility workers raised concerns over working on energized lines from concrete poles. If the reinforced steel is not installed at a uniform depth there is the potential of shock or electrocution. It is believed that these poles are now engineered to such a standard that this will not be an issue. However, it does raise concerns for older concrete poles already in place.

c) Operational flexibility

The wood pole offers utilities the maximum amount of flexibility of all utility pole options including steel, fibreglass and concrete. In an emergency if a shorter pole is required, a longer one can be quickly and efficiently cut to size. Wood poles can be ordered by size and the various pieces of hardware can be added without additional pre-planning and special order requirements. The various configurations for concrete poles would require additional attention to storage and handling. This is not to conclude that this not acceptable, but rather to note that for a utility that is set up to handle wood, moving to any other alternative would require additional training, from pole setting to the configuration of electrical systems for these alternative poles.

d) Intangibles

A media-driven public that polarizes the various issues of utility poles could enter into the decision-making process very abruptly. The most preferred option for the public is to receive power to their household without above-ground wires. Buried lines are now the standard in most new communities where it is feasible and where the utilities can be installed in the lot servicing process. However, in the majority of older communities and in some locations, the underlying geology will not allow for burial of power lines. Power quality is less

reliable and ease of service is more costly with underground service. So then the type of pole that is used can be the issue.

How a utility reacts to these situations, the policies it has, the type of research it is prepared to conduct, and the public consultation it is prepared to undertake all contribute to possible intangible costs and effects to a utility.

Should a utility be fined or issued an environmental order by a provincial environmental regulator due to contamination of soil or ground water from utility poles, the costs and effects from such an action will be very expensive. The unplanned remediation projects and prolonged groundwater monitoring that could occur can be accounted for, but the intangible costs related to negative public perception from negative media that could affect sales and profits in a competitive market place often are not.

8.0 CONCLUSIONS

The purpose of this thesis is to address the following objectives:

1. Based on the four utility pole options studied in this thesis – non-treated western red cedar, CCA treated western red cedar, life-enhanced CCA treated western red cedar, and stressed concrete — which is the most viable for future consideration from an environmental, total cost, and quality perspective?

Based on this study, life-enhanced CCA treated western red cedar offers the lowest life cycle environmental impact, the lowest life cycle total costs, and the highest quality considerations. It should be noted that operational requirements, such as installation near environmentally sensitive areas or in locations subject to extremes of weather, might influence a utility to choose a different option. In fact, given site-specific requirements, a utility may wish to utilize the full range of utility pole options. A life cycle assessment can point to the right option in a general sense, but specific conditions and situations needs to be incorporated into the decision-making process.

2. Through the process of this assessment, provide comments on the experience of conducting a life cycle assessment so that future assessments in this area can benefit from it.

Initially this study was undertaken with the intent to seek as much of the source data as possible, and use manual data collection and simple computer tools such as electronic spreadsheets. Given the limited time and resources a number of observations can be made:

- a) Given the complexity of the life cycle assessment process and the desire to incorporate cost, quality and other decision-making factors into the analysis, we can conclude that a comprehensive analysis does take considerable time and resources to complete. Certainly, the learning

curve of the process will reduce the time factor and experience will assist in productivity in gathering the right information. However, for individuals not specializing in the LCA area, the investment in time and difficulty collecting data would result in marginal use of the tool, if any use at all.

- b) Source companies do not always keep data that is compatible with the needs of the life cycle assessment analysis. Some companies can provide cost data but not power consumption, for example. Communications of data requirements and the format of data to sources outside of a company must be made early in the process.
- c) The time required for data collection can be extensive despite the best intentions of companies that are willing to participate. Contacting multiple companies will broaden the database and ensure that the likelihood of gaps in the data will be minimal. Researchers that need to contact companies to collect life cycle data need to make their requests at the earliest stages of the research. It will take time and will not be a priority for companies that are not directly involved.
- d) If life cycle assessment is to be useful for both internal decision making and as a widespread tool of pollution prevention and sustainability, a database of environmental impact (raw materials database), and simple cost valuations for environmental impacts must be centrally established. This database could be sponsored or supported by government or by a non-profit organization in conjunction with users. The web-based life cycle model that the United States EPA is in the process of developing would serve as an excellent example for Canada.
- e) U.S. data is reliable, and European data provides a good basis for comparison; however, Canada is unique because of geography, population, and a highly variable social and physical infrastructure. The best data source for Canadian life cycle assessments is Canadian.

- f) Any life cycle assessment that is communicated publicly will require a third-party validation or some form of critical peer review, otherwise public or industry will suspect the data's credibility. Conducting a sensitivity analysis as part of the overall lifecycle assessment would build additional credibility to the overall process.
- g) It is conceivable that based on a negative conclusion from a life cycle assessment, manufacturers or suppliers of that product could threaten legal action if the results are made public. This is a possible threat to research and the development of LCA as a widespread tool.
- h) Although the use of a spreadsheet program is effective for LCA analysis, the development of methodologies and adaptive programs would save considerable amounts of time. Although there are some very sophisticated programs available, these are very expensive and fairly complex for part time users.
- i) Data for life cycle assessment is highly dependent on time, geography, and regional infrastructure set-up. Analysis of an Alberta process, which may include electricity, would be very different than a process that uses electricity in Manitoba. Alberta has a high level of coal-based power generation where as Manitoba's is largely hydroelectric. Variables such as these can affect life cycle outcomes.

8.1 Recommendations

The recommendations reported here are divided into three categories: general recommendations, recommendations for electrical utilities, recommendations for life cycle studies.

8.1.1 General Recommendations

- Given that this analysis has based its findings on a variety of assumptions related to timeframes, a further enhancement to this study would be to conduct a sensitivity analysis on the various timeframes for financial planning and life expectancies related to the various utility pole options.
- There is a need for identification of other disposal, recycling and possible life enhancement technologies for all utility pole options to minimize disposal to landfills. One interim opportunity that may exist would be to return the used poles to treated wood companies, who would peel the treated portion of the pole thereby reducing the volume of waste substantially. The remaining wood could be used for other uses.
- Research is required to determine the levels of impact related to the copper naphthenate and boron life enhancement process.
- Research into the long-term environmental effects of concrete utility poles in various soil types is needed.
- To determine the social concerns around treated wood, treated wood manufacturers and utility associations should consider doing public opinion research to determine what the public issues are around utility poles. This information would assist in directing research that would formulate company policies.
- More research is required in determining the energy inputs resources consumed, and environmental impacts associated with the gathering and formation of the CCA raw materials.

8.1.2 Recommendations for Electrical Utilities

- Given the unique nature of soil, weather conditions, and wood species used throughout Canada, a standard testing protocol and statistically valid testing of potential CCA impacted soil should be conducted by utilities. The results of individual utility testing could be consolidated by the industry association to determine the level of CCA leaching on a national basis given the wide variety of variables.
- Management plans, including pollution prevention measures for wood storage yards and after-utility use, should be established. This would include tracking of poles both going into, and also coming out of service.
- Leach testing of copper naphthenate and boron systems should be undertaken to determine if there is any significant environmental impact.
- Engineering research is required to test the effects of age and salt on concrete utility poles, in particular concrete poles containing various configurations of transformers, to determine the amount of ground-line stress.
- Utilities that currently use concrete poles may already have inspection standards for concrete poles. If they do not, one should be developed and shared among utilities through industry associations.
- Research on the safety aspects of concrete utility poles is required.
- In amassing this and other life cycle and environmental data, it will be important for utilities to develop policies and communication tools directed at the public. Grounding of corporate policies in science rather than speculation or not having a policy will establish a position of strength.

8.1.3 Recommendations for Life Cycle Assessment Studies

- The development of any life cycle tool (computer software, etc.) for treated wood and alternatives may be best served as a generic life cycle tool that could be used for environmental management and pollution prevention. Specialized modules for treated wood and alternatives, as well as waste management options or any number of other topic areas, would probably be more useful for industry and government than a life cycle assessment tool developed in isolation.
- Practitioners in life cycle assessment including non-profit organizations need to co-operate with government to develop and participate in life cycle data sharing. Given the time required to gather this data, the issue of proprietary information and initial investment needs to be addressed. This may be accomplished through royalties being returned to the source from users paying fees to access the data.
- A generally accessible computer-based life cycle assessment tool needs to be available for generalist environmental managers. Medium and small firms could benefit from a life cycle assessment tool, but currently would be discouraged by the amount of resources and the general lack of information available to conduct an assessment.
- To ensure companies utilize and see the benefits of a life cycle assessment, it is important to include and as much as possible adopt total cost assessment and the other factors of decision making such as longevity and quality into the assessment. More research is required to quantify these factors into either a numeric or cost association value. Doing these would further enhance the analysis.
- Risk areas such as weather (e.g., ice storm and flooding) need to be incorporated into the financial analysis as an impact and probability assessment.

- Determination is required in the life cycle methodology for products that are used by a company and sold or otherwise given away that benefit another company. The fact that the product is not going to landfill is a benefit to the company, but it has still not addressed the total end of life scenario of the product.
- There is a need to develop either a qualitative or quantitative evaluation for products that are renewable.

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Appendix A: Impact Assessment – Detailed Calculations and Assumptions

Table A.1 Resource use and emissions – forest harvest and milling – Athena database

Assumptions: The manufacturing component of this data was not included since the process milling that Athena follows is for dimensional lumber. Preparation of utility poles consumes fewer resources and fewer by-products.

	<i>Extraction</i>	<i>Manufacturing</i>	<i>Transport</i>	<i>Total</i>
Primary Energy Consumption (includes fuels used to produce electricity) Mj)	29.3	84.0	1.5	114.9
Solid Waste (kg)		5.8	-	5.8
Air Toxicity Index	0.4	0.5	-	0.9
Water Toxicity Index	-	-	-	-
Global Warming Potential (kg)	6.0	12.2	0.0	18.2
Weighted Resource Use (kg)	28.5	-	-	28.5
Data Based upon Vancouver B.C. - 0.75 Cu. Meters = Class 3/ 40 foot pole.(0.03125 mbf)				
A. Resource Use				
Wood Fiber (kg)	28.5			28.5
Total Excluding Water	28.5			28.5
B. Solid Waste				
Bark/ Wood Waste (kg)	5.8			5.8
Other Solid Waste (kg)	0.0			0.0
Total	5.8			5.8
C. Water Emissions				
BOD (mg)		16.6		16.6
Suspended Solids (mg)		305.0		305.0
Dissolved Solids (mg)		16,938.0		16,938.0
Chemical Oxygen Demand		236.8		236.8
Cyanide		0.0		0.0
Phenols (micro gr.)		0.0		0.0
Phosphates (mg)		0.1		0.1

	<i>Extraction</i>	<i>Manufacturing</i>	<i>Transport</i>	<i>Total</i>
Ammonia & Ammonium (mg)		0.3		0.3
Chlorides (mg)		76,798.2		76,798.2
Oil & Grease (mg)		296.8		296.8
Sulfates (mg)		60,353.2		60,353.2
Iron (mg)		0.4		0.4
Other Metals		1.8		1.8
Acids		0.0		0.0
Total (mg)		154,947.2		154,947.2
D. Air Emissions				
Carbon Dioxide (kg)	2.4	9.6	0.0	12.0
Carbon Monoxide (g)	20.5	3.3	0.0	23.9
Sulphur Oxides (g)	5.9	13.8	0.0	19.8
Nitrogen Oxides (g)	23.1	15.3	0.0	38.5
Particulates (g)	0.0	8.4	-	8.4
VOC (g)	4.5	4.9	0.0	9.4
Methane (g)	1.9	4.9	0.0	6.8
Phenols (g)	0.0	0.0	-	0.1
Metals (g)	0.0	0.0	-	0.0
Hydrogen Chloride (g)	0.0	0.0	-	0.0
Hydrogen Fluoride (g)	0.0	0.0	-	0.0
Total Excluding (CO2) (g)	56.1	50.7	0.1	106.8
E. Energy Consumption				
Electricity (kWh)	0.6	2.3	-	2.9
Natural Gas (MJ)	0.8	35.0	-	35.8
Coal	-	-	-	-
Diesel	26.3	4.9	1.5	32.7
Gasoline (MJ)	2.2	3.3	-	5.5
Biofuel (MJ)	-	41.8	-	41.8
Total Primary Fuel (MJ)	29.3	84.9	1.5	115.8

Table A.2 Resource use and emissions – concrete manufacturing – Athena database

Assumptions: Since the concrete utility poles considered in this study are manufactured in Burlington, Ontario, the Athena database construction site chosen is based on Toronto, Ontario (65 km west of Burlington).

	<i>Extraction</i>	<i>Manufacturing</i>	<i>Transport</i>	<i>Total</i>
Primary Energy Consumption (includes fuels used to produced electricity) Mj)	119.95	1,423.30		1,543.25
Solid Waste		51.83		51.83
Air Toxicity Index	3.02	15.04		18.06
Water Toxicity Index		0.80		0.80
Global Warming Potential (kg)	52.30	604.23		656.53
Weighted Resource Use (kg)	2,671.65			2,671.65
Data Based upon Toronto Ont. - .75 Cu. Meters				
A. Resource Use				
Limestone (kg)	491.65			491.65
Clay & Shale (kg)	54.16			54.16
Iron Ore (kg)	23.98			23.98
Sand (kg)	17.98			17.98
Ash (kg)	3.44			3.44
Gypsum (kg)	29.08			29.08
Semi-cementitious material (kg)	24.18			24.18
Coarse Aggregate (kg)	1,016.76			1,016.76
Fine Aggregate (kg)	726.84			726.84
Water	169.24			169.24
Coal (kg)	6.60			6.60
Other (kg)	1.22			1.22
Total Excluding Water	2,395.89			2,395.89
B. Solid Waste				
Concrete Solid Waste	40.70			40.70
Other Solid Waste (kg)	11.13			11.13
Total	51.83			51.83
C. Water Emissions				
BOD (mg)		14.00		14.00
Suspended Solids (mg)		149,962.53		149,962.53
Dissolved Solids (mg)		5,097.07		5,097.07
Chemical Oxygen Demand		341,000.60		341,000.60
Cyanide		0.01		0.01
Phenols (micro gr)		7,982.01		7,982.01
Phosphates (mg)		299.73		299.73
Ammonia & Ammonium (mg)		690.62		690.62
Chlorides (mg)		671,296.80		671,296.80
Aluminum & Alumna (mg)		509.31		509.31
Oil & Grease (mg)		2,848.97		2,848.97
Sulphates (mg)		199,143.33		199,143.33
Sulphides (mg)		20.31		20.31
Iron (mg)		3,140.80		3,140.80

	<i>Extraction</i>	<i>Manufacturing</i>	<i>Transport</i>	<i>Total</i>
Other Metals		1,057.11		1,057.11
Acids		601.24		601.24
Nitrates & Nitrates (mg)		1,794.15		1,794.15
Dissolved Organic Compounds (mg)		3,509.46		3,509.46
Phosphorus (mg)		3.86		3.86
Total (mg)		1,388,971.91		1,388,971.91
D. Air Emissions				
Carbon Dioxide (kg)	23.29	460.93		484.22
Carbon Monoxide (g)	80.07	107.33		187.40
Sulphur Oxides (g)	84.88	451.15		536.03
Nitrogen Oxides (g)	180.97	862.34		1,043.31
Particulates (g)	174.00	518.70		692.70
VOC (g)	18.23	34.12		52.35
Methane (g)	29.76	221.49		251.25
Phenols	0.01	0.01		0.02
Metals	0.04	0.23		0.27
Hydrogen Chloride (g)	0.85	4.78		5.63
Hydrogen Fluoride (g)	0.15	0.82		0.97
Total Excluding (CO2) (g)	568.96	2,200.97		2,769.93
E. Energy Consumption				
Electricity (kWh)	8.83	49.86		58.69
Natural Gas (MJ)		195.77		195.77
Coal	23.81	910.61		934.42
Diesel	96.14	245.65		341.79
Gasoline (MJ)				
Feed Stock (MJ)	-	1,423.30		1,423.30
Total Primary Fuel (MJ)	119.95	2,775.33		2,895.28

Table A.3 Resource use and emissions – rebar manufacturing – Athena database

Assumptions: Since the concrete utility poles considered in this study are manufactured in Burlington, Ontario, the Athena database construction site chosen is based on Toronto, Ontario (65 km west of Burlington).

	<i>Extraction</i>	<i>Manufacturing</i>	<i>Transport</i>	<i>Total</i>
Primary Energy Consumption (includes fuels used to produced electricity - Mj)	29.9	1,055.8		1,085.7
Solid Waste		34.5		34.5
Air Toxicity Index	0.7	28.0		28.7
Water Toxicity Index		0.2		0.2
Global Warming Potential (kg)	7.8	255.1		262.8
Weighted Resource Use (kg)	34.0			34.0
Data Based upon Toronto, Ont.				
A. Resource Use				
Limestone (kg)	1.7			1.7
Clay & Shale				
Iron Ore	11.5			11.5
Sand				
Ash				
Other				
Gypsum				
Semi Celmentitous Material				
Coarse Aggregate				
Fine Aggregate				
Water	1,301.9			1,301.9
Scrap Steel				
Coal	5.6			5.6
Total Excluding Water	18.8			18.8
B. Solid Waste				
Blast Furnace Slag (kg)		10.9		10.9
Blast Furnace Dust (kg)		2.8		2.8
Other Solid Waste (kg)		20.9		20.9
Total		34.5		34.5
C. Water Emissions				
BOD (mg)		26.2		26.2
Suspended Solids (mg)		81,808.4		81,808.4

	<i>Extraction</i>	<i>Manufacturing</i>	<i>Transport</i>	<i>Total</i>
Dissolved Solids (mg)		9,550.7		9,550.7
Polycyclic Aromatic Hydrocarbons (micro gr)				
Chemical Oxygen Demand		169.3		169.3
Cyanide		13.0		13.0
Phenols (micro gr)		1,874.7		1,874.7
Phosphates (mg)		561.6		561.6
Ammonia & Ammonium (mg)		146.2		146.2
Chlorides (mg)		756.7		756.7
Oil & Grease (mg)		1,895.5		1,895.5
Sulphates (mg)		420.4		420.4
Iron (mg)		6,809.4		6,809.4
Other Metals (mg)		1,980.8		1,980.8
Acids (mg)		1,126.6		1,126.6
Total (mg)		107,139.5		107,139.5
D. Air Emissions				
Carbon Dioxide (kg)	4.7	158.7		163.4
Carbon Monoxide (g)	4.8	701.4		706.2
Sulphur Oxides (g)	20.5	841.2		861.8
Nitrogen Oxides (g)	18.0	514.5		532.4
Particulates (g)	3.1	285.9		289.1
VOC (g)	2.9	76.7		79.6
Methane (g)	6.5	304.8		311.3
Phenols (g)	0.0	0.0		0.0
Metals (g)	0.0	0.4		0.4
Hydrogen Chloride (g)	0.2	9.0		9.1
Hydrogen Fluoride (g)	0.0	1.5		1.6
Total Excluding (CO2) (g)	56.0	2,735.4		2,791.4
E. Energy Consumption				
Electricity (kWh)	1.9	93.4		95.3
Natural Gas (MJ)	6.3	475.7		482.0
Coal (MJ)	5.0	522.5		527.5
Diesel (MJ)	18.5	57.6		76.1
Gasoline (MJ)	0.1	0.0		0.1
Total Primary Fuel (MJ)	29.9	1,055.8		1,085.7

Energy and Fuel Consumption Assumptions

Tractor Trailer Unit = 6.5 miles/gal (U.S. based equipment)

Tractor Trailer Unit = 0.417 Litres/km (Canadian based equipment)⁶

Wood Pole

Distance⁷: Lumby, B.C. to Calgary, Alberta = 576 Km

Revelstoke, B.C. to Calgary, Alberta = 410 Km

Estimated # of Pole/Rail Car⁸ = 75 pieces; Truck⁹ = 45 pieces /43,000 pounds

Rail Fuel Consumption¹⁰ – per car = 3.765 km/Litre

Electricity ¹¹ = Estimated 420 kWh (Bell Pole, Carseland, Alberta)

Natural Gas¹² = Estimated @ 0.13125 GJ per Pole (Bell Pole, Carseland, Alberta)

Concrete ¹³

Transportation:

Montreal, P.Q. to Burlington, Ontario estimated 25% supply.

603 km = 251.5 litres X 25% = 62.9 Litres

Woodstock, Ontario to Burlington, Ontario estimated 75% supply

89 km = 37.1 Litres X 75% = 27.8 Litres

Total Weighted Consumption = 90.7

Assume 18,142 kg Load of Cement

Cement Portion of a single pole = 1,383 kg

=0.076 X 90.7 = 6.9 Litres

⁶ Environment Canada, 1999b. Pollution Data Branch Gas Division, Appendix B2, Canada's Greenhouse Gas Inventory. P. 90

⁷ Davenport Maps Ltd. 1997. British Columbia Road Map and Parks Guide, scale 1:1,463,600

⁸ Visual Estimate – Site Visit – Bell Pole Company, Carseland. Alberta, November 21, 2000

⁹ Sluggett, Gord; Woodlands Manager, Bell Pole Company, Salmon Arm, B.C.; Personal Communication, Oct. 27, 2000

¹⁰ U.S. Department of Transportation, Fuel Consumption and Travel by Class 1 Rail in Freight Service. Table 4-19 1996. Accessed from URL:

<http://www.bts.gov/btsprod/NTS/Chp4/tb14x19.htm>

¹¹ Estimated Consumption Converted from Cost per Pole Provided by Bell Pole, Carseland

¹² ATCO Gas Company, Rate Schedule November 2000.

Concrete Pole Production = 90/day X 21 day month = 1,800 poles/month

Electrical Energy Consumed/Month = 35,168.57 kWh

40 foot Pole Production = 40% of monthly production = 720 poles

48.8 kWh/pole

Steel

There was no data available on raw materials to plant. Assuming the closest supplier is Stelco, Halton Works – Hamilton, Ontario. Estimated distance <10 km, energy input is insignificant.

Shipping Concrete Poles

(Burlington, Ontario to Calgary, Alberta)

Trucking legal limit 32,727 kg. Each concrete utility pole weighs¹⁴ 1,245 kg.

Total legal capacity = 26 poles, however physical constraints would limit the load to a maximum¹⁵ of 19.

Distance:

Burlington, Ontario to Calgary, Alberta via United States route = 3,503 km.

Fuel Consumption = 0.417 Litres/ km

Total Fuel Consumed = 1,461 Litres

Fuel Consumed per pole = 77 Litres

¹³ Day, Chris; Sales Manager, Stress Crete Company, Site Visit, September 28, 2000

¹⁴ StressCrete Limited, Distribution Pole Specifications, Accessed from URL:

<http://www.stresscrete.com/html>

¹⁵ Day, Chris, Manager Sales, StressCrete Limited, Personal Interview, September 26, 2000

Option:

Ship by Rail

Assuming the same distance as truck = 3,503 km

Rail fuel Consumption = 3.765 km/Litre

Total Car Fuel Consumed = 930 Litres

Assuming 40 poles per car = 23 Litres/Pole

Conversion to Energy Equivalent¹⁶

Gasoline = 115,400 BTU (gal/net)

Diesel = 128,700 BTU (gal/net)

1 BTU = 1,055 J 1 gallon = 4.544 Litres

Gas = 1 Litre = 25,396 BTU X 1,055 = 26792780 J

Diesel = 1 Litre = 28,323 BTU X 1,055 = 29880831 J

Determination of Waste Products***Cement Pole – Disposal at end of life¹⁷***

Finished weight = 1,245 kg

Steel weight = 68 kg

Cement weight = 1,177 kg

Table C.4 CCA Treatment Waste Products¹⁸

	Annual (kg)	Per Pole (kg)
Arsenic	0.44	0.0244
Chromium	0.23	0.0128
Copper	0.20	0.0111

¹⁶ United States Department of Energy, Transportation Energy Data Book: Edition 18, 1998

¹⁷ Rosati, Geno, Engineering Manager, The StressCrete Group, personal Interview September 28, 2000

¹⁸ Environment Canada, 1998. National Pollutant Release Inventory (NPRI), Facility Report – Bell Pole Company Carseland Operation. Accessed from URL: <http://www.npri-inrp.com> (NPRI ID – 5220)

Note, a waste figure was received from the chemical supplier of 2,000 kg every 2 years. However, without knowing their total plant production, arriving at a volume for each product they produce and then a volume per pole it was assumed that the waste produced at this stage was insignificant.

CCA Treated Pole

Assumed = Pole weight 440 kg + 12 kg treatment = 452 kg

Non Treated Cedar Pole – Disposal at end of life

Assumed waste weight of a 40-foot pole = 440 kg

Emission Assumptions and Calculations

(a) Heavy Duty Diesel Trucks¹⁹

CO₂ = 2,730 g/Litre

CH₄ = 0.13 g/Litre

N₂O = 0.1 g/Litre

(b) Rail¹⁴

CO₂ = 2,730 g/Litre

CH₄ = 0.13 g/Litre

N₂O = 1.1 g/Litre

PM = 1.8 g/Litre²⁰

(c) Pick up Truck

CO₂ = 2,360 g/Litre

CH₄ = 0.25 g/Litre

N₂O = 0.21g/Litre

¹⁹ Environment Canada – Canada's Greenhouse Gas Inventory, P. 102

²⁰ US-EPA – Emission Factors for Locomotives (1997a) P.2 – EPA 420 F-97-OS1

(d) Chain Saw²¹CO₂ = 1,730 g/LitreCH₄ = 0.52 g/LitreN₂O = 0.046 g/Litre

PM = 2.06 g/Litre

(e) Honda Portable Generator 8 hp.CO₂ = 406 g/LitreCH₄ = 0.39 g/LitreN₂O = 0.27 g/Litre

PM = 7.70 g/Litre

Global Warming Potentials (100 year) ²²

Carbon Dioxide (CO ₂)	1
Methane (CH ₄)	21
Nitrous Oxide	310

²¹ US-EPA – Non Road & Vehicle Emission Study (1991) P. 30 – EPA 21A-2001

²² US EPA – National Emissions – Global Warming Potential Accessed from: URL:
<http://www.epa.gov/globalwarming/emissions/national/gwp.html>

Table A.5 Energy estimates – log milling operation

Process	Conversion data	Energy Elec kWh	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Internal movement of logs	Log loader (Patrick) with fuel consumption estimated at 6 gallons (22 L) per hour. Assume 15 min. per pole			5.5			
Bark peeling and stump removal	Estimated electrical consumption 200 kWh, for 20 min.	10					

Table A.6 Energy estimates – CCA manufacturing from raw material sources

Process	Conversion data	Energy Elec	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Chromic acid flake shipped from chemical manufacturer OxyChem - Castle Hayne, N.C, to Timber Specialties Co. in Tangent, Oregon	1 rail car 80,000 lbs., 40,829 litres - 5232 km, Rail fuel consumption = 3.765 km/l, CCA consumption per pole = 121.15 litres**, Chrome Flake = 26% = 31.499 litres*				1.1		32.0
Arsenic acid shipped from parent company in Memphis, Tenn. To T.S. in Tangent ,Oregon.	1 rail car 74,000 lbs. - 3,851Km. Rail fuel consumption = 3.765 km/l. CCA consumption per pole = 121.15 litres. Acidic Acid = 35.96% = 43.57 litres*				1.1		33.3
Copper - Shipped in bags from New Jersey or Australia (Australian copper used in Campbellville, Ontario) plant. Assume New Jersey for Tangent, Oregon. Shipped by rail.	1 Boxcar, Trenton NJ To Tangent Or. = 4768.3 Km Rail Fuel Consumption = 3.765 km/l- 1,200 kg bags, estimated 25 per pallet, X 12 pallets =360,000 kg CCA Consumption = 121.15 litres. Copper = 10.67% = 12.93 litres = 454 kg*				1.6		47.7

Process	Conversion data	Energy Elec	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Add water							
Mixing and handling of constituents. Storage for shipment to wood treaters. Production 93,700 lbs of product.							
Shipped by truck - 48,000 lbs per load Tangent ,Oregon to Carseland , Alberta (Distance 948 miles)	Assume 6.5 miles/gal (1)				0.09		2.8
Notes: U.S. Dept of Commerce Data 1992 Truck Inventory and Use Survey Table 7.7 Truck Fuel Economy by fuel Type and Size Class * Chemical allocation based upon formulation provided by Timber Specialties Co., September 2000 ** CCA consumption per pole based upon Class 3/ 40 foot pole. Application based on CSA Standard 080-97 Bell Pole Company, Nov. 2000							

Table A.6 Energy estimates - CCA treatment

Process	Conversion data	Energy Elec kWh	Energy Nat Gas Mj	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Pole is transported from mill (Lumby & Revelstoke, B.C) to treatment facility Carseland, Alberta.	Estimated 50% from each site and 50% movement by rail, Distance: Lumby = 576 Km, Revelstoke = 410, trainload = 75 poles, truck = 45. Fuel Consumption = 0.417 l/km				3.16		94.42
Pole is unloaded with pole mover (Patrick)	Patrick fuel consumption is estimated at 6 gallons (22L) per hour assume 5 min per pole unload time				0.306		9.14
Pole is moved from storage to bark stripper and inciter	Patrick fuel consumption is estimated at 6 gallons (22L) per hour assume 5 min per pole unload time				0.306		9.14
Pole stripper	Estimated 200 kWh for 10 min per pole	20					
Pole is placed in tram for treating	Patrick fuel consumption is estimated at 6 gallons (22L) per hour assume 5 min per pole unload time				0.36		10.76
Pressure treating process - 8 hours and fixation process	Estimated electric and Gas consumption converted from cost per pole provided	440	313.25				

Process	Conversion data	Energy Elec kWh	Energy Nat Gas Mj	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Pole mover removes treated poles and stores for transport to customer	Patrick fuel consumption is estimated at 6 gallons (22L) per hour assume 5 min per pole unload time				0.36		10.76
Pole is transported by truck to customer (Calgary) 45 km one way	Truck fuel consumption = 0.417 l/km, assume delivery load of 40 poles.				0.47		14.01

Table A.7 Energy estimates – concrete utility pole manufacturing

Process	Conversion data	Energy Elec kWh	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Transport dry cement from Montreal or Woodstock, Ontario by truck	Assume 75% supplied from Woodstock - Distance Woodstock 88.98 km, Montreal 603.21 km. Fuel Consumption 0.417 l/km				6.92		206.78
Yard and mobile equipment	Assume a consumption rate of 6 gallons 22L hour, 20 min. of movement time per pole				7.30		218.13
Fabricate concrete pole	Average monthly electricity consumption 35,168 kWh	48.84					
Ship Pole from Burlington, Ont. to Calgary, Alberta. via Truck	Ship 19 poles, 3503 km, at a fuel consumption rate of 0.417 l/km				76.90		2297.84
Option: Ship pole by rail	Assume the same distance as truck 3503 km, 40 poles, at a fuel consumption rate of 0.2656 l/km				23.70		708.18

Table A.8 Energy estimates – operations – install wood and cement poles

Process	Conversion data	Energy Elec	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Pole hauler (Pettibone) moves pole from storage to trailer	Fuel consumption 6 gallons (22L) per hour* - assume 5 min. per pole loading time.				1.83		54.78
Auger Truck and Trailers Transport poles to site, drills hole, and sets pole in place. (Note: hole may be hand dug depending on soil type).	Estimated fuel consumption = 46.37 l/hour**; assume 1.5 hour travel and set time per pole				69.56		2078.36
Tamper to set pole	Estimated fuel consumption, 12 litres/hr. Time to set 25 min.			5.00			133.98
Auger Tuck lifts pole into place	Concrete pole - loading assume 6 gallons (22L) per hour - assume 10 min. Per pole loading				3.67		109.59
Tamper sets pole	Concrete pole - estimated fuel consumption = 46.37 l/hour**; assume 2.45 *** hour travel and set time per pole				113.61		3394.66
Truck returns to service centre							
Notes: * Eric Furlong, City of Calgary Supply Management Services, October 2000, Figure based on current consumption ** Jess Debnam, Supervisor, Fleet Services, ENMAX Power Corp., estimated from horsepower rating and consumption. Estimated time and distance standards for work planning *** Concrete pole handling and installation will use the same equipment but take longer due to weight and handling requirements							

Table A.9 Energy consumption estimates – life enhancement wood pole & concrete

Process	Conversion data	Energy Elec	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - MJ	Fuel Diesel - MJ
Pole Inspection - wood	3/4 ton pickup, in operation 20 min per pole. Consumption = 0.154 l/km* or 0.154 l/min			3.08		82.52	
Pole wrap installation	Air hammer use, rechargeable hand tools. No data for use. Estimated to be insignificant on a per pole basis			N/A			
Pole inspection - concrete	3/4 ton pickup, in operation 10 min. per pole. Consumption = 0.154 l/km* or 0.154 l/min			1.54		41.26	
Pole maintenance - concrete	Cement patch, paint, quantities will vary upon amount of maintenance required			N/A			
Notes: Environment Canada - Canada's Greenhouse Gas Inventory, Appendix B2 1999 P. 90 - Light duty gasoline trucks							

Table A.10 Energy estimates – pole removal and disposal/reuse options

Process	Conversion data	Energy Elec	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
Chainsaw to cut pole estimated use 5 min.	Estimated consumption 1.5 l/hr of operation*			0.13		3.35	
Digger/derrick truck - dig hole, remove core, lift pole and hold in place, transport to service centre	Estimated fuel consumption = 46.37 L/hr. Assume 1.0 hour removal and transport time.				46.37		1385.57
Concrete - remove pole, hand digging to expose base. Transport back to service centre	Estimated fuel consumption = 46.37 L/hr. Assume 2.0 hour removal and transport time**				92.74		2771.15
Concrete pole - cut with cement saw in 6 foot lengths for recycler and ease of handling	Estimated fuel consumption - Honda generator for power supply of saw = 4 litres /hr (Honda 8 hp gen.). 40 foot pole into 6 foot lengths will require 6 cuts at 10 min. each			4		107.17	
Options (A) Treated Wood:							
a. Haul to landfill	300 Hp truck to haul to landfill, 30 pole equivalent - Consumption = 0.417 L/Km, Distance 15 Km				0.21		6.23
b. Haul to auction	20 poles hauled by trailer - 3 ton truck- consumption = 0.175 l/km assume distance 20 km				0.18		5.23
c. Haul to secondary user	10 poles hauled by trailer 50 km - 3 ton truck - consumption = 0.175				0.87		26.15

Process	Conversion data	Energy Elec	Energy Nat Gas	Fuel - Gas Litres	Fuel Diesel Litres	Fuel Gas - Mj	Fuel Diesel - Mj
	l/km						
d. Haul to cement kiln	40 Poles hauled by tractor trailer - consumption = 0.417 to Exshaw, Alberta distance = 108 km				1.13		33.64
Options (B) Concrete:							
a) Haul to landfill	300 Hp truck to haul to landfill, 15 pole equivalent - consumption = 0.417 L/Km. Distance 15 Km				0.42		12.46
b) Haul to recycler	300 Hp truck to haul to landfill, 15 pole equivalent - consumption = 0.417 L/Km. Distance 15 Km				0.42		12.46
c) Recycler	600 Hp diesel engine - 30 min. @54 L/hr consumption = 27 L. 30 pieces crushed.				1.11		33.17
Notes: * Estimated consumption based upon actual use ** It is estimated that time for removal and weight of product will account for more removal time.							

Table A.11 Resource use and emissions – LCA processing unit and options

	CCA Prod.	CCA Treating	CCA Treating Pole	Non Treated Pole	Cement Pole Assembly	Cement Pole	Install Wood Pole	Install Cement Pole	Inspect. /Life Enhance - Cement	Inspect. /Life Enhance - Wood	Removal Wood /Landfill	Reuse Secondary User	Removal Cement/Landfill	Recycling Cement	Secondary Energy - Wood
Primary energy consumption	115.84	434.69	281.93	2,722.74	2,267.12	3,504.24	41.26	82.52	1,395.15	1,420.30	2,890.78	12,751.50	1,422.57		
Solid waste (kg)	29.58	1.55	-	-	-	-	-	-	451.61	-	-	-	1,245.11	451.61	
Air toxicity index															
Water toxicity index															
Global warming potential (kg)	1.19	1.42	1.22	25.18	19.73	32.41	0.37	0.75	12.89	13.09	26.44	26.44	13.15		
Weighted resource use (kg)															
A. Resource Use															
Water	33.16			1.84					1.75						
Cu nap															
B. Solid Waste															
Hazardous sludge	1.21														
Waste wood* (kg)	28.37	1.50	1.50						439.98					439.98	
Waste steel* (kg)				n/a					68.04					68.04	
Waste cement* (kg)				n/a										1,177.07	
Waste CCA treated wood (kg)									451.61						451.61
Arsenic (kg)		0.02													
Chromium III (kg)		0.01													
Copper (kg)		0.01													
Total solid waste (kg)	29.58	1.55	-	-	-	-	-	-	451.61	-	-	-	1,245.11	1,245.11	451.61
* Recycled Forestry															

	CCA Prod.	CCA Treating	Non Treated Pole	Cement Pole Assembly	Install Wood Pole	Install Cement Pole	Inspect. /Life Enhance - Cement	Inspect. /Life Enhance - Wood	Removal Wood /Landfill	Reuse Seconda ry User	Removal Cement / Landfill	Recycling Cement	Seconda ry Energy - Wood
Electricity (A) B.C.													
CO2 (kg)	0.20												
Electricity (B) Alta.													
CO2 (kg)		453.20											
Electricity (C) Ont.													
CO2 (kg)				12.70									
E. Energy Consumption													
Electricity (kWh)		470.00	30.00	48.84									
Natural gas (Mj)		131.25											
Coal													
Diesel (Mj)	115.8393	303.4393	281.9256	2722.741	2267.116	3504.242			1391.804	1416.949	2783.608	127407.32	1419.217
Gasoline (Mj)							41.26108	82.52217	3.34898	3.34898	107.172	107.172	3.34898
Biofuel (Mj)													
Total Primary Fuel (Mj)	115.8393	434.6893	281.9256	2722.741	2267.116	3504.242	41.26108	82.52217	1395.153	1420.298	2890.78	127514.49	1422.566

Table A.12 Resource use & emissions – calculation of global warming potential

	CCA Prod.	CCA Treating	Non Treated Pole	Cement Pole Assembly	Install Wood Pole	Install Cement Pole	Inspect. /Life Enhance - Cement	Inspect. /Life Enhance - Wood	Removal Wood /Landfill	Reuse secondar y User	Removal Cement / Landfill	Recycling Cement	Secondar y Energy - Wood
Transportation													
CO ₂ (kg)	1.06	1.35	1.16	24.88	19.49	32.02	0.36	0.73	12.74	12.93	26.11	26.11	12.99
CH ₄ (g)	0.58	0.68	0.55	11.85	9.28	15.25	0.39	0.77	6.12	6.75	14.19	14.19	6.24
N ₂ O (g)	4.17	2.08	2.00	9.11	7.14	11.73	0.32	0.65	4.66	4.86	9.50	9.50	4.76
CO (g)	15.49	19.84	3.59	364.48	285.55	469.10			186.31	186.31	372.63	372.63	189.98
Sulphur (g)	0.39	3.81	2.25	9.11	7.14	11.73			14.23	14.23	27.86	27.86	14.51
Particulate (PM) (g)	6.72	1.49	0.42	27.34	21.42	35.18			3.72	3.72	9.31	9.31	3.81
Total	27.35	27.90	8.83	421.89	330.52	542.98	0.71	1.42	215.05	215.88	433.49	433.49	219.30
Option -Transportation by rail Concrete Poles													
CO ₂ (kg)				10.35									
CH ₄ (g)				4.93									
N ₂ O (g)				3.79									
CO (g)				151.68									
Sulphur (g)				3.79									
Particulate (PM) (g)				67.12									
Total				231.31									
Global Warming Potential													
CO ₂ (kg)	1.057	1.354	1.157	24.875	19.488	32.015	0.363	0.727	12.737	12.928	26.112	26.112	12.988
CH ₄ (kg)	0.001	0.001	0.001	0.025	0.019	0.032	0.001	0.002	0.013	0.014	0.030	0.030	0.013
N ₂ O (kg)	0.129	0.064	0.062	0.282	0.221	0.363	0.010	0.020	0.145	0.151	0.294	0.294	0.147
	1.19	1.42	1.22	25.18	19.73	32.41	0.37	0.75	12.89	13.09	26.44	26.44	13.15

	CCA Prod.	CCA Treating	Non Treated Pole	Cement Pole Assembly	Install Wood Pole	Install Cement Pole	Inspect. /Life Enhance - Cement	Inspect. /Life Enhance - Wood	Removal Wood /Landfill	Reuse secondar y User	Removal Cement / Landfill	Recycling Cement	Secondar y Energy - Wood
Option 1 -Transportation by rail Concrete Poles													
Global warming potential													
CO ₂ (kg)				10.352									
CH ₄ (kg)				0.0104									
N ₂ O (kg)				0.118									
				10.48									

Appendix B - LEACHING OF CCA TREATED WOOD

On February 4, 1997 the National Coalition Against the Misuse of Pesticides and in Canada the Sierra Club, issued a press release (Sierra Club of Canada, 1997) based on the findings of a sponsored study - *Poison Poles: A report about their toxic trail and safer alternatives*. This report highlighted that from the production of all treated wood chemicals, to the wood treatment facility, to the treated wood poles in use and the final landfilling, there is alarming levels of toxic chemicals that can affect humans from touch, soil leaching and leaching into ground and surface water.

In 1997, the report indicates that the US distribution of utility poles was pentachlorophenol (Penta)/Oil – 45%, Arsenicals (such as CCA) 42%, and Creosote 13%. The report cites a large number of treatment facilities in the United States as listed Superfund clean up sites. The same report cites Occupational Health Administration risks from penta as ranging from 7 in 1,000, to 1 in 100 (Feldman & Shistar, 1997).

The Poison Pole Report illustrated the in-situ contamination issues, “Toxic chemicals can seep out of poles, resulting in high concentrations of highly contaminated soil, or pooled liquid residue at the base of poles. Many of these poles are in cities, parks, playgrounds and backyards” (Feldman & Shistar, 1997).

This illustration did highlight the issue of chemicals in the environment. It heightened awareness in the public of yet another pathway to such things as drinking water and children in playgrounds to the issue of exposure. The CBC Consumer affairs program Market Place profiled treated wood and possible exposure to children in playgrounds on Nov. 17, 1998 (CBC, 1998).

What follows is a summary of the most current Canadian scientific evidence on the subject of localised contamination of CCA. This data will also be compared

against the 1999 *Canadian Environmental Quality Guidelines* prepared by the Canadian Council of Ministers of Environment.

Dr. Paul Cooper of the University of Toronto, Faculty of Forestry has spent the over a decade studying the science of treated wood. He has conducted numerous field tests to measure short and long term effects of treated wood on soil, surface water and groundwater. His research has uncovered some very interesting characteristics about CCA treated wood.

Of concern to the general public, as the *Poison Pole* and *Marketplace* reports suggest are the presence and effect Chromium VI and Arsenic. Chromium VI (Hexavalent Chromium) is water soluble, highly toxic and mobile in soil, but after proper fixation it is transformed into Chromium III (Trivalent Chromium) (Cooper, 1990 draft report). Arsenic is more understood from its association with gold mining and associated base metal refining. It enters the environment by air, surface water and groundwater, eventually residing in the ocean as its world-wide sink (Environment Canada, 1993).

Once in contact with the soil, complex geological and biological reactions occur between soils and its micro-organisms and the inorganic leachates. Copper, Chromium and Arsenic are all largely immobilised by soil (Cooper, 1997 draft). However, his research also notes that sandy soil with low organic content and a low pH reduces the binding quality of soil. Studies on the mobilization of CCA from treated wood and solution spills indicate high immobilisation and/or high dilution of its constituents in soil. One report indicated that a spill of 20,000 litres containing arsenic did not contaminate water wells 75 and 125 meters away (Cooper, 1990).

Cooper (1990) indicates the follow factors for leaching of CCA from wood:

- **Improper or incomplete fixation** – The process of allowing the treated wood to sit at relatively high humidity and temperature of 30 degrees C. for a period of 6 to 8 hours, followed by a stand time ranging from 2 to 8 hours

(Norman, Bell Pole, personal communication, 2000). This process allows a set of complex set of chemical reactions to occur, in particular the transformation of Chromium VI to Chromium III.

- **Exposure Conditions** – Exposure in wetter climates such as coastal B.C. will tend to leach more than drier climates such as southern Alberta.
- **Wood Species** – Higher density, lower permeability species such as western red cedar, tend to be more resistant to leach than lower density and higher permeability species such as pine and Douglas Fir.
- **Age in Service** – The tendency is for the highest level of leaching is just after installation.
- **CCA Formulation** – There has been three different formulations of CCA since the development of the formulation. Each formulation indicates a different level of specific chemical leaching. For example CCA – B exhibits high Arsenic leaching due to the 65.5% composition level of Arsenic. The current formulation CCA – C used in Canada for the past 10 years indicates the lowest level of leaching (its Arsenic composition level is 47.5%).
- **Effects of pH, Salts and Organic acids** – There is a tendency for increased leaching with exposure to low pH (high acid) environments. Exposure to acid rain (surface physical exposure) will offer increased leaching potential.

Given these factors, the combinations and permutations of conditions will widely affect leaching levels. Each region (no matter how it is defined, geologically, physographically, or even politically) throughout the world will have highly variable tendencies to leaching.

The tables that follow are field samples of soil, water and surface leaching from various CCA products and various wood species. There were no studies found of leaching from CCA wood products in the Canadian Prairie Provinces or east of

Rocky Mountain in the United States. Most of the research that was found was from central Canada and the United States (Great Lakes Area). The current Canadian and Alberta environmental criteria are provided with the table to compare the field data to the current criteria levels.

The Alberta Tier 1 cleanup criterion is quoted because the utility that is the subject of this study is located in Alberta. Utilities located in other provinces may as well have different provincial clean up guidelines. It should be noted that the CCME guidelines are generally regarded in both the environmental industry and within Alberta Environment as more grounded in recent scientific research. However, the determination between which guideline to use is a source of confusion. In Alberta the regulator will cite the most stringent depending upon the location. This is important for determining if site specific impact and remediation either at the treatment facility, the storage yard or at each pole location is a concern.

Table B.1 Leachate concentration from CCA wood products (Cooper, 1990)

Solution	Product	Exposure	Concentration (PPM)		
			Copper (Cu)	Chromium (Cr)	Arsenic (As)
CCA – B	Cedar Shakes	Natural Rain (Langley B.C.) 1 st Year	1 – 7	–	2 - 12
CCA – B	Cedar Shakes	Natural Rain (Langley B.C.) 2 nd Year	0.5 – 2.5	–	1 - 5
CCA – C	Cedar Shakes	Natural Rain (Langley B.C.) 1 st Year	1 – 5	–	1 - 4
CCA – B	Roof Boards	Natural Rain (Norway after 2 years)	.29	0.076	1.11
CCA – B	Roof Boards	Natural Rain (Norway) Max. Levels (1 st rain)	4 - 5	0.5 – 0.9	7.3
CCA – C	LPP pole (new)	Natural Rain Toronto pH 6	1.8	0.4	0.3
CCA – C	SPF Fence 1 Year	Natural Rain Toronto pH 6	4 - 5	7	6.5
CCA – C	39X140X900 mm new JP board	Natural Rain Toronto pH 5.1	2.8	1.0	–
CCA – C	39X140X900 mm aged JP board (1 month)	Natural Rain Toronto pH 5.1	2.7	0.9	–
CCA – C	39 X 185 mm new JP board	Natural Rain Toronto pH 5.1	1.8	2.7	–
CCA – C	39 X 140 mm decking 10 years in service	Natural Rain Toronto pH 6	<0.1	<0.1	–
CCA – C	19X140X610 mm SPF Boards	Simulated rain 1 week	14.5	12.1	7.3
CCA – C	19X140X610 mm SPF Boards	Simulated Rain 4 weeks	3.0	1.5	5.0
CCA – C 2%	50X150X300 mm SYP Boards	Simulated rain (30 min)	<0.2	3.2	<0.5

**CCME Guidelines 1999 (Canada Wide Standards)
(Parts Per Million – PPM)**

Copper – 63* - 93**
 Total Chromium 64* - 87**
 Chromium IV – 0.4* - 1.4**
 Arsenic – 12
 * Agriculture & Parkland Residential
 ** Commercial & industrial

**Alberta Tier 1 Criteria for
Contaminated soil (1994)
(Parts Per Million PPM)**

Copper – 80
 Total Chromium – 100
 Chromium IV - 5
 Arsenic – 10

**CCA Formulations (Cooper, 1990)
% Composition**

	CCA-A	CCA-B	CCA-C
Cr	65.5	35.3	47.5
Cu	18.1	19.6	18.5
As	16.4	45.1	34.0

The next impact area of concern is surface and ground water. This would include the result of water cascading over a pole and infiltrating the soil/ground water or the surface water systems.

It is required in the provincial licensing of treatment facilities in most jurisdictions to have regular on-site ground water monitoring programs in place (B.C. Environment & Alberta Environment, 2000). Specific information about treatment facilities was not available, but there was no indication from any CCA pole treater's that they have had any exceedence in the ground water parameters.

Paul Cooper's studies have indicated that CCA constituent levels were generally low. However just like soil, there were some cases above the aquatic and drinking water standard. Concentrations of constituents followed a patten of highest to lowest of copper, then arsenic and with chromium being the lowest (Cooper & Ung, 1997:26-30).

Table B.2 Levels of CCA contaminants in ground water sampled near CCA treated poles. Depth between 1.5 and 2 meters (ppm) (Cooper & Ung, 1997)

Pole #	Years in Service	Soil/Site	Times sampled	Distance to Pole (m)	pH	Cr	Cu	As
355	1	Wet	1	0	6.66	<0.01	0.20	<0.03
				0.25	6.93	0.04	0.11	<0.03
				0.50	6.73	<0.01	0.50	<0.03
				1.0	7.08	0.02	0.11	<0.03
356	1	Wet	1	0.25	6.99	<0.01	0.17	<0.03
				0.50	7.63	<0.01	0.04	<0.03
				1.0	7.77	<0.01	0.02	<0.03
				25	7.12	<0.01	0.03	<0.03
342	2	Clay	1	0.25	6.81	<0.01	0.30	<0.03
344	6	Clay	1	0	6.80	<0.01	0.02	0.04
			6	0.25	6.81	0.03	0.09	<0.03
			2	1.0	7.01	0.09	0.32	0.20
			2	25	6.86	0.04	0.10	<0.03
398	6	Wet	1	0	6.29	0.16	0.65	0.26
			1	1.0	5.97	0.03	0.10	0.10
359	8	Clay	1	0	6.92	<0.01	0.05	0.05
			1	1.0	6.86	0.02	0.97	0.19
			1	25	7.23	<0.01	0.04	<0.03
688	13	Wet	1	0	5.77	0.57	1.32	0.49
			1	1.0	5.73	0.21	0.81	0.40

Table B.3 Regulated groundwater criteria (ppm)

	CCME – Canadian Environmental Quality Guideline 1999		Alberta – Surface Water Quality Guideline
	Drinking Water	Aquatic Life	
Arsenic (As)	0.025	5.0	5.0
Chromium (Cr)	0.05	8.9* 1.0**	8.9* 1.0**
Copper (Cu)	<15	2 – 4 ***	2 – 4 ***
pH	6.5 – 8.5	6.5 – 9	6.5 – 8.5****

*Chromium III

** Chromium VI

*** The copper guideline is dependent upon the hardness of water

**** The Alberta Guide states that pH cannot exceed 0.5 pH units from background values

The final area of assessment is based upon the dislodgability of CCA from treated wood. In other words, how mobile is chemical from wood to humans through ingestion or absorption?

Based upon the work of Cooper (1990) in which he compiled data from a wide variety of sources, he concluded that dislodgability was higher in ACA than CCA.

As the wood ages the amount available components decreases. Higher volumes are dislodged from the end wood than the sides.

Based upon a variety of scientific research the U.S. EPA in 1984 concluded that absorbency from dry Arsenic treated wood to be negligible. Studies in which fish were dried on CCA-B treated wood racks absorbed relatively small amounts of CCA (about 1.0, 0.18 and 3.0 mg/fish of Cu, Cr and As respectively). CCA-C treated wood resulted in slight Cu contamination (0.24 mg/fish) only (Cooper, 1990).

Up to this point there has been no discussion about the environmental impacts of concrete utility poles. No literature was found on the direct environmental impacts related to concrete utility poles in use. Based upon the direct knowledge of the author the only impacts may be associated with altered pH levels. Since the point source of an individual utility pole is so small in contrast to large slab concrete objects the impact on pH can be inconsequential. Environmental impacts for concrete largely resonate at the raw material extraction and processing levels.

Appendix C - TOTAL COST ASSESSMENT DETAILED CALCULATIONS AND ASSUMPTIONS

Table C.1 External cost calculations

	Non Treated Wood	CCA Treated Wood	Concrete Utility Pole
CO2 @ .15/kg	5.37	5.55	109.59
SO2 @\$1.80/kg	0.07	0.10	4.50
NOx @ \$4.47/kg	0.16	0.21	2.50
Particulates @ \$2.62/kg			2.62
Drinking Water Quality .05/kg	0	0	74.81
Water Consumption @ \$ /L	N/A	N/A	N/A
Total Life Cycle Cost	\$ 5.60	\$ 5.86	\$ 194.02

All valuated costs are from – Cooper, Paul; Full Cost Accounting Evaluation of CCA Treated Wood Poles Manufactured by Guelph Utility Pole Company Ltd., Guelph, Ontario. Prepared for Guelph Utility Pole Company Limited. July 31, 1994. P. 4 – 7.

CCA Treated Pole

(a) Storage Yard Clean up – 40 foot pole storage = 1,584 sq. Feet for 100 poles

Volume = Length X Width X Depth

$$13.42 \text{ m} \times 10.98 \text{ m} \times .6 \text{ m} = 88.4 \text{ m}^3$$

Soil Density = 1.8 tonnes per cubic meter

$$1.8 \times 88.4 = 159.12 \text{ Tonnes}$$

Disposal Cost = \$48 tonne x 159.12 = \$7,637.76

Hauling and Manifesting = \$ 10,000

Replacement fill* = \$ 1,838.72

*Assumption that truck loads would back haul clean fill.

Total Cost = \$ 19,476 / 100 poles = \$194.76/pole

(b) Site Specific - Removal of contamination at each pole site

Assuming a contaminated area of 60 cm (R)

And a depth of 0.5 meters (D)

$$\begin{aligned}\text{Volume} &= \pi \times R^2 \times D \\ &= 3.14 \times (0.6)^2 \times 0.5 = 0.57 \text{ m}^3\end{aligned}$$

Soil Density = 1.8 tonnes per cubic meter

$$1.8 \times 0.57 = 1.03 \text{ Tonnes}$$

Disposal Cost = \$48.00 Tonne X 1.03 = \$49.24

Hauling & Excavation = \$300

Total Cost = \$ 349.24/pole

Concrete Pole

(a) Storage Yard Clean up

No Costs – Limited Storage time. No direct contact with the soil while stored.

No contamination expected.

(b) Site Specific - Removal of contamination at each pole site

Concrete over time may affect pH of the soil above the Alberta Tier 1

Remediation criteria after 50 years in soil. Assuming an impacted area of 30 cm and a depth of .75 meters.

$$\text{Volume} = \pi \times R^2 \times D$$

$$3.14 \times (0.3)^2 \times 5 = 0.21 \text{ m}^3$$

$$\text{Soil Density} = 1.8 \text{ tonnes per cubic meter}$$

$$1.8 \times 0.21 = 0.38 \text{ Tonnes}$$

$$\text{Disposal Cost} = \$48.00 \text{ Tonne} \times 0.38 = \$18.32$$

$$\text{Hauling \& Excavation} = \$250.00$$

$$\text{Total Cost} = \$268.32/\text{pole}$$

Economic Assumptions

Non Treated Pole = \$305.00 delivered (Zeegers, 2000)

CCA Pole Cost = \$390.00 delivered (Zeegers, 2000)

Cement Pole Costs = \$850/ pole (Day, 2000)

Transportation of Concrete poles is from Burlington Ontario at a cost of \$6,000 per load (31,955 Kg) 19 poles = \$315.79/pole. (Day, 2000)

Storage = 45% of the cost of the product which covers handling, administration and operational and capital equipment costs.

Installation of a wood utility pole takes a 3-person crew 1.5-hour. No additional hardware or transformers are included.

A pole installation crews labour rate is \$102.59/hour

A digger and trailer is required for a pole installation at a rate of \$55/hour

Overhead and Administration includes –

Surveyor at 1 hour @ \$50.00/hour

Planner at 4 hours @ \$65.00/hour

Supervision includes –

Foreman at 1 hour @ \$66.00/hour

Wood Poles – Disposal Costs

Disposal costs = \$60.00 /Tonne – 1 wood pole = 450 kg 4.2 poles = 1 Tonne

Hauling Costs = \$40.00/ Load – 1 Load = 4 poles = \$10.00/pole

Concrete Poles – Disposal Costs

Disposal costs = \$60.00 /Tonne - 1 concrete pole = 1,681 Kg. = \$100.80/pole

Hauling Costs = \$40.00/Load – 1 Load = 2 poles = \$20.00/pole

Life extension treatment and inspection costs \$50.00/pole (Hanna, 2000)

Table C.3 Costs Over 100 year time horizon – non treated cedar pole

(Replacement frequency 15 years)

	Year 1	Year 15	Year 30	Year 45	Year 60	Year 75	Year 90	Year 100
A. Non Treated Cedar Utility Pole								
Direct Materials incl. Shipping	\$ 305.00	\$ 305.00	\$ 305.00	\$ 305.00	\$ 305.00	\$ 305.00	\$ 305.00	\$ 203.31
Storage	\$ 167.75	\$ 167.00	\$ 167.00	\$ 167.00	\$ 167.00	\$ 167.00	\$ 167.00	\$ 111.32
Operations - Installation	\$ 153.89	\$ 153.89	\$ 153.89	\$ 153.89	\$ 153.89	\$ 153.89	\$ 153.89	\$ 102.58
Equipment Costs - Installation	\$ 101.63	\$ 101.63	\$ 101.63	\$ 101.63	\$ 101.63	\$ 101.63	\$ 101.63	\$ 67.75
Operations - Removal	\$ -	\$ 153.00	\$ 153.00	\$ 153.00	\$ 153.00	\$ 153.00	\$ 153.00	\$ 101.99
Equipment Costs - Removal	\$ -	\$ 74.00	\$ 74.00	\$ 74.00	\$ 74.00	\$ 74.00	\$ 74.00	\$ 49.33
Administration & Overhead	\$ 310.00	\$ 310.00	\$ 310.00	\$ 310.00	\$ 310.00	\$ 310.00	\$ 310.00	\$ 206.65
Supervision	\$ 66.00	\$ 66.00	\$ 66.00	\$ 66.00	\$ 66.00	\$ 66.00	\$ 66.00	\$ 44.00
Regulatory	\$ -	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 6.67
Disposal Fees	\$ -	\$ 14.29	\$ 14.29	\$ 14.29	\$ 14.29	\$ 14.29	\$ 14.29	\$ 9.53
Hauling Costs	\$ -	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 6.67
Testing/Lab Fees	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Record Keeping	\$ -	\$ 25.00	\$ 25.00	\$ 25.00	\$ 25.00	\$ 25.00	\$ 25.00	\$ 16.67
Storage Yard Liabilities	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Site specific Clean-up Costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Life Cycle Costs	\$ 5.60	\$ 5.60	\$ 5.60	\$ 5.60	\$ 5.60	\$ 5.60	\$ 5.60	\$ 3.73
Total	\$ 1,109.87	\$ 1,395.41	\$ 1,395.41	\$ 1,395.41	\$ 1,395.41	\$ 1,395.41	\$ 1,395.41	\$ 930.18

Table C.4 Costs over 100 year time horizon – CCA treated cedar pole
(Replacement frequency 35 years)

	Year 1	Year 35	Year 70	Year 100
B. CCA Treated Cedar Utility Pole				
Direct Materials incl. Shipping	\$ 390.00	\$ 390.00	\$ 390.00	\$ 334.23
Storage	216.00	216.00	216.00	185.11
Operations – Installation	153.89	153.89	153.89	131.88
Equipment Costs – Installation	101.63	101.63	101.63	87.10
Operations – Removal	-	153.00	153.00	131.12
Equipment Costs – Removal	-	74.00	74.00	63.42
Administration & Overhead	310.00	310.00	310.00	265.67
Supervision	66.00	66.00	66.00	56.56
Regulatory	-	25.00	25.00	21.43
Disposal Fees	-	14.29	14.29	12.25
Hauling Costs	-	10.00	10.00	8.57
Testing/Lab Fees	-	350.00	350.00	299.95
Record Keeping	-	150.00	150.00	128.55
Storage Yard Liabilities	-	-	-	200.00
Site specific Clean-up Costs	-	350.24	350.24	300.16
Life Cycle Costs	5.86	5.86	5.86	5.02
Total	\$ 1,243.38	\$ 2,369.91	\$ 2,369.91	\$ 2,231.01

Table C.5 Costs over 100 year time horizon – CCA treated cedar with life enhancement
 (Replacement frequency 65 years)

	Year 1	Year 35	Year 45	Year 55	Year 65	Year 100
C. CCA Treated Cedar Utility Pole Life Enhanced						
Direct Materials incl. Shipping	\$ 390.00	\$ -			\$ 390.00	\$ 297.18
Storage	216.00	-			216.00	164.59
Operations – Installation	153.89	-			153.89	117.26
Equipment Costs – Installation	101.63	-			101.63	77.44
Life Enhancement Cost	-	50.00	\$ 50.00	\$ 50.00	-	50.00
Operations – Removal	-	-			153.00	116.59
Equipment Costs – Removal	-	-			74.00	56.39
Administration & Overhead	310.00	-			310.00	236.22
Supervision	66.00	-			66.00	50.29
Regulatory	-	25.00			25.00	19.05
Disposal Fees	-	-			14.29	10.89
Hauling Costs	-	-			10.00	7.62
Testing/Lab Fees	-	-			350.00	266.70
Record Keeping	-	150.00			150.00	114.30
Storage Yard Liabilities	-	-			-	194.76
Site specific Clean-up Costs	-	-			350.24	266.88
Life Cycle Costs	5.86	0.11	0.11	0.11	5.86	5.97
Total	\$ 1,243.38	\$ 225.11	\$ 50.11	\$ 50.11	\$ 2,369.91	\$ 2,052.14

Table C.6 Costs over 100 year time horizon – cement pole

(Replacement frequency 50 years)

	Year 1	Year 50	Year 100
D. Cement Pole			
Direct Materials incl. Shipping	\$ 1,183.33	\$ 1,183.33	\$ 1,183.33
Storage	650.83	650.83	650.83
Operations - Installation	307.77	307.77	307.77
Equipment Costs - Installation	203.19	203.19	203.19
Operations - Removal	-	307.77	307.77
Equipment Costs - Removal	-	203.19	203.19
Administration & Overhead	380.00	380.00	380.00
Supervision	66.00	66.00	66.00
Regulatory	-	10.00	10.00
Disposal Fees	-	30.00	30.00
Hauling Costs	-	20.00	20.00
Testing/Lab Fees	-	60.00	60.00
Record Keeping	-	50.00	50.00
Storage Yard Liabilities	-	-	-
Site specific Clean-up Costs	-	268.32	268.32
Life Cycle Costs	194.02	194.02	194.02
Total	\$ 2,985.14	\$ 3,934.42	\$ 3,934.42

Appendix D - FIELD NOTES: CONCRETE POLE QUALITY ASSESSMENT

The following are field note observations and pictures related to a visual quality assessment that was performed in April 2000, in the City of Toronto. In each of the tables the sample size is indicated. It must be noted that although the poles may have surface damage caused by various reasons, this may not be an indication of product quality or integrity. It is however indicative of the potential for quality issues that would be evaluated utilizing engineering integrity techniques.

Area 1

Street: Kingston Rd., Bellamy Rd to Markham Rd. – Distance 1.0 Km

Estimated total distance in which concrete poles are utilized on this street

11km - sample size = 10%

Date of Survey: April 28, 2000

Location: City of Toronto – Former Borough of Scarborough

Notes: The street runs in a south-west to north-east direction. All poles surveyed were along the eastbound driving lanes. Distance to roadway was .25 meters. The street exposure is to the west and north side of the pole.

Type = Electrical distribution Poles

Table D.1 Visual pole quality assessment - Area 1

Pole #*	Date of Manufacture	Manufacturer	Conditions
71-301	1972	TEC **	Minor cracking base to 5 m.
71-315	No date	N/A	Rust staining. Cracking on seam. Crack on west side.
71-311	1972	TEC	Cracking base to 1 m. North & West Side. Rust staining east side.
71-313	1972	TEC	Cracking base to 1 m seam west side
71-318	No date	N/A	Horizontal cracking at base and vertical cracks north side. Missing access plate.
71-320	No date	N/A	Cracking on seam north & east side. Rust north side. Missing access plate.
71-322	No date	N/A	Cracking on both seams 1 meter from base. Missing access plate.
71-329	No date	N/A	Cracking on seam 1.8 meters. Crack on North east side extending 4 meters. Missing access plate
71-331	1972	TEC	Cracking west side seam. Minor cracking and rust north and east side.
71-332	No date	N/A	Cracking west side 2.5 m. Rust at support base with cracks associated. Missing access plate.
71-336	1971	TEC	Cracking east side at seam.
71-337	1971	TEC	No damage
71-341	1971	TEC	No damage. (Surrounded by trees on three sides)
71-342	1972	TEC	Minor cracks on west seam. Surrounded by trees
71-345	No date	N/A	Patched and painted up to 1.5 m. from base. Extensive cracking street side. May have been hit located at intersection.
71-349	No date	N/A	Extensive cracking from base to 1.2 m. Many rust spots on west side. Missing access plate.
71-350	No date	N/A	Extensive cracking, spawling, severe rust stains north side. Missing access plate.
71-350	No date	N/A	Extensive cracking, spawling, many rust stains north side. Missing access plate.
71-356	No date	N/A	Extensive cracking north and west side. Many rust spots overall. Missing access plate.
71-357	No date	N/A	Extensive cracking north and west side. Cracks on both seams up to 4 m. Missing access plate.
71-360	No date	N/A	Patched and painted up to 3 meters. Cracks forming in patch. Extensive repairs Pole appears to have been hit. Missing access plate.
71-362	No date	N/A	Extensive cracks north and west side up to 2 meters. Many rust spots throughout the pole. Missing access plate.
71-125	1971	N/A	Spawling and rust north & west side. Many cracks at base.

* Utility developed registration number for pole. ** TEC = Stress Crete

Area 2

Street: Ellesmere Rd., from Brimley Rd. to Borough Dr. West access – Distance 0.25 Km

Estimated total distance in which concrete poles are utilised on this street 6km, sample size = 4%

Location: City of Toronto – Former Borough of Scarborough

Date of Survey: April 29, 2000

Notes: The street runs east & west. All poles are located on the north side. The two drive lanes are west bound. The south and east side of the pole is exposed to the street. The pole is located 2.5 meters from the street.

Type = Street Lighting Poles

Table D.2 Visual pole quality assessment - Area 2

Pole #*	Date of Manufacture	Manufacturer	Conditions
50-146	1972	TEC	Fracture at access plate. Otherwise excellent.
50-145	No date	N/A	Access plate missing. Excellent
50-144	No date	N/A	Extensive crack at base extending vertically .5 m
50-143	1972	TEC	Excellent. Two transformers on top.
50-142	1972	TEC	Excellent
50-141	1972	TEC	Facturing extending vertically from access plate north east side.
50-140	1972	TEC	Cracks and some small amounts of rust north and east side.
50-405	1972	TEC	Small cracks at access plate. Small cracks ate west and east side.
50-137	1972	TEC	Small cracks and rust 1 meter above base
50-136	1972	TEC	Small cracks with rust north & east side.
50-135	1972	TEC	Large cracks 1.2 meters above base on east side.
50-134	1972	TEC	Major cracks at base extending vertically to .75 m. Pole may have been hit. (Intersection).

* Utility developed registration number for pole. ** TEC = Stress Crete Inc.

Area 3

Street: Brimley Rd., from Ellesmere Rd. to Omni Ave. – Distance 0.25 Km

Estimated total distance in which concrete poles are utilised on this street 1 km, sample size = 20%

Location: City of Toronto – Former Borough of Scarborough

Date of Survey: April 29, 2000

Notes: The street runs north & south. All poles are located on the east side. The drive lane is north bound. The south and west side of the pole is exposed to the street. The pole is located 1.25 meters from the street.

Type = Street Lighting Poles

Table D.3 Visual pole quality assessment – Area 3

Pole #*	Date of Manufacture	Manufacturer	Conditions
40C-8100F-3-34	1984	Stress Crete	Minor cracks at base – minor cracks with rust west side
40B-13002 D-46-21	1993	Stress Crete	Excellent – early signs of cracks developing
40C-13637-3-32	1993	Stress Crete	Minor chips out - Discoloration
E40C-13980-3-43	1994	Stress Crete	Minor chips out at seams - Discoloration

*Utility Pole Manufacturer developed registration number for pole.

Area 4

Street: Brimley Rd., Ellesmere Rd. to Progress Ave. – Distance 0.6 Km

Estimated total distance in which concrete poles are utilised on this street = 1 km, sample size = 75%

Location: City of Toronto – Former Borough of Scarborough

Date of Survey: April 29, 2000

Notes: The street runs north & south. All poles are located on the west side. The drive lane is south bound. The north and east side of the pole is exposed to the street. The pole is located 1.25 meters from

Table D.4 Visual pole quality assessment – Area 4

Pole #*	Date of Manufacture	Manufacturer	Conditions
E40-16259-34-20	1996	Stress Crete	Excellent
	1979	Barratt Spun Concrete	Small cracks near access plate
	1994	Utility Structures Inc.	Discoloured. Excellent.
	1972	TEC **	Damaged at access plate. Small cracks with small rust spots
	1972	TEC	Broken access plate. Cracks at base to .2 meters with rust.
	1972	TEC	Broken access plate. Major cracks at south west side
	1972	TEC	Minor crack at access plate. Minor crack at base.
40B-1499D-3-121A	1996	Stress Crete	Vary minor cracks at seam.

*Pole company registration number (no utility pole number available).

** TEC = Stress Crete Inc.