Life Cycle Assessment of Overhead versus Underground Primary Power Distribution in Southern California

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Annual US Electricity Sales by Sector
(billion kilowatt-hours)

Source: Energy Information Administration, 2008
Two Options:

- Overhead
- Underground
<table>
<thead>
<tr>
<th></th>
<th>Overhead</th>
<th>Underground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Safety</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Reliability</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cost</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Lifetime</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Environmental Impacts</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
Project Goal

Is to perform life cycle assessments of overhead and underground primary power distribution systems.
Southern California Edison Service Area
Medium Voltage Distribution

Transmission = 12,600 miles

Distribution = 85,000 miles
Cable Choice

Overhead

336.4 kcmil, 18/1, ACSR “Merlin”

Underground

1,000 mcm AL 17kV 200 mil Single Conductor UD Aluminum with Copper Concentric MV
Unit of Comparison

One circuit mile of power line for the delivery of medium voltage power over one year, including infrastructural components
- Treated Wooden Utility Pole (25 per mile)
- Treated Wooden Crossarm (30 per mile)
- Polyethylene Insulator (4 per pole)
- Galvanized Steel Casting Parts
- 1 Mile of OH circuit (4 cables)

- Concrete Vaults (~5 per mile)
- Concrete Duct (1 mile)
- Plastic Conduit (6 per duct)
- 1 Mile of UG circuit (3 cables)
Treated Wooden Utility Pole (25 per mile)

Product Data:
- Wood Type: Douglas Fir
- Dimensions: Class 2
- Height: 45 ft, Width: top radius 0.33 ft, ground radius 0.53 ft
- Treatment: Pentachlorophenol (PCP)
- Producer: McFarland Cascade located in Eugene, OR
- Treated utility pole mass: ~356 kg
Treated Wooden Utility Pole (25 per mile)

Process Data

- Wood Harvesting
- Pole Production
- Pole Treatment
- Pentachlorophenol Production
- Installation
- Maintenance
- Decommissioning
- Landfill
- Transportation between all stages above
- Treated Wooden Utility Pole (25 per mile)
- Treated Wooden Crossarm (30 per mile)
- Plastic Insulator (4 per pole)
- Galvanized Steel Casting Parts
- 1 Mile of OH Cable
- Concrete Vaults (~ 5 per mile)
- Concrete Duct (1 mile)
- Plastic Conduit (6 per duct)
- 1 Mile of UG Cable
Life Cycle Inventory

- Raw Materials Acquisition
- Manufacturing and Processing
- Distribution and Transportation
- Use and Maintenance
- Waste Management
- Recycle

Environmental Impacts

Raw Materials

Energy

Data Mix

General Data

Client Specific Data
Toolbox

SOFTWARE
• GaBi 4.3 Life Cycle Assessment Software System

DATA
• Client & Supply Chain Collaboration
• Inventory Databases
  – ECOINVENT
  – GaBi 4.3
GaBi 4.3 LCA Software
Overhead Cradle-to-Grave Model

OH Production-Reel
9.7011 kg

OH Production-Cable
100.77 kg

OH Production-Cable & Reel Packaging
110.47 kg

OH Production-Castings
8.3915 kg

OH Production-Insulator
1.8144 kg

OH Production-Crossarm Sawn Timber
7.5286 kg

OH Production-Utility Pole Sawn Timber
179.21 kg

OH EOL-Reel

OH EOL-Cable

OH EOL-Castings

OH EOL-Insulators

OH EOL-Pole & Crossarm

OH Phase-Use
Overhead Use Phase

- CH Insulator Storage
- CH Pole Storage USE
- CH Crossarm Storage
- CH Steel casing part Storage
- CH Cable/Reel Storage
- USI Diesel at refinery PE
- Cargo1 USE PHASE
- Cargo2 USE PHASE
- Cargo3 USE PHASE
- Insulator to AAA
- Steel casing part to AAA
- Poles & Crossarm to AAA
- Cable scrap to AAA
- Steel Reel from SCE Service Center to SCE Warehouse
- US: Steam from light fuel oil (385% Inverted PE)
- CIS: Power Mix Inverted (Avoided Carbon)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH Cable Lifetime</td>
<td>30-50 yrs</td>
</tr>
<tr>
<td>UG Cable Lifetime</td>
<td>20-40 yrs</td>
</tr>
<tr>
<td>OH Infrastructure Capacity</td>
<td>1-4 circuits</td>
</tr>
<tr>
<td>UG Infrastructure Capacity</td>
<td>1-6 circuits</td>
</tr>
<tr>
<td>UG Infrastructure Lifetime</td>
<td>100-140 yr</td>
</tr>
<tr>
<td>UG Cable Recycling Rate</td>
<td>0.727-0.950</td>
</tr>
<tr>
<td>OH Cable Recycling Rate</td>
<td>0.911-0.950</td>
</tr>
<tr>
<td>OH Failure Frequency</td>
<td>63-117 events / 100 circuit miles</td>
</tr>
<tr>
<td>UG Failure Frequency</td>
<td>7-13 events / 100 circuit miles</td>
</tr>
<tr>
<td>PCP Leaching from Poles</td>
<td>0-100%</td>
</tr>
</tbody>
</table>
Environmental Impact Indicators

Chose CML 2001 (Dec. 07) Indicators:

ADP: Abiotic Depletion Potential
AP: Acidification Potential
EP: Eutrophication Potential
FAEP: Freshwater Aquatic Ecotoxicity Potential
GWP: Global Warming Potential (100 years)
HTP: Human Toxicity Potential
POCP: Photochemical Ozone Creation Potential
TETP: Terrestrial Ecotoxicity Potential
## Absolute Values

<table>
<thead>
<tr>
<th>Impact Indicator</th>
<th>Unit</th>
<th>OH LIFE CYCLE IMPACTS (per year per mile)</th>
<th>UD LIFE CYCLE IMPACTS (per year per mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADP</td>
<td>(kg Sb eq)</td>
<td>7.00</td>
<td>63.65</td>
</tr>
<tr>
<td>AP</td>
<td>(kg SO2 eq)</td>
<td>4.01</td>
<td>32.66</td>
</tr>
<tr>
<td>EP</td>
<td>(kg PO4 eq)</td>
<td>2.41</td>
<td>3.73</td>
</tr>
<tr>
<td>FAETP</td>
<td>(kg DCB eq)</td>
<td>83.57</td>
<td>527.07</td>
</tr>
<tr>
<td><strong>GWP</strong></td>
<td>(kg CO2 eq)</td>
<td>1402.39</td>
<td>7680.95</td>
</tr>
<tr>
<td>HTP</td>
<td>(kg DCB eq)</td>
<td>248.87</td>
<td>1376.11</td>
</tr>
<tr>
<td>POCP</td>
<td>(kg C2H4)</td>
<td>0.44</td>
<td>3.65</td>
</tr>
<tr>
<td>TETP</td>
<td>(kg DCB eq)</td>
<td>5.73</td>
<td>29.15</td>
</tr>
</tbody>
</table>
## Significance of Impact Indicator Magnitude

<table>
<thead>
<tr>
<th></th>
<th>GWP from primary power distribution for 1 mile over 1 year [kg CO2 eq]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OH</td>
</tr>
<tr>
<td><strong>kW-h, from hard coal</strong></td>
<td>1.27</td>
</tr>
<tr>
<td><strong>kW-h, from hydro</strong></td>
<td>58.4</td>
</tr>
<tr>
<td><strong>gasoline consumed, gallons</strong></td>
<td>159</td>
</tr>
<tr>
<td><strong>power use by 1 home over one year</strong></td>
<td>0.19</td>
</tr>
</tbody>
</table>
Environmental Impacts

<table>
<thead>
<tr>
<th>Environmental Indicators</th>
<th>UG</th>
<th>OH</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADP</td>
<td>1.0E-09</td>
<td>0.0E+00</td>
</tr>
<tr>
<td>AP</td>
<td>5.0E-10</td>
<td>0.0E+00</td>
</tr>
<tr>
<td>EP</td>
<td>2.5E-09</td>
<td>0.0E+00</td>
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Impacts Normalized by US Totals (CML 2001)
Underground Hot Spot Analysis

![Bar chart showing environmental indicators normalized by US total (CML 2001). The chart includes categories such as Cable Production, Use Phase, Other Processes, Reel Reuse & Recycle, and Cable Recycling. Each category is represented by a different color and the impacts are measured in units of 10^-9.]
Overhead Hot Spot Analysis

Environmental Indicators

Impacts Normalized by US Total (CML2001)

- ADP
- AP
- EP
- FAETP
- GWP
- HTP
- POCP
- TETP

Legend:
- Cable Production
- Use Phase
- Other Processes
- Tree Trimming Credits
- Reel Reuse & Recycle
- Cable Recycling
## Material Intensity

<table>
<thead>
<tr>
<th>Materials</th>
<th>Cable masses, kg/foot</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>OH</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.57</td>
</tr>
<tr>
<td>Steel</td>
<td>0.09</td>
</tr>
<tr>
<td>Copper</td>
<td>-</td>
</tr>
<tr>
<td>Plastic</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total Mass</strong></td>
<td><strong>0.66</strong></td>
</tr>
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</table>
Assumptions & Limitations

• Simplest topography assumed
• Selected trucks with Euro 4 emission standards
• Did not take into account differences due to:
  – Transformers
  – Voltage Drops
  – Land Use Requirements
  – Electromagnetic Fields (EMFs)
## Overhead vs. Underground

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<td>🟥</td>
</tr>
<tr>
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<td>🟦❓</td>
<td>🟥❓</td>
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Recommendations

• Encourage stakeholders nationwide to consider the larger environmental impacts of underground primary power distribution

• Southern California Edison should further engage in green supply chain management

• Make decreasing cable failure events a management priority for OH & UG systems

• Project in final stages: developing SCE-specific management recommendations
Thank You!

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