DONALD BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

GROUP PROJECT BRIEF

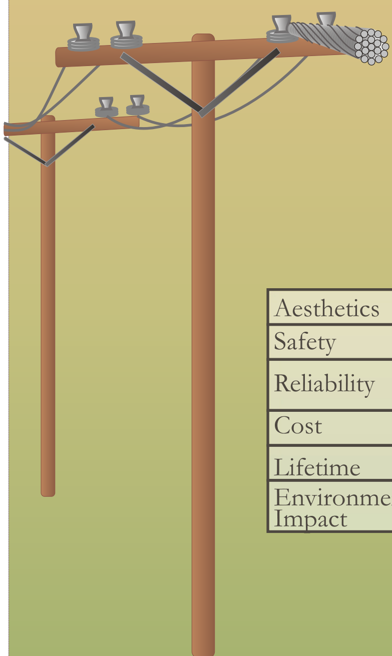
Life Cycle Assessment (LCA) of overhead versus underground primary power distribution systems in Southern California

Project Members:
Sarah Bumby
Katya Druzhinina
Rebe Feraldi
Danae Werthmann

Faculty Advisor:
Roland Geyer

Client:
Southern California Edison

ON THE WEB AT HTTP://FIESTA.BREN.UCSB.EDU/~CABLE/ SPRING 2009



	Overhead (OH)	Underground (UG)
Aesthetics	−	+
Safety	−	+
Reliability	±	±
Cost	+	−
Lifetime	+	−
Environmental Impact	?	?

Project Goal :

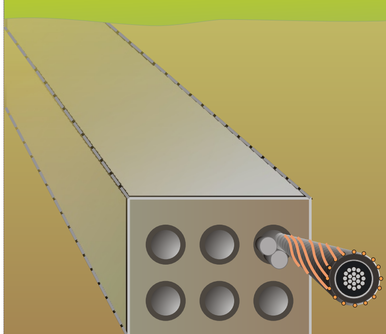
Perform a comparative Life Cycle Assessment of overhead (OH) versus underground (UG) primary power

OVERVIEW

This project uses life cycle assessment (LCA) methodology to assess and compare potential environmental impacts of overhead and underground primary power distribution systems in Southern California.

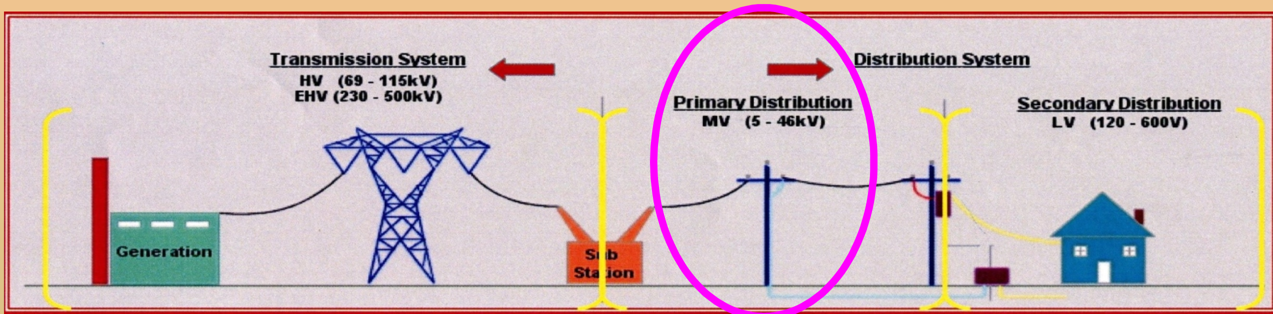
INTRODUCTION

High electric power demand has spurred discussions on the tradeoffs between overhead and underground power distribution in managing the existing and expanding grid. Many factors contribute to the tradeoffs between overhead and underground power distribution. In the literature, the most widely discussed factors are aesthetics, safety, reliability, cost, and lifetime (see table to the left). Many regions in the United States, European Union, and Australia are considering revising the protocol for new power distribution installations or conversion of existing infrastructure to underground mode. However, current literature lacks a full investigation into the life cycle environmental impacts of both distribution methods, including all infrastructure components.



BACKGROUND

In 2008, Southern California Edison (SCE), one of the largest electric utility suppliers in the United States, commissioned the Bren School to investigate the life cycle of overhead and underground power delivery systems. SCE's 50,000 square-mile service area is considered one of the most rapidly developing areas in the United States. SCE's system-wide load-growth for 2008-2017 is estimated at 2.22% per year. This growth will require 564 new distribution circuits of various lengths. SCE has fairly comprehensive environmental programs and practices in place. The utility has initiated green supply chain management by collaborating with many of its main suppliers and end-of-life contractors in order to improve environmental performance. Investigating overhead and underground primary power distribution services, as provided by an industry leader in environmental performance, compares these two systems in the most efficient settings available.



SCOPE

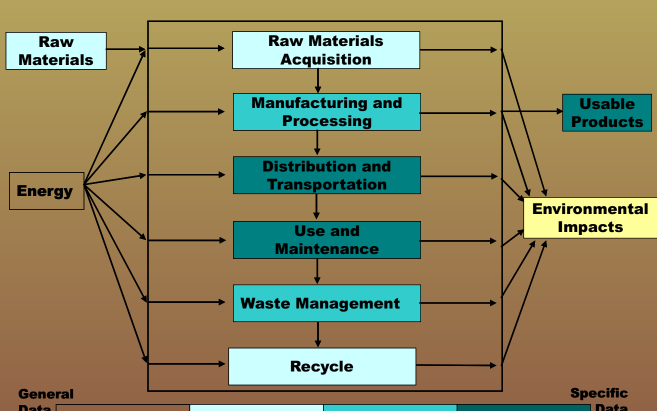
This study chose to evaluate cables and infrastructure associated with primary power distribution (see diagram above). The reason for choosing this area of power distribution, as compared to power transmission, is its location in densely populated areas where the majority of stakeholders are affected by the selection between overhead or underground systems. Also, primary power distribution comprises 90% of the length of SCE's electrical lines. This comparative study provides a basis for more informed decision-making in electricity grid planning and management by adding a new dimension into the discussion: a full life cycle assessment of the environmental impacts.

FUNCTIONAL UNIT

One circuit mile of power line for the delivery of medium voltage power over one year, including infrastructural components.

METHOD & TOOLS

The analysis is based on a complete life cycle assessment (LCA), examining the cradle-to-grave environmental impacts by using GaBi 4.3 LCA software developed by PE International. This software is a tool that balances complex process networks and connects inventory data with environmental impact categories. The software includes a collection of proprietary industry inventories for basic materials and processes.



DATA SPECIFICITY

Data collection for the Life Cycle Inventory (LCI) was performed in close collaboration with SCE and their suppliers and contractors. In the flow diagram below-left, the darker colors indicate SCE and supply chain specific data while the lighter colors indicate industry average data acquired from the Ecoinvent and GaBi 4.3 Databases.

PARAMETERIZATION & SENSITIVITY ANALISYS

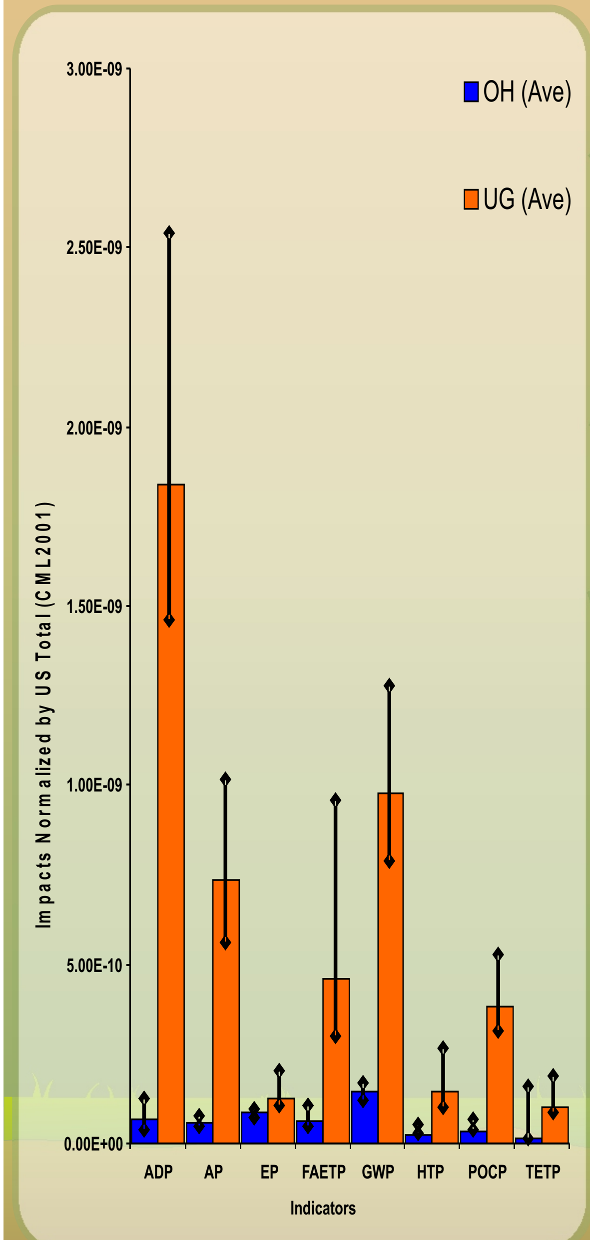
Several factors in each product system are associated with significant uncertainty. These factors were parameterized in the model to facilitate sensitivity analysis and examine the associated range of results. The validity of the comparison results is ensured by including the range of estimated values and modeling all related scenarios (see table below).

Parameter	Range
OH Cable Lifetime	30-50 years
OH Infrastructure Capacity	1-4 circuits per pole
UG Cable Lifetime	20-40 years
UG Infrastructure Capacity	1-6 circuits per duct
UG Infrastructure Lifetime	100-150 years
OH Recycling Rate	0.911 - 0.95
UG Recycling Rate	0.727 - 0.95
PCP Leaching to Soil	0% to 100% PCP leaching

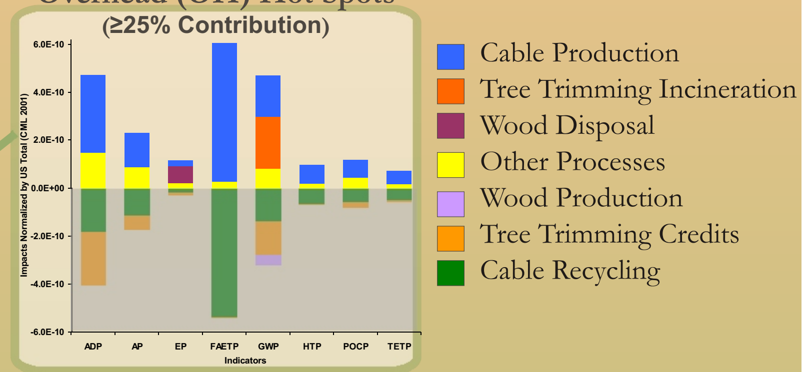
ASSUMPTIONS & LIMITATIONS

- Simplest topography assumed (straight line and no obstacles: roads, hard rocks, etc.)
- Did not include transformers
- Did not account for impacts from land use and electromagnetic fields, due to the controversy and complexity of the issues
- Environmental impacts resulting from physical and human capital were assumed to be negligible and were excluded from the analysis

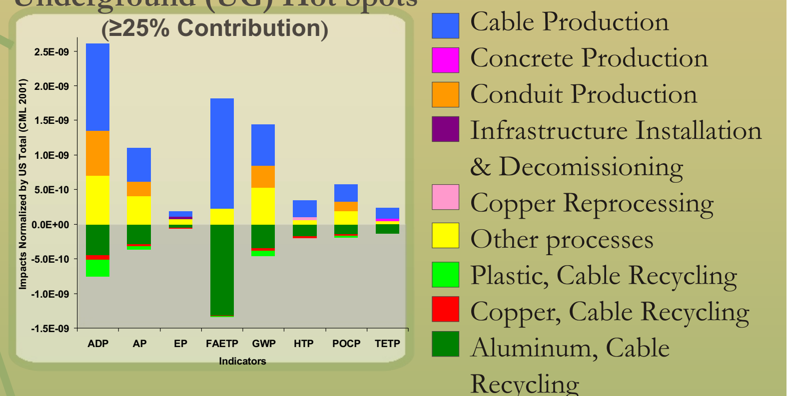
ADP: Acidification Potential
EP: Eutrophication Potential
GWP: Global Warming Potential (100 years)
POCP: Photochemical Ozone Creation Potential
ADP: Abiotic Depletion Potential
FAETP: Freshwater Aquatic Ecotoxicity Potential
HTP: Human Toxicity Potential
TETP: Terrestric Ecotoxicity Potential

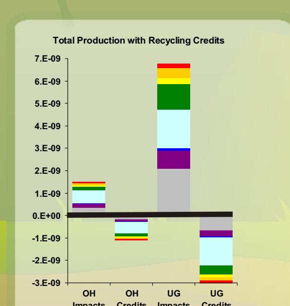


Overhead (OH) Hot Spots

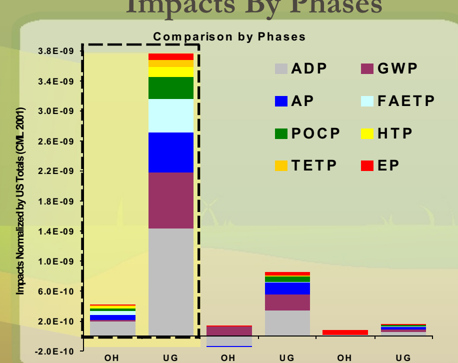


Underground (UG) Hot Spots





Impacts By Phases



Overhead system has less impact across all indicators, in most scenarios

OVERALL COMPARISON

The results of the comparison show that in primary power distribution, the underground system has more environmental impact potential than the overhead system in all categories and most scenarios. This difference is primarily due to the higher material intensity for underground cables. Moreover, as the higher material intensity of underground cable is related to the inherent physical conditions of underground systems, there are no simple management solutions to reduce the impacts of the underground system to those of the overhead. However, there are opportunities for improving the environmental performance of each analyzed system.

UNDERGROUND HOT SPOTS:

Cable production is the process dominating impacts in the underground system (see graphs on previous page). Within cable production, it is the process of liquid aluminum production that is responsible for the majority of impacts. The next highest contribution in this system is the cradle-to-gate production of the polyvinyl chloride (PVC) required for the cable conduits.

OVERHEAD HOT SPOTS:

In the overhead system, production of the cable again dominates environmental impact indicators. The lower material intensity of the overhead cable is the reason the associated impacts in the overhead system are at least an order of magnitude smaller than those of the underground. The majority of GWP in the overhead system results from the incineration of tree trimmings during the maintenance phase. However, in the studied utility, the incineration process also generates heat and electricity that is utilized within the SCE service area and thus, credited to the use phase. The magnitude of these credits compensates total use phase impacts in many indicators. Finally, landfilling of the wooden utility poles and the resulting nutrient runoff contributes most to EP in the overhead system.

RECOMMENDATIONS

- Encourage stakeholders nationwide to consider the larger environmental impacts of an underground system in the decision-making process regarding primary power distribution;
- Southern California Edison should engage in green supply chain management since most environmental impacts occur upstream of their corporate boundaries;
- Use the developed model and 'hot spot' analysis to investigate alternatives for materials, and component and process designs;
- Within the utility's corporate boundaries, impacts are dominated by diesel production for, and fuel emissions during, the installation, maintenance, and decommissioning of the cable systems. Thus, management and logistics of the service fleet should be a major consideration in reducing the overall environmental impacts for either system in their corporate boundaries.

Acknowledgment: Southern California Edison: Jack Sahl, Director of Environment & Resource Sustainability; Michael A. Hughes, Technical Specialist, Technical Innovation; Glenn G. Sias, Manager, EMF Issues; Tom Beamish, Manager, Investment Recovery; Audel De La Torre, Joshua L. Nichols, Vincent Oatis, Arthur Peralta, Steve Ford, and Vincent Jacobo Jr. Southwire Company: Carol Godfrey , Vice President Marketing; Denise Quarles, Director of Business Development Young & Company: Ray C. Harlow, P.E., Vice President Alpert & Alpert Iron & Metal Inc.: A. Greg Tellier, Director of Ferrous & Utilities Brooks Manufacturing: Shannon Terrell, National Sales Manager, Transmission / Export Bren School of Environmental Science and Management: Vered Doctori Blass, Ph.D. candidate; Brandon Kuczenski Ph.D. Postdoctoral Scholar; Marc Binder, technical director, PE Americas