Externalities of Overhead Power Lines on Residential Housing Values

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Abstract

Overhead electricity transmission lines (OHLs) create negative externalities on nearby housing values largely from perceived factors including aesthetics, safety, and health. Studies have been performed outside of the US to determine the specific value impact of power lines by proximity. It is not, however, well researched within the United States–specifically in suburban and urban areas. To assess the value loss from overhead power lines, this study examines housing transactions in North Carolina from 1997 to 2020 with a particular emphasis upon cities and townships. With GIS software, proximity variables are calculated such that a difference-in-difference regression can estimate the impact of distance to OHL on transaction values.

This is important for local policy regarding whether municipalities may want to invest into burying power lines as a means of improving local property values. The results attempt to illustrate how burying high impact lines (HILs) can generate high public benefit relative to cost through marginal value of public funds (MVPF) calculations. These HILs may be chosen based on a variety of factors including proximity to dense, high value housing to maximize value improvement by burial.

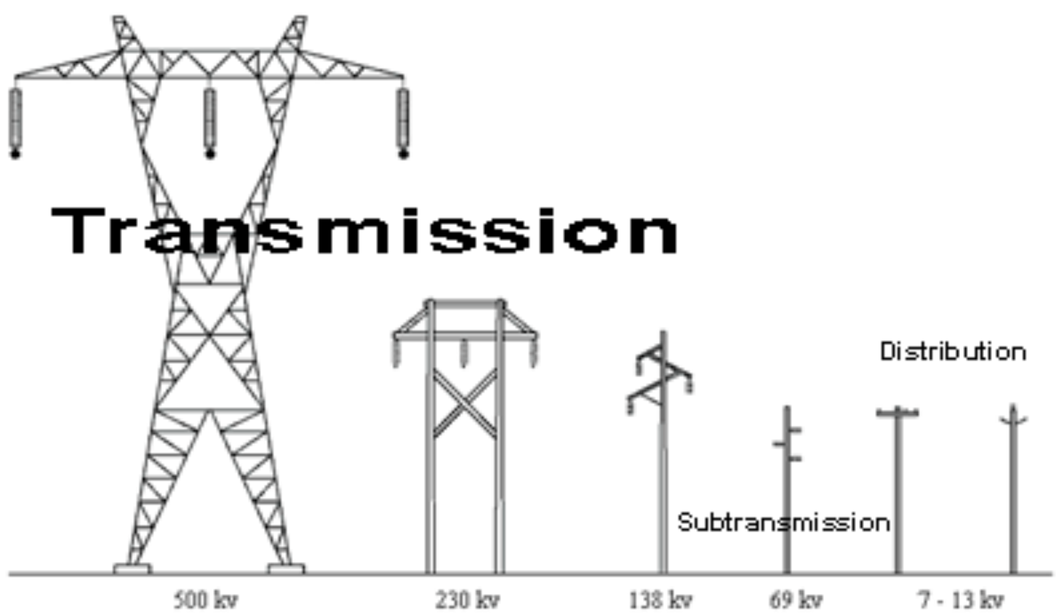
Keywords: Electric Utilities, Policy Evaluation, Local Government Expenditure

JEL classification: L940, H760, D040

I. Introduction:

Overhead transmission lines (OHLs) are high-voltage cables attached to visible towers which transmit electricity over large distances. Higher voltage classes necessitate taller OHLs constructed of less visually appealing materials like steel. Voltage classes typically include low voltage (1-69 kV), medium voltage (70-100 kV), and high voltage (101+ kV), although there is no official standardization of terminology. A 7-13 kV OHL is most common in neighborhoods, though more rural areas may be in close proximity to lines closer to 500 kV.

Figure 1: Appearances and heights of various OHL voltages.



Proximity to OHLs is associated with reduced property values often as a result of home buyer perception. First, nearby power lines reduce perceived aesthetic appeal especially when the home's surroundings play a significant role in perceived value. For example, a line may block a view or diminish a property's 'curb appeal' which is effectively how attractive a home is from the street. Second, there are perceived safety concerns such as fires caused by OHLs being more susceptible to extreme weather than buried lines (Bard, 2023). In areas like Western North Carolina which are prone to severe storms, there may be a hesitancy to purchase a home where a power line is near enough to cause an electrical fire. This also extends to whether a home's electricity is believed to be supplied via a nearby OHL through either a visible or underground connection. For example, a homebuyer may possess the common belief that if a large OHL several hundred meters away falls, their power will subsequently be disrupted.

Finally, there are perceived health concerns, regardless of legitimacy, due to electromagnetic frequencies (EMFs) which are often thought to be carcinogenic (Crespi, et. al, 2016). As a result, prospective homeowners may be more reluctant to purchase residential property within a certain proximity of an OHL for fear of negative health outcomes.

These power lines can be buried and run underground as is common in newer developments, especially in more urban settings. Underground OHLs, however, are typically 3-5 times more expensive per foot (Lane Electric, n.d.) and are more difficult to service. This often means that utility companies and local municipalities do not find the extra cost worthwhile and choose to leave the lines above ground. Across municipalities and service areas, it is also often ambiguous on whom the cost of new transmission lines should fall (Clifford, 2023). Depending on whether the local government, local service provider, or homeowner bears the brunt of the cost can dictate if more expensive options are chosen. In North Carolina, Duke Energy and various electric cooperatives own all lines. Oftentimes, the cost of burying an OHL is retroactively added to the electricity bill of the serviced residents.

Previous research has shed light on the negative externalities of overhead OHLs on housing values in various regions. Across England and Wales, for example, it was found that the “construction of new overhead power lines reduces prices by 4% for properties up to 1200 meters away.”[1] This led to an estimated property value loss in excess of £22 billion. In a similar study that examined rural farmland and housing in the United States, it was found that housing values declined by 2.74% for every 1 kilometer of distance closer to an OHL (Lu, et. al, 2023). Conversely, if that OHL was used in conjunction with a renewable energy source, the nearby property values actually increased (Lu, et. al, 2023). This may be attributable to rural areas having more consistent access to energy through which they can increase standards of living than to the OHLs themselves. It may also reflect the presence of wind turbines which lead to increased income for rural farmland owners. While there is wide consensus that home values are negatively affected by closer OHLs, it is uncertain the exact dollar effect per meter of proximity in urban areas, the marginal value of public funds spent to retroactively bury lines, and the potential breakeven period should the county pay for it.

In this study, I examine differences in housing value dependent upon proximity to OHLs controlling for various factors like county, housing attributes, and transmission line voltage. This is to answer the primary questions: (1) what is the specific dollar per meter impact of an OHL’s proximity to a residential single-family home in urban North Carolina; (2) is the cost of proactively or retroactively burying OHLs profitable for county governments through increased taxable property value; (3) under what conditions does the marginal value of public funds (MVPF) for burying an OHL indicate that the public benefit outweighs the net fiscal cost? Attempting to answer these questions is important for whether local municipalities may want to invest into underground power lines as a means of improving local property values, investor

[1] Tang and Gibbons (2021), pp. 1.

confidence, and prospective homeowners' perceived value of homes for sale. This would not only increase the taxable base for the municipality, but also bolster home value for homeowners.[2]

Figure 2: Wood and metal OHLs of different voltages above a residential street in Durham, North Carolina.

[2] It must also be taken into consideration, however, that this may have detrimental effects for marginalized communities. Should the taxable value of a property increase significantly, current residents may no longer be able to afford to live in an area. This is often seen with gentrification projects and must be considered when making conclusions about public benefit.

II. Literature Review:

Multiple publications in recent years investigate housing values and proximity to overhead power lines. Tang and Gibbons (2021) conduct a study of power lines and their negative externalities in England and Wales from 2002 to 2017. Similar to my own study, they rely upon perceived externalities from homebuyers such as aesthetic value and health concerns. Using a difference-in-difference approach, Tang and Gibbons compare neighborhood level price changes before and after the construction of overhead power lines. They note, however, the empirical difficulties that arise when considering that the placement of overhead power lines is often not random because companies seek certain areas based on the costs of compensation for infringing upon property. Consequently, the willingness to pay of homeowners may be more representative of marginalized areas where it is easier to place an OHL than of the population as a whole. My study attempts to mitigate this self-selection bias by comparing homes in urban areas which are already relatively well-established. In doing so, the lines are placed in proximity to homes due to power demand as opposed to availability of land. For example, a town's population increases substantially, as in the case of Asheville since 1997, and OHLs are thus constructed to service local power needs. Controlling for all extraneous factors that could create differences in housing price, I attempt to isolate the value impact of proximity to OHLs amongst otherwise similar housing.

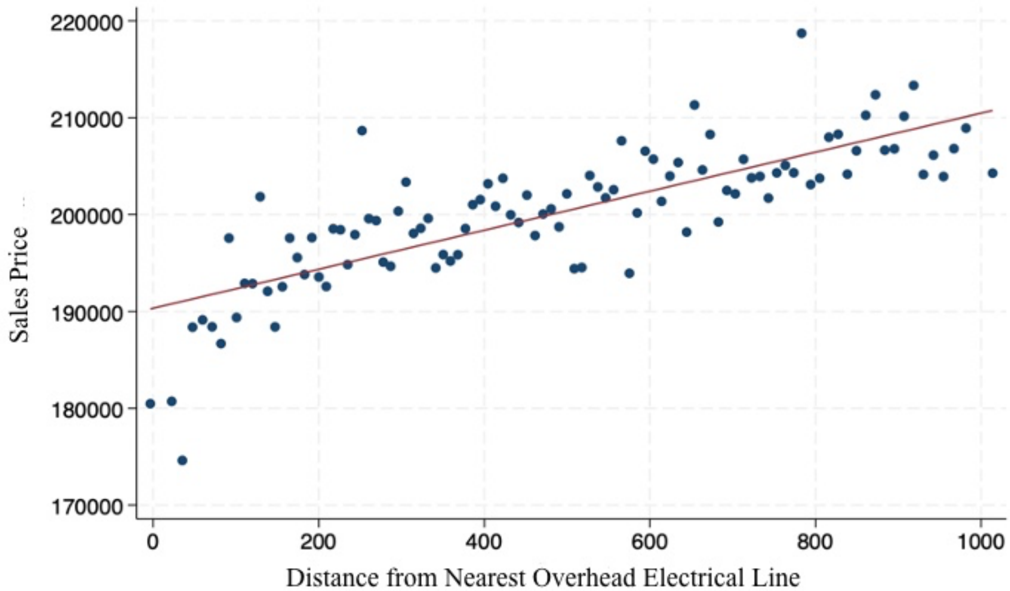
While there are previous studies that focus on the United States, they do not necessarily examine explicit differences in the impact of these externalities across developed urban areas or the marginal value of burying OHLs. For example, Cheng, Liu, Lu, and Zhang (2023) find that electricity transmission lines affect farmland values and housing differently. They focus, however, on the Midwest and local differences between the value of land and housing by considering whether the power lines are connected to solar or wind farms. Colwell (1990) also draws only from a small sample of only 200 sales between 1968 and 1978 within one town in Illinois to establish that property values decrease when nearer to an OHL. Colwell also says nothing about the marginal value of public funds.

My paper instead focuses on differences across more developed regions in North Carolina to investigate housing value impacts in a manner applicable to relatively more heavily populated areas. For example, rather than focusing on rural areas, I examine cities which have populations at or above 100,000 like Asheville, Fayetteville, and Gastonia. I also examine 239,641 housing transactions which broadens the sample size well beyond previous studies in the US.

Finally, Tang and Gibbons (2021) include a cost-benefit analysis of burying the powerlines and determined that the cost would exceed the estimated benefit by approximately £7 billion. It does not, however, discuss the tax policy implications for local governments or the marginal value of public funds.

My paper focuses on the potential benefits of increasing taxable property value for a local government. For example, if a municipality shoulders the cost of burying transmission lines directly or through subsidies provided for an energy company, it is unknown if it would ever be profitable, and if so, what the length of the breakeven period would be. This would have implications for debates over whether future power lines should be buried without fears of government over-expenditure. Additionally, this policy may have implications for debates surrounding who should pay for the installation of new power lines because local governments might find an economic benefit to doing so themselves or in partnership with local energy companies.

Figure 3: Home values and distance from nearest overhead electrical line.



Note: Scatterplot with observations condensed into 100 bins and fitted line demonstrating the positive correlation between distance to OHL and sales prices in North Carolina for homes within 1 kilometer of an OHL.

III. Data Description:

I primarily utilize property transaction data from CoreLogic[3] with my focus being on deeds associated with ownership transfers both for existing and newly constructed properties. CoreLogic's transaction-deed records are themselves pulled from the formal documents signed and issued when a real estate transaction occurs. Each record includes details such as transfer date, transaction value, housing characteristics, and geolocation data. Housing characteristics are important for isolating fixed effects and include variables such as square footage, improvements, bedrooms, bathrooms, year of construction, lot square footage, and others. Additionally, the dataset includes latitude and longitude coordinates which are crucial for my proximity analysis. Transaction dates range from 1997 to 2020 and include 2,917,891 observations.

First, nominal sales prices are put into real 2020 dollars and are recorded in thousands of dollars. Second, the analysis is taken on single-family homes between $30,000 and $10,000,000 within 1 kilometer of an OHL. Multifamily properties, condominiums, apartments, and unimproved land are removed given that they may have additional confounding factors which are difficult to isolate largely due to unrecorded amenities like shared pools, parking garages, elevators, and total units in the building. Including homes further than 1 kilometer is also likely to confound the study because housing value is largely due to perceived appeal. It is unlikely that an OHL greater than 1 kilometer away would be thought to be dangerous or have an impact upon residency. Finally, price outliers were removed as they may be subject to different factors which affect perceived value. For example, a home below $30,000 may be subject to government subsidized housing laws in which case living near OHLs is economically unavoidable due to an

[3] https://datacatalog.cookcountyil.gov/Property-Taxation/Assessor-Archived-05-11-2022-Residential-Sales-Dat/5pge-nu6u/about_data

inability to relocate. Further, any duplicates as measured by same property address, sale date, and sale price are removed along with observations which did not have complete information for all needed variables. This leaves 239,641 observations.

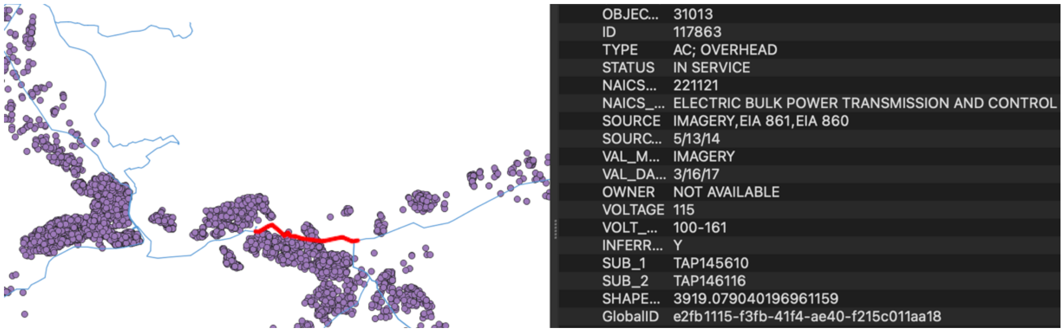
It is important to note that the under 1 kilometer sample is representative of the full dataset as demonstrated by summary statistics (see Appendix A). Listed are the summary statistics for the full dataset (A.1, A.2) and the sample (A.3). Square footage (A.2) is summarized separately from the full dataset due to missing observations and is listed with as many observations as possible. The mean real sales price of the sample's dataset is $201,304.55, which though different from the sample's $245,102.63, is not unrealistically representative. The average square footage in the sample is 2166.99 which is highly representative of the overall dataset's 2238.85. Consequently, it is reasonable for the sample with 239,641 observations to represent the full dataset.

It is also important to note that these observations include repeated sales of the same property at different dates. While transactions were removed if they were the same sale on the same date (i.e., duplicates), repeat sales of the same home at different points in time were retained because property modifications may have led to different transaction values.

I use the Geospatial Management Office's Homeland Infrastructure Foundation Level Database (HIFLD) Transmission Lines dataset for geolocation data on OHLs in North Carolina.[4] Each segment of OHL includes an ID, current type (overhead AC, overhead DC), latitude and longitude coordinates, and voltage.

[4] https://hifld-geoplatform.hub.arcgis.com/datasets/bd24d1a282c54428b024988d32578e59_0/explore?filters=eyJUWVBFIjpbIkFDOyBPVkVSSEVBRCIsIk9WRVJIRUFEIiwiQUMiLCJEQzsgT1ZFUkhFQUQiLCJEQyIsIk5PVCBBVkFJTEFCTEUiXX0%3D&location=41.887555%2C-87.644448%2C10.64

Figure 4: Sample data selection of an OHL segment (red) within QGIS software.



IV. Methodology:

GIS:

I first create proximity values for each housing unit. By downloading a shapefile of North Carolina's overhead power line grid from the Geospatial Management Office's Homeland Infrastructure Foundation Level Database (HIFLD), I can overlay it with geolocational data from the housing dataset. Consequently, a map is created with housing and power line location overlays which can be used to compute proximity values. Each property is assigned a distance value according to the closest OHL linearly.

Figure 5: QGIS overlay of single-family homes sample (purple points) within North Carolina onto overhead power grid (yellow lines).

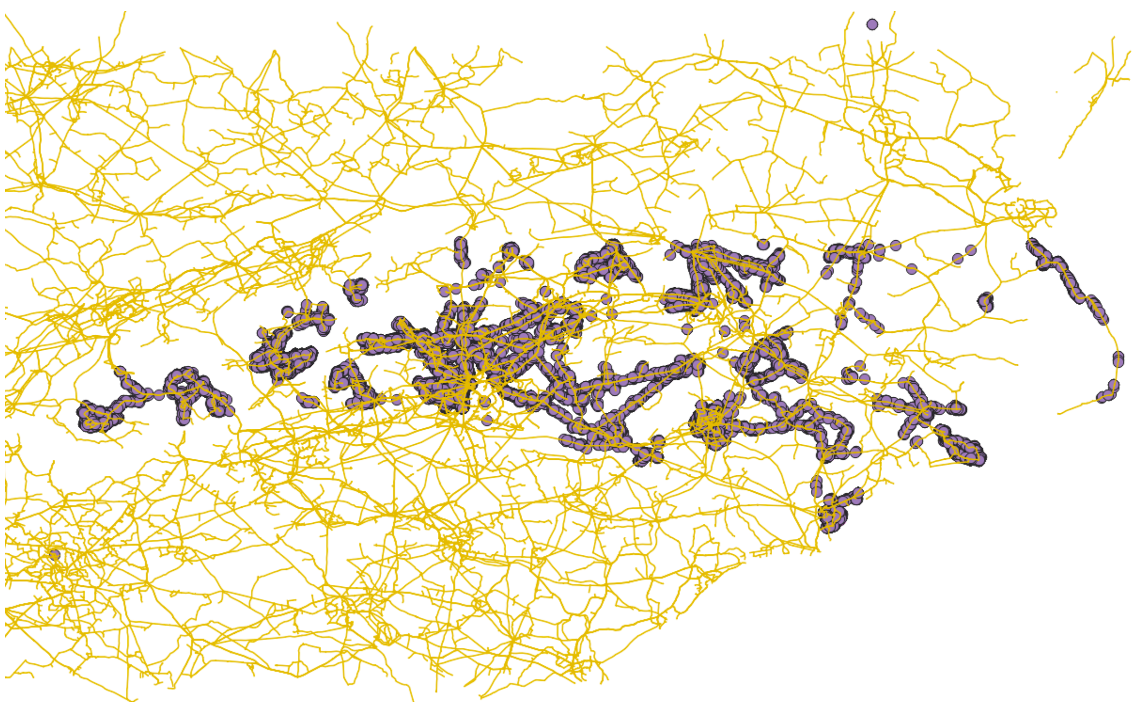
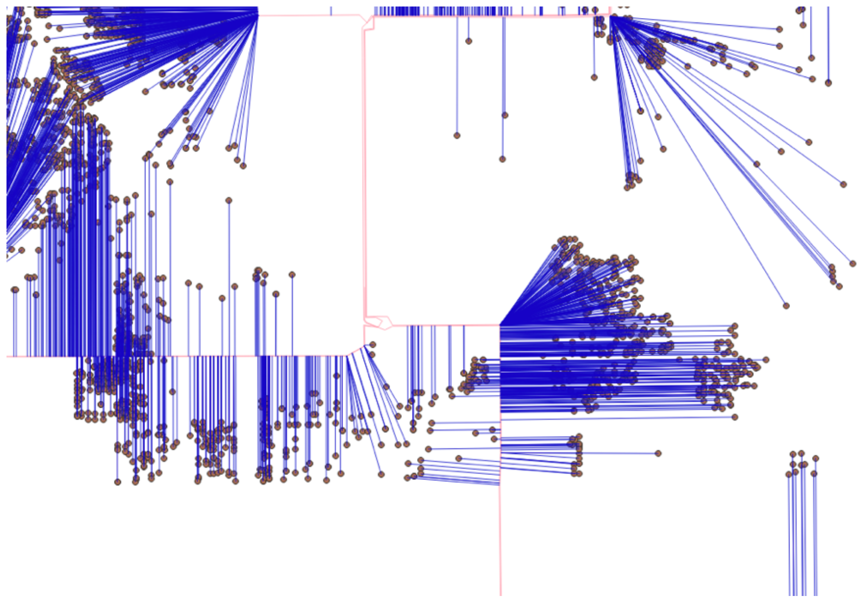


Figure 6: Proximity-to-closest mapping in QGIS (red lines indicate OHLs, brown dots represent single-family homes, blue lines represent shortest distance between).



Empirical Specification:

Given that the form of an overhead power line varies drastically, an ideal empirical framework controls for differences in voltage class which alter height and material. Additionally, housing characteristics vary drastically and need to be accounted for. Some of these variables include square footage, number of beds and bathrooms, year of construction, and lot size.

The empirical specification for analyzing the relationship between the proximity of an overhead power line (OHL) and property sales prices in North Carolina can be represented as:

Equation 1:

$$
\begin{aligned}
\ln(RealSalesPrice_i) \\
&= \beta_0 + \sum_j \delta_j PropertyZipCode_{ij} + \beta_1 \ln(Distance_i) + \beta_2 YearBuilt_i \\
&+ \beta_3 SqFeet_i + \beta_4 LotSizeSqFeet_i + \beta_5 HalfBaths_i + \beta_6 FullBaths_i \\
&+ \beta_7 TotalBedrooms_i + \beta_8 Voltage_i + \beta_9 (\ln(Distance_i) * Voltage_i) + \varepsilon_i
\end{aligned}
$$

This equation represents a pooled cross-sectional regression model designed to estimate how the proximity of an OHL impacts sales price while controlling for OHL, property, and regional characteristics. A limitation of this pooled cross-sectional approach is that it treats repeat sales as unique observations. A panel structure was considered, however, only 78,000 homes were sold at least twice in data over this time period. Utilizing a longitudinal methodology also creates issues for whether repeat sales only exist for certain properties in the presence of confounding factors. For example, a home may be sold twice because it is undesirable which indicates that a lower transaction price may not be a result of a nearby OHL. Thus, the effect of proximity cannot be as clearly isolated for repeat sales using a panel regression.

Not using a panel, however, means that the model cannot directly control for unobserved property-specific characteristics that may influence sales prices. Suppose, for example, two homes are identical in terms of square footage, number of bedrooms, lot size, year built, and even their proximity to an overhead power line (OHL). One, however, has a beautifully landscaped yard with freshly painted exteriors, while the other has overgrown weeds and peeling paint. Buyers are likely to value the first house higher which would result in a higher sales price. In this model, curb appeal is not included as a variable because it is unobserved which thus contributes to the residual. Examining the same property at multiple points in time, as with a panel regression, would allow some of these unobserved characteristics to be captured. Nonetheless, the inclusion of zip code fixed effects and a plethora of control variables attempt to mitigate this by ensuring that comparisons are made among relatively homogeneous properties.

The dependent variable in this model is the natural log of the real sales price in thousands of 2020 dollars. Transforming sales prices into natural logs serves two critical purposes. First, it allows for the interpretation of coefficients as elasticities if the independent variable is also in logs, where β_1 represents the percentage change in sales price for a 1% increase in distance from the OHL. For example, a coefficient of .05 indicates that for every 1% increase in distance from an OHL, the sales price is expected to increase by 0.05%. Thus, a \$100,000 home that is moved from 100m to 101m from an OHL would then be expected to transact at \$100,050.

Second, the natural log transformation helps address the non-linear relationship between OHL distance and property values. For example, increasing an OHL's distance from 1 to 2m has a greater effect than 100 to 101m. Essentially, it is reasonable to assume that the marginal impact of a meter of proximity diminishes non-linearly. The logarithmic transformation captures this diminishing sensitivity by compressing larger values of distance and allowing the model to more effectively represent these nuances.

Dummy variables for property zip codes are included to control for location-specific fixed effects. These dummies, represented as $PropertyZipCode_{ij}$, absorb average differences in property prices attributable to time invariant factors such as average school district quality, local economic conditions, or proximity to urban centers. For example, properties in an affluent zip code near Charlotte may have higher baseline prices than those in a more rural area even if other characteristics like square footage and number of bedrooms are the same. By including zip code dummies, the regression isolates within-zip-code variation to ensure that the estimated effect of OHL proximity reflects only differences among comparable properties within the same zip code.

Location-based heterogeneity may also extend beyond average price differences. Properties within the same zip code may exhibit correlated error terms due to shared unobserved factors such as localized economic shocks or neighborhood-level amenities. To address this issue, standard errors are clustered at the zip code level. Clustering adjusts for potential heteroskedasticity and intra-cluster correlation to ensure that the estimated standard errors are robust. This adjustment is essential because failing to cluster could lead to underestimated standard errors and inflated significance of coefficients.

It is important to note that clustering by zip code and including zip code dummy fixed effects serve distinct purposes. Fixed effects control for observable and constant differences between zip codes, while clustering corrects for patterns in the residuals. For example, including zip code dummies would account for the average difference in property values between two neighborhoods, but clustering ensures that any shared noise within a neighborhood does not bias the standard errors.

Structural property characteristics such as year built, square footage, lot size, number of half and full bathrooms, and number of bedrooms are included as control variables. This ensures that the analysis accounts for differences in property quality and size. These controls are crucial because they allow the model to compare properties that are as similar as possible apart from their distance to an OHL. For instance, a three-bedroom house built in 1990 with 2,000 square feet is more directly comparable to a newly built five-bedroom house with 3,000 square feet because the impact of these features are isolated. Including these fixed effects ensures a more accurate estimation of the OHL effect by isolating it from other factors which influence property value.

OHL voltage class is also included as a control variable because not all power lines are perceived equally. Higher voltage lines are often more visually unappealing because they tend to be taller and made of less natural materials like steel. They also amplify perceived health risks because a larger line would be perceived to release more EMFs than lower voltage lines. By explicitly controlling for voltage, the model captures the direct effect of the power line's technical specifications on property prices, independent of other factors.

An important component of the specification is also the interaction term between logged distance and voltage, (ln $(Distance_i) * Voltage_i$). This term allows the model to account for the effect of distance on property values potentially varying dependent on the voltage of the nearby OHL. For example, a property 50m from a high voltage line might experience a 20% price reduction, while a property 50m from a low voltage line might only experience a 10% reduction. Similarly, as distance increases, the price effect of a high voltage line may diminish more slowly than that of a low voltage line. This may be because a taller line is simply more visible from further distances. Capturing the compounding effects of proximity and voltage makes the model more flexible and realistic to allow for nuance in how different voltages of OHLs impact property values at varying distances.

In practice, this interaction can provide policy-relevant insights. For example, if the results indicate that the negative impact of proximity diminishes rapidly for low voltage lines but persists for high voltage lines, policymakers could prioritize burying or relocating only lines above a certain voltage.

Equation 2:

$$\ln(RealSalesPrice_i) = \beta_0 + \sum_j \delta_j PropertyZipCode_{ij} + \beta_1 \ln(Distance_i) + \beta_2 YearBuilt_i + \beta_3 SqFeet_i + \beta_4 LotSizeSqFeet_i + \beta_5 HalfBaths_i + \beta_6 FullBaths_i + \beta_7 TotalBedrooms_i + \sum_k \gamma_k VoltageClass_{ik} + \sum_k \beta_k (\ln(Distance_i) * VoltageClass_{ik}) + \varepsilon_i$$

Equation 2 replaces the continuous voltage variable with categorical voltage class buckets. This adjustment allows different voltage levels to have distinct, non-continuous effects on property prices. By categorizing voltage into discrete classes–low (0-99 kV), low-medium (100-161 kV), high-medium (162-300 kV), and high (300+ kV)–the model more accurately captures these threshold effects. This is important for the assumption that an OHL is not noticeably different within voltage classes. [5]

Voltage was retained as a continuous variable in equation 1 because there is no official standardization of terminology or OHL construction standard practice. For example, there may actually be a large difference in the aesthetics of 105 and 106 kV lines, especially across North Carolina, though the buckets would categorize them as the same. Thus, using a continuous variable in equation 1 mitigates inaccuracy which may result within the buckets or at the cutoff points.

The dynamic nature of power line technology further complicates the use of voltage buckets. Advances in engineering mean that newer power lines, even within the same voltage

[5] Number of observations: low_voltage (36,017), low_medium_voltage (125,537), high_medium_voltage (70,291), high_voltage (7,796)

range, may look or function differently from older lines. For example, a 20-foot-tall metal OHL installed in 1990 may appear more similar to a ten-foot-tall wooden line installed in 2020 due to the advancement of technology despite both being in the same voltage class. These changes render static classifications less useful over time and highlight the need for a more granular, continuous approach that considers the actual voltage of each line.

Equation 3:

$$\begin{aligned}
&\ln(RealSalesPrice_i) \\
&\quad = \beta_0 + \sum_j \delta_j PropertyZipCode_{ij} + \sum_m \beta_m DistanceBucket_{im} \\
&\quad + \beta_2 YearBuilt_i + \beta_3 SqFeet_i + \beta_4 LotSizeSqFeet_i + \beta_5 HalfBaths_i \\
&\quad + \beta_6 FullBaths_i + \beta_7 TotalBedrooms_i + \beta_8 Voltage_i \\
&\quad + \sum_m \beta_{m8}(DistanceBucket_{im} * Voltage_i) + \varepsilon_i
\end{aligned}$$

Similar to equation 2, equation 3 considers OHL distance in categorical buckets (0-10m, 11-25m, 26-50m, 51-100m, 101-500m, 501-1000m). A continuous distance measure, even when logged, assumes a smooth relationship between proximity and price effects. However, the impact of OHLs may change at specific distance thresholds rather than declining uniformly.

Equation 1 does not include distance buckets, however, because there is a loss of detail when grouping properties into arbitrary ranges. Distance buckets average the effects within each range which can obscure significant differences. For example, a property located 1m from an OHL may experience a substantially greater impact than one 9m away, yet both would fall within the same range. By treating distance as continuous, the model captures this finer-grained variation. Additionally, the log transformation of both sales price and distance accounts for the likely non-linear relationship between these variables.

Ultimately, creating buckets requires establishing arbitrary classification boundaries because there is a lack of standardization. This subjectivity and lack of consistency make voltage and distance buckets unreliable. Thus, I focus primarily on the results from equation 1 which uses continuous variables because they are likely more objective measures of the effect of voltage and OHL distance on property values.

V. Results

Table 1: Regression results for impact of distance on housing sales price.

Variables	**Equation 1**	**Equation 2**	**Equation 3**
ln_realsalesprice	No buckets	Voltage buckets	Distance buckets
OHL_0_10			1.028*** (0.0309)
OHL_10_25			1.035*** (0.0205)
OHL_25_50			1.052*** (0.0215)
OHL_50_100			1.051*** (0.0159)
OHL_100_500			1.070*** (0.0132)
OHL_500_1000			1.083*** (0.0175)
yearbuilt	0.0031*** (0.0005)	0.0031*** (0.0005)	0.0031*** (0.0005)
sqfeet	0.0001*** (9.06e-06)	0.0001*** (9.07e-06)	0.0001*** (9.06e-06)
lotsizesquarefeet	1.43e-07*** (2.95e-08)	1.43e-07*** (2.92e-08)	1.43e-07*** (2.95e-08)
halfbath	0.134*** (0.0133)	0.133*** (0.0132)	0.134*** (0.0133)
fullbath	0.196*** (0.018)	0.196*** (0.018)	0.196*** (0.018)
totalbedrooms	0.036*** (0.0076)	0.0357*** (0.0076)	0.0361*** (0.00761)
voltage	-7.19e-05 (0.0001)		-7.60e-05 (0.0001)
distvolt_interact	1.17e-07 (8.84e-08)	1.20e-07 (8.75e-08)	1.25e-07 (9.62e-08)
ln_distance	0.0111* (0.0059)	0.0109* (0.00572)	
low_voltage		0.104** (0.0520)	
low_medium_volt		0.0438 (0.0402)	
high_medium_volt		0.0728** (0.0364)	
Constant	4.885*** (0.947)	4.878*** (0.945)	5.505*** (0.951)
Zip Code Dummies	Yes	Yes	Yes
Observations	239,126	239,126	239,609
R-squared	.435	.435	.436

**** p<0.01, ** p<0.05, * p<.1*

Note: robust standard errors in parentheses

Table 1 demonstrates the impact of OHL proximity to overhead power lines, specifically in terms of distance and voltage, on housing sale prices. Given that the coefficient on ln_distance is an elasticity due to the log-log empirical specification, the findings suggest that a 1% increase in distance from a power line is associated with a 0.011% increase in the sale price of an average home, holding all other factors constant. This positive relationship implies that homes situated farther from OHLs tend to have higher market values which is consistent with my hypothesis and previous literature. This result is statistically significant at the 10% level.

When distance is represented using categorical buckets rather than a continuous measure, the positive and statistically significant coefficients across all distance buckets also suggests that homes farther from OHLs tend to have higher sales prices.

The equation 1 elasticity can be converted to a dollar impact for the average house and distance in the sample. Given that sales price is proportional to $(distance)^{.011}$ [see Appendix C.1], burying an overhead power line is akin to increasing distance to 'significantly large.' For example, distance can be increased to 1000 meters as a comparable result to burying the line. Thus, percentage change in sales price for the average house real sales price ($201,304.55) and average distance (481.09m) can be represented by $(.011) * \ln\left(\frac{1000}{average\ distance}\right)$ = .805% [see Appendix C.2]. Consequently, 0.00805 * (average sales price) yields a $1,629.24 gain in value if the OHL is buried.

1000m is chosen as a 'significantly large' distance because the study has thus far already assumed that OHLs further than 1 kilometer are unlikely to carry a perceived impact on appeal. Given that greater burial distance increases a home's value improvement, it follows that a more generous estimate be reached as well. For the purposes of comparison, 10,000m is also used as a burial distance for the same calculations. 10,000m was chosen because it encapsulates 99.7% of the total dataset including outliers. It must be understood that I am assuming the log linear relationship which exists in my sample also continues to hold past 1000m simply for the purpose of this comparative calculation.

This study thus treats 1000m as the conservative estimate of home value improvement from OHL burial and 10,000m as the generous estimate. From this point forward, the study will duplicate calculations with both burial distances using the terminology “conservative” and “generous.” It must be noted that the line which is closest is assumed to be the only line of relevance. So, when its distance is moved to significantly large, it is akin to moving all lines beyond it to the significantly large distance as well.

Repeating the elasticity conversion with the assumption that OHLs are buried at 10,000m yields the following results: $(.011) * \ln\left(\frac{10{,}000}{average\ distance}\right)$ = 3.34%. Consequently, 0.0334 * (average sales price) yields a generous average gain in value of $6,718.97 if the lines are buried.

Table 1 also examines the effect of voltage on sale prices. The equation 1 coefficient on voltage is -.00007, with a p-value of 0.542, indicating that no statistically significant relationship is detected between voltage and housing sale prices in this model. This suggests that the level of voltage for overhead power lines, on its own, does not have a measurable impact on property values. This finding contrasts with our expectations that higher voltage lines might negatively influence property values due to perceived visual, safety, and health concerns.

In contrast, equation 2 indicates that homes near low-voltage OHLs experience a significant positive price effect (0.104, $p < 0.05$), while properties near high-medium-voltage OHLs also exhibit a smaller but statistically significant price premium (0.0728, $p < 0.05$). The lack of statistical significance for the coefficient on low-medium voltage OHLs, however, raises questions about whether the effect of OHL voltage follows a predictable pattern. This lack of consistency may ultimately reflect differences in how homebuyers perceive various voltage classes and the lack of standardization concerning their categorization and construction.

For both the continuous and bucketed voltage variables, the inconclusive coefficients may simply reflect homebuyers' limited awareness regarding differences in voltage. Given that most buyers focus more on the visual presence of power lines rather than their operational specifics, it would be far more appropriate to include variables for OHL height and material. These datapoints are not often recorded, however, due to being relatively unimportant in recordkeeping compared to voltage. Essentially, home buyers may mistake a low voltage line for one that is high voltage and vice versa. This causes the regression to not detect any pattern in perceived value attributable to voltage.

In addition, regulatory and infrastructural factors could further explain the lack of significance. High voltage lines are often subject to safety regulations, such as mandatory clearance zones around an OHL, which can mitigate perceived health risks and ensure consistent market responses regardless of voltage levels. While distance would still matter because of perceived threats of outages, aesthetics, safety concerns, and health outcomes, a higher voltage line may effectively be viewed the same as a low voltage line. In effect, a home buyer views a line as a line and there is a negligible perceived difference between living near an OHL which is high or low voltage. More important to the homebuyer is simply living near a line or not.

The analysis also includes an interaction term between distance and voltage (distvolt_interact) to capture any combined effects on sale prices. The interaction term is also not significant with a coefficient of .000000117 likely for the same aforementioned reasons.

The regression results reveal that the controls (year built, square feet, lot size, bathrooms, and bedrooms) are all positive and highly significant, aligning with existing literature (Tang and

Gibbons, 2021). These findings make intuitive sense as each of these characteristics directly contributes to the utility, desirability, and overall value of a home. Newer homes (year built) are generally more appealing due to modern designs, better technology, and lower maintenance needs, while greater square footage and lot size provide more space for living and recreation which buyers are willing to pay a premium for. The positive coefficients for both bathrooms and bedrooms are also intuitive.

To make any non-aggregated conclusions, the gain in value from burying nearby OHLs must be computed for each individual property. Every observation in the sample is thus assigned a percentage change in value according to $\beta_1 * \ln\left(\frac{Burial\ Distance}{Distance_i}\right)$. Consequently, two percentage changes are generated for each property, one for the conservative burial distance of 1000m and another for the more generous 10,000m. The conservative estimate for mean percentage change in value across all properties is 1.19% and the generous estimate is 3.91%.

The percentage changes are made more intuitive by converting them to dollar figures. This is done by multiplying the real sales price by the percentage change. Each property is thus assigned two dollar amounts representative of value improvement with the nearest OHL buried. The generous estimate for mean change in value is $7,799.45 and the conservative estimate is $2,323.03. It is worth noting that the generous range of value gain is [$874.16, $488,468.30] and the conservative range is [$.06, $275,985.90]. While it may be unreasonable for some properties to gain nearly $500,000 while others gain less than a dollar, this is a demonstration of the two levers for value improvement. Properties which regain a larger value are both close to the $10,000,000 transaction price and are a small distance from an OHL. Thus, the percentage change in value for burial is high while simultaneously being multiplied against a larger base. The opposite is true for properties which gain almost nothing. They are simultaneously close to the $30,000 minimum transaction price and are abnormally far from an OHL. While potentially unreasonable, outliers in value gain cannot be arbitrarily eliminated. A wealthy home buyer's perception of a visible powerline directly beside their $10,000,000 home may in fact be worth $488,000 given their high optionality in home choices. Conversely, a poor home buyer may not have the optionality to avoid an OHL and thus cannot diminish the value of an inexpensive home simply due to its presence.

These property value improvements are then summed to create a total for each county. Every county is thus assigned a generous and conservative estimate of value gain for the sample. This value gain represents a portion of the counties' total value gain if multiplied to represent all housing units. For example, if the value gain in a county's sample is $1 million and the sample represents 10% of total housing units, then the county's total value gain from burying the power lines would be $10 million. The generous and conservative value gains for three selected counties are listed below in Tables 2 and 3. See Appendix D for the total value gains for all counties represented in the sample.

Buncombe, Cumberland, and Gaston counties were chosen for their high number of observations relative to others in the sample and their inclusion of well-established urban areas. Buncombe County includes Asheville, Cumberland County includes Fayetteville, and Gaston County includes Gastonia.

Figure 7: Selected counties (from left to right: Buncombe, Gaston, Cumberland).

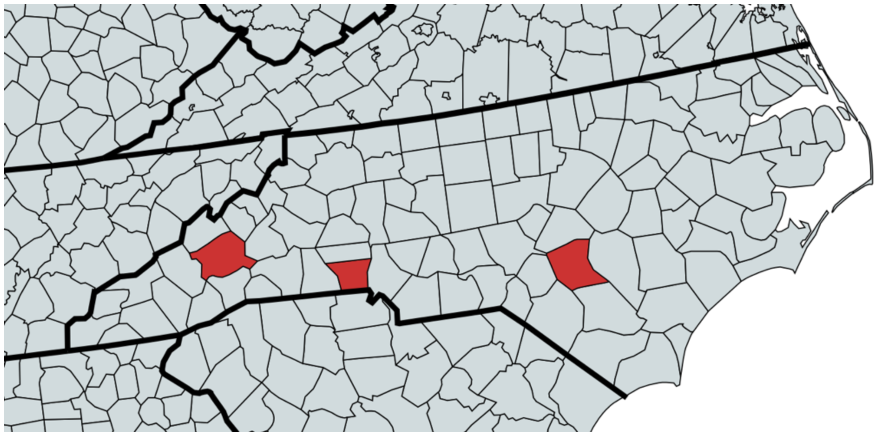


Table 2: Sample's value gain per county (generous).

County	Sample Value Gain (Generous)	Observations
BUNCOMBE	$ 321,696,384	32,402
CUMBERLAND	$ 353,677,536	57,476
GASTON	$ 266,186,816	36,827

Table 3: Sample's value gain per county (conservative).

County	Sample Value Gain (Conservative)	Observations
BUNCOMBE	$ 95,404,402	32,402
CUMBERLAND	$ 115, 521,792	57,476
GASTON	$ 85,631,296	36,827

These calculations could have been replicated for other counties in North Carolina with similar results. Isolating three diverse counties in different areas of North Carolina simply attempts to demonstrate that the results hold across the state. With each county's value gain from the representative sample, I can then estimate the total value gain utilizing US Census Bureau data[6] for the total single-family homes in each county. This is represented in Tables 4 and 5.

Table 4: Total value gain per county (generous).

County	Total Value Gain (Generous)	Sample % of Total
BUNCOMBE	$ 1,154,034,399	27.886%
CUMBERLAND	$ 793,663,812	44.563%
GASTON	$ 656,298,279	40.559%

Table 5: Total value gain per county (conservative).

County	Total Value Gain (Conservative)	Sample % of Total
BUNCOMBE	$ 342,250,028	27.886%
CUMBERLAND	$ 259,234,632	44.563%
GASTON	$ 211,128,684	40.559%

The marginal value of public funds (MVPF) can be defined as the dollars of public benefit for every dollar of public investment. Effectively a policy's "bang for its buck." An MVPF above 1 indicates that there is more than $1 of public benefit for every dollar spent. MVPF in this study can be defined by the formula:

$$MVPF = \frac{\text{Public Benefit (Est. Housing Value Improvement)}}{\text{Net Fiscal Cost (Direct Cost to Bury} - \text{Increased Tax Revenue)}}$$

[6]https://data.census.gov/table/DECENNIALDP2020.DP1?q=single%20family%20housing%20&t=Housing%20Units&g=040XX00US37_050XX00US37021,37025,37051,37071,37097,37101

Public benefit is simply the increase in housing value for a selected area. Net fiscal cost is composed of the difference between the cost to bury N meters of line and the increase in local tax revenue. The cost to bury an OHL depends on a multitude of factors including soil condition, ground slope, level of urbanization, ease of accessibility, and line length. North Carolina conducted a survey in 2003 to estimate the costs of OHL burial across the state. The report[7] found that burying a suburban OHL cost $1,635,899 (adjusted to 2020 dollars) per mile (1609.34m). The increase in local tax revenue can be calculated by multiplying improvement in house value by the local tax rate. It is important to note that MVPF can be calculated for different time horizons. The only factor which would change is the increase in tax revenue by multiplying the estimated gain for one year by the time horizon. Housing value improvement and cost of burial would both be one-time fiscal events.

Assuming that the assumptions made in this paper hold, then the following MVPF calculations can stand as an illustration of the potential return for burying OHLs. There may be additional costs and assumptions which introduce further complexity that were not represented for the purposes of simplifying the illustration. These are discussed in the results.

Using Buncombe County, it can be demonstrated that burying all lines across any county is infeasible and not a beneficial use of public funds. Buncombe County has approximately 405,000m of OHL which have an estimated burial cost of $411,683,731. For the purposes of this basic demonstrative calculation, it is assumed that all lines were suburban. The report does indicate that burying a heavily urban or commercial OHL would cost $2,731,043 per mile and a rural OHL would cost $696,113 per mile (both in 2020 dollars). With an average county property tax rate of .78%, Buncombe's generous increase in tax revenue is estimated to be $9,001,468 per

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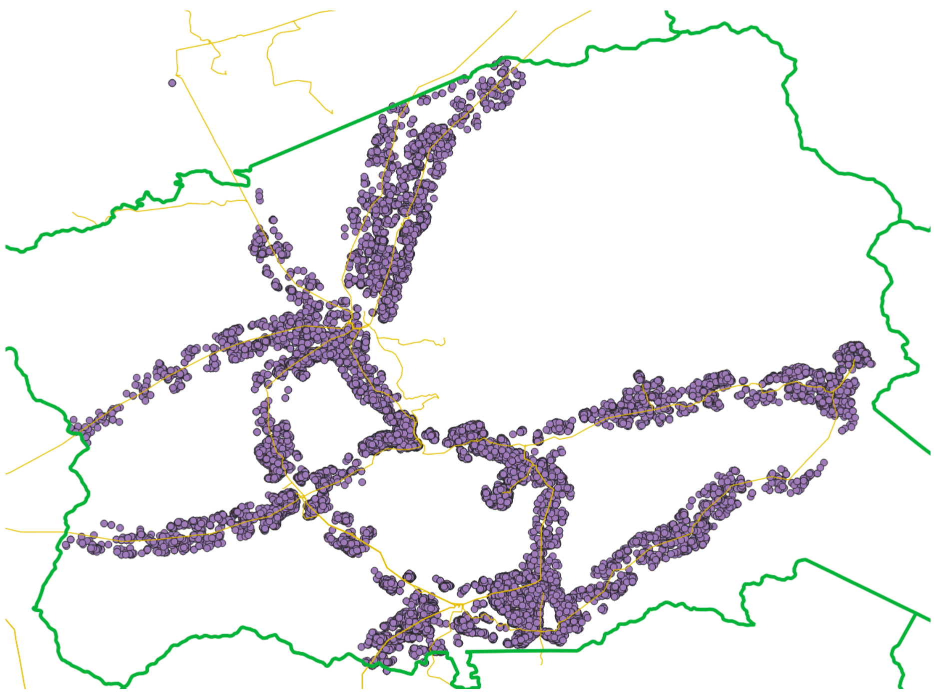
7 https://web.archive.org/web/20060601191853/http://www.ncuc.commerce.state.nc.us/reports/undergroundreport.pdf

year and the conservative increase in tax revenue is estimated to be $2,669,550 per year. This creates a generous 1-year MVPF of 2.87 and a conservative 1-year MVPF of 0.84. Effectively, it's unclear whether a dollar of public funds would generate more than a dollar of public benefit, especially if the lines face additional costs in burial from factors like delay or material shortages. It is worth noting that even a 10-year conservative MVPF which allows net fiscal cost to decrease given 10 years of collected tax revenue is still only 0.89. More notably, the breakeven period would be a generous estimate of 46 years and a conservative estimate of 154 years.

Figure 8: QGIS representation of Buncombe County (housing units in purple, OHLs in yellow, county outline in green).



It is expected that burying the power lines for an entire county would not generate the highest returns on public funds. This is because burying all lines includes those which have very little effect upon housing values, yet still face the same cost to bury. It is far more strategic for county governments and local municipalities to target high impact lines (HIL) which have an outsized impact relative to their cost. These lines can be chosen on the basis of both tangible and intangible factors. Revisiting the two levers of value regeneration, an HIL should be a segment in close proximity to high value housing. Optimally, it would also be near a high density of housing units such that the impact of burying is extended to as many properties as possible. Intangibly, an HIL might be placed in an area where maintenance costs are high for OHLs, such as those that are disaster or flood prone.

Consequently, I choose an HIL from each county to demonstrate the outsized impact that burying a strategically targeted line can have. For Buncombe County, a 3073m segment of OHL is selected. There are 1,808 single family housing within 1000m of this OHL in the sample. The generous and conservative total value gain estimates for these homes when the OHL is buried is $14,089,237 and $3,770,712 respectively. This is representative of the public benefit.

At a voltage of 115 kV, the chosen HIL is assumed to be a 'suburban line' and can be buried at the cost of $1,635,899 per mile. Thus, the total cost to bury the line is estimated to be $3,133,449. At a local property tax rate of .8626%, the generous and conservative increases in tax revenue per year are $121,534 and $32,526 respectively. The generous and conservative 1-year net fiscal costs (assuming one year of tax revenue) are estimated to be $3,011,915 and $3,100,923 respectively. Finally, the generous and conservative 1-year MVPFs are 4.68 and 1.22 respectively.

It is important to note that these results are only for the housing listed in my sample. Unlike with the full county where I extrapolated the total value gain based on percentage of total homes represented, it is not possible to know the percentage of homes represented for an individual portion of the county. This is advantageous, however, because any MVPF will likely be conservative as there should be more homes that will experience value improvement than those represented. The results for three selected HILs are listed below. All chosen HILs have a voltage less than 115 kV and so are assumed to be suburban lines with the same cost of burial.

Table 6: Generous MVPF inputs for selected HILs

County	HIL length	Home obs.	Value gain	Cost to bury	Local tax rate	Inc. tax rev. / yr
Buncombe	3073m	1,808	$14,089,237	$3,133,449	0.8626%	$121,534
Cumberland	1874m	3,133	$18,331,540	$1,910,863	1.429%	$261,958
Gaston	2377m	1,703	$12,521,050	$2,423,758	1.069%	$133,850

Table 7: Generous net fiscal costs and MVPFs

County	1-Yr NFC	5-Yr NFC	10-Yr NFC	1-Yr MVPF	5-Yr MVPF	10-Yr MVPF
Buncombe	$3,011,915	$2,525,780	$1,918,111	4.68	5.58	7.35
Cumberland	$1,648,906	$601,075	-$708,714	11.12	30.50	N/A (Paid Off)
Gaston	$2,289,908	$1,754,508	$1,085,258	5.47	7.14	11.54

(NFC: Net Fiscal Cost)

Table 8: Conservative MVPF inputs for selected HILs

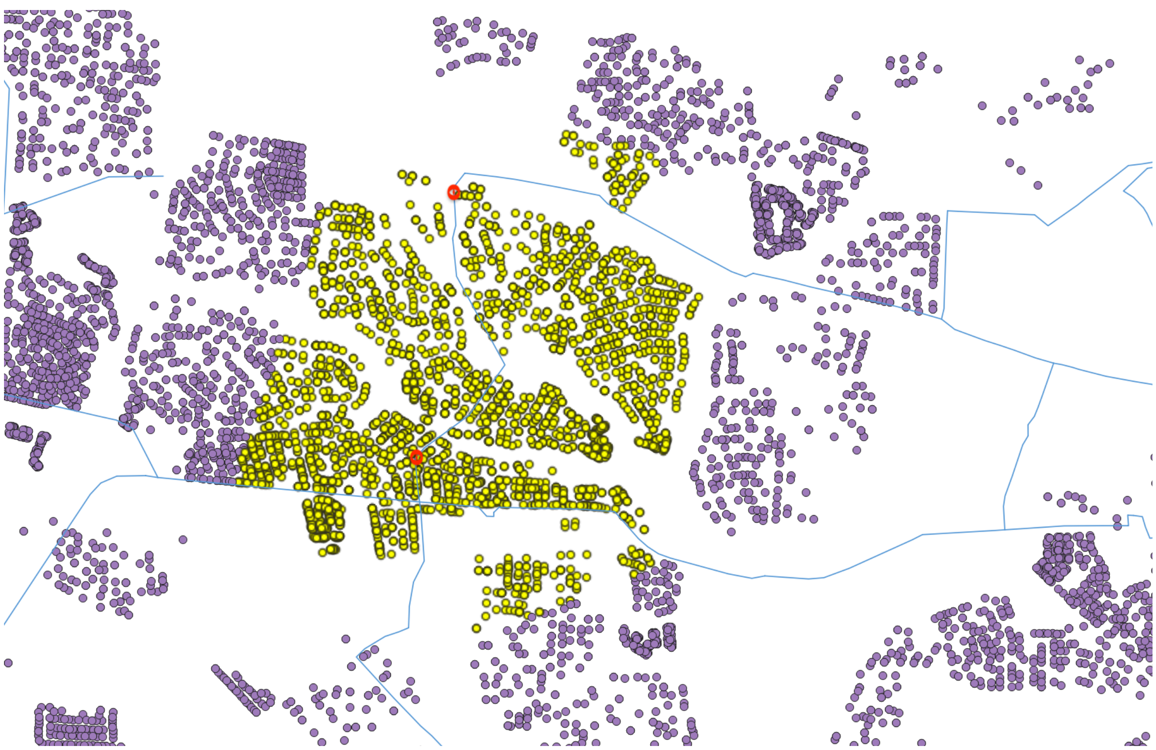
County	HIL length	Home obs.	Value gain	Cost to bury	Local tax rate	Inc. tax rev. / yr
Buncombe	3073m	1,808	$3,770,712	$3,133,449	0.8626%	$32,526
Cumberland	1874m	3,133	$7,300,883	$1,910,863	1.429%	$104,330
Gaston	2377m	1,703	$3,697,896	$2,423,758	1.069%	$39,531

Table 9: Conservative net fiscal costs and MVPFs

County	1-Yr NFC	5-Yr NFC	10-Yr NFC	1-Yr MVPF	5-Yr MVPF	10-Yr MVPF
Buncombe	$3,100,923	$2,970,818	$2,808,187	1.22	1.27	1.34
Cumberland	$1,806,534	$1,389,215	$867,567	4.04	5.26	8.42
Gaston	$2,384,228	$2,226,105	$2,028,453	1.55	1.66	1.82

(NFC: Net Fiscal Cost)

Figure 9: Selected Cumberland County HIL (housing units in purple, housing units <1000m from HIL in yellow, OHLs in blue, HIL endpoints in red).



Under my assumptions, each county's selected HIL has an MVPF greater than 1 in all time horizons. Cumberland County's HIL faces the most significant public benefit for its investment. Should the county choose to bury the selected HIL, its generous 5-year MVPF estimates that each dollar spent will generate $30.50 dollars of public benefit. Additionally, the

HIL's generous and conservative breakeven periods purely from increased tax revenue are estimated to be 7.3 and 18.3 years respectively. Thus, the generous 10-year MVPF is indeterminate because the net fiscal cost becomes negative, indicating a profit. Essentially, there would be dollars of public benefit being generated from this policy for every $0 of public funds invested.

The worst-faring county given these selected HILs is Buncombe, with a conservative 1-yr MVPF of 1.22. This, however, still indicates a positive return on the investment of public funds via increased public benefit. Should Buncombe's HIL be paid off before it is replaced, its MVPF would also become indeterminate and continue to generate public benefit without a fiscal cost. Buncombe's HIL has a generous breakeven period of 25.8 years which is within the average 40+ year lifespan[8] of an underground power line.

[8] https://www.xcelenergy.com/staticfiles/xe/Corporate/Corporate%20PDFs/OverheadVsUnderground_FactSheet.pdf

VI. Conclusion

A Duke Energy article[9] from 2014 highlights pros and cons of burying power lines. It highlights how, on the surface, it makes sense to bury lines given that fewer outages occur in areas with those that are underground. The primary challenges that they note are the following: (1) underground lines are more expensive to install; (2) maintenance and repairs take longer and are more expensive; (3) it is best to install underground lines as part of comprehensive planning for new developments.

After a severe storm in 2002, the state of North Carolina explored burying OHLs in an effort to mitigate future power outages. Ultimately, the report concluded that it would cost ~$41 billion (2002 dollars) and take 25 years to complete. Additionally, funding the project would double electricity costs for customers.

North Carolina's report is a less targeted version of this study's county-level analysis. Less granularity in the selection of OHL burial increases the likelihood that funds are wasted on low impact lines. These low impact lines may be those that only supply power to a relatively small cluster of homes and are largely not at risk from severe weather events. By exploring the possibility of burying all lines across the state, North Carolina included all low impact lines in their assessment. It is far more strategic to create a methodology that identifies the most important lines to bury from a combination of tangible and intangible factors specific to a county.

As seen with the demonstrative example from Buncombe County, exploring the burial of all OHLs across a county is likely prohibitively expensive and lacks a clearly positive return on public funds. There may be certain counties, however, especially in the far west of the state, in which the burial of all lines becomes critical. An increase in severe weather events like Hurricane

[9] https://www.durhamnc.gov/DocumentCenter/View/24283/UndergroundLinesWNA_Final_081814

Helene has demonstrated the necessity of a safer power grid. This is likely not the case for the majority of counties in North Carolina or the broader US.

This study focuses on counties because they are the recipients of property taxes in North Carolina. Under my assumptions, the study has attempted to demonstrate that while the burial of all lines in a county is not the best use of public funds, a county can select segments of OHL called high impact lines (HILs) which have outsized public returns on investment. Example criteria for an HIL may be as follows: (1) in close proximity to high value housing to maximize the increase in property taxes; (2) in close proximity to a high density of housing units such that the impact of burying is extended to as many properties as possible; (3) in disaster or flood prone areas where maintenance is frequent or expensive for existing OHLs.

Should the appropriate HILs be buried, there may be several benefits for the county, local power companies, and homeowners. First, the MVPF (public benefit return on investment) is likelier to be above 1 which indicates that for every $1 of public expenditure there is more than $1 of public benefit. This public benefit is realized from tangible factors like the improvement of local property values and intangible factors, which were not included in the MVPF calculation, such as increased positive perception of a living area for prospective home buyers.

Second, the public funds are recouped by the county government directly. The increase in property value leads to higher property taxes from the affected homes which directly repays the cost of burial. While it is not guaranteed that the full cost of an HIL's burial is repaid directly through property taxes, it is not an impossibility. Under my assumptions, the selected HIL in Cumberland County, for example, is estimated to be paid off in as few as 7.3 years with the remainder of its life span being profitable for the local government.

There are several assumptions not factored into this analysis. First, there are likely additional costs not included in the burial estimates that may lower MVPF including political and planning costs, risks of construction, and more expensive maintenance. While underground power lines also have a decreased maintenance schedule compared to OHLs, it is difficult to estimate the true cost difference.

It also depends on whom the cost of maintenance falls. For example, it is likely that it is the responsibility of the local power company to pay for all maintenance. This is important because if the cost does not fall on the county or the homeowner, then there is potentially room for negotiation. Local governments may thus be able to work with companies like Duke Energy to shoulder a portion of the burial cost. The county government, local homeowners, and Duke Energy would benefit because the cost is recouped through higher property taxes, homeowners benefit from increased perceived safety and property value regeneration, and Duke Energy faces lower maintenance costs and risks of outage during severe weather events. Should Duke Energy agree to pay for a portion of the HIL burial, the MVPF may increase due to a decrease in the net fiscal cost.

Another notable reason why this study's MVPF calculations simply serve as an illustration for the policy lies with the assumption that burying the nearest OHL is akin to burying all other lines behind it as well. While this should not affect the value improvement calculations, it certainly has effects upon cost and thus MVPF results. For example, if there are two lines within 1000m of a home, then the cost doubles despite the study only accounting for the nearer. The policy strategy implication may thus be that the qualifications for an HIL only include lines without another in close proximity so that only one needs burial. For example, older urban OHLs which are surrounded by zones of newer economic development with underground lines can be targeted.

Finally, there is potential for indirect economic benefit when lines are buried which could be factored into MVPF calculations by assigning estimated dollar values. HIL selection criteria can be expanded to include OHLs which are in zones marked for development. Local 'city-beautiful' or urban revitalization projects can benefit significantly from the removal of large and unattractive power lines. Thus, the burial of HILs can be included as part of broader economic stimulus packages by improving public perception of an area. Thus far in the study, I have only mentioned the positive impact for local home buyers and homeowners. The burial of an OHL, however, may also benefit renters, public amenity users such as park goers, and those considering moving into a region. Including HIL burial as part of a broader revitalization spending package may also increase the likelihood of budget approval.

It must be mentioned that there are potential downsides for HIL burial. First, gentrification and the increase of property taxes could drive marginalized populations out of an area. As seen with many urban revitalization projects, current homeowners and renters are often forced to leave an area as home prices increase. As already mentioned in HIL selection criteria (1), HIL selection could thus target areas which already have high property values. This would both maximize property tax increases and target homeowners who are more price inelastic and less likely to be forced to move. HIL selection should also be within areas with high urban growth to avoid burying a line which may appear to be an HIL now but would be unlikely to still have been considered an HIL in 10 to 20 years.

There is clearly uncertainty in how MVPF calculations would fluctuate both up and down should the aforementioned excluded benefits and detriments be included. Counties can create their own qualifications for whether these factors are included in addition to what constitutes an HIL. The MVPF portion of this study simply stands as an illustration of the policy possibilities for OHL burial and taxable base improvement under certain assumptions in addition to a demonstration that MVPF can be above one.

Finally, this study is performed at the county level in North Carolina, but it could be extended to municipalities or governments across the United States. A town in Florida, for example, may have an abundance of HILs due to extreme weather risks and high value retirement housing and could fund the burial itself by petitioning their county government to pass on the projected increase in property taxes. HIL burial at high levels of granularity, which smaller local governments tend to have more visibility of, is likely most effective.

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Appendix A

A.1 Summary Statistics – All Observations

	N	Mean	Median	SD	Min	Max
realsalesprice2020	2,917,891	245,102.63	193,130	230,686.61	30,065	9,977,350
distance	2,917,891	1484.62	1129.26	1480.29	0	33,065.95

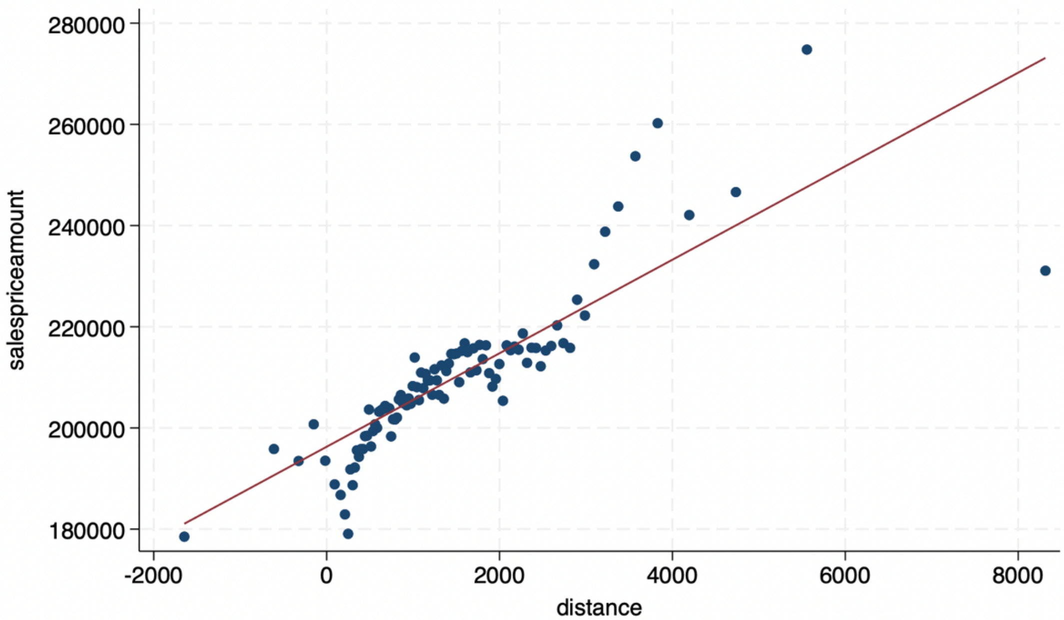
A.2 Summary Statistics – Most Sq. Ft. Obs. Possible

	N	Mean	Median	SD	Min	Max
sqfeet	1124676	2238.847	1882.000	1249.695	101	25555

A.3 Summary Statistics – Sample

	N	Mean	Median	SD	Min	Max
realsalesprice2020	239,641	201,304.55	166,460	173,248.56	30,205	9,274,999
distance	239,641	481.09	469.67	278.83	0	999.99
sqfeet	239,641	2166.91	1777	1238.77	0	21,456

Appendix B



Scatterplot with 100 bins and fitted line demonstrating the positive correlation between meters to an OHL (distance) and transaction value (salespriceamount) in North Carolina.

Appendix C

C.1

The regression equation is:

$$\ln(RealSalesPrice_i) = \beta_0 + \cdots + \beta_1 \ln(Distance_i) + \cdots + \varepsilon_i$$

Taking the exponential of both sides of the equation undoes the logarithm:

$$RealSalesPrice_i = e^{\beta_0 + \cdots + \beta_1 \ln(Distance_i) + \cdots + \varepsilon_i}$$

Using the logarithmic rule $\ln(a^b) = b \ln(a)$, I can simplify:

$$e^{\beta_1 \ln(Distance)} = (Distance)^{\beta_1}$$

Thus, sales price is proportional to $(Distance)^{\beta_1}$:

$$RealSalesPrice_i \propto (Distance)^{\beta_1}$$

C.2

The proportionality can be represented by:

$$RealSalesPrice_i = k * (Distance)^{\beta_1}$$

Taking the natural log of both sides simplifies the equation:

$$\ln(RealSalesPrice_i) = \ln(k) * \beta_1 \ln(Distance)$$

Represent the percentage change in price (RealSalesPrice ~ RSP; Distance ~ D):

$$\ln(RSP_{2i} - RSP_{1i}) = \ln(k) * \beta_1 (\ln(D_2) - \ln(D_1))$$

Thus:

$$\% \, \Delta \text{ Real Sales Price} = \beta_1 \ln\left(\frac{D_2}{D_1}\right)$$

Appendix D

D.1 Sample Value Gain per County (Generous)

County	Sample Value Gain (Generous)	Observations
ALEXANDER	$ 968,095	184
ALLEGHANY	$ 942,222	114
ANSON	$ 398,266	109
AVERY	$ 4,067,740	574
BUNCOMBE	$ 321,696,384	32,402
BURKE	$ 13,372,019	2,436
CABARRUS	$ 139,569,584	14,969
CALDWELL	$ 1,697,894	275
CASWELL	$ 22,179	5
CARTERET	$ 25,531,482	2,862
CATAWBA	$ 59,762,344	6,921
CHEROKEE	$ 18,016,300	2,672
CHOWAN	$ 2,564,287	315
CRAVEN	$ 18,131,184	3,314
CUMBERLAND	$ 353,677,536	57,476
CURRITUCK	$ 12,529,340	1,331
DARE	$ 979,872	78
DAVIDSON	$ 17,823,164	3,691
DAVIE	$ 20,726,482	2,572
DUPLIN	$ 4,652,666	623
EDGECOMBE	$ 55,423	16
GASTON	$ 266,186,816	36,827
GATES	$ 15,358	2
GRANVILLE	$ 13,988,690	1,626
GREENE	$ 85,471	14
GRAHAM	$ 422,995	37
HALIFAX	$ 9,252,137	1,401
IREDELL	$ 153,694,544	16,278
JACKSON	$ 5,849,215	627
JOHNSTON	$ 101,312,192	13,711
JONES	$ 201,228	43
LEE	$ 21,424,390	2,725
LINCOLN	$ 68,711,448	6,049
MACON	$ 3,096,318	356

MONTGOMERY	$ 2,686,599	424
MOORE	$ 2,021,557	311
NASH	$ 18,307	1
NEW HANOVER	$ 69,676,312	6,973
NORTHAMPTON	$ 36,689	8
ORANGE	$ 50,458,596	5,218
PAMLICO	$ 270,949	55
PENDER	$ 2,230,650	249
PERSON	$ 8,669,930	1,171
POLK	$ 471,036	49
RICHMOND	$ 3,813,721	699
ROCKINGHAM	$ 19,582,696	3,913
ROWAN	$ 4,099,673	703
RUTHERFORD	$ 5,819,226	1,137
SAMPSON	$ 4,050,098	739
SCOTLAND	$ 3,531,015	796
STANLY	$ 10,549,995	2,232
SURRY	$ 2,179,045	508
SWAIN	$ 2,774,361	463
VANCE	$ 4,276,948	581
WATAUGA	$ 3,962,192	395
YANCEY	$ 2,696,491	381

D.2 Sample Value Gain per County (Conservative)

County	Sample Value Gain (Conservative)	Observations
ALEXANDER	$ 245,928	184
ALLEGHANY	$ 247,843	114
ANSON	$ 98,389	109
AVERY	$ 970,458	574
BUNCOMBE	$ 95,404,952	32,402
BURKE	$ 4,432,119	2,436
CABARRUS	$ 38,665,988	14,969
CALDWELL	$ 570,115	275
CASWELL	$ 7,811	5
CARTERET	$ 8,548,301	2,862
CATAWBA	$ 16,237,567	6,921
CHEROKEE	$ 5,265,532	2,672

CHOWAN	$	908,616	315
CRAVEN	$	4,144,234	3,314
CUMBERLAND	$	115,521,792	57,476
CURRITUCK	$	3,628,207	1,331
DARE	$	424,525	78
DAVIDSON	$	5,261,884	3,691
DAVIE	$	5,310,287	2,572
DUPLIN	$	1,419,211	623
EDGECOMBE	$	10,465	16
GASTON	$	85,631,296	36,827
GATES	$	4,912	2
GRANVILLE	$	4,013,524	1,626
GREENE	$	20,847	14
GRAHAM	$	131,266	37
HALIFAX	$	2,812,982	1,401
IREDELL	$	42,919,596	16,278
JACKSON	$	1,752,876	627
JOHNSTON	$	27,689,194	13,711
JONES	$	47,756	43
LEE	$	7,564,414	2,725
LINCOLN	$	21,292,386	6,049
MACON	$	994,819	356
MONTGOMERY	$	647,332	424
MOORE	$	559,554	311
NASH	$	4,944	1
NEW HANOVER	$	18,461,788	6,973
NORTHAMPTON	$	12,086	8
ORANGE	$	12,453,832	5,218
PAMLICO	$	68,694	55
PENDER	$	512,447	249
PERSON	$	2,372,031	1,171
POLK	$	124,982	49
RICHMOND	$	1,108,849	699
ROCKINGHAM	$	5,443,066	3,913
ROWAN	$	984,919	703
RUTHERFORD	$	1,663,483	1,137
SAMPSON	$	1,057,105	739
SCOTLAND	$	892,276	796
STANLY	$	2,756,227	2,232
SURRY	$	545,786	508

SWAIN	$ 731,241	463
VANCE	$ 1,344,190	581
WATAUGA	$ 850,348	395
YANCEY	$ 776,377	381