Life Cycle Assessment of Creosote-Treated Wooden Railroad Crossties in the U.S. with Comparisons to Concrete and Plastic-Composite Ties

6 LCAs Completed

- ACQ-Treated Lumber Decking

- Borate-Treated Framing Lumber
  - Journal of Cleaner Production (as above)

- Pentachlorophenol-Treated Utility Poles
  - Renewable and Sustainable Energy Review at http://dx.doi.org/10.1016/j.rser.2011.01.019

- Creosote-Treated Railroad Ties (open access)
  - Journal of Transportation Technologies at http://scirp.org/journal/jtts

- CCA-Treated Guard Rail Systems (open access)
  - Journal of Transportation Technologies at http://scirp.org/journal/jtts

- CCA-Treated Marine Pilings
  - Journal of Marine Environmental Engineering
  - http://www.oldcitypublishing.com/JMEE/JMEEcontents/JMEEv9n3issuecontents.html (Contact Jeff Miller, TWC)
LCA Summaries Available

• Request from TWC

• On RTA Website

• Recommended to Creosote Council
What is (Environmental) Life Cycle Assessment (LCA)?

• What are environmental impacts associated with a product (ties)?

• LCA includes
  – Goal and Scope
  – Inventory
    • Inputs
    • Outputs
  – Assessment
  – Comparisons (optional)
Life Cycle Inventory

• Inventory-Creosote-Treated Ties
  – Inputs-Wood, Creosote, Energy
  – Outputs
    • Products-Treated ties
    • Releases-CO2, NOx, PAH, etc.

• Inventory Alternate Products
  – Concrete Ties
  – Plastic/Composite Ties
Railroad Crossties Life Cycle

Coke Ovens → Tar distillation and creosote production → Creosote
  ↘ Fuel/solvent oil → Oil carrier
  ↗
Hardwood growth → Hardwood harvest → Tie milling → Tie drying (air/Boulting)
  ↘ Creosote preserving
  ↗
Use in rail track → Secondary use
  ↘ Landfill
  ↗
Concrete or P/C tie manufacture → Cement or P/C tie manufacture
  ↘ Combustion for energy
  ↗
Raw material extraction/recycled product collection and processing → System boundary
  ↘ Emissions to air, releases to land and water
  ↗ Solid waste

Gate-to-grave processes combined
## Assumptions

<table>
<thead>
<tr>
<th>Description</th>
<th>Creosote</th>
<th>Concrete</th>
<th>Plastic/Comp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>7”x9”x8.5’</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Avg. Life</td>
<td>35 yr</td>
<td>40 yr</td>
<td>40 yr</td>
</tr>
<tr>
<td>Spacing c-c</td>
<td>19.5”</td>
<td>24”</td>
<td>19.5”</td>
</tr>
<tr>
<td>Weight</td>
<td>235 lb</td>
<td>700 lb</td>
<td>250 lb</td>
</tr>
<tr>
<td>Post use recycle</td>
<td>71% cogen</td>
<td>63% grind for aggregate</td>
<td>42% grind for plastic</td>
</tr>
<tr>
<td></td>
<td>12% landscape, farm, etc.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Treaters Surveyed for Data, Including Creosote and Oil Use Rates

<table>
<thead>
<tr>
<th>Product</th>
<th>Total (lb)</th>
<th>% of total</th>
<th>Product (lb/cf)</th>
<th>Wt. Avg. (lb/Mcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1/P13 Creosote</td>
<td>31,933,160</td>
<td>8%</td>
<td>12.21</td>
<td>452</td>
</tr>
<tr>
<td>P2 Creosote</td>
<td>353,109,891</td>
<td>85%</td>
<td>6.13</td>
<td>5001</td>
</tr>
<tr>
<td>P3 Petroleum Oil</td>
<td>28,680,438</td>
<td>7%</td>
<td>2.77</td>
<td>406</td>
</tr>
<tr>
<td>Total</td>
<td>413,723,489</td>
<td></td>
<td>5.86</td>
<td>5860</td>
</tr>
</tbody>
</table>

Note that the calculated avg. retention of 5.45 pcf is 22% less than AWPA spec. of 7 pcf. Result is logical since white oak ties treated to refusal and may be significantly less than 7 pcf.

<table>
<thead>
<tr>
<th>Use for all products</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Creosote</td>
<td>5454</td>
<td>lb/Mcf</td>
<td>594</td>
<td>gal/Mcf</td>
</tr>
<tr>
<td>Diluent oil</td>
<td>406</td>
<td>lb/Mcf</td>
<td>50</td>
<td>gal/Mcf</td>
</tr>
</tbody>
</table>
Creosote Loss Model

All models are wrong, but some are useful.

<table>
<thead>
<tr>
<th>Assumption for constituents</th>
<th>Assumed loss/yr</th>
<th>Fraction to air</th>
<th>Fraction to ground</th>
<th>Mass loss fraction/yr</th>
<th>Mass loss to air fraction/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>For each constituent with a VP of Xe-1 (Naphthalene)</td>
<td>2.0%</td>
<td>30%</td>
<td>70%</td>
<td>0.0019</td>
<td>0.00057</td>
</tr>
<tr>
<td>For each constituent with a VP of Xe-2 (Quinolene, Methyl Naph., Acenaphthene)</td>
<td>1.5%</td>
<td>15%</td>
<td>85%</td>
<td>0.0037</td>
<td>0.00056</td>
</tr>
<tr>
<td>For each constituent with a VP of Xe-3 (Fluorene, Anthracene, Phenanthrene)</td>
<td>1.0%</td>
<td>5%</td>
<td>95%</td>
<td>0.0024</td>
<td>0.00013</td>
</tr>
<tr>
<td>For each constituent with a VP of Xe-4+ (Carbazole, Fluoranthene, Pyrene)</td>
<td>0.5%</td>
<td>0%</td>
<td>100%</td>
<td>0.0014</td>
<td>0</td>
</tr>
</tbody>
</table>

Total measured mass fraction: 0.863
Sum: 0.0094 0.0013
% of total measured: 1.09% 0.15%

Projected release for 35 years: 0.33 0.044
Release as fraction of initial treatment: 38.0% 5.1%

Result for above at 32 years equals approximately 35% loss of creosote with 3% loss to air.
## Inventory Summary

<table>
<thead>
<tr>
<th>Infrastructure Process</th>
<th>Units</th>
<th>Creosote-Treated RR Tie Cradle-to-Grave (/tie)</th>
<th>Concrete RR Tie Cradle-to-Grave (/tie)</th>
<th>Plastic/Composite RR Tie Cradle-to-Grave (/tie)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Service life = 35 yrs</td>
<td>Service life = 40 yrs</td>
<td>Service life = 40 yrs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spacing = 19.5 in</td>
<td>Spacing = 24 in</td>
<td>Spacing = 19.5 in</td>
</tr>
<tr>
<td>Inputs from technosphere</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity, at grid, US</td>
<td>kWh</td>
<td>-54</td>
<td>128</td>
<td>123</td>
</tr>
<tr>
<td>Natural gas, processed, at plant (feedstock)</td>
<td>ft³</td>
<td>-99</td>
<td>260</td>
<td>635</td>
</tr>
<tr>
<td>Natural gas, combusted in industrial boiler</td>
<td>ft³</td>
<td>101</td>
<td>23</td>
<td>269</td>
</tr>
<tr>
<td>Diesel fuel, combusted in industrial equipment</td>
<td>gal</td>
<td>0.81</td>
<td>0.23</td>
<td>0.050</td>
</tr>
<tr>
<td>Gasoline, combusted in industrial equipment</td>
<td>gal</td>
<td>0.028</td>
<td>0.023</td>
<td>0.011</td>
</tr>
<tr>
<td>Hogfuel/biomass (50%MC)</td>
<td>lb</td>
<td>7.0</td>
<td>3.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Coal-bituminous &amp; sub. combusted in boiler</td>
<td>lb</td>
<td>26</td>
<td>0.12</td>
<td>0.034</td>
</tr>
<tr>
<td>Coal (feedstock)</td>
<td>lb</td>
<td>0</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Truck transport, diesel powered</td>
<td>ton-miles</td>
<td>45</td>
<td>75</td>
<td>69</td>
</tr>
<tr>
<td>Rail transport, diesel powered</td>
<td>ton-miles</td>
<td>84</td>
<td>390</td>
<td>90</td>
</tr>
<tr>
<td>Harvested hardwood</td>
<td>ft³</td>
<td>3.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Creosote</td>
<td>lb</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Landfill capacity</td>
<td>ton</td>
<td>0.012</td>
<td>0.26</td>
<td>0.10</td>
</tr>
<tr>
<td>Inputs from nature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>gal</td>
<td>6.9</td>
<td>84</td>
<td>83</td>
</tr>
<tr>
<td>Unprocessed coal</td>
<td>lb</td>
<td>10</td>
<td>98</td>
<td>81</td>
</tr>
<tr>
<td>Unprocessed U3O8</td>
<td>lb</td>
<td>-0.000074</td>
<td>0.00020</td>
<td>0.00018</td>
</tr>
<tr>
<td>Unprocessed crude oil</td>
<td>gal</td>
<td>2.0</td>
<td>2.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Unprocessed natural gas</td>
<td>ft³</td>
<td>107</td>
<td>71</td>
<td>674</td>
</tr>
<tr>
<td>Hydropower</td>
<td>Btu</td>
<td>-13,665</td>
<td>36,287</td>
<td>33,468</td>
</tr>
<tr>
<td>Other renewable energy</td>
<td>Btu</td>
<td>-1,078</td>
<td>2,507</td>
<td>2,399</td>
</tr>
<tr>
<td>Biogenic carbon (from air)</td>
<td>lb</td>
<td>11</td>
<td>0</td>
<td>-2.8</td>
</tr>
<tr>
<td>Other mined mineral resources</td>
<td>lb</td>
<td>16</td>
<td>1,580</td>
<td>24</td>
</tr>
</tbody>
</table>

So, what do all these numbers mean? ➔ Assessment
## Life Cycle Assessment

### Cradle to Grave Impact Values

<table>
<thead>
<tr>
<th>Impact Indicator</th>
<th>Units</th>
<th>Creosote Tie</th>
<th>Concrete Tie</th>
<th>P/C Tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse Gas Emissions</td>
<td>lb-CO2-eq</td>
<td>5,355</td>
<td>30,928</td>
<td>26,978</td>
</tr>
<tr>
<td>Net GHG</td>
<td>lb-CO2-eq</td>
<td>-1,769</td>
<td>31,175</td>
<td>27,268</td>
</tr>
<tr>
<td>Fossil Fuel Use</td>
<td>MMBTU</td>
<td>88</td>
<td>154</td>
<td>220</td>
</tr>
<tr>
<td>Acid Rain Potential</td>
<td>lb-mole H+</td>
<td>143</td>
<td>9,783</td>
<td>10,277</td>
</tr>
<tr>
<td>Water Use</td>
<td>gal</td>
<td>644</td>
<td>5,571</td>
<td>6,771</td>
</tr>
<tr>
<td>Smog</td>
<td>g NOx-eq/m</td>
<td>25</td>
<td>58</td>
<td>29</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>lb-N-eq</td>
<td>1.9</td>
<td>3.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Ecotoxicity</td>
<td>lb-2,4-D-eq</td>
<td>-7</td>
<td>188</td>
<td>64</td>
</tr>
</tbody>
</table>

OK, these are better, but still hard to understand. ➡️ Normalize
Assessment
Normalized Impacts (Max. = 1.0)

<table>
<thead>
<tr>
<th></th>
<th>Greenhouse Gases</th>
<th>Net GHG</th>
<th>Fossil Fuel Use</th>
<th>Acid Rain</th>
<th>Water Use</th>
<th>Smog</th>
<th>Eutrophication</th>
<th>Ecotoxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creosote-treated tie</td>
<td>0.17</td>
<td>-0.06</td>
<td>0.40</td>
<td>0.01</td>
<td>0.10</td>
<td>0.44</td>
<td>0.51</td>
<td>-0.037</td>
</tr>
<tr>
<td>Concrete tie</td>
<td>1.0</td>
<td>1.0</td>
<td>0.70</td>
<td>1.0</td>
<td>0.82</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Plastic/composite tie</td>
<td>0.87</td>
<td>0.87</td>
<td>1.0</td>
<td>1.00</td>
<td>1.0</td>
<td>0.51</td>
<td>0.37</td>
<td>0.34</td>
</tr>
</tbody>
</table>

One picture worth many words. Advantages of wood relative to alternates are clear.
Do impacts matter?
Compared to other sources...

<table>
<thead>
<tr>
<th>Impact Indicator</th>
<th>As % of U.S. Total</th>
<th>As % of Class 1 RR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Creosote Wood Ties</td>
<td>Concrete Ties</td>
</tr>
<tr>
<td>Greenhouse Gas Emissions</td>
<td>0.007%</td>
<td>0.043%</td>
</tr>
<tr>
<td></td>
<td>1.1%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Fossil Fuel Use</td>
<td>0.022%</td>
<td>0.039%</td>
</tr>
<tr>
<td></td>
<td>3.1%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Acid Rain Potential</td>
<td>0.001%</td>
<td>0.046%</td>
</tr>
<tr>
<td></td>
<td>0.03%</td>
<td>1.86%</td>
</tr>
</tbody>
</table>

U.S. total 2007 emissions per DOE/EIA
Ties for 216,818 miles track in U.S.
Class 1 RR freight of 1,777,236 ton-miles.
Wood is Different!
Sensitivity Analysis

WHAT IF ??
What if all wood ties disposed in landfills instead of current practice?
What if 1) borate added & wood life increased to 40 year & 2) if concrete ties allowed 25% of benefit in rolling resistance?
Not all LCAs are the same
Steel Market Development Institute (SMDI) news release

• PR Newswire - August 7, 2013
• “New Life Cycle Assessment Study Shows Replacing Wood Utility Poles With Steel Significantly Lowers Key Environmental Impacts”
• Written by SCS Global Services (SCS)
• Referred to as “SCS LCA”
SCS LCA Scenarios

• 1) Business as Usual (BAU) – Wood poles replaced as needed with wood poles.
• 2) Steel Pole Replacement (SPR) – Wood poles replaced as needed with steel poles.
SCS LCA Assumptions

• **Service life of wood = 40 years vs. 80 for steel**
• Compare using Grade B and ignore that Grade C is most common
• Arsenic assumed mined in China, rather than as secondary process from metals.
• No inspections for steel, 8-yr cycle for wood.
• CCA pole disposal = “untreated hazardous waste” disposal
SCS LCA Indicators

• Indicators “counted”
  – 35 Indicators
  – 21 Steel better than wood
  – 10 Wood better than steel
  – 4 About equal

• Counting method equates all counted impacts as if equal.
### Example – Resource Depletion

(11 indicators)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>BAU (tonnes)</th>
<th>SPR (tonnes)</th>
<th>Winner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>3,380</td>
<td>0 to-4,000</td>
<td>Steel</td>
</tr>
<tr>
<td>Barite</td>
<td>62</td>
<td>54</td>
<td>Steel</td>
</tr>
<tr>
<td>Boron</td>
<td>1</td>
<td>.7</td>
<td>Steel</td>
</tr>
<tr>
<td>Chromium</td>
<td>4,160</td>
<td>0 to-4,000</td>
<td>Steel</td>
</tr>
<tr>
<td>Copper</td>
<td>22</td>
<td>41</td>
<td>Wood</td>
</tr>
<tr>
<td>Fluorspar</td>
<td>136</td>
<td>93</td>
<td>Steel</td>
</tr>
<tr>
<td>Lead</td>
<td>0.8</td>
<td>2.8</td>
<td>Wood</td>
</tr>
<tr>
<td>Manganese</td>
<td>17</td>
<td>11</td>
<td>Steel</td>
</tr>
<tr>
<td>Nickel</td>
<td>48</td>
<td>17</td>
<td>Steel</td>
</tr>
<tr>
<td>Tin</td>
<td>149</td>
<td>112</td>
<td>Steel</td>
</tr>
<tr>
<td>Zinc</td>
<td>43</td>
<td>26,100</td>
<td>Wood !!</td>
</tr>
<tr>
<td>Sum</td>
<td>8,019</td>
<td>26,432</td>
<td>Steel-8, Wood-3</td>
</tr>
</tbody>
</table>

Steel used 3 x more resources than Wood
SCS LCA Seems Biased

• Over emphasis on Chinese arsenic but ignore Chinese steel.

• **Emphasis on forestry impacts**
  – Comparison to “pre-industrial” conditions
  – Active forestry = “impact”
  – No benefits
    • Continued forest land use vs. alternatives
    • Carbon sequestered in product and forest
    • Sustainable
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.
Met with SCS Global

• Meeting on February 19 at SCS office
• Offered comments of TWC, NAWPC, WWPI perspective
  – Scott Conklin, Kevin Ragon, John Horton, Jeff Miller, Stephen Smith attended
• Understand SCS Global perspective
• Goal was discussion and understanding
• Written comments provided
• SCS Global to provide response, possible addendum
Are we weak on forestry?
Better data may help.

Swamp Logging...

The Road Less Traveled
By Gary Williams, Koppers Inc.

Logging sites can be visually impressive, whether it’s a team of horses pulling two logs down a lazy mountain trail on a sunny summer afternoon or a diesel-powered Timberjack skidder straining to move several logs from the stump to the landing through several inches of snow. But nothing can compare to the sheer investment in time, money and effort required to move logs out of the swamps of eastern North Carolina.

Goodson All Terrain Logging (made famous by the Discovery Channel reality required nearly 100 mats at a cost of around $300 each just to make it from the highway to the log landing.

Steel bridge sections or combinations of steel and wooden mats are used to build bridges over moving water and will have to be removed when the job is done. To begin the logging operation, a large fellerbuncher on tracks cuts trees in a wide swath on its way to the backside of the tract. A track knuckle boom (called a shovel) follows and lays the downed trees end to end and side by side to make a wooden road that will be used to support large rubber tired skidders needed to pull logs out to the land-

ash, maple, and some oak, and are clear-cut jobs so everything goes, typically yielding
Questions and Discussion

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