EXECUTIVE SUMMARY

Environmental Life Cycle Assessment of Southern Yellow Pine Wood and North American Galvanized Steel Utility Distribution Poles

Applying the Life Cycle Impact Assessment (LCIA) Framework Described in LEO-SCS-002 (Committee Draft Standard, ANSI Process)

April 5th, 2013

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SCS Global Services
2000 Powell Street, Suite 600
Emeryville, CA 94608
www.SCSGlobalServices.com

SCIENTIFIC CERTIFICATION SYSTEMS

1 EXECUTIVE SUMMARY

1.1 Introduction

The American Iron and Steel Institute (AISI) estimates that approximately 185 million utility poles are in service in North America.[1] Wood poles comprise the majority of utility poles in the U.S. [2] However, some states and utilities have begun switching to steel poles, due to economical advantages over wood, for example Nevada, Arizona in 1997, and Austin, Texas in the early 1990's. [3,4] As different materials, steel and wood not only have different physical properties, but also different environmental impact profiles.

The goal of this study is to use life cycle assessment (LCA) to compare the environmental performance of utility poles made from wood and galvanized steel. To achieve this goal, the study compares the use of utility poles in the Southeastern United States, made from each of these competing materials. Today, utility poles in this region are primarily wood made from Southern yellow pine, often treated with chromated copper arsenate (CCA); this study assesses the implications of replacing these wood poles with galvanized steel poles over time.

This report provides a detailed documentation of a complex assessment. The intended audience of the Executive Summary is a knowledgeable member of the utility industry, while for the main body of the report; the intended audience is a knowledgeable LCA practitioner.

The intended application of this study is the consequential life cycle assessment comparing a system of wood utility poles, with a system of galvanized steel utility poles, in the Southeastern United States. The study conforms to ISO-14044 and the Final Committee Draft Standard, LEO-SCS-002[5] using advanced environmentally relevant indicators which provide a foundational basis for comparisons between the two systems.

1.2 Summary of Findings

This study compared two scenarios: Business-As-Usual (BAU) and Steel Pole Replacement (SPR), comparing the implications of the use of wood and galvanized steel utility poles in the Southeast. Of the thirty-five independent category indicators which were assessed, twenty-one show a clear benefit for the use of galvanized steel utility poles, four do not show a clear benefit towards either material choice, and ten show a clear benefit for the use of wood utility poles. (Note: This statement is not meant to imply that all environmental indicators should be "weighted" equally. Individual indicators should be considered separately in the context in which they will be used.)

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[1] Utility Poles. American Iron & Steel Institute. [http://www.smdisteel.org/en/Construction/Utility%20Poles.aspx] Accessed 3/28/13.

[2] Shaban, A.O. *Power Pole Research*. Cal Poly San Luis Obispo, Electrical Engineering. 1/14/02.

[3] Oliver, D., Arizona Public Service Co. *APS Selects Steel.* Transmission & Distribution World. 8/1/01. [http://tdworld.com/mag/power_aps_selects_steel/index.html]

[4] Padavick, J., Austin Energy. *Austin Energy Embraces Steel.* Transmission & Distribution World. 7/1/03. [http://tdworld.com/mag/power_austin_energy_embraces/index.html]

[5] Type III Life-Cycle Impact Profile Declarations for Products, Services, and Systems, is being developed under the open American National Standards Institute (ANSI) Process, administrated by the Leonardo Academy. See http://www.leonardoacademy.org/services/standards/life-cycle.html

Sections 1.2.1 through 1.2.4 of the Executive Summary describe the relative benefits of the SPR scenario for all impacts considered in the study. The remainder of the Executive Summary further explains the basis of the study findings, presents final results, and discusses the environmental advantages and trade-offs of the SPR scenario in more detail.

1.2.1 Impacts Showing a 75% or Greater Reduction in the SPR Scenario

Of all the category indicators assessed in this study, twelve showed a 75% or greater reduction in the SPR scenario, when compared to the BAU scenario. These category indicators include: Arsenic Resource Depletion; Chromium Resource Depletion; Terrestrial Biome Disturbance (SE Temperature Broadleaf & Mixed Forests); Terrestrial Biome Disturbance (SE Temperature Coniferous Forests); Terrestrial Forest Habitat Disturbance (Red-Cockaded Woodpecker); Terrestrial Habitat Disturbance (Eastern indigo snake); Terrestrial Habitat Disturbance (Frosted flatwoods salamander); Terrestrial Habitat Disturbance (Gopher tortoise); Terrestrial Habitat Disturbance (Indiana bat); Terrestrial Habitat Disturbance (Red Wolf); Terrestrial Habitat Disturbance (Reticulated flatwoods salamander); and Terrestrial Nesting Habitat Disturbance (Red-Cockaded Woodpecker).

In addition, there were a large set of impacts which could not be measured, but for which impact reductions of 75% or greater are anticipated if measurements were possible. This includes: the exposure of humans, flora, and fauna to toxic substances, resulting from arsenic ore extraction and refining in China; the exposure of workers to toxic herbicides in the United States Southeast as a result of herbicide application during forestry in this region; disturbance to wetland and freshwater biomes in the United States Southeast, resulting from forestry in this region; disturbance to suitable freshwater and wetland habitats for species in the United States Southeast, resulting from forestry in this region.

1.2.2 Impacts Showing a 25% to 75% Reduction in the SPR Scenario

Of all the category indicators assessed in this study, nine show an impact reduction between 25% and 75% in the SPR scenario, when compared to the BAU scenario. These category indicators include: Energy Resource Depletion; Water Use; Boron Resource Depletion; Fluorspar Resource Depletion; Manganese Resource Depletion; Nickel Resource Depletion; Tin Resource Depletion; Global Climate Change (Net); and Untreated Hazardous Waste (CCA-Treated Wood).

1.2.3 Impacts Showing a -25% to 25% Reduction in the SPR Scenario

Of all the category indicators assessed in this study, four show an impact reduction between -25% and 25% in the SPR scenario, when compared to the BAU scenario. These indicators should be interpreted as those without a clear benefit for either scenario, and include: Barite Resource Depletion; Arctic Climate Change; Ocean Acidification; and Ocean Thermal Loading (Net).

1.2.4 Impacts Showing a 25% Increase or Greater in the SPR Scenario

Of all the category indicators assessed in this study, ten show an impact increase of 25% or greater in the SPR scenario, when compared to the BAU scenario. These indicators are trade-offs for the SPR scenario, and include: Copper Resource Depletion; Lead Resource Depletion; Zinc Resource Depletion; Terrestrial Biome Disturbance (Western Great Lakes forests); Terrestrial habitat disturbance (Blanding's Turtle); Terrestrial Habitat Disturbance (Kirtland's Warbler); Terrestrial Habitat Disturbance (Wood turtle); Regional Acidification; Ground Level Ozone; and PM2.5.

1.3 Scope

1.3.1 Utility Pole System

For this study, the functional unit is the use of a system of one million 45-foot tall, Class 2/Grade B distribution poles, including production, installation, upkeep, and disposal of the poles over a 40 year period in the Southeastern United States. It is assumed that poles are uniformly distributed across the region falling under the purview of the Southern Electrical Reliability Council (SERC); this region represents most of the electrical distribution system in the US Southeast.

The pole height and class used in the utility pole system were chosen to be representative of a competitive pole specification. Steel poles are not typically competitive at present with the smaller Grade C wood poles and do not represent a realistic option for utilities. On the other hand, Class 2 steel poles are economically competitive with Grade B wood poles and are more likely to be considered by a utility interested in alternatives to wood.

In terms of design criteria, pole height is based mostly on desired clearance from surroundings. Most wood distribution poles in operation in this region are estimated to be between 35 and 50 feet tall.[6]

SCS selected a representative pole of each type of material for use in this study:

- Wood poles made from Southern yellow pine, grown in the Southeastern United States, and treated with chromated copper arsenic (CCA).
- Steel pole: galvanized steel produced using North American hot rolled steel coil.

The reference flows required to fulfill the functional unit are examined for both of these material choices, for two scenarios, to understand the implications to human health and the environment from these differing material choices. In order to examine life cycle impacts of the poles in the most straight-forward manner possible, this study assumes that 45-foot tall, Class 2, Grade B distribution steel and wood utility poles are functionally equivalent from the perspective of utility providers, and can be substituted on a one-to-one basis.

1.3.1.1 Average Service Lifetimes

In this study, the average service lifetime was estimated for each material type; this average lifetime was used to calculate annual average failure rates, determining the number of poles requiring replacement in each year of the study time horizon. These annual average failure rates were assumed to include replacements due to pole failure, including: catastrophic failure due to weather and other causes; failure due to corrosion or decay; and replacement due to defective materials. The average service lifetimes used in the study are described in Sections 1.3.1.1.1 and 1.3.1.1.2.

The replacement of poles for reasons other than failure (such as removal due to changes in right-of-way) was excluded from the assessment due to a lack of data. This bias does not significantly affect the results of the study, as pole failure is the dominant cause of pole replacements.

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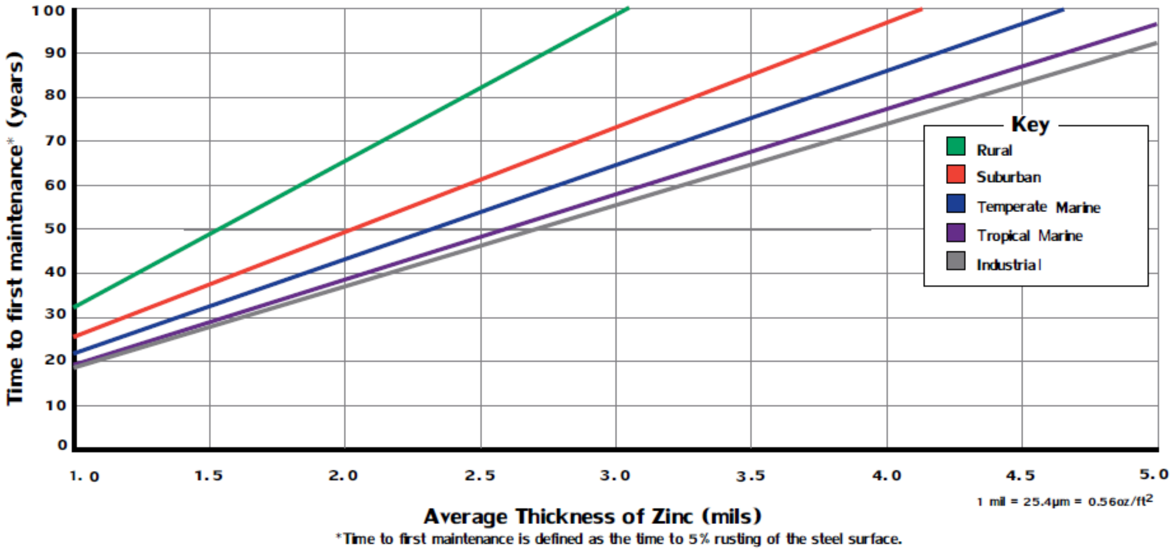
[6] Shaban, A.O. *Power Pole Research*. Cal Poly San Luis Obispo, Electrical Engineering. 1/14/02.

1.3.1.1.1 Galvanized Steel Utility Poles

While galvanized steel utility poles have not been used for a long enough period to determine average service lifetimes directly, research into similar steel structures, and known corrosion rates for galvanized steel, were used to estimate the average service lifetime.

In North Carolina, lattice transmission structures made from galvanized steel have proved to have 80-year lifespans.[7] While structurally different from galvanized steel poles, the coating used is very similar to that used for galvanized steel poles, and similar lifetimes can be expected.

The American Galvanizers Association provides estimates of the time to the first maintenance event for hot dipped galvanized steel based on the thickness of the zinc coating and the local climate (see Figure 1).



*Time to first maintenance is defined as the time to 5% rusting of the steel surface.

Figure 1. Time to the first maintenance event for galvanized steel.[8]

Applying this coating thickness to Figure 1, the time to first maintenance event (i.e., 5% surface rust) for a galvanized pole can be estimated as 65 years for tropical marine climate, 73 years for temperate marine, 81 years for suburban, and over 100 years for rural. The tropical and temperate marine climates comprise a relatively small portion of the study area, with much larger portions of the region represented by suburban and rural climates. Steel poles exhibiting surface rust may be coated, and the life of the pole extended beyond those estimates in Figure 1.

Based on this evidence, the average service lifetime of steel utility distribution poles in the US Southeast is estimated to be 80 years, corresponding to an annual average failure rate of 1.25%. Regular application of surface retreatments would likely extend the average service lifetime of steel poles beyond 80 years; however, these retreatments are not included in this study.

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[7] Terry, T. Tennessee Valley Authority. *TVA Linemen Install Poles in Hard-to-Reach Areas.* Transmission & Distribution World. 7/1/08.

[8] *Hot-Dip Galvanizing for Corrosion Protection – a specifier's guide."* American Galvanizers Association. 2012. http://www.galvanizeit.org/images/uploads/publicationPDFs/Galvanized_Steel_Specifiers_Guide.pdf?tracked=yes

1.3.1.1.2 Wood Utility Poles

It was determined that pole purchasers (i.e., utilities) would have the best understanding of the average service lifetime of wood poles. According to a survey of over 260 utilities in the United States, with a sample representing ~25% of poles in service, utilities have estimated the average wood pole service life as between 30 and 40 years.[9] This study uses the top end of the range from the survey: 40 years, corresponding to an annual average failure rate of 2.5%.

1.3.2 Selected Functional Unit and Study Time Horizon

For this study, the functional unit is the use of a system of one million 45-foot tall, Class 2/Grade B[10] distribution poles over a 40 year period in the Southeastern United States. This use encompasses only the required load-bearing support for distribution wires used in local power and telecommunications applications, not the use of the distribution wire infrastructure itself (i.e. electrical power distribution is excluded from the scope). The use of the wire infrastructure will not vary based on the type of support structure used, and was excluded from the scope.

This functional unit reflects the infrastructure required for supporting local distribution, not regional transmission, which requires a substantially different support infrastructure. A third alternative, the burial of distribution wires was not included in the study, as the goal of the study is to help inform decision making between different pole material options.

The timeframe of 40 years was chosen to capture differences in durability between the poles. The dynamics of the utility pole system over this 40 year period were assessed by including results at the beginning of the time horizon, and after 10, 20, 30, and 40 years. This provides clear “snapshots” of the benefits and trade-offs of phasing in steel poles at several points in time.

1.3.3 Scenarios Considered in the Assessment

The study considers the use of the utility system in the Southeast given two different scenarios, with a scope that is cradle-to-grave for both:

- The “business-as-usual” scenario (“BAU” scenario). As Class 2 wood poles fail, they continue to be replaced by Class 2 wood poles. This is the typical practice in the region.
- The “steel pole replacement” scenario (“SPR” scenario). As Class 2 wood poles fail, they are instead replaced by Grade B galvanized steel utility poles.

In both the BAU and SPR scenarios, the total number of utility poles in operation is held constant at one million poles, maintaining the same functional equivalency. The consequences to human health and the environment as a result of these two scenarios were assessed over a 40-year time horizon; the total number of poles of each type in service, for both scenarios, is shown in Figure 2. As can be seen, in the SPR scenario, after 40 years most (over 60%) utility poles are galvanized steel.

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[9] *Wood Pole Purchasing, Inspection, and Maintenance: A Survey of Utility Practice.* Mankowski, M., et al. Forest Products Journal. 52(11/12): 43-50. 2002.

[10] *IEEE 2012 National Electrical Safety Code (NESC).* NESC-2012. IEEE Standards. 2012.

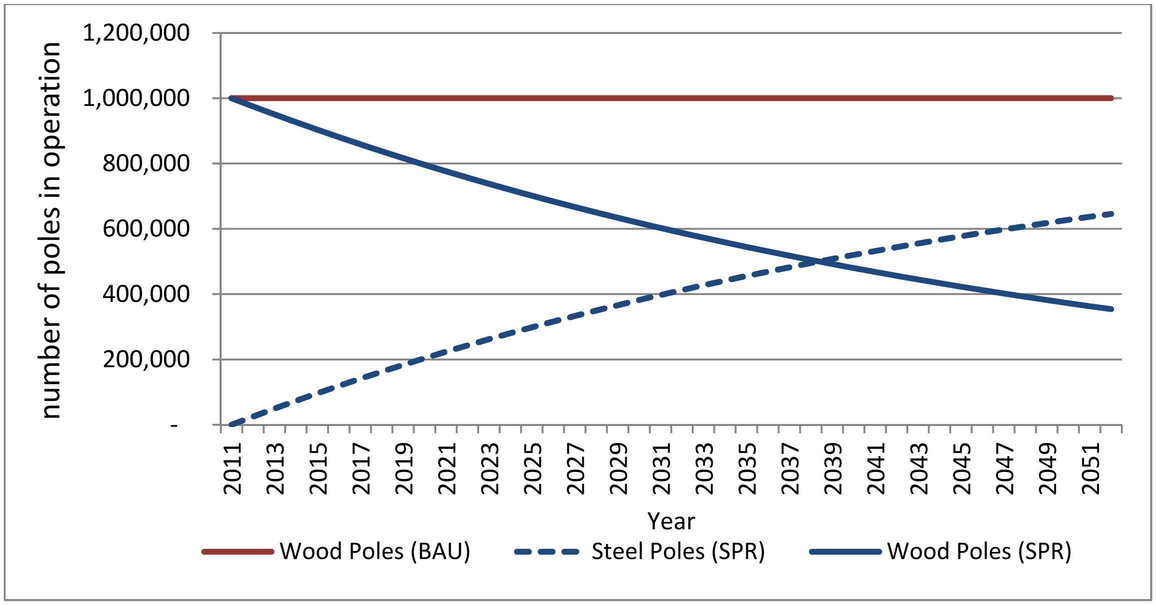

Figure 2. The number of wood and steel poles in service over the study time horizon in each scenario.

1.3.3.1 Reference Flows

In each scenario, there are four outputs required to fulfill the function expressed by the functional unit, which is the maintenance of a system of 1 million utility poles. These four outputs are: production of utility poles (including installation); inspection of utility poles; retreatment of utility poles; and disposal of utility poles. In the SPR scenario, these outputs include the inspection, retreatment, and disposal, of wood poles which were in place in at the beginning of the study time horizon. The reference flows for ten year intervals within the study time horizon are shown in Table 1 and Table 2.

Table 1. Reference flows for BAU scenario. Values shown are the reference flows in the year of the time horizon shown.

		BAU Scenario		
Year	Poles Produced (Wood)	Pole Inspections (Wood)	Pole Retreatments (Wood)	Poles Disposed Of (Wood)
2012	25,000	125,000	66,667	25,000
2022	25,000	125,000	66,667	25,000
2032	25,000	125,000	66,667	25,000
2042	25,000	125,000	66,667	25,000
2052	25,000	125,000	66,667	25,000

Table 2. Reference flows for SPR scenario. Values shown are the reference flows in the year of the time horizon shown.

			SPR Scenario			
Year	Poles Produced (Steel)	Pole Inspections (Steel & Wood)	Pole Retreatments (Wood)	Poles Landfilled (Wood)	Poles Recycled (Steel)	Poles Landfilled (Steel)
2012	25,000	125,000	66,667	25,000	0	0
2022	22,702	97,041	51,755	19,408	2,962	76
2032	20,420	94,806	40,179	15,067	5,026	129
2042	18,648	75,967	31,192	11,697	6,628	170
2052	17,273	76,316	24,215	9,081	7,871	202

The number of poles required to be produced is significantly less for the SPR scenario, due to the longer average service lifetime of galvanized steel utility poles. The number of required inspection events is also less, as steel poles require less frequent inspections than wood poles.

1.3.4 Unit Processes included in the Scenarios

The unit processes included in the scope of the SPR scenario are those which are affected by the production, inspection, retreatment, or disposal of poles occurring in this scenario. This includes unit processes which are in the value chain and are directly affected by the continuing inspections, retreatments, and disposal of wood poles already existing at the beginning of the study time horizon, and those in the value chain of steel utility pole production, maintenance, or disposal. These unit processes must increase or maintain their output to meet market demand in the SPR scenario. Impacts from these unit processes are the *primary consequences* of the SPR scenario.

The scope additionally includes those unit processes which show a significant decrease in operations from decreased market demand due to the declining use of wood utility poles; these are *secondary consequences* of the SPR scenario. In the SPR scenario, the assessment considers a strategy of utility pole deployment of sufficient scale to have large-scale consequences in other product systems, such as the production of CCA treatment chemical. This scope is required for an LCA with this goal, according to the additional references of the LEO-SCS-002 standard.[11]

Five primary criteria were used to identify the unit processes included in the scope of the analysis, affected by the secondary consequences of the SPR scenario:

1. The geographical scale and time horizon of the potential change to unit processes.
2. The current limits of the market supplied by each unit process, including thresholds.
3. Trends in the volume of the market for the product supplied by the unit process.
4. Changes in supply and demand for the product supplied by the unit process, and its required inputs.
5. The relative scale of production of the unit process to the total relevant market.

These guidelines are based on research to date in consequential LCA modeling.[12,13] In the SPR scenario, wood utility pole production is reduced by 25,000 each year; utility pole inspections decline by 40% after 40 years; and the required number of CCA-treated wood poles which must be disposed of each year decreases by over 20,000 by the end of the study time horizon. It is anticipated that these declines in production, inspections, and pole disposals will result in market effects affecting several unit processes.

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[11] See Provisions 6.5.4. and 7.2.4 of the International Reference Life Cycle Data System: ILCD handbook. *General guide for Life Cycle Assessment-Detailed Guidance.* First edition. Joint Research Center of the European Commission. 2010. The decision context of this LCA is considered to be “Situation B” under this handbook, corresponding to an LCA providing “decision support for strategies with large-scale consequences in the background system or other systems.”

[12] Ibid.

[13] Weidema BP, Ekvall T, Heijungs R (2009) *Guidelines for application of deepened and broadened LCA*. Technical Report of CALCAS project. http://www.calcasproject.net

The unit processes included in the scope of the BAU scenario are those which are affected by the production, inspection, retreatment, and disposal of wood poles in this scenario. Since this scenario describes the utility pole system in the Southeast as it exists today, these unit processes are active currently. As there are no projected changes in market dynamics for any product systems for the BAU scenario, there are no secondary consequences. While the unit processes included in the SPR scenario include both primary and secondary consequences, the BAU scenario includes only primary consequences of wood utility pole production, inspection, retreatment, and disposal.

The key unit processes which are major contributors to final indicator results are shown for both scenarios in Table 3.

Table 3. Key unit processes included in the scope of assessment for the two scenarios.

SPR Scenario	BAU Scenario
Iron Ore Mining in North America	Forest Management and Timber Harvest for Utility Poles
Zinc Ore Mining	Milling and Kiln Drying
Steel Production	Pressure Treatment
Pole Fabrication	Chromated and Copper Arsenate (CCA) Chemical Production
Galvanization	Installation of Wood Utility Poles
Zinc Smelting	Maintenance of Wood Utility Poles
Transportation	Pesticide Production for Pole Maintenance
Installation of Steel Utility Poles	Other Use Phase Impacts for Wood Utility Poles
Maintenance of Steel Utility Poles	End-of-Life for Wood Utility Poles
End-of-Life for Steel Utility Poles	
Reduction in Wood Pole Pressure Treatment	
Reduction in Chromated Copper Arsenate (CCA) Chemical Production	
Reduction in Inspections of Wood Utility Poles	
Reduction in End-of-Life for Wood Utility Poles	

1.4 Life Cycle Inventory

For galvanized steel poles, inventory data from the WorldSteel Association representing North American hot rolled coil steel was used to model steel production and associated upstream processes. Pole fabrication data were available directly from participating suppliers in Canada (Ontario) and the US Midwest (Kansas). This study assumes a 50/50% split in pole production from these two fabricators. The electricity supply mix from appropriate regional grids was used for each fabricator, calculated according to data for the relevant North American Electric Reliability Council (NERC) region. These data were used in lieu of the national average of electricity generation data. All other unit processes were modeled using representative data from the Ecoinvent[14] and US LCI[15] databases.

For wood poles, the Timber Product Output Reports and Forest Inventory Data Online (FIDO) databases provided by the Forest Inventory and Analysis (FIA) Research Work Unit of the USDA Forest Service (USFS) were used to quantify land use impacts and timber and pole production statistics.[16] SCS data for CCA production was based on a previous SCS study for the production of a 50% solution of this chemical. Specific data for the retreatment pesticides were not available, and

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[14] Ecoinvent v2.2. Swiss Centre for Life Cycle Assessment.

[15] US Life-Cycle Inventory Database http://www.nrel.gov/lci/

[16] Accessible at http://srsfia2.fs.fed.us/

this study used data for production of a generic pesticide[17]. Data for application quantities of pesticide were based on publically available information for pesticide treatment depth and thickness. The electricity supply was modeled in the same fashion as for steel utility poles, based upon the relevant NERC regions. All other unit processes were modeled using generic data from the Ecoinvent and US LCI databases.

1.5 Summary of Results

The time horizon of the study is 40 years; results for this horizon are shown in Table 4.

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[17] *pesticide unspecified, at regional storehouse, RER, [kg] (#116).* Ecoinvent v.2.2. 2010. Swiss Centre for Life Cycle Inventories.

Table 4. Summary of results for each scenario, by category indicator. All units of tons refer to metric tons. Impact Groups are shown in bold. Category indicators shown without bold.

Category Indicator	Units	Business as Usual (BAU)	Steel Pole Replacement (SPR)
Extracted Resource Depletion Group			
Energy Resource Depletion	Thousand Barrels of Oil eq.	698	364
Water Use	Thousands of acre-feet	299	185
Arsenic Resource Depletion	Tons Arsenic (As) eq.	3,375	-3,377
Barite Resource Depletion	Tons Barite ($BaSO_4$) eq.	62	54
Boron Resource Depletion	kg Boron Trioxide (B_2O_3) eq.	1,145	720
Chromium Resource Depletion	Tons Chromium (Cr) eq.	4,158	-4,098
Copper Resource Depletion	Tons Copper (Cu) eq.	22	41
Fluorspar Resource Depletion	Tons Fluorspar (CaF_2) eq.	136	93
Lead Resource Depletion	kg Lead (Pb) eq.	849	2,832
Manganese Resource Depletion	Tons Manganese (Mn) eq.	17	11
Nickel Resource Depletion	Tons Nickel (Ni) eq.	48	17
Tin Resource Depletion	kg Tin (Sn) eq.	149	112
Zinc Resource Depletion	Tons Zinc (Zn) eq.	43	26,093
Land Use Ecological Impact Group			
Biome Disturbance (Western Great Lakes Forests)	Acres fully disturbed biome eq. * yrs	0	615
Biome Disturbance (SE Mixed & Broadleaf Forest)	Acres fully disturbed biome eq. * yrs	276,000	0
Biome Disturbance (SE Conifer Forest)	Acres fully disturbed biome eq. * yrs	202000	0
Wetland Biome Disturbance	Not measured		
Habitat Disturbance (Blanding's turtle)	Acres fully disturbed habitat eq. * yrs	0	615
Habitat Disturbance (Wood Turtle)	Acres fully disturbed habitat eq. * yrs	0	615
Habitat disturbance (Kirtland's warbler)	Acres fully disturbed habitat eq. * yrs	0	615
Forest Habitat Disturbance (Red-Cockaded Woodpecker)	Acres fully disturbed habitat eq. * yrs	386,000	0
Habitat Disturbance (Eastern indigo snake)	Acres fully disturbed habitat eq. * yrs	386,000	0
Habitat Disturbance (Frosted flatwoods salamander)	Acres fully disturbed habitat eq. * yrs	153,000	0
Habitat Disturbance (Gopher tortoise)	Acres fully disturbed habitat eq. * yrs	145,000	0
Habitat Disturbance (Indiana bat)	Acres fully disturbed habitat eq. * yrs	386,000	0
Habitat Disturbance (Red Wolf)	Acres fully disturbed habitat eq. * yrs	386,000	0
Habitat Disturbance (Reticulated flatwoods salamander)	Acres fully disturbed habitat eq. * yrs	145,000	0
Nesting Habitat Disturbance (Red-Cockaded Woodpecker)	Acres fully disturbed habitat eq. * yrs	540,000	0
Wetland & Freshwater Habitat Disturbance	Not measured		
Impacts from GHG/BC Emissions Group			
Global Climate Change (Cooling Only)	Thousands of tons CO_2 eq.	474	286
Global Climate Change (Warming Only)	Thousands of tons CO_2 eq.	-197	-170
Global Climate Change (Net)	Thousands of tons CO_2 eq.	277	114
Arctic Climate Change	Thousands of tons CO_2 eq.	23	28
Ocean Acidification	Thousands of tons CO_2	226	237
Ocean Warming	Thousands of tons CO_2 eq.	618	553
Ocean Cooling	Thousands of tons CO_2 eq.	-158	-136
Ocean Thermal Loading (Net)	Thousands of tons CO_2 eq.	460	417
Regional Environmental Impacts from Emissions Group			
Regional Acidification	Tons of SO_2 eq.	2,470	3,670
Ecotoxicity	Not measured		
Human Health Impacts from Emissions Group			
Ground Level Ozone Exposure Risks	Persons * hours * ppm O_3	45,000	74,000
PM2.5 Exposure Risks	Persons * hours * µg PM2.5 eq. / m^3	15,000	23,000
Toxic Air Emissions – Effects from Inhalation	Not measured		
Toxic Air and Water Emissions – Effects from Ingestion	Not measured		
Risks from Untreated Hazardous Waste Group			
CCA-Treated Pole Disposal	Tons of CCA-treated wood	593,000	162,000

** Negative indicator results indicate net reductions in impact when secondary consequences are considered.*

1.6 Discussion of the Environmental Advantages of SPR Scenario

1.6.1 Reduction in Greenhouse Gas and Aerosol Emissions Contributing to Global Climate Change

When considered over the entire 40-year time horizon, the accumulated emissions contributing to Global Climate Change are higher for the BAU scenario (see Table 4). In the BAU scenario, the major contributors to these results are: fossil fuel combustion during electricity consumption required for the production of CCA treatment chemical; emissions of greenhouse gases and aerosols from installation of wood poles; and the production of wood from Southern yellow pine, from forest management practices based in even-aged forest management, which results in large losses of forest carbon storage, between 20 to 30% per acre, equivalent to the loss of storage of 20 to 40 tons of carbon dioxide per acre.

To better understand the significance of the indicator results for Global Climate Change, a simplified uncertainty analysis was conducted. This simple analysis provides a clear picture of the significance of the differential observed between the BAU and SPR scenarios in Table 4. This assessment included three contributions to uncertainty:

- Uncertainty related to Stressor Characterization Factors. The Intergovernmental Panel on Climate Change (IPCC) estimates that GWP factors based on direct effects have an uncertainty of ±35% for the 5 to 95% (90%) confidence range.[18] This uncertainty was used for all S-CFs for this category indicator.
- Uncertainty related to inventory data. There was no way to evaluate the uncertainty related to inventory data in these scenarios. An uncertainty of ±15% for the 5 to 95% (90%) confidence range was assumed, which is considered to be reasonable given the overall data quality of the study, which used specific data for most of the key unit processes.
- Additional uncertainty inherent in sulfur dioxide emissions. This includes the uncertainty related to the Precursor Conversion Factor for sulfur dioxide forming tropospheric sulfate aerosols, and the uncertainty related to the trends in projections of these emissions over time. Recent research in establishing the P-CF independently found a factor very close to the value used in this study, suggesting the uncertainty is low for this factor. Furthermore, the sensitivity of results to the projections of sulfur dioxide emissions over time was found to be low, as described in Section 5 of the report body. [19,20] An additional uncertainty of ±15% for the 5 to 95% (90%) confidence range was used for results from sulfur dioxide emissions.

These three sources of uncertainty were combined in quadrature to obtain an overall uncertainty of ±38% (±41% for the characterization of sulfur dioxide emissions) for both the BAU and SPR scenarios, which was used for the 90% confidence range. The category indicator results are shown in a whisker plot in Figure 3.

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[18] Intergovernmental Panel on Climate Change: Fourth Assessment Report. *Climate Change 2007: Working Group I: The Physical Science Basis. 2.10.2: Direct Global Warming Potentials.* Retrieved on 8/2/2012 from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

[19] Shindell, D.T., G. Faluvegi, D. M. Koch, G. A. Schmidt, N. Unger, S. E. Bauer. *Improved Attribution of Climate Forcing to Emissions.* 30 October 2009. Vol 326, 716-719. Science Magazine.

[20] Based on SCS internal data.

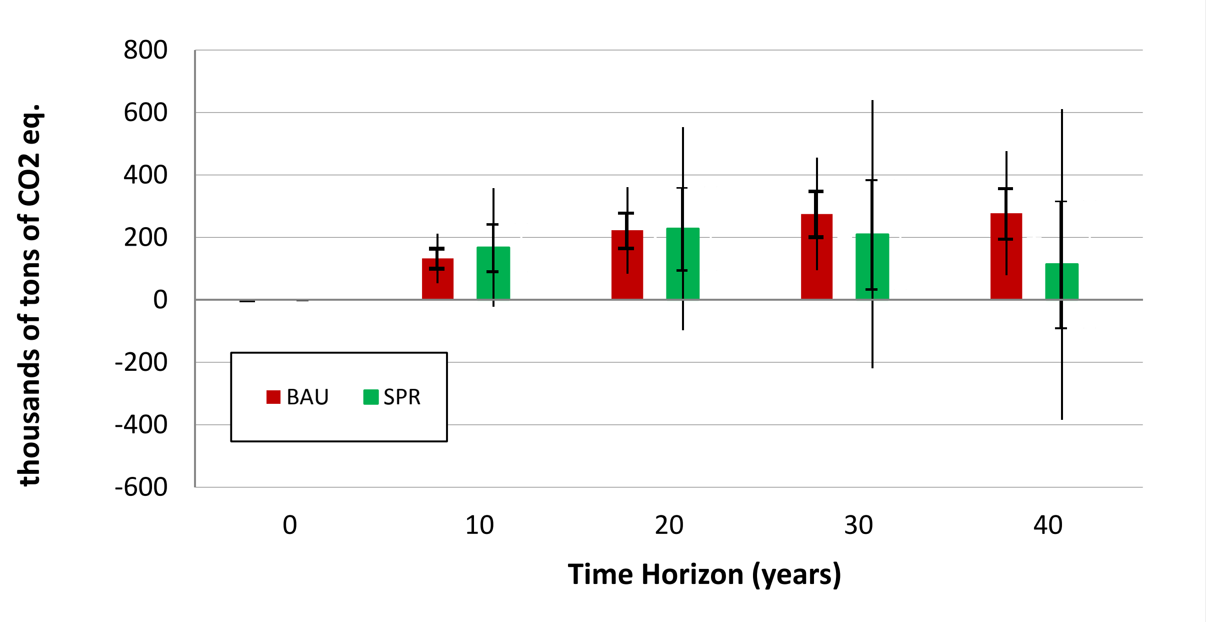

Figure 3. A whisker plot of category indicator results for Global Climate Change (Net). The 90% confidence intervals are shown for all results in the time horizon, along with the first and third quartiles for each scenario.

As this figure shows, there is an overlap in category indicator results, due to the uncertainties of the results in BAU and SPR scenarios. The uncertainty is a result of the emissions in both scenarios, which are contributing to warming and cooling. In both scenarios, the negative sign of indicator results related to sulfur dioxide emissions reduces the mean value of the category indicator results; however, the uncertainty related to this flow increases the magnitude of the overall uncertainty additively. Furthermore, for the SPR scenario, the secondary consequences have associated uncertainty, which further increases the uncertainty.

Based on this uncertainty analysis, it is estimated that there is a 70% likelihood that the SPR scenario has a lower indicator result for Global Climate Change (Net) after 40 years.

1.6.2 Reduction in Land Use Ecological Impacts

While not directly comparable due to the different biomes and species affected, the scale of the results shown in Table 4 indicates that the land use ecological impacts in the SPR scenario are dramatically less. When averaged over the 40-year time horizon, the results for terrestrial biome disturbance are equivalent to the full disturbance of approximately 12,000 acres for the BAU scenario, compared to only approximately 15 acres in the SPR scenario.

The differential in the disturbance to wetlands is even larger; if data were available to quantify a result for Wetland Biome Disturbance arising from forest plantations of Southern yellow pine, it is anticipated that the differential between the two scenarios would be nearly four orders of magnitude.

When the impacts from disturbance to wetlands and freshwater habitats are included, the number of species impacted in the SPR scenario is less than 5% of that in the BAU scenario (see Table 5). This does not consider the floral species which are impacted, which is again expected to be a substantially longer list for forestry. If data were available to quantify the severity and spatial extent of disturbance to suitable habitat for these species, the BAU scenario is expected to have indicator results three to four orders of magnitude higher than the SPR scenario, for twenty times as many species.

Given all of these considerations, the reduction in land use ecological impacts is considered a primary advantage of the SPR scenario.

1.6.2.1 Land Use Ecological Impacts from Southern Yellow Pine Production

1.6.2.1.1 Terrestrial Biome Disturbance to Forests in the Southeast

The United States Forest Service estimates that in 2009 in the Southeast, roughly 55 million acres were covered in Loblolly-shortleaf pine forests, and 13 million acres were covered in Longleaf-slash forests; the two forest types which produce Southern yellow pine. Most forest management in the region utilizes even-aged forestry in ”plantation” stands, where entire stands of forest are cut at one time, and allowed to re-grow before being cut again on a regular cycle. This type of forest management is designed to optimize wood production and profit, with little or no consideration of the quality of the forest ecology. In the South in 2007, 159 million out of 200 million acres were in plantations, accounting for nearly 80% of all timberland in the region. This type of forest management creates a landscape consisting of a patchwork of forests in different age classes (see Figure 4).

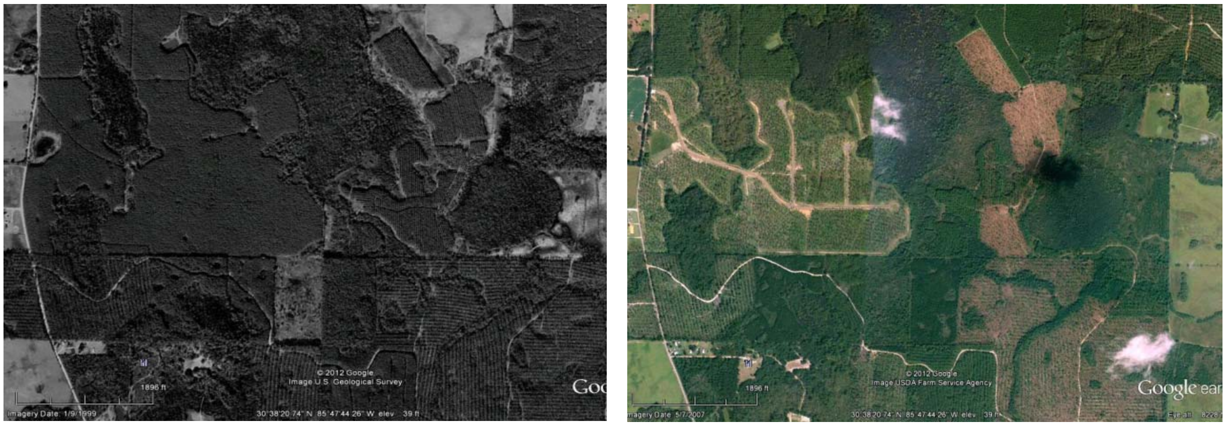

Figure 4. A site in Alabama showing a patchwork of clear cuts. The photo on the left was taken in January, 1999; the photo on the right in May, 2007. Lat/Lon: 30°38'12.07"N, 85°47'35.52"W.

Of the plantation forest in the region producing Southern yellow pine, 97% are 40 years old or less; 75% are less than 20 years old. This indicates that the majority of wood produced in the region is from even-aged forestry, on rotation cycles less than 40 years. These practices impact two types of forest biome in the Southeast, as defined by the WWF scheme; “Temperate Broadleaf and Mixed Forest,” and “Temperate Coniferous Forest”.

The forests in this region undergoing plantation forestry are maintained in a state which is highly disturbed compared to a natural forest, resulting in a wide set of land use ecological impacts which have significantly altered plant communities in both of these biomes. These forest management practices have threatened the long-term persistence of many species; a large part of the undisturbed biomes are now irreversibly lost, having been converted to agriculture or plantation-based forestry ("tree farms"). Longleaf-slash forests are currently on the decline across the entire region, as a result of fire suppression and conversion of forests to faster-growing loblolly-shortleaf forests.[21]

All of these impacts contribute to a biome which is highly disturbed, across large areas of forest. Based on the study findings, the plantation style forestry in this region creates a landscape which is on the average over 50% disturbed compared to a natural forest.

1.6.2.1.2 Wetland Biome Disturbance

As a result of forestry in the Southeastern United States, a substantial number of wetlands in the Southeast have been disturbed since the baseline condition in the late 1880s. The hardwood species which can be planted and harvested in wetland areas are significantly less productive than Southern yellow pine species, and conversion from wetland forest to managed pine plantations accounts for most of the historic changes in the freshwater forested category of wetland in the southeastern United States.[22] Many wetlands have been drained ("de-watered") and fully converted to harvestable forestland, resulting in full disturbance to the wetland biome over very large areas.

As well as the direct disturbance to converted wetlands, these activities indirectly affect downstream receiving water bodies and wetlands. Conversion of wetlands to forests leads to significant nutrient loadings from the decomposition of dewatered coastal plains soils, with affected downstream biomes including rivers, downstream freshwater wetlands, and coastal brackish wetlands. These indirect effects have resulted in large areas of wetlands experiencing partial disturbance throughout the Southeastern United States, as wetlands are converted from one form to another (e.g. from forested freshwater wetland to emergent wetland). These impacts have resulted in significant disturbance to the hydrology of affected freshwater and wetland biomes over very large areas, in addition to the areas of wetland which were directly converted to forest.[23]

While disturbance to wetlands is still ongoing, the majority of wetland conversion occurred in the 19th and early 20th century; from the 1780's to the mid-1980's, Alabama lost between 50-95% of its wetlands, with Georgia and Florida losing as much as 50%.[24] The conversion to even-aged plantation stands was at its peak in the early 1900s, when ambitious attempts to drain and convert wetlands were well underway. In the 1930's, the U.S. Government provided essentially free engineering services to farmers to drain wetlands; in the 1940's, the Government continued to share the cost of drainage projects. This included coordinated efforts to remove surface water from wetlands, resulting in notable wetland losses between 1900 and 1950 in Alabama, Georgia, and Florida.[25]

Even after this era of significant wetland conversion, until the mid-1990s, the impacts of forestry on wetlands were virtually unregulated. Activities such as earthmoving, planting, seeding, cultivating, minor drainage, and harvesting, were exempt from regulation under Section 404 of the Clean Water

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[21] *Forest Resources of the United States.* United States Forest Service. 2007.

[22] U.S. Fish and Wildlife Service, Fisheries and Habitat Conservation: Status and Trends of Wetlands in the Conterminous United States, 1987-1998. (Report to Congress). T.E. Dahl.

[23] Personal correspondence, Steven I. Apfelbaum, Applied Ecological Services, Inc. Dated 3/22/3012, 4:13AM.

[24] Dahl, T.E. and G.J. Allord. 1996. History of wetlands in the conterminous United States. In. J. D. Fretwell, J.S. Williams, and P. J. Redman (compilers) National Water Summary on Wetland Resources. U.S. Geological Survey.

[25] Ibid.

Act.[26] In the 1990s, state and federal government regulatory agencies began to provide guidance to clarify circumstances where forestry operations required permitting under the Clean Water Act. Permits were required, however, only in certain forested wetland types.

While large-scale conversion rates of wetlands to forest management operations have declined in the region since the first half of the 20th century, the converted and disturbed wetlands are in a persistently disturbed state; these impacts are still attributed to the wood utility pole system, due to the historical nature of the baseline condition.

Additionally, disturbance is still occurring to wetlands as a result of silviculture. Some activities associated with forest plantations which cause disturbance to freshwater biome and wetlands include: site preparations and timber stand management practices that alter or eliminate site hydrology; construction of forest roads required to access cut timber sites; installation of drainage ditches through existing wetlands; bedding of sites; subsurface drainage; and levee construction, filling, and channelization (see Figure 75). [27]

Figure 5. The drainage ditch in the foreground effectively altered wetland hydrology and was still functional several years following development of this pine plantation. Examples like this demonstrate the persistent wetland disturbance in the region.

The first half of the 20th century was the period since the baseline condition when the most significant levels of disturbance occurred as a result of conversion to even-aged Southern yellow pine stands in the region. Since this period, the rate of wetland loss has declined by as much as 85% nationwide, when considering all causes. [28] However, the available data can only characterize impacts to wetlands in roughly the last 15 years, which accounts for a very small fraction of the total historic disturbance level.

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[26] U.S. Fish and Wildlife Service, Fisheries and Habitat Conservation: Status and Trends of Wetlands in the Conterminous United States, 1987-1998 (Report to Congress). T.E. Dahl.

[27] Ibid.

[28] U.S. Fish and Wildlife Service, Fisheries and Habitat Conservation: Status and Trends of Wetlands in the Conterminous United States, 2004-2009 (Report to Congress). T.E. Dahl.

The scale of wetland conversion in the years where data are available sets a lower bound on the disturbance level associated with Southeastern forestry; data from the United States Geological Survey was used to understand the extent of wetlands converted for silviculture from 1986-2009.[29, 30,31] These data indicate that approximately 470,000 acres of freshwater wetlands were converted in this 23-year period nationwide, compared to approximately 14,000 acres of wetlands converted in the Mesabi Iron Range since the late 1880s. These values include all disturbed lands in the United States; the wetland area disturbed by forestry is six times greater than the entire area affected by mining activities, including both terrestrial and wetland areas.

Nationally, in the last 23 years, nearly one hundred times more area of wetlands were disturbed for silvicultural purposes than the wetland area disturbed in the Mesabi Iron Range in the last 130 years. This corresponds to a rate of wetland conversion which is 600 times as high for the production of wood products on a holistic basis; however, this does not include the much higher rate of wetland disturbance which occurred in the early 1900s, and this should be considered a significant underestimate, and the actual differential is very likely to be as high as a million-fold. Wetland Biome Disturbance is a significant impact in the BAU Scenario. This is illustrative of the significant impacts to wetlands of the forest management system used to produce wood utility poles.

1.6.2.1.3 Key Species Loss

Key species included in the study were those on the USFS Threatened and Endangered Species list, or the International Union for the Conservation of Nature Red List of Threatened Species. [32,33] The assessment for terrestrial habitat disturbance was based on the same methods used to assess terrestrial biome disturbance; however, as no data were able to quantify the spatial extent or severity of disturbance to wetland or freshwater biomes, the list of species impacted was compiled without quantification of these distinct category indicators.

The number of species impacted for each scenario is shown in Table 5. This table shows that when considering all species impacted, without considering for the severity or spatial extent of habitat loss, the BAU scenario has significantly higher impacts, affecting almost 90 species. The Southeastern United States is considered a hot spot for threatened and endangered species, particularly those existing in wetland and freshwater habitats.

Table 5. Summary of the number of species impacted in both scenarios.

	BAU Scenario	SPR Scenario
Number of key species affected	89	3

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[29] U.S. Fish and Wildlife Service, Fisheries and Habitat Conservation: Status and Trends of Wetlands in the Conterminous United States, 1987-1998. (Report to Congress). T.E. Dahl.

[30] U.S. Fish and Wildlife Service, Fisheries and Habitat Conservation: Status and Trends of Wetlands in the Conterminous United States, 1998-2004. (Report to Congress). T.E. Dahl.

[31] U.S. Fish and Wildlife Service, Fisheries and Habitat Conservation: Status and Trends of Wetlands in the Conterminous United States, 2004-2009. (Report to Congress). T.E. Dahl.

[32] United States Fish and Wildlife Service: Endangered Species Program. *Species Searchmap.* Accessed on 2/24/2012 from http://www.fws.gov/endangered/species/index.html.

[33] International Union for the Conservation of Nature: Red List of Threatened Species. Accessed on 2/24/2012 from http://www.iucnredlist.org/

1.6.3 Reduction in Hazardous Emissions Affecting Humans, Flora, and Fauna

Emissions from arsenic and chromite ore extraction, required for CCA production, have impacts which are significant in nature and large in spatial extent; additionally, workers exposed to toxic herbicides during forestry are another significant impact to human health. None of these impacts occur as a result of the primary consequences of the SPR scenario, and the secondary consequences are projected to lead to a decline in arsenic ore mining and smelting activities in China, resulting in significant impact reductions for human health and the environment.

1.6.3.1 Emissions from Arsenic Ore Extraction

Due to environmental concerns from mining and smelting, arsenic trioxide has not been produced in the United States since 1985. In response to environmental concerns and human health issues, the wood-preserving industry made a voluntary decision to stop using CCA to treat wood for decks and outdoor residential use in 2003; however, because of known performance and lower costs, CCA is still used in nonresidential applications, such as the treatment of utility poles.[34]

Due to this voluntary ban on CCA use for most wood products, imports of arsenic trioxide (the primary chemical constituent of CCA) into the United States have declined since 2003 by roughly 70%, when roughly 20,000 tons of this material was imported. The arsenic trioxide used in the BAU scenario is mined in China, by far the largest producer of arsenic trioxide worldwide.[35] China produces significant amounts of arsenic ores (primarily realgar and orpiment), and also manufactures arsenic trioxide from these materials. While no inventory or environmental characterization data for arsenic mining were available to calculate indicator results, case studies of several representative arsenic ore mining facilities in China were analyzed to determine the severity of impacts from this step in the supply chain for CCA production. Severe impacts from arsenic mining and smelting were found to be well documented.

A study of a site in Wenshan County in Yunnan Province, China, revealed severe impacts which can be attributed directly to mining and smelting of arsenic. This site was formerly an extensive mining and smelting complex, consisting of four arsenic processing plants several kilometers apart (see Figure 6). When the plant was closed in 2004, it had been operating for 40 years, resulting in decades of accumulated mining and smelting residues, all stored using primitive technology with no environmental protections.[36] At this site, residues from kilns used to smelt the arsenic ore (including oxidized arsenic fume) were shoveled and dumped over the hillside next to the facility parking lot; about 60,000 tons of residue are estimated at this single dumpsite.

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[34] USGS Minerals Commodity Summary 2012. *Arsenic.* http://minerals.usgs.gov/minerals/pubs/commodity/arsenic/mcs-2012-arsen.pdf

[35] The Encyclopedia of Earth: Arsenic. Retrieved on 4/6/2012 from http://www.eoearth.org/article/Arsenic?topic=49557#gen1

[36] Remediation of Legacy Arsenic Mining Areas in Yunnan Province, China. Blacksmith Institute Journal of Health & Pollution. Vol. 1, No. 1-Feb 2011. Retrieved on 4/6/2012 from http://www.journalhealthpollution.org/ojs/ojs-2.2.4/index.php/journalhealthpollution/article/view/23/7

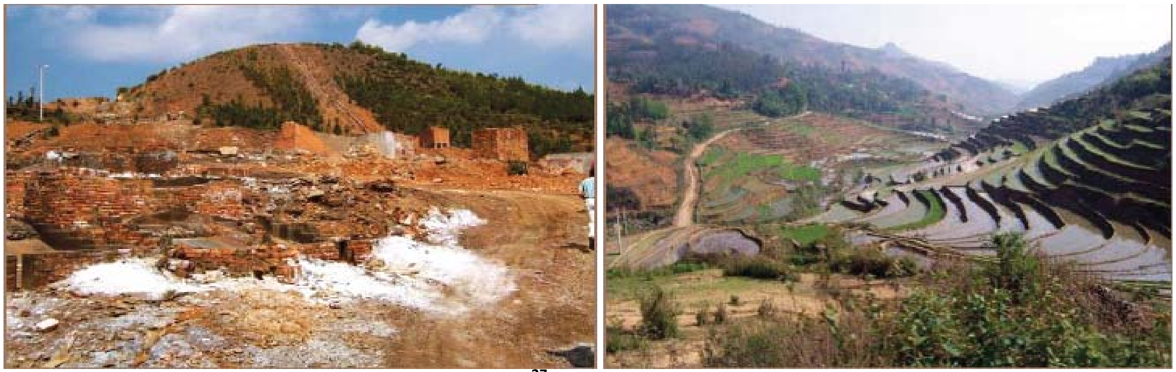

Figure 6. (Left) Refining process area, Wenshan site.[37] (Right) Area surrounding Wenshan arsenic mine site. In 2000, a tailings pond retention wall collapsed, discharging significant amounts of highly toxic arsenic residues into the rice paddies shown in the photograph.

A survey documented in 2000 the collapse of a dam for one of the tailings ponds at this site, causing arsenic residues to enter terraces of rice paddies, severely impacting dozens of terraced farms (see Figure 6). As a result of poor containment such as this, emissions of hazardous substances are expected on a regular basis. These emissions have resulted in the contamination of local streams to levels of more than 1.0 mg/L arsenic, significantly exceeding the 0.01 mg/L arsenic health thresholds identified by the US EPA.[38,39,40]

Other surveys around China have documented arsenic concentrations as high as 73 mg/L in water bodies adjacent to arsenic mining and processing operations, which can be linked directly to wind and storm water runoff from waste materials which are inadequately armored. Arsenic concentrations such as these are thousands of times higher than relevant guidelines established by agencies such as the US EPA.[41] Other studies assessing concentrations of arsenic in rice produced in China found that arsenic concentrations were greater than four times as high for rice sampled from mining and smelting districts, indicating another significant exposure pathway for humans.[42]

Mine sites such as described here are located in many parts of China, and these examples are considered to be representative of current arsenic mining practices in this region. These data all indicate that arsenic ore production in China, used in the production of CCA preservative, is a significant impact which could be resulting in the exposure of millions of people to elevated levels of arsenic, known to be chronically toxic and carcinogenic. Although health effects in the local human population are extremely likely, these are not well documented due to a lack of environmental health monitoring in the area. Due to the persistent nature of arsenic, chronic exposures and health impacts are expected to be significant, and are almost certainly still affecting substantial numbers of people.

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[37] Ibid

[38] Ibid

[39] United States Environmental Protection Agency: Arsenic in Drinking Water. Retrieved on 4/6/2012 from http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/index.cfm

[40] Although US EPA has no jurisdiction in China, US EPA thresholds are described because they are health-based thresholds and have applicability irrespective of location. US EPA maximum contaminant level for arsenic is 0.01 ppm or 0.01 mg/L.

[41] United States Environmental Protection Agency: Arsenic in Drinking Water. Retrieved on 4/6/2012 from http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/index.cfm

[42] Zhu, Y.G., et al. *High Percentage Inorganic Arsenic Content of Mining Impacted and Nonimpacted Chinese Rice.* Environ. Sci. Technol., 2008, 42 (13), pp 5008-5013.

1.6.3.2 Herbicide Use During Forestry in the Southeast

Typically, herbicide application is infrequent at the site of forest management operations, occurring only after clear cutting in intervals of between 10 and 40 years, to aid in the reestablishment of desired tree species. However, the chemicals used are extremely toxic, with data indicating that both atrazine and 2,4-D are commonly used;[43,44] atrazine is a known endocrine disruptor and considered a possible carcinogen by the World Health Organization, while 2,4-D is considered a possible carcinogen by the International Agency for Research on Cancer.[45,46] These applications can be done using aerial or ground spraying, both of which are likely to be occurring on significant scales directly after the harvesting of sawtimber used in utility poles.

Due to their tendency to photodegrade in the environment, atrazine, 2,4-D, and other herbicides used in forestry in this region do not present a significant risk of contamination of water supplies or food supplies. However, these chemicals will expose workers in cases where protective equipment are not adequately utilized. Past research by SCS has indicated that this is a significant route of exposure, as workers will frequently have clothes which become saturated with very toxic herbicides and adjuvants. While no inventory or characterization data were available to quantify this impact, it is considered to result in significant human exposures to toxic chemicals in the BAU scenario.

1.6.4 Reduction in Generation of Untreated Hazardous Waste

CCA-treated poles are considered hazardous under the definition of hazardous waste in Resource Conservation and Recovery Act (RCRA). The primary consequences of the SPR scenario have negligible production of hazardous waste, and the secondary consequences will include a significant reduction in the production of CCA-treated wood and associated hazardous waste from disposal. This is a major benefit of the SPR scenario.

At end-of-life, CCA treated poles are removed and are typically disposed of in a landfill, but may be also illegally reused (see Figure 93) or incinerated. Only legal disposal of used CCA treated poles in a landfill is considered in this study.

To classify a waste as hazardous under RCRA, the Toxicity Characteristic Leaching Procedure (TCLP) is used; a test method determines the mobility of chemicals as a way of measuring how the material may behave in the environment. Wood treated with CCA fails the TCLP for arsenic and meets the definition of a hazardous waste; however, the US EPA has provided an exemption for CCA wood used for utility poles to avoid classification as a hazardous waste.[47] Failure to meet TCLP for arsenic suggests that if disposed in a landfill, the wood will leach mobile arsenic. This presents a serious risk to human health and the environment if wood poles are disposed of in municipal landfills. In many cases, wood poles will be illegally disposed of, used in commercial or even residential settings; such

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[43] University of Florida: Institute of Food and Agricultural Sciences. *Herbicides Registered for Pine Management in Florida – 2008.* Retrieved on 4/6/2012 from http://edis.ifas.ufl.edu/pdffiles/FR/FR15800.pdf.

[44] Georgia Forestry Commission. *Herbicides.* Retrieved on 4/6/2012 from http://www.gfc.state.ga.us/ForestManagement/Herbicide.cfm

[45] Environmental Working Group. *Health Effects of Atrazine.* Retrieved on 5/24/2012 from http://www.ewg.org/node/25735

[46] International Agency for Research on Cancer. *Agents Classified by the IARC Monographs, Volumes 1-104.* Retrieved on 5/24/2012 from http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf

[47] *Chromated Copper Arsenate (CCA) Compliance Strategy.* US EPA. June 22, 2004. http://www.epa.gov/oppad001/reregistration/cca/cca_strategy5.pdf

inappropriate disposal methods present a direct risk to humans, flora, and fauna, through leaching of toxic chemicals into soils and water (see Figure 7).

Figure 7. Examples of illegal re-use of treated utility poles, for fence construction in the Southeastern United States. The greenish hue of these poles indicates that CCA was the treatment chemical used. In these situations, these poles represent a severe risk to contamination of local soils from the leaching of arsenic and chromium.

Indicator results in Table 4 show that a significant volume of untreated hazardous waste is generated in the BAU scenario, over 590 thousand tons after the 40 year time horizon. This is enough hazardous waste to completely fill over 400 Olympic-size swimming pools.

1.7 Disadvantages of the SPR Scenario

1.7.1 Zinc Resource Depletion

The depletion of zinc resources is a clear trade-off associated with the SPR scenario; for galvanized steel utility poles, zinc provides a sacrificial coating and very little zinc is recovered at end-of-life.

Global mine reserves of zinc are approximately 250,000,000 tons, and world production from mining in 2011 was 12,400,000 tons;[48] at this rate of consumption, primary zinc resources will be depleted in approximately 20 years. However, the total world reserve also includes zinc which is currently in use, which can be considered a secondary mineral supply. Including both primary and secondary zinc resources, the USGS estimates that there are nearly 2 billion tons total of zinc resources in the world.

However, of the secondary zinc resources (those already in use), only 19% can be recovered, due to this metal's most common use in dissipative applications which cannot be recycled (e.g. zinc coatings, and brass in brake linings).[49] Even at this low recovery rate, these data indicate that there is a volume of retrievable reserves of secondary zinc which meet or exceed the current reserves of primary zinc. It is anticipated that as primary zinc reserves are depleted, the price of primary zinc will increase, resulting in increased zinc recycling. Nevertheless, the depletion of primary zinc reserves is an important impact, especially if only a small fraction of zinc in-use can ever be recovered.

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[48] United States Geological Survey. *Mineral Commodity Summaries 2012.* US Department of the Interior.

[49] Gordon, R.B., M. Bertram, T.E. Graedel. *Metal stocks and sustainability.* Proceedings of the National Academy of Sciences. 2006 January 31; 103(5): 1209–1214.

In the SPR scenario, consumption of zinc resources are a very small portion of the total primary zinc production, with an annual average consumption of approximately 650 tons over the study time horizon, less than 0.005% of the total world primary zinc production in 2012, according to the United State Geological Survey.[50] While it is contributing to the depletion of a significant resource, the depletion of zinc in the SPR scenario is not considered a major driver of zinc resource depletion globally.

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[50] USGS Minerals Information. *Zinc: Statistics and Information. Mineral Commodity Summaries 2012.*