Do the Benefits of Underground Power Lines Outweigh the Costs?

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Overview

America's reliance on electricity has continued to grow. Disruptions in electric service from weather events or natural disasters have tended to repeatedly prompt the seemingly logical next question "does it make sense to underground (UG) power lines to help minimize outages?" Additionally, there has been a continuing trend for the removal of poles and overhead (OH) power lines to improve the aesthetics of a neighborhood or area. While undergrounding power lines may seem on the surface to be a good way to go, the reality is that making the decision to put power lines underground is more complicated, and considerably more expensive. Over the years, electric cooperatives and their regulating agencies or bodies have studied the undergrounding of power lines. The large majority of these studies conclude that the cost of undergrounding is far more expensive than OH power systems. New construction of UG facilities or conversion of existing OH power system facilities are both high cost alternatives for undergrounding. These costs can also vary from location to location, but are considerably higher for UG than OH in all instances. Besides the cost and aesthetics, factors regarding reliability need to be considered. Overall, the question becomes "would the benefits achieved outweigh the costs incurred?"

The Edison Electric Institute (EEI) is the association of shareholder-owned electric companies that represent approximately 70 percent of the U.S. electric power industry. They conducted a 2012 poll of electric customers to determine how willing they might be to pay for undergrounding. The results of their poll showed the following:

The results indicated that 60 percent of electric customers were willing to pay at least 1–10 percent more on their power bills for undergrounding and another 11 percent of customers were willing to pay up to 20 percent more. However, fewer than 10 percent of the customers polled were willing to incur a bill increase of 100 percent to pay the more realistic cost for undergrounding. This information confirms the experience of most utilities and state commissions that the *cost of undergrounding is a very important consideration and that customers have limited tolerance for higher costs for utility services to pay for undergrounding. (Hall, 2013, p. v)*

The cost of undergrounding continues today to remain a challenge for electric cooperatives and their customers who want lines put underground. If UG costs were the same as OH costs, the decision would be an easy one. Despite the higher cost of UG, electric cooperatives do find value in building UG facilities in some instances. For instance, new housing developments in the US are more and more being constructed with UG distribution power lines. But, the construction of new UG transmission lines has been more varied and more rare as UG transmission lines are much more expensive.

Hall (2013) also cites U.S. Energy Information Administration (EIA) data as showing that for all different types of storms or "disturbances", hurricanes/tropical storms, summer storms, and winter storms (ice/snow) make up "more than 97.8 percent of all the events recorded" (p. 14). All events included earthquake, flooding, heat storm, hurricane/tropical storm, summer storm (lightning/high winds), wildfire, and winter storms (ice/snow). The EIA deducted that storms that produce strong winds are the "major cause of warm weather and grid failures" (p. 15). The data further showed that "hurricanes/tropical storms and summer storms cause 80 percent of all major outages and that snow and ice accumulation are the major cause of system outages during the winter" (pp. 15-16). Given this, one might conclude that UG systems would be less susceptible to damage. But, in reality, most underground systems are generally fed electricity by overhead facilities. So, an event that causes overhead line power disruption will inevitably cause disruption to the underground system as well.

The EEI also studied major storm data for a period of nine years to determine trends and impacts these events had on the electric industry. The data was somewhat inconclusive in that storm patterns were increasing, but average outage time per customer declined in some instances. This may have been due to improvements in restoration response time due to increased use of mutual assistance from other electric utility companies. Additionally, UG facilities seemed to have had a slightly better performance than OH facilities in some instances, while a much better performance in others. UG facilities were particularly susceptible to poor performance in areas where flooding occurs.

In order to get an understanding of how to determine the decision to go underground, one needs to understand the benefits and challenges associated with these decisions. The following lists of benefits and challenges is provided directly from the 2012 EEI poll responses (Hall, 2013), and is a comprehensive listing of all aspects surrounding these. Each of these listed may or may not apply to one specific area or company, but instead represent the poll feedback from their association members across the US. Benefits include improved reliability in some instances, aesthetics, and others as listed. Challenges include costs, operation and maintenance, failure issues, and others as listed.

Benefits of Undergrounding

Reliability

- Benefits such as robustness to most weather events and less exposure to wildlife
- Increased reliability during high winds and storms
- Reduced exposure to lightning
- Reduced exposure to outages caused by trees
- Better voltage support
- Decreased tree trimming costs
- Newer UG cable systems, in general, tend to be more reliable and require less maintenance than OH installations

- In very dense urban areas, overhead construction becomes impractical, so the utility benefits by having the option of installing underground network systems in these areas where overhead can't be installed

Aesthetics

- Customers prefer underground construction
- Easier to obtain an easement for underground lines
- Helps with public image
- The primary benefit to an electric utility for an underground system is customer satisfaction
- One of the major benefits is to help create positive community relations by mitigating visual impact

Other

- Transmission - less public EMF concerns
- Transmission - fewer maintenance repairs
- Reduced congestion in high density areas
- Ability to maintain facilities at ground level, rather than from poles and bucket trucks
- Better public safety
- Lower feeder energy losses
- The cost of tree maintenance is removed entirely during the life of underground facilities
- Reduced route congestion near substations
- Increased customer acceptance for new projects
- Less resistance from towns for project approvals
- Significant reduction in right-of-way (R/W) maintenance costs and vehicular caused outages

Challenges of undergrounding

Costs

- Underground systems are normally more expensive to install than overhead systems
- Higher facility replacement costs
- Increased project costs associated with UG systems
- Increased material costs and longer installation timeframes vs. overhead
- Design redundancy/significantly higher capital costs for installation
- Higher operations and maintenance (O&M) cost offsets corresponding reduction in R/W maintenance costs
- Geographic areas with severe frost and rocky conditions can increase costs significantly
- Underground cable mitigation tends to be very expensive compared to other types of equipment repairs/replacements. This is due to the labor intensive nature of locating faults and repairing cable, the need for specialty contractors for replacement or mitigation work, and the need for additional crew resources to restore customers' power when a failure occurs.

Operation and Maintenance

- Older cables are more likely to fail and older tile or fiber duct systems are more likely to collapse when failed cable is pulled
- Repair times for UG construction are substantially higher than for OH construction, driving up maintenance costs and duration-based reliability indices
- Underground facilities experience many dig-ins by those who do not follow proper procedures to identify the location of underground facilities before excavating
- More complex operational needs, such as visual inspection, is impossible, making it more difficult and costly to maintain and repair
- Difficult repair due to frozen ground
- Installation of underground services requires much more coordination between the utility and customer than similar overhead service installations
- Although UG construction eliminates some outage causes, UG systems are still vulnerable to lightning and equipment failure

- Difficulty locating space for padmounted gear
- Increased stray voltage concerns
- Specialized training/equipment for manhole/vault access
- Surface-mounted equipment inspections critical to protect public
- Difficult access for outage restoration in heavy snow areas
- Underground facilities are susceptible to flooding

Failure Issues

- Much of the cable installed in the 1970s and 1980s is reaching the end of its useful life, creating a peak in the need for infrastructure investment
- Customer satisfaction is at risk due to the connected nature of UG feeds. Multiple failures in a segment on a single tap interrupt power to the same set of customers. Customers often become frustrated since it is not visually apparent as to the cause/location and because failures often occur under warm, dry conditions.
- Power outages last longer because damage is more difficult to locate and takes longer to repair
- Outages involving the underground system take more time to resolve as faulted cable/ equipment takes more time to locate and subsequently replace
- Customer perception that undergrounding their service or neighborhood should dramatically improve their reliability, not taking into account exposure of overhead portions of the system upstream

Other

- Submersible transformers, in particular, have created a significant safety hazard for crews attempting to locate and repair failed equipment
- Conflicts with other subsurface construction and utilities
- More specialized skillset and equipment required for installation and repairs (pp. 25-27)

Costs of Undergrounding

The EEI also collected data in it's 2012 survey on cost per mile of UG vs. OH construction. The following tables on the next page represent their findings.

Recovery of costs

The cost of UG facilities is paid by the utility ratepayers. So, the higher cost of UG vs. OH facilities is paid by charging higher utility rates. In many cases, these higher rates can extend for decades. The North American Wood Pole Council (2017) reported the following:

Studies on undergrounding proposals in North Carolina and Florida suggested that placing lines underground would require rate increases of 80 percent to 125 percent annually. Virginia calculated the annual cost of undergrounding lines statewide would equal about $3,000 per customer. These higher rates are not one-time, single year charges. To make them more affordable, these higher rates are planned to extend for a quarter century or more. The City of Anaheim in 1990 voted to underground its entire electrical system. The project is expected to take more than 50 years and it will be funded by a 4 percent surcharge on every electric bill, collected for the duration of the project. (p. 4)

Interestingly, the EEI poll found that no utility indicated that they had a special rate to charge for OH to UG conversion customers or that their state rate regulators had related additional compliance policies.

Another method of paying for UG facilities is through a charge to the individual customer that may be requesting the undergrounding project. These fees, charged as Contribution in Aid of Construction (CIAC), can be expensive to the customer as they would bear the cost as their sole responsibility. In many electric

Table Legend: Urban: 150+ customers per square mile
Suburban: 51 to 149 customers per square mile
Rural: 50 or fewer customers per square mile

Table 6.1 Cost per Mile: New Construction Transmission

	Overhead			Underground		
	Urban	Suburban	Rural	Urban	Suburban	Rural
Minimum	$377,000	$232,000	$174,000	$3,500,000	$2,300,000	$1,400,000
Maximum	$11,000,000	$4,500,000	$6,500,000	$30,000,000	$30,000,000	$27,000,000

For rural electric cooperatives, the survey data suggested that new construction transmission costs at the Minimum level could range 8 times the amount of overhead costs to construct underground facilities while at a Maximum level could range 4 times the amount.

Table 6.2 Cost per Mile: New Construction Distribution

	Overhead			Underground		
	Urban	Suburban	Rural	Urban	Suburban	Rural
Minimum	$126,900	$110,800	$86,700	$1,141,300	$528,000	$297,200
Maximum	$1,000,000	$908,000	$903,000	$4,500,000	$2,300,000	$1,840,000

For rural electric cooperatives, the survey data suggested that new construction distribution costs at the Minimum level could range 3.5 times the amount of overhead costs to construct underground facilities while at a Maximum level could range 2 times the amount.

Table 6.3 Cost per Mile: Converting Overhead to Underground Transmission

	Urban	Suburban	Rural
Minimum	$536,760	$1,100,000	$1,100,000
Maximum	$12,000,000	$11,000,000	$60,000,000

For rural electric cooperatives, the survey data suggested that the cost of converting overhead to underground transmission facilities could range from a Minimum of $1,100,000 per mile to a Maximum of $6,000,000 per mile.

Table 6.4 Cost per Mile: Converting Overhead to Underground Distribution

	Urban	Suburban	Rural
Minimum	$1,000,000	$313,600	$158,100
Maximum	$5,000,000	$2,420,000	$1,960,000

For rural electric cooperatives, the survey data suggested that the cost of converting overhead to underground distribution facilities could range from a Minimum of $158,100 per mile to a Maximum of $1,960,000 per mile. (Hall, pp. 30-31)

cooperatives, policy exists whereby UG facilities are required to be paid by the individual requesting party so that the entire cooperative membership is not burdened by the cost. The prohibitive cost of UG facilities can be a deterrence to individual customers to invest in undergrounding facilities.

Summary

The trend of utilities placing electric services underground is expected to continue in the future. Some of the reason for these decisions are to meet customer demands on aesthetics. But, the growth in new projects requiring distribution or transmission lines, either OH or UG, is anticipated to grow by less than 1 percent a year. While most industry experts contend that wide-spread undergrounding of power infrastructure is not cost-effective, studies have shown benefits in reduced tree trimming costs/ needs and reduced restoration costs from severe storms. When the public believes there is a value, they have been willing to pay the additional costs. As long as the cost remains a small percentage of the overall new home cost, new home buyers will likely continue to prefer UG facilities.

Some states and utility companies have developed policies that encourage the utility and local customers to work together to convert "select" OH areas to UG. Some of the reasons this might be encouraged include susceptibility to outages, a large number of customers being served by a power line, and the ability to recover the costs from benefitting customers. No state has, to this date, recommended wholesale undergrounding of a utility's system. Davis (2020) has noted that "Electric utilities can accomplish grid resilience in different ways, but most efforts are focused on either a plan to harden the overhead system or place facilities underground" (para. 3). Any plans to implement UG facilities should be data-driven, using an approach that identifies critical OH equipment as candidates for proactive undergrounding. Davis concludes that "A strategic undergrounding program helps identify the lines most prone to outages and considers undergrounding to improve grid resilience and the total time of restoration of overhead distribution lines" (para. 4).

With the increased occurrence of recent storms, some have been pointing out that there are human, business, and societal costs also associated with power outages. These costs, in the past, have tended to not be included in a utility company's cost vs. benefit analysis. Because utilities aren't required to consider these costs, some believe they may not be considering the complete picture of costs in their decision-making analysis. UT News (2021) cites Ben Leibowicz regarding this point:

"We have a very incomplete picture of the full economic cost of big power outages," said Ben Leibowicz, an assistant professor in the UT Austin Cockrell School's Walker Department of Mechanical Engineering who co-authored the report. "Very relevant to the recent blackouts in Texas, we find that people aren't really estimating the costs borne by electricity customers of being without power for a long period of time." (para. 3)

Energy Professionals (2021), a consulting firm in the utility industry, reports that power outages "cost an average of about $18 billion to $33 billion per year in the United States" (para. 4). These figures do not include brownout outages, which when included would increase the cost. Brownouts are a reduction or restriction in available power by the utility to an area, intended to control electricity supply during periods of high demand to avoid a more severe power interruption. These types of outages

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can cost businesses in terms of spoiled inventory, and delayed or missed business opportunity. As we see an increased occurrence and intensity of disrupting storm events, there may be increased discussion by the public, regulators, politicians, and the media regarding the human, business, and societal costs that have up until now gone uncaptured in most utility companies strategic policies in UG infrastructure investment decisions.

For electric cooperative finance and accounting professionals, it is recommended that you become knowledgeable regarding your electric cooperative's strategic policies regarding undergrounding policies and practices. Additionally, the cooperative would benefit from an open dialogue and information sharing between the finance/accounting area and the other departments within your organization when formulating decisions on UG investments. The engineering, operations, customer service, regulatory and governance, and public relations/marketing areas could all add value in presenting their expertise and perspectives on "if and how" undergrounding could make sense for your cooperative members. Since the cost of undergrounding is one of the key challenges that has prevented more wide-spread investment in UG infrastructure, adding data-driven financial analysis to key decision-making regarding undergrounding cost vs. benefit analysis would be beneficial to the cooperative members.

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North American Wood Pole Council. (April, 2017). Technical Bulletin – Undergrounding: Hidden Lines, Hidden Costs. Retrieved May 19, 2021 from the following website: https://woodpoles.org/portals/2/documents/TB_Undergrounding.pdf

UT News. (March 1, 2021). True Cost of Major Power Outages Remains a Mystery, Report Finds. Retrieved May 19, 2021 from the following website: https://news.utexas.edu/2021/03/01/true-cost-of-major-power-outages-remains-a-mystery-report-finds/

Further articles of interest on undergrounding:

Cost-Benefit Analysis of Hardening Utility Lines.
(Report by Public Utility Commission of Texas analyzing costs and benefits of placing utility lines underground.)
10 pages, 03/09
URL: https://woodpoles.org/portals/2/documents/TexasPUC_Hardening.pdf

Cost-Effectiveness of Undergrounding Utility Lines.
(Presentation by Kevin Mara, PE, of HiLine Engineering on the trends and economic costs in placing utility lines underground.)
16 pages, 10/06
URL: https://woodpoles.org/portals/2/documents/Mara_Undergrounding.pdf

Florida Utilities Research: Undergrounding Electric Lines.
(Three-part report analyzing the costs of placing utility lines underground vs. the marginal benefits in protecting distribution systems.)
2007/2008
URL: https://woodpoles.org/portals/2/documents/UndergroundingAssessment_P1.pdf

Life-Cycle 2017.
(Connecticut Siting Council Investigation into the Life-cycle Costs of Electric Transmission Lines, Final Report)
10/18
URL: https://portal.ct.gov/-/media/CSC/Publications/2017LIFECYCLEFINALRptpdf.pdf

Out of Sight, Out of Mind.
(Original 2003-06 Edison Electric Institute study of the costs of undergrounding overhead power lines.)
32 pages, 07/06
URL: https://woodpoles.org/portals/2/documents/OutofSightOutofMind.pdf

Power Outages Often Spur Questions Around Burying Power Lines.
(U.S. Energy Information Administration)
07/12
URL: https://www.eia.gov/todayinenergy/detail.php?id=7250

Technical Bulletin – Hardening of Utility Lines: Implications for Utility Pole Design and Use.
(Despite calls for "hardening" utility systems in response to storms, qualitative evaluations indicate current systems perform as expected and potential actions to harden the system are expensive and offer questionable benefits.)
8 pages, 11/07
URL: https://woodpoles.org/portals/2/documents/TB_HardeningUtilityLines.pdf

Updated! Dirt Report on striking underground utilities.
(Report from Common Ground Alliance on the record 534,151 events in North America where underground utilities were struck or damaged during 2019.)
65 pages, 10/20
URL: https://woodpoles.org/portals/2/documents/DIRT_2019.pdf