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Powering Change: A Methodology for Prioritizing Locations When Burying Power Lines to Minimize Wildfire Damage in Communities

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Powering Change: A Methodology for Prioritizing Locations When Burying Power Lines to Minimize Wildfire Damage in Communities

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Abstract

Purpose: Overhead power lines can spark and cause extremely devastating wildfires. This has happened with power lines from utility companies such as Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). One method of preventing widespread wildfires is to bury power lines underground. When planning to bury lines, utility companies must evaluate where power lines should be buried to minimize collateral damage from wildfires while enhancing infrastructure strength. This research paper advances a novel methodology for identifying and prioritizing the ideal locations for underground power lines.

Methodology: Using California as a case study, I examine low, medium, and high wildfire risk locations in PG&E's, SCE's, and SDG&E's jurisdictions. I determine which locations should be prioritized regarding the construction of underground lines by looking at the following factors in geographic information system (GIS) mapping: overhead power lines, critical infrastructure, past wildfire activity, population density, disadvantaged communities, and thermal hotspots.

Findings: The results reveal the importance of considering variables like population and infrastructure density when mitigating wildfire risk with underground power lines, expanding the evaluation beyond typical factors like dry vegetation.

Unique Contribution to Theory, Practice and Policy: My methodology can be used by utility companies in order to conserve resources and time due to the structured approach. Doing so will also expedite the process of burying power lines which minimizes the impact of wildfires caused by overhead lines.

Keywords: *Wildfire Prevention, Underground Power Lines, Burying Power Lines, Utility Companies, Geographic Information System Mapping*

INTRODUCTION

The Dixie Fire was the largest and most devastating wildfire in California in 2021 ("Dixie Fire"). It burned almost 1 million acres of land and cost $637.4 million to extinguish ("How Much"). Over 9,500 people were evacuated throughout Northern California (Holcombe, 2021). Even firefighters themselves were uncertain if their homes were still intact. Jesse Alexander, a California Fire Chief on the scene of the Dixie Fire, highlighted the fire's ruin: "I was talking to individuals who had no idea where their family was. They were pretty confident that their house was gone and they knew their family was there during that period of time, but where is my family? Did they make it out safe?" (Gray, 2021). The cause of all of this severe damage was a blown fuse on a PG&E utility pole that connected with a fallen tree ("California Wildfires"). One single spark had the power to trigger a disaster.

In the United States, wildfires result in 394 to 893 billion dollars of damage each year ("Climate-Exacerbated Wildfires," 2023). Wildfire smoke itself kills 16,000 Americans annually, and this number could rise to 30,000 as climate change makes wildfires more frequent and severe (Borunda, 2024). California is consistently the state with the most wildfires—with over 7,500 a year—partly due to its warm, dry climate that is optimal for sparking fires ("Defending People"; "Wildfires in the US," 2023. While wildfires are a natural disaster, around 95 percent of wildfires are started by humans, and their destruction is only worsening as climate change increases temperatures and droughts (Little, 2023; "Wildfire Climate").

Statement of the Problem

Overhead power lines are known to induce wildfires in multiple ways. For example, when a line's high-voltage downed conductor touches the surrounding dry vegetation, it can result in a conflagration which is a large fire that causes extensive damage ("Common Causes"). Burying power lines underground can mitigate some of these issues as there is less chance of the electrical systems burning foliage. Some utility companies such as Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas and Electric are considering burying power lines ("CPUC Undergrounding"). However, as utility companies move towards underground lines, they must appropriately prioritize locations with higher wildfire risk. Resource limitations prevent the burial of all lines. Instead, utilities should bury lines in order of decreasing risk. This encompasses factors such as the number of people and buildings affected in the event of a wildfire. The decision about when and where to bury a power line is crucial because it prevents future wildfire damage by removing the threat of overhead lines; it also improves the resilience of communities, starting with those that are most at risk. Therefore, this research paper proposes a new methodology for identifying and prioritizing locations for underground power lines in the jurisdictions of PG&E, SCE, and SDG&E across various levels of wildfire risk. This paper's guiding research question is: Where should utility companies bury power lines to decrease the collateral damage of wildfires and improve infrastructure resilience?

LITERATURE REVIEW

Theoretical Review

While overhead power lines have caused only 10 percent of wildfires in California, the devastation they cause is much more significant. Throughout California's history, these power lines have been responsible for almost half of the state's most destructive wildfires ("Wildfire and Wildfire

Safety"). Three prominent utility companies have repeatedly experienced their overhead lines sparking and catching fire: PG&E, SCE, and SDG&E (Garcetti et al., 2019). This background highlights the importance of investigating underground power lines to create effective wildfire prevention methods.

Conceptual Framework

One emerging solution to this problem is to have utility companies bury their power lines. This method has proven to be effective, as underground power lines prevent around 98% of wildfires started by electrical lines (Walton, 2024).

Empirical Review

Multiple research papers have been written to analyze the feasibility of burying power lines and how it prevents wildfires. In their study, Cody Warner, Duncan Callaway, and Meredith Fowlie focus on PG&E and use a prediction model to evaluate the effectiveness of underground power lines regarding decreased wildfire risk (Warner et al., 2024). Furthermore, the paper compares the cost-effectiveness of underground power lines as opposed to other wildfire prevention tactics such as removing vegetation. In addition to effectiveness, Zachary D. Berryman analyzes the benefits of burying power lines, specifically under the guidance of the Federal Energy Regulatory Commission (Berryman, 2024). Instead of requiring state-by-state approval of underground lines, the paper advises a more cooperative effort. Continuing the recommendations for underground planning, Sofia Taylor and Line A. Roald explore the importance of prioritizing the burying of certain lines before others due to the cost and time required (Taylor & Roald, 2022). The study uses an optimization model to look at wildfire risk in a synthetic network along with existing lines in California; then, it explains the upgrade selection for certain lines.

Research Gaps

Ultimately, research that analyzes areas to bury lines primarily considers environmental criteria that lead to high wildfire risk. However, this leaves out other factors that contribute to destruction, including population, disadvantaged communities, and infrastructure density. This paper fills this gap by expanding the criteria to include these critical factors.

METHODOLOGY

In order to assess the areas for underground lines, I began by reviewing relevant academic papers, industry reports, and news articles about burying power lines to decrease wildfire risk. This review helped me identify my case studies and gain insight into how different factors affect the severity of a wildfire when sparked by a power line. After noticing a trend of three main utility companies sparking wildfires in California—PG&E, SCE, and SDG&E—I analyzed their progress and official statements regarding underground power lines. California has had many instances where wildfires started due to utility poles, and utility companies in California are becoming more aware of wildfire risks, which is communicated in their official statements and fire prevention measures ("Wildfire and Wildfire Safety"; Ciampoli, 2024). Therefore, this paper uses these California utility companies as case studies. I next compiled criteria from the extant literature regarding where power lines should be buried and identified missing variables that could have devastating impacts if not incorporated into the decision to bury power lines; based on these criteria, I used ArcGIS (Geographic Information System) datasets of each factor along with datasets of each utility company's power lines. Using this data, I assessed which lines were in the most vulnerable areas;

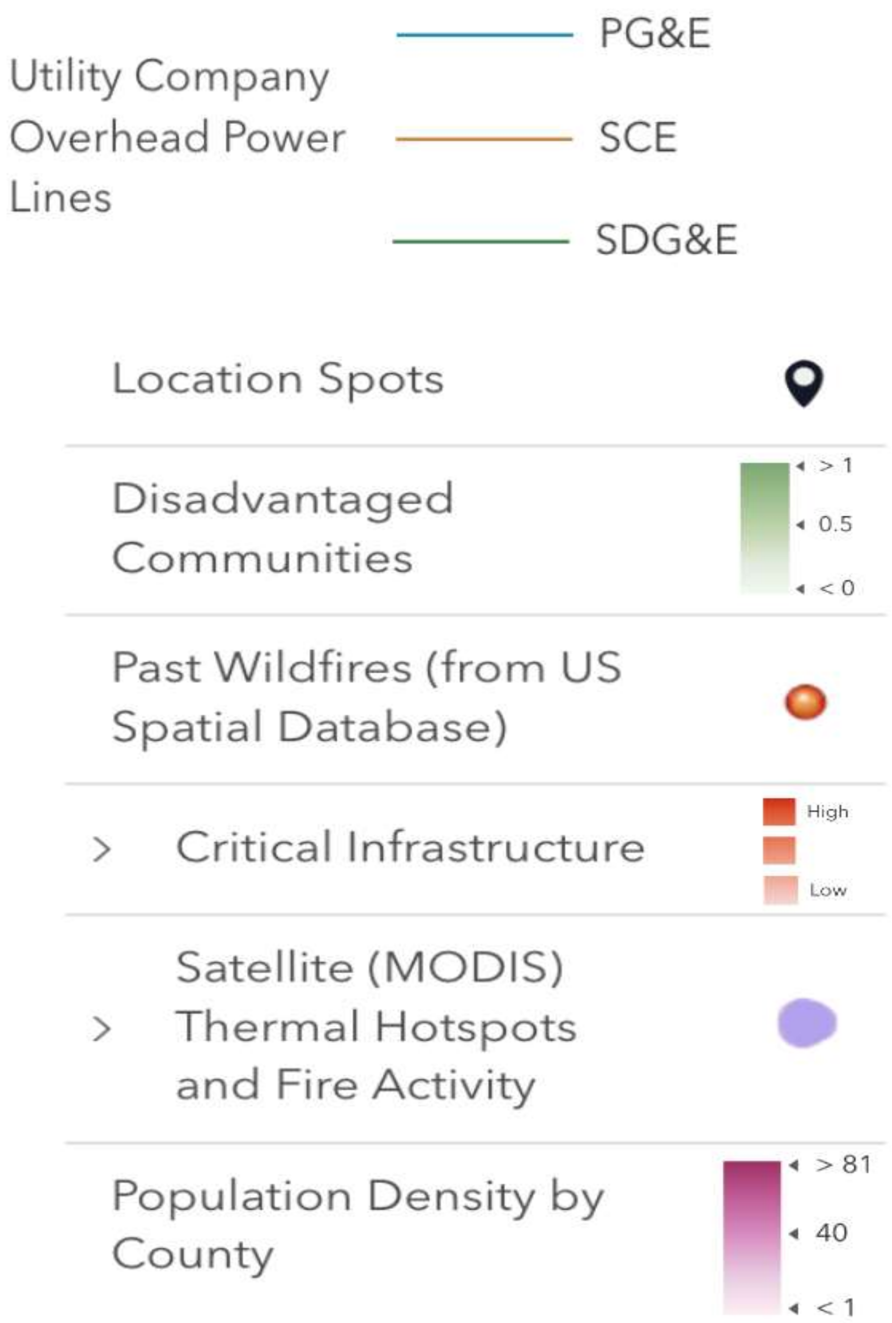
I especially prioritized looking at population density, critical infrastructure, and past wildfire history as these play a major role in the impact of a wildfire. These findings revealed the locations that should be prioritized as PG&E, SCE, and SDG&E begin the process of burying power lines.

For comparison purposes, I chose three locations in each utility company's jurisdiction. The locations represent areas with high, medium, and low wildfire risk. I evaluated the risk based on a combination of overlapping GIS factors: overhead power lines, critical infrastructure, past wildfire activity, population density, disadvantaged communities, and thermal hotspots. Each of the locations has the same area of 3,671.04 square miles to ensure an equal evaluation of wildfire risk. It is important to keep in mind that these nine areas cannot represent an exact comparison due to natural differences in their respective features. However, the comparison's purpose is to understand the optimal locations for underground power lines; this will help create a methodological approach that can be applied to other parts of California and the United States.

For each power company, I found an area with low, medium, and high wildfire risk. For PG&E, the low wildfire risk location was in San Luis Obispo County, the medium wildfire risk location was in Placer County, and the high wildfire risk location was in Santa Clara County. For SCE, the low wildfire risk location was in San Bernardino County, the medium wildfire risk location was in Ventura County, and the high wildfire risk location was in Los Angeles County. For SDG&E, the low wildfire risk location was in Imperial County, the medium wildfire risk location was in San Diego County, and the high wildfire risk location was also in San Diego County. Each of these cities was approximately at the center of the 3,671.04 square miles being measured.

RESULTS

GIS Map Legend



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Pacific Gas & Electric Company (PG&E)

Low Wildfire Risk - San Luis Obispo County

XY Coordinate: -120.4, 35.6

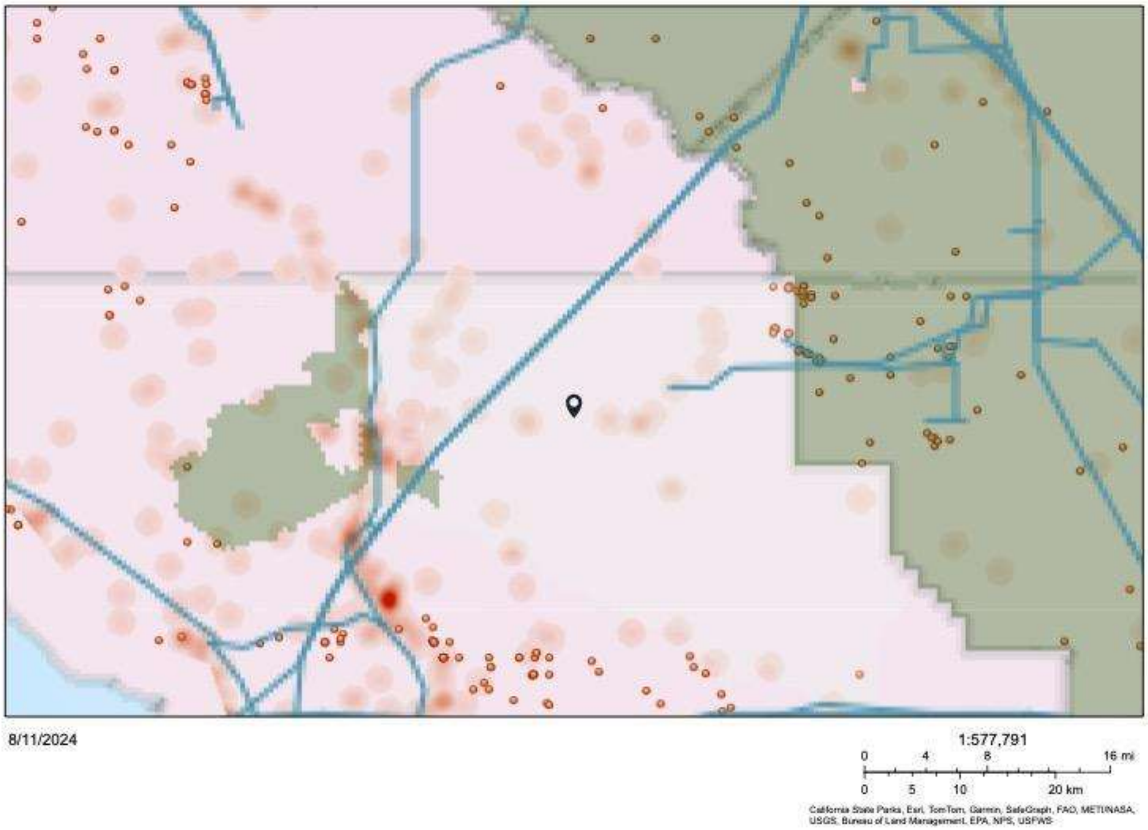


Figure 1: Map of Low Wildfire Risk in San Luis Obispo County

This location in San Luis Obispo County represents an area with low wildfire risk. There is a low population density surrounding the location spot. In addition, the map displays a low amount of critical infrastructure in the surrounding area that would be damaged due to wildfires. The region has not had many wildfires in the past, and they are mostly scattered. While there are some disadvantaged communities present, the combination of the other wildfire factors being unthreatening means this area is still low risk. Consequently, PG&E would not need to prioritize burying power lines in this zone. This area should be one of the last places for PG&E to roll out underground power lines since it is less vulnerable.

Medium Wildfire Risk - Placer County

XY Coordinate: -120.6, 39.2

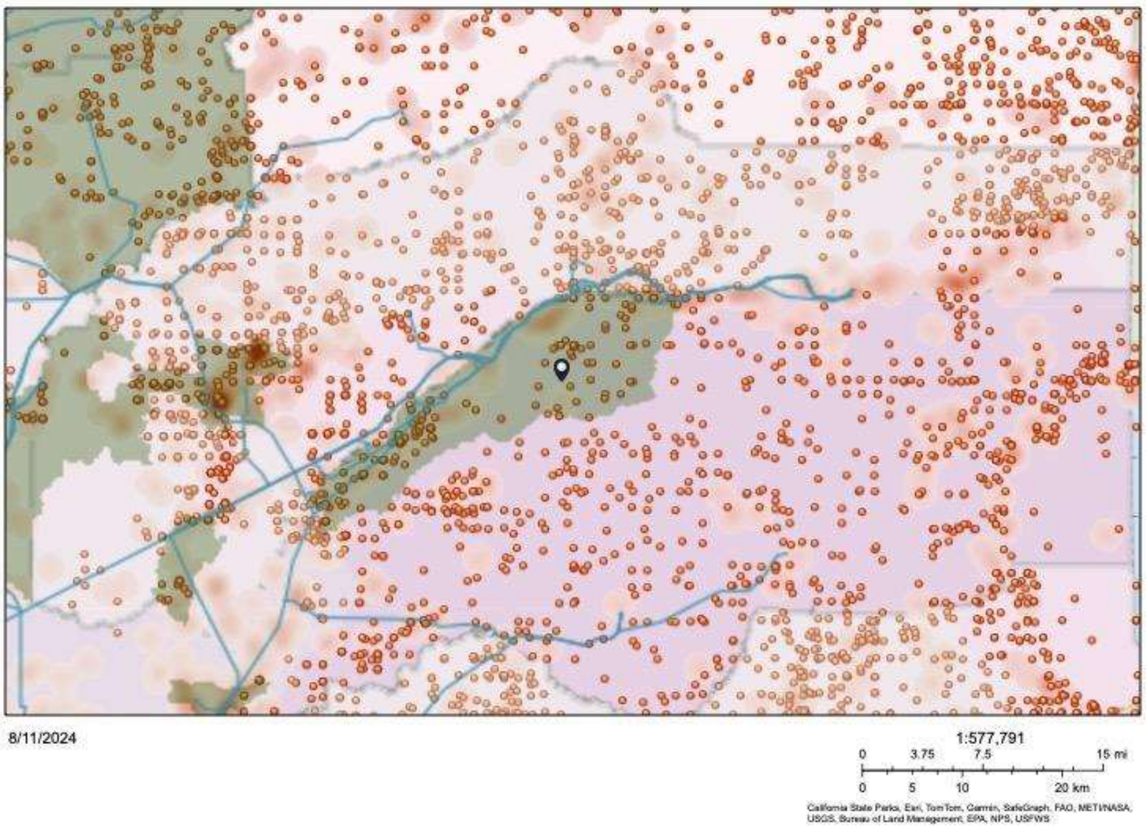


Figure 2: Map of Medium Wildfire Risk in Placer County

This location in Placer County represents an area with medium wildfire risk. The population is low to medium density. The critical infrastructure is dispersed throughout the region, with many parts of the area having a low density of critical infrastructure. Most notably, the history of past wildfires is numerous and evenly dispersed throughout the area. There are some disadvantaged communities in the area, and these are more at risk due to the other wildfire factors being more extreme. PG&E would eventually need to bury power lines in this zone, but it would not be the first priority. This area would fall in the middle of the list for underground power lines because the communities are vulnerable, although not highly at risk in terms of population and critical infrastructure density.

High Wildfire Risk - Santa Clara County

XY Coordinate: -121.9, 37.4

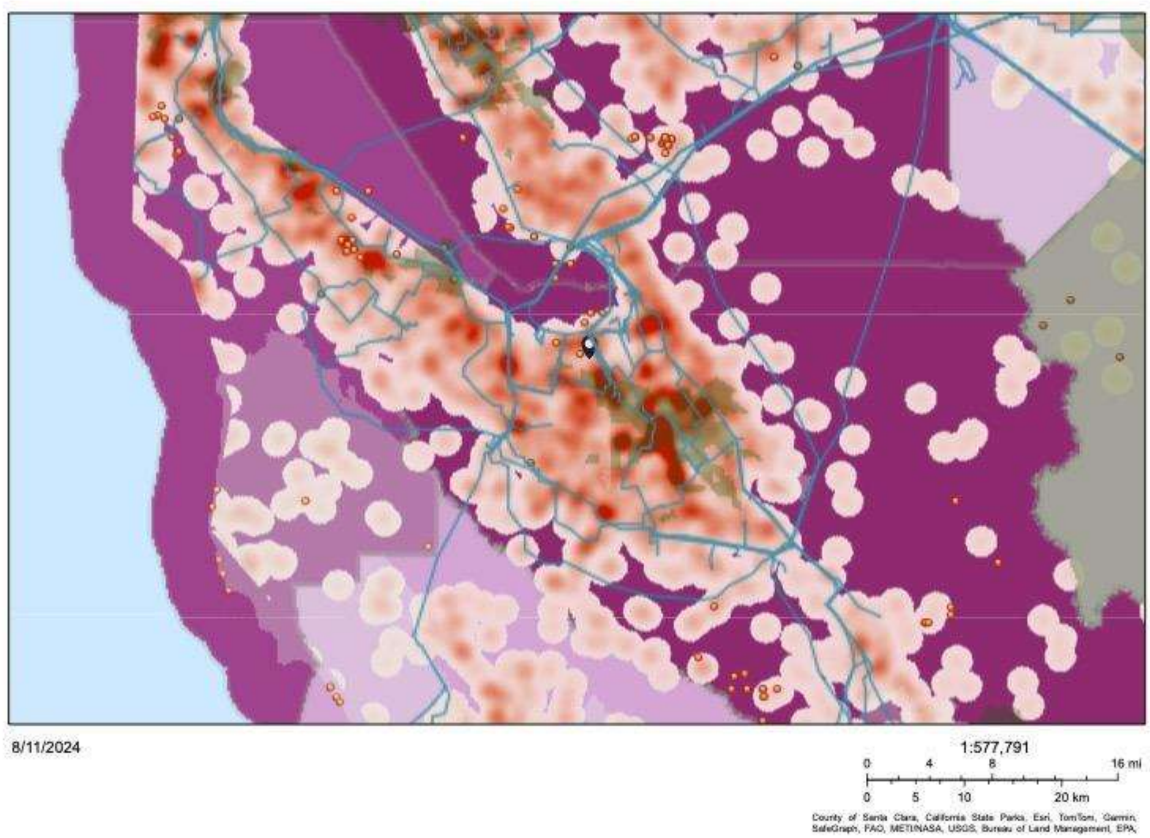
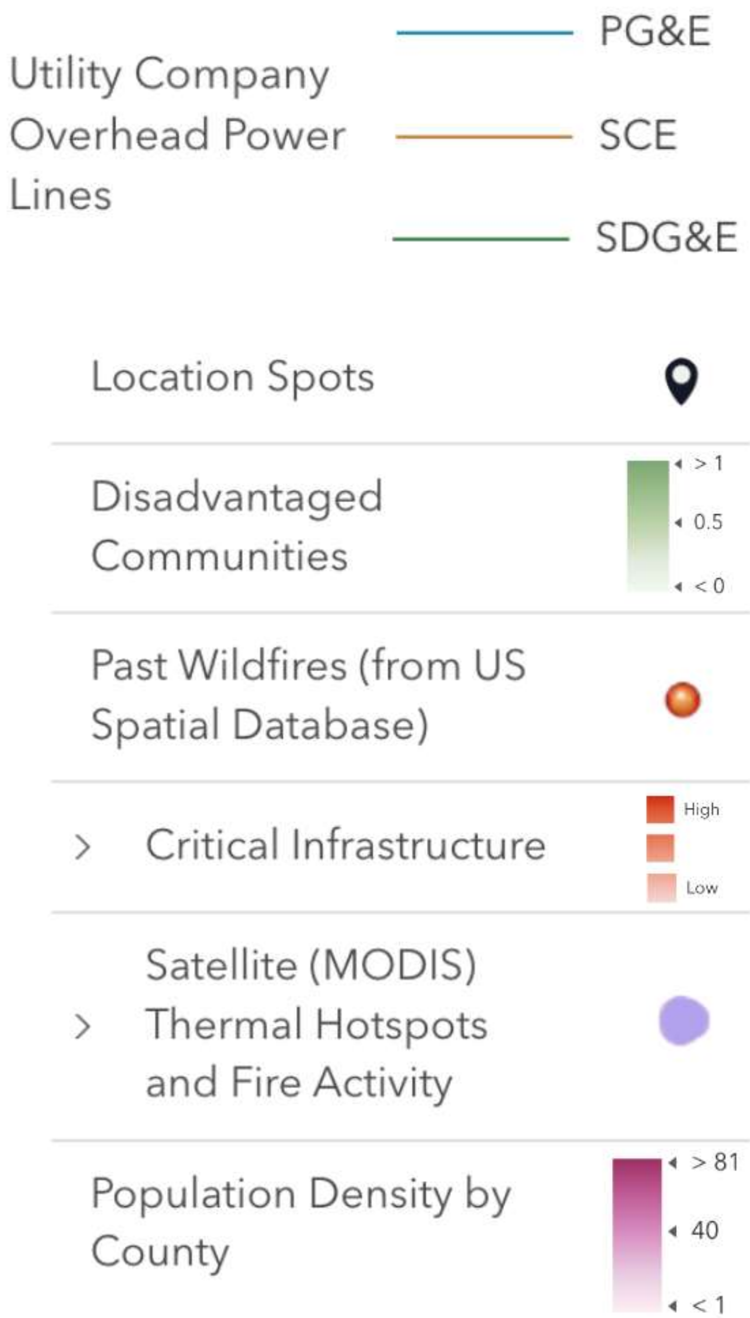


Figure 3: Map of High Wildfire Risk in Santa Clara County

This location in Santa Clara County represents an area with high wildfire risk. The population density in the area is very high. Furthermore, the critical infrastructure is extremely concentrated throughout the region. There is also a substantial number of overhead power lines near the location of interest. Despite the low amount of past wildfires and disadvantaged communities, the merging of all the other factors could result in dangerous wildfires that severely impact the high number of people and buildings. Due to the amount of people, power lines, and infrastructure, this location should be one of the first places for PG&E to take action in building underground lines.

GIS Map Legend



Southern California Edison (SCE)

Low Wildfire Risk - San Bernardino County

XY Coordinate: -115.9, 34.3

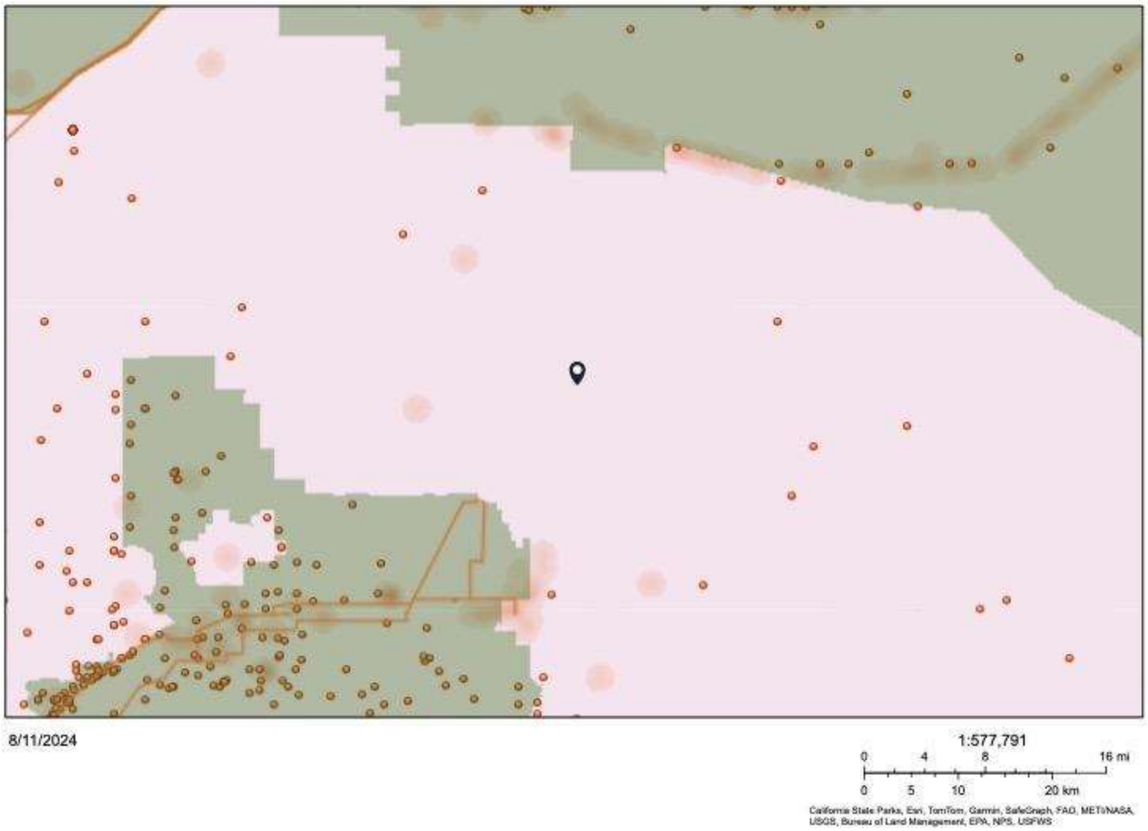


Figure 4: Map of Low Wildfire Risk in San Bernardino County

This location in San Bernardino County represents an area with low wildfire risk. The region has a low population density. There is not much critical infrastructure that could be at risk in the event of a wildfire. There are some clusters of previous wildfires, but the rest of the area is relatively unaffected. Although there are a few disadvantaged communities, the other conditions are low so this area is not very vulnerable to conflagrations. SCE should bury power lines in this location eventually, but it is not urgent when considering the minor impact of these variables.

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Medium Wildfire Risk - Ventura County

XY Coordinate: -118.8, 34.2

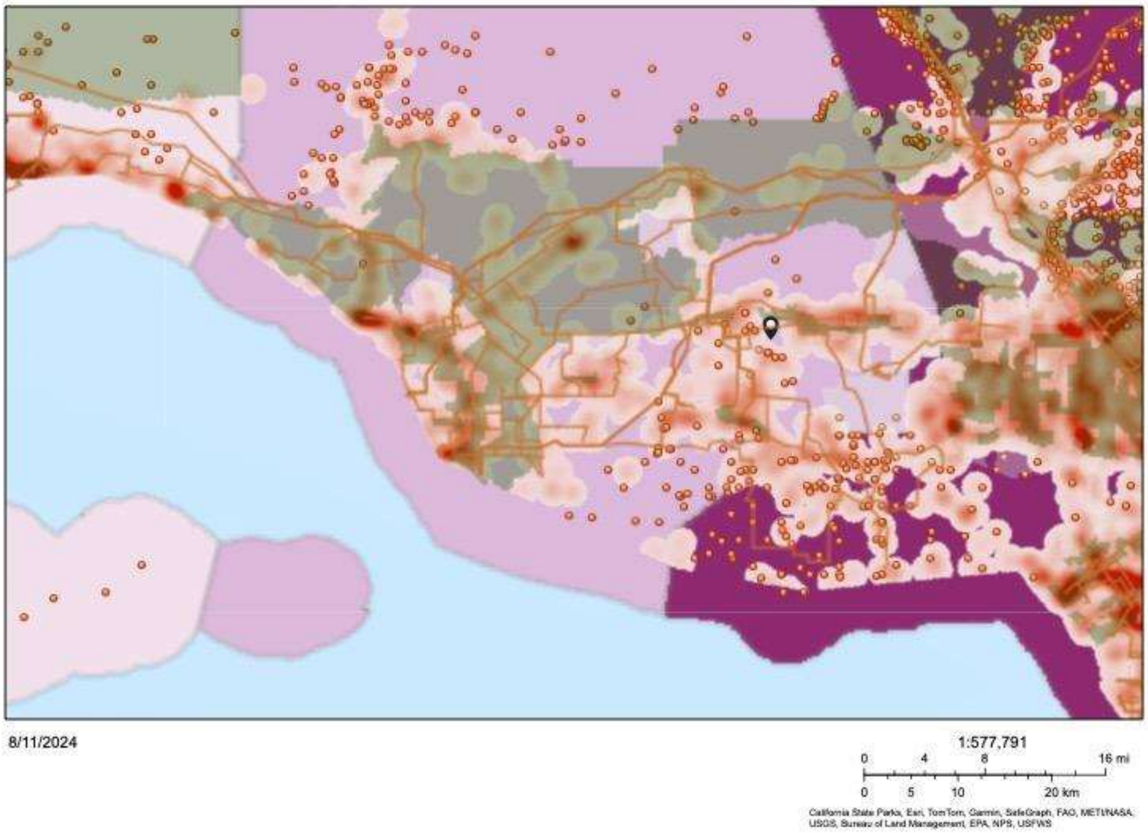

Figure 5: Map of Medium Wildfire Risk in Ventura County

This location in Ventura County represents an area with medium wildfire risk. The immediate population density is medium, but it is also bordered by a more densely populated region on the right. The location is surrounded by critical infrastructure that spans the entire area. While past wildfires have occurred here, the frequency is moderate relative to other counties with SCE power lines. There are multiple disadvantaged communities in the area and they often overlap with the high amount of power lines and infrastructure; this could lead to a hazardous wildfire situation. This location would rank as a medium-priority for SCE to bury power lines since the threat is notable but not the highest.

High Wildfire Risk - Los Angeles County

XY Coordinate: -118.3, 34.2

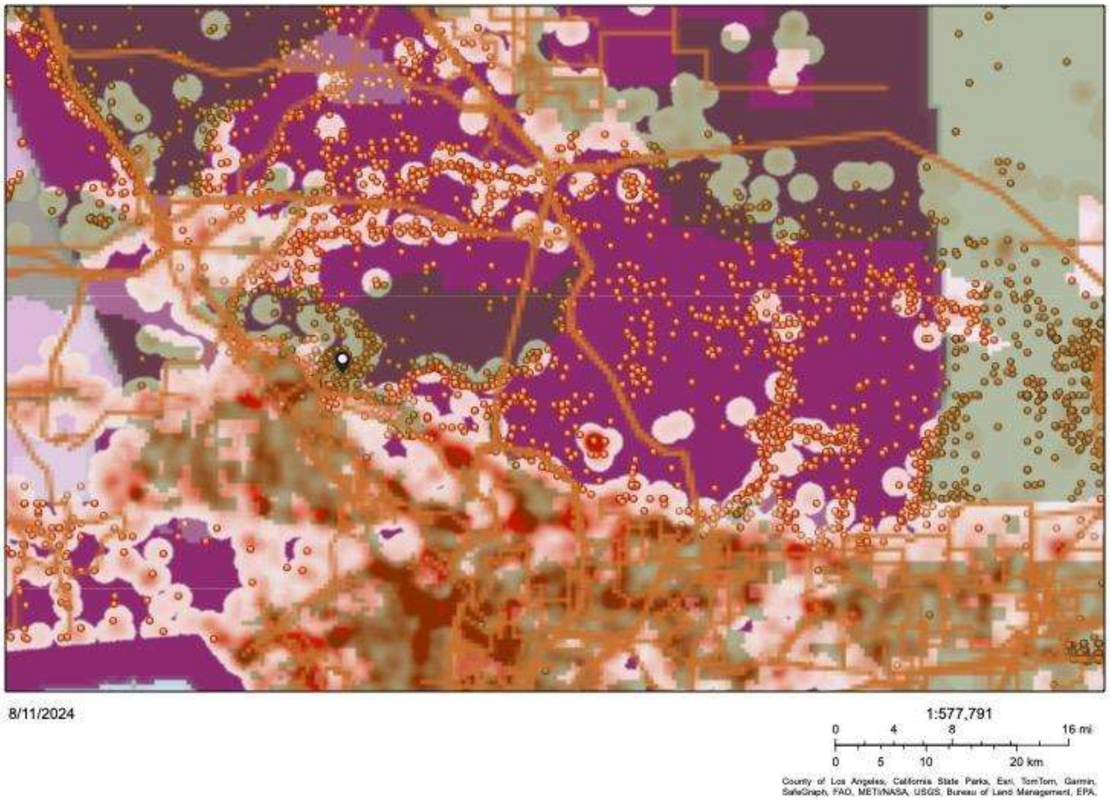

Figure 6: Map of High Wildfire Risk in Los Angeles County

This location in Los Angeles County represents an area with high wildfire risk. Firstly, the population density in the county is extremely high on the scale. There is also a significant number of SCE power lines that run throughout the area, increasing the possibility of sparking a wildfire. The map shows a pattern of critical infrastructure that overlaps with the location of the overhead power lines. The county also has an extensive history of wildfires, which are numerous and spread out across the area. Lastly, the presence of disadvantaged communities is dispersed across the region. One of the first areas to receive underground SCE power lines should be Los Angeles County. Almost every element that contributes to destructive wildfires can be found here, so SCE should immediately initiate the burial of power lines.

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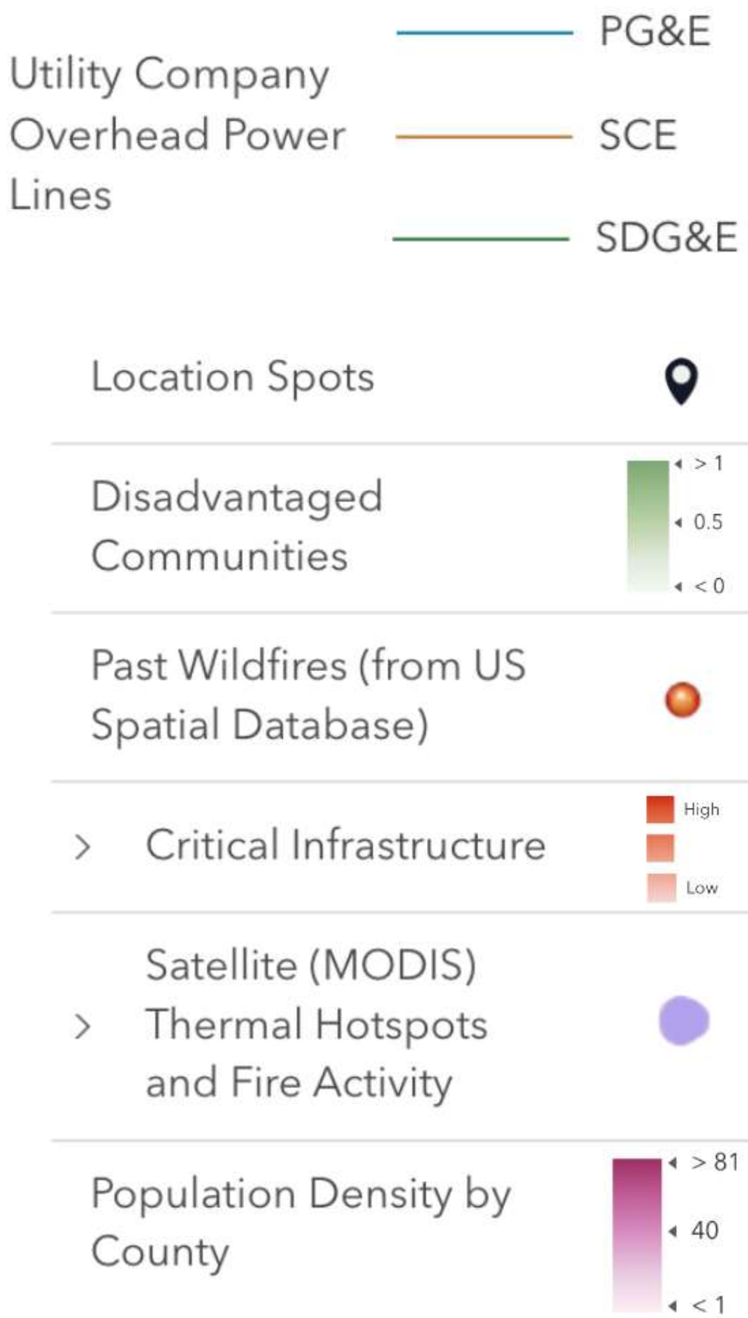
GIS Map Legend



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San Diego Gas & Electric (SDG&E)

Low Wildfire Risk - Imperial County

XY Coordinate: -114.7, 32.9

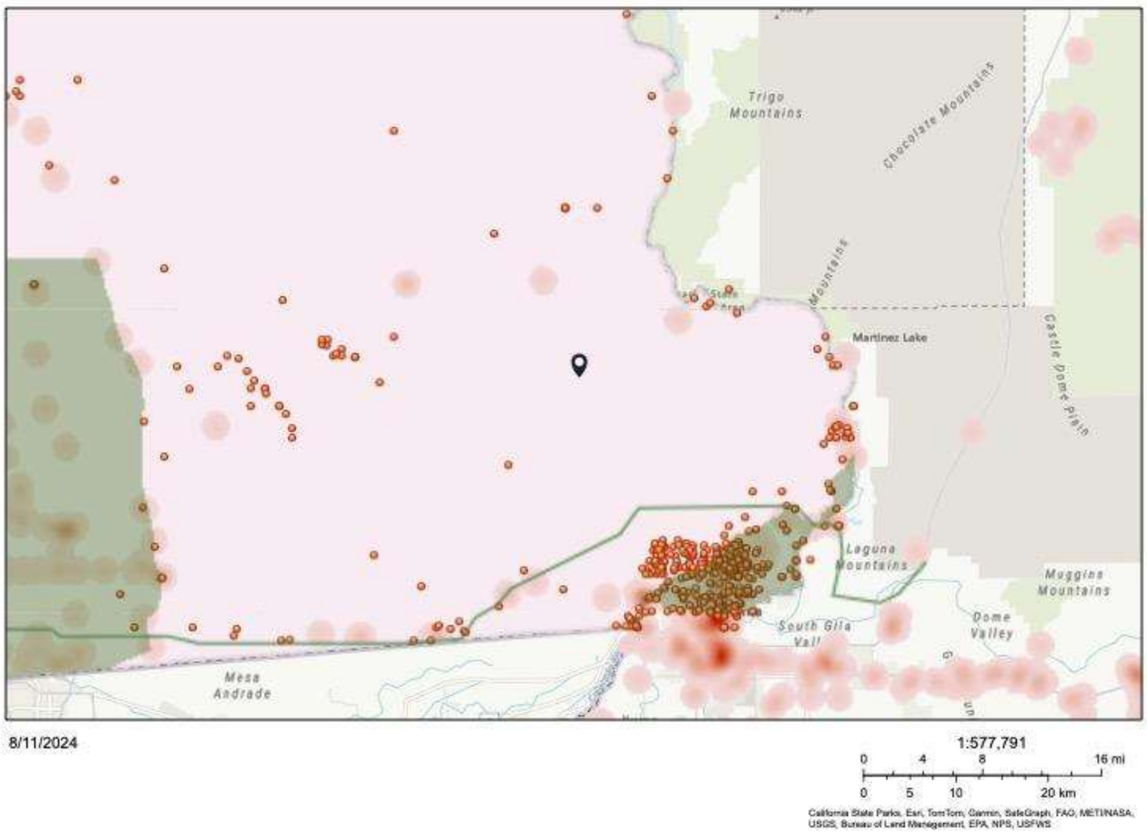

Figure 7: Map of Low Wildfire Risk in Imperial County

This location in Imperial County represents an area with low wildfire risk. The population density is low in the county. Most of the region does not have critical infrastructure, and the biggest cluster is far from the spot. Historically, there have been few wildfires in the area; there is one main cluster but it is quite south of the location. There are a couple of disadvantaged communities dispersed throughout the county. Overall, SDG&E should not prioritize underground power lines in this location because it is less critical compared to other areas with greater amounts of people, infrastructure, disadvantaged communities, and lines.

Medium Wildfire Risk - San Diego County

XY Coordinate: -116.9, 33.0

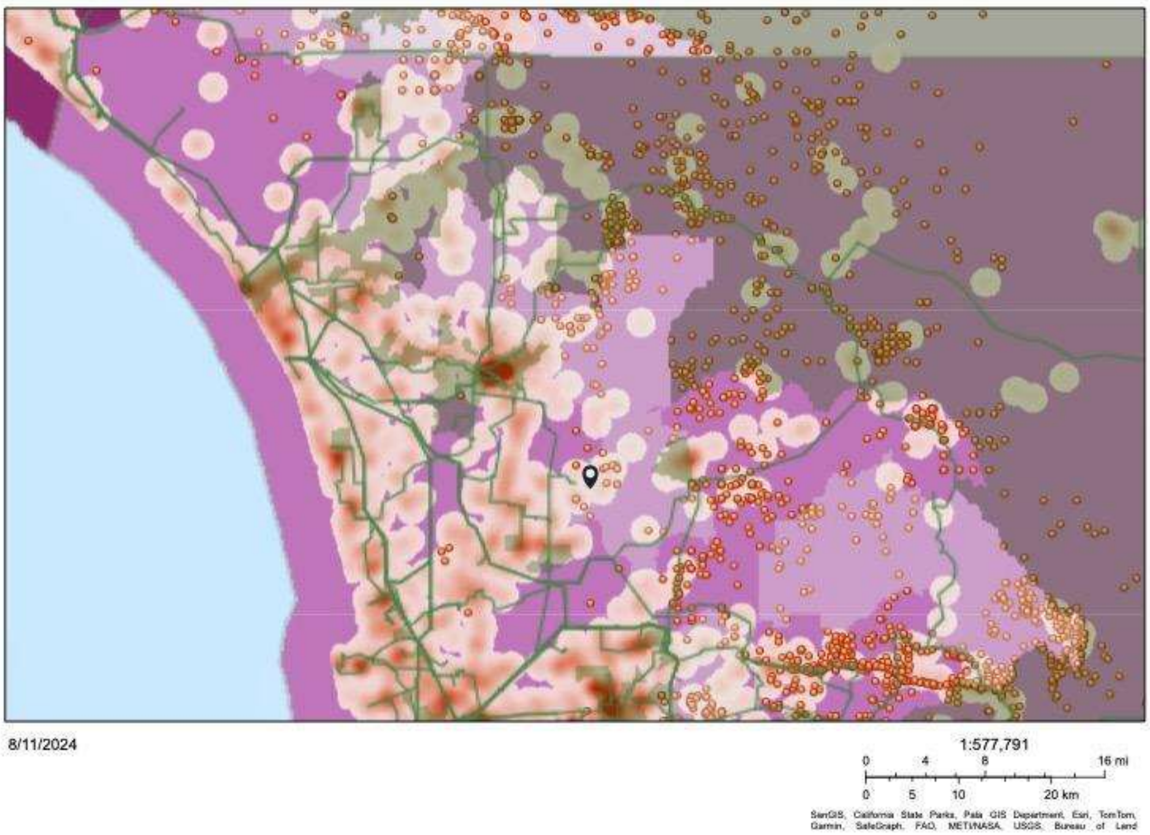

Figure 8: Map of Medium Wildfire Risk in San Diego County

This location in San Diego County represents an area with medium wildfire risk. The population density is a mix between medium and medium-high. The critical infrastructure is moderately concentrated throughout the entire county. The map also displays the high amount of SDG&E overhead power lines in the area, which overlap with much of the critical infrastructure. There is a significant history of past wildfires, although some spots are more clustered than others. It is important to note the disadvantaged communities in the area, especially the large amount to the east of the spot; these communities are especially at risk due to limited resources for wildfire preparation and recovery. SDG&E should address this location with medium urgency because it is relevant but not the most pressing.

High Wildfire Risk - San Diego County

XY Coordinate: -116.9, 32.7

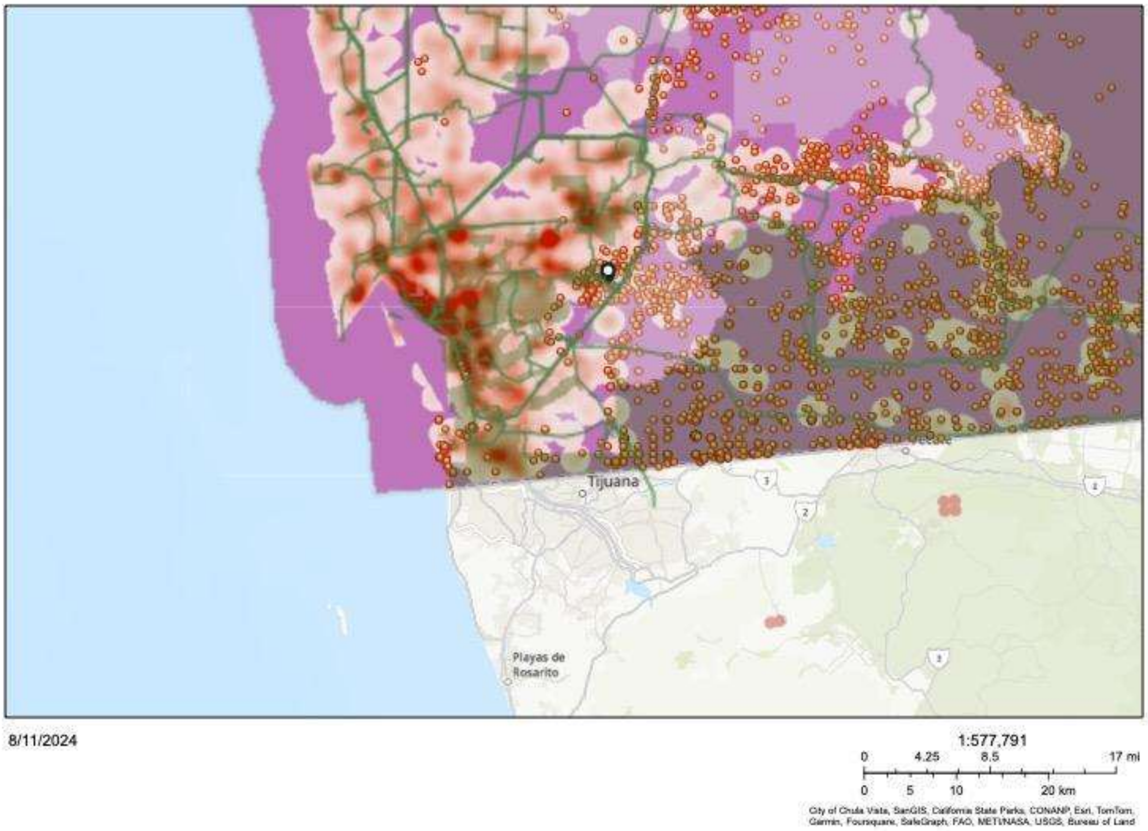

Figure 9: Map of High Wildfire Risk in San Diego County

This location in San Diego County represents an area with high wildfire risk. While the previous location was also located in San Diego County, this spot is a higher risk for multiple reasons. The population density in the county is still medium-high. There are also many SDG&E overhead power lines that span the area. However, one main difference in this map is the higher concentration of critical infrastructure that intersects with the power lines. Another notable factor is the past wildfires, which are more numerous around the spot and show a clear history of wildfires throughout the area. Although there are fewer disadvantaged communities near the location, the mix of many people, buildings, power lines, and wildfires lead to this being a high-risk area. SDG&E should prioritize burying power lines in this area as soon as possible.

CONCLUSION AND RECOMMENDATIONS

Summary

This research paper proposes an innovative methodology for determining and prioritizing locations to bury power lines while reducing the impact of wildfires on people and infrastructure. These nine case studies can set the tone for future underground power line projects. By analyzing the location of power lines in relation to an array of variables, I was able to identify areas of high, medium, and low combined risk which allows for the systematic prioritization of resource-intensive buried power line projects. The higher-risk areas that have the highest concentration of people, past wildfires, disadvantaged communities, critical infrastructure, and thermal hotspots should be prioritized by PG&E, SCE, and SDG&E.

Conclusions

While identifying the priority areas for these power lines is beneficial for the California utility landscape, this paper contributes more than just a case study analysis. Rather, it proposes and tests a unique methodology applicable to all utilities exposed to wildfire risk. Only looking at areas of high wildfire risk may suggest that an overwhelming amount of power lines be buried; instead, this methodology provides a way to prioritize power lines in a systematic manner that is more considerate of the resource-intensive nature of burying power lines. By doing so, it ensures that utilities consider that the impact of wildfires extends beyond acres burned. People, buildings, and entire communities can be irreversibly damaged when a wildfire is not prevented. Moreover, these criteria for wildfires are not separate; it is important to observe these multiple GIS layers because our environment is interconnected and these factors can often exacerbate each other. For example, dry vegetation can ignite and spread fire to surrounding buildings ("Brush Fires"). This can lead to further fires in a densely built area, endangering people and infrastructure. This paper's strategy confirms that the lines in these high-risk areas are addressed first, mitigating the most amount of damage possible.

Based on my methodology, the burial of power lines should be prioritized based on the concentration of overhead power lines, critical infrastructure, past wildfire activity, population density, disadvantaged communities, and thermal hotspots. This standardizes the burying process, eventually tackling all overhead power lines while protecting the most vulnerable regions first. Furthermore, this strategy is reinforced by scientific findings from publicly available data; this establishes that utility plans will be more effective and better shielded from legal liability because they are grounded in empirical evidence and detailed analysis. Another benefit of this methodology's scientific approach is its appeal to potential investors. Utility companies need to raise funds for these extensive burying projects, and donors may be swayed by the data that demonstrates a systematic approach to protecting the greatest number of people, with an eye towards protecting vulnerable communities (Walton, 2024).

Recommendations

Looking to the future, I urge utility companies to incorporate this methodology into their plans for burying power lines throughout California and eventually the greater United States. Based on the increasing wildfire risk due to climate change along with the vast amount of wildfires, people, infrastructure, and disadvantaged communities in California, utility companies should act swiftly. PG&E, SCE, and SDG&E should individually examine their jurisdictions and add other high, medium, and low-risk areas to their timelines by following my strategy. This will ensure that power lines in other counties beyond these case studies are assessed, encouraging safer communities throughout the state.

When utility companies create plans to bury power lines, they will likely need to conduct a similar analysis of areas and choose the order of initiation. Higher-risk areas will always have the most overlap between the GIS layers. However, utility companies may have trouble prioritizing certain locations above others when they are in the same risk category. In this case, I recommend an emphasis on the factors of population density, critical infrastructure, and past wildfires. Studying these key factors helps save the most amount of lives and prevent further damage. It also ensures that utility companies are using past wildfire experiences to improve their plans for new power lines.

While this methodology has been used here to prioritize the burial of existing power lines, it is just as, if not more, critical that it be used as new power lines are built. However, considering the high cost of burying power lines as compared to building them above ground, utility companies may not utilize this methodology or always prioritize underground lines ("Underground vs. Overhead," 2023). Consequently, policymakers should require that utility companies apply this methodology when burying power lines or building new lines. This expectation will prompt utility companies to use data to evaluate the advantages and disadvantages of constructing power lines in any location, thus building wildfire resilience into the infrastructure.

Though the analysis conducted here and the method proposed for future projects is critical for utilities, there are still many unanswered questions that require research on the topic of burying power lines to prevent wildfires. Researchers should conduct an economic analysis of the amount of money saved by preventing wildfire damage with underground lines. The findings could quantify the importance of underground lines in terms of safety and financial benefits to lawmakers, utility companies, and other businesses. Another area of further study could highlight how buried power lines affect ecosystems and wildlife around them. These findings could minimize the environmental disruptions of underground lines and advance their wider adoption.

This research paper presents a novel methodology that could significantly improve underground power line planning and decrease wildfire risk. Events such as the Dixie Fire all started with a single spark from an overhead power line, and climate change is only exacerbating wildfires and increasing their devastation. In order to prevent these situations, utility companies need to take action. By employing my method that features GIS mapping, utility companies can address the key factors that contribute to wildfire destruction: overhead power lines, critical infrastructure, past wildfire activity, population density, disadvantaged communities, and thermal hotspots. This allows utility companies to accurately prioritize locations to bury power lines that prevent catastrophic wildfires, strengthen a region's infrastructure, and increase public safety.

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