CONCEPTUAL STUDY TO UNDERGROUND UTILITY WIRES IN BERKELEY

PRESENTED BY PUBLIC WORKS, DISASTER AND FIRE SAFETY AND TRANSPORTATION COMMISSIONS

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ACKNOWLEDGEMENTS

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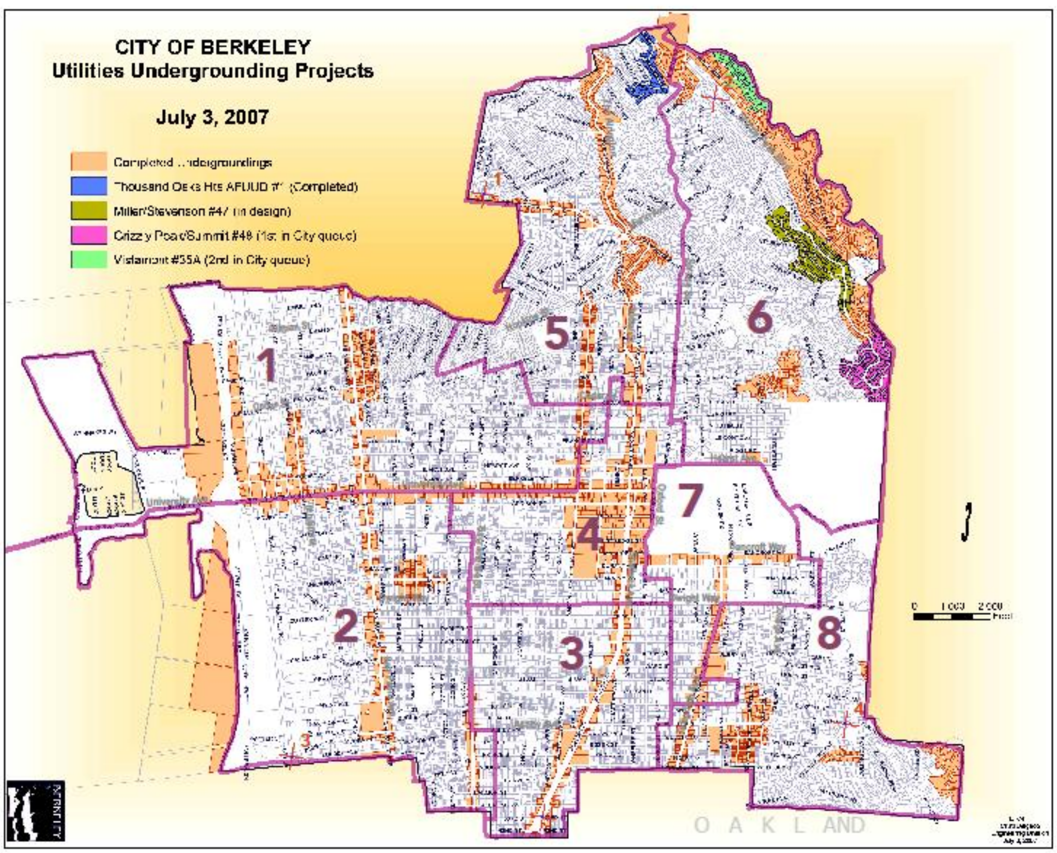
EXECUTIVE SUMMARY

Introduction and Background

This report presents the findings of Phase 2, of a four-phase program, to respond to a City Council request to "develop a comprehensive plan for the funding of the undergrounding of utility wires on all major arterial and collector streets in Berkeley". To meet this goal, a subcommittee was formed of representatives from the Public Works, Disaster and Fire Safety, and Transportation Commissions. This report was prepared after literature review, interviews with knowledgeable municipalities and utility providers, and input from two U.C. Berkeley's Goldman School of Public Policy Master's degree candidates. The subcommittee also reviewed the Harris and Associates report and reports authored by Peter Larsen of the Lawrence Berkeley National Laboratory.

The history of undergrounding in Berkeley goes back at least to the 1970's. Of the 25.6 miles of arterial streets, 12.5 miles have been undergrounded (49%). Of the 36.1 miles of collector streets, 11.3 miles have been undergrounded (31%). Funding for undergrounding projects has come primarily from the California Public Utilities Commission (CPUC) Rule 20 tariff program. Funding has also come from other sources, such as BART, Caltrans, Redevelopment and U.C. Berkeley. A map showing the undergrounding completed or scheduled to be completed in Berkeley follows.



The potential need for evacuation exists throughout the City. An earthquake, a firestorm, a hazard spill, gas line explosion, significant flooding or pandemic are all possible disaster scenarios requiring a large portion of our population to evacuate. The objective is to keep our evacuation routes clear by eliminating the danger of dangling or fallen overhead wires. We recommend the major streets that are also evacuation routes be the highest priority for utility undergrounding.

Community Resilience

Public Safety

The City of Berkeley's stated goal, as outlined in the General Plan, Disaster Preparedness and Safety Element, is to ensure the City's disaster related efforts are directed toward preparation, mitigation, response and recovery from disaster shocks. Integrating safety into all City decisions for the purpose of sustaining the community is the guiding principle of policy decision making. The 2014 Berkeley Hazard Mitigation Plan states that our two greatest disaster challenges are a Hayward Fault rupture and wildland urban interface (WUI) fire.

Predicted climatic change means periods of drought followed by very wet winters producing heavy vegetation, dry summers, and hot easterly winds in the late summer. These conditions are known to create significant fires such as the 1991 Oakland Hills Tunnel Fire and the North Bay fires (renamed by Cal Fire as the Fire Siege) in October, 2017.

Methods to reduce the threat of overhead wires creating WUI fires include aggressive vegetation management and other fire hardening techniques. Overhead power lines, more so than undergrounded wires, can exacerbate unsafe conditions either by contributing to the disaster itself or hampering public safety efforts post disaster. Earthquakes and landslides can knock over utility poles creating a special hazard. In an earthquake, poles have a tendency to sway in opposite directions causing wires to snap and throw sparks. Some of California's biggest fires have started because of live wires in contact with combustible fuel. Other power disruptors to overhead lines acting as potential fire starters are squirrels, rodents and birds as well as vehicles knocking down utility poles.

Image 1: Downed power poles and lines in 2017 Fire Siege

Source: Brian van der Brug, Los Angeles Times

Power and Communications Reliability

Power reliability is key to the way we live now - to public safety and well-being, as well as to limit economic fallout after a disaster event. Outages are costly, having an injurious effect on life safety as well as the City's economic viability.

Benefits to Undergrounding Across Berkeley

Berkeley is a city made up of diverse neighborhoods, some with a mix of commercial and residential properties and others that are primarily residential. It is important that whatever program is adopted by the City be designed to maximize equitable power assurance across the city. A well-designed undergrounding program provides numerous benefits to our entire community.

- Safety: Berkeley needs to plan ahead for the eventuality of natural disasters and the ability to recovery from them. Public safety is of primary importance.
- Quality of life: Power stability offers peace of mind to all our residents when they do not have to concern themselves with how prolonged power outages affect their lives. For the community as a whole, post disaster recovery is dependent on reliable power.
- Robust economic vitality: Discussions with PG&E, other California utilities, cities with robust undergrounding programs and energy expert Peter Larsen lead us to the conclusion that the commercial sector places a very high value on power reliability because reliable power is key to business continuity.
- Community Beautification: Visual clutter can be drastically reduced by careful zoning requirements that limit how much any block must carry communication wires and equipment on overhead poles. We believe that Berkeley can significantly reduce visual clutter by adopting smart lighting. These city light pole systems house communications cables and other apparatus in the pole itself. Adding charging stations on street light poles opens up a new source of revenue for the owners of these poles. (FutureStructure 10-12-17)

Technology Trends that May Affect Undergrounding

The Subcommittee considered the high cost and current approaches to undergrounding and evaluated technology trends that may affect undergrounding. The objective is to ensure that current approaches would not become obsolete or have stranded expenditures. This evaluation was done through literature research and was the focus of Mr. De En Ni's master's project at U.C. Berkeley.

- Electric power. The development of microgrids could change the structure of the utility delivery enough that we should pay attention to it. The primary concept of the microgrid is that a small group of entities are connected to a common source of power generation (such as solar) and storage, which will allow the sharing of those resources. Since this is a newer technology, prior to deploying micro-grids on any wide scale a significant amount of engineering design will be required.
- Telephone. Traditional telephone delivered on copper wires is being replaced by advances in Voice over Internet Protocol (VoIP). All calls will likely be originated and terminated on Internet lines. For the foreseeable future, the CPUC will require AT&T to continue to provide landlines to anyone who wants one.
- Cable TV. It is the opinion of the subcommittee that cable television will follow the predicted path of traditional telephone. More and more video is being delivered over Internet connections thus less reliant on cable providers.
- Internet. The need for Internet connectivity will remain for the foreseeable future. Wireless delivery will continue to improve its speed, such as with 5G technology. Wi-Fi availability will

increase. The technology being deployed most widely as this time is fiber optic communications. Fiber lines can be installed via overhead lines or underground.

Master's project by Mr. De En Ni, Technology Trends Affecting Berkeley's Utility Undergrounding. This analysis was conducted by De En Ni as the capstone project of his Masters of Public Affairs degree at U.C. Berkeley's Goldman School of Public Policy. The purpose of the study was to determine what future trends that might make current investments obsolete. Mr. Ni identified two technological changes that could disrupt the electric distribution network: the increasing number of electric vehicles in use and the adoption of solar and other sustainable sources of distributed power generation. Berkeley supports the reduction of greenhouse gases and the use of clean energy. Berkeley has one of the highest electric vehicle penetration rates in the nation. Mr. Ni suggests that this favors undergrounding because the wide-spread adoption of electric vehicles requires a highly reliable source of electric power.

Benefit and Cost Analysis

Benefits of Undergrounding

Primary benefits most often cited with undergrounding can be divided into four areas:

Potentially reduced maintenance and operating costs

- Lower post-storm and WUI fire restoration cost
- Lower tree-trimming cost
- Lower maintenance costs

Improved reliability

- Increased reliability during severe weather
- Less damage during severe weather allowing for more reliable continuation of service
- Noticeably fewer momentary interruptions

Improved public safety

- Reduced fire danger
- Fewer motor vehicles colliding with utility poles
- Reduced live-wire contact injuries
- Improved access and egress during and after storms and disasters

Improved community aesthetics

- Removal of unsightly poles and wires
- Fewer utility poles on sidewalks improving pedestrian mobility and visibility
- Enhanced tree canopies which have both a pleasing effect and a cooling effect

Estimated Cost to Complete Undergrounding in Berkeley

The consulting firm of Harris and Associates (Harris) was retained to prepare a baseline study of utility undergrounding in Berkeley. Using the Harris cost estimate as a baseline and comparing to other cost estimates, we suggest a rough guideline of total costs to Berkeley as follows.

Estimate by Harris	$3.6 million per mile
Engr. and CM @ 15 - 25%	0.5 – 0.9 million per mile
Service panels & private lines @ 10 - 15%	0.4 – 0.7 million per mile
Cost to City	$4.5 – 5.2 million per mile

For the 37.9 miles of arterial and collector streets to be undergrounded, the preliminary cost to Berkeley is estimated to be in the range of $170 – 200 million.

Benefit/Cost Analysis of Undergrounding

Two examples show how key criteria can be important in preparing a Benefit/Cost Analysis (BCA), both conducted by Mr. Peter Larsen. One example is in Cordova, Alaska where lower operations and maintenance costs, avoided cost of power interruptions, and enhanced aesthetics produced a highly favorable Benefit/Cost Ratio (BCR) of 16. In a second example, Mr. Larsen conducted a study to underground Texas investor owned utilities and concluded a BCR of 0.3. The main reasons for the low BCR was the low density of users per line mile, the relative low value of avoided power interruptions, and the relatively low value of avoided aesthetics costs.

In another example, Mr. Daniel Bradway conducted a BCA for undergrounding the remaining arterial and collector streets in Berkeley. His analysis included increased property values, avoided cost of power interruptions, avoided cost of vegetation management, and avoided cost of vehicle crashes and produced a BCR of 1.1. Mr. Bradway's study was conducted as the capstone project of his Masters of Public Affairs degree at U.C. Berkeley's Goldman School of Public Policy.

Additional Considerations

Funding Options for Berkeley

The CPUC established Tariff Rule 20 in 1967 to underground utilities in California. Rule 20 consists or four parts, A, B, C and now D, which was added specifically for San Diego Gas & Electric in 2014. Currently under review, among other things, is how the existing program is being administered by the various utility companies operating in California and the definition of what projects are to be included in the public interest. Topics of interest to Berkeley include:

- Categorize public streets and roads in a Wildland Urban Interface Zone as eligible for Rule 20 funding.
- Provide a more equitable distribution of credits to cities with Wildland Urban Interface Zones.
- Provide a mechanism to utilize, borrow, or trade credits among participants.

Funding options used by other cities include the following:

1. Cities can trade or sell unallocated Rule 20A credits to fund undergrounding projects.
2. The City of San Diego, working with San Diego Gas & Electric and the CPUC, adopted, without a ballot measure, a local franchise surcharge tax to fund undergrounding projects. This option has also been adopted by the City of Santa Barbara.

3. San Diego Gas & Electric applied for and received additional Rule 20 funds (referred to as Rule 20D funds) to be used for undergrounding and other fire hardening techniques in their state designated Very High Hazard Fire Zone (VHHFZ).

Besides the above options, another funding strategy is to evaluate an increase to Berkeley's utility user tax to provide funding for undergrounding. Berkeley could also work closely with PG&E, the CPUC and other Bay Area cities to seek release of Rule 20 funds for Berkeley's VHHFZ.

Case Studies from Other Municipal Undergrounding Programs

The subcommittee visited the City of San Diego and the City of Palo Alto after researching undergrounding programs in multiple California cities. From both of these cities, we learned four key elements for a successful comprehensive municipal undergrounding program.

- There needs to be a public mandate to support the program.
- A strong partnership between city and utility agencies is a necessary element for success.
- The financing strategy must be broadly shared, but not burdensome, by all members of the community.
- Leadership has the vision and drive to create and complete a comprehensive undergrounding program designed to meet the needs of the 21st Century and beyond.

Conclusions and Recommendations

Conclusions

Undergrounding enhances public safety by removing a catastrophic cause of fire ignition, the spread of fire and a major impediment to evacuate if necessary. Undergrounding stabilizes power and communications reliability, protects our businesses and the city's sources of revenue expended for the benefit of all our residents, and beautifies our urban environment. The devastating fires in Oregon and California and especially the North Bay Fires in October 2017 and the fires in Southern California in December 2017 showed the devastating effects of climatic changes and overhead power lines. The North Bay fires have raised the concern that the entire City of Berkeley is vulnerable to wildfire originating in the VHHFZ on the east side of the city.

Unlike previous proposals to underground specific neighborhoods, we propose a city-wide plan to underground overhead wires on two to four East-West streets that run across the entire city. The primary purpose of the plan is to provide safe access/egress in all areas of the city in the event of a catastrophe, whether it be earthquake, wildfire, flooding, tsunami, or gas line explosion. Streets to be undergrounded will coincide with officially designated evacuation routes determined by the Fire Department and Office of Emergency Services.

Unfortunately, the past three months have been particularly instructive. The devastating North Bay fires and multiple fires in Southern California have implicated overhead wires and equipment as a possible cause. PG&E has announced that they are considering turning off power, if certain weather conditions prevail, in order to avoid the possibility of starting a fire. In addition, the CPUC has recognized that overhead utility wires are a potential threat to public safety and have issued more stringent rules for pole maintenance and tree clearance. The recent evidence is clear regarding the threat posed by overhead wires.

Recommendations

We recommend the Council authorize proceeding with Phase 3 of the program as described below.

Phase 3 Work Tasks
Task 1 – Define the Phase 3 projects We are recommending the following projects for Phase 3. A. <u>Major and Collector Streets</u>**.** We recommend that undergrounding of the remaining arterial and collector streets be done with the following stages: Stage 1 – initial 2 to 4 east/west arterial or collector streets; highest priority to those streets listed as evacuation routes Stage 2 – future consideration for remaining arterial and collector streets The major east/west routes to be undergrounded shall facilitate the travel of first responders and evacuation of residents. Selection of the initial streets requires further evaluation. When weighing two or more options and one of them could also underground wires on the garage/parking area entrance for (in order of priority) fire stations, schools or senior centers, that option should be given a higher priority over other alternatives. This may entail picking up an extra block to be undergrounded or creating another access point in a building that would lead to the street to be undergrounded. B. <u>Coordination with microgrid development</u>**.** Power reliability is critical to recovery after a disaster. Many cities throughout the United States are experimenting with microgrids to determine their success in meeting their climate change goals and objectives. Not all areas initially require undergrounding for fire safety reasons but some areas experience significant power outages (e.g. west and southwest Berkeley) and it is recommended that microgrid pilot areas be considered including undergrounding the grid's cable/wire facilities. C. <u>Review code standards</u>**.** Increased pole load caused by service providers stringing wires in neighborhoods surrounding new construction to avoid costs of undergrounding their cable and wires adds to the visual clutter of surrounding streets. Adopt code standards to ensure neighborhoods without undergrounded wires are not carrying extra cable and equipment that visually clutters the skyline. Adopt smart lighting pole requirements for every replacement light pole.
Task 2 -- Develop the financing plan A. <u>Refine cost estimates for undergrounding</u>. Based on the Harris report, the estimated cost for the Stage 1 streets are: • Length = 10 – 15 miles • Cost = $50 – 75 million These cost estimates need to be further refined with field reconnaissance. B. <u>Participate in CPUC Rule 20 review</u>. The CPUC issued in May 2017 an Order Instituting Rulemaking to Consider Revisions to Electric Rule 20 and Related Matters. Berkeley should participate with the objective of getting funding for its VHHFZ and the maximum Rule 20A allowance. C. <u>Evaluate funding options</u>**.** Evaluate the various options to fund the Phase 3 projects in Berkeley.
Task 3 – Conduct community input A. Develop an outreach and communications plan**.** B. Conduct community workshops**.**

Phase 3 Work Tasks
Task 4 – Coordinate with utilities Meet with PG&E and tele-communications companies to discuss the Phase 3 projects.
Task 5 – Prepare an implementation plan Prepare a Program Plan for the implemenation of the Phase 3 projects.

A pictorial representation of Berkeley streets that have overhead lines and streets having undergrounded wires follows.

Image 2: Potter Street

Image 3: Sojourner Truth Ct & Ward Street

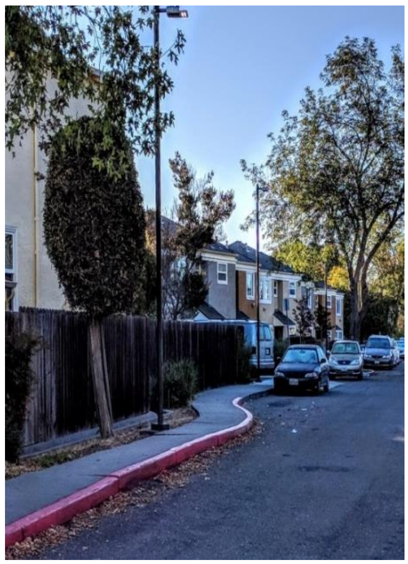
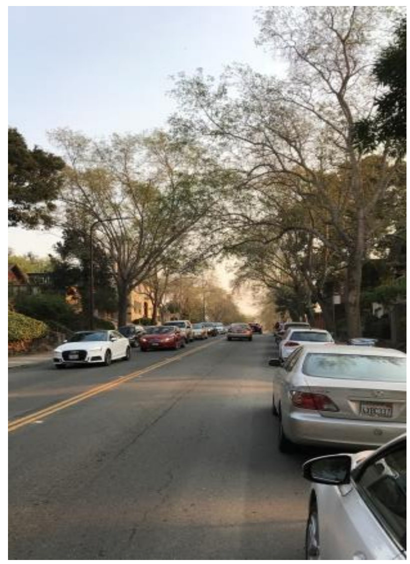


Image 4: MLK Jr. Way



Section 1
INTRODUCTION AND BACKGROUND

City Council Referral

The Berkeley City Council prepared a request to "develop a comprehensive plan for the funding of the undergrounding of utility wires on all major arterial and collector streets in Berkeley". The Council referred this request to the Public Works Commission, Disaster and Fire Safety Commission and the Transportation Commission on December 16, 2014.

Phased Program Approach

The three commissions organized an Undergrounding Subcommittee to respond to the referral. This subcommittee structured the study into four phases, as follows.

Phase 1: Conduct a baseline study to summarize Berkeley's current status of undergrounding utilities, cost to complete the undergrounding of arterial and collector streets, and examples of where undergrounding programs have been implemented. This phase has been completed and findings presented to city council on March 28,2017.

Phase 2: Conduct a conceptual study to determine the feasibility of utility undergrounding and report back to the City Council. The work in this phase includes our synthesis of literature on undergrounding, guiding our two Goldman School masters candidates' thesis project on matters related to undergrounding, meetings with utility and communications service providers, and meetings with municipalities having robust undergrounding programs. Our findings from the work of Phase 2 are the subject of this report.

Phase 3: Prepare a financial and implementation plan for the recommended streets to be undergrounded. The work may include community input, refinement of cost estimates, financing plan, relationship with utility service providers, implementation program design and schedule and other related matters. Additional information on Phase 3 can be found in Section 6 of this report.

Phase 4: Organize the financing, design and construction and performance monitoring of the approved program.

Progress Reports to Council

The subcommittee presented progress reports to the City Council on September 29, 2015 and March 28, 2017. The 2017 report included an updated work plan, the Harris and Associates baseline study, a proposal for studies by U.C. Berkeley's Goldman School of Public Policy graduate students, and notes from meetings held with utility and communications service providers. The Council authorized the Subcommittee to complete the work through Phase 2 and report back to them.

History of Undergrounding

The history of undergrounding utilities in the United States spans 125 years. It was after the Great Blizzard of 1888 that Manhattan decided to put all its infrastructure (power, water, gas, steam and subways) underground and at great cost at that time. A second notable example was in Galveston, Texas in 1900. As the largest city in Texas at the time, Galveston was destroyed by a great storm on Sept. 8, 1900. The 8,000+ people killed by that storm is still the largest single loss-of-life event from a natural disaster in U.S. history. Galveston built a 17-foot-high seawall that has protected the city from subsequent 44 hurricanes, but they also put all other vital infrastructure underground (natural gas, water, sewage, electric and telecom).

History of Utility Undergrounding in California

The California State Legislature in 1911 enacted laws to regulate the erection and maintenance of poles and lines for overhead construction. Additionally, the "Municipal Improvement Act" of 1913 allowed for the financing of or acquisition of public improvements. This California State act is the enabling statue that municipalities use to construct and finance public works projects.

Currently, utility customers in California pay about a dollar a month to finance a program intended to bury all wires. This ratepayer charge is based upon the California Public Utilities Commission (CPUC) action on September 19, 1967, as a result of their Case No. 8209. The CPUC adopted a rule requiring electric and telephone companies to initiate and participate in an active program to underground utilities in areas of general public benefit to "stimulate, encourage, and promote the undergrounding, for esthetic as well as economic reasons". Subsequent CPUC rule making rationale was expanded to include safety and reliability … "As discussed in earlier Commission decisions, the public overwhelmingly supports the undergrounding of electric facilities for a variety of reasons. Undergrounding enhances safety and reliability, provides aesthetic benefits, and increases property values."

The CPUC instituted the current undergrounding program in 1967. It consists of two parts. The first part, under Tariff Rules 15 and 16, requires new subdivisions (and those already undergrounded) to provide underground service for all new connections. The second part of the program, Tariff Rule 20, governs both when and where a utility may remove overhead lines and replace them with new underground service, and who shall bear the cost of the conversion.

Tariff Rule 20 is the vehicle for the implementation of the underground conversion programs. Rule 20 provides three levels, A, B, and C, of progressively diminishing ratepayer funding for the projects. There is also rule 20D adopted in 2014, which currently applies only to San Diego Gas & Electric utility for undergrounding and other fire hardening techniques in their state designated Very High Hazard Fire Zone. Under Rule 20, the CPUC requires the utility to allocate a certain amount of money each year for conversion projects. Upon completion of an undergrounding project, the utility records its cost in its electric plant account for inclusion in its rate base. Then the CPUC authorizes the utility to recover the cost from ratepayers until the project is fully depreciated. Rule 20 requires the utility to reallocate funds to communities having active undergrounding programs in amounts initially allocated to other municipalities but not spent. Cities may also commit to future 20A allocations for five years. The following table is a summary of the Rule 20 categories.

Table 1: Summary of Rule 20 Categories and Ratepayer Contribution

Rule 20 categories	California Ratepayer Contribution	Applicability
20 A	About 100%	Primarily ratepayer financed
20B	20%	Shared ratepayer and homeowner financed
20C	Minimal	Primarily homeowner financed
20D	About 80%	Used by San Diego Gas & Electric

For more information on Rule 20 funding, please see Section 5, Funding Options for Berkeley, of this report.

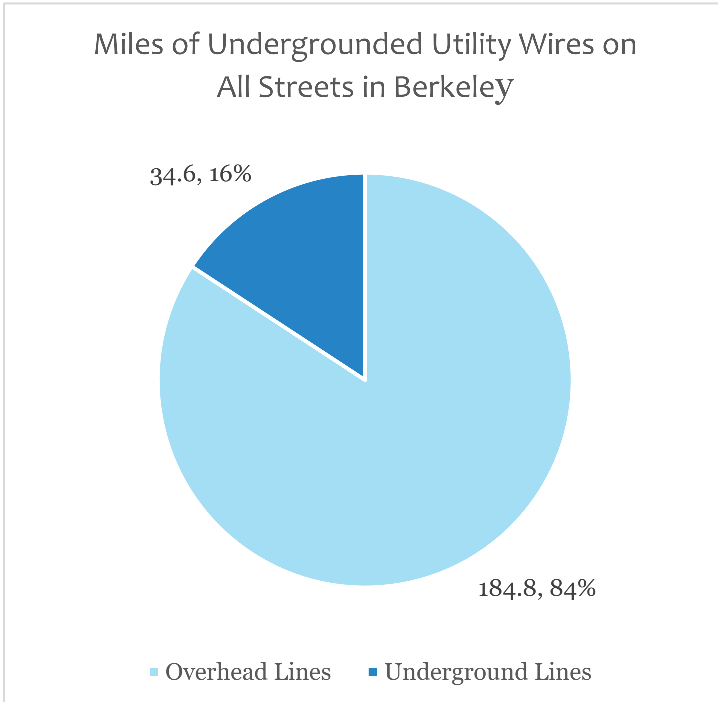
The following is a brief summary of CPUC actions on undergrounding.

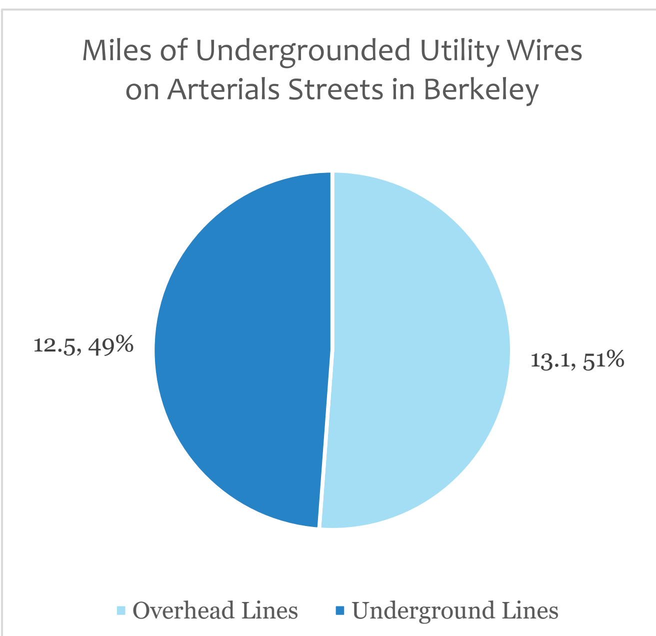
- **1967** – Decision 73078 required tariffs for replacement of overhead to underground distribution facilities, annual allocation amounts for overhead conversions, and reports of conversion work completed for the preceding years. Tariff Rule 20 was established for electric conversions and Rule 32 for telecommunication.
- **2000** – CPUC opened its Rulemaking R.00-01-005 to implement Assembly Bill 1149 regarding undergrounding of electric and telecommunication facilities.
- **2001** – The CPUC issued Decision (D.) 01-12-009 in Phase I of the OIR directing expanded use of Rule 20 funds and listing issues for Phase 2
- **2002** – The CPUC issued D.02-11-019 to signal consideration of a new rulemaking to address Phase 2 issues.
- **2002** – The CPUC in Resolution E-3788 approved franchise fee surcharges within the City of San Diego for electric conversions not eligible for Rules 20.
- **2005** – D.05-04-038 closed OIR 00-01-005. D.01-12-009 remains effective until a new proceeding is opened consistent with the CPUC's resources and priorities.
- **2006** – D.06-12-039 authorized AT&T to impose a special surcharge to customers in the City of San Diego for a limited time duration to recover undergrounding cost as a result of the City of San Diego Underground Utilities Procedural Ordinance.
- **2014** – D.14-01-002 added Rule 20D to facilitate undergrounding in high fire zone areas of San Diego Gas & Electric Company.

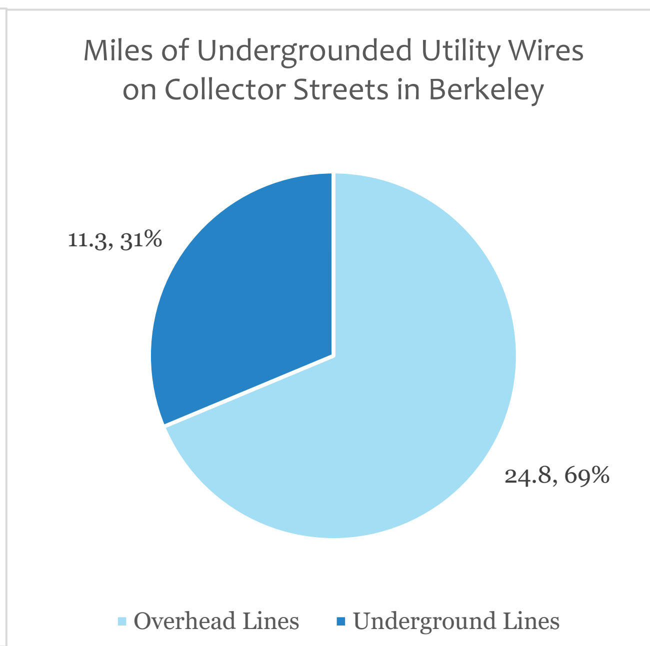
History of utility undergrounding in Berkeley

The current level of utility undergrounding in Berkeley is depicted by the following graphs.

Figure 1: Undergrounded Street Miles







Prior to 2009, Berkeley had a number of residential districts approved by PG&E in the queue for undergrounding. Because their allocated Rule 20A monies were committed years into the future, City Council issued a moratorium on Rule 20A districts until a new policy for future Rule 20A monies could be developed. Although never agendized, the Public Works and Transportation Commissions, in January of 2009, recommended that the Council adopt priority routes that met the following criteria:

- Major arterial route as designated by the General Plan
- Major emergency/first responder/evacuation route as designated by the General Plan
- Highest traffic volumes as determined by the Public Works/Transportation divisions

Two existing Rule 20 A funded undergrounding districts, formed in the early 1990s, are scheduled for completion in 2020 and 2025 respectively.

- Berkeley Grizzly Peak Summit, UUD #48 – in the engineering phase
- Berkeley Vistamont, UUD#35A - in the planning phase

Both undergrounding districts have paid their share for connection from the street to service boxes and for street light replacement. PG&E's current allocation of 20A funds for Berkeley means that new 20A funds for additional undergrounding projects will not be available until 2025.

The City rolled out 20B project guidelines (See Appendix F) in December 2000 for neighborhoods interested in forming Rule 20B districts. Although many neighborhoods have expressed interest and continue to do so, one neighborhood, Thousand Oaks Heights, formed and completed an undergrounding district. One other 20B project, Bayview Place, has recently received Council approval to form a district consisting of 14 properties.

Below is a summary of areas undergrounded in Berkeley (the table may be incomplete). The source of information was from City staff reports and City Council agendas.

Table 2: Historical Undergrounded Areas in Berkeley

1970's	1980's	1990's	2000's
Hearst (Freeway to 6th)	Oxford Street (Heart to University)	Ashby, Benvenue	Los Angeles, Mariposa
Sixth Street (University to Cedar)	Sacramento Street (Oregon to South City limit)	Hearst Avenue (LaLoma to Cyclotron)	Park Hills
Sutter/Henry Street	Ajax Place/Hill Road	Grizzly Peak, Cragmont	Miller Stevenson
San Pablo Avenue	Kains, Cedar, Hopkins, Jones, Page	Vicente, Alavarado	Grizzly Peak, Summit (est. completion 2020)
Eastshore Freeway (Hearst to Gilman)	Oakvale Avenue (Claremont to Domingo)	MLK Jr. Way	Vistamonte, Woodmont (est. completion 2025)
Stannage Avenue (Gilman to Hopkins)	LaLoma (Buena Vista to Cedar)	Woodmont Avenue	Bayview approved by Council in 2017
Buena Vista Way	Channing, Bonar	Spruce Street, Vassar	
Colby (Ashby to Webster)	MLK Jr. Way (University to Hopkins)	LeRoy, Euclid	
So. Hospital Drive (Ashby to Webster)	Amador Avenue (Shattuck to Sutter)	Benvenue (Woolsey to Stuart)	
Telegraph (Bancroft to South City limit)	Woodmont Avenue area	Cragmont	
	Spruce Street, Vassar	Arlington Avenue (Marin Circle to City limit)	

1970's	1980's	1990's	2000's
	Benvenue Avenue (Ashby to Stuart)	1991 Fire District	
	University Avenue		
	Solano Avenue		

Undergrounded projects identified as completed with alternative funds:

Table 3: Alternative Funding Undergrounding Projects

Street	Source of Funding
Shattuck, Adeline	BART
University Avenue	Caltrans, private
6th Street	Redevelopment
Kains, etc.	Community Development Grant Block
Bancroft Avenue	U.C. Berkeley
San Pablo Avenue	Caltrans

The following two maps show the utility undergrounding that has been completed or will be completed in Berkeley. Figure 2 shows the land use zones, arterial and collector streets, and where utility undergrounding has been completed. Figure 3 shows Berkeley by City Council Districts and where utility undergrounding has been completed.

Figure 2: Utility Undergrounded by Land Zones

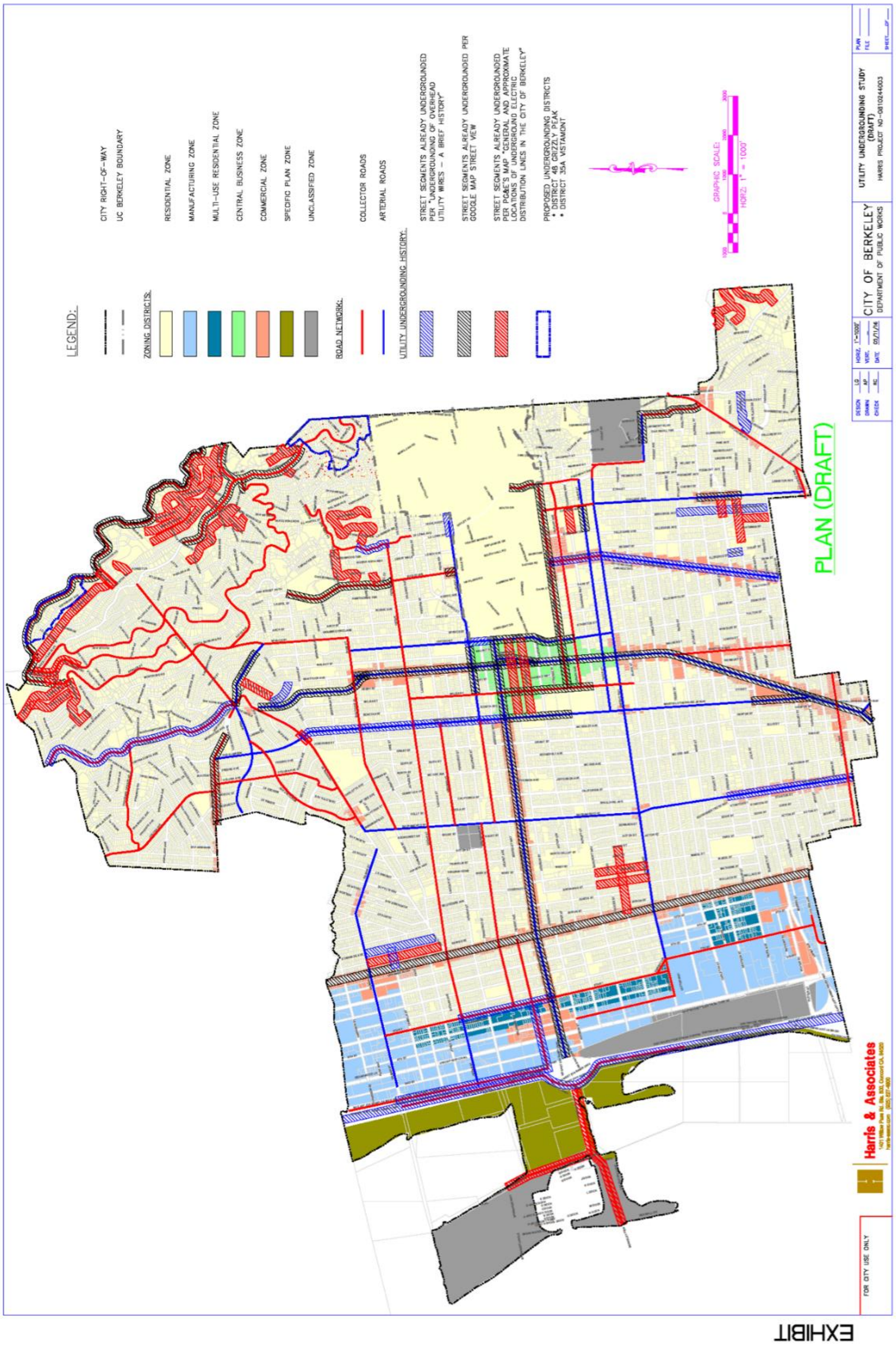
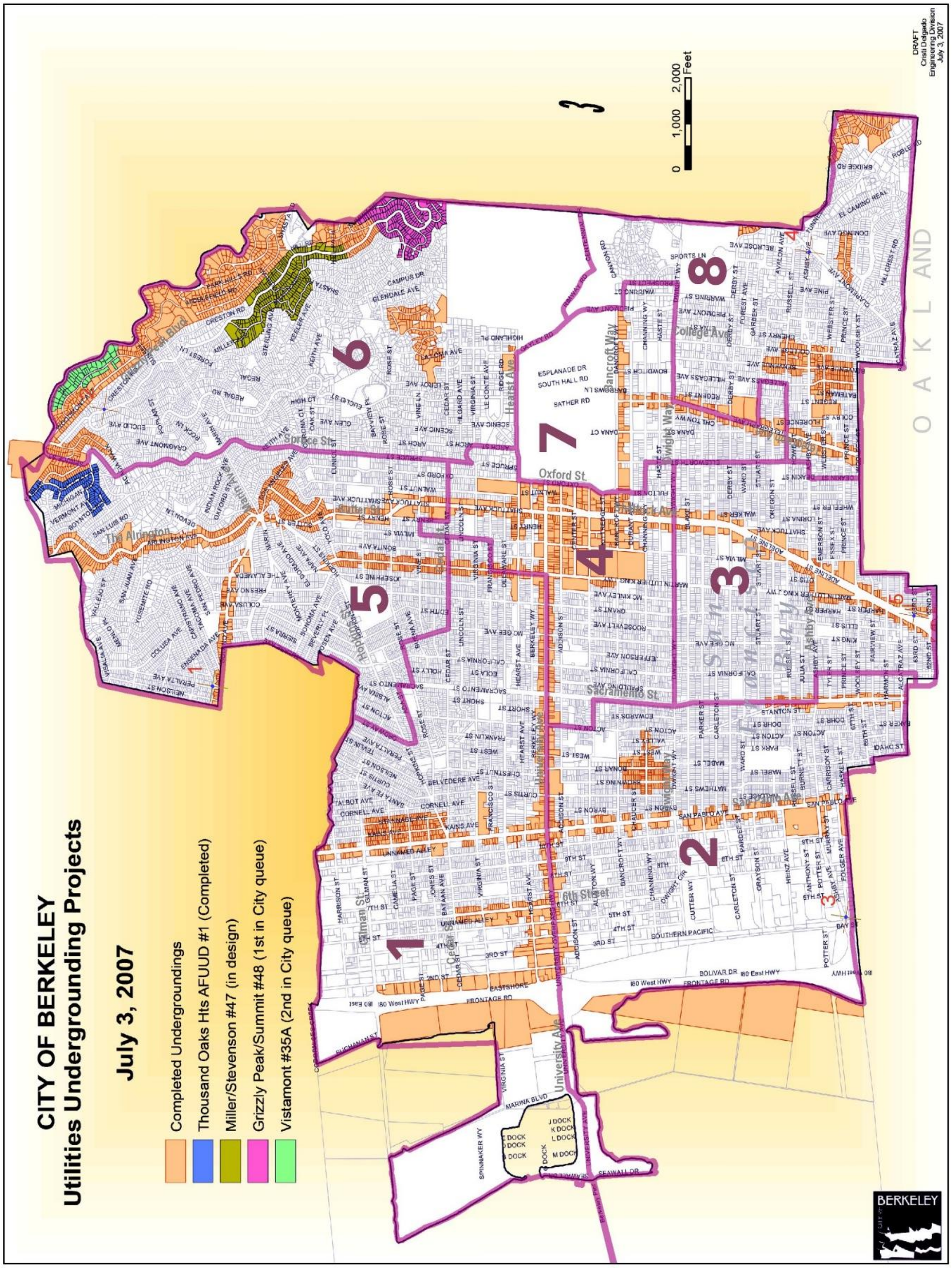


Figure 3: Utility Undergrounded by Council District



Emergency access routes

The potential need for evacuation exists throughout the city. An earthquake, a wildfire or a multi-structure urban fire, a hazardous spill, significant flooding or pandemic are all possible disaster scenarios requiring a large portion of our citizens to evacuate. It is in the city's best interest to ensure that there are evacuation routes, from multiple points within the city, to accommodate a very large number of people headed toward safety.

The objective is both safety and power reliability. Eliminating the danger of dangling or fallen overhead wires is a key concern. If fires travel 200 yards a minute as reported in the North Bay fires Berkeley could rapidly be overcome by fire. In the 1991 Oakland Hills fires, a home was consumed every 11 seconds. Under these circumstances, unimpeded evacuation is paramount.

After an earthquake both damage and potential fires (and the ability to contain them) suggest that effective evacuation may be required. If there is a fault rupture or a fast-moving wildland urban interface fire, the eastern most part of the Berkeley will be separated from the rest of the city. Aside from one fire station, there are no city services. Creating several "obstruction-free" routes from the hills into the more defensible city is critical to the overall safety of residents throughout the city. Currently, our evacuation routes with heavy overhead power and communications wires are often attached to leaning wooden poles. For all of us, an overhead free evacuation route will save lives.

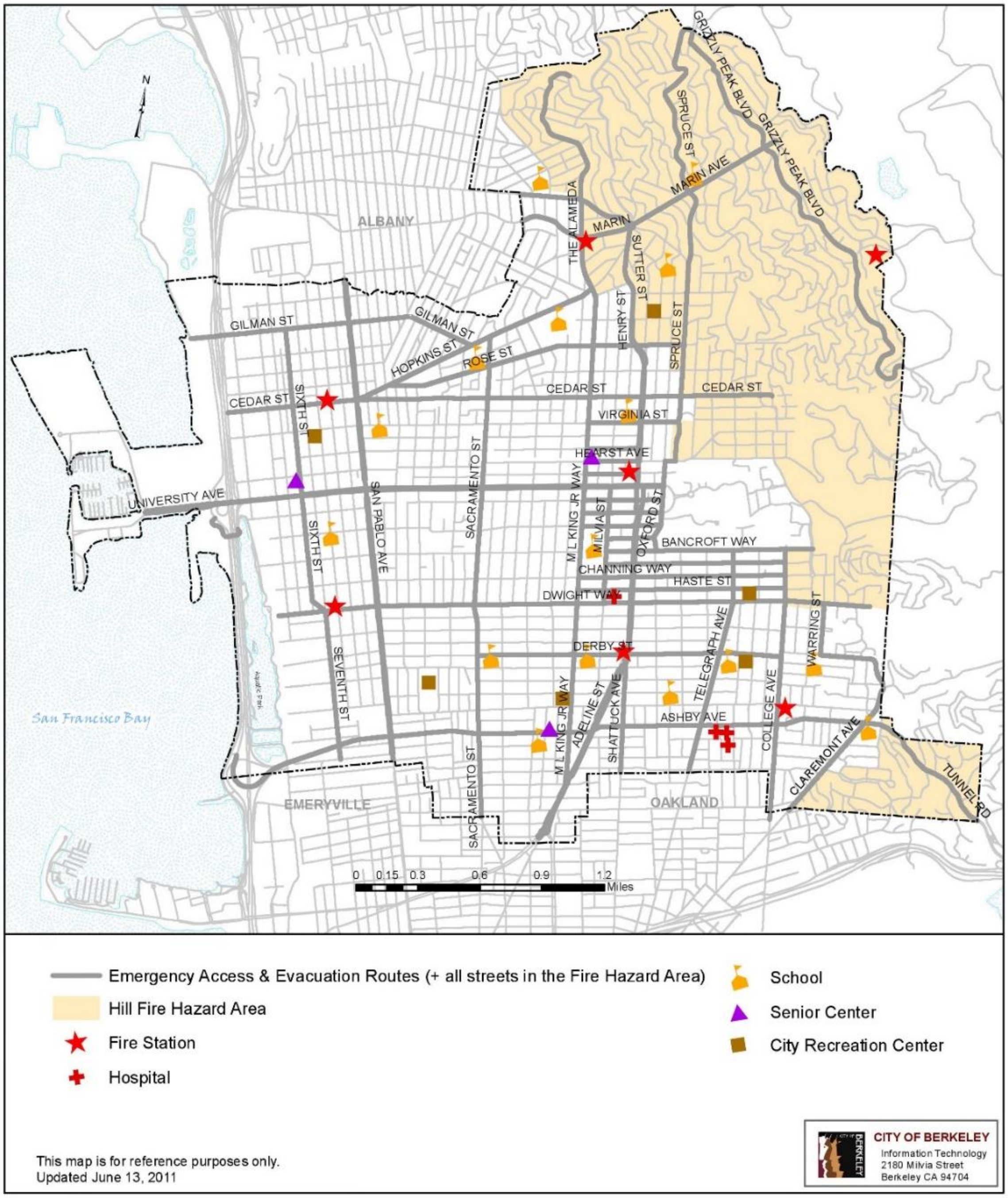
The City has already designated priority evacuation routes, along with a hierarchy of roadways. See Figure 4 from the Transportation Element of the General Plan. The evacuation routes generally follow with the City's established major streets (i.e., arterials and boulevards) and the collector streets. We recommend the streets that are in both the evacuation route descriptions and are major streets be the highest priority for utility undergrounding. We further recommend a hierarchy of prioritization that continues to follow the logical of the General Plan designations and enable a prioritization of major roadway utility undergrounding, as follows:

Highest priority, in order:

1. Emergency access & evacuation routes, including state highways.
2. Emergency access & evacuation routes designated in the City's General Plan as major streets.
3. Emergency access & evacuation routes designated in the City's General Plan as collector streets.
4. All other emergency access & evacuation routes not designated as either major streets or collector streets.
5. All other major streets not designated as an emergency access & evacuation route.
6. All bicycle routes not designated as an emergency access & evacuation route.
7. All other collector not designated as an emergency access & evacuation route.

As part of the development of a multi-year phased utility undergrounding program, and in coordination with other city infrastructure improvements such as paving, streetscape improvements and water and sewer maintenance and upgrades, these priorities may be sequenced out of priority order to ensure maximum efficiency and delivery of the combination of projects whenever possible.

Figure 4: Emergency Access and Evacuation Network



Section 2
COMMUNITY RESILIENCE

The City of Berkeley's 2016 Resilience Strategy defines resilience as the ability of individuals, institutions, businesses, and systems within the community to survive, adapt, and grow no matter what chronic stress or acute shock it experiences. A resilient city lives well in good times and bounces back quickly and strongly from hard times.

Our community is an older densely populated city located in a much larger urbanized area made up of nine counties with three major cities, two world renowned universities and the home base for the tech economy. It is important to keep in mind that although public safety, mitigation and recovery concerns are local, our economy, our roadways and our utilities are shared resources throughout the Bay Area. What nearby cities do or don't do does have an impact on our community - to our benefit such as mutual aid cooperation or potentially to our detriment such as an airborne hazard affecting Berkeley. Regional response to disaster will be prioritized, just as our local response will be prioritized, based on what needs to be addressed first.

To quote directly from the Resilience Strategy, "A sound disaster resilience program must be founded on reliable information about the types and scale of damage that different hazards could cause". Although this report focuses exclusively on undergrounding arterial and collector streets within Berkeley, risk mitigation is always multi-faceted. Undergrounding can reduce some, but not all, aspects of the hazard risks we face. And under certain circumstances, undergrounded wires are materially beneficial for saving lives and reducing property damage.

Public Safety

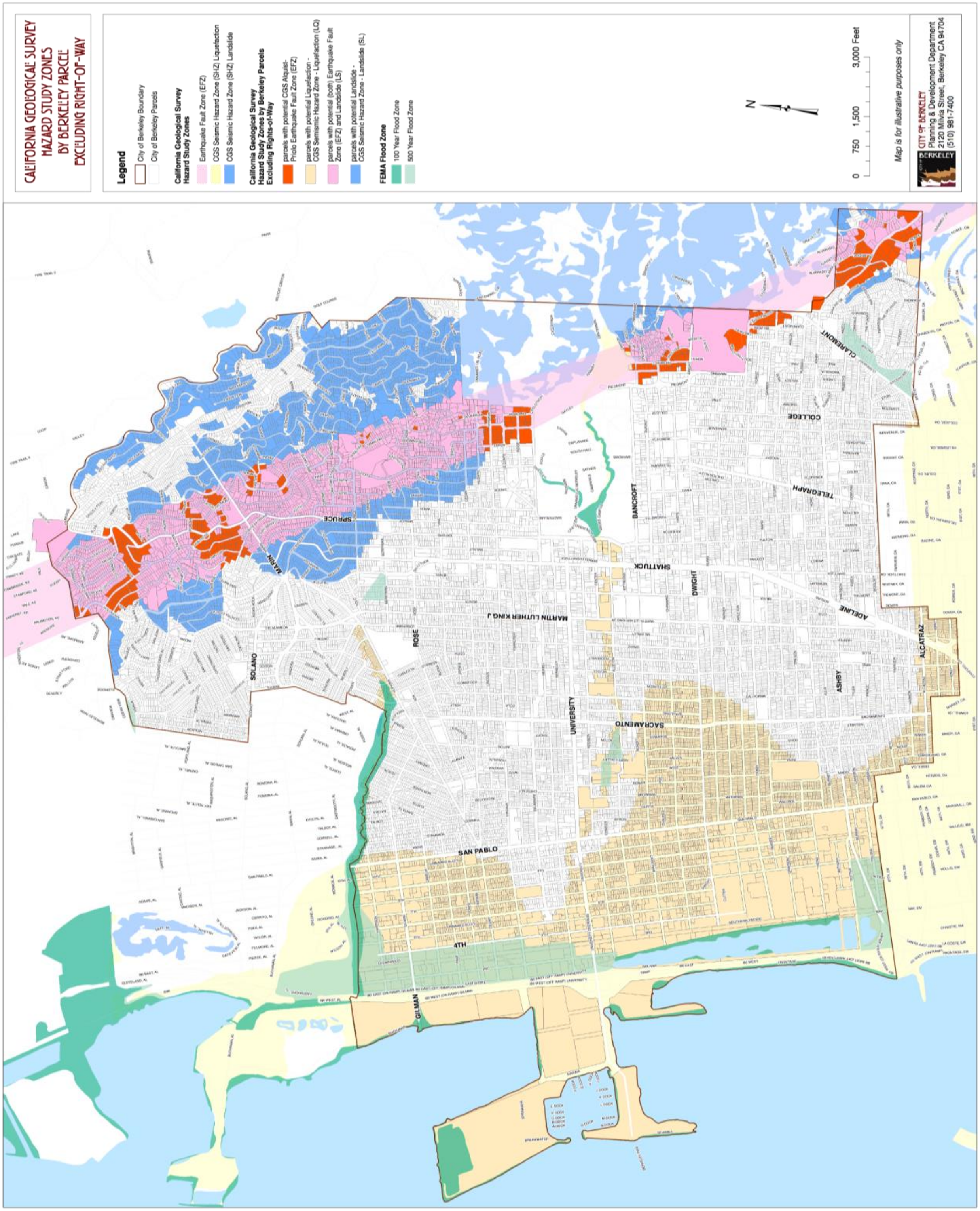
The City of Berkeley's stated goal, as outlined in the General Plan, Disaster Preparedness and Safety Element, is to ensure the City's disaster related efforts are directed toward preparation, mitigation, response and recovery from disaster shocks. Integrating safety into all City decisions for the purpose of sustaining the community is the guiding principle of policy decision making.

Berkeley's General Plan's list of hazards, natural and otherwise, that that face our community are:

- Earthquakes
- Fires
- Landslides
- Floods
- Hazmat accidents

The 2014 Berkeley Hazard Mitigation Plan and The Resilience Strategy Work Session Report dated March, 2015 both state that our two greatest disaster challenges are a Hayward Fault rupture and wildland urban interface (WUI) fire.

Figure 5: Berkeley Hazard Zones



Earthquake Risk

USGS's September 2016 earthquake forecast predicts a 72% chance of a 6.7 or greater fault eruption somewhere in the Bay Area in the next 27 years and predicts a 33% likelihood of a Hayward-Rogers Creek earthquake in the next 30 years, the highest probability of any rupture in the area.

Berkeley's 2014 hazard plan estimates 100 people could be killed and an unspecified number injured in a 6.9 magnitude earthquake along the Hayward Fault with liquefaction likely in West Berkeley and landslides in the Berkeley Hills (Figure 5). "The extent of both landslide and liquefaction damage will depend on whether the earthquake of this magnitude occurs during our dry or wet season. Prolonged shaking can translate into even higher numbers of landslides and greater areas of liquefaction. We can expect public roads will be disabled or destroyed and utilities will be non-functional throughout the city "(p 2). The General Plan describes the expected utility failures - water, gas, storm, and wastewater mains and pipes, electrical systems, and telecommunications are all vulnerable to extensive damage (General Plan, Disaster Preparedness and Safety Element p.10). The extent of damage is largely a function of the power of the earthquake, the location of the epicenter and the shallowness of the fault rupture, per Berkeley's Hazard Plan.

The General Plan spells out why the combination of earthquake-induced ground shaking, potential lateral spread, fault rupture and fire is of particular concern in the residential hill areas of Berkeley east of the Hayward Fault line. "In these areas, many homes are on steep slopes, and access to many of these areas is difficult for emergency vehicles due to narrow, winding roads, some of which are cul-de-sacs. The eastern edge of the city is heavily wooded, which provides fuel for earthquake-induced fire. These areas are entirely residential and do not have easy access to any City emergency services. If the northern Hayward Fault were to rupture, many of the roads leading from the City's emergency service facilities (police and fire stations) to these residential areas could be made impassible and the areas would then be isolated" (General Plan, Disaster Preparedness and Safety Element p.8-9).

Wildland Urban Interface Fire

The City of Berkeley faces a constant threat from both urban and Wildland Urban Interface (WUI) fires. Fire following earthquake is common. The hazard plan points out that these often-spontaneous ignitions are caused by ruptured gas mains and service lines, damaged or fallen overhead transmission or distribution power lines or poles, or caused by unbraced or inadequately braced gas or electric appliances and equipment. Under certain conditions a fire could break out outside of city limits and spread into Berkeley, most likely from a WUI fire. Conditions especially ripe for these fire outbreaks are the first summer after a winter of drought busting rain, and during a period of hot "Diablo winds" blowing east to west. A draft report prepared by East Bay Regional Parks dated 2-1-2017 describes this phenomenon:

> *"These hot, dry winds blow from the east, often in the early morning when major fires are least expected. They can fan the flames of small sparks into wildfires that have been observed to move down from a ridge top in 30 minutes, expand to one square mile in an hour, and consume hundreds of residences in one day. The few days each year when all of the high fire danger conditions—low humidity, high temperatures, and hot, dry Diablo winds blowing in from the east—are extreme are labeled Red Flag days, and usually occur in the fall months. During the 75-year period between 1923 and 1998, 11 Diablo wind-driven fires in the Berkeley/Oakland hills burned a total of 9,840 acres, destroyed more than 4,000 homes, took 26 lives, and resulted in over $2 billion in financial losses. The most significant fire in this period was the October 20, 1991 Tunnel Fire in the Oakland-Berkeley hills, which ranks as one of the worst wildland-urban firestorm disasters to ever strike the United States. The fire resulted in 25 deaths, 150 injuries, and the displacement of over 10,000 persons."*

The draft report further states "Most of the major historical wildland fires have been in the eastern part of the Park District. However, … most of the high-density development in high fire risk areas is in the East Bay Hills."

Expected increased incidence of drought conditions, higher vegetation loads throughout the parks system and the East Bay Hills, and higher average temperatures will make WUI fires more likely. The 2009 Berkeley Climate Action Plan points out that risk of large wildfires could increase by as much as 55% by 2100. A report prepared by PG&E dated November, 2016 suggests a possible 200% increase in the incidence of wildland fires in certain areas of the state by 2050.

Expected climate ramifications for Berkeley will not only increase the frequency and magnitude of wildfires but drought induced water shortages will have a material impact on firefighting capability. Including the December, 2017 Thomas Fire, thirteen of the twenty most destructive fires in California have occurred since 2000 (Table 4).

Table 4: Top 20 Most Destructive California Wildfires

Top 20 Most Destructive California Wildfires

	FIRE NAME *(CAUSE)*	DATE	COUNTY	ACRES	*STRUCTURES*	DEATHS
1	**TUBBS*** *(Under Investigation)*	October 2017	Sonoma	36,432	**5,300***	22
2	**TUNNEL - Oakland Hills** *(Rekindle)*	October 1991	Alameda	1,600	**2,900**	25
3	**CEDAR** *(Human Related)*	October 2003	San Diego	273,246	**2,820**	15
4	**VALLEY** *(Electrical)*	September 2015	Lake, Napa & Sonoma	76,067	**1,955**	4
5	**WITCH** *(Powerlines)*	October 2007	San Diego	197,990	**1,650**	2
6	**NUNS*** *(Under Investigation)*	October 2017	Sonoma	54,382	**1,200***	2
7	**OLD** *(Human Related)*	October 2003	San Bernardino	91,281	**1,003**	6
8	**JONES** *(Undetermined)*	October 1999	Shasta	26,200	**954**	1
9	**BUTTE** *(Powerlines)*	September 2015	Amador & Calaveras	70,868	**921**	2
10	**ATLAS*** *(Under Investigation)*	October 2017	Napa & Solano	51,624	**741***	6
11	**PAINT** *(Arson)*	June 1990	Santa Barbara	4,900	**641**	1
12	**FOUNTAIN** *(Arson)*	August 1992	Shasta	63,960	**636**	0
13	**SAYRE** *(Misc.)*	November 2008	Los Angeles	11,262	**604**	0
14	**CITY OF BERKELEY** *(Powerlines)*	September 1923	Alameda	130	**584**	0
15	**HARRIS** *(Under Investigation)*	October 2007	San Diego	90,440	**548**	8
16	**REDWOOD VALLEY*** *(Under Investigation)*	October 2017	Mendocino	36,523	**540***	8
17	**BEL AIR** *(Undetermined)*	November 1961	Los Angeles	6,090	**484**	0
18	**LAGUNA** *(Arson)*	October 1993	Orange	14,437	**441**	0
19	**ERSKINE** *(Under Investigation)*	June 2016	Kern	46,684	**386**	2
20	**LAGUNA** *(Powerlines)*	September 1970	San Diego	175,425	**382**	0

* Fires are uncontained and totals are likely to change.
**"Structures" include homes, outbuildings (barns, garages, sheds, etc) and commercial properties destroyed.
***This list does not include fire jurisdiction. These are the Top 20 regardless of whether they were state, federal, or local responsibility.

10/20/2017

Source 1: Cal Fire 2017

8.5 million acres burned in the summer of 2017 located primarily in the Pacific Northwest, Montana and Northern California. By the end of August and again in October, 2017 Berkeley and surrounding communities suffered from dangerously unhealthy smoky haze caused by multiple fires in Northern California and Oregon.

Like the Oakland Hills Fire, the North Bay fires, renamed by Cal Fire as the October 2017 Fire Siege, was an incredibly fast-moving wind driven fire siege after drought busting record winter rains. The death toll and structure loss surpassed that of the Oakland Hills Fire even before the Fire Siege was considered containable. There was little outside help in the first 24 to 36 hours when the fires ran unchecked through neighborhoods destroying everything in their path. There was little that could be done except to urge people to evacuate. It was dangerous work. An article in the Press Democrat dated October 12, 2017 pointed out that "the fire traveled at a pace of about 3 mph, burning an acre a minute".

Image 5: Downed power poles and lines in 2017 Fire Siege

Source: Brian van der Brug, Los Angeles Times

The economic damage (estimated $9 billion of insured losses alone) is triple the estimated economic cost, $3 billion in today's dollars, of the 1991 Oakland hills fire. Estimates of the extent of damage from these fires as of this writing are:

- Over 10,000 structures destroyed
- 100,000 people evacuated
- 400 square miles burned
- 11,000 firefighters and support personnel battled the fires
- 43 known deaths from the fires

Although the cause of these fires are not yet known, local news outlets have made public that about a dozen firefighter dispatch calls were made to report downed live power lines, exploding transformers, and low hanging power lines throwing sparks. PG&E has publicly conceded that trees, branches and new vegetation growth impacted their power lines in the North Bay.

Image 6: PG&E ordered to preserve Evidence, David Baker, The Chronicle, October 13, 2017

PG&E ordered to preserve evidence

By David R. Baker

California utility regulators have told Pacific Gas and Electric Co. to preserve any evidence that could be connected to this week's deadly wildfires in the North Bay, including all broken power poles and electrical conductors.

State fire officials are investigating whether power poles and electrical lines knocked down by a severe windstorm Sunday night played a role in sparking the fires, which have killed at least 31 people and displaced thousands.

On Thursday, the California Public Utilities Commission sent PG&E a note reminding the utility to preserve all evidence related to potential causes of the fires. That includes not just physical equipment such as damaged poles but also emails and documents related to PG&E's tree-trimming program in the area.

Fire officials are investigating whether power poles and electrical lines played a role in sparking the fires.

The letter, from the director of the commission's safety division, notes that commission staff first verbally notified PG&E's senior director of regulatory affairs on Tuesday evening to preserve evidence related to the fires. According to the letter, "PG&E acknowledged that it would do so."

A PG&E spokesman said Thursday that the company had received the CPUC's letter and would support "the reviews by any relevant regulator or agency."

The utility, California's largest, has acknowledged that Sunday's windstorm knocked trees and tree limbs into power lines and poles across the North Bay. But PG&E has insisted that blaming the fires on that equipment remains premature. Officials with the California Department of Forestry and Fire Protection, known as Cal Fire, say they are examining the utility's electrical equipment as one of several potential causes of the fires.

"Since the wildfire began Sunday night, in the cases where we have found instances of wires down, broken poles and impacted infrastructure, we have reported those to the Commission and continued to share that information with Cal Fire," said PG&E spokesman Keith Stephens, in a statement. "We understand that there will likely be reviews of these wildfires by the appropriate agencies, but right now we are focused on life safety and service restoration."

Over the course of the week, the windstorm and fires have cut off power to 255,218 PG&E customers, according to the company. By Thursday afternoon, electricity had been restored to 80 percent of those customers. Most of those still blacked out are in Santa Rosa.

The letter from the utilities commission instructs PG&E to tag and catalog all physical evidence so the commission's safety division staff can reconstruct the poles for analysis. The company must also notify the commission in advance before moving physical evidence from the field to a storage facility.

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PG&E does not meet their mandate on maintenance in numerous areas of Berkeley. These photos show examples of utility poles in Berkeley in need of PG&E's attention.

Image 8: Cedar St

Image 7: Olympus

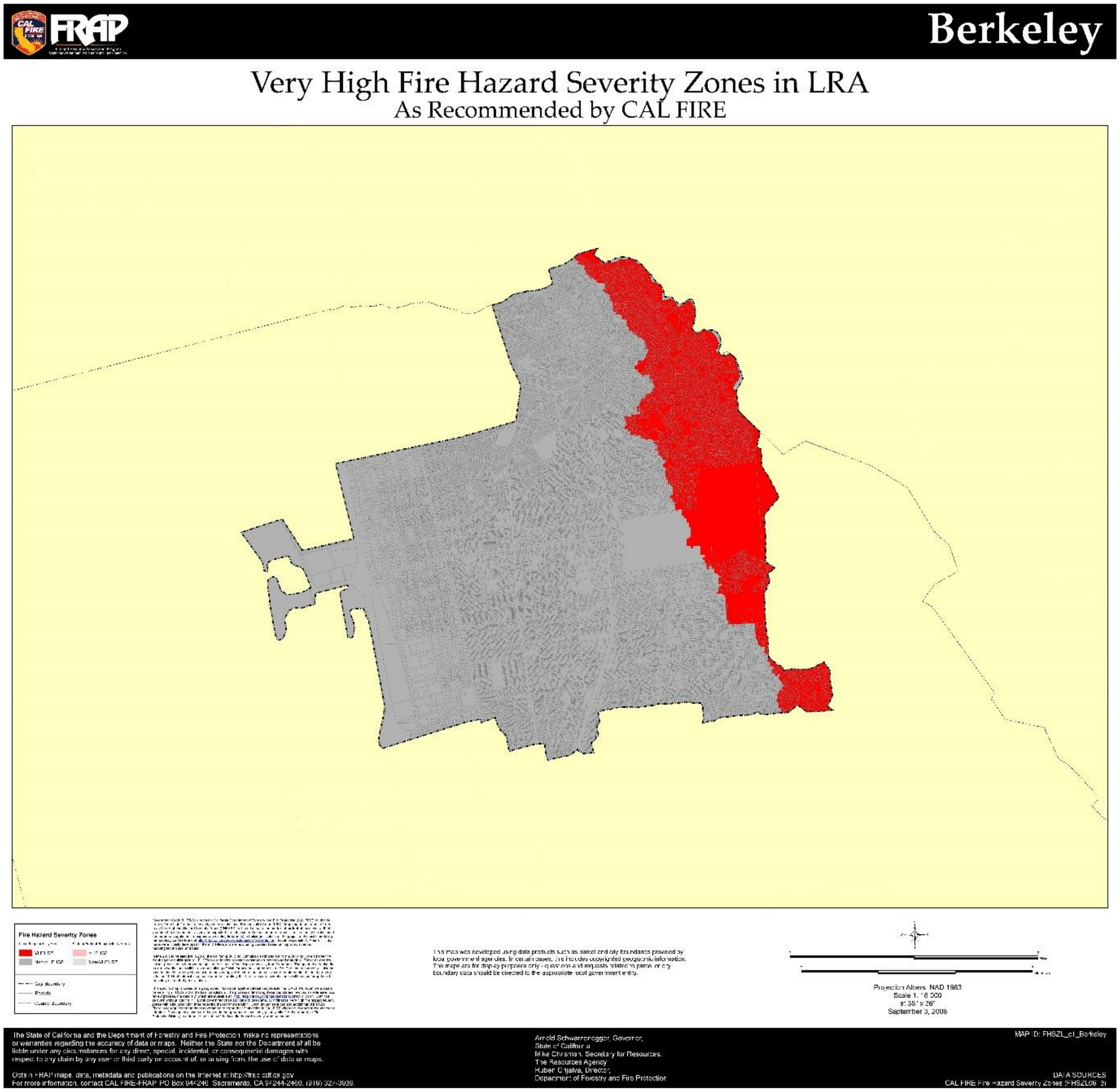
The California Department of Forestry and Fire Protection (Cal Fire) maps areas of significant fire hazards by rating fire hazard severity based on fuels, terrain, and weather conditions such as temperature, humidity, and wind. This map represents the likelihood of an area, in Berkeley, burning over a 30- to 50-year time period. (See Figure 6) The last big fire in Berkeley was in 1923.

At a press conference held on October 15, 2017, Cal Fire acknowledged the Very High Hazard Fire Zone (VHHFZ) designation for urban areas may be inadequate to reflect the risk associated with WUI fires including post fire risk of debris flow as evidenced in the Thomas Fire. Although we expect their maps will be redrawn earmarking a larger VHHFZ for Berkeley, the map shown is the most current map sourced by Cal Fire that is relevant to Berkeley.

PG&E's current practice of treating overhead poles with fire retardant in front of an advancing wildfire is intended to diminish the spread of an out of control fire (PG&E meeting of 7.10.17). It is worth noting that fire spread far faster in the 2017 Fire Siege than this technique could even be attempted. We are not familiar with their other fire mitigation practices though we are aware PG&E does remove vegetation but not always where and when they should. PG&E installs spark arrestors on poles but we do not know the extent of their practice of doing so.

Multiple fire hardening methods have been aggressively adopted by San Diego Gas and Electric. After experiencing mega fires in 2003 and again in 2007, San Diego Gas and Electric takes its power line safety practices very seriously. Techniques include replacing wooden poles with fire hardened steel poles which are built to better withstand the strength of Santa Ana winds; increasing vertical and horizontal spacing of conductors, interrupter switches and other equipment; installing stronger transmission lines that can withstand powerful winds; aggressive vegetation clearing practices, monitoring and follow-up actions; all in addition to undergrounding wherever feasible (tdworld 5.1.12). San Diego has one of the most comprehensive and aggressive undergrounding programs in the country.

Figure 6: Cal Fire Berkeley Very High Fire Hazard Severity Map



Power reliability

Power reliability is key to the way we live now - to public safety and to limiting economic fallout after a disaster event. Power outages and severe weather go hand in hand. Scientists published a study in Geophysical Research Letters in February, 2016 posturing that cyclical atmospheric river storms will become more common by as much as 20 additional days from our current yearly average of 25 to 40 days by the end of this century. These storms will lead to more flooding and thus impact vulnerable electrical substations and transmission lines. Landslides will become more common, potentially tearing out utility services in affected areas. In the event of a disaster or big storm, the ability to successfully coordinate disaster response and life safety services could be diminished because power needs cannot be met. Daily higher temperatures and aging infrastructure tax the energy grid at times when air conditioning needs are greatest, causing added life safety issues for our population, especially seniors.

Outages are costly, having an injurious effect on life safety as well as the City's economic viability. In a Berkeleyside article published in June 13, 2016, it was reported that in the first five months of 2016 Berkeley experienced eight outages affecting at least 2,500 customers in each incident. The largest, impacting 43,000 customers, reported the power loss after an explosion at a substation in El Cerrito. In 2015, Berkeley experienced "several significant outages". The largest was blamed on a squirrel causing an equipment breakdown in the El Cerrito substation. 45,000 customers lost power. On a Friday evening in early October, 2017 power was lost to some 3,400 customers in Berkeley's downtown area affecting performances and restaurants during a typically very busy Friday night.

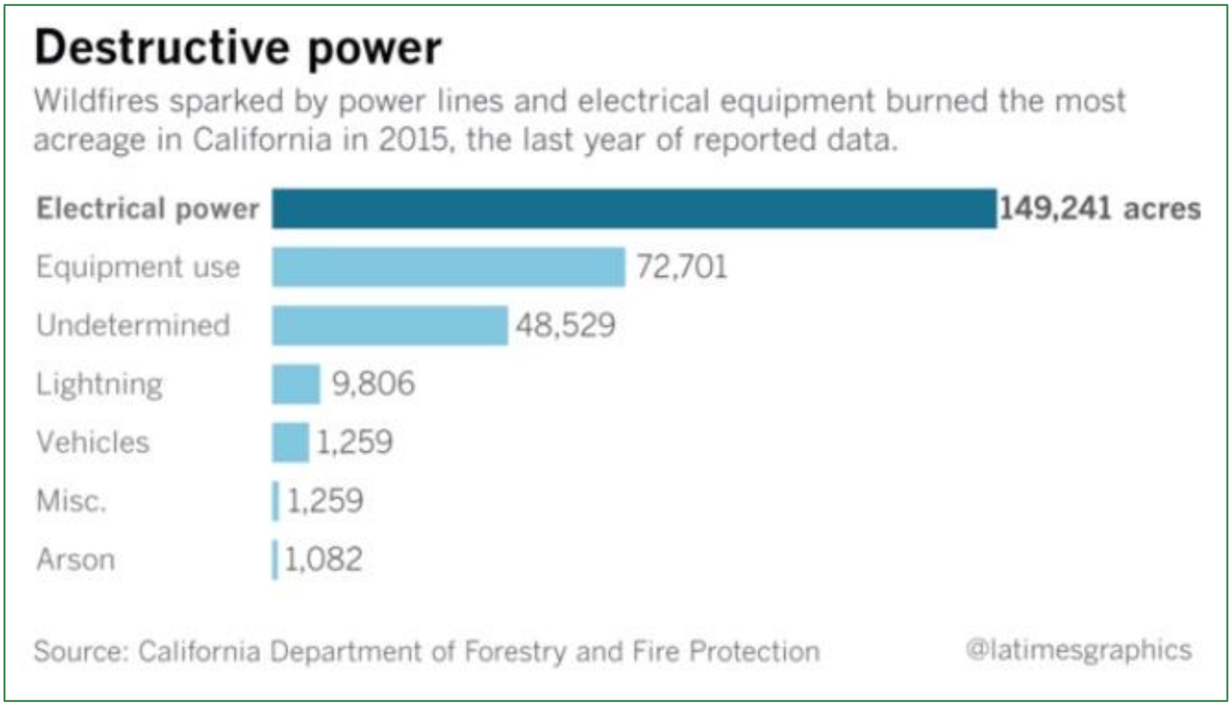
The Harris Report mentions that French Telecom determined a 47% improvement in power reliability where utility wires are undergrounded. A 2006 Los Angeles water and power study also concluded a 47% improvement in frequency of power interruptions when utility lines are undergrounded.

Berkeley is well known for its near perfect temperate climate. The tradeoff is exposure to various natural disasters. As a general statement, undergrounded utility wires have the greatest benefit overall in areas of high frequency severe weather events occurring in areas having a concentrated utility customer base.

Overhead power lines, more so than undergrounded wires, can exasperate unsafe conditions either by contributing to the disaster itself or hampering public safety efforts post disaster. Earthquakes and landslides can knock over utility poles creating a special hazard. In an earthquake, poles have a tendency to sway in opposite directions causing wires to snap and spark. Some of California's biggest fires have started because of live wires in contact with combustible fuel. Other power disruptors to overhead lines acting as potential fire starters are squirrels, rodents and birds, lightning, and vehicles knocking down utility poles (Figure 7).

In certain topographies undergrounding presents design challenges which can be addressed to enhance power reliability. Where the exposure to earth rupture or water, especially sea water, is high undergrounded utility equipment can be damaged and lead to periods without electricity. Climate change driven extreme rainfall could lead to more flooding and could contribute to increased risk of landslides in the hills and thus decreased power reliability, no matter how the wires are installed. Earthquake or landslide induced changes to the landscape may necessitate replacement damaged utility trenches in some locations. Excess water can disrupt utility services whether underground or aboveground until waters have receded and utility damage rectified.

Figure 7: Wildfire Destructive Power by Cause 2015



Arizona State Fire Historian Stephen Pyre sees powerlines as a "notorious" ignition source for fires, much like locomotives were in the late 19th century and into the 20th century.

The risk of poles contributing to the spread of an out of control fire is reduced by utility providers' fire hardening practices to increase safety and power reliability. Undergrounding is one tool. Since the trenches where undergrounded wires are located tend to move in the same direction as earth movement, undergrounding power lines can mitigate the high risk of fire from overhead wires sparking. Undergrounded wires don't fall down and block roadways. Undergrounded wires are considerably less susceptible to environmental damage, especially sunlight, and thus enhance power reliability for users. The City of Palo Alto pointed out to us that undergrounded wires installed 100 years ago are still working fine.

PG&E advises to keep a 100-foot clearance from downed power lines. Our first responders will not drive over fallen power lines until they are advised by the utility company that the power has been turned off. We can climb over, drive over, cut, push or pull out of the way smaller tree limbs and tree trunks; we cannot do the same with power poles.

Commercial enterprises are also deeply affected by prolonged power outages after earthquakes or other disasters. According to FEMA, 40% of small businesses will close their doors immediately after a disaster event and another 25% will fail within a year after a disaster event. As a city that favors small businesses, the magnitude of small business failures will have a widespread effect on our entire community.

Critical public safety services, businesses, cache neighborhood groups and residential customers who want backup power have been protecting themselves against power failures by relying on 20th century technology dependent on stored oil based fuels in order to run on-site generators. This works as long as these entities have fuel. Reports of nursing home deaths in Florida and widespread suffering in Puerto Rico because of power loss after hurricanes, show us how power interruption of critical services endangers lives in the face of extensive prolonged power outages. Undergrounding would have protected both those nursing home residents and the entire population of Puerto Rico, whose unofficial death toll now exceeds 1,000 people.

Communications Reliability

Compromised communications capability due to power disruption during a disaster can critically impede disaster response effectiveness. Wi-Fi, internet, landline and mobile telephony services cannot be reestablished until electric power is restored. Power cannot be restored until roads are cleared of debris and repaired. In areas where undergrounded wires were damaged after the 2014 Napa quake, AT&T, in response to the pressing need for reliable communications set up temporary poles to string cable from areas with power to areas without power so that internet and cellular services could be quickly restored (Appendix D). Also, good communications make it much easier for people who need help to request that help, and for people to report problems they see occurring. Without communications, the ability of the city to respond to an emergency is drastically reduced.

When we met with AT&T and Comcast they talked about how they were trying to bring Smart Home, Smart Healthcare and Smart City technology to market. However, as these technologies become more prevalent, the need for internet communications increases. AT&T talked quite a bit about 5G wireless technology which will allow much more robust internet communications to cellular devices. They admitted that the cell density would probably have to be increased and that the cell towers require both power and internet feeds (generally fiber for internet) to operate.

In terms of how communications are transported the same issues which apply to power also apply to wired communications. With communications wiring, the materials are changing. As noted in the Future of Technology section, in the midterm timeframe (less than 20 years) it is reasonable to expect that a technologically sophisticated community will be operating with almost 100% fiber, and give up all need for copper or coaxial connections. In Berkeley there is very little fiber installed to residences at this time. Fixing this will require significant rewiring of most of Berkeley.

De En Ni, a graduate student at the Goldman School of Public Policy, points out that connectivity through internet and WI-fi will become increasingly important in how we go about our daily lives. His report can be found in Appendix C.

The Subcommittee favors a comprehensive undergrounding program because technology is changing rapidly and Berkeley's aging utility infrastructure impedes adoption of using not only rapidly developing fiber technology but also power technology that will be environmentally cleaner and make us less dependent on an aging and increasingly less reliable centralized power grid. A city sponsored undergrounding effort could go a long way towards providing vendor neutral Internet options to the residents of the city. In many cases, this could result in savings to the residents of 50% to 75% of their monthly Internet bill. It could also provide additional choice now that Net Neutrality is no longer FCC policy. In addition, with a well-engineered system, the city could run its own internal Intranet to provide emergency and other civic services. Doing this with overhead lines leaves these lines for communication far more vulnerable and limits how much capacity can be installed.

Benefits of Undergrounding Across Berkeley

Berkeley is a city made up of diverse neighborhoods, some with a mix of commercial and residential properties and others that are primarily residential. It is important that whatever program is adopted by the City is designed to maximize equitable value across the city. A well-designed undergrounding program provides numerous benefits to our community.

Public Safety

Berkeley needs to plan ahead for the eventuality of natural disasters and the ability to recovery from them. Public safety is of primary importance. This has been discussed in Section 2.

Quality of life

Power stability offers peace of mind to all our residents when they do not have to concern themselves with how prolonged power outages affect their lives. For the community as a whole, post disaster recovery is dependent on reliable power.

An uninterrupted supply of power provides first responders and governmental agencies up to date information so that they can direct their resources to those most in need. Senior community members can shelter in place. Hospitals and senior care centers can deliver needed patient and client care. Mass care shelters can be powered to take care of the displaced. Libraries can be opened so residents can communicate with family members, offering peace of mind knowing loved ones are safe.

Property owners can begin rebuilding lost or damaged structures if there is a reliable power source. If housing needs cannot be met, workers vital to our economy will likely seek work elsewhere. This forced migration out of the Bay Area is detrimental to the well-being of communities especially where housing is already expensive and inadequate to meet the needs of those who live and work here.

Having electricity, schools could open quickly, lending normalcy for school aged children and allowing parents to turn their attention to recovery and to their livelihood. When students cannot attend school, school district loses money for each non-attending student thus having an adverse impact on school budgets. A Lake County school district official estimated it took 2.5 years after the 2015 Valley fire for student count to return to its pre-fire student population.

Robust economic vitality

Discussions with PG&E, other California utilities, cities with robust undergrounding programs and energy expert Peter Larsen lead us to the conclusion that the commercial sector places a very high value on power reliability because reliable power is key to business continuity. As much as 65% of small businesses in Berkeley could fail within two years due to prolonged and widespread power outages after a disaster event. Businesses are far more likely to have a stable power supply if wires are undergrounded. With power, commercial enterprises can more quickly turn their attention to recovery which, in turn, protects the community from the longer term negative economic impacts of disaster.

Community Beautification

It is common everywhere for communities to invest in undergrounding infrastructure, most typically in business and retail zones. We visited the City of San Diego and San Diego Gas and Electric as well as the City of Palo Alto who owns its own utility company. Although both highlight the social and economic benefits of the aesthetically pleasing effect of undergrounded utility wires for their communities, both also see power reliability as an important determinant for undergrounding in their cities. San Diego Gas and Electric, especially, is dedicated to mitigating its severe fire hazard risk. For both cites, undergrounding residential streets is an important component to their master plan and both emphasized that their success hinges on widespread support for undergrounding by their residents and by their public officials.

Berkeley has a problem of adverse selection for the installation of new and often bundled communications lines and other equipment strung up on poles in neighborhoods bordering undergrounded areas. This is especially acute in the downtown area where there is considerable new construction activity. Although we have been assured by AT&T and Comcast that the addition of these cables and equipment does not exceed the CPUC weight standards for poles, we do not know how well PG&E, the majority owner of these poles, performs its oversight function of overloaded power poles. Secondarily, it has been reported to us that bundled overhead cable lines become highways for rodents and other small animals, potentially causing electrical sparking or power interruptions. These added cables and cell towers are an eyesore wherever they are placed.

Visual clutter can be drastically reduced by careful zoning requirements that limit how much any one block must carry communication wires and equipment on overhead poles for the benefit of communications customers on undergrounded streets. We also believe Berkeley can significantly reduce visual clutter by adopting smart lighting. These city light pole systems house communications cables and other apparatus in the pole itself. Both San Jose and San Francisco are now using these poles on a trial basis. Los Angeles has adopted a pilot pole replacement project that includes charging ports for phones and cars, speakers to broadcast announcements, an emergency beacon above the street light and the capacity to add sensors. Adding charging stations on street light poles opens up a new source of revenue for the owners of these poles. (FutureStructure 10-12-17)

Image 9: Oxford Street

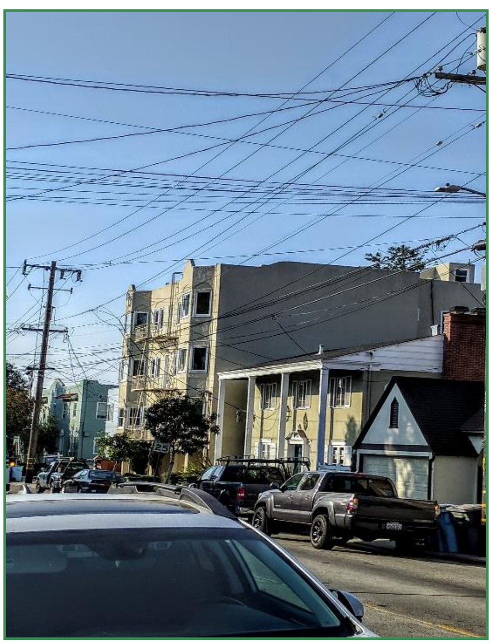
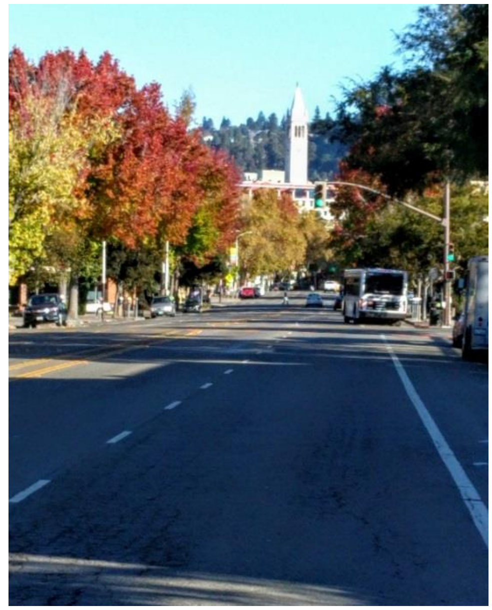


Image10: Sixth Street

Image12: Ashby Avenue

Image11: Telegraph Avenue



The City of Berkeley's stated goal, as outlined in the General Plan, Disaster Preparedness and Safety Element, is to integrate safety into all City decisions for the purpose of sustaining the community is the guiding principle of policy decision making.

Climate change will likely bring record breaking heat waves, severe rain storms, powerful hurricanes, typhoons and tornados and cataclysmic firestorms - all of them leaving damaged infrastructure in their wake. Earthquakes are infrequent events but extreme weather events and destructive fires are recurring with greater frequency and veracity each year. This year alone, Southeast Texas; the state of Florida; the island of Puerto Rico; Alaska and Northwest British Columbia; Southern Oregon, Montana and Northern California; three North Bay counties and Southern California were all directly affected by extreme events. Disrupted overhead utility services, especially power, added to the social and economic fallout in almost all these events.

Twentieth century models that utility companies rely on to back up their claim that stringing up overhead lines is cheaper than undergrounding power lines don't tell the whole story. Utilities will state that an overhead system can be more quickly repaired but fail to take into account that undergrounded wires has a superior record for power reliability over a longer period of time than overhead wires do. Undergrounded wires installed 100 years ago are still delivering electricity to utility customers.

The costs associated with rebuilding after high wind storm events and disasters is climbing due to the increased frequency and severity of such events, adding significant costs to an overhead system. Events like the Butte fire in 2015 and the 2017 Fire Siege where PG&E clearly bears responsibility will cost PG&E's shareholders and ratepayers: $750,000,000 has been set aside for claims from the 2015 Butte Fire and $800,000,000 set aside in 2017 (CBS news October 15, 2017). Actual liabilities from both fires are not yet known but the estimates are now much higher than the monies set aside. For example, Cal Fire estimates their costs to fight the October 2017 Fire Siege to be $189 million while insured losses are expected to exceed $9 billion. Detailed information on benefits and costs of undergrounding can be found in Section 4 of this report.

Section 3
TECHNOLOGY TRENDS INFLUENCING UNDERGROUNDING

Two significant concerns to the Subcommittee when researching the viability of moving utility lines underground is:

a) Whether technology would make the undergrounded utilities obsolete.

b) Design considerations for 21st century needs.

This section provides an overview on technology trends looking to address these concerns.

Electric Power

For most people in the Bay Area, power is delivered to residences and businesses via the "Power Grid" (hereinafter called the Grid). Conceptually, the Grid takes power from a number of sources, synchronizes the frequency of the power delivered, and provides this combined power as a resource that customers can access as they need to provide power for the home or business. The process is somewhat complex in that the demand for power and supply of power must exactly match for the system to work properly.

In general terms, residents, visitors and businesses in the City of Berkeley are going to require electrical power from the Grid for the foreseeable future. At this time, there are not enough resources in the City to completely disconnect from a common power source, and with the technology available today, that ability is unlikely to occur for at least another 50 years. Even if it does occur, it is highly unlikely that all entities in the city will ever be able to operate in a purely isolated manner for at least a century. Having said that, there is disruptive technology available today that could change the structure of the utility delivery enough that we should pay attention to the method of deploying any underground power and not simply replace overhead line with underground. The most notable of these disruptive technologies is Microgrids.

Microgrids

Microgrids are a newer, but tested, technology that is expected to grow throughout the United States over coming decades. When combined with solar power, microgrids can have a profound effect on the overall power usage and power reliability, and thus on fossil fuel usage and greenhouse gas emissions. However, implementation of microgrids requires a significant change in how residences and businesses are connected to the "Power Grid". The primary concept of the microgrid is that a small group of entities are connected to a common source of power generation and storage and share those resources. For example, a block of forty houses may form a microgrid and share the connection to the electric utility (PG&E in our case). Since at the utility level PG&E is only responsible for one connection, transport and maintenance costs are reduced, some reliability increase might be gained.

When solar voltaic energy is added to the basic microgrid, solar energy can be used to supplement or replace power provided by the utility. In a grid tied system, solar electric power is generated via solar panels as DC power, and converted to AC power via an inverter. The inverter synchronizes the produced power with the power from the Grid. If the energy produced is less than the immediate need of the residence or business, power from the Grid supplements the solar power and the two combine to provide the needed power. If the power produced is excess to the current needs, the excess power is fed back into the Grid and is used in the same manner as any other power produced by other power contributors to the Grid.

For a solar power system with storage, such as the batteries in a Tesla PowerWall, excess power is delivered to the batteries until the batteries are "full", at which time the excess power is sent to the Grid. If the generation level of power is less than that being collected by the system, power is provided from the battery until the battery level drops below a predetermined level, then power is taken from the Grid. In this case, if power from the Grid is lost, the system continues to provide power to the building, whether from the solar source, or from the batteries (until they are "empty").

Most functioning microgrids are composed of more than a single residence or small business. Part of what the Grid provides is an averaging or leveling of power usage for a large number of people. While most usage is predictable, parties may choose to use larger amounts at different times. In this fashion, the larger number of people that connect to a grid, the more predictable power requirements are, and the less peak capacity is required. Looked at in terms of batteries, a single building with a known average power load would need a battery of at least half again as much usable capacity. But then building would probably only need ten or fifteen percent added capacity. The actual percentage increase would depend very much on the habits of each of the parties involved, but in almost all cases, the larger the number of participants in a grid design, the smaller the safety factor that is required.

Since this is a newer technology, prior to deploying Microgrids on any wide scale a significant amount of engineering design will be required. Ultimately, implementation of this technology will require a significantly different wiring model to get power from the Grid to individual buildings. If this is not taken into account prior to undergrounding, a lot of work will be required to update the wiring pattern. However, if the undergrounding is designed to support Microgrids, it will actually enhance the functionality of those Microgrids.

Communications Technology

Telephone

Over any span of years, it has become clear that traditional telephone service delivered on copper pairs,as has been the case for well over a century now, will cease to exist. The reasons for this are multiple, but advances in Voice over Internet Protocol (VoIP) have radically changed the way calls are handled, and have significantly reduced the need for traditional voice switching. In the not too distant future, all calls will originate and terminate on Internet lines. This process will be enhanced and sped up by the expansion of Unified Communication Systems (similar to Skype for Business) which include video, data sharing, voice and other interactive media all in a single product available as an Internet service. The CPUC will require AT&T to continue to provide landlines to anyone who wants one.

Cable Television

Although the demise of cable television is not as obvious to many, it is the opinion of the Subcommittee that cable television will follow the above predicted path of traditional telephone. More and more video is being delivered over Internet connections and less is reliant on cable providers (except as that provider also provides Internet connectivity).

Internet

This is the most complex of the three existing communications technologies. Like with power, the need for Internet connectivity will remain for the foreseeable future. However, the form this technology will take is up for debate.

> <u>Wireless communications</u> -- All smart phones provide access to the Internet via Wireless communications (Carrier controlled cellular communications access points). They can also link into Wi-Fi (short range wireless network) communications, but that is not currently the primary connection method for connection to the Internet for these devices. Over a longer period of time, if/when Wi-Fi connections are readily available as a public service, smartphones can be disconnected from the currently primary Wireless and do all of their communications through the Internet. Wireless communications with the Internet is not very fast. 5G, the next technology in cellular communications will allow up to a maximum of about 1GigaBit per second (1Gb). However, the specification has not been finalized, so based on historical precedence, this capacity will not be generally available at anywhere this speed for another five years, and then not ready to be replaced for another five to ten years after that. Wi-Fi can already handle 1Gb communications, although that is limited by the number of users. As such, Wireless is highly unlikely to replace land based lines at any foreseeable time in the future.
>
> <u>Wi-Fi</u> -- Wi-Fi is another technology which can deliver Internet to a final destination without wires. Wi-Fi is a short-range protocol, so physical barriers such as walls can severely limit the availability of a Wi-Fi signal. Wi-Fi routers are also prone to hacking, meaning that a residence using a metered connection to the Internet could easily find itself paying for Internet for its neighbors, or random mobile stations without protection. Wi-Fi can already handle 1Gb communications. In fact, the latest routers can handle speeds up to about 2Gb. However, this is a total speed, so if ten users are all connected to the same router, their maximum speed per user would be 200Mb per user on average. While this is still higher than most houses have, it does not realistically serve the needs of a community either from a capacity standpoint or a security standpoint. For many users, the simplicity of being able to connect to a public Wi-Fi hotspot might be easier than getting a wired connection, for other users the lower reliable speed and lower security will be an unacceptable compromise. In addition, any public Wi-Fi hotspots will require connections to a "Central Office" or "Internet Hub" for which any Wireless technology would be completely inadequate. Ultimately, even for a Wi-Fi signal, a higher speed connection will be required. Arguably, the ideal setup as Microgrids are implemented would be to provide that higher speed connection to the location of the central Microgrid node, and provide Wi-Fi from that location.
>
> <u>Fiber optic</u> -- The technology being deployed most widely at this time is fiber optic communications, commonly referred to simply as "Fiber". Fiber requires a physical connection between endpoints, which can be accomplished via overhead lines, or underground. Where Wi-Fi is currently limited to about 2Gb, a single pair of multi-mode fibers (the cheapest type of fiber) routinely carries 10Gb for distances of up to half a mile. Single mode fiber (thinner, but somewhat more expensive) can routinely carry 100Gb for distances in excess of 20 miles. Thus, for any data critical applications, fiber is going to be the preferred medium for Internet communications for the foreseeable future. Add to this that as things currently stand, the only limit to data speed on single mode fiber is the speed of the lasers that feed the cable. Laboratory experiments have already demonstrated speeds of over 40Tb (40,000 Gb) with currently available fiber. In addition, if the process of installing

underground fiber were undertaken by the City of Berkeley, and appropriate infrastructure were established, any vendor could provide service to all undergrounded areas via a single hookup point to the city's "Internet Grid". This would favor network neutrality, and discourage poor practices common with monopoly ISPs as currently exist in most of Berkeley. The city could easily rent the cables, for an amount well in excess of average maintenance, helping to repay part of the undergrounding cost, but still attractive to ISPs for the foreseeable future.

While this analysis is fairly brief, we believe it demonstrates that any long-term investment in undergrounding would retain its value long beyond a fifty year financial horizon. In addition, the replacement of the existing overhead infrastructure, combined with the implementation of both power and communications microgrids could have a very positive impact on power reliability, reduction of reliance on non-renewable resources and the attendant reduction in greenhouse gases, community resilience, increased freedom of expression and a variety of other benefits.

Master's Thesis: *Technology Trends to Affecting Berkeley's Utility Undergrounding, by De En Ni*

This analysis was conducted by De En Ni as the capstone project of his Masters of Public Affairs degree at U.C Berkeley. The purpose of the study was to determine if there are future trends that might strand current investments.

Mr. Ni found an interdisciplinary study by the Massachusetts Institute of Technology on the future of the electric grid that identified two technological changes that could disrupt the electric distribution network: the increasing number of electric vehicles in use and the adoption of solar and other sustainable sources of distributed power generation. His analysis considered the following scenarios:

Current state: Electric vehicles at 1% of market share and residential solar meets 1% of electric demand

Scenario 1: Electric vehicles at 35% of market share and low adoption of residential solar

Scenario 2: Electric vehicles at 1% of market share and residential solar meets 100% of residential demand

Scenario 3: Electric vehicles at 35% of market share and residential solar at 100% of residential demand.

Under scenario 1, electric vehicle charging needs will increase and there will be a greater reliance on the electric grid. The benefits of undergrounding will increase with this scenario. Under scenario 2, there will be widespread distributed generation and less dependence on the electric grid. This will reduce the benefits of undergrounding. Under scenario 3, the rise of both distributed generation and electric vehicles offers consumers the option of defecting off the grid entirely. This scenario has the most challenges to the current approach to undergrounding and financing grid infrastructure improvements in general. Mr. Ni concludes that it is unlikely that the explored technological changes will enhance the value proposition of converting existing overhead utility lines to undergrounded ones significantly.

Berkeley supports the reduction of greenhouse gases and the use of clean energy. We have one of the highest electric vehicle penetration rates in the nation. The future trend in Berkeley is more likely to be scenario 1 (a higher adoption of electric vehicles than solar) than the other scenarios. This is because the Bay Area has mild climate and there is not a lot of roof top for large solar generation. Mr.

Ni would suggest that this favors undergrounding. For reference, Mr. Ni's master's thesis has been included as Appendix C.

Section 4
BENEFIT AND COST ANALYSIS

The economic feasibility of undergrounding was conducted on the following benefits and cost topics.

- Benefits of undergrounding
- Estimated cost to complete undergrounding in Berkeley
- Benefit/cost analysis of undergrounding
- Community costs to keep overhead wires

Benefits of Undergrounding

Primary benefits most often cited with undergrounding can be divided into four areas:

Potentially reduced maintenance and operating costs
- Lower storm and WUI fire restoration cost
- Lower tree-trimming cost
- Lower maintenance costs

Improved reliability
- Increased reliability during severe weather
- Less damage during severe weather allowing for faster service up time.
- Potentially far fewer momentary interruptions occurring from lightning, animals and birds, and tree branches falling on wires which can de-energize a circuit and then re-energize it a moment later

Improved public safety
- Reduced fire danger
- Fewer motor vehicles colliding with utility poles.
- Reduced live-wire contact injuries
- Improved access and egress during and after storms and disasters

Improved community aesthetics
- Removal of unsightly poles and wires
- Fewer utility poles on sidewalks improving pedestrian mobility and visibility thereby reducing pedestrian accidents
- Enhanced tree canopies which have both a pleasing effect and cooling effect

There are numerous studies on the benefits of undergrounding. The following are two examples, one for the State of Virginia and the second for Los Angeles.

State of Virginia

The Virginia State Corporation Commission conducted a study of undergrounding the state's entire electric distribution system. The estimated annual cost savings were approximately $104 million.

Table 5: Virginia State Corporation Commission Cost Savings

Cost Saving Item:	$/Year
Operations & Maintenance	no savings
Tree Trimming	$ 50,000,000
"Hundred-Year" Post Storm Rebuild	$ 40,000,000
Reduction in Day-to-Day Lost Electricity Sales	$ 12,000,000
Elimination of Lost Electricity Sales From "Hundred-Year" Storms	$ 2,000,000
Total	$ 104,000,000

Source: Virginia State Corporation Commission, January 2005, "Placement of Utility Distribution Lines Underground"
Societal Benefits

The following summarizes some of the societal benefits the Virginia Commission found, including enhanced electric reliability to the economy, reduced economic losses to customers due to fewer power outages after major storms, and reduced injuries and deaths from automobiles striking utility poles.

Table 6: Virginia State Corporation Commission Social Benefits

Cost Saving Item:	$/Year
Avoided Impact of Day-to-Day Outages	$ 3,440,000,000
Avoided Impact of "100-Year" Storm Outages	$ 230,000,000
Avoided Impact of Motor Vehicle Accidents	$ 150,000,000

The State of Virginia study, while not directly applicable, gives us a template to use. We can substitute the "100-year storm" with known earthquake science that sees that approximately every 35 years (Nate Silver in "The Signal and Noise") the Bay Area experiences a greater than 6.0 quake. The risk is knowable but the exact timing is uncertain. Using a yearly per capita savings, based on the summary savings above, Berkeley can benefit from undergrounding of utilities by nearly $3.1 million for earthquake savings annually and $51 million for all the priced economic externalities above. This estimate is based on the state of Virginia is population of 8.4 million and Berkeley's population of 113,000.

Los Angeles, CA

The Los Angeles Department of Water and Power (LADWP) in a 2006 study determined that underground service is generally more reliable than overhead, but also three times more expensive to install. Underground facilities have fewer power outages, but when they occur, they typically last longer. The study examined advantages of an all underground distribution system and outlined key differences in overhead versus underground systems:

> Installation - Overhead electric facilities are less expensive averaging about 30 percent the cost of an equivalent underground system. This cost advantage increases when

undergrounding takes you into well-established streets containing other underground structures or when new circuit conductors can simply be added to existing poles.

Cost to Maintain Overhead versus Underground - 2006 data indicate that overhead and underground distribution typically costs $5,858/mile/year and $5,137/mile/year to maintain, respectively. It could be concluded that every mile of underground distribution installed saves LADWP approximately $721/year or 12 percent.

Outages - Overhead areas have more frequent electric outages than underground because overhead lines are exposed to the gamut of above-ground hazards including bad weather, animals, and errant drivers. Overhead outages will be shorter because repairing or replacing overhead lines takes less time than repairing or replacing underground lines.

Reliability is measured by two primary indices: SAIFI and SAIDI. SAIFI is the average frequency of outages a customer would see annually. SAIDI is the average duration of all outages a customer would experience annually. A reliability review done in 2006 for the City over the previous five years found, that if LADWP were to have a 100% underground system, we could expect reliability to improve as follows:

Table 7: LADWP SAIFI & SAIDI Calculation

Present	Totally UG	Change	
SAIFI (Frequency)	0.73 times/yr.	0.39 time/yr.	-47%
SAIDI (Duration)	81.2 min./yr.	86.3 min./yr.	+5.9%

Based on the contribution of overhead to the reliability indices, having a completely underground system would benefit the SAIFI by 47 percent because overhead fails 1.9 times more often than underground. SAIDI does not improve because it takes longer to repair underground than overhead.

Because the indices above reflect existing LADWP distribution systems, it is expected reliability would be measurably better when new underground replaces aging overhead facilities which are subject to failure from fatigued lines and components. It is one goal of LADWP's Power Reliability Program (PRP) to leverage this advantage through its Rule No. 20 program by accelerating conversion of overhead lines approaching the end of their replacement cycle.

There is also the cost to individuals and businesses, when power or telecom services are disrupted, that are rarely calculated or compensated. Individual and business insurance is one solution but at a cost born externally to the utility providing the service. It is estimated by FEMA that businesses, that do not or cannot afford business interruption insurance, caused by the unreliability a utility's continuous power or telecom provision due to 'natural disasters', 40% will most likely go out of business soon after the occurrence and another 25% will fail within a year. Unpriced economic externalities have not been included in the benefit/cost calculations for undergrounding utilities until recently, when deciding on the economic viability of proceeding to underground utilities.

Estimated Cost to Complete Undergrounding in Berkeley

The consulting firm of Harris and Associates (Harris) was retained to prepare a baseline study of utility undergrounding in Berkeley. The report was completed in July of 2016 and is in Appendix A. The baseline study included the following topics:

- Cost estimate to complete undergrounding in Berkeley

- Funding options for undergrounding projects
- Status of Rule 20 funding
- The process to create an undergrounding district
- An analysis of emerging technologies
- Advantages and disadvantages of undergrounding

Harris prepared a map of the undergrounding that has occurred in Berkeley (see Figure 2). In summary, 49% of arterial streets, 31% of collector streets, and 7% of residential streets have been undergrounded.

Harris was asked to prepare an estimate of the cost to underground the remaining overhead utility lines on arterial and collector streets in Berkeley and their results are summarized, as follows.

Table 8: Cost to Underground Estimate by Street Type

	Length, miles	Ratio, %	Harris estimate to underground	Adjusted estimated cost to underground
Arterial streets				
Currently undergrounded	12.5	49	n/a	
Not undergrounded	13.1	51	$43 million	
Sub-total	25.6			
Collector streets				
Currently undergrounded	11.3	31	n/a	
Not undergrounded	24.8	69	$92 million	
Sub-total	36.1			
Total to be undergrounded	37.9		$135 million	$170 – 200 million

The estimated construction cost to underground power lines on the remaining arterial and collector streets is estimated at $135 million. This estimate equates to about $3.6 million per mile. The cost estimate prepared by Harris does not include the additional costs to install private property trench and conduits, service panel conversions or the costs for financing and engineering, and construction management (CM).

In our discussions with utility companies and cities with undergrounding programs, we have collected the following data on the cost of undergrounding.

- City of San Diego – Cost to the City is typically $4 million per mile and SDG&E's portion is $1 million per mile, for a total of $5 million per mile.
- City of Palo Alto – Staff budgets $2 million per mile.

Using the Harris cost estimate as a baseline and comparing to other cost estimates, we suggest a rough guideline of total costs to Berkeley as follows.

Estimate by Harris	$3.6 million per mile
Engr. and CM @ 15 - 25%	0.5 – 0.9 million per mile
Service panels & private lines @ 10 - 15%	0.4 – 0.7 million per mile
Cost to City	$4.5 – 5.2 million per mile

For the 37.9 miles of arterial and collector streets to be undergrounded the cost to Berkeley could fall in the range of $170 – 200 million.

Benefit/Cost Analysis Methodology

Benefit/Cost Analysis (BCA) accounts for the equivalent money value of the benefits and costs as a means to determine the value of a project. BCA is required by the U.S. Corps of Engineers and the Federal Emergency Management Agency and is standard practice in both governmental and commercial sectors. The end result is a benefit/cost ratio (BCR), which is derived from a project's total net benefits divided by its total project cost. The BCR is a numerical expression of the cost effectiveness of a project. A project is considered to be cost effective when the BCR is 1.0 or greater, indicating the benefits of a prospective project are sufficient to justify the costs.

The subcommittee reviewed two examples of community undergrounding benefit/cost analyses for undergrounding utilities in a community and worked closely with UC Berkeley Masters of Public Policy candidate Daniel Bradway to develop an analysis for the City of Berkeley.

BCA analysis for undergrounding is highly sensitive to the assumptions made. For example, PG&E looks only at internal costs, as does much of the literature on the subject. However, more sophisticated analysis which incorporates community specific factors is being developed. Both Mr. Larsen and Mr. Bradway enlarged the scope of consideration when making an attempt to quantify the true economic benefits and costs to underground a utility system. They both looked at quantifiable losses for the communities they studied. In general, Mr. Larsen found that undergrounding is far more attractive costwise in areas that are densely populated and have a high incidence of severe weather events. Given the nature and timeframe of his project Mr. Bradway followed Mr. Larsen's suggestions on which factors to consider in his analysis for Berkeley.

PhD Dissertation: "Severe Weather, Power Outages, and a Decision to Improve Electric Power Reliability", by Peter Larsen

Peter Larsen, an energy specialist at the Lawrence Berkeley National Laboratory, prepared his PhD dissertation on "Severe weather, power outages, and a decision to improve electric power reliability" at Stanford University in 2016. The dissertation systematically evaluated the reliability U.S. power system and introduces an analysis framework to estimate the costs and benefits of implementing one strategy to improve reliability -- undergrounding power transmission and distribution lines. Mr. Larsen's work covered the following topics:

- Factors that affect the duration and frequency of power interruptions
- Historical review of the literature on value based reliability planning
- Developing a cost/benefit analysis framework
- Case study of Cordova, Alaska's effort to underground their system

Cordova, Alaska is a community of about 2,300 residents located on Prince William Sound. Cordova's industry relies heavily on the commercial fishing and fish processing industries. In 1978, the community transitioned to a municipal run power system to a community owned electric cooperative. At that time, a decision was made to underground the community's electric distribution system. The potential benefits of undergrounding were: lower operations and maintenance costs, decreased ecosystem restoration costs, avoided costs due to less frequent power outages, avoided aesthetic costs, and decreased chance of community fatalities and accidents. The potential costs of undergrounding were: increased chance of worker accidents, additional administrative costs associated with maintaining undergrounding, and the increased capital costs for undergrounding.

Cordova is unique in that it has a single industry which also has a high economic value to the community. This example sheds light on the factors to consider when evaluating the economic worth of a project. Mr. Larsen calculated a BCR of 16.1 for Cordova. A summary of his evaluation is in Table 9.

Table 9: Larson BCR Analysis for Cordova, Alaska

Impact Category	100% Underground	Status Quo	Net Cost ($millions)
Health & safety costs	$0.2	$0	$0.2
Lifecycle costs	$35.3	$31.1	$4.1
Total net costs (Undergrounding)			$4.3
Impact Category	**100% Underground**	**Status Quo**	**Net Avoided Costs ($millions)**
Interruption costs	$130.1	$194.7	$64.6
Aesthetic costs	$27.9	$24.4	$3.5
Environmental Restoration Costs	$2.4	$3.1	$0.6
Total net benefits (Undergrounding)			$68.7
Net Social Benefit (Undergroundng)			
Net social benefit (millions of $2015)			$64.5
Benefit-cost ratio			16.1

Mr. Larsen conducted another study to underground Texas investor owned utilities and concluded a BCR of 0.3. The main reasons for the low BCR were low density of users per line mile, relative low value of avoided power interruptions, and the relatively low value of avoided aesthetics costs.

Master's Thesis: Benefit/Cost Analysis for City of Berkeley, by Daniel Bradway

The Subcommittee approached U.C. Berkeley's Goldman School of Public Policy for assistance in conducting a cost/benefit analysis on undergrounding in Berkeley. The author, Daniel Bradway completed this analysis as the capstone project of his Masters of Public Affairs degree in 2017.

Using a 40-year planning period, Mr. Bradway, with guidance from Mr. Larsen, evaluated twelve economic impacts to Berkeley that are relevant to undertaking an undergrounding project. Based on the assumptions made by the author, undergrounding the remaining arterial and collector streets in Berkeley would have a positive BCR 1.09. His analysis is summarized below.

Table 10: Bradway BCR Analysis for Berkeley, CA

	$, millions
Benefits	
Increased property values	134.7
Avoided costs of fire losses	4.6
Avoided costs of power interruptions	55.7
Reduced vegetation management	38.6
Avoided costs of vehicle crashes	52.3
Increased horizon value	21.3
Marginal excess burden of taxation	5.3
Total benefits	312.5

Costs	
Construction	136.5
Operations and maintenance	13.0
Customer conversions	59.4
Risk of earthquake losses	43.0
Marginal excess burden of taxation	34.1
Total costs	286.0
Benefit/cost ratio	+1.09

Mr. Bradway's report is included in Appendix B.

The above examples were selected to show how key criteria can be important in preparing a BCA. In Cordova, Alaska, lower operations and maintenance cost, avoided cost of power interruptions, and avoided aesthetics costs produced a high positive BCR. In the study conducted by Mr. Bradway, increased property values, avoided cost of power interruptions, avoided cost of vegetation management, and avoided cost of vehicle crashes produced a positive BCR.

Community Costs to Keep Overhead Wires

The 1991 Oakland hills fire and the North Bay fires allow us to observe, up close, how the kind of disaster events we are vulnerable to impact the social and economic viability of communities affected by power lines. In the 1991 Oakland fire, fire hydrants were inoperable because the power had been cut. In the North Bay downed power lines and transformer failures, at the very least, contributed to the spread of multiple fires. Damaged transformers may be a contributing factor in the start and spread of the Thomas Fire.

Ratepayers get nothing back when paying more for other utility use to cover PG&E's contributions to disasters except more deferred maintenance and less protection against power outages. This becomes another added cost to our community, affecting us personally and also the city's budget when economic enterprises cannot operate due to repeated power failures from aging and damaged infrastructure.

We don't typically think about what it might mean to lose our communications, to lose our water delivery system, to lose our cooling and heating systems and our means to safeguard our food, our medications, and our ability to cook our meals. These are social costs measured in inconvenience and time spent just to meet our basic needs and not easily quantified in dollars and cents.

PG&E doesn't account for the health impacts from these fires, especially the effect on the community from ash and toxic smoke. PG&E's calculations do not include what it will cost insurance companies to rebuild our homes and businesses, our uninsured costs to rebuild nor our increased insurance premiums or inability to even obtain insurance. Their calculations fail to capture the cost of firefighting and rescue operations, the cost of evacuations and protecting the public post disaster. Or, the loss of tax revenue used by and for the community, the cost to replace community owned infrastructure or even the loss of sighting what once was our favorite roofline. Nor do their calculations account for the impact of our changing climate and how often they will be required to string new wires and set new poles.

PG&E will say that replacing existing overhead poles and wires with underground wires is prohibitively expensive. However, tunneling methods have changed making trenching in some areas both cheaper and quicker. Allowing communities to hire contractors to complete the work will stimulate competition thus further driving down installation costs. Maintenance costs for overhead wires steadily increases now that the infrastructure in place is reaching the end of its useful life and is inadequate to withstand the effects on the environment of our changing climate.

Section 5
FUNDING & ADDITIONAL CONSIDERATIONS

Funding Options for Berkeley

The City Council referral asked for a "comprehensive plan for the funding of undergrounding ...". An initial review of funding options for Berkeley was completed by Harris & Associates and is included in Appendix A.

CPUC Rule 20

As discussed in Section 1 of this report, the CPUC established Tariff Rule 20 in 1967 to underground utilities in California. Rule 20 consists or four parts, A, B, C and now D, which was added specifically for San Diego Gas & Electric in 2014. The following is a brief description.

Rule 20A

Rule 20A projects are typically in areas of a community that are used most by the general public. There is a set of criteria to qualify for this, including that the street is an arterial or collector. The annual allocation of 20A funds is based upon a formula. These projects are paid for by customers through future electric rates.

Berkeley's 20A allocation was cut in half to $539, 000 a year in the 2000's and this reduction appreciably slowed our ability to underground anywhere in the city.

Rule 20B

Under Rule 20B, the ratepayer contribution is about 20% of the undergrounding project and property owners are responsible for 80% of the costs. Rule 20B projects are usually done with larger developments. Undergrounding under Rule 20B is available under circumstances where the area to be undergrounded does not fit the Rule 20A criteria but still involves both sides of the street for at least 600 feet. Under Rule 20B, the applicant is responsible for the installation of the conduit, substructures and boxes.

Rule 20C

Rule 20C projects are usually smaller projects involving a few property owners and the costs are almost entirely borne by the applicants.

Rule 20D

Rule 20D was established in 2014. Funds are specifically earmarked for the Very High Hazard Fire Zone (VHHFZ) area that San Diego Gas & Electric serves and as currently written, exclusively addresses high voltage distribution lines. The ratepayer contribution is about 80% and may be more, depending on who pays for the connection from the street to the meter.

Because ratepayers contribute the bulk of the costs of Rule 20A programs through utility rates, the projects must be in the public interest by meeting one or more of the following criteria:

- Eliminate an unusually heavy concentration of overhead lines
- Involve a street or road with a high volume of public traffic
- Benefit a civic or public recreation area or area of unusual scenic interest
- Be listed as an arterial street or major collector as defined in the Governor's Office of Planning and Research Guidelines.

The determination of "general public interest" under these criteria is made by the local government, after holding public hearings, in consultation with the utilities.

Under Rule 20, the CPUC requires the utility to allocate a certain amount of money each year for conversion projects. Upon completion of an undergrounding project, the utility records its cost in its electric plant account for inclusion in its rate base. Then the CPUC authorizes the utility to recover the cost from ratepayers until the project is depreciated. Rule 20 requires the utility to reallocate to communities having active undergrounding programs amounts initially allocated to others but not spent. Cities also may be allocated mortgage 20A funds in advance for five years.

As an example of a 20C project, cost estimates are being updated based on the experience of Thousand Oaks Heights. At that time, the range was $25 - $30k per household depending on the number of participating properties or scale, not including the conversion costs on each parcel of $2.5k - $5K. In broad terms this translated into approximately $2,000 annual costs added to county property tax bills. We can assume these costs would be higher today.

In May 2017, the CPUC issued an Order Instituting Rulemaking to Consider Revisions to Electric Rule 20 and Related Matters. The CPUC focuses primarily on revisions to Rule 20A however we understand their attention is also on the VHHFZ as well as other parts of Rule 20. The results of the review are expected in July, 2018. The review encompasses:

- Collecting preliminary information from electric utilities
- Audit of electric utilities Rule 20A programs
- Initial scoping questions
- Hold public hearings

Public hearings were scheduled from mid-September to the end of October, 2017. We are aware a number of Berkeley residents commented formally to the CPUC and think it would be valuable for the City of Berkeley to also participate in the rulemaking review process. Potential topics for Berkeley to pursue include:

- Categorize public streets and roads in any Wildland Urban Interface Zone as eligible for Rule 20 funding
- Provide a more equitable distribution of credits to cities with Wildland Urban Interface Zones
- Make it easier to utilize, borrow, or trade credits among participants

Hearings held by the CPUC on Rule 20 began in September, 2017. Under review, among other things, is how the existing program is being administered by the various utility companies operating in California and the definition of what projects are to be included in the public interest. Also included in this review is CPUC's examination of Rule 20D funding, a category developed in 2014 for the benefit of San Diego Gas & Electric to use in their state defined High Hazard Fire Zone. At the time of this writing, we believe Berkeley qualifies for 20D funds but the city would have to actively pursue this opportunity in partnership with PG&E and the CPUC.

Funding sources to supplement Rule 20A, B, C

Due to the high costs for undergrounding utility wires, most agencies work with property owners to establish a funding mechanism that will allow bonds to be sold so that property owners can pay for undergrounding over a long period of time. The most commonly used funding by cities is the Municipal Improvement Act of 1913 and Mello-Roos Community Facilities District.

- The 1913 Act requires the formation of an assessment district and is subject to the requirements of Proposition 218. Approval of 50% of the property owners in the undergrounding district is required.
- The Mello-Roos Act allows for the creation of a Community Facilities District and the ability to impose a special tax on parcels in the utility undergrounding district. Approval of 2/3 of the registered voters in the undergrounding district is required.

Other funding options to be explored

Funding options used by other cities include the following:

1. Cities can trade or sell unallocated Rule 20A credits to fund undergrounding projects.
2. The City of San Diego, working with San Diego Gas & Electric and the CPUC, adopted, without a ballot measure, a local franchise surcharge tax to fund undergrounding projects. This option has also been adopted by the City of Santa Barbara.
3. San Diego Gas & Electric applied for and received additional Rule 20 funds (referred to as Rule 20D funds) to be used for undergrounding and other fire hardening techniques in their state designated Very High Hazard Fire Zones (VHHFZ).

Besides the above options, a funding strategy for Berkeley is to evaluate Berkeley's utility user tax and see if it can be increased to provide funding for undergrounding. Berkeley could also consider working closely with PG&E, the CPUC and other Bay Area cities to seek release of Rule 20 funds for the VHHFZ.

Case Studies From Other Municipal Undergrounding Programs

The Subcommittee visited the City of San Diego and the City of Palo Alto after researching undergrounding programs in other California cities. From both of these cities we learned four key elements for a successful comprehensive municipal undergrounding program.

- There needs to be a public mandate to support the program.
- A strong partnership between city and utility agencies is a necessary element for success.
- The financing strategy must be broadly shared, but not burdensome, by all members of the community.
- Leadership having the vision and drive to create and complete a comprehensive undergrounding program which is designed to meet the needs of the 21st Century and beyond.

City of San Diego

The City of San Diego has one of the most aggressive undergrounding programs in the country, typically completing 15 street miles annually and now gearing up to double the number of street miles completed each year. The City has 1,400 miles of streets of which 400 miles are undergrounded. City residents, backed by an enthusiastic mayor and utility service company, are key to the program's success.

San Diego began its undergrounding efforts in the 1970s using Rule 20A funds for aesthetic and power reliability reasons. From 2003 forward funding dollars have been substantially increased by the adoption of a 3.5% Franchise Surcharge Tax based on gross receipts generated within city limits. The tax generates about $70 million annually which is added to the annual 20A fund allotment of $18 million earmarked for undergrounding utility projects. More recently, the City and SDG&E worked together to successfully establish a CPUC tariff for the use of Rule 20D public funds in the very high hazard fire areas of San Diego.

Image 23: "A Clear View of San Diego" Utilities Undergrounding Program

Some areas of canyon lands, hills, and landslide prone areas, are considered unsuitable for undergrounding. In such areas, SDG&E will make other investments to harden the infrastructure to reduce fire risk by changing equipment, switching out wood poles with metal/steel poles, or replacing poles with taller ones. Because of two megafires occurring in 2003 and 2007, San Diego Gas & Electric and the City of San Diego have invested in substantial post fire planning around alternative redundancies, mutual aid assistance and insurance reimbursement for damaged infrastructure.

City of Palo Alto

Palo Alto has been building up its self-owned utilities (gas, electricity, water, waste) for 100 years. The City started undergrounding in 1965 based on aesthetic appeal and outage reliability. Their project priorities are business districts, major thoroughfares and areas experiencing poor power reliability performance. Since business districts are nearing completion, more residential projects will soon be in the planning stages.

Undergrounding projects are funded by 1% of utility revenues set aside specifically for undergrounding projects. As in San Diego, their utility customers enthusiastically support the goal to have the entire city undergrounded. From a public safety perspective, storms are of concern as outages can occur from falling tree limbs.

Section 6
CONCLUSIONS AND RECOMMENDATIONS

Conclusion

A goal we share is to promote those projects that enhance the benefits of public safety and power reliability and ensure these benefits are broadly shared by all residents of Berkeley. We believe the social and economic benefits of undergrounding outweigh the costs to the community. To continue to rely on aging overhead utility infrastructure which has a well-documented risk to set off or contribute to the spread of dangerously large and difficult to control destructive fires, whether they occur during periods of Diablo winds, after an earthquake or by other causes is short-sighted and dangerous.

Rebuilding our utility wire infrastructure by placing wires underground protects us from the ill effects of downed overhead wires caused by severe weather events, disasters, vehicle collisions and other causes of wire sparking and power failures. Rebuilding our utility infrastructure also gives us the opportunity to mitigate the loss of power and communications with thoughtful design - whether it be trench strengthening, adding capacity for widespread adoption of decentralized power generation, adoption of next generation 5G Wi-Fi capacity, or removing visual overhead clutter that has become an aesthetic challenge for all of us.

Undergrounding enhances public safety by removing overhead wires, a primary cause of fire ignition and spread of fire, and removes a major impediment to evacuation. Undergrounding stabilizes power and communications reliability, protects our businesses against failure thus protecting our sources of revenue expended for the benefit of all our residents. Most importantly, undergrounding beautifies our urban environment.

Recommendations

The recommendation of this Conceptual Study is to move to Phase 3 of the program. A well thought out funding and implementation plan can shorten the time and lower the cost to complete a comprehensive undergrounding program. The work scope for Phase 3 is described on the following pages and arranged in such a way that the role of the subcommittee members and of staff can be defined.

<table>
<tr><th>Work Task</th><th>Role of Commissions</th><th>Role of City Staff</th></tr>
<tr><td>Task 1 – Define the Phase 3 projects

We are recommending the following projects for Phase 3.

A. <u>Major and Collector Streets</u>. We recommend that undergrounding of the remaining arterial and collector streets be done with the following stages:

• Stage 1 – initial 2 to 4 east/west arterial or collector streets; highest priority to those streets listed as evacuation routes
• Stage 2 – future consideration for remaining arterial and collector streets

The major east/west routes be undergrounded shall facilitate the travel of first respoders and evacuation of residents. Selection of the initial streets requires further evaluation. When weighing two or more options and one of them could also underground wires on the garage/parking area entrance for (in order of priority) fire stations, schools or senior centers, that option should be given a higher priority over other alternatives. This may entail picking up an extra block to be undergrounded or creating another access point in a building that would lead to the street to be undergrounded.

B. <u>Coordination with microgrid development</u>. Power reliability is critical to recovery after a disaster. Many cities throughout the United States are experimenting with microgrids to determine their success in meeting their climate change goals and objectives. Not all areas initially require undergrounding for fire safety reasons but some areas experience significant power outages (e.g. west and southwest Berkeley) and it is recommended that microgrid pilot areas be considered including the undergrounding the grid's cable/wire facilities.

C. <u>Review code standards</u>. Increased pole load caused by service providers stringing wires in neighborhoods surrounding new construction to avoid costs of undergrounding their cable and wires adds to the visual clutter of surrounding streets. Adopt code standards to ensure neighborhoods without undergrounded wires are not carrying extra cable and equipment that visually clutters the skyline. Adopt smart lighting pole requirements for every replacement light pole.</td><td>Support Task 1 A</td><td>Lead Tasks 1 A, B, and C</td></tr>
<tr><td>Task 2 -- Develop the financing plan

A. <u>Refine cost estimate for undergrounding</u>. The Harris report estimated the cost to underground the remaining arterial and collector streets. Based on that work, the estimated cost for the Stage 1 streets are:
• Length = 10 – 15 miles</td><td>Lead Tasks 2A and C, support Task 2B</td><td>Lead Task 2B, support Tasks 2A and C</td></tr>
</table>

Work Task	Role of Commissions	Role of City Staff
• Cost = \$50 – 75 million These cost estimates need to be further refined with field reconnaissance. The estimates need to include design, construction, construction management, financing, homeowner connections, inflation, street lighting and other cost components. The Goldman School study estimated the benefit/cost ratio at 1.09:1. This means that undergrounding is conceptually feasible. We recommend that the BCA be recalculated with more refined cost estimates and monetized estimates of benefits. B. Participate in CPUC Rule 20 review. In May 2017, the CPUC issued an Order Instituting Rulemaking to Consider Revisions to Electric Rule 20 and Related Matters. The CPUC will primarily focus on revisions to Rule 20A but may make conforming changes to other parts of Rule 20. Berkeley should participate in the CPUC process and should look for opportunities to promote the following: • Categorize public streets and roads in the Wildland Urban Interface Zone as eligible for Rule 20A funding • Provide a more equitable distribution of credits to cities with Wildland Urban Interface Zones • Provide a mechanism to utilize, borrow, or trade credits among participants • Advocate for release of 20D funds (now earmarked exclusively for San Diego Gas and Electric) to be used for more aggressive and thorough fire hardening techniques for aboveground utility poles and equipment, for undergrounding power lines and for more aggressive utility pole and vegetation management practices in the Very High Hazard Fire Zone within Berkeley's city limits. C. Evaluate funding options. Evaluate funding options for Phase 3 projects in Berkeley.		
Task 3 – Conduct community input **A.** Develop an outreach and communications plan. Prepare a plan that will inform and engage the community, including the following: • Brochures • Website • Survey • Workshops **B.** Conduct community workshops. Develop and conduct a series of workshops with the community. The workshops shall seek community input on the following subjects:	Lead Tasks 3 A and B	Support Tasks 3 A and B

Work Task	Role of Commissions	Role of City Staff
• Review priority arterial and collector streets to underground • Review benefits of undergrounding • Review funding options and cost to residents		
Task 4 – Coordinate with utilities Meet with PG&E and tele-communications companies to discuss the Phase 3 projects. The evaluation shall include the following topcis. • Roles and responsibilities for conducting the work • Financial responsibilities • Contractual responsibilities	Support Task 4	Lead Task 4
Task 5 – Prepare an implementation plan Prepare a Program Plan for the implemenation of the Phase 3 projects. The Plan shall include the following topics. • Objectives and outcome goals • Funding plan • Program budget • Overall schedule • Staff and consultant resources • Required City Council, CPUC, and other approvals • Performance monitoring and independent oversight	Support Task 5	Lead Task 5

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APPENDIX A

"BASELINE STUDY FOR THE DEVELOPMENT OF A UTILITY UNDERGROUNDING PROGRAM", HARRIS & ASSOCIATES, JULY 2016

CITY OF BERKELEY

Baseline Study for the Development of a Utility Undergrounding Program

July 22, 2016

Prepared by:

Harris & Associates

Harris & Associates

Mr. Kenneth Emeziem
Senior Civil Engineer
City of Berkeley
1947 Center Street, 4th Floor
Berkeley, CA

Re: Baseline Study for the Development of a Utility Undergrounding Program – Final Submittal

Dear Mr. Emeziem:

The attached "Baseline Study for the Development of a Utility Undergrounding Program" incorporates the comments received from the commission and City staff. As the baseline, it occupies the starting point for the future studies and developing an undergrounding program with the goal of undergrounding all of the overhead utilities in the City of Berkeley.

From the study we identified that there are approximately 13.1 miles of Arterial and 24.8 miles of Collector streets remaining to be undergrounded. The estimated cost of undergrounding the total 37.9 miles is $134,800,000.

We are pleased to have provided this study and be a part of the City's goal to underground the City.

If you have any questions, please contact me at (925) 348-1098.

Sincerely,

Harris & Associates

Rocco Colicchia

Project Manager

Baseline Study for the Development of a Utility Undergrounding Program

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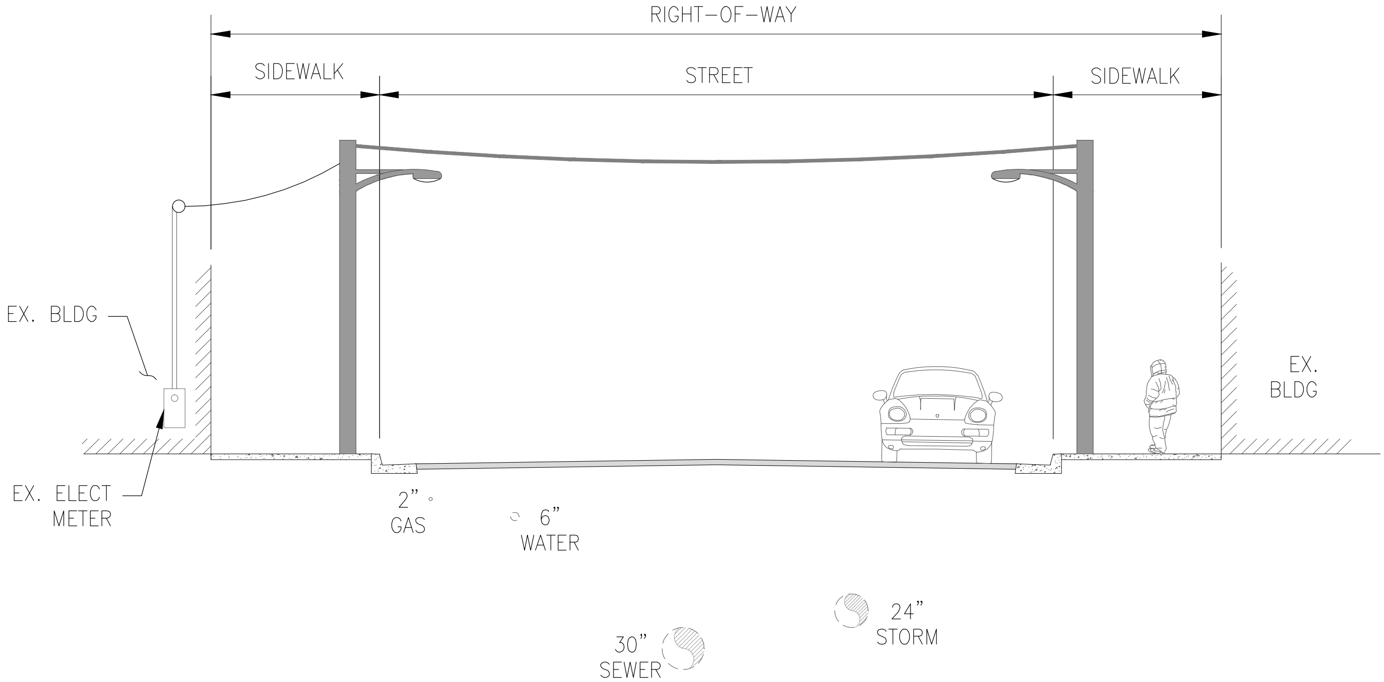
INTRODUCTION

Harris & Associates has been retained by the City of Berkeley to prepare this "Baseline Study for the Development of a Utility Undergrounding Program". This document will provide a starting point, as the City develops a plan to underground all of the overhead facilities in the City of Berkeley. This study includes identification of the streets to be undergrounded, high level costs and high level timing. Both costs and timing will be further developed in subsequent studies.

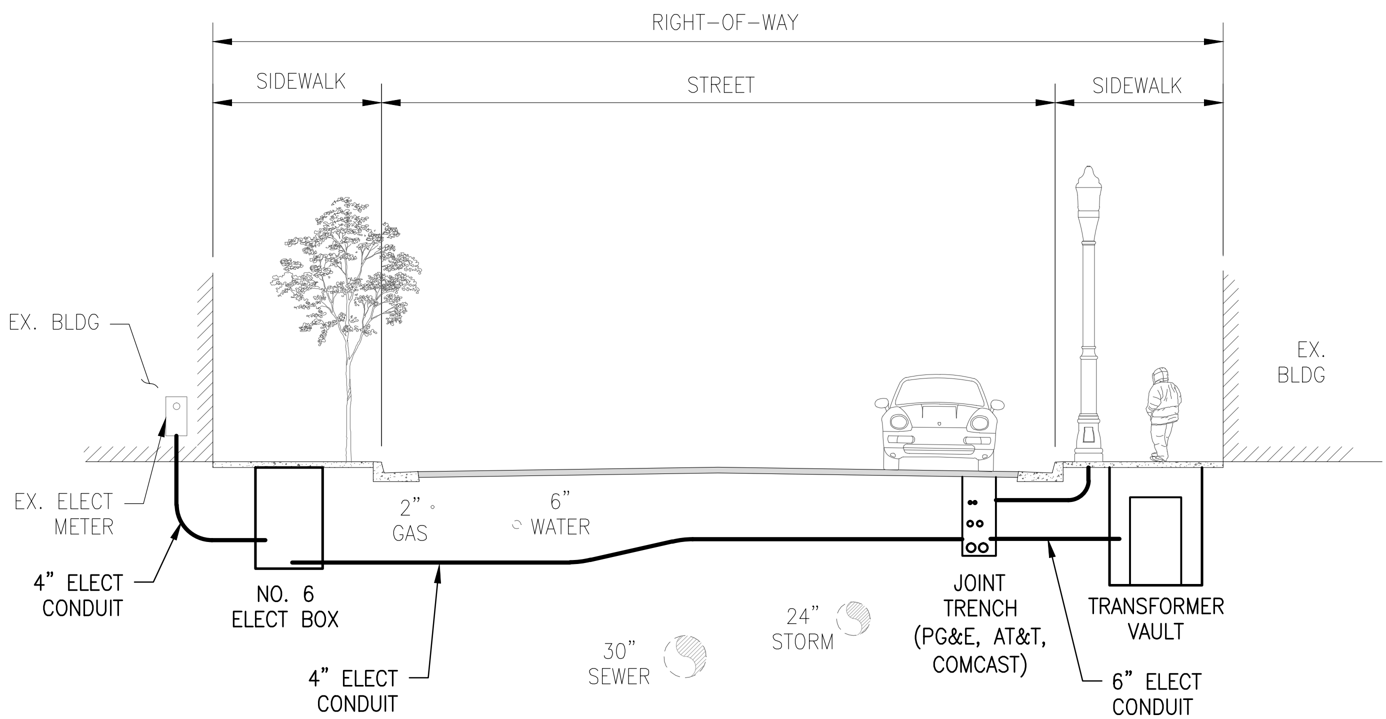
The City of Berkeley has been involved in utility undergrounding for many years. Most of the undergrounding projects within the City have relied on the provisions of electric Rule 20A and telephone Rule 32.1, to fund the undergrounding in various areas of the City. In addition, the City has also seen interest from property owners within specific neighborhoods who have worked together to fund the undergrounding of the existing overhead utilities within their neighborhood after submitting a petition to the City and agreeing to fund a majority of the costs of the undergrounding through the formation of an assessment district.

This study includes information we have developed and collected based upon our scope of work, and is intended to provide the baseline information and data needed as the City begins the development of a comprehensive citywide strategy for undergrounding the City's overhead utilities. The following items are included as part of this baseline study and help to describe the starting point for the undergrounding program:

1. A map showing the arterial and collector streets in Berkeley and current zoning. This information was taken from the city website. In addition, the map also shows those streets where the utilities have already been undergrounded. This map will become the basis for the underground plan.
2. A planning level estimate of the construction costs for utility undergrounding. These costs do not include the cost of undergrounding service on private property or the cost of the electric service panel conversion.
3. A description of Rule 20A, 20B, and 20C, and how those programs could be used to fund future utility undergrounding projects in the City.
4. An overview of other funding options that could be used, including a discussion of how other communities have funded their utility undergrounding programs, and the pros/cons of those approaches.
5. The current status of the City's Rule 20A funding and anticipated future contributions
6. The process of creating an underground district.
7. A review of emerging technologies and their impact on the cost of utility undergrounding programs.
8. A discussion of the pros and cons of undergrounding arterial and collector streets in non-residential areas.
9. The City's undergrounding history.
10. A "Diagram of a Typical Street Section"



BEFORE: STREET SECTION WITH OVERHEAD UTILITIES



AFTER: STREET SECTION WITH UNDERGROUND UTILITIES

NOTES:

1. LOCATIONS ASSUME ADEQUATE CLEARANCES
2. SHADED FACILITIES ARE EXISTING

FIGURE - 1

DIAGRAMS OF TYPICAL STREET SECTION SHOWING OVERHEAD AND UNDERGROUND FACILITIES IN COMMERCIAL AREA

SCALE: NTS

I. PROJECT OBJECTIVES

The City of Berkeley's City Council has requested that three commissions (Public Works, Disaster and Fire Safety, and Transportation) collaborate to develop a comprehensive funding plan to underground utilities along arterials and collector streets in Berkeley. The commissions shall work with Public Works staff and specialty consultants to draft a plan for the Council's consideration.

The goal of the City of Berkeley is improve public safety by undergrounding utility lines. Undergrounding minimizes the impacts of fallen electric lines and poles. Downed power lines can spark a serious fire, negatively affect power delivery to households for an extended period of time, impact the ability of persons to leave their homes and/or first responders to reach persons in need. Undergrounding increases the safety of residents while strengthening the infrastructure of the region's delivery of these utility services increasing reliability, all of which positively contributes to the capability of our community. Undergrounding increases pedestrian access and beautifies the streetscape.

The overall project objective is to develop a comprehensive plan to underground the overhead facilities in a manner that will provide the greatest benefit to all of Berkeley. This study is the first step in that effort. The following are some guiding principles for the project:

- The primary driver is to provide reliability of utility service and safety to Berkeley's residents in an emergency.
- The scope of the study shall be all of the City of Berkeley.
- Implementation of the plan shall be prioritized to the streets that will have the greatest benefit to all of Berkeley. These will be the arterial and collector streets.
- Learn from other cities that have studied and implemented programs to underground utilities.
- Incorporate new concepts (such as utility corridors) and work with various utility pole users (such as cable TV, power, telephone) to find cost effective solutions.
- Conduct the study in two phases to allow for effective decision making and use of resources.

II. ARTERIAL AND COLLECTOR STREET AND ZONING MAP

The first task in creating this study was to assemble the available information and create a map showing the streets that have already been undergrounded. The attached Arterial and Collector Street and Zoning Map (See Attachment 1 in Appendix 1) shows the streets that have been undergrounded and consolidates the information requested by the City.

The map shows all of the arterial and collector streets based on the City's Circulation Element, current zoning, and the streets that have already been undergrounded within Berkeley city boundaries. In order to identify the streets that have already been undergrounded, Harris utilized the history document provided by the City, reviewed streets on Google, and we obtained undergrounding information from PG&E. This information was then field verified for the arterial and collector streets in the areas zoned non-residential. The multi-colored hatched areas represent the street segments that have been utility undergrounded. The residential streets located outside the arterial and collector street network that have been undergrounded were mapped and tabulated based on the available resources. The varying colors denote where or how the data was obtained. We have also shown the 2 upcoming underground utility districts (Grizzly Peak and Vistamont) in the residential areas that will be completed in the future.

The arterial and collector streets have been separated by residential and non-residential to aid in a future prioritization model.

III. PLANNING LEVEL ESTIMATE OF THE CONSTRUCTION COSTS OF UTILITY UNDERGROUNDING.

Table 1 below summarizes the costs tabulated in Attachment 2 (see Appendix 1) and shows the estimated lengths and percentages of the arterial and collector streets in the City of Berkeley that have been undergrounded and needs to be undergrounded. A list of residential streets that have been undergrounded based on data provided by the City has been added to Attachment 2. Residential streets shown in the residential zones (R and MUR) that have not been undergrounded were not included in Attachment 2, however, we estimated in the table below the percentage of residential streets to be undergrounded. Attachment 2 also includes" impact ratings", which were considered when determining the unit cost for undergrounding. The costs to install the private property trench and conduits, and the service panel conversions have not been included as well as costs for financing and engineering and construction management.

The impact ratings were based on a scale of 1 to 5 with 1= Low Impact to 5= High Impact. This rating represents a level of difficulty associated with utility undergrounding based on the existing conditions of the street layout and facilities. In the field, we looked at the impacts to sidewalk clearances, traffic volume, and utility density on the existing joint poles and assessed the 1 to 5 rating scale. Sidewalk impact rating was based on space availability for locating the proposed underground utility vaults, existing obstructions in the sidewalk and pedestrian traffic. Traffic volume impact rating was based on the number of vehicles using the street and estimate of traffic control that may be required during the utility trench construction. Utility density impact rating was based on the estimate of number of utilities that needed to be undergrounded and the quantity and quality (thickness and existing connectivity at poles) of the overhead wires.

The unit costs were based on current unit prices from utility underground projects that we have designed. We used typical bid items including trench excavation, pavement resurfacing, basic utility conduits for PG&E, AT&T, and Comcast, street lighting, traffic control and mobilization to calculate a base unit cost per foot for construction. The base unit cost was used as our baseline for medium level of difficulty streets. We then added and subtracted 30% to the baseline to establish the high and low level unit cost.

Our estimate produced a baseline of joint trench construction costs based on current bid unit costs. We assumed number of vaults and length of conduits needed for each utility, without actual designs from utility agencies, and added a 25% contingency. Field measurements were not taken at peak driving times, therefore, traffic volumes were estimated.

The estimate does not include trenching on private property, service conduits, service panel conversions, cost of financing, engineering, construction management, and street lighting.

Disclaimer: The impact ratings and costs were developed and gathered for the purpose of this report in order to produce a baseline of unit costs. The costs may change in future years due to inflation and also the fluctuation of oil prices that affect the cost of PVC conduit and asphalt material.

TABLE 1: Summary of Undergrounding Lengths and Costs				
Arterial Streets	**Length (Feet)**	**Length (Miles)**	**Estimated Cost**	**% Underground**
Total arterial streets	135,095	25.6	N/A	N/A
Total arterial streets undergrounded	66,015	12.5	N/A	49%
Non-residential arterial streets to be undergrounded*	14,830	2.8	$11,380,000	11%
Residential arterial streets to be undergrounded**	54,250	10.3	$31,550,000	40%
Total arterial streets to be undergrounded	69,080	13.1	$42,930,000	51%
Collector Streets				
Total collector streets	190,460	36.1	N/A	N/A
Total collector streets undergrounded	59,660	11.3	N/A	31%
Non-residential collector streets to be undergrounded*	23,275	4.4	$15,100,000	12%
Residential collector streets to be undergrounded**	107,525	20.4	$76,770,000	57%
Total collector streets to be undergrounded	130,800	24.8	$91,870,000	69%
Residential Streets				
Total residential streets***	832, 666	157.7	N/A	N/A
Total residential streets undergrounded	57,267	10.8	N/A	7%
Total residential streets to be undergrounded	775,399	149.9	N/A	93%

* Non-residential includes Zones M, C-DMU, C, and SP
** Residential includes Zones MUR and R
*** Residential Streets include all non-arterial and non-collector streets falling in multiple zones

IV. FUNDING UTILITY UNDERGROUNDING PROJECTS

This section looks at the options available to the City and property owners for funding utility undergrounding projects. Some of the funding options may be limited in terms of the types of projects that can be funded, or require the approval of property owners or registered voters.

A.1 Rule 20A Funds

The California Public Utilities Commission (CPUC) and utility companies established a program to underground utilities across the State in 1967, commonly known as Rule 20. Rule 20 consists of three parts, A, B and C (for San Diego Gas & Electric ((SDG&E) there is also a D). Under Rule 20A, each utility company regulated by the Public Utilities Commission (PUC) allocates funds annually to each entity within its service boundaries to be used to convert existing overhead electrical facilities to underground electrical facilities within the community. Based upon the funds available each agency is able to prioritize undergrounding projects within their respective jurisdictions. Because of the high costs of most undergrounding projects, agencies must accumulate Rule 20A funds until they have accumulated the funds needed. Since a portion of the rates collected from all rate payers are used to fund the Rule 20A program, to qualify a project for Rule 20A funds, the City is required to:

- determine that the undergrounding of the existing overhead utilities will be in the public's interest,
- receive concurrence from utility that they have set aside or accumulated sufficient Rule 20A funds for the proposed undergrounding,
- create an Underground Utility District by City Ordinance which will require all property owners within the undergrounding district to convert their service connections to the undergrounded utilities at their expense, and
- meet at least one of the 4 criteria in the rate tariff to qualify for Rule 20A funds which include:
    1. the undergrounding will eliminate a heavy concentration of overhead facilities,
    2. the street to be undergrounded must be at least one block or 600 feet,
    3. the street is heavily travelled by pedestrian or vehicular traffic,
    4. the street adjoins a civic area, a recreation area or an area of unusual scenic interest, and/or
    5. The street is an arterial or collector in the General Plan.

The annual allocation of Rule 20A funds to agencies is based upon a formula, in the Rule, that compares the above ground facilities to underground facilities and the total number of overhead utility meters within the City in relationship to the total number of overhead utility meters within the utility's service area. The City of Berkeley is currently allocated approximately $533,000 per year for undergrounding of electrical services that are eligible for funding under Rule 20A. The City currently has a balance in its Rule 20A account of $6.4 million that could be used for undergrounding. In addition, the City can also "mortgage" up to 5 years of future Rule 20A allocations. Additionally, the City can "borrow" allocation from the County. The allocation can also be used to fund the installation of the service conduit up to 100 feet and the conversion of the electric service panel up to $1,500. Rule 20A allocations continue to be made by PG&E for projects that meet the criteria established in the Rule.

A.2 Other Financing Options under Rules 20B and 20C

Since the use of Rule 20A funds are limited to utility undergrounding projects typically along major roadways or other locations which provide a public benefit, Tariff Rule 20 includes two other options in addition to Tariff Rule 20A for financing utility undergrounding projects: Rules 20B and 20C.

Under Rule 20B, the utility is responsible for approximately 20 percent of undergrounding project costs (using rate payer revenues), and property owners and/or the local jurisdiction is responsible for 80 percent of costs. Under Rule 20C, projects are paid for entirely by property owners, with no utility (ratepayer) funds used, though the electric utility is still involved in the installation of the underground wiring. Undergrounding projects approved under these two options are still subject to CPUC regulations and project criteria.

Since a majority or all of the project costs are the responsibility of property owners under Rule 20B or 20C, most agencies work with property owners to create special tax or benefit assessment districts which allow bonds to be sold to fund the undergrounding projects and allow property owners to pay for the projects over a 20-30-year period. State law, either as part of the Government Code or the Streets & Highways Code, governs the rules for the formation of a special tax or benefit assessment district. The following provides a general description of the steps required for the formation of a benefit assessment or special tax district to fund utility undergrounding projects.

B. Funding sources to Supplement Rule 20A, B and C

Due to the high costs for undergrounding existing overhead utilities, most agencies work with property owners to establish a funding mechanism that will allow bonds to be sold and allow property owners to repay their financial obligation over a 20-25-year period. If a property is sold, the remaining financial obligation is the responsibility of the new property owner. The most commonly used funding mechanism by City's is the Municipal Improvement Act of 1913 or the Mello-Roos Act of 1982 as described below.

B.1 Municipal Improvement Act of 1913 (the "1913 Act")

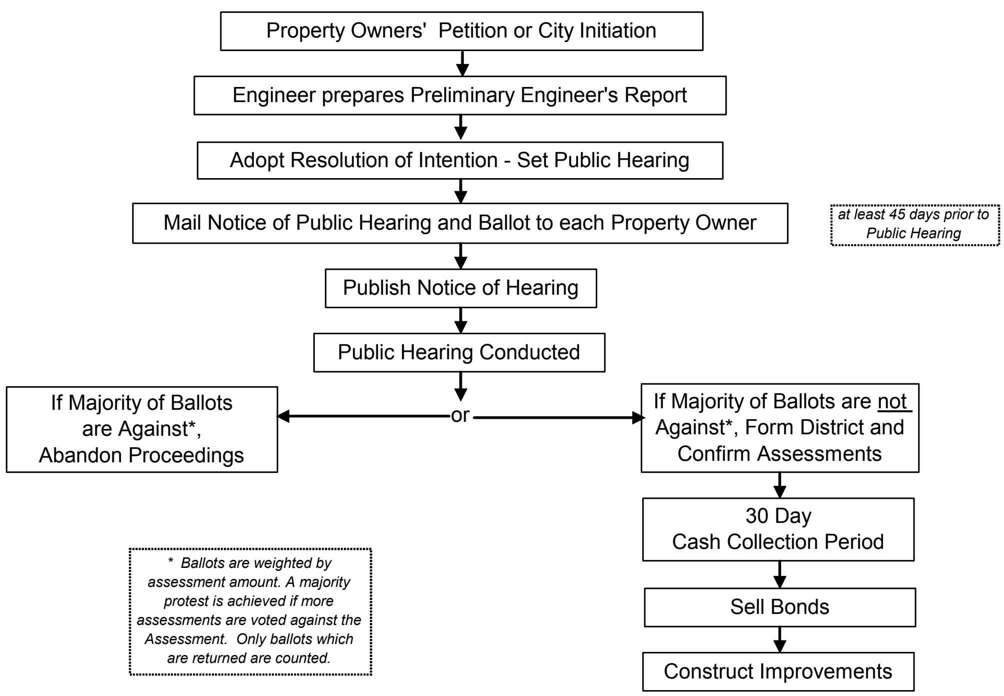
The 1913 Act has been used by many cities throughout the state working with property owners within the area to be undergrounded to create an assessment district to fund the non-utility portion of the costs for utility undergrounding. Under the 1913 Act, the City can fund the utility undergrounding project including the costs of design and other related project costs. The Act also authorizes the sale of bonds under the Improvement Bond Act of 1915 to allow repayment by property owners over an extended period (typically 20-25 years).

Formation of the assessment district is based upon the requirements of Proposition 218, and as such requires an analysis of special / general benefit (general benefits may not be assessed), and the approval of 50% of the property owners based upon the ballots returned weighted by assessment amount. Below are some pros and cons of this approach:

Pros:	Cons:
1. authorizes the sale of bonds under the 1915 Improvement Bond Act 2. requires 50% approval, by assessment amount, of the property owners returning their ballots 3. once bonds are issued, assessment to pay back bond debt is protected by Federal Law	1. requires the identification of "special benefit" and development of a benefit methodology to allocate costs to each parcel 2. must include public property and identify a funding source to pay for any general benefit since it may not be assessed. 3. Additional limitations imposed by recent case law

The flowchart below shows the steps required for the formation of a 1913 Act District.

Municipal Improvement Act of 1913
Formation Procedure



Note: Majority of property owners must sign petition to initiate the formation of the assessment district based upon the requirements of the Municipal Improvement Act of 1911, or the City must contribute 50% of the project costs if the City initiates the formation of the assessment district.

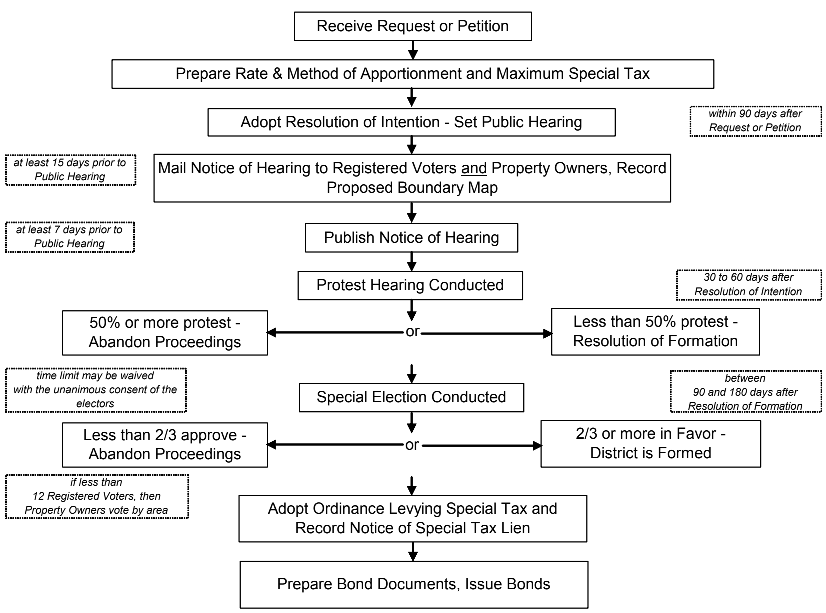
B.2 Mello-Roos Community Facilities District

The Mello-Roos Community Facilities Act of 1982 allows an agency to create a Community Facilities District (CFD) to finance the costs of utility undergrounding by the adoption of a special tax on parcels within the utility undergrounding district. Since a CFD imposes a special tax on parcels and not an assessment, it does not require the allocation of costs based upon special benefits as required by Prop. 218 for benefit assessment.

Since a CFD creates subject parcels to a special tax, it requires a two-thirds majority approval of the registered voters within the boundary of the CFD. It can be approved at a general election or special election. The special tax to be levied upon parcels is based upon the special tax formula that is established at the time the district is created. Although, there is no requirement that the special tax formula be based upon benefit, it must be reasonable. This allows the Agency a great deal of flexibility to create a special tax formula that will be acceptable to both the Agency and the registered voters. In the case of a utility undergrounding district, the special tax formula could levy a uniform tax on each parcel within the undergrounding district, which might not be possible in an assessment district, since some parcels may receive a greater benefit than others may. It also allows the tax to change over time, although it can never exceed the maximum special tax approved by the voters when the district is created. This flexibility can allow the tax to change based upon changes to a parcel. For example, if there are underdeveloped parcels within the undergrounding district, the special tax formula might levy a reduced tax on those parcels until such time as they develop. In addition, under the Mello-Roos Act, all publically owned properties in existence at the date of formation of the CFD are exempt from the CFD special tax.

The following is a flowchart of the formation process for a Mello-Roos CFD:

Mello-Roos Community Facilities Act of 1982
Formation Procedure



Harris has assisted many neighborhood groups and also cities such as Tiburon, Belvedere, Oakland, Newport Beach, Manhattan Beach, Laguna Beach, and others to utilize assessment district funding to underground overhead utilities.

V. FUNDING OPTIONS USED BY OTHER COMMUNITIES

A. Inter-Municipal Trading of Tariff Rule 20A Credits

Cities and counties are able to trade or sell unallocated Rule 20A credits if they will not be used to fund local undergrounding projects. There have been several cases where one agency has sold their unused credits, often for less than the full dollar value of the credits themselves to another agency. For example, in July of 2013, the City of Newport Beach entered into a memorandum of understanding (MOU) with the City of Mission Viejo to purchase unallocated Rule 20A credits at a cost of $0.55 on the dollar. Mission Viejo also granted Newport Beach the first right of refusal to purchase future Rule 20A allocations between July 1, 2013 and July 1, 2015 at the same rate of $0.55 on the dollar. In June of 2014, the City of Mission Viejo agreed to sell the City of Newport Beach a balance of $99,143 in Rule 20A funds. Newport Beach will pay Mission Viejo a total of $54,528 for the allocation. Mission Viejo agreed to sell its credits because it did not have undergrounding projects planned for the near future.

Similarly, the City of Foster City recently negotiated the transfer of $1.7 million of its Rule 20A credits to the City of Belmont. According to a representative from PG&E, cities and counties in the service area can create agreements between themselves to transfer Rule 20A credits under varying conditions as long as they provide PG&E documentation of the agreements.

B. Establishment of Local Surcharge for Undergrounding

Given the limited availability of Rule 20A funds for undergrounding, the City of San Diego working with SDG&E and the CPUC adopted a local surcharge as part of the utility rate structure to fund undergrounding projects. Until 2002, the undergrounding program in San Diego (as in the rest of California) proceeded under CPUC Rule 20-A. However, the amount of funding generated for Rule 20-A projects and the expenditure of those funds had significant limitations, including:

- the funds could only be used for undergrounding streets that would effect a "general public benefit" (such as arterial rights of way) and generally excludes residential streets;
- the funds could not be used to cover the cities' costs related to the replacement of traffic signals and street lights, or street trees as part of a utility undergrounding project, and
- the funds could not be used to cover the property owns costs of converting their service to connect to the street trench wiring.

In 2002, the City of San Diego and SDG&E entered into an agreement (which required the approval of the CPUC) to adopt a small surcharge on the electric bills of all residential power users to provide a stream of revenue that would be sufficient to cover the costs of a phased program to underground all the utility wires on all of the City's residential streets. This was adopted without a ballot measure. The surcharge funds non-Rule 20A projects. While in place for many years, the surcharge is being challenged in court. The case will be heard in 2017. Other agencies have adopted similar surcharges to fund utility undergrounding projects.

C. Adoption of Local Sales Tax or Utility Tax for Undergrounding

Another strategy for funding local undergrounding projects would be the adoption of a local sales tax or Utility User's Tax that would be dedicated to funding utility undergrounding projects. Both of these would be a "special tax" as defined by Proposition 218 and Proposition 26 and require 2/3's voter approval for adoption. Bonds could be issued secured by the sales tax or utility user's tax to fund the costs of the undergrounding projects. One benefit of this approach is that it could be done on a citywide basis and it may spread the tax burden across a broader base of taxpayers beyond just property owners. One agency, which is using this strategy, is the City of Anaheim, which has implemented a 4% surcharge on all electric bills and is used to underground the arterials and collector streets including services. Phone and cable pay to underground their facilities. The approach has been very successful and well received by the public.

D. Rule 20D (SDG&E only)

Rule 20D (http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-RULES_ERULE20.pdf) applies to circumstances other than those covered by Rule 20A or 20B where the utility will at its expense replace overhead with underground where after consultation with the utility and the local fire agency and after holding public hearings that the undergrounding is in the general public interest. The undergrounding will "(1) Occur in the SDG&E Fire Threat Zone as developed in accordance with the California Public Utilities commission (D.) 09-08-029: and (2) Occur in an area where the utility has determined that undergrounding is a preferred method to reduce fire risk and enhance the reliability of the facilities to be undergrounded."

While currently included only in SDG&E's Rule 20, the option may be a consideration for Berkeley to explore.

VI. STATUS OF RULE 20A, 20B, AND 20C FUNDING IN THE CITY OF BERKELEY.

PG&E continues to provide an allocation to the City of Berkeley under Rule 20A. The following table describes the allocation balance for 2016:

City of Berkeley 2016 Estimate of Current Rule 20A Account Balance		
	Allocations	Estimated Expenditures
(a) Account Balance as of 05/13/14	$6,365,851	
(b) 2015 Allocation	+$528,394	
(c) 2016 Allocation	+$523,888	
(d) 5 year borrow	+$2,619,440	
(e) Total Available Allocations	=$10,037,573	
(f) Grizzly Peak Blvd - Current FAC		-$4,682,736
(g) Vistamont Ave - Preliminary Ballpark Figure		-$6,085,703
(h) Adjusted Account Balance as of 5/17/16	=$730,866	

The factors making up the table are:

(a) Account Balance as of 5/13/14. This is the balance as of 5/13/14 of the annual Rule20A allocation. The balance is then added to the allocations to determine the amount available to fund Rule 20A projects.
(b) 2015 Allocation. This is the amount of Rule 20A allocation received by the City of Berkeley in 2015. It is added to the Account Balance as of 2014.
(c) 2016 Allocation. This is the amount of Rule 20A allocation received by the City of Berkeley in 2016. It is added to the Account Balance as of 2014.
(d) 5 year borrow. Under the provisions of Rule 20A the City can borrow forward 5 years of allocation. The $2,619,440 is 5 times the 2016 allocation. Please note that if the City uses the 5-year borrowing provision, the negative balance must be repaid from future allocations before another project can be done.
(e) Total Available Allocations. The Total Available Allocations is the sum of the Account Balance as of 5/13/14, the 2015 Allocation, the 2016 Allocation and the 5 year borrow.
(f) Grizzly Peak Blvd. The estimated value of the Grizzly Peak Blvd. Rule 20A is subtracted from the Total Available Allocations.
(g) Vistamont Ave. The estimated value of Vistamont Ave. is subtracted from the Total Available Allocations.
(h) Adjusted Account Balance as of 5/17/16. The Adjusted balance is the Total Available Allocations minus the next project where resolutions have been passed. The balance can still change depending on the actual construction cost of the Grizzly Peak project.

It is anticipated that PG&E will continue to provide an annual allocation for the near future to fund Rule 20A projects. However, in recent years PG&E has changed the allocation methodology. Under Rule 20A, the City can borrow forward up to 5 years of allocation to fund a qualified project. The allocation can also be used to fund the service lateral, up to 100 feet and the service panel conversion, up to $1,500. The City of Berkeley has undergrounded many miles utilizing Rule 20A funds. The City utilizes a streetlight assessment to fund the installation of the streetlights in a Rule 20A district. Rule 20A continues to be an available funding mechanism to underground the arterial and collector streets within the City of Berkeley. If the street is not an arterial or collector, but is heavily conductored, heavily travelled or is scenic, it may also qualify for funding under Rule 20A

Under Rule 20B, the source of funding is typically an assessment or special tax district to fund the property owner's share of the costs. Prior to the dissolution of the RDA's they were also used to fund the local share of undergrounding projects. The City of Berkeley has done one undergrounding project under Rule 20B using an assessment district. Neighborhoods such as Bay View, Terrace View and La Loma have shown interest in pursuing undergrounding using Rule 20B. These are in areas of the City that are predominately residential and where it appears that funding with Rule 20A will not be available for many years. Rule 20B seems to be gaining interest with certain neighborhoods that would not qualify under Rule 20A, but still have a desire to enjoy the benefits associated with underground utilities.

It should also be noted that other than the arterials and collectors the remaining residential streets would not qualify for Rule 20A funding.

Under Rule 20C, the costs with the exception of a small salvage credit are all borne by the property owners. These projects are less popular than Rule 20A and Rule 20B projects and are usually done where small groups of property owners are interested in undergrounding a small area. While available, no projects have been identified as Rule 20C, and has not been utilized in the City. Generally having a project that is large, enough for a Rule 20B is more advantageous.

Rule 20D is specific to projects within SDG&E's service boundaries.

VII. CREATING A DISTRICT TO FUND NEIGHBORHOOD UNDERGROUNDING PROJECTS

The steps required to create a special district to fund utility undergrounding projects typically consists of five stages, including Public Hearing/Outreach, District Formation, Design, Notification, and Construction. Each element is described in greater detail below.

Step 1. Establish Utility Undergrounding District

In accordance with the City's Municipal Code, the City Council holds public hearings in order to create an Underground Utility District (UUD) which provides the legal mechanism to require property owners to convert their existing overhead utility services to underground service. All residents and property owners with the proposed UUD are mailed a Public Hearing Notice and a map of the proposed UUD location. The Public Hearing Notice informs property owners that they are within an area being considered for undergrounding by the City Council. The notice explains the potential impacts of the project. Any member of the public may attend or speak at a public hearing. Prior to the start of design work, the City Council must create an underground utility district.

Step 2. Identify Funding Mechanism.

As discussed there are several ways that the undergrounding of utilities can be funded. If the costs will not be fully funded under Rule 20A or other City funds, the City will typically work with property owners to form an assessment or special tax district. The first step in the creation of an assessment district is to develop a preliminary costs estimates and a map showing the parcels that would be included in the assessment district that will be used during the petition process. The petition must be signed by property owners representing at least of 50% of the land area within the proposed boundary of the district. The specific steps for the formation of the financing district (either special tax or benefit assessment) is governed by either the Government Code or the Streets & Highways Code, depending upon the type of district. In both cases the City, typically create a financing team, that includes a special tax consultant/assessment engineer, bond counsel and legal counsel. District formation typically takes 3-6 months. Once established, the financing district establishes the financial obligation of each property owner and the manner in which each property owner will pay their portion of the project's costs. Typically, bonds would be sold and property owners would repay their share of the project costs over a 20-25-year period. The annual obligation is collected as part of the annual property tax bill. If a property is sold, the remaining obligation is the responsibility of the new property owner.

Step 3. Design Process.
Once an Underground Utility District and financing district has been created, the design process starts. Design typically takes 1-2 years after SCE has approved the project and involves field surveying, utility research, and coordination among impacted utilities.

Step 4. Notification.
Prior to the start of undergrounding, residents and property owners will receive additional outreach materials regarding planned construction activities. If trenching on private property is required, utility companies will coordinate right-of-entry permits from property owners. In addition, immediately prior to construction, utility companies will distribute additional construction notices making the public aware of construction dates and times.

Step 5. Construction.
Depending on the size of an undergrounding project, construction can range in duration from a few months to over a year. The initial step in construction involves installation of the underground plastic conduit below the surface of the roadway. Trenching may also occur up to individual properties to allow for conversion to underground services. Next, contractors install new utility lines within the conduit and new transformers/pedestals adjacent to trench areas. These boxes are necessary for the underground system and are placed above ground. Once utility lines are installed, each property's electrical panel is modified to allow for underground service and then transitioned from overhead to underground services. Finally, once all properties are converted to underground services, poles are removed in the project area.

VIII. EMERGING TECHNOLOGIES

Harris was also asked to look at emerging technologies and the effect they may have on undergrounding. The following technologies were investigated:

- Photovoltaics and energy storage,
- Distributed generation and micro grids,
- Trenchless construction using horizontal directional drilling.

Photovoltaics and energy storage. While solar (photovoltaics) is gaining in popularity and energy storage is more and more efficient, the effect of solar on electric distribution systems is still unclear. The issue continues to be the lack of an efficient method of storing the power generated by photovoltaic system. The Village of Minster in Ohio, has constructed a utility scale storage project combined with a solar array. The battery storage is owned by the utility and works to offset power purchased on the open market. (Solar Meets Energy Storage, T&D World Magazine, April 25, 2016). In a separate article, the author compares the growth of solar to that of mobile phones and speculates that people will cut utilities ties in much the same way as they have with telephone wires. (Why living off the grid will be easier in 25 years, Cadie Thompson). However, energy storage continues to be a significant factor in the success of solar, distributed generation or micro grids. While still very expensive, there is progress in technologies such as Lithium-ion battery storage, Vehicle-to-Grid, and Fuel Cell energy storage. (Mayor's Undergrounding Task Force, October 2013)

Distributed generation and micro grids refers to small size electric generation (typically from a renewable fuel) located close to electric load centers. This would eliminate the need for large transmission towers to deliver electric energy from a large generation facility to a city. However, there is still a need for a local distribution network. The issue with this technology is properly sizing the generation, or having a consistent fuel source, so that a back-up source is not needed. (Mayor's Undergrounding Task Force, October 2013) Similar to solar, the ability to store energy during times of low demand so that is available during peak load periods is a significant factor with this technology as well.

Horizontal directional drilling (HDD) is a steerable trenchless method of installing underground pipe, conduit, or cable in a shallow arc along a prescribed bore path by using a surface-launched drilling rig, with minimal impact on the surrounding area. It is a relatively common method for installation of power and communication conduits. It is generally used where there is a desire not to "open cut" a trench and where the presence of existing underground facilities is well defined.

A brief description of the process starts with a pilot hole drilled from the surface to the required depth on the designed alignment. Lengths of 300' are relatively common. The pilot drill pushes its way through the soil and is tracked and guided by electronic signals emanating from the drill head. The pilot drill head surfaces at the termination point and a back reamer is attached to the pilot drill rod. At this point, the drilling is reversed and the back reamer is pulled back toward the drilling rig enlarging the hole to the desired diameter for the plastic conduit carrier pipe. The conduit, which has been fuse welded together in one continuous pipe string, is then pulled back in the hole created by the reamer to the starting point. Costs can be as much as half of what open-cut construction would be and can range from $60 to $150 per foot depending on the conduit size and specific site constraints.

HDD is a viable option for use in Berkeley in streets that are not congested with existing underground utilities and for locations where landscaping and hardscape cannot be disturbed. However, to avoid damaging existing underground facilities it is imperative to know their exact locations.

IX. SUMMARY OF THE ADVANTAGES AND DISADVANTAGES OF UNDERGROUNDING ARTERIALS AND COLLECTORS

The structure of Rule 20 favors undergrounding in areas used frequently by the public. Roads that are heavily conductored (many overhead wires) and heavily travelled benefit the public by being undergrounded. Public buildings since the public also frequents them also benefits. Expanding the qualifications of Rule 20A by including arterials and collectors provide more confirmation that utility funded undergrounding should benefit the public.

ADVANTAGES

1. Enhanced public safety (during fire and earthquake events).
2. Enhanced reliability (less frequent outages)
3. Improved aesthetics.
4. Improved pedestrian access.
5. A reduction in car pole accidents.

6. Eliminate tree limb contacts with overhead wires
7. Improved public perception.
8. Reduced tree trimming cost.

DISADVANTAGES

1. High construction costs.
2. Construction noise.
3. Impacts to traffic.
4. Higher utility rates.
5. Finding space for conduits and substructures in already crowded streets.
6. Complaints from the public during construction.

Comment on undergrounding the arterials and collectors within residential areas

Undergrounding the arterials and collectors in the residential areas will share similar pros and cons as the non-residential areas. Property owners and the public alike benefit from a safety and reliability standpoint. Views are enhanced by removing the overhead conductors and poles.

However, there is much more effort in public education and information required in working with homeowners in residential areas. One of the biggest challenges in this regard is identifying homeowner participation in costs and estimating an early, accurate construction cost estimate.

X. CONCLUSION

As this study is intended to provide a base case for future studies on undergrounding the City of Berkeley conclusions may be pre-mature. It appears there are compelling reasons to underground all or a portion of the remaining streets in Berkeley. The utility funded program (Rule 20A) can continue to be used to fund the undergrounding on the arterials and collector streets. The remaining streets may need to be funded by neighborhood groups, or some type of City –wide assessment.

There are several potential next steps to this process, they include:

- Refining the costs,
- Developing a prioritization model,
- Developing the funding model,
- Exploring the impact of technology.

XI. HISTORY OF UNDERGROUNDING OF OVERHEAD UTILITIES

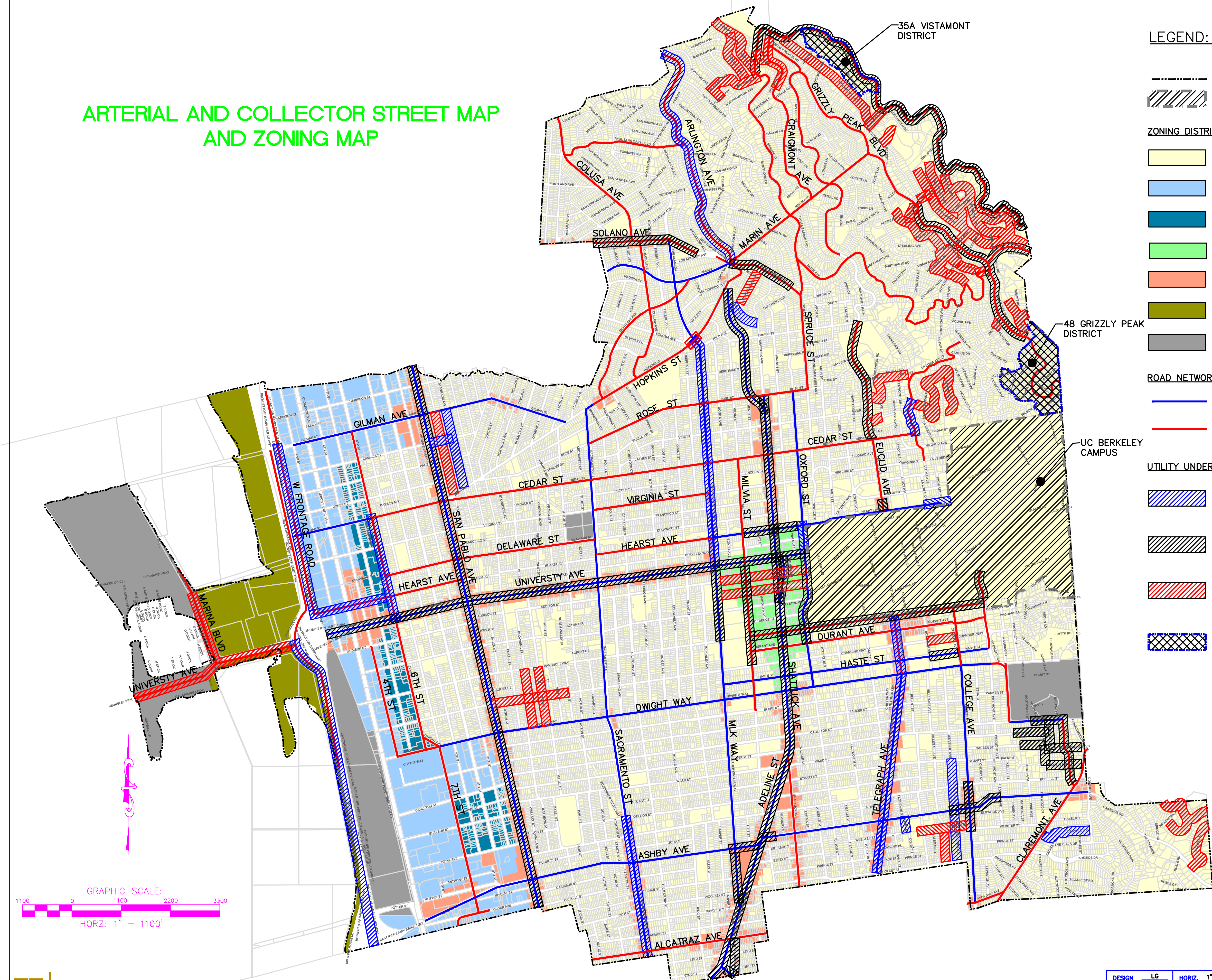
For reference, attached in Appendix 2 is the City's "Undergrounding of Utility Wires – A Brief History, December 2015" document.

XII. COMMENTS FROM COMMISSIONERS

For reference, attached in Appendix 3 are the comments and questions from Commissioners and the Harris response.

APPENDIX 1

ARTERIAL AND COLLECTOR STREET MAP AND ZONING MAP



LEGEND:

- CITY RIGHT-OF-WAY
- UC BERKELEY CAMPUS

ZONING DISTRICTS:

- RESIDENTIAL (DISTRICTS R-1, R-1A, R-2,R-2A, R-3, R-4, R-5, ES-R, R-S, R-SMU)
- MANUFACTURING (DISTRICTS M, MM, MULI)
- MIXED USE-RESIDENTIAL (DISTRICT MUR)
- COMMERCIAL DOWNTOWN MIXED USE (DISTRICT C-DMU)
- COMMERCIAL (DISTRICTS C-1, C-E, C-N, C-NS, C-SA, C-SO, C-T, C-W)
- SPECIFIC PLAN (DISTRICT SP)
- UNCLASSIFIED (DISTRICT U)

ROAD NETWORK:

- ARTERIAL ROADS
- COLLECTOR ROADS

UTILITY UNDERGROUNDING HISTORY:

- STREET SEGMENTS ALREADY UNDERGROUNDED PER "UNDERGROUNDING OF OVERHEAD UTILITY WIRES – A BRIEF HISTORY"
- STREET SEGMENTS ALREADY UNDERGROUNDED PER GOOGLE MAP STREET VIEW
- STREET SEGMENTS ALREADY UNDERGROUNDED PER PG&E'S MAP "GENERAL AND APPROXIMATE LOCATIONS OF UNDERGROUND ELECTRIC DISTRIBUTION LINES IN THE CITY OF BERKELEY"
- PROPOSED UNDERGROUNDING DISTRICTS
  * DISTRICT 48 GRIZZLY PEAK
  * DISTRICT 35A VISTAMONT

NOTE:

- THIS BASELINE STUDY IS PRIMARILY FOCUSED ON UNDERGROUNDING THE EXISTING OVERHEAD UTILITIES IN THE ARTERIAL-COLLECTOR STREET NETWORK.
- THE ENTIRE STREET SEGMENTS OUTSIDE THE ARTERIAL-COLLECTOR ROAD NETWORK HAVE NOT BEEN TABULATED AND PLOTTED AS PART OF THIS STUDY.
- THE UNDERGROUNDED SEGMENTS OUTSIDE THE ARTERIAL-COLLECTOR ROAD NETWORK SHOWN IN THIS MAP ARE PER AVAILABLE DATA PROVIDED BY THE CITY.

ATTACHMENT 1

Harris & Associates
1401 Willow Pass Rd. Ste. 500, Concord CA. 94520
harris-assoc.com (925) 827-4900

DESIGN	LG	HORIZ.	1"=1100'	CITY OF BERKELEY	BASELINE STUDY FOR THE DEVELOPMENT OF A UTILITY UNDERGROUNDING PROGRAM	PLAN
DRAWN	AP	VERT.		DEPARTMENT OF PUBLIC WORKS	HARRIS PROJECT NO-0810244003	FILE
CHECK	RC	DATE	07/26/16			SHEET___OF___

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

ARTERIAL ROAD NETWORK

STREET NAMES AND LIMITS					SECTIONS UNDERGROUNDED			OVERHEAD SECTIONS PER ZONE (NOTE: ZONES BASED ON CITY'S ZONAL MAP)								IMPACT RATING (SEE NOTE 1)					
NO	STREET	FROM	TO	TOTAL LENGTH (FT)	FROM	TO	LENGTH (FT)	FROM	TO	M ZONE (FT)	MUR ZONE(FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	R ZONE (FT)	(1) SIDEWALK CLEARANCE IMPACT RATING (SCALE 1-5)	(2) TRAFFIC VOLUME IMPACT RATING (SCALE 1-5)	(3) UTILITY DENSITY IMPACT RATING (SCALE 1-5)	RATING TOTAL (1)+(2)+(3)	HIGH LEVEL COST TO UNDERGROUND FOR M, CB, C-DMU AND SP ZONES ($)	HIGH LEVEL COST TO UNDERGROUND FOR MUR AND R ZONES ($)
1	ADELINE ST	WARD ST	CITY LIMIT	5280																	
					WARD ST	CITY LIMIT	5280														
2	ALAMEDA/MLK WAY	SOLANO AVE	CITY LIMIT	15380																	
								SOLANO AVE	HOPKINS ST						2340	1	2	2	5	$ -	$ 1,170,000
					HOPKINS	BANCROFT WAY	6780														
								BANCROFT WAY	DWIGHT WAY						1160	2	4	3	9	$ -	$ 846,800
								DWIGHT WAY	DWIGHT WAY				640			2	4	3	9	$ 467,200	$ -
								DWIGHT WAY	ASHBY AVE						2690	2	4	3	9	$ -	$ 1,963,700
					ASHBY AVE	ADELINE ST	1450														
					ADELINE ST	CITY LIMIT	320														
																			Total	$ 467,200	$ 3,980,500
3	ASHBY AVE	BAY ST	DOMINGO AVE	15465																	
								EAST OF BAY ST	SAN PABLO AVE				2730			2	3	2	7	$ 1,992,900	$ -
								SAN PABLO AVE	SACRAMENTO ST						1965	2	2	4	8	$ -	$ 1,434,450
								SACRAMENTO ST	SACRAMENTO ST				315			2	2	3	7	$ 229,950	$ -
								SACRAMENTO ST	MLK WAY						2020	2	2	3	7	$ -	$ 1,474,600
					MLK WAY	ADELINE ST	1160														
								ADELINE ST	LORENA ST				720			2	2	4	8	$ 525,600	$ -
								LORENA ST	TELEGRAPH AVE						1470	2	2	3	7	$ -	$ 1,073,100
					TELEGRAPH AVE	TELEGRAPH AVE	450														
								TELEGRAPH AVE	BENEVENUE AVE						1275	2	2	2	6	$ -	$ 637,500
					BENEVENUE AVE	PIEDMONT AVE	1215														
								PIEDMONT AVE	CLAREMONT AVE						1535	2	2	2	6	$ -	$ 767,500
								CLAREMONT AVE	DOMINGO AVE				610			2	1	2	5	$ 305,000	$ -
																			Total	$ 3,053,450	$ 2,478,100
4	CEDAR ST	EASTSHORE HWY	6TH ST	1765																	
								EASTSHORE HWY	4TH ST	1120						2	2	3	7	$ 817,600	$ -
								4TH ST	6TH ST		645					2	2	3	7	$ -	$ 470,850
																			Total	$ 817,600	$ 470,850
5	COLLEGE AVE	DWIGHT WAY	ALCATRAZ AVE	5300																	
								DWIGHT WAY	RUSSELL ST						2500	2	3	4	9	$ -	$ 1,825,000
					DWIGHT WAY	WEBSTER ST	1125														
								WEBSTER ST	ALCATRAZ AVE						1500	2	3	3	8	$ -	$ 1,095,000
								ALCATRAZ AVE	ALCATRAZ AVE				175			2	3	3	8	$ 127,750	$ -
																			Total	$ 127,750	$ 2,920,000
6	DERBY ST	WARRING ST	BELROSE AVE	1195																	
								WARRING ST	MID DERBEY ST						480	2	3	3	8	$ -	$ 350,400
					MID DERBY ST	BELROSE AVE	715														
																			Total	$ -	$ 350,400
7	DWIGHT WAY	7TH ST	PIEDMONT AVE	12445																	
								7TH ST	9TH ST	675						2	3	2	7	$ 492,750	$ -
								9TH ST	SAN PABLO AVE				685			2	3	2	7	$ 500,050	$ -
								SAN PABLO AVE	SACRAMENTO ST						2130	2	3	2	7	$ -	$ 1,554,900
								SACRAMENTO ST	SACRAMENTO ST				375			2	3	2	7	$ 273,750	$ -
								SACRAMENTO ST	MLK WAY						2380	2	3	4	9	$ -	$ 1,737,400
								MLK WAY	MLK WAY				270			2	3	4	9	$ 197,100	$ -
								MLK WAY	SHATTUCK AVE						990	2	3	4	9	$ -	$ 722,700
								SHATTUCK AVE	FULTON ST				880			2	3	5	10	$ 642,400	$ -
								FULTON ST	TELEGRAPH AVE						1810	2	3	5	10	$ -	$ 1,321,300
								TELEGRAPH	TELEGRAPH AVE				440			2	3	5	10	$ 321,200	$ -
								TELEGRAPH	PIEDMONT AVE						1810	2	3	4	9	$ -	$ 1,321,300
																			Total	$ 2,427,250	$ 6,657,600
8	GILMAN ST	2ND ST	HOPKINS ST	6290																	
								2ND ST	9TH ST	2320						3	5	4	12	$ 2,320,000	$ -
								9TH ST	SAN PABLO AVE				710			3	5	4	12	$ 710,000	$ -
								SAN PABLO AVE	SANTA FE AVE						1580	3	4	3	10	$ -	$ 1,153,400
								SANTA FE AVE	TEVLIN ST				740			2	3	3	8	$ 540,200	$ -
								TEVLIN ST	HOPKINS ST						940	2	3	3	8	$ -	$ 686,200
																			Total	$ 3,570,200	$ 1,839,600

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

ARTERIAL ROAD NETWORK

STREET NAMES AND LIMITS					SECTIONS UNDERGROUNDED			OVERHEAD SECTIONS PER ZONE (NOTE: ZONES BASED ON CITY'S ZONAL MAP)								IMPACT RATING (SEE NOTE 1)					
NO	STREET	FROM	TO	TOTAL LENGTH (FT)	FROM	TO	LENGTH (FT)	FROM	TO	M ZONE (FT)	MUR ZONE(FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	R ZONE (FT)	(1) SIDEWALK CLEARANCE IMPACT RATING (SCALE 1-5)	(2) TRAFFIC VOLUME IMPACT RATING (SCALE 1-5)	(3) UTILITY DENSITY IMPACT RATING (SCALE 1-5)	RATING TOTAL (1)+(2)+(3)	HIGH LEVEL COST TO UNDERGROUND FOR M, CB, C-DMU AND SP ZONES ($)	HIGH LEVEL COST TO UNDERGROUND FOR MUR AND R ZONES ($)
9	HASTE AVE	MLK WAY	PEIDMONT AVE	5980																	
								MLK WAY	MILVIA						650	2	2	3	7	$ -	$ 474,500
								MILVIA	SHATTUCK AVE						500	2	3	4	9	$ -	$ 365,000
								SHATTUCK AVE	SHATTUCK AVE			535				2	3	4	9	$ 390,550	$ -
								SHATTUCK AVE	FULTON AVE						265	2	3	4	9	$ -	$ 193,450
								FULTON AVE	TELEGRAPH AVE						1935	2	2	3	7	$ -	$ 1,412,550
								TELEGRAPH AVE	TELEGRAPH AVE				350			2	2	3	7	$ 255,500	$ -
								TELEGRAPH AVE	BOWDITCH						475	2	2	3	7	$ -	$ 346,750
					BOWDITCH AVE	COLLEGE AVE	640														
								COLLEGE AVE	PIEDMONT AVE						630	2	2	3	7	$ -	$ 459,900
																			Total	$ 646,050	$ 3,252,150
10	HEARST AVE	MLK AVE	HIGHLAND PL	5160																	
								MLK AVE	MILVIA ST						660	2	2	2	6	$ -	$ 330,000
					MILVIA ST	OXFORD AVE	1360														
								OXFORD AVE	SCENIC AVE						1225	2	3	3	8	$ -	$ 894,250
								SCENIC AVE	LA LOMA						1525	4	3	3	10	$ -	$ 1,113,250
					LA LOMA AVE	HIGHLAND PL	390														
																			Total	$ -	$ 2,337,500
11	HENRY ST	EUNICE ST	ROSE ST	1360																	
					EUNICE ST	ROSE ST	1360														
12	MARIN AVE	TULARE AVE	THE CIRCLE	2920																	
								TULARE AVE	THE CIRCLE						2920	2	3	2	7	$ -	$ 2,131,600
																			Total	$ -	$ 2,131,600
13	OXFORD ST	ROSE ST	DWIGHT WAY	6620																	
								ROSE ST	CEDAR AVE						1320	2	3	3	8	$ -	$ 963,600
								CEDAR AVE	HEARST						1670	1	2	3	6	$ -	$ 835,000
					HEARST AVE	DURANT AVE	2670														
								DURANT AVE	DWIGHT WAY						960	2	3	3	8	$ -	$ 700,800
																			Total	$ -	$ 2,499,400
14	SACRAMENTO ST	HOPKINS ST	ALCATRAZ AVE	12375																	
								HOPKINS ST	CEDAR AVE						1565	2	3	3	8	$ -	$ 1,142,450
								CEDAR AVE	UNIVERSITY AVE						2330	2	2	2	6	$ -	$ 1,165,000
					UNIVERSITY AVE	UNIVERSITY AVE	360														
								UNIVERSITY AVE	DWIGHT AVE						2620	2	3	3	8	$ -	$ 1,912,600
								DWIGHT AVE	BLAKE ST				540			2	2	2	6	$ 270,000	$ -
								BLAKE ST	OREGON ST						1780	2	2	2	6	$ -	$ 890,000
					OREGON ST	ALCATRAZ AVE	3180														
																			Total	$ 270,000	$ 5,110,050
15	SAN PABLO AVE	N CITY LIMIT	S CITY LIMIT	12405																	
					N CITY LIMIT	S CITY LIMIT	12405														
16	SHATTUCK AVE	ROSE ST	WARD ST	8250																	
					ROSE ST	WARD ST	8250														
17	SHATTUCK PL	ROSE ST	SHATTUCK AVE	400																	
					ROSE ST	SHATTUCK AVE	400														
18	SUTTER ST	HOPKINS ST	EUNICE ST	1200																	
					HOPKINS ST	EUNICE ST	1200														
19	TELEGRAPH AVE	DWIGHT WAY	WOOLSEY ST	4475																	
					DWIGHT WAY	WOOLSEY ST	4475														
20	UNIVERSITY AVE	EASTSHORE HWY	OXFORD ST	10830																	
					EASTSHORE HWY	OXFORD ST	10830														
			TOTAL LENGTH (FT)=	135095		TOTAL LENGTH (FT)=	66015		TOTAL LENGTH (FT)=	4115	645	535	10180	0	53605				TOTAL COST=	$ 11,379,500	$31,549,650

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

SUMMARY OF STREETS TO BE UNDERGROUNDED SHOWING TOTAL LENGTH PER ZONE AND TOTAL COSTS

CLASS	M ZONE (FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	TOTAL LENGTH (FT)	Total Cost ($)
Arterial (Non-residential)	4115	535	10180	0	14830	$11,380,000
CLASS	**MUR ZONE (FT)**	**R ZONE (FT)**				**Total Cost ($)**
Arterial (Residential)	645	53605			54250	$31,550,000

LEGEND:

(green)	SECTION OF STREETS TO BE UNDERGROUNDED
(blue)	SECTION OF STREETS ALREADY UNDERGROUNDED

NOTE:

1. IMPACT RATING IS THE LEVEL OF DIFFICULTY ASSOCIATED WITH UTILITY UNDERGROUNDING. IT IS ASSESSED IN THREE AREAS AS SHOWN BELOW PER FIELD REVIEW. IMPACT RATING IS TABULATED IN A SCALE FROM 1 (LOW IMPACT) TO 5 (HIGH IMPACT). REFER TO THE BASELINE STUDY IN SECTION III FOR MORE INFORMATION ON IMPACT RATING.

ABBREVIATIONS:

M Zone = Manufacturing (Districts M,MM, MUU)
MUR Zone = Mixed Use-Residential (District MUR)
C-DMU Zone = Commercial Downtown Mixed Use (District C-DMU)
C Zone = Commercial (Districts C-1, C-E, C-N, C-NS, C-SA, C-SO, C-T, C-W)
SP Zone = Specific Plan (District SP)
R Zone = Residential (Districts R-1, R-1A, R-2A, R-3, R-4,R-5, ES-R, R-S, R-SMU)

Cost Conditions

	Cost/FT			Total Cost ($)
IF	1000	+37 %	Cost/FT * Total Ft	Total Cost
IF	730	Base	Cost/FT * Total Ft	Total Cost
IF	500	-31.5%	Cost/FT * Total Ft	Total Cost

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

COLLECTOR ROAD NETWORK

STREET NAMES AND LIMITS					SECTIONS UNDERGROUNDED			OVERHEAD SECTIONS PER ZONE (ZONES BASED ON CITY'S ZONAL MAP)								IMPACT RATING (SEE NOTE 1)			RATING TOTAL (1)+(2)+(3)	HIGH LEVEL COST TO UNDERGROUND FOR M, CB, C-DMU AND SP ZONES ($)	HIGH LEVEL COST TO UNDERGROUND FOR MUR AND R ZONES ($)
NO	STREET	FROM	TO	TOTAL LENGTH (FT)	FROM	TO	LENGTH (FT)	FROM	TO	M ZONE (FT)	MUR ZONE(FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	R ZONE (FT)	(1) SIDEWALK CLEARANCE IMPACT RATING (SCALE 1-5)	(2) TRAFFIC VOLUME IMPACT RATING (SCALE 1-5)	(3) UTILITY DENSITY IMPACT RATING (SCALE 1-5)			
1	4TH ST	ADDISON ST	DWIGHT WAY	2535																	
								ADDISON ST	DWIGHT WAY	2535						1	2	4	7	$ 1,850,550	$ -
																			Total	$ 1,850,550	$ -
2	6TH ST	GILMAN ST	DWIGHT WAY	7290																	
								GILMAN ST	CAMELIA ST	670						2	2	3	7	$ 489,100	$ -
								CAMELIA ST	CEDAR ST		1325					2	2	3	7	$ -	$ 967,250
					CEDAR ST	UNIVERSITY AVE	2295														
								UNIVERSITY AVE	DWIGHT WAY		3000					2	2	2	6	$ -	$ 1,500,000
																			Total	$ 489,100	$ 2,467,250
3	7TH ST	DWIGHT WAY	FOLGER AVE	3810																	
								DWIGHT WAY	CARLETON ST	1210						2	3	4	9	$ 883,300	$ -
								CARLESTON ST	HEINZ AVE	1300						2	3	4	9	$ 949,000	$ -
								HEINZ AVE	ANTHONY ST	480						2	3	4	9	$ 350,400	$ -
								ANTHONY ST	ASHBY AVE				450			2	3	4	9	$ 328,500	$ -
								ASHBY AVE	FOLGER AVE	370						2	3	4	9	$ 270,100	$ -
																			Total	$ 2,781,300	$ -
4	ALCATRAZ AVE	COLLEGE AVE	CLAREMONT AVE	850																	
								COLLEGE AVE	COLLEGE AVE				300			2	2	2	6	$ 150,000	$ -
								COLLEGE AVE	CLAREMEONT AVE						550	2	2	2	6	$ -	$ 275,000
																			Total	$ 150,000	$ 275,000
5	ALCATRAZ AVE	W OF IDAHO ST	E OF ADELINE ST	3970																	
								W OF IDAHO ST	SACRAMENTO ST						1220	2	2	2	6	$ -	$ 610,000
								SACRAMENTO ST	E OF CALIFORNIA ST						965	3	3	3	9	$ -	$ 704,450
								E OF CALIFORNIA ST	ADELINE ST				850			3	3	3	9	$ 620,500	$ -
								ADELINE ST	E OF ADELINE ST				935			3	3	3	9	$ 682,550	$ -
																			Total	$ 1,303,050	$ 1,314,450
6	ARLINGTON AVE	BOYNTON AVE	MARIN AVE	5515																	
					BOYNTON AVE	MARIN AVE	5515														
7	BANCROFT WAY	MILVIA ST	PIEDMONT AVE	5270																	
					MILVIA ST	PIEDMONT AVE	5270														
8	BELROSE	DERBY ST	CLAREMONT AVE	1550																	
					DERBY ST	CLAREMONT AVE	1550														
9	CEDAR ST	6TH ST	LALOMA AVE	12290																	
								6TH ST	SAN PABLO AVE						1660	2	2	3	7	$ -	$ 1,211,800
								SAN PABLO AVE	ACTON ST						2670	1	2	3	6	$ -	$ 1,335,000
								ACTON ST	SACRAMENTO ST						700	2	2	3	7	$ -	$ 511,000
								SACRAMENTO ST	MLK AVE						2590	2	2	2	6	$ -	$ 1,295,000
								MLK AVE	SHATTUCK AVE						1350	2	2	3	7	$ -	$ 985,500
								SHATTUCK AVE	EUCLID AVE						2350	2	2	3	7	$ -	$ 1,715,500
								EUCLID AVE	LA LOMA AVE						970	3	2	2	7	$ -	$ 708,100
																			Total	$ -	$ 7,761,900
10	CLAREMONT AVE	ALCATRAZ AVE	TANGLEWOOD RD	4015																	
								ALCATRAZ AVE	PARKSIDE DR						1275	2	2	2	6	$ -	$ 637,500
								PARKSIDE DR	PRINCE ST				370			2	2	2	6	$ 185,000	$ -
								PRINCE ST	ASHBY PL						1070	2	2	2	6	$ -	$ 535,000
								ASHBY PL	RUSSELL ST				640			2	2	2	6	$ 320,000	$ -
								RUSSELL ST	AVALON AVE						300	2	2	2	6	$ -	$ 150,000
								AVALON AVE	TANGLEWOOD RD						360	2	2	2	6	$ -	$ 180,000
																			Total	$ 505,000	$ 1,502,500
11	CLAREMONT AVE	WILDCAT CANYON RD	MARIN AVE	4390																	
					WILDCAT CANYON RD	ACACIA AVE	1565														
								ACACIA AVE	MARIN AVE						2825	4	3	4	11	$ -	$ 2,825,000
																			Total	$ -	$ 2,825,000
12	COLLEGE AVE	BANCROFT WAY	DWIGHT WAY	1310																	
								BANCROFT WAY	DWIGHT WAY						1310	2	3	3	8	$ -	$ 956,300
																			Total	$ -	$ 956,300
13	COLUSA AVE	SOLANO AVE	HOPKINS ST	3290																	
								SOLANO AVE	HOPKINS ST						3290	2	2	2	6	$ -	$ 1,645,000
																			Total	$ -	$ 1,645,000

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

COLLECTOR ROAD NETWORK

STREET NAMES AND LIMITS					SECTIONS UNDERGROUNDED			OVERHEAD SECTIONS PER ZONE (ZONES BASED ON CITY'S ZONAL MAP)								IMPACT RATING (SEE NOTE 1)					
NO	STREET	FROM	TO	TOTAL LENGTH (FT)	FROM	TO	LENGTH (FT)	FROM	TO	M ZONE (FT)	MUR ZONE(FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	R ZONE (FT)	(1) SIDEWALK CLEARANCE IMPACT RATING (SCALE 1-5)	(2) TRAFFIC VOLUME IMPACT RATING (SCALE 1-5)	(3) UTILITY DENSITY IMPACT RATING (SCALE 1-5)	RATING TOTAL (1)+(2)+(3)	HIGH LEVEL COST TO UNDERGROUND FOR M, CB, C-DMU AND SP ZONES ($)	HIGH LEVEL COST TO UNDERGROUND FOR MUR AND R ZONES ($)
14	COLUSA AVE	SOLANO AVE	VISALIA AVE	3430																	
								SOLANO AVE	VISALIA AVE						3430	2	3	4	9	$ -	$ 2,503,900
																			Total	$ -	$ 2,503,900
15	DELAWARE ST	6TH ST	SACRAMENTO ST	4750																	
								6TH ST	SAN PABLO AVE						1660	2	1	2	5	$ -	$ 830,000
								SAN PABLO AVE	SACRAMENTO ST						3090	2	2	3	7	$ -	$ 2,255,700
																			Total	$ -	$ 3,085,700
16	DURANT AVE	MILVIA ST	PEIDMONT AVE	5280																	
								MILVIA ST	SHATTUCK AVE			730				1	2	2	5	$ 365,000	$ -
								SHATTUCK AVE	FULTON ST			530				1	2	2	5	$ 265,000	$ -
								FULTON ST	TELEGRAPH AVE						1700	1	2	2	5	$ -	$ 850,000
								TELEGRAPH AVE	BOWDITCH ST				1100			1	3	3	7	$ 803,000	$ -
								BOWDITCH ST	COLLEGE AVE						630	1	3	3	7	$ -	$ 459,900
								COLLEGE AVE	PEIDMONT AVE						590	1	2	3	6	$ -	$ 295,000
																			Total	$ 1,433,000	$ 1,604,900
17	DWIGHT WAY	4TH ST	7TH ST	960																	
								4TH ST	6TH ST		650					2	2	2	6	$ -	$ 325,000
								6TH ST	7TH ST		310					2	2	2	6	$ -	$ 155,000
																			Total	$ -	$ 480,000
18	DWIGHT CR	6TH ST	DWIGHT WAY	420																	
								6TH ST	DWIGHT WAY		420					2	2	2	6	$ -	$ 210,000
																			Total	$ -	$ 210,000
19	EAST SHORE HWY	HEARST AVE	N CITY LIMIT	5100																	
					HEARST AVE	GILMAN ST	3770														
								GILMAN ST	N CITY LIMIT	1330						3	3	3	9	$ 970,900	$ -
																			Total	$ 970,900	$ -
20	EUCLID AVE	CEDAR ST	HEARST AVE	1615																	
								CEDAR ST	RIDGE RD						1240	2	2	2	6	$ -	$ 620,000
					RIDGE RD	HEARST AVE	375														
																			Total	$ -	$ 620,000
21	EUCLID AVE	GRIZZLY PEAK BLVD	CRAGMONT AVE	5185																	
								GRIZZLY PEAK BLVD	CRAGMONT AVE						5185	3	3	4	10	$ -	$ 3,785,050
																			Total	$ -	$ 3,785,050
22	EUCLID ST	EUNICE ST	CEDAR ST	2780																	
					EUNICE ST	CEDAR ST	2780														
23	FOLGER AVE	HOLLIS ST	EAST OF 7TH ST	880																	
								HOLLIS ST	EAST OF 7TH ST	880						2	3	4	9	$ 642,400	$ -
																			Total	$ 642,400	$ -
24	GRIZZLY PEAK BLVD	CRAIGMONT AVE	EUCLID AVE	930																	
								CRAIGMONT AVE	EUCLID AVE						930	5	4	4	13	$ -	$ 930,000
																			Total	$ -	$ 930,000
25	GRIZZLY PEAK BLVD	EUCLID AVE	GOLF COURSE DR	10885																	
								EUCLID AVE	MARIN AVE						2570	5	4	5	14	$ -	$ 2,570,000
								MARIN AVE	LATHAM LN						1635	4	3	4	11	$ -	$ 1,635,000
					LATHAM LN	HILL RD	4260														
								HILL RD	GOLF COURSE DR						2420	4	3	4	11	$ -	$ 2,420,000
																			Total	$ -	$ 6,625,000
26	HEARST AVE	SACRAMENTO ST	MLK WAY	2640																	
								SACRAMENTO ST	MLK WAY						2640	2	2	2	6	$ -	$ 1,320,000
																			Total	$ -	$ 1,320,000
27	HEARST AVE	SAN PABLO AVE	EASTSHORE HWY	3395																	
					6TH ST	EASTSHORE HWY	1740														
								6TH ST	SAN PABLO AVE						1655	3	1	3	7	$ -	$ 1,208,150
																			Total	$ -	$ 1,208,150
28	HOPKINS ST	HOPKINS CT	MARIN CR	4900																	
								HOPKINS CT	MC GEE AVE				530			2	2	2	6	$ 265,000	$ -
								MCGEE AVE	MARIN CR						4370	2	2	2	6	$ -	$ 2,185,000
																			Total	$ 265,000	$ 2,185,000

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

COLLECTOR ROAD NETWORK

STREET NAMES AND LIMITS					SECTIONS UNDERGROUNDED			OVERHEAD SECTIONS PER ZONE (ZONES BASED ON CITY'S ZONAL MAP)								IMPACT RATING (SEE NOTE 1)					
NO	STREET	FROM	TO	TOTAL LENGTH (FT)	FROM	TO	LENGTH (FT)	FROM	TO	M ZONE (FT)	MUR ZONE(FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	R ZONE (FT)	(1) SIDEWALK CLEARANCE IMPACT RATING (SCALE 1-5)	(2) TRAFFIC VOLUME IMPACT RATING (SCALE 1-5)	(3) UTILITY DENSITY IMPACT RATING (SCALE 1-5)	RATING TOTAL (1)+(2)+(3)	HIGH LEVEL COST TO UNDERGROUND FOR M, CB, C-DMU AND SP ZONES ($)	HIGH LEVEL COST TO UNDERGROUND FOR MUR AND R ZONES ($)
29	KEITH AVE	SPRUCE ST	GRIZZLY PEAK BLVD	8080																	
								SPRUCE ST	MILLER RD						7800	5	4	5	14	0	$ 7,800,000
					MILLER RD	GRIZZLY PEAK BLVD	280														
																			Total	$ -	$ 7,800,000
30	LA LOMA AVE	GLENDALE AVE	VIRGINIA ST	3705																	
								GLENDALE AVE	BUENA VISTA WAY						2250	4	4	4	12	$ -	$ 2,250,000
					BUENA VISTA WAY	CEDAR ST	790														
								CEDAR ST	VIRGINIA ST						665	2	2	3	7	$ -	$ 485,450
																			Total	$ -	$ 2,735,450
31	LOS ANGELES AVE	THE CIRCLE	SPRUCE ST	1795																	
					THE CIRCLE	OXFORD ST	1495														
								OXFORD ST	SPRUCE ST						300	2	2	2	6	$ -	$ 150,000
																			Total	$ -	$ 150,000
32	MARIN AVE	MARIN CR	GRIZZLY PEAK BLVD	3985																	
								MARIN CR	GRIZZLY PEAK BLVD						3985	3	4	4	11	$ -	$ 3,985,000
																			Total	$ -	$ 3,985,000
33	MARINA BLVD	UNIVERSITY AVE	SPINNAKER WAY	2300																	
					UNIVERSITY AVE	VIRGINIA ST EXT	1665														
								VIRGINIA ST EXT	SPINNAKER WAY					635		1	1	1	3	$ 317,500	$ -
																			Total	$ 317,500	$ -
34	MENDOCINO AVE	MARIN CR	MID-BLOCK	330																	
								MARIN CR	MID-BLOCK						330	2	2	2	6	$ -	$ 165,000
																			Total	$ -	$ 165,000
35	MILVIA ST	CEDAR ST	BLAKE ST	5640																	
								CEDAR ST	VIRGINIA AVE						660	2	2	2	6	$ -	$ 330,000
								VIRGINIA AVE	FRANCISCO ST						340	2	2	2	6	$ -	$ 170,000
								FRANCISCO ST	UNIVERSITY AVE						1300	2	2	3	7	$ -	$ 949,000
					UNIVERSITY AVE	CHANNING WAY	2300														
								CHANNING WAY	HASTE AVE						360	2	2	2	6	$ -	$ 180,000
								HASTE AVE	BLAKE ST						680	2	3	3	8	$ -	$ 496,400
																			Total	$ -	$ 2,125,400
36	MONTEREY AVE	HOPKINS ST	MARIN AVE	3550																	
								HOPKINS ST	MARIN AVE						3550	2	1	2	5	$ -	$ 1,775,000
																			Total	$ -	$ 1,775,000
37	PIEDMONT AVE	HASTE ST	OPTOMETRY LN	1750																	
								HASTE ST	BANCROFT AVE						1025	2	3	3	8	$ -	$ 748,250
					BANCROFT AVE	OPTOMETRY LN	725														
																			Total	$ -	$ 748,250
38	ROSE ST	SACRAMENTO ST	SPRUCE ST	5090																	
								ROSE ST	MLK WAY						2675	2	2	3	7	$ -	$ 1,952,750
					MLK WAY	MLK WAY	225									2	2	3	7		
								MLK WAY	HENRY ST						810	2	2	3	7	$ -	$ 591,300
					HENRY ST	SHATTUCK PL	550									2	2	3	7		
								SHATTUCK PL	SPRUCE ST						830	2	2	3	7	$ -	$ 605,900
																			Total	$ -	$ 3,149,950
39	SHASTA RD	GRIZZLY PEAK BLVD	BAYTREE LN	1100																	
					GRIZZLY PEAK BLVD	BAYTREE LN	1100														
40	SHATTUCK AVE	WARD ST	CITY LIMIT	2930																	
								WARD ST	ASHBY				1520			2	3	3	8	$ 1,109,600	$ -
								ASHBY	CITY LIMIT				1410			2	3	3	8	$ 1,029,300	$ -
																			Total	$ 2,138,900	$ -
41	SOLANO AVE	TULARE AVE	LOS ANGELES AVE	2390																	
					TULARE AVE	LOS ANGELES AVE	2390														
42	SPRUCE ST	WILDCAT CANYON RD	ROSE ST	9135																	
					WILDCAT CANYON RD	MICHIGAN AVE	1135														
								MICHIGAN AVE	MONTROSE RD						2860	3	3	4	10	$ -	$ 2,087,800
								MONTROSE RD	LOS ANGELES AVE						2900	4	4	4	12	$ -	$ 2,900,000
								LOS ANGELES AVE	ROSE ST						2240	2	2	3	7	$ -	$ 1,635,200
																			Total	$ -	$ 6,623,000

ATTACHMENT 2
CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE
07/22/16

COLLECTOR ROAD NETWORK

STREET NAMES AND LIMITS					SECTIONS UNDERGROUNDED			OVERHEAD SECTIONS PER ZONE (ZONES BASED ON CITY'S ZONAL MAP)								IMPACT RATING (SEE NOTE 1)					
NO	STREET	FROM	TO	TOTAL LENGTH (FT)	FROM	TO	LENGTH (FT)	FROM	TO	M ZONE (FT)	MUR ZONE(FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	R ZONE (FT)	(1) SIDEWALK CLEARANCE IMPACT RATING (SCALE 1-5)	(2) TRAFFIC VOLUME IMPACT RATING (SCALE 1-5)	(3) UTILITY DENSITY IMPACT RATING (SCALE 1-5)	RATING TOTAL (1)+(2)+(3)	HIGH LEVEL COST TO UNDERGROUND FOR M, CB, C-DMU AND SP ZONES ($)	HIGH LEVEL COST TO UNDERGROUND FOR MUR AND R ZONES ($)
43	TELEGRAPH AVE	BANCROFT WAY	DWIGHT WAY	1310																	
					BANCROFT WAY	DWIGHT WAY	1310														
44	THOUSAND OAKS BLVD	COLUSA AVE	ARLINTON AVE	2840																	
								COLUSA AVE	SANTA CLARA AVE						1510	2	1	3	6	$ -	$ 755,000
								SANTA CLARA AVE	ARLINTON AVE						1330	2	3	3	8	$ -	$ 970,900
																			Total	$ -	$ 1,725,900
45	UNIVERSITY AVE	SEAWALL DR	FRONTAGE RD	3825																	
					SEAWALL DR	FRONTAGE RD	3825														
46	VIRGINIA ST	SACRAMENTO ST	MLK WAY	2640																	
								SACRAMENTO ST	MLK WAY						2640	2	1	2	5	$ -	$ 1,320,000
																			Total	$ -	$ 1,320,000
47	W FRONTAGE RD	ACROSS DWIGHT WAY	GILMAN ST	7500																	
					ACROSS DWIGHT WAY	UNIVERSITY AVE	3000														
								UNIVERSITY AVE	GILMAN ST	4500						2	2	1	5	$ 2,250,000	$ -
																			Total	$ 2,250,000	$ -
48	WARRING ST	DWIGHT WAY	DERBY ST	1580																	
								DWIGHT WAY	DERBY ST						1580	2	3	2	7	$ -	$ 1,153,400
																			Total	$ -	$ 1,153,400
49	WILDCAT CANYON RD	WOODMONT AVE	CITY LIMIT	9750																	
					WOODMONT AVE	CITY LIMIT	9750														
			TOTAL LENGTH (FT)=	190460		TOTAL LENGTH (FT)=	59660		TOTAL LENGTH (FT)=	13275	5705	1260	8105	635	101820				TOTAL COST=	$ 15,096,700	$ 76,761,450

SUMMARY OF STREETS TO BE UNDERGROUNDED SHOWING TOTAL LENGTH PER ZONE AND TOTAL COSTS

CLASS	M ZONE (FT)	C-DMU ZONE (FT)	C ZONE (FT)	SP ZONE (FT)	TOTAL LENGTH (FT)	Total Cost ($)
Collector(Non-Residential)	13275	1260	8105	635	23275	$15,100,000
CLASS	**MUR ZONE (FT)**	**R ZONE (FT)**				**Total Cost ($)**
Collector (Residential)	5705	101820			107525	$76,770,000

LEGEND:

- SECTION OF STREETS TO BE UNDERGROUNDED
- SECTION OF STREETS ALREADY UNDERGROUNDED

NOTE:

1. IMPACT RATING IS THE LEVEL OF DIFFICULTY ASSOCIATED WITH UTILITY UNDERGROUNDING. IT IS ASSESSED IN THREE AREAS AS SHOWN BELOW PER FIELD REVIEW. IMPACT RATING IS TABULATED IN A SCALE FROM 1 (LOW IMPACT) TO 5 (HIGH IMPACT). REFER TO THE BASELINE STUDY IN SECTION III FOR MORE INFORMATION ON IMPACT RATING.

ABBREVIATIONS:

M Zone = Manufacturing (Districts M,MM, MUU)
MUR Zone = Mixed Use-Residential (District MUR)
C-DMU Zone = Commercial Downtown Mixed Use (District C-DMU)
C Zone = Commercial (Districts C-1, C-E, C-N, C-NS, C-SA, C-SO, C-T, C-W)
SP Zone = Specific Plan (District SP)
R Zone = Residential (Districts R-1, R-1A, R-2A, R-3, R-4,R-5, ES-R, R-S, R-SMU)

Cost Conditions				
	Cost/FT			Total Cost ($)
IF	1000	+ 37 %	Cost/FT * Total Ft	Total Cost
IF	730	Base	Cost/FT * Total Ft	Total Cost
IF	500	-31.5%	Cost/FT * Total Ft	Total Cost

ATTACHMENT 2

CITY OF BERKELEY ARTERIAL AND COLLECTOR ROAD NETWORK UTILITY UNDERGROUNDING PLANNING LEVEL ESTIMATE

07/22/16

RESIDENTIAL ROADS ALREADY UNDERGROUNDED

STREET NAMES AND LIMITS				
NO	STREET	FROM	TO	TOTAL LENGTH (FT)
1	ADDISON ST	MLK WAY	OXFORD ST	2040
2	ALTA RD	SPRUCE ST	CRAIGMONT AVE	390
3	ALVARADO RD	CITY LIMIT	WILLOW WALK	1890
4	AMADOR AVE	SUTTER ST	SHATTUCK AVE	920
5	ARCADE AVE	GRIZZLY PEAK BLVD	FAIRLAWN DR	310
6	ATLAS PL	HILL RD	SUMMIT RD	200
7	AVALON AVE	OAK KNOLL TERRACE	CLAREMONT AVE	800
8	BENVENUE AVE	ASHBY AVE	WOOLSEY ST	1165
9	BONAR ST	BANCROFT WAY	DWIGHT WAY	1320
10	BOYNTON AVE	COLORADO AVE	FLORIDA AVE	280
11	BROWNING ST	BANCROFT WAY	DWIGHT WAY	1320
12	BUENA VISTA WAY	EUCLID AVE	LEROY AVE	380
13	BUENA VISTA WAY	LA LOMA AVE	DEAD END	3340
14	CAMELIA ST	SAN PABLO AVE	STANNAGE AVE	520
15	CENTER ST	MLK WAY	OXFORD ST	2020
16	CHANNING WAY	SAN PABLO AVE	VALLEY ST	1750
17	CHANNING WAY	BOWDITCH ST	COLLEGE AVE	670
18	COLBY ST	ASHBY AVE	WEBSTER ST	299
19	COLORADO AVE	BOYNTON AVE	MICHIGAN AVE	510
20	CLAREMONT BLVD	DERBY ST	BELROSE ABE	1400
21	FOREST AVE	MID POINT	CLAREMONT BLVD	600
22	GARBER ST	OAK KNOLL TERRACE	DEAD END	550
23	THE CRESCENT	PARK HILLS RD	PARK HILLS RD	1020
24	HAWTHORNE TERR	EUCLID AVE	LEROY AVE	365
25	HILL RD	GRIZZLY PEAK BLVD	DEAD END	950
26	HILLGRASS AVE	WESBTER ST	CITY LIMIT	840
27	HILLVIEW RD	WOODSIDE RD	PARK HILLS RD	1265
28	KAINS AVE	GILMAN ST	HOPKINS ST	1900
29	KENTUCKY AVE	VASSAR AVE	MICHIGAN AVE	1315
30	LATHAM LN	MILLER AVE	GRIZZLY PEAK BLVD	550
31	LATHAM LN	CRESTON RD	OVERLOOK RD	275
32	LEROY AVE	ROSE ST	HAWTHORNE TERR	735
33	MARIN AVE	CRESTON RD	DEAD END	450
34	MARIPOSA AVE	AMADOR AVE	LOS ANGELES AVE	1070
35	MIDDLEFIELD RD	PARK HILLS RD	LIMIT	1185
36	MILLER AVE	NORTH OF LATHAM LN	SHASTA RD	2180
37	MUIR WAY	GRIZZLY PEAK BLVD	PARK HILLS RD	385
38	OAK KNOLL TERRACE	GARBER ST	AVALON AVE	475
39	OAKVALE AVE	CLAREMONT AVE	DOMINGO AVE	1190
40	OVERLOOK RD	PARK HILLS RD	DEAD END	1715
41	PARK HILLS RD	MUIR WAY	SHASTA RD	1575
42	PARK HILLS RD	MUIR WAY	WILDCAT CANYON RD	1500
43	ROSE ST	LA LOMA AVE	LEROY AVE	750
44	STANNAGE AVE	GILMAN ST	HOPKINS ST	1685
45	STERLING AVE	WHITAKER AVE	SHASTA RD	710
46	STEVENSON AVE	GRIZZLY PEAK BLVD	MILLER AVE	520
47	SUNSET LN	CRESTON RD	WILDCAT CANYON RD	468
48	VASSAR AVE	NORTH CITY LIMIT	SPRUCE ST	1535
49	VINCENTE RD	ALVARADO RD	EAST CITY LIMIT	550
50	VINCENTE RD	TUNNEL RD	CITY LIMIT	1310
51	WEBSTER ST	COLLEGE AVE	REGENT ST	1070
52	WHITAKER AVE	STERLING AVE	MILLER AVE	550
53	WOODMONT AVE	WILDCAT CANYON RD	SUNSET LN	3055
54	WOODSIDE RD	CRESCENT RD	PARK HILLS RD	1450
			TOTAL LENGTH (FT)=	57267

APPENDIX 2

Undergrounding of Overhead Utility Wires – A Brief History

Berkeley, CA Public Works Commission – December 2015

Pursuant to a referral from the Berkeley City Council in December 2014 and approval by the Council on September 28, 2015 –

1) "Approve a work plan, as attached hereto, to develop a comprehensive plan (the "Undergrounding Plan") for the funding of the undergrounding of utility wires for all streets in Berkeley. The Undergrounding Plan would be developed in coordination with the City's existing related plans and activities, including the City's Resiliency Program.
2) Establish a Utility Undergrounding Special Commission consisting of the Public Works Commission, Transportation Commission, the Disaster and Fire Safety Commission representatives, and subject matter experts as needed to oversee the preparation of the Undergrounding Plan. The Special Commission shall be a manageable size and composed similar to the commission that developed the downtown Street and Open Space Improvement Plan".

Background:

The history of undergrounding utilities in the United States is over 125 years old, it was after the Great Blizzard of 1888[1] that Manhattan decided to put all its infrastructure from power to water, to gas lines, steam and subways, all went underground, and at great cost at that time. A second notable example was the Galveston, Texas in 1900. As the largest city in Texas at the time, Galveston, was the Wall Street of the South, but was destroyed by a great storm on Sept. 8, 1900. The 8,000+ people killed by that storm, 20 percent of the island's total population, is still the largest single loss-of-life event from a natural disaster in U.S. history. Galveston built a 17-foot-high seawall that has protected the city from subsequent 44 hurricanes. But they also put all other vital infrastructure underground (natural gas, water, sewage and electricity telecom).

The California State Legislature in 1911 enacted laws to regulate erection and maintenance of poles and lines for overhead construction. Additionally, the "Municipal Improvement Act' of 1913 allowed for the financing of or acquisition of public improvements. This California State act is the enabling statue that municipalities use to construct and finance public works projects.

The history of undergrounding of overhead utility wires for older cities in the US is varied in its funding approach but mostly characterized by the incompleteness of efforts to fully experience the attributes and benefits of utility wire undergrounding. Currently utility customers in California pay about a dollar a month for a program that is supposed to bury all wires. (The amount that is in PG&E's energy bill is to fund undergrounding that has already been completed.)

This ratepayer charge is based upon the California Public Utilities Commission action on September 19, 1967, as a result of their Case No. 8209. The California Public Utilities Commission (CPUC) adopted a rule requiring electric and telephone companies to initiate and participate in an active program to underground utilities in areas of general public benefit.

[1] http://www.history.com/this-day-in-history/great-blizzard-of-88-hits-east-coast

European countries have much more of their power and telecommunications utilities undergrounded, as part of the post-WWII rebuilding and much like in the US where overhead wires are buried for new construction in the suburbs or special circumstances like the Oakland/Berkeley hill fires of 1991. Additionally, for example, there is an incentive for the State owned monopolies, like the French Post and Telegraph (now French Telecom) to see the long term view of the cost/ benefit of undergrounding utility wires. The "incident of repair" for buried utility wires during normal conditions is 47% lower. There are increased costs for construction to underground utility wires, which most current analysis sees as prohibitively expensive at $2-$4 (Should be $3-$5 million)a mile in urban areas, and repairs of utility outages do take longer in an undergrounded system2. However, these long term cost/benefits studies do not include the economic externalities, like business and individual loss of life and lost productivity, resulting from fire caused by the lack of tree trimming, snow/ice storms, earthquakes and other climate costs related to extreme weather phenomenon. Nor do these studies clearly address the time horizon for the payback period for their 'prohibitively expensive' judgments – 10, 20, 30, 50 or 100 years.

Understanding the consequences of undergrounding of utilities:

There have been a number of studies on the consequence of utility undergrounding by both private and public sources. They almost start out from the perspective that power outages over extended periods present major health and safety concerns and economic losses. According to a report by the Edison Electric Institute, "almost 70 percent of the nation's distribution system has been built with overhead power lines. "Over the past 15 years or so, however, "approximately half the capital expenditures by U.S. investor -owned utilities for new transmission and distribution wires have been for underground wires." Making such a conversion is rarely justified solely on the basis of costs. For utility companies, undergrounding provides potential benefits through reduced operations and maintenance (O&M) costs, reduced tree trimming costs, less storm damage, reduced loss of day -to-day electricity sales, and reduced losses of electricity sales when customers lose power after storms[3].

Potential Benefits of Underground Electric Facilities

An advocacy group called Underground 2020 summarizes the potential benefits of undergrounding as the following;

Advantages of underground lines include aesthetics, higher public acceptance, perceived benefits of protection against electromagnetic field radiation (which is still present in underground lines), fewer interruptions, and lower maintenance costs. Failure rates of overhead lines and underground cables vary widely, but typically underground cable outage rates are about half of their equivalent overhead line types.

Potentially far fewer momentary interruptions occur from lightning, animals and tree branches falling on wires which de-energize a circuit and then re-energize it a moment later.

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[2] http://www.ncuc.net/reports/undergroundreport.pdf

[3] http://www.underground2020.org/documents/Advantages%20of%20Undergrounding%20Utilities%20White%20Paper%2005-09.pdf

Primary benefits most often cited can be divided into four areas:

Potentially-Reduced Maintenance and Operating Costs

- Lower storm restoration cost
- Lower tree-trimming cost

Improved Reliability

- Increased reliability during severe weather (wind-related storm damage will be greatly reduced for an underground system, and areas not subjected to flooding and storm surges experience minimal damage and interruption of electric service.
- Less damage during severe weather
- Far fewer momentary interruptions
- Improved utility relations regarding tree trimming

Improved Public Safety

- Fewer motor vehicle accidents
- Reduced live-wire contact injuries
- Fewer Fires (Lake County, Ca just a current example)

Improved Property Values

- Improved aesthetics (removal of unsightly poles and wires, enhanced tree canopies)
- Fewer structures impacting sidewalks

Tangible Savings

The following chart, which summarizes the total benefits that the Virginia State Corporation Commission calculated Virginia utilities might realize if the state's entire electric distribution system were placed underground, shows tangible metrics for projecting savings to utilities. It shows an annual projected savings of approximately $104 million.

Cost Saving Item:	**$/Year**
Operations & Maintenance	no savings
Tree Trimming	$ 50,000,000
"Hundred-Year" Post Storm Rebuild	$ 40,000,000
Reduction in Day-to-Day Lost Electricity Sales	$ 12,000,000
Elimination of Lost Electricity Sales From "Hundred-Year" Storms	$ 2,000,000
Total	$ 104,000,000

Source: Virginia State Corporation Commission, January 2005, "Placement of Utility Distribution Lines Underground" Societal Benefits

The following summarizes some of the societal benefits, including enhanced electric reliability to the economy, reduced economic losses to customers due to fewer power outages after major storms, and reduced injuries and deaths from automobiles striking utility poles.

Cost Saving Item:	**$/Year**
Avoided Impact of Day-to-Day Outages	$ 3,440,000,000
Avoided Impact of "100-Year" Storm Outages	$ 230,000,000
Avoided Impact of Motor Vehicle Accidents	$ 150,000,000
Total	$ 3,820,000,000

The State of Virginia study, while not directly applicable, it does give us a template to use. We can substitute the "100-year storm" with know earthquake science that sees that every 35 years approximately the Bay Area experiences a greater than 6.0 quake. The risk is knowable the exact timing is uncertain.[4] Using a yearly per capita savings, based on the summary savings above, Berkeley can benefit from undergrounding of utilities by nearly $60 million annually.

The PG&E Program:

PG&E places underground each year approximately 30 miles of overhead electric facilities, within its service area. This work is done under provisions of the company's Rule 20A, an electric tariff filed with the California Public Utilities Commission.
Projects performed under Rule 20A are nominated by a city, county or municipal agency and discussed with Pacific Gas and Electric Company, as well as other utilities. The costs for undergrounding under Rule 20A are recovered through electric rates after the project is completed. Rule 20 also includes sections B and C. Sections A, B and C are determined by the type of area to be undergrounded and by who pays for the work.

Rule 20A

Rule 20A projects are typically in areas of a community that are used most by the general public. These projects are also paid for by customers through future electric rates. To qualify, the governing body of a city or county must, among other things, determine, after consultation with Pacific Gas and Electric Company, and after holding public hearings on the subject, that undergrounding is in the general public interest for one or more of the following reasons:

- Undergrounding will avoid or eliminate an unusually heavy concentration of overhead electric facilities.
- The street or road or right-of-way is extensively used by the general public and carries a heavy volume of pedestrian or vehicular traffic.
- The street, road or right-of-way adjoins or passes through a civic area or public recreation area or an area of unusual scenic interest to the general public.
- The street or road or right-of-way is considered an arterial street or major collector as defined in the Governor's Office of Planning and Research General Plan Guidelines.

[4] "The Signal and the Noise; Why So Many Predictions Fail -but Some Don't", Nate Silver, 2012

Rule 20B

Rule 20B projects are usually done with larger developments. The majority of the costs are paid for by the developer or applicant.
Undergrounding under Rule 20B is available for circumstances where the area to be undergrounded does not fit the Rule 20A criteria, but still involves both sides of the street for at least 600 feet. Under Rule 20B, the applicant is responsible for the installation of the conduit, substructures and boxes. The applicant then pays for the cost to complete installation of the underground electric system, less a credit for an equivalent overhead system, plus the ITCC (tax), if applicable. Berkeley has one 20B District - Thousand Oaks Heights

Rule 20C

Rule 20C projects are usually smaller projects involving a few property owners and the costs are almost entirely borne by the applicants.
Undergrounding under the provisions of Rule 20C is available where neither Rule 20A nor Rule 20B applies. Under Rule 20C, the applicant pays for the entire cost of the electric undergrounding, less a credit for salvage.

Rule 20 Process Flow

A cross-functional team that includes representatives from Pacific Gas and Electric Company, the phone and cable companies, local governments and the community at-large oversees Rule 20A projects. Projects are accomplished by:

- Identifying and reviewing potential projects
- Developing preliminary costs for the projects
- Refining associated boundaries and costs
- Coordinating the schedules of other public works projects
- Developing final project plans
- Passing a municipal underground resolution
- Developing an underground design
- Converting service panels for underground use
- Starting construction
- Installing underground services
- Completing all street work
- Removing existing poles from the project area

City of Berkeley's Undergrounding Efforts

Berkeley has a total of 237 miles of utility wires, with 86 miles or 36% of the total miles currently undergrounded and 151 miles or 64% remain aboveground. Arterials and Emergency access routes comprise 29% of the total 237 miles. Of the nearly 86 miles currently undergrounded 51% are Arterials and Emergency access routes – thus barely ½ of the Arterials and Emergency Access routes have been undergrounded out of the total that experienced undergrounding using statewide PG&E ratepayer 20A funds. Nearly 50% of the 20A undergrounding funds from PG&E funds have been allocated to residential streets or nearly $26(??) million of the total $65(??) million PG&E rate payer 20A funds that Berkeley received.

Undergrounding Districts Completed

1970s	1980s	1990s	2000s
Hearst (Freeway to 6th)	Oxford St (Hearst to University)	Ashby/Benvenue	Los Angeles/Mariposa
Sixth St (University to Cedar)	Sacramento St (Oregon to South City Limit)	Hearst Ave (LaLoma to Cyclotron)	Park Hills
Sutter/Henry St	Ajax PL/Hill Rd.	Grizzly Peak/Cragmont	Miller Stevenson
San Pablo Avenue	Kains/Cedar/Hopkins/Jones/Page	Vicente/Alvarado	Grizzly Peak/Summit (estimated completion date 2020)
Eastshore Highway (Hearst to Gilman)	Oakvale Ave (Claremont to Domingo)	MLK Jr Way	Vistamont/Woodmont (estimated completion date 2025)
Stannage Ave (Gilman to Hopkins)	LaLoma (Buena Vista to Cedar)	Woodmont Ave	
Buena Vista Way	Channing/Bonar	Hill Rd	
Camelia St. (Stannage to San Pablo)	West Frontage Rd (South to North City Limit)	Spruce Vassar	
Colby (Ashby to Webster)	MLK Jr Way (University to Hopkins)	Leroy/Euclid	
So. Hospital Drive (Ashby to Webster)	Amador Ave (Shattuck to Sutter)	Benvenue (Woolsey to Stuart)	
Telegraph (Bancroft to South City Limit)	Woodmont Ave Area	College /Hillegas	
	Hill Rd/ Atlas Pl	Cragmont	
	Spruce St/Vassar	Arlington Avenue (Marin Circle to City Limit)	
	Benvenue Ave (Ashby to Stuart)		
1970s	**1980s**	**1990s**	**2000s**

	University Avenue		
	Solana Avenue		

Districts Completed with Additional Funds other than PG&E Ratepayer 20 A funds

Shattuck/Adeline	BART
University Avenue	Caltrans, Private
6th Street	Redevelopment
Kains, etc.	CDGB
Bancroft Ave	UC
San Pablo	Caltrans

Districts formed since 1990:

- Number of Districts formed: 9
- Criteria for Selection: First come/first served based upon organization and initiative of citizens in local area/district
- Annual obligations committed to these Undergrounding districts can borrow up to 5 years in advance on PG&E ratepayer 20A funds

Rule 20A Districts in Berkeley as written by PWC in 2004

"Berkeley and Oakland were two cities who aggressively went after Rule 20A funds and formed a long queue of assessment districts in their areas. They convinced PG&E to bend the guidelines and use Rule 20A monies in residential neighborhoods where residents were more willing to pay for private connection costs ($2000+ per parcel).

When PG&E started to face their own problems (rapid demand caused by internet server farms & bankruptcy hearings) they began to refuse to deviate from the original criteria established by the CPUC under Rule 20. The first instance was PG&E's outright rejection of a proposed Rule 20A district in Oakland's Piedmont Pines neighborhood.

At that point, Berkeley still had a number residential districts approved by PG&E in queue and their Rule 20A monies committed years into the future. As a result, the City Council issued a moratorium on Rule 20A districts until a new policy for future Rule 20A monies could be developed.

Today there are still three residential districts which have paid their connection and street light costs, but are still waiting for PG&E to schedule construction.

1) Miller/Stevenson/Grizzly Estimated construction 2007-2008
2) Grizzly Peak/Summit To be scheduled
3) Vistamont (Woodmont) To be scheduled

Rule 20B -Most Residential Neighborhoods

- In December 2000, the City rolled out guidelines for neighborhoods interested in forming Rule 20B districts. Although many neighborhoods have expressed interest and continue to do so, only one neighborhood (Thousand Oaks Heights) actually formed a district which is now complete.
- Although cost estimates are being updated based on the experience of Thousand Oaks Heights, the estimates from August 2005 give you some indication. At that time the range was $25-$30k per household, not including the conversion costs on each parcel or $2.5k-$5K. In broad terms this translated into approximately $2000 annual costs added to county property tax bills. Of course, these costs would probably be a little higher today."

Moratorium established in 2000 on forming new districts until new criteria for forming districts:

Criteria developed passed unanimously by both the Public Works Commission and Transportation Commission in January of 2009

- It recommends that the Council reaffirm its December 19, 2000, to prioritize major arterial routes which were additionally emergency and evacuation routes, by adopting priority routes that meet the convergence of three criteria
- a major arterial route as designated by the General Plan
- major emergency/first responder/evacuation route as designated by the General Plan
- highest traffic volumes as determined by the Public Works/Transportation division

<u>This recommendation to Council was never agenized or acted upon by Council</u>.

<u>Current Situation - 2015</u>: These Districts were established between FY 1991 and FY 1992

- Berkeley Alameda Grizzly Peak Blvd "Engineering Phase"
- Berkeley Alameda Vistamont Ave "Planning Phase"

These two remaining Undergrounding Districts will not be completed until 2020 and 2025 respectively. Additionally, PG& E current allocation of 20 A funds for those districts being completed means that new 20A funds will not be available until 2025

Funding Decisions

Few alternatives exist for utilities themselves when it comes to financing the undergrounding of power lines; primarily through either rate increases or special charges to monthly utility bills. Conversely, jurisdictions have much greater flexibility and alternatives to consider in paying for undergrounding, for example:

- Charging a flat fee to all property owners within the jurisdiction;
- Create special districts within communities which could be added to monthly utility bills or tax bills;
- Community-financing through their operating budgets and General Obligation Bonds;
- Pooling monies from residents to pay for their own lines, or at least the portion that runs from the pole to their home meters;
- Implementing a small local tax on rooms, meals, liquor, and/ or retail sales;
- Using economic development, housing and community development, and other creative grant funding from resources such as the State Highway Administration, FEMA, and the State General Assemblies;

- Coordinate the timing and location with State and local infrastructure projects such as road, water, or gas line replacement to save on overall costs. [5]

All the above.

[5] Prepared by: Navigant Consulting, Inc., A Review of Electric Utility Undergrounding Policies and Practices March 8, 2005

APPENDIX 3

Comments and Questions from Commissioners

1. Inclusion of a street cross section diagram showing placement of trench, transformers, etc. compared to the public right of way and potential private land. This would not even have to have measurements just a crude diagram to help a laymen understand what the actual underground looks like.
   a. We have attached Figure 1 “Diagram of Typical Street Section Showing Underground Facilities in Commercial Area”
2. Please mention if Harris has come across in your research any cities that have had private organizations fund any portion of the undergrounding such as a telecom company funding it in coordination with replacement of their own infrastructure. If yes, expand a bit on how that worked out.
   a. There have been projects where PG&E has offered a credit to underground in lieu of an overhead relocation for a road widening, but not for maintenance. In this case, PG&E credited the City with the avoided cost of the overhead relocation. This does involve a great deal of coordination, so that the undergrounding does not interfere with the road widening project.
3. Include a table showing the time it takes per mile to underground on various street or topography types.
   a. We have attached typical schedules for 1 mile of undergrounding under Rule 20A and Rule 20B.
4. If possible, put some numbers to the potential cost savings in maintenance and power outage avoidance in the pro and con discussion.
   a. Harris does not have this information.
5. Summary totals for all areas where data is presented.
   a. Done.
6. Summary of new information about Rule 20 that is not available on the City's and PG&E’s websites and put Rule 20 discussion in appendix.
   a. In reviewing the rule, there is a new provision acknowledging “that wheelchair access is in the public interest and will be considered as a basis for defining the boundaries of projects that otherwise qualify for Rule 20A”.
7. Expanded discussion of the time frame to realistically complete undergrounding given various funding mechanisms (bonding, surcharge, combination, etc.)
   a. See schedules.
8. Totals miles and % of total residential of non-Arterial and Collector residential streets that already have been undergrounded and remaining total of residential streets to be undergrounded.

TABLE 1: Summary of Undergrounding Lengths and Costs				
Arterial Streets	**Length (Feet)**	**Length (Miles)**	**Estimated Cost**	**% Underground**
Total arterial streets	135,095	25.6	N/A	N/A
Total arterial streets undergrounded	66,015	12.5	N/A	49%
Non-residential arterial streets to be undergrounded*	14,830	2.8	$11,380,000	11%
Residential arterial streets to be undergrounded**	54,250	10.3	$31,550,000	40%
Total arterial streets to be undergrounded	69,080	13.1	$42,930,000	51%
Collector Streets				
Total collector streets	190,460	36.1	N/A	N/A
Total collector streets undergrounded	59,660	11.3	N/A	31%
Non-residential collector streets to be undergrounded*	23,275	4.4	$15,100,000	12%
Residential collector streets to be undergrounded**	107,525	20.4	$76,770,000	57%
Total collector streets to be undergrounded	130,800	24.8	$91,870,000	69%
Residential Streets				
Total residential streets***	832, 666	157.7	N/A	N/A
Total residential streets undergrounded	57,267	10.8	N/A	7%
Total residential streets to be undergrounded	775,399	149.9	N/A	93%

* Non-residential includes Zones M, C-DMU, C, and SP
** Residential includes Zones MUR and R
*** Residential Streets include all non-arterial and non-collector streets falling in multiple zones

9. Expand the discussion of PROS AND CONS OF UNDERGROUNDING (e.g., if it is high cost CON - what about safety and emergency situations and associated risk assessment costs). Does Harris have any expertise in this area?
   a. Harris does not have this expertise.
10. Create discussion on savings that can be accrued to the City when the City's Transportation Engineering and Paving Engineering are combined with Undergrounding Construction.

   a. While we do not have actual cost savings, combining paving projects with undergrounding would have several savings. Paving the street after an undergrounding project, would help to complete the cleaner aesthetics of the projects. The pole and wires would be underground and the newly paved street would help the street look new. The public's perception of the project would be improved, especially if the paving is performed directly after the undergrounding, instead of several years later. Related to the timing, if the paving were done after the undergrounding, the public would be inconvenienced less.

11. Can we figure out the percentage of street underground from the figures we already have? The Harris report specifies how many feet are already undergrounded and how many feet remain to accomplish, right?

    a. See summary Table 1.

12. Overall, I think the report is pretty good. It would be nice to have the map in a scalable digital format (AutoCAD or ARC-GIS type format preferably, but at least a vector based map rather than a low resolution raster format), but I assume that is not part of the contract.

    a. Thank you. Harris will provide 6 full size color copies and the CAD file.

13. On the map, and in the list of Arterials and collectors, Ashby Ave is not listed, and San Pablo is not listed. Even if this has to be dealt with through the State, these streets should be shown as Arterials.

    a. The map now includes Ashby Ave. and San Pablo as arterials.

14. The unfilled outlines designated for the proposed areas are shown in the map legend, but are not marked on the map.

    a. The map now shows the proposed areas as cross hatched.

15. Doing a Google inspection of MLK Jr. Way, the section at the south end of Berkeley to the Boarder with Oakland (actually, all the way to the bay) appear to already be undergrounded. Also the section of MLK north from Adeline to Ashby.

    a. This has been updated.

16. In the Undergrounding Planning Level Estimate charts, where are the zones (M, MR, CB, C, SP and R) defined? It would be nice to have this definition as part of the chart legend for those not intimately familiar with the City zoning maps.

a. The planning zones have been defined on the map and the estimate.

17. To be clear, the cost per foot (or mile) of undergrounding should include the cost to extend the conduits to the property line of each property. If this is not included, this should be clearly stated, and some estimate or formula should be provided, as this will ultimately be included in the cost to the city.

    a. The estimate does include the cost of the conduits from the main trench or splice box to the property line.

18. I am not sure where to fit this, but a discussion of the cost of connecting a house from the property line extension to the house itself should be discussed. Depending on current codes, this could include the cost of a pull box or the cost of a new service panel, the cost of the conduit, the cost of trenching, etc. Utility imposed rules not normally covered by code (for instance two-foot radius bends in two-inch conduit) should be noted. I would expect this cost (and the control of some of the specific details) would be the responsibility of the property owner.

    a. Since there are many variables in the cost of the service, we have included Table 2 below with the range of costs for commercial and residential services.

	TABLE 2: SERVICE CONVERSION COSTS FOR:	
	RESIDENTIAL (SINGLE FAMILY)	**Range of Costs**
A	Trench from property line to meter	$50-$100/foot
B	Conduits for electric, cable and phone	$6-$15/foot
C	Service Panel Conversion	$1500-$3000/each
D	Driveway restoration	$25-$50/foot
E	Landscape restoration	$10-$25/square foot
F	Trenching in steep slopes > 10%	$100-$200/foot
G	Drain box where meter is lower than sidewalk grade	$200-$400/each
	COMMERCIAL	**Range of Costs**
	Trench from property line to meter	$50-$100/foot
	Conduits for electric, cable and phone	$6-$15/foot
	Service Panel Conversion (Up to 400 amps)	$3000-$10000/each
	Driveway restoration	$25-$50/foot
	Landscape restoration	$10-$25/square-foot
	Trenching in steep slopes > 10%	$100-$200/foot

For example, the approximate cost to provide the trench, conduit and service panel conversion where the slope is greater than 10% for a residence would be: (B+D+E+F) x Footage +C =+/- $$$

19. Please provide a link to the details of San Diego's use of 20D funding and the San Diego utility lawsuit re: rate setting for 20D funds.

    a. Here's the link to Rule 20D

    http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-RULES_ERULE20.pdf

    and an article about the Rule 20 lawsuit. We didn't see anything specific to a Rule 20D lawsuit.

    http://www.sandiegoreader.com/news/2016/may/13/ticker-sdge-undergrounding-case-court/

Comments from Commissioner Bruzzone

1. Pages 3 and 4. I think I'd have a summary here that there are 35 miles of street to underground for 100%. Of that 35 miles, about 11 miles is on arterials and the remaining on collector streets.
A summary has been included on this version.

If I am doing the math right, the cost is $40 million for the 11 miles of arterial streets (about $3.6 million per mile) and about $90 million for the 24 miles of collector streets (about the same cost per mile).

I think if the costs per mile are unit costs, we should note that and note if there is a cost difference between arterial and collectors. *The unit costs have been noted.*

2. I'd like some discussion of any efficiencies we gain if we package all street rights-of-way improvements at once (i.e., sewer, water, gas, electric, telecom) along with repaving. This can be a range or a percentage.
We have included a limited discussion.

3. I'd like some discussion on what, in the future, needs to be directly connected to the building (house/office/etc.). I'm hearing that the telecom companies want to beam wireless into the residential units, eliminating that hard-wire link. Let's have a discussion on this (doesn't have to be a conclusion).
This is outside the scope of this study. It could be provided on a future phase.

4. If we don't need to have hard connections for telecom, how much does that save?
We can address this in a future submittal.

5. Thinking of which, the stated cost per mile (I believe) does not include the hard wire connection to the utility user. We should state that explicitly, and then give a range of what that cost would be (a range is fine, as I understand and appreciate Rocco's observation on the vastly different costs to provide access to the individual utility users).
We have provided items that would make up estimated costs per foot of the trench, conduit and service panel conversion.

6. Street lighting should be included in all estimates of undergrounding. Many streets (especially those around the University) are much to dark -- this is a public safety issue.
This is outside the scope of this study however, we could provide a unit cost to replace the street lights in a future submittal.

7. After listening to Rocco's comments, and the comments of the Subcommittee, I think we have a real opportunity to rethink the architecture of our utilities. On the energy side, with solar, we can work with PG&E and design the system to actually work for renewables -- i.e., storing power, islanding microgrids for both storage and for emergencies when the rest of the

gird goes down, etc. -- as well as recognizing that the telecoms may be changing their technology for access into the homes. If the study could include this as a sidebar someplace, I think that will be valuable.
This is interesting, but outside the scope of this study.

8. Some discussion of reliability increases that come with undergrounding -- including during an earthquake and the impacts of falling poles -- will also be valuable.
This is outside the scope of this study.

9. Finally, from my point of view, this work cannot be funded under the CPUC ratepayer program for a very long time, and, as is said, in the long-run we're all dead. We need to look at a citywide GO Bond -- or a series of bonds -- to get this done within at least some of our lifetimes. I think a broad discussion of developing an undergrounding program that coordinates with other utility and street infrastructure over a 20-year period, at a reasonable number of distances annually, will be our most effective way forward. We'll need to prioritize any program based on these coordinations and also based on important places to clear the wires from first (like fire stations!).
This is outside the scope of this study however, we could provide some discussion in a future phase.

CHAPTER IX

TYPICAL SCHEDULE

7/20/2016

Typical Rule 20A (approximately 1 mile, 100 parcels)

1 2 3 4 5 6 7 8 9 10 11 12 Varies (V) 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

+V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V 5+ +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V +V

Discuss with utilities	6 months
Create district boundaries	4 months
Pass Resolution	2 months
Allocation Available at $500k/year	varies
Engineering and Land	9 months
Construction and Procurement	12 months
Install service trench and conduits	3 months
PG&E installs underground facilities	5 months
Panel conversion and cut over (PG&E)	6 months
Phone installs underground facilities	3 months
Cut over phone	2 months
Cable installs underground facilities	3 months
Cut over cable	2 months
Install and cut over street lights	3 months
Remove Poles	3 months

Typical Rule 20B (approximately 1 mile, 100 parcels)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 34 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65

Fund preliminary estimate	4 months
Prepare preliminry estimate	2 months
Property Owner Petition	4 months
Fund detailed design and assessment engineering	3 months
Prepare detailed design, assessment engineering and identify needed easements	9 months
Bid construction project	3 months
Finalize assessment	3 months
Pass Resolution	2 months
Acquire bonds	2 months
Construction and Procurement	12 months
Install service trench and conduits	3 months
PG&E installs underground facilities	5 months
Panel conversion and cut over (PG&E)	6 months
Phone installs underground facilities	3 months
Cut over phone	2 months
Cable installs underground facilities	3 months
Cut over cable	2 months
Install and cut over street lights	3 months
Remove Poles	3 months

FIGURE 1

APPENDIX B

"A BENEFIT-COST AND SOCIAL EQUITY ANALYSIS OF UNDERGROUNDING UTILITIES IN BERKELEY, CA", DANIEL BRADWAY, MAY 2017

A Benefit-Cost and Social Equity Analysis of Undergrounding Utilities in Berkeley, CA

CITY OF BERKELEY

May 7, 2017

Prepared By:

Daniel Bradway

RICHARD AND RHODA
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EXECUTIVE SUMMARY

This report presents a benefit-cost analysis (BCA) of undergrounding utilities along remaining arterial and collector streets in Berkeley, CA. Utilities include power (which includes power for street lighting), telephone, Internet and cable TV. Currently there are 13.1 miles of arterial streets (51% of total) and 24.8 miles of collector streets (69% of total) that have not been undergrounded. The purpose of this report is to examine the economic efficiency of the undergrounding alternative compared to the status quo.

The content contained in this report is intended to support Phase 2 of the Berkeley Undergrounding Sub-Committee's Comprehensive Plan to underground utility wires along all arterial and collector streets in Berkeley. Phase 2 of the Plan, "Conceptualize the Undergrounding Program," seeks to understand the long-term benefits and costs to society. It builds upon the July 2016 Harris & Associates baseline report.

Twelve key economic impacts that would likely result from the undergrounding project were examined. The largest benefits are increased property values, avoided costs of power interruptions and avoided costs of vehicle accidents. The largest costs are construction costs, customer service conversions and risk of earthquake damage. Other Impacts, such as the value of improved ingress and egress routes for evacuation and emergency vehicle access are considered but not included. In line with the emphasis of public safety, impacts related to disaster preparedness are examined more extensively than others. Below is a summary of the included benefits and costs.

Benefits	
Property Values	$134,711,874
Avoided Costs of Fire Losses	$4,638,139
Avoided Costs of Power Interruptions	$55,731,760
Vegetation Management	$38,606,298
Avoided Costs of Vehicle Crashes	$52,317,895
Horizon Value	$21,384,838
Marginal Excess Burden of Taxation (MEBT) Year 39	$5,346,210
Total Benefits	$312,737,013
Costs	
Construction	-$136,552,400
Operations and Maintenance (O&M)	-$12,972,478
Customer Conversions	-$59,445,628
Risk of Earthquake Losses	-$43,050,609
Marginal Excess Burden of Taxation (MEBT) Year 0	-$34,138,100
Total Costs	-$286,159,215
Benefits + Costs =	**$26,577,798**

The base case net present value (NPV) amounts to $26,577,798, or approximately a 1.1:1 benefit-cost ratio (BCR). When the model is subjected to a Monte Carlo simulation to test the robustness of the results, the undergrounding project yields a positive NPV in 35.5% of trials, with a mean NPV of -$29,734,115. The variance in results from the base case is due to the 250% upper bound estimate of construction costs, a figure guided by historical example and expert opinion (City of San Francisco, 2015; personal communication, April 2017). Sensitivity analysis reveals that if construction costs exceed $162M, the project will likely produce a negative NPV.

Benefits and costs of the undergrounding project would not be experienced equally across stakeholder groups. Current homeowners who live along streets to be undergrounded stand to gain the most, with properties estimated to appreciate by 5% which represents approximately $54,760 per housing unit. This primarily benefits areas with high rates of homeownership like the Berkeley Hills. Residents along the Berkeley Flats have a higher rental-occupation rate so will experience much less gain. Utility companies will experience a net gain from the avoided costs of vegetation management, even though operations and maintenance (O&M) costs are expected to increase. Businesses will also gain from improved electrical reliability that comes with undergrounding. Taxpayers will bear most of the cost of the project.

The undergrounding alternative can be economically efficient for the city compared to the status quo, but much of the gains are not related to the stated purpose of the project (improved public safety and electrical reliability). Other alternatives should be considered and compared to the undergrounding project to achieve similar resiliency goals in the most cost-effective and equitable manner possible.

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1. INTRODUCTION

Electric power networks are particularly critical during natural disasters. Besides the direct impacts to residential and business consumers that may result from power outages, there are cascading effects: many other infrastructure also rely on power supply for their operation, such as water systems that require power for pumps and hospitals that require power for essential equipment. Sustained power outages can also cause a significant decrease in societal productivity (Sullivan, Mercurio, Schellenberg, & Freeman, 2015). Despite its importance, electric power networks are among the least reliable lifelines during natural disasters, routinely suffering severe damage and requiring substantial public resources to repair (Kongar, Giovinazzi, & Rossetto, 2016). Investing in a disaster-resilient electrical power infrastructure can break the costly damage, repair, damage cycle and ultimately save money.

1.1. Problem Statement. Public infrastructure that cannot withstand natural hazards represents a missed opportunity for societal gains. Inexpensive, fragile critical utility systems that fail during emergencies can ultimately cost many times more than it saves when considering larger societal costs, such as rebuilding, recovery and lost productivity (Rose et al. 2005).

1.2. Project Alternatives. The primary goals for the undergrounding program is to improve public safety and reliability of utility service during an emergency. This report examines the cost-efficiency of the program by conducting a benefit-cost analysis (BCA) of two policy alternatives:

1) The status quo, where the city maintains its current underground facilities (12.5 miles/49% of arterial streets and 11.3 miles/31% of collector streets). This is referred to as the status quo alternative.

2) Underground the remaining arterial and collector streets (13.1 miles/51% and 24.8 miles/69%, respectively). This is referred to as the undergrounding alternative.

Examining only two alternatives is done for analytic practicality and does not intend to suggest that there are only two alternatives available. There are various combinations of areas that can be undergrounded, as well as other hazard mitigation strategies that should be examined.

Many BCA's have been conducted to evaluate undergrounding programs. Most consider damages associated with routine weather events on the East Coast and in the Mid-West, such as rain, high winds, lightening and winter storms. Berkeley is unique to other areas studied in that the risk associated with "routine" weather events is relatively low, but risk of major disasters such as wildland-urban (WUI) fires and earthquakes (along with seismically-induced events like landslides, fault zone ruptures and liquefaction) is high. In fact, a M6.7+ earthquake and major WUI fire are *likely* to occur in Berkeley over the project useful life, although the effect of these events on overhead and underground systems is extremely difficult to predict. However, in the interest of comprehensiveness, I make rough order of magnitude (ROM) estimates with large uncertainty margins (+/- 50%) on the effects these events will likely have on underground and overhead systems. These estimates are based on a review of the literature on the performance of utility systems during fires and earthquakes, as well as the hazard profile in Berkeley.

1.3. Standing and Perspective. In this study, all Berkeley city residents have standing, that is whose benefits and costs are included. It is conducted from the perspective of society as a whole, not just the city government. That means that benefits and costs will be viewed holistically by monetizing impacts to society. In viewing benefits and costs through society's perspective, *it is possible that the city could experience a cost overruns but still yield a net benefit to society*.

1.4. Methodological Approach. Given the high degree of uncertainty associated with some estimates and the general support in favor of the undergrounding project, a deliberate effort was made to estimate benefits conservatively and costs on the high end. This approach is sometimes referred to as *a fortiori* ("from the stronger argument"). It is a way to confidently address large amounts of uncertainty by intentionally biasing against desired results. If assumptions bias benefits downwards and the analysis still yields a positive NPV, then *a fortiori* there will be positive net benefits under most other assumptions. This approach is done out of a desire for analytical integrity and to instill confidence in the results.

1.5. Time Horizon. The useful life of the undergrounding project in this analysis is 40 years, as estimated by Larsen (2016). The horizon value was calculated using the depreciated value method assuming a straight-line depreciation. The depreciation rate is 5%, based on an estimation by the Bureau of Economic Analysis (BEA) for electrical transmission, distribution, and industrial apparatus (Bureau of Economic Analysis).

2. ECONOMIC IMPACTS

This section explains the sources and calculations used to place dollar values impacts of undergrounding utilities along arterial and collector streets. All costs and benefits are measured against the status quo alternative to yield net benefits and costs.

2.1. Costs. The following section describes the costs of the undergrounding alternative.

2.1.1. Construction Costs. The cost of labor, equipment and supply of construction make up the largest expense in the undergrounding program. Research shows that underground utilities can cost 5 to 10 times greater than overhead systems (Hall, 2012).

Undergrounding construction cost estimates are taken from the Harris & Associates baseline study estimates for the city of Berkeley (2016). Harris & Associates based their estimates on current unit prices from utility underground projects that the firm had designed, using typical bid items including trench excavation, pavement resurfacing, basic utility conduits for PG&E, AT&T, and Comcast, street lighting, traffic control and mobilization to calculate a base unit cost for construction. The base unit cost was used as the baseline for medium level of difficulty streets, then added and subtracted 30% to the baseline to establish the high and low level unit cost. The estimate produced a baseline of joint trench construction costs based on current bid unit costs. The number of vaults and length of conduits needed for each utility was assumed and added a 25% contingency. The estimate does not include trenching on private property, service conduits, service panel conversions, cost of financing, engineering, construction management, and street lighting. In converting overhead systems underground, materials could possibly be salvaged that might offset some of the costs, but that is not included in this analysis (Hall, 2012). Construction costs accrue in year 0. The table below summarizes the cost of construction.

Construction Cost Estimates (2017$)			
	Distance (mi)	Cost per Mile	Best Estimate
Arterial (Non-Residential)	2.8	-$4,117,121.43	-$11,527,940.00
Arterial (Residential)	10.3	-$3,102,927.18	-$31,960,150.00
Collector (Non-Residential)	4.4	-$3,476,431.82	-$15,296,300.00
Collector (Residential)	20.4	-$3,812,157.35	-$77,768,010.00
Total	37.9	-$3,602,965.70	-$136,552,400.00
Source: Harris & Associates, Baseline Study for the Development of a Utility Undergrounding Program, July 22, 2016			

Past undergrounding projects have experienced significant cost overruns. In San Francisco, the 1996 utility undergrounding program was based on an estimated cost of $1 million per mile, yet actual costs of undergrounding averaged $3.8 million per mile, a 280% increase (City of San Francisco, 2015). During a meeting with the undergrounding subcommittee, an AT&T design engineer estimated a 200-300% cost overrun of the Harris & Associates estimates (personal communication, April 2017). Because of this, estimation parameters of -25% and 250% of the baseline estimate were used. Construction costs accrue at year 0.

2.1.2. Customer Conversion Costs. To convert an overhead to an underground utility system, individual customers incur a direct cost to have their electrical service connection point converted. For most customers, a conversion will require them to hire an electrician to replace the overhead meter base with an underground meter base. In some cases, additional work may be required to bring the customer's service up to the current electrical code requirements (Hall, 2012).

Harris & Associates also provided an estimate of private and commercial cost of conversion (2016). Each private customer can expect a conversion cost between $2,935 and $16,900 and a commercial customer can expect between $5,410 and $33,250. These estimates include trenching, conduits, drain boxes, service panel conversion as well as driveway and landscape restoration. Estimates of the amount of residential and commercial customers along streets considered for undergrounding came from census data (2010). The baseline estimate for customer conversions is $59,438,203. Conversion costs accrue in year 0. Below is a summary estimate of customer conversion costs.

Customer Conversion Costs (2017$)				
	Customer Type	**Estimate per Unit**	**# of Units**	**Total Estimate**
Undergrounding Alternative	Residential	$ 9,918	2635	$ 26,132,613
	Commercial	$ 19,330	1723	$ 33,305,590
Status Quo Alternative	Residential	$ -	2635	$ -
	Commercial	$ -	1723	$ -
Net Cost				$ 59,438,203

Source: Harris & Associates, Baseline Study for the Development of a Utility Undergrounding Program, July 22, 2016

2.1.3. Operations and Maintenance (O&M) Costs. From a review of the literature and existing data, it is not clear that routine O&M is costlier for underground or overhead utility systems. Peter Larsen, an expert in examining the economic impacts of undergrounding has commented on the lack of published evidence as late as 2016. It appears that underground utility systems are more resilient to common weather hazards such as rain and wind and have a lower outage frequency, but the duration of the outages tend to be substantially longer. This is because underground lines are more difficult and expensive to work on when problems arise (Hall, 2012). Damage is difficult to locate and access; routine repairs can require earth-moving equipment and specialized technicians (Entergy, 2008). Improved technology and training may increase underground maintenance efficiency in the future, but there is no readily available research that suggests that.

In line with the *a fortiori* approach, an upward-biased cost estimate was used. A state-wide study in Maryland was used which stated that per mile O&M costs twice that of overhead installations (Albeck & Estomin, 2003). Other studies have validated this estimate (North Carolina Natural Disaster Preparedness Task Force, 2003). I used Larsen's baseline estimation of annual O&M costs equal to 0.5% of the initial construction cost with an upper and lower bound of 0.2% and 0.9%, respectively and assumed overhead systems cost half as much to maintain (2016). It is likely that O&M costs incrementally increase over the project useful life, but for this analysis a constant rate is assumed. O&M costs accrue in years 2-39. The baseline estimate for O&M cost is $341,381, or $12,972,478 over the project useful life.

Operations and Maintenance (O&M) Costs (2017$)		
	Annual Estimate	**Estimate over Project Lifespan**
Undergrounding Alternative	$682,762.00	-$25,944,956.00
Status Quo Alternative	$341,381.00	-$12,972,478.00
Net Cost	$341,381.00	-$12,972,478.00

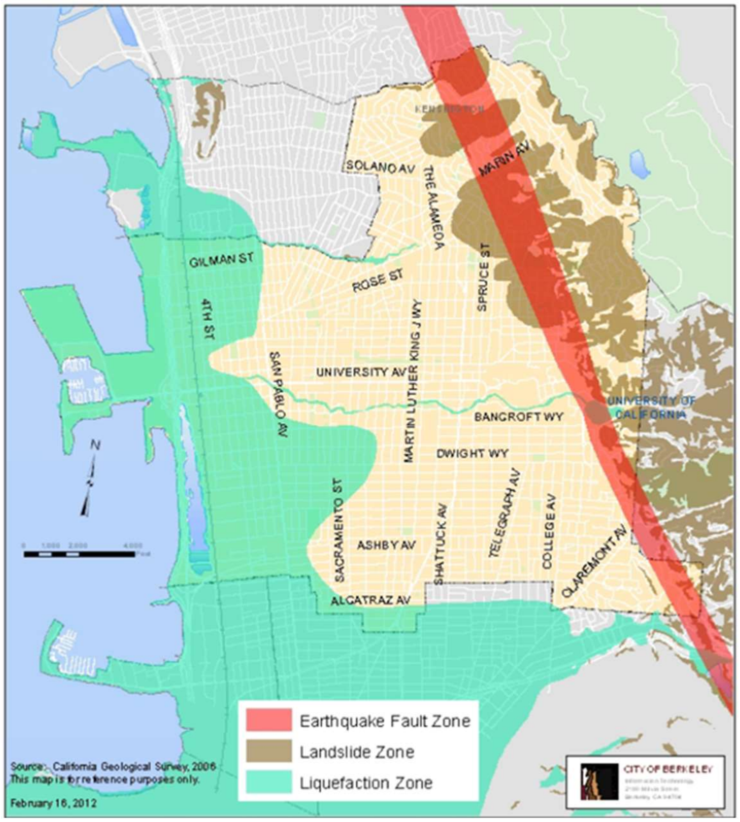
Source: Maryland State Highway Research Report - Cost Benefits for Overhead/Underground Utilities, 2003; Larsen, Peter, A Method to Estimate the Costs and Benefits of Undergrounding Electricity Transmission and Distribution Lines, 2016

2.1.4. Earthquake Costs. Seismic hazards pose the greatest risk to utility systems in Berkeley. As of 2008, there is a 64% chance that an earthquake of magnitude 6.7 or greater will strike the Bay Area over the next 30 years (City of Berkeley, 2014). To provide historical context, the 1994 Northridge earthquake in Los Angeles was a magnitude 6.7 earthquake and caused an economic loss of $42.6 billion dollars (2017$) (City of Berkeley, 2014).

Earthquake damage to critical lifelines such as electric power systems has substantial costs beyond the direct damages to the utility system. Electric power is essential to the continued functionality of emergency services and other lifelines such as water supply, fuel supply, wastewater treatment, and communications, and also plays a major role in economic vitality (Fujisaki, Takhirov, Xie, & Mosalam, 2014). The compounding impact a single malfunction has across multiple systems, sectors, and processes is sometimes correctly called “cascading failures” (ABAG). Quick restoration of electric power is critical to disaster response and recovery efforts.

There are three types of earthquake-induced ground failures that could occur in Berkeley and affect overhead and underground utility systems: liquefaction, surface fault rupture and landslides. Liquefaction is where loose soil saturated with water can behave like a liquid when shaken by an earthquake and is a hazard in the western area of the city. Earthquake induced-liquefaction could cause permanent ground deformations, surface fault rupture and landslides that would extensively damage both overhead and underground utility structures (City of Berkeley, 2014). A surface fault rupture could occur along the Hayward Fault, causing displacements of up to several feet and severely damaging overhead and underground utility lines, especially those running perpendicular to the fault (personal communication, April 2017). Lastly, landslides are also expected in the Berkeley Hills during the next earthquake, especially if the earthquake occurs during a period of high rainfall which can topple or break utility poles. Falling trees or collapsing structures can also damage overhead utility lines. Underground systems may be damaged as well, depending on the magnitude of the slide.

Berkeley Seismic Hazard Planning Map



A review of the available literature reveals that underground systems are especially vulnerable to liquefaction and fault rupture, where overhead systems performed comparably well. One report concluded that the main hazard affecting buried cables is liquefaction (Kongar et al., 2016). This is especially concerning, considering over 60% of Berkeley's total area is prone to liquefaction. Fujisaki et al. discussed underground vs. overhead utility performance in the Canterbury Earthquakes in Christchurch, New Zealand, which struck in a sequence of three significant events between September, 2010 and June, 2011:

> Buried electric transmission and distribution cables may be vulnerable to permanent ground deformation (PGD) resulting from liquefaction or landslide depending on the details of construction. Overhead transmission in contrast is generally very rugged. However, failures have been observed due to foundation failure such as landslide, or very high amplification of motions such as at the tops of ridges...During these earthquakes, above ground electric equipment and systems performed quite well. In the M7.1 event, the transmission system suffered minor damage including failed

> porcelain surge arresters mounted on the transformer radiators, and non-structural substation building damage...Damage to buried distribution systems was more significant largely due to liquefaction-induced ground displacement. The electric distribution systems serving Christchurch sustained serious damage to buried cables.

Kongar et. al. also state that "buried cable damage was found to be the most costly type of damage to the power system and the main reason for long outages after the February 2011 earthquake" (2016). These analyses suggest that the vulnerability of buried cables is primarily influenced by liquefaction and lateral spread associated with fault zones.

These reports also summarize other important considerations. Insulation material is a critical factor influencing cable fragility, with paper-insulated lead covered armored cables experiencing considerably higher repair rates than cross-linked polyethylene cables. The primary attribute used to classify cable typologies is the insulation material, which provides the structure to a cable that is susceptible to ground movements (Kongar et al., 2016). The primary mechanism of failure over underground systems in liquefaction zones is cracking of the slurry backfill from ground displacement, leading to widening at discrete locations, followed by shearing, compression, and buckling of the cable across the crack due to increasing and cyclic ground displacement (Fujisaki et al., 2014). Additionally, "design issues" are often cited as the cause of damages or failure, such as poorly detailed, improperly restrained, or unanchored equipment (Fujisaki et al., 2014).

Many collector streets that are planned to have utilities undergrounded are on or near the Hayward Fault. These included Cragmont Ave, Euclid Ave, Arlington Ave and others. Underground and overhead systems along these routes would likely suffer severe losses during a Hayward Fault plate shift. Based on experience from the Christchurch earthquakes, underground systems would likely suffer worse damage than an overhead system in a liquefaction zone, which covers approximately 2/3 of Berkeley's area (primarily along the shoreline). Overhead systems would also be much less costly and quicker to repair or replace.

It is very difficult to accurately model the performance of overhead and underground utility systems in the next earthquake. Loss estimation systems, such as FEMA's HAZUS-MH (Hazards U.S. – Multiple Hazards) model large scale impacts to society, including economic losses from direct, indirect and induced damages, but the system does not directly estimate losses of transmission and distribution lines. For this study, a rough order of magnitude (ROM) estimate was made to predict the damage done to both underground and overhead utility systems during a 6.7M Hayward Fault earthquake scenario. In both a liquefaction and fault zone, underground systems are estimated to experience 60% damage, whereas overhead systems would suffer a 40%. Assuming a 65% probability of occurrence over the 40-year project life cycle (2.13% annual probability) that equates to a net annual cost of $1,132,910, or $43,050,609 over the project useful life. Due to the high degree of uncertainty associated with these estimates, an upper and lower bound of +/-50% was used. Power outages are not included in this impact due to risk of double counting costs with the "improved electrical reliability" impact. Costs accrue year 2-39.

Earthquake Damage Costs (2017$)									
	Length Under Consideration for Undergrounding (Miles)	Estimated Cost per Mile	% covered by Liquefation Hazard	% covered by a Fault Zone	Est. % Loss	Total Estimated Repair/Replace Cost of Systems	Est. Annual Major Fire Probability	Total Annual Monetized Risk	Cost of Lifecycle
Status Quo	37.9	$ 596,533	33%	20%	40%	$4,793,025.24	2.13%	$102,251	$3,885,545.79
Undergrounding Alternative	37.9	$ 3,602,966	33%	20%	80%	$57,898,217.60	2.13%	$1,235,162	$46,936,155.07
Total								-$1,132,911	-$43,050,609

2.1.5. Marginal Excess Burden of Taxation (MEBT) Year 0. There will be a deadweight loss (DWL) from increased taxation to pay for the project. This DWL is a form of economic inefficiency. Construction and O&M costs will be drawn from tax revenue which reduces the standard of living among the taxed population by preventing them from buying what they otherwise would. According to guidance from the Office of Management and Budget (OMB), the marginal excess burden from taxation (MEBT) is 25% of total costs (1994). Therefore, an MEBT cost of $63,742,425 is incurred in year 0.

2.2. Benefits. The following section discusses the societal benefits of the undergrounding alternative. Benefits are assumed to start accruing at year 2, based on Harris & Associate's projection of how long the project will take to complete (2016).

2.2.1. Property Values. Undergrounding utility lines enhances the aesthetics of an area. Monetization of aesthetic improvement can be captured by observing the change in property values along streets that are undergrounded and those that are not, attempting to hold other property value variables constant.

There is no readily available research examining the change in residential property values caused by undergrounding in Berkeley. However, there are many studies that examine the effect powerlines have on property values, but conclusions vary. A meta-analysis of the effects of powerlines stated that prices of residential properties are determined by five interplaying factors: proximity to towers and lines, the view of poles and lines, the type and size of structures, the appearance of easement landscaping, and surrounding topography (Pitts & Jackson, 2007). When negative impacts are evident, studies report an average discount of between 1% and 10% of property value. This reduction in value is attributable to the visual unattractiveness of the lines, perceived health hazards and safety concerns. These impacts diminish as distance from the line increases. Research has also shown that the negative impacts on lots adjacent to or with a direct view of a utility line are greater than impacts on lots further from the tower. Where views of the lines and towers are completely unobstructed, negative impacts can extend up to a quarter of a mile (Pitts & Jackson, 2007). If the utility lines are covered from view by trees, landscaping, or topography, any negative effects are reduced (Pitts & Jackson, 2007).

A number of factors unique to Berkeley and the Bay Area should be considered when applying this research. The Berkeley Hills neighborhoods are widely-known to have exceptional views of the San Francisco Bay. It is likely that residents and buyers interested in living in the area value this view and are willing to pay a substantial cost to enhance it. Trees and vegetation in almost all of Berkeley are abundant but many times do not obstruct the view of utility lines. The density of homes and streets in the residential areas and sloping terrain in the Berkeley Hills make powerlines easily observable from relatively large distances. This makes it possible that undergrounding on one street would improve the property value in a large area around it.

For the purposes of this study, a price appreciation parameter between 2% and 9% is assumed with a baseline average of 5%. This is based on interviews conducted in 2007 of local realtors and appraisers in several central California communities: Discovery Bay near Brentwood, Summer Lake near Oakley, and Sierra View in Roseville, who estimated average price discounts of homes directly adjacent to powerlines (Pitts & Jackson, 2007). A Contra Costa County, CA government document also estimates an average appreciation of 5% (2012). Due to the current high home value price, a relatively small percentage appreciation would still represent a large increase in price. As of April 2017, Zillow's Home Value Index Price for homes in Berkeley is $1,095,200. A 5% increase to a home at that price represents an appreciation of $54,760.

Due to limitations of available data, analytical feasibility and the *a fortiori* approach, it is assumed that only homes directly adjacent to undergrounded lines would experience a property valuation increase. It is also assumed that property valuation will occur after project completion (year 2). Lastly, it is also assumed that there would only be an increase in owner-occupied residential homes and not businesses or rental-occupied homes, although it is possible.

The net increase in residential property values was calculated by estimating the number of owner-occupied units along streets to be undergrounded using the Harris Report and census data (2016; 2010). The estimated total value for property appreciation is $144,306,727 (before discounting).

Property Value Appreciation (2017$)				
	Estimated Owner-Occupied Homes Along Streets to be Undergrounded	Zillow's Home Value Index Price (Apr 2017)	Price Appreciation	Total Valuation
Undergrounding Alternative	2635	$ 1,095,200.00	5%	$ 144,306,727
Status Quo Alternative	2635	$ 1,095,200.00	0%	$ -
Net Benefit				$ 144,306,727
Source: Pitts, Jennifer and Jackson, Thomas, Power Lines and Property Values Revisited, 2007				

2.2.2. Vegetation Management. Tree trimming is a significant expense related to maintaining overhead utility systems (this is not captured in the O&M cost discussed earlier). This cost is bore by PG&E. One study estimates that tree trimming costs can range from $8,431 to $84,312 (2017$) per mile depending on the size and height of trees, the climate and annual rate of growth, the number of trees per mile, accessibility of necessary equipment, and whether the work is being done in rural or urban locations (Brown, 2007). Since Berkeley is relatively densely populated with trees, has a long growing season and is largely a built-up, the cost is likely to be on the higher end. However, the average between the two figures was used, which amounts to $50,587 annual cost per mile. This equates to $1,917,247 for all streets considered under the undergrounding alternative and $72,855,397 over the project useful life (before discounting). Underground utility systems are assumed to directly incur no cost for vegetation management. Benefits accrue years 2-39.

Vegetation Management Cost (2017$)			
	Est. Tree Trimming Cost per mile	Est. Tree Trimming Cost for remaining Arterial and Collector Streets	Est. Cost over Project Lifecycle
Underground Alternative	$ -	$ -	$ -
Status Quo Alternative	$ 50,587	$ 1,917,247	$ 72,855,397
Net Benefit			$ 72,855,397
Source: Brown, Richard, Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion, 2007			

2.2.3. Avoided Costs from Vehicle Accidents. Collisions with fixed objects such as utility poles are a major cause of vehicular accidents. According to a National Highway Traffic Safety Administration (NHTSA) report, 3% of all property damage caused by vehicular accidents is attributed to crashes with poles, along with 3.1% of injuries and 4.3% of fatalities (2014). Undergrounding utility lines along arterial and collector streets would likely reduce the frequency of vehicular accidents.

Vehicle accidents cause direct damage in terms of property damage and medical costs as well as indirect economic and social costs. An NHTSA report studied the comprehensive long-term effects of vehicle accidents (2015). The report discusses the cost of vehicle accidents to society:

> The value of societal harm from motor vehicle crashes, which includes both economic impacts and valuation for lost quality-of-life, was $836 billion in 2010. Seventy-one percent of this value represents lost quality-of-life, while 29 percent is economic impacts. The lifetime comprehensive cost to society for each fatality is $9.1 million. Eighty-five percent of this amount is attributable to lost quality-of-life. Each critically injured survivor has comprehensive costs that average of $5.6 million. Lost quality-of-life accounted for 82 percent of the total harm for this most serious level of non-fatal injury.

The report goes on to discuss who bears the costs of vehicle accidents:

> Approximately 7 percent of all motor vehicle crash costs are paid from public revenues. Federal revenues accounted for 4 percent and States and localities paid for approximately 3 percent. An additional 1 percent is from programs that are heavily subsidized by public revenues, but for which the exact source could not be determined. Private insurers pay approximately 54 percent of all costs. Individual crash victims pay approximately 23 percent while third parties such as uninvolved motorists delayed in traffic, charities, and health care providers pay about 16 percent. Overall, those not directly involved in crashes pay for over three-quarters of all crash costs, primarily through insurance premiums, taxes and congestion related costs such as travel delay, excess fuel consumption, and increased environmental impacts. In 2010 these costs, borne by society rather than by crash victims, totaled over $187 billion.

When the long-term, comprehensive impacts to society are considered, projects that even marginally improve traffic safety can yield substantial cost saving to society. In this analysis, I consider these long-term, comprehensive costs as outlined by NHTSA when estimating.

California Office of Traffic Safety (OTS) data for Berkeley was used to develop utility pole collision estimates (2014). NHSTA data was used to estimate injury probabilities from utility pole collisions along with Insurance Institute for Highway Safety (IIHS) data to determine probabilities of fatalities and injuries (2014; 2016). An exponential smoothing algorithm was then used to forecast values of pole-related injuries and fatalities under the status quo and undergrounding alternatives, assuming the rate of pole-related collisions would remain constant in relation to population growth. In 2017 alone, it is predicted that there will be 24 accidents involving utility poles that involve injuries or property damage in Berkeley.

The NHTSA categorizes injuries according to the Abbreviated Injury Scale (AIS), an internationally accepted tool for ranking injury severity developed by the Association for the Advancement of Automotive Medicine (AAAM). Below is a summary.

Abbreviated Injury Score		
AIS-Code	**Injury**	**AIS % prob. of death**
1	Minor	0
2	Moderate	1 – 2
3	Serious	8 – 10
4	Severe	5 – 50
5	Critical	5 – 50
6	Maximum	100

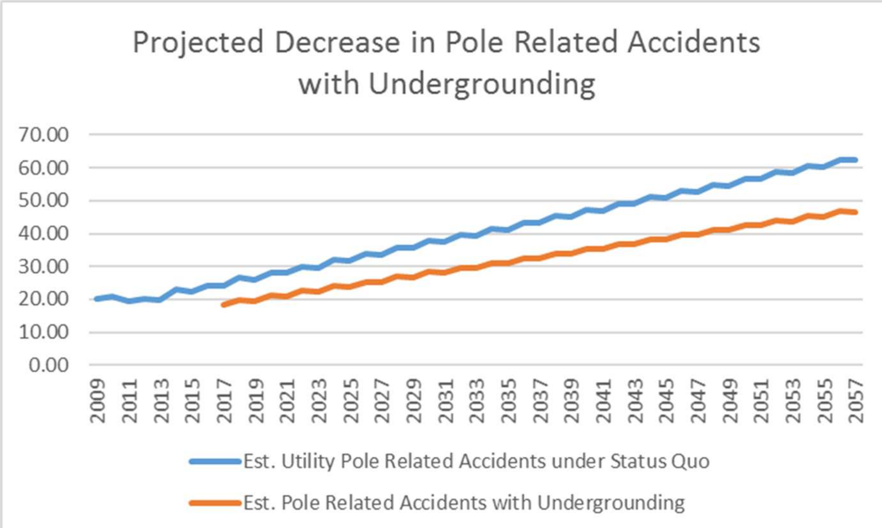
There is no information readily available that describes the percentages of injury occurrences associated with each AIS code, except for fatalities (AIS6). After reviewing NHSTA and IIHS literature, I estimated a conservative allocation of injuries per AIS code, with 72.65% of vehicular utility pole accidents producing property damage only (PDO) to the vehicle but no injuries. With the other AIS codes, I estimated a 10% to 1% percent of all crashes, diminishing as severity increased. Below is the summary table of the estimated comprehensive costs avoided from the undergrounding alternative.

Comprehensive Summary of Net Benefits from Avoided Vehicular Accidents with Undergrounding Alternative (2017$)									
	PDO Vehicle	AIS0	AIS1	AIS2	AIS3	AIS4	AIS5	AIS6	Total
Medical	$ -	$ -	$ 3,135	$ 12,827	$ 54,454	$ 152,675	$ 430,386	$ 12,675	$ 666,152
EMS	$ 31	$ 24	$ 100	$ 217	$ 466	$ 939	$ 958	$ 1,010	$ 3,744
Market	$ -	$ -	$ 3,053	$ 21,682	$ 72,059	$ 157,714	$ 378,120	$ 1,045,253	$ 1,677,881
Household	$ 67	$ 50	$ 965	$ 7,959	$ 25,411	$ 42,046	$ 106,856	$ 324,699	$ 508,053
Insurance	$ 214	$ 160	$ 3,694	$ 5,218	$ 17,216	$ 31,615	$ 81,228	$ 28,322	$ 167,667
Workplace	$ 69	$ 52	$ 382	$ 2,961	$ 6,469	$ 7,124	$ 12,422	$ 13,197	$ 42,676
Legal Costs	$ -	$ -	$ 1,324	$ 3,753	$ 13,890	$ 29,868	$ 92,635	$ 119,267	$ 260,737
Subtotal	$ 382	$ 286	$ 12,653	$ 54,618	$ 189,964	$ 421,981	$ 1,102,604	$ 1,544,423	$ 3,326,911
Congestion	$ 1,206	$ 851	$ 1,242	$ 1,341	$ 1,606	$ 1,692	$ 1,712	$ 6,406	$ 16,057
Prop. Damage	$ 2,737	$ 2,047	$ 6,052	$ 6,471	$ 12,188	$ 18,287	$ 16,903	$ 12,557	$ 77,244
Subtotal	$ 3,944	$ 2,899	$ 7,295	$ 7,812	$ 13,794	$ 19,980	$ 18,616	$ 18,964	$ 93,302
Total Economic Impact	$ 4,325	$ 3,184	$ 19,947	$ 62,430	$ 203,758	$ 441,961	$ 1,121,220	$ 1,563,387	$ 3,420,213
QALYs	$ -	$ -	$ 26,030	$ 381,777	$ 902,381	$ 2,281,981	$ 5,127,948	$ 8,676,732	$ 17,396,848
Comp. Total	$ 4,325	$ 3,184	$ 45,977	$ 444,207	$ 1,106,139	$ 2,723,942	$ 6,249,168	$ 10,240,119	$ 20,817,061
Percent of all Crashes	72.65%	10.0%	7.0%	4.0%	3.0%	2.0%	1.0%	0.37%	100%
Total Avoided Accidents	195	27	19	11	8	5	3	1	269
Total	$ 845,314	$ 85,654	$ 865,749	$ 4,779,663	$ 8,926,541	$ 14,654,808	$ 16,810,261	51200596	$ 98,168,585

Source: NHSTA, The Economic and Societal Impact Of Motor Vehicle Crashes (Revised), 2015

This table describes as the cost to society that overhead utility poles incur from to vehicular accidents. Because there would still be streetlights and other objects present along roads, I estimate that the undergrounding alternative would decrease pole-related vehicle accidents by 15%, with a lower bound estimate of 5% and an upper bound estimate of 25%. These benefits would accrue years 2-39. At the end of the project useful life, it is projected that 269 vehicle accidents, including 73 injuries and 1 fatality would be prevented, representing a total net benefit of $98,168,585 (before discounting). This estimate includes costs of property damage, emergency services, medical treatment, insurance and legal fees, as well as reduced quality of life year (QALY). The costs associated with possible lost electric service and repairs are not included for risk of double counting with the “improved electrical service reliability” impact. It is also assumed that project construction will not cause additional vehicle accidents.

The following graphs illustrate the projected decrease in accidents from undergrounding measured against the status quo alternative.



2.2.4. Avoided Wildland-Urban Interface Fire Costs. Berkeley is vulnerable to wind-driven fire starting along the city's eastern border. The fire risk facing the people and properties in the hills is compounded by the area's mountainous topography, limited water supply as well as minimal access and egress routes (City of Berkeley, 2014).

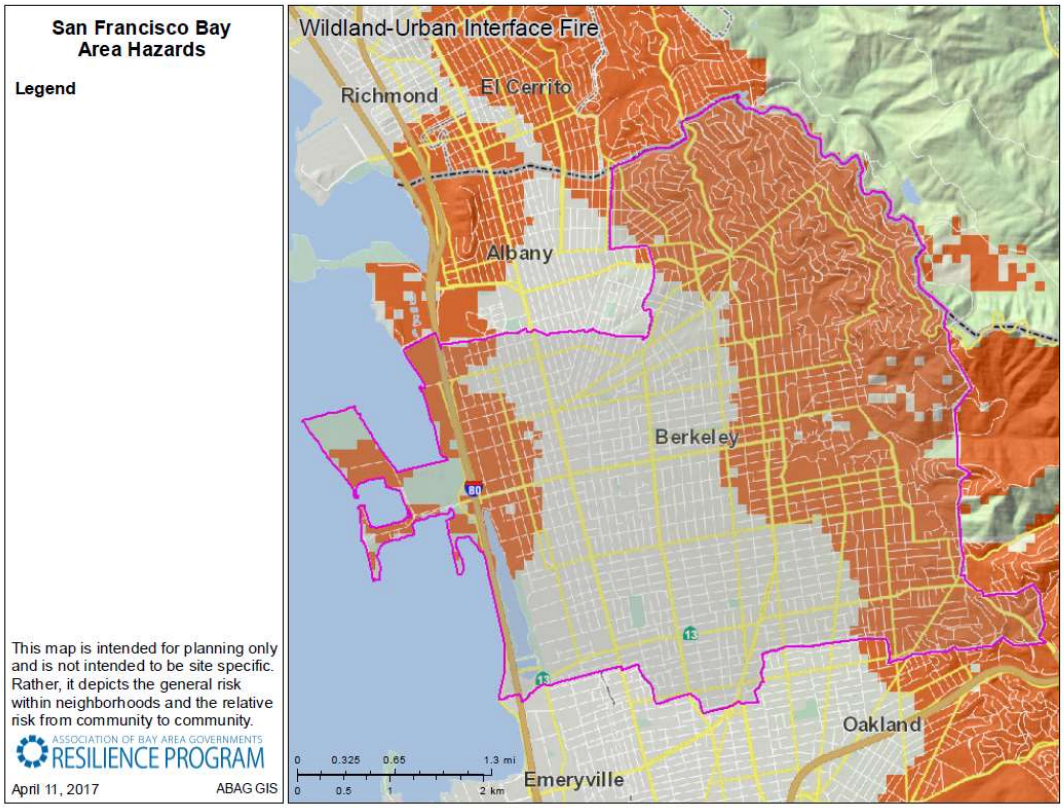
The high risk of wildland-urban interface (WUI) fire in Berkeley was clearly demonstrated in the 1991 Oakland Hills Firestorm (sometimes called the "Tunnel Fire"), which destroyed 62 homes in Berkeley and more than 3,000 in Oakland. Tens of thousands of people were evacuated from the hills area and 25 were killed (City of Berkeley, 2014). While the fire burned a greater area in Oakland, it raged across city boundaries between Oakland and Berkeley, destroying entire neighborhoods in both cities and remaining out of control for more than 48 hours. FEMA estimated the damage at $2.7 billion (2017$) and caused $3 million of damage to Berkeley's public Infrastructure, including burning power lines and melting underground services resulting in a loss of power early in the fire (1991).

The Oakland Hills Firestorm was not the only destructive fire to occur in the region. Below is a summary of the major historical WUI fires in the Oakland/Berkeley Area.

History of Major Wildland-Urban Interface (WUI) Fires in the Oakland/Berkeley Area		
Date	**Event**	**Damage**
9/17/1923	Berkeley Fire	568 Structures
9/22/1970	Fish Canyon Fire (Oakland)	39 Structures
12/14/1980	Wildcat Canyon Fire (Berkeley)	5 Structures
10/20/1991	Tunnel Fire (Oakland/Berkeley)	3,354 Dwellings; 25 lives lost
Source: City of Berkeley 2014 Local Hazard Mitigation Plan (LHMP)		

It is very difficult to quantitatively determine the probability and impact of the next WUI fire on overhead and underground utility systems. From the limited historical data above, these events occur an average of every 26.7 years. Additionally, climate change-related weather effects, such as a decline in annual rainfall and more frequent extreme heat days will increase the risk of WUI fire (City of Berkeley, 2014).

Despite the severe drought conditions that existed in the Bay Area from 2011-2017, it is possible that a major WUI fire has not occurred in the Oakland/Berkeley area recently because of a number of proactive fire hazard mitigation initiatives (USGS California Water Science Center, 2017). These include updated building codes and code enforcement, local amendments for new and renovated construction, vegetation and other fuels management programs, increased fire inspections and improvements in the disaster-resistance of the natural gas delivery system. The Berkeley Fire Department has also maintained a high state of readiness with 7 stations open, made possible through the Fire Protection and Emergency Response and Preparedness Tax, passed by Berkeley voters in November 2008. The revenue from this tax is used to keep fire stations open, improve and expand paramedic services and medical service response, improve disaster preparedness in the community, and invest in a unified communication system that allows police and firefighters to better coordinate with other agencies (City of Berkeley, 2017). Despite these efforts, the City of Berkeley still describes the current threat of a WUI fire as “very likely” (City of Berkeley, 2014). The map below illustrates the area of moderate-severe fire threat.



Not only are overhead utility systems susceptible to fire damage, they can cause fires. One report describes several ways which overhead utility lines can cause fires:

> Large bird droppings can build up on insulators to the point that a flash-over between conductors and the cross-arm can occur. This situation can cause a line fault and glowing debris to fall to the ground. Second, during take-off or landing, large birds' wings can touch two conductors simultaneously and create a short circuit. This situation can cause the bird to fall to the ground, sometimes in flames, and ignite dry vegetation below the conductors…Small animals resting on transformers in substations or on power poles can also start fires by causing short-circuits when their bodies come into contact with both transformer bushings…Other conditions that may lead to potential fire problems are damaged hardware, damaged insulators, weather- or bird-damaged poles, and broken strands on conductors (CPUC, 2008).

Additionally, diablo winds often cause power lines to arc or short out, causing sparks rain down on dry grass and brush (FEMA, 1991). Fire records maintained by the California Department of Forestry and Fire Protection ("Cal Fire") show that power lines are currently responsible for about 3% of all ignitions within their jurisdiction in California (Mitchell, 2009). In an extreme example, half of the catastrophic October 2007 Southern California fires have been attributed to power lines (Mitchell, 2009).

There is currently no comprehensive study on the effect fire has on overhead or underground utility systems, but a review of available literature illustrate their performance during fire events. The poles of overhead systems are a source of fire fuel and burning poles are prone to toppling, blocking emergency access and evacuation. A FEMA report documenting the Oakland Firestorm describes the issues with overhead systems:

> The power began to fail early in the fire, as wooden poles burned, lines dropped, and transformers exploded…[another] phenomenon that was observed at this fire was the ignition of the tops of wooden power poles ahead of the fire. The tops of the poles were high enough to project into the thermal layer and were ignited by convective heat transfer over the heads of firefighters working below. This suggests that the firefighters were working in an area that was being preheated by radiant heat transfer from the superheated gases above, as well as from the approaching flame front…In some areas, firefighters simply ran out of water, as there was no power to refill the emptied reservoirs (1991).

According to the Berkeley Local Hazard Mitigation Plan (LHMP), underground cables are vulnerable to melting, but it is not clear under what conditions (2014). Information documenting the performance of underground utility systems in a major fire event could not be found, but it is likely that aside from melted wires in certain areas, there would be no or minor damage to the underground system itself.

From the available materials, it is evident that a WUI fires damage overhead utility systems to a significantly greater degree than underground systems. Due to the enhanced fire mitigation measures in place, I estimate the annual probability of another major WUI fire is 1/40 (3% annual risk) instead of the historical average of 1/22.6. This means that another major fire is likely during the project useful life (40 years). The increased likelihood of fires from overhead systems is not included in this analysis.

To estimate the damage to overhead systems, I multiplied Harris & Associates' figure of total distance of above ground systems along arterial and collector streets (37.9 miles) with the total fire hazard area identified by ABAG (approximately 60% of the total area of Berkeley). It is assumed that 80% of the above ground systems would be destroyed in that area. I used the EEI's estimation average for constructing new overhead utility systems in an urban area, adjusted to 2017 dollars ($596,533 per mile). The total estimated cost associated with overhead systems in this fire scenario is $10,852,128. Multiplied by the estimated annual fire probability of 3%, the total annual risk expressed monetarily is $271,303.

Next, the damage to underground systems in the same WUI fire event scenario is estimated in the same manner. Assuming that only wires would be damaged and that the cost to replace or repair would be 2% of replacement costs, applied to a 3% probability is $40,996 of annualized risk, or $1,556,697 over the project useful life. This result is an annual net benefit of undergrounding of $230,337 annually, or $8,752,825 over the useful life of the project (before discounting) with an upper and lower bound estimate of +/-50%. Benefits accrue year 2-39.

Avoided Costs of Fire (2017$)								
	Total arterial and collector streets to be undergrounded	% of Berkeley covered by a Moderate-Severe Fire Hazard	Cost per Mile to Replace	Est. % Destroyed in Moderate-Severe Fire Hazard Area	Total Estimated Replacement Cost	Annual Probabilty of Major Fire	Total Annual Monetized Risk	Risk over Project Useful Life
Status Quo	37.9	60%	$ 596,533	80%	$ 10,852,128	3%	$ 271,303	$ 10,309,522
Undergrounding Alternative	37.9	60%	$ 3,602,966	2%	$ 1,638,629	3%	$ 40,966	$ 1,556,697
Net Benefit							$ 230,337	$ 8,752,825

There are a number issues with this estimate that could be improved on in future studies. First, the estimations for the probability of major WUI fire occurrence and percent of overhead systems destroyed are ROM estimates based on a review of available literature. Second, it does not take into account the cost of removing the destroyed systems during recovery. Third, it only estimates direct damage from the fire scenario and assumes that fallen utility lines will not be directly responsible for injuries or fatalities (the impact of fallen utility poles on ingress/egress routes is discussed later). Forth, the current age of above ground systems is unknown so there is no lifecycle discounting. The first, second and third issues introduce a downward bias and the forth issue introduces an upward bias. Taken collectively, there is a downward bias in the benefits estimation, which is in line with the report's *a fortiori* approach.

2.2.5. Improved Service Reliability. An initiative by the Electric Power Research Institute (EPRI) and the Electricity Innovation Institute (EII) suggests that across all business sectors, the U.S. economy is losing between $145 billion and $228 billion (2017$) annually to electric power outages and power quality disturbances (Commonwealth of Virginia State Corporation Commission, 2005). A significant portion of these economic losses are due to interruptions affecting loss productivity in business sectors. Estimates of costs per a minute without power for medium to large businesses range from $1000 to $5000

(Sullivan et al., 2015; Disaster Recovery Preparedness Benchmark, 2014). According to one survey, 73% of businesses are unprepared for a substantial power outage (Disaster Recovery Preparedness Benchmark, 2014). Power outages can result in inconvenience and economic hardships for residential consumers as well.

Studies of existing overhead and underground distribution systems demonstrate that underground systems are more reliable than overhead systems during both normal and severe weather conditions (Hall, 2012). Underground utility systems experience substantially fewer outages, however the outages that do occur are for a longer duration. According one study, during five-year period underground distribution systems in North Carolina experienced 53% of the number of interruptions per mile as overhead systems during normal weather conditions, but it took 58% longer to repair and might involve digging up a front yard, sidewalk, or street (North Carolina Natural Disaster Preparedness Task Force, 2003). However, estimating any improvement to service reliability is still difficult due to the highly-interrelated nature of electrical utility systems. Customers in an area with undergrounded utilities may experience outages due to damage to an overhead transmission lines in other areas.

To estimate the societal benefits of improved service reliability that would occur from undergrounding, a Virginia State Corporation Commission Study was used. The study estimates annualized reduction in day-to-day lost electricity sales for utility companies as well as societal benefits from avoided losses to productivity for residents and businesses from undergrounding all utilities in the state. The statewide estimate of societal losses due to lost electricity sales and avoided day-to-day impacts was adjusted to 2017$ and scaled to Berkeley's population and proportion of utility lines under consideration for undergrounding. The annual net benefit is $2,767,724, or $103,872,402 net benefit over the project useful life (before discounting). Benefits accrue years 2-39.

This estimate is likely very conservative. Virginia has large rural areas, as opposed to Berkeley's high density of medium to large companies that are technologically sophisticated as well as a major research university. However, this is the best estimate that could be found, and it is in keeping with the *a fortiori* approach.

2.2.6. MEBT (Year 39). The horizon value of the project means that there is a MEBT benefit associated with the salvage value of the materials used in the undergrounding project. This is 25% of the horizon value and is $ $5,346,210 and appears in year 39.

2.3. Other Impacts. The following are additional potential impacts of the undergrounding alternative, but are negligible, difficult to monetize, and/or affect population with no standing. This section is intended to inform decision makers of some of non-economic aspects of the undergrounding alternative.

2.3.1. Improved Ingress/Egress Routes. Undergrounding utility lines would improve ingress and egress routes during an emergency, such as a fire or earthquake. Overhead utility systems can topple and present electric hazards to evacuating personnel and emergency responders. During an earthquake, residents' injuries may worsen due to a delayed response. During a fire, people attempting to evacuate who are stuck in traffic can be exposed to intense heat and smoke inhalation. In the Oakland Hills fire, most of the 25 people killed in the blaze died attempting to evacuate (City of Berkeley, 2014). Those who did escape but were exposed to extended periods of smoke inhalation could suffer long-term health effects that can degrade quality of life years (QALYs) and incur medical costs.

According to reports, fallen utility lines undoubtedly disrupted evacuation and response efforts. However, the effect of fallen power lines is difficult to isolate from the effects of reduced visibility, vehicle accidents, narrow/winding roads and general confusion and disorientation. It is therefore problematic to attempt to monetize the impact of improved trafficability from undergrounded utility lines and so will not be included in the BCA. But because of the emphasis of public safety, a qualitative description of the effects downed powerlines in emergency response and evacuation has been included. The following is an excerpt a California Office of Emergency Services (Cal OES) report describing the effect of utility poles during the fire (1992):

> The fire was in a mountainous area with limited access. Most of the roads leading into the fire area were narrow and winding, and many terminated in cul-de-sacs. In some cases, fire apparatus could not pass one another on the same road. Around large apartment complexes, where roads were considered to be fully adequate, traffic jams resulted from the mass of people moving to a safe area. Downed power lines significantly impeded evacuation efforts. In some cases, fire apparatus and private vehicles were trapped in areas for several hours. Smoke severely limited vision and further complicated any movement in the fire area. Those conditions, coupled with the fact that many fire personnel from out of the area were not familiar with the complex road system, caused a number of people to become disoriented and lost in their attempts to evacuate or find their next assignment. (Cal OES, 1992)

One particularly notorious street was Charing Cross Road in Oakland, just southeast of the Berkeley border, where five residents and Oakland Police Officer John Grubensky were killed. It appeared that the cars were jammed at a narrow point part of the road, and the occupants were unable to escape the advancing flames (FEMA, 1991). It is possible that these fatalities occurred because of blocked traffic caused by reduced visibility (less than 20 feet), winding routes and fallen utility lines (East Bay Regional Park District, 2017). According to one account, “power lines [were] five feet above the road, bobbing slowly up and down” (East Bay Regional Park District, 2017). Advanced age and disabilities may have prevented the victims from escaping on foot.

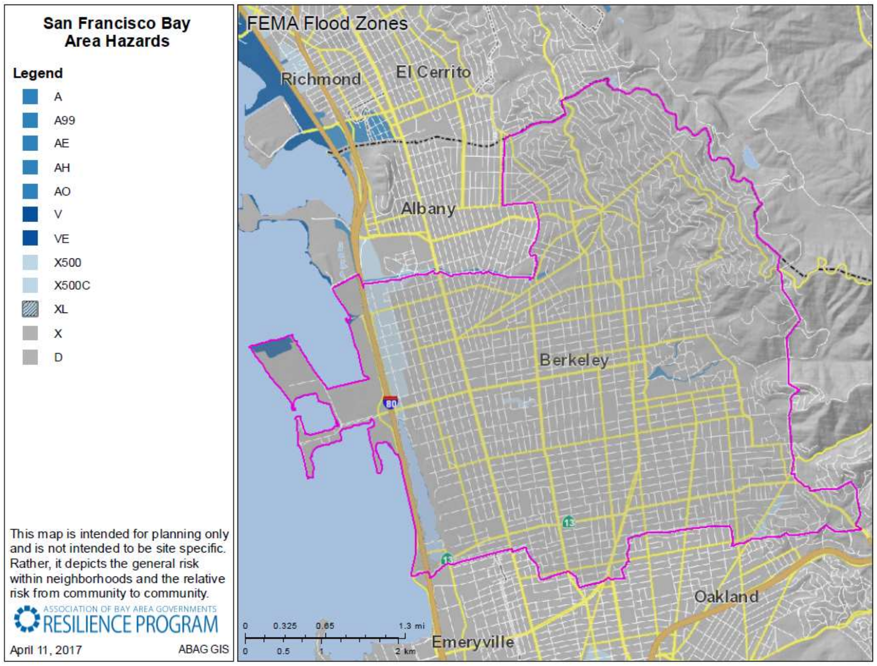
However, in relating the experience of the Oakland Hills Fire on the effect powerlines may have during a fire today, several things should be considered. Fire mitigation efforts that were mentioned earlier will likely reduce the severity of the next WUI fire. Also, the City of Berkeley has partnered with the Berkeley Path Wanderers Association to maintain and improve the rustic paths in the hills, which serve as pedestrian evacuation routes (City of Berkeley, 2014). Berkeley also maintains signage to identify and provide safe and accessible pedestrian evacuation routes from the hill areas, updating maps of all emergency access and evacuation routes to include pedestrian pathways and coordinating with UC Berkeley and Berkeley Lab to ensure that evacuation route options account for paths on UC and Berkeley Lab (City of Berkeley, 2014).

2.3.2. Tsunami Damage. Given the known history of tsunamis within the San Francisco Bay, tsunamis are considered possible, but the risk in Berkeley is considered low (City of Berkeley, 2014a). Because of Berkeley’s sloping terrain and the Bay’s waters at their current levels, tsunami inundation will not extend far inland from the shoreline.

Berkeley Tsunami Inundation Zone

2.3.3. Flood Damage. Berkeley's flood risk, both coastal and riverine pose a low threat to underground and overhead utility systems. The one area of moderate risk (shaded in blue in figure the map below) comprises Ceasar E. Chavez Park and does not contain utility systems or related equipment (Harris & Associates, 2016). The rest of the city, due to its increasing elevation moving eastward has a risk of X or D, described by FEMA as an area of minimal or undetermined flood hazard as depicted in FEMA's Insurance Rate Map (FIRM). In addition, even though the City of Berkeley maintains its participation in the National Flood Insurance Program (NFIP), it classifies the overall risk of flooding as low (2014). The risk of sea-level rise associated with climate change will increase the zone of potential inundation, but this is a limited concern during the project lifecycle (City of Berkeley, 2014a). For these reasons, flood risk is not included in the BCA.

Berkeley Flood Zones Map



2.3.4. Electromagnetic Field Radiation. Some people believe that the electromagnetic field (EMF) poses a human health hazard. However, the World Health Organization (WHO) reports that after a recent in-depth review of the scientific literature, current evidence does not confirm the existence of any health consequences from exposure to low level EMF, such as that emitted from utility systems (2016). The fear of EMF may have an economic impact of property values close to overhead utility systems, and this impact is possibly captured in housing prices.

2.3.5. Increased Pedestrian and Bicycle Traffic. Improved aesthetics from lack of overhead utility wires may inspire more pedestrian and bicycle activity. This could improve health, lower downstream medical costs and increase overall quality of life. However, it could also cause more collisions with vehicles and/or motorcycles. Due to lack of data to substantiate these claims, this impact is left out of the BCA.

2.3.6. Inconvenience Due to Construction. Project construction will cause increased commute times and increased noise levels, posing an inconvenience for residents. Construction may also cause vehicular accidents. However, hese impacts are difficult to monetize, so they are left out of the BCA.

2.3.7. Safety. According to Larsen, "replacing a large amount of overhead infrastructure with underground infrastructure will lead to relative increase in risk to utility operational staff working in the field" (2016). However, other sources suggest that undergrounding will ultimately reduce the risk to utility workers due to less vegetation management (Hall, 2012). For the purposes of this study, it is assumed that project construction will temporarily increase risk to workers, but underground utilities are relatively safer once installed, so any injuries or fatalities incurred during project construction might be offset. There is no readily available data on public injury rates caused by underground vs. overhead utility systems.

2.3.8. Ecosystem Impacts. Both overhead and underground electric utility infrastructure affect the natural environment around them. Wildlife, such as birds and squirrels, die by electrocution from overhead utility lines, which may also cause a power outage. Collisions with power transmission and distribution lines may kill anywhere from hundreds of thousands to 175 million birds annually, and power lines electrocute tens to hundreds of thousands more birds annually (Larsen, 2016). Undergrounding lines may reduce mortality rates of birds, rodents, and squirrels and allow vegetation to grow more freely. However, the process of installing underground power delivery infrastructure could also disturb ecosystems and be subject to tree root infiltration and rodents infestation (Delaney, Tsay, & Mahnovski, 2013). Measurements of the economic value of an ecosystem is controversial, and since wildlife is not listed as having standing, it falls outside the scope of the BCA.

2.3.9. Urban Forest. Undergrounding utilities would allow trees along streets to grow more fully and naturally. An enhanced urban forest might bring a host of benefits, such as increased carbon sequestration, property values, safety, water and air quality and climate change mitigation (Most & Weissman, 2012). However, these impacts have not been sufficiently quantified to include in this study.

2.3.10. Finance Costs. The substantial cost of undergrounding would likely require the City of Berkeley to finance the project over long periods of time. For example, as of 2015 the City of San Francisco projects roughly 17 years before it can repay an advance and resume using 20A funds for undergrounding. Large-scale projects require financing with an interest rate. Since the method of financing the project is not yet known, it is left out of this analysis.

2.3.11. Reduced Flexibility for Upgrading and Reconfiguring Circuits. According to one expert, it is much easier to modify, extend, and add equipment to an overhead circuit when compared to an underground circuit (Brown, 2007). Operational and planning flexibility is more limited for underground systems. This is especially relevant in areas that are considering upgrades or future development.

2.3.12. Reduced System Life Expectancy. The life expectancy for overhead distribution equipment is typically assumed to be 50-60 years whereas the life expectancy for underground equipment is 30-40 years (Brown, 2007; Larsen, 2016). In this analysis, under normal conditions underground systems are expected to have a lifespan of 40 years, which is Larsen's estimate.

2.3.13. New Data Bandwidth. It is relatively cheap and easy for utility companies to install new cables on utility overhead systems. On underground systems, new telecommunications cables must also be buried which would incur a substantial cost. This may be a disincentive for phone companies, cable television companies, and broadband companies to add new bandwidth (Brown, 2007).

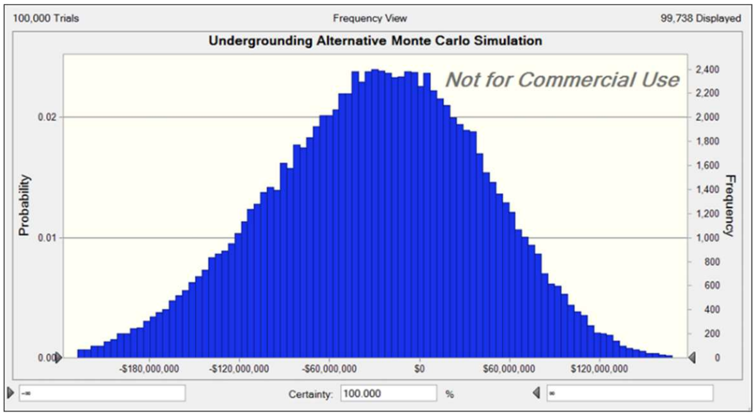
2.3.14. Underground System Damage due to Digging. It is possible that residents and businesses will damage underground systems by digging, which is typically only 2-3 feet below the surface. This could cause injuries or cause a power outage for nearby residents, both incurring an economic cost However, I could not any data on how often this occurs and what the impact has been, so it is not included.

3. ANALYSIS

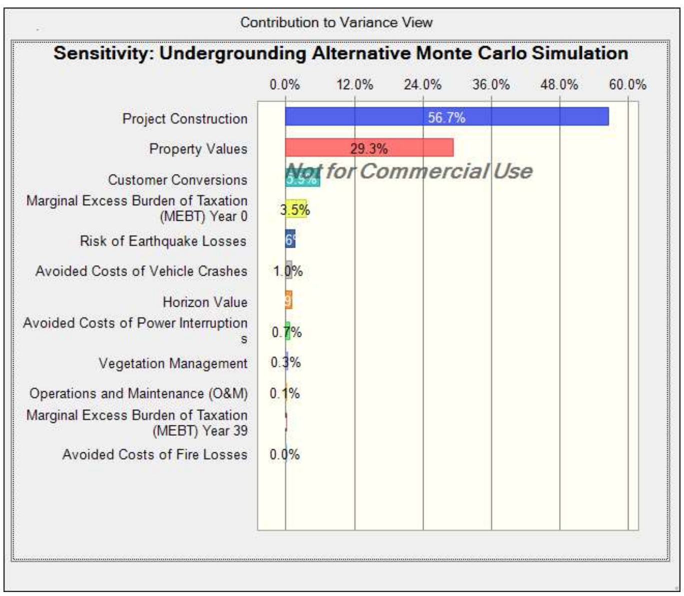
3.1. Social Discount Rate (SDR). In order to account for future inflation, a social discount rate must be used to compare projected costs and benefits in future years in current dollars. Discounting reflects the generally accepted idea that resources available at some future date are worth less today than the same amount given right now (Boardman, Greenberg, Vining, & Weimer, 2011). In this analysis, Boardman et al.'s recommended SDR for intergenerational projects of 3.5% is used.

3.2. Benefit-Cost Outcome. The net costs and benefits discussed were computed over the chosen 40-year time horizon. Using baseline estimates for each cost and benefit, the undergrounding alternative passes BCA by $26,577,798, which is a BCR of 1.1:1.

3.3. Monte Carlo Simulation. Given that parameters fall within a range of possible values, a Monte Carlo simulation was performed to test the robustness of the benefit-cost outcome. Using Oracle Crystal Ball software, 100,000 trials were performed where each parameter was allowed to vary according to distributions described in Appendix B. In the Monte Carlo simulation, the undergrounding alternative passes BCA 35.5% of the time and yields a mean NPV of -$29,734,115. In the best-case scenario, the project passes by $201,588,001. In the worst-case scenario, the project fails by -$286,719,023. The following histogram illustrates the distribution of the Monte Carlo simulation.



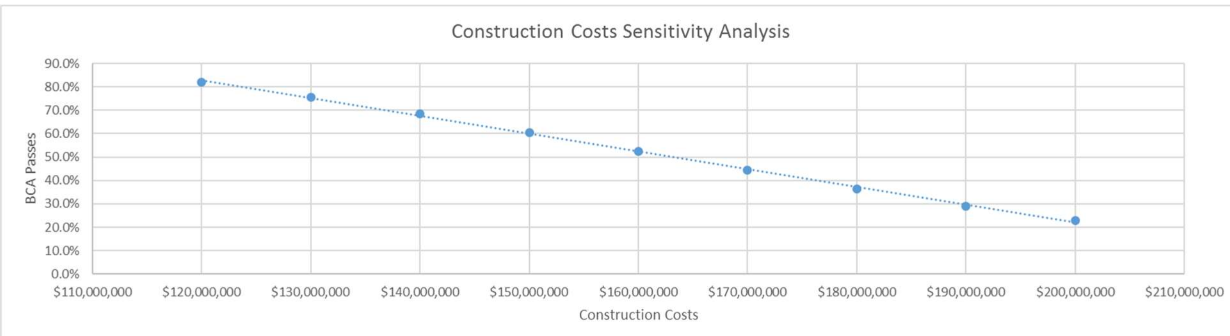
The poorer perfromance of the undergrounding alternative in Monte Carlo simulation is primarily caused by the large upper bound used to estimate project construction costs (+250%). The sensitivity chart indicates that construction costs account for 56.7% of the variance in the results.



To make sense of the the uncertainty associated with construction costs in the model, a second Monte Carlo simulation was run, this time with project costs held constant at the baseline estimate. In this scenario, 71.1% of scenarios yielded a positive net benefit, with a mean NPV of $66,746,786. This means that by controlling construction costs to baseline estimates, the chances of the project producing net benefits increase by 35.6%.

3.4. Sensitivity Analysis. To further explore the impact construction costs can have on the overall BCA outcome, a sensitivity analysis was performed with construction costs held at various specific numbers, while all other parameters varied. The following table and chart present results of the sensitivity analysis.

Construction Cost Sensitivity Analysis		
Construction Cost	**% BCA Passes**	**Mean NPV**
$120,000,000	82.0%	$44,100,548
$130,000,000	75.6%	$33,815,720
$140,000,000	68.5%	$23,913,194
$150,000,000	60.6%	$13,933,894
$160,000,000	52.5%	$3,808,058
$170,000,000	44.4%	-$5,971,787
$180,000,000	36.5%	-$16,133,818
$190,000,000	29.1%	-$26,008,419
$200,000,000	22.9%	-$36,656,065



The sensitivity analysis shows that if construction costs are $130M, there is a 75.6% chance that the undergrounding alternative will pass BCA. At $200M, there is only a 22.9% chance that it will pass. At a construction cost of $160M, the undergrounding alternative is still likely to pass BCA, with more than 52.5% of the trials yielding positive results and an NPV of $3,808,058. $162M is the upper threshold where BCA still passes in more than 50% of trials and yields a positive NPV, but anything exceeding that will likely fail BCA. Both the Monte Carlo simulation and sensitivity analysis tell us that for the undergrounding alternative to produce a positive net benefit for society, construction costs should be carefully controlled.

4. SOCIAL EQUITY CONSIDERATIONS

Berkeley is an economically and racially diverse city. Any major public investment, such as the undergrounding program, would inevitably benefit some groups more than others. An overview of key demographic information can help us better understand how different groups might be impacted by the undergrounding alternative.

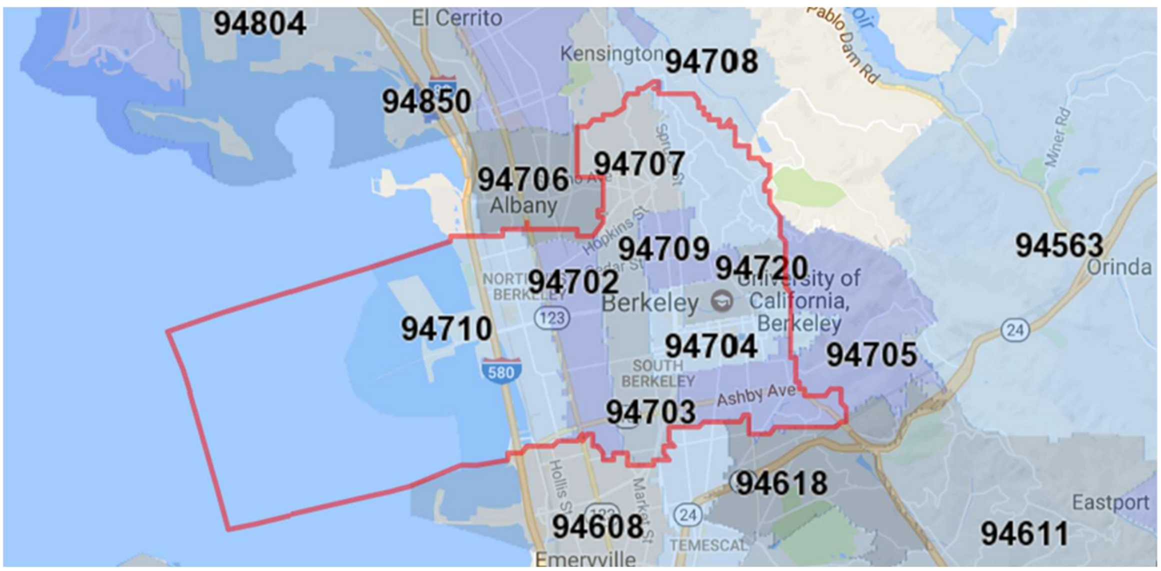
4.1. Distributional Outcomes. The distributional outcome table describes who will experience the benefits and who will bear the costs of the undergrounding alternative. Outcomes are organized according to four main stakeholder groups: homeowners, utility companies, taxpayers and businesses. There is overlap with the taxpayers group; all other groups are also taxpayers, but the group exists to represent those who will primarily fund the project but are not directly impacted by other costs and benefits. The table below shows the costs and benefits for each stakeholder group in the undergrounding alternative.

Distributional Outcomes (2017$)					
	Homeowners	**Utility Companies**	**Taxpayers**	**Businesses**	**Society**
Benefits					
Property Values	$134,711,874				$134,711,874
Avoided Costs from Fires			$4,638,139		$4,638,139
Avoided Costs of Power Interruptions				$55,731,760	$55,731,760
Vegetation Management		$38,606,298			$38,606,298
Avoided Costs of Vehicle Crashes			$52,317,895		$52,317,895
Horizon Value			$21,384,838		$21,384,838
Marginal Excess Burden of Taxation (MEBT) Year 39			$5,346,210		$5,346,210
Total Benefits	$134,711,874	$38,606,298	$83,687,082	$55,731,760	$312,737,013
Costs					
Construction			-$136,552,400		-$136,552,400
Operations and Maintenance (O&M)		-$12,972,478			-$12,972,478
Customer Conversions	-$13,078,038			-$46,367,590	-$59,445,628
Loss from Earthquakes			-$43,050,609		-$43,050,609
Marginal Excess Burden of Taxation (MEBT) Year 0			-$34,138,100		-$34,138,100
Total Costs	-$13,078,038	-$12,972,478	-$213,741,109	-$46,367,590	-$286,159,215
Distribution of Benefits and Costs	**$121,633,836**	**$25,633,820**	**-$130,054,027**	**$9,364,170**	**$26,577,798**

The biggest winner in the undergrounding alternative is homeowners, netting $121,633,836 from the projected increase in property values. Utility companies would gain a net benefit of $25,633,820 from avoided vegetation management costs after the increased O&M costs. Improved service reliability would offset conversion costs for businesses, netting $9,364,170. The biggest loser in the undergrounding alternative is taxpayers, who would be the primary funders, even after the substantial savings from avoided costs of vehicle crashes.

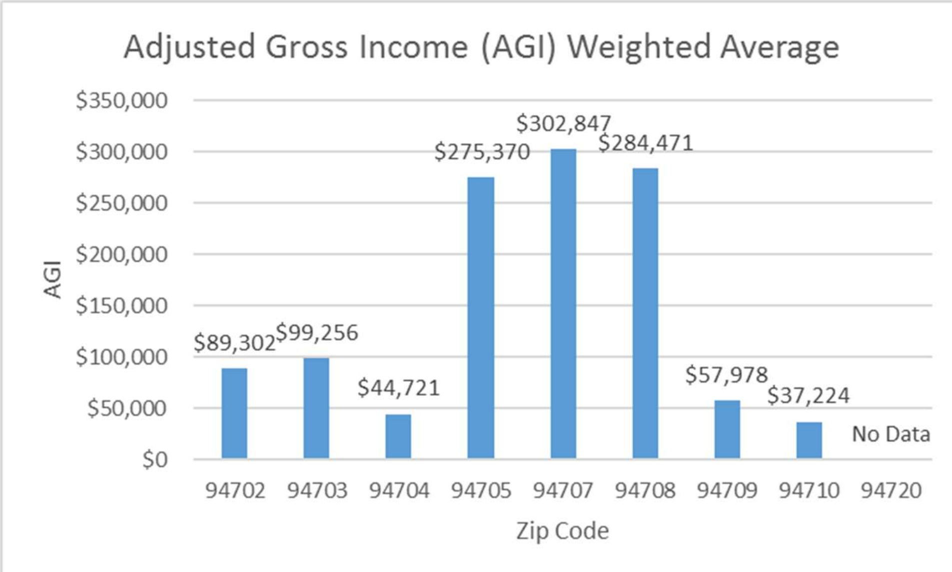
4.2. Demographic Characteristics. This section provides information on adjusted gross income (AGI), owner-/renter-occupied housing rates and racial composition of Berkeley in order to gain a better understanding of distributional outcomes. It examines these features by zip code. Zip codes generally don't align with how many understand Berkeley's neighborhoods, but it is how most data is available. To simplify the analysis, zip codes that share similarities are divided into two areas: Zip codes 94702, 94703, 94704, 94709 and 94710 represent the "Flats" and 94705, 94707 and 94708 are the "Hills." 94720 lies within the U.C. Berkeley campus and is not included in either area. This simplification is meant to highlight the main socio-economic differences in the city.

Berkeley Zip Code Map



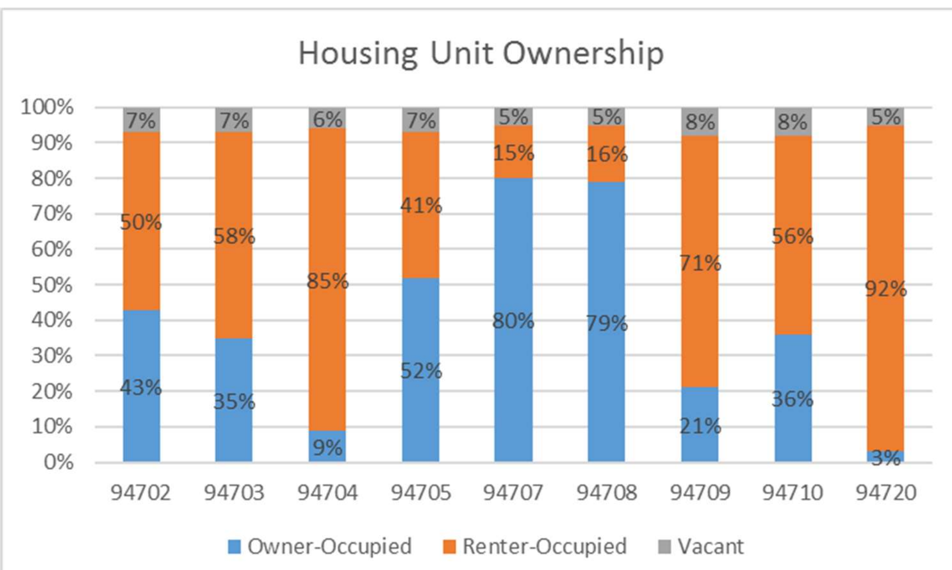
Source: https://www.unitedstateszipcodes.org/

4.2.1. Adjusted Gross Income (AGI): AGI is defined as gross income minus adjustments to income. Gross income is sales price of goods or property, minus cost of the property sold, plus other income. It includes wages, interest, dividends, business income, rental income, and all other types of income. Since it is a more comprehensive measurement, it is generally a better indicator of wealth than median household income alone. The data comes from 2014 IRS "AGI_stub" categories (size of adjusted gross income), weighted by the number of returns within each category (Internal Revenue Service).



The data indicates a wide variance in Berkeley's wealth distribution. In the Flats, AGI average is $65,696, while the Hills is $287,563, more than a four-fold increase.

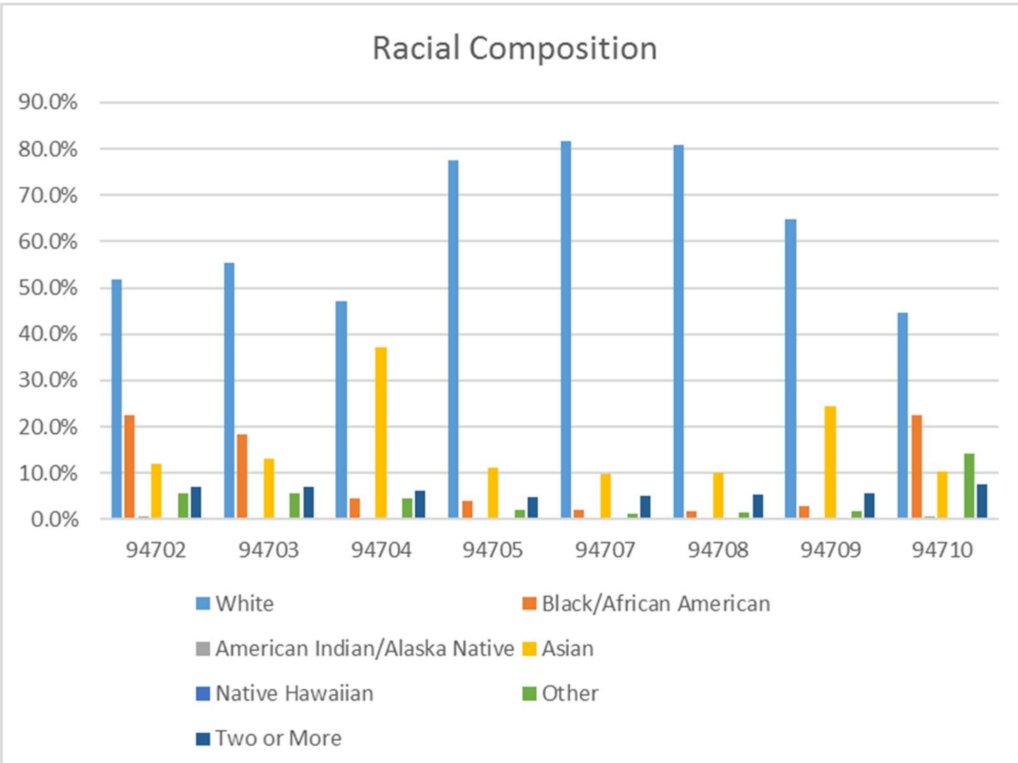
4.2.2. Housing Occupancy. The data comes from the U.S. Census Bureau, adjusted to fit current zip code boundaries (2010).



Like AGI, the contrast between the Flatland and Hills is significant. The average housing ownership rate in the Flats is 29% (not including U.C. Berkeley), while in the Hills it averages 70%. The contrast is so distinct in part because of the large student population residing in Berkeley and the extremely high housing costs exclude many residents from home ownership.

Since the largest societal benefit of the undergrounding alternative is increased property values, homeowners will gain the most benefit. The housing ownership information tells us that the gains would be primarily experienced by residents in the Hills.

4.2.3. Racial Composition: Berkeley is a racially diverse city, and the benefits and costs of the undergrounding alternative will bear on some racial groups more than others. The following data comes from the U.S. Census Bureau, adjusted to fit current zip code boundaries (2010).



The Hills are predominately white, making up an average of 80% of Hills residents. Whites still make up the largest group in the Flats as well, but to a lesser degree. This means that the majority of benefits will likely disproportionately fall to whites, and to a lesser degree African Americans, Asians and other minority groups in Berkeley. This information is provided to give policy makers an appreciation the undergrounding alternative is likely to have on minority groups.

4.3. Analysis. Homeowners in the Hills would gain the most economic benefit from the undergrounding alternative from increased property values. The increase in property values make it even more cost-prohibitive in an already sky-high housing market for those looking to purchase a home. This would further stratify socio-economic divisions in the city and provide an additional barrier to home ownership for those attempting to enter the market. Also, residents in the Hills would also benefit from the decreased risk of fire, since that area has the highest risk of fire hazard. The benefits again generally fall to the affluent, non-minority home owners in the Hills. This is a matter of coincidence, but some might see the project as specifically meant to favor powerful groups. The perception of favoritism may put the politically infeasibility of the undergrounding project at risk.

To make the distributional outcomes more equitable, policy makers should bring the cost of financing the construction of the project in line with benefits for each group. Tariff Rule 20 financing provides a means to do this. Under Rule 20B, property owners and/or local jurisdictions pay 80% of project construction costs while utility companies are responsible for 20%. Under Rule 20C, projects are paid for entirely by property owners, so they would bear much of the costs as well as the benefits.

IV. CONCLUSIONS AND RECOMMENDATIONS

The undergrounding alternative is most likley economically efficient for the city of Berkeley compared to the status quo, with the base case yielding an NPV of $26,577,798. This conclusion is strengthened by the *a fortiori* approach taken in this study that estimates benefits conservatively and costs boldly. The most underestimated benefit is probably the increased reliability of power. The greatest source of uncertainty in the project is construction costs. If construction costs can be kept under $162M, then the undergrounding alternative would likely yield a net benefit. However, the majority of benefits are not related to public safety, the stated goal of the project, and the benefits of the current alternative would primarily fall to homeowners in the Berkeley Hills.

To enhance public safety benefits and mitigate costs, policy makers should prioritize undergrounding areas, such as those areas at greatest risk of conflagration hazards and those along routes deemed most critical for emergency responder access and resident evacuation. The most cost-effective approach to undergrounding is to selectively target areas where relocation of lines underground would yield the greatest net benefit. Ultimately, other alternatives should be considered and compared to the undergrounding alternative to achieve similar disaster preparedness goals in the most cost-effective and equitable manner possible.

Further study can help better understand the benefits and costs of the project, if time and resources allow. The following are suggestions for further research.

1. Conduct studies of the individual impacts with the potential largest magnitude and greatest amount of uncertainty. This includes construction costs, effects of earthquakes and fires on underground and overhead systems and the benefit of increased power reliability to residents and business customers.

2. Conduct a site suitability analysis using Geographic Information Systems (GIS), such as ArcGIS, to determine the optimal areas to underground. The criteria should be: 1) Avoid liquefaction zones, 2) Avoid steep terrain or rocky soils that makes construction cost-prohibitive, 3) Avoid Fault Zones, 3) Prioritize streets determined to be critical for emergency vehicle access and resident evacuation and 4) Prioritize areas with a high risk of fire.

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Appendix A. Benefit-Cost 40-Year Projection

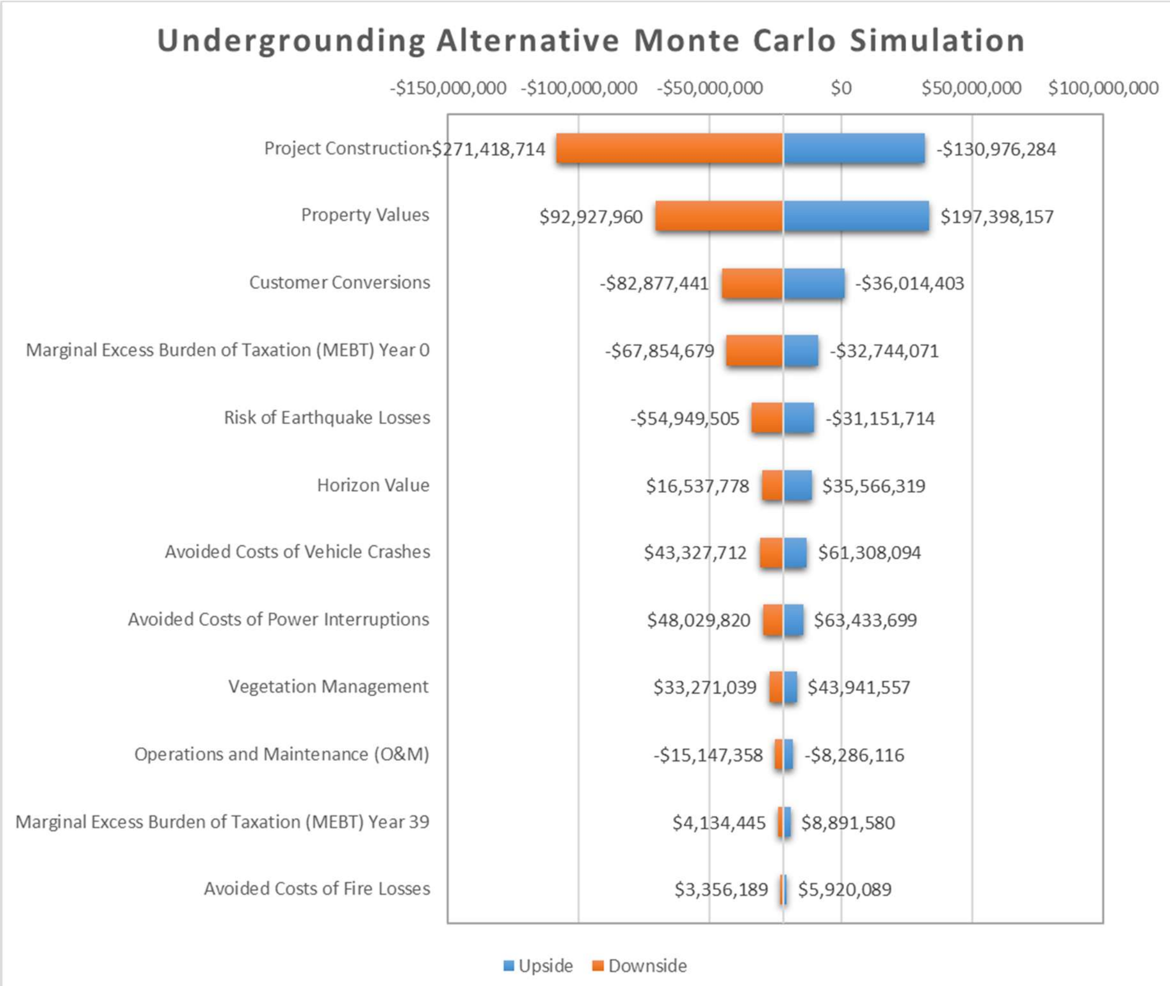
Estimate	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Nominal$	Property Values			$ 144,306,727																	
	Avoided Costs from Fires			$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337
	Avoided Costs of Power Interruptions			$1,466,625	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724
	Vegetation Management			$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247
	Avoided Costs of Vehicle Crashes			$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384
	Horizon Value																				
	Construction	-$136,552,400																			
	Customer Conversions	-$59,445,628																			
	Operations and Maintenance (O&M)			-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381
	Loss from Earthquakes			-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911
	MEBT (Year 0)	-$34,138,100																			
	MEBT (Year 39)																				
2017$	Property Values			$134,711,874																	
	Avoided Costs from Fires			$215,022	$207,751	$200,725	$193,938	$187,379	$181,043	$174,921	$169,005	$163,290	$157,768	$152,433	$147,278	$142,298	$137,486	$132,837	$128,345	$124,004	$119,811
	Avoided Costs of Power Interruptions			$2,583,700	$2,496,328	$2,411,911	$2,330,349	$2,251,545	$2,175,406	$2,101,841	$2,030,765	$1,962,091	$1,895,740	$1,831,633	$1,769,694	$1,709,849	$1,652,028	$1,596,163	$1,542,186	$1,490,035	$1,439,647
	Vegetation Management			$1,789,771	$1,729,247	$1,670,770	$1,614,271	$1,559,682	$1,506,939	$1,455,980	$1,406,744	$1,359,173	$1,313,210	$1,268,802	$1,225,896	$1,184,440	$1,144,387	$1,105,688	$1,068,297	$1,032,171	$997,267
	Avoided Costs of Vehicle Crashes			$2,425,434	$2,343,415	$2,264,169	$2,187,603	$2,113,626	$2,042,151	$1,973,092	$1,906,370	$1,841,903	$1,779,616	$1,719,436	$1,661,291	$1,605,112	$1,550,833	$1,498,389	$1,447,719	$1,398,762	$1,351,461
	Horizon Value																				
	Construction	-$136,552,400																			
	Customer Conversions	-$59,445,628																			
	Operations and Maintenance (O&M)			-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381
	Loss from Earthquakes			-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911
	MEBT (Year 0)	-$34,138,100																			
	MEBT (Year 39)																				

Estimate	Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	SUM
Nominal$	Property Values																					$144,306,727
	Avoided Costs from Fires	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$230,337	$8,752,806
	Avoided Costs of Power Interruptions	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$2,767,724	$103,872,402
	Vegetation Management	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$1,917,247	$72,855,397
	Avoided Costs of Vehicle Crashes	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$2,583,384	$98,168,592
	Horizon Value																					$21,384,838
	Construction																					-$136,552,400
	Customer Conversions																					-$59,445,628
	Operations and Maintenance (O&M)	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$12,972,478
	Loss from Earthquakes	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$43,050,609
	MEBT (Year 0)																					-$34,138,100
	MEBT (Year 39)																				$5,346,210	$5,346,210
2017$	Property Values																					$134,711,874
	Avoided Costs from Fires	$115,760	$111,845	$108,063	$104,408	$100,878	$97,466	$94,170	$90,986	$87,909	$84,936	$82,064	$79,289	$76,608	$74,017	$71,514	$69,096	$66,759	$64,502	$62,320	$60,213	$4,638,139
	Avoided Costs of Power Interruptions	$1,390,964	$1,343,926	$1,298,479	$1,254,569	$1,212,144	$1,171,154	$1,131,550	$1,093,285	$1,056,314	$1,020,593	$986,080	$952,734	$920,516	$889,388	$859,312	$830,253	$802,177	$775,050	$748,841	$723,518	$55,731,760
	Vegetation Management	$963,543	$930,960	$899,478	$869,061	$839,672	$811,277	$783,843	$757,336	$731,726	$706,981	$683,074	$659,975	$637,657	$616,093	$595,259	$575,130	$555,681	$536,890	$518,734	$501,192	$38,606,298
	Avoided Costs of Vehicle Crashes	$1,305,760	$1,261,604	$1,218,941	$1,177,720	$1,137,894	$1,099,415	$1,062,236	$1,026,315	$991,609	$958,076	$925,678	$894,374	$864,130	$834,908	$806,675	$779,396	$753,039	$727,574	$702,970	$679,198	$52,317,895
	Horizon Value																					$21,384,838
	Construction																					-$136,552,400
	Customer Conversions																					-$59,445,628
	Operations and Maintenance (O&M)	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$341,381	-$12,972,478
	Loss from Earthquakes	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$1,132,911	-$43,050,609
	MEBT (Year 0)																					-$34,138,100
	MEBT (Year 39)																				$5,346,210	$5,346,210
																					Benefits	$312,737,013
																					Costs	-$286,159,215
																					Net Benefit	$26,577,798

Appendix B. Benefit-Cost Overview

Benefits and Costs Overview After Discounting (2017$)						
Parameter	**Baseline Estimate**	**Lower Bound**	**Upper Bound**	**Monte Carlo Simulation**	**Distribution**	**Notes**
Social Discount Rate	0.035	0.035	0.035	N/A	N/A	SDR is recommended by Boardman et al. for inter-generational projects, based on the optimized growth method (2011).
Benefits						
Property Values	$134,711,874	$53,884,750	$242,481,373	$0	Triangular	Baseline estimate based on Pitts & Jackson of 5% property value increase with a lower and upper bound of 2% and 9% (2007).
Avoided Costs of Fire Losses	$4,638,139	$2,319,070	$6,957,209	$34,187,111	Triangular	Baseline estimate based on author's assessment with an lower and upper bound of -/+50%.
Avoided Costs of Power Interruptions	$55,731,760	$41,798,820	$69,664,699	$53,462,391	Triangular	Baseline estimate based on Virginia State Corporation Commission's research with a lower and upper bound of -/+25% (2005).
Vegetation Management	$38,606,298	$28,954,724	$48,257,873	$0	Triangular	Baseline estimate based on Brown (2009). Lower and upper bound -/+25%.
Avoided Costs of Vehicle Crashes	$52,317,895	$36,054,497	$68,581,313	$44,569,191	Triangular	Baseline estimate based on National Highway Transportation Safety Administration (NHTSA) and California Office of Transportation (OTS) data assuming undergrounding alternative would reduce collisions with utility poles by 15% with a lower and upper bound of 5% and 25% (2015; 2014).
Horizon Value	$21,384,838	$10,440,367	$44,410,412	$18,516,928	Triangular	Baseline estimate based on U.S. Bureau of Economic Analysis guidance of 5% depretiation value, with a lower and upper bound of 7% and 3%. Estimate represents salvage value at the end of the project useful life.
Marginal Excess Burden of Taxation (MEBT) Year 39	$5,346,210	$2,610,092	$11,102,603	$0		Estimate represents 25% of horizon value, based on OMB guidance (1994).
Total Benefits	$312,737,013	$176,062,319	$491,455,481	$150,735,621		
Costs						
Construction	-$136,552,400	-$102,414,300	-$341,381,000	$0	Triangular	Baseline estimate provided by Harris and Associates (2016). Lower bound represents -25% and upper bound represents +250%.
Operations and Maintenance (O&M)	-$12,972,478	-$5,188,976	-$17,512,832	$0	Triangular	Baseline estimate provided by Larsen et al. (2016). Cost calculated as .5% of the sum construction costs per year, with a lower and upper bound is .2%/.9% measured against current O&M costs under the status quo. Estimate includes administrative, permitting and siting costs.
Customer Conversions	-$59,445,628	-$17,057,990	-$101,834,022	-$44,198,038	Triangular	Costs are based on Harris & Associates' estimates. Number of homes and businesses along arterial and collector streets to be undergrounded based on 2010 Census and 2012 Economic Census.
Risk of Earthquake Losses	-$43,050,609	-$21,525,305	-$64,575,914	$0	Triangular	Baseline estimate calculated accounting for expected impact and probabilty. Lower and upper bound is -/+50%.
Marginal Excess Burden of Taxation (MEBT) Year 0	-$34,138,100	-$25,603,575	-$85,345,250	-$36,731,969	Triangular	Estimate is 25% total construction costs to represent deadweight loss (DWL), based on OMB guidance (1994).
Total Costs	-$286,159,215	-$146,186,571	-$525,303,768	-$80,930,007		
Benefits + Costs =	**$26,577,798**	**$29,875,748**	**-$33,848,287**	**$69,805,614**		

Appendix C. Tornado Diagram



Appendix D. Damage Severity Index (based on author's estimates)

	Overhead Utility System	Underground Utility System	
Wildland-Urban Interface Fire			Fires have been shown to almost completely destroy overhead systems, whereas underground cables are prone to melting in extreme heat.
Flood			Flooding could cause damage to utility poles but wiring would remain intact; flash floods could sweep away overhead systems; underground systems are especially prone to flood damage
Tsunami			A tsunami would likely destroy all overhead utility systems in an inundation zone; undergound systems would experience flood damage. Salt water immerses all of the pad-mounted and sub-surface electrical equipment in the storm surge area.
Earthquake-Induced Ground Shaking			Overhead utility poles have more elasticity but are prone to toppling in M7+ events; Underground systems perform well if the right insulation material is used.
Earthquake-Induced Liquefaction			Underground systems deformed and suffered severe damage in the Canterbury earthquakes, whereas overhead systems proved resilient.
Earthquake-Induced Fault Rupture			Both overhead and underground systems running perpendicular against the faultline would suffer a localized break, but overhead lines are expected to have more elasticity to spread along the faultline.
Landslide			Localized landslides would topple overhead systems. Underground systems would remain undamaged in most scenarios.

None - 0% Damage
Slight - 20% Damage
Moderate - 40% Damage
Strong - 60% Damage
Severe - 80% Damage
Total Destruction

APPENDIX C

"TECHNOLOGY TRENDS AFFECTING BERKELEY'S UNDERGROUNDING PROJECT", DE EN NI, MAY 2017

Technology Trends Affecting Berkeley's Utility Undergrounding Project

Picture: Utility Wires at Grant and Bancroft. Source: Berkeleyside.com

Report by: De En Ni, Spring 2017

The author conducted this study as part of the program of professional education at the Goldman School of Public Policy, University of California at Berkeley. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Affairs degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Goldman School of Public Policy, by the University of California or by any other agency.

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Executive Summary

Introduction

The City of Berkeley wishes to study the feasibility of undergrounding its overhead utility wires. As this is a multi-year, multi-million-dollar project, the City wishes to consider the impact of technological changes before embarking on the project.

Impetus for Change

Undergrounded utility wires will enhance public safety by enhancing access to emergency ingress and egress routes, as well as enhance aesthetics in the city, which could lead to property price increases. Public safety is a public good, and there may be under-provision of the good if left to the market due to the free-rider problem (as it would not be possible to exclude non-payers from enjoying the benefits).

While there is an existing revenue stream under the California Public Utilities Commission Rule 20 guideline to fund undergrounding efforts along major streets in the city for public benefit, it would take approximately 250 years to accrue sufficient funds to convert all the remaining major streets (about 60%) in the city which have not yet been undergrounded.

Possible Approach and Evaluation Criteria

The City is considering whether to raise funds to accelerate the undergrounding effort, possibly through a bond measure, tax or surcharge on utility consumption. In this regard, it is could consider the benefits of undergrounding in providing emergency access, the provision of uninterrupted utility service as well as the overall cost of the project to the city. It could also consider how the benefits would be distributed amongst city residents.

Technological Driving Forces

An interdisciplinary study by MIT on the future of the electric grid identifies two technological changes which may have a disruptive impact on the electric distribution network, namely the increasing penetration of electric vehicles, and distributed generation.

<u>Electric vehicles</u> currently constitute only 1% of total vehicles sold on the market, but the number of electric vehicles sold has increased at a 32% compound annual growth rate since 2011. The key impediments to widespread adoption - high initial costs and limited range - appear to be waning, with several automakers announcing sub-$40,000, 200-mile range vehicles to be

launched by 2018. Bloomberg New Energy Finance projects electric vehicles achieving cost parity with conventional vehicles by 2025, paving the way for mass market adoption. Even if electric vehicle sales do not take off as rapidly as projected, the geographical distribution of electric vehicles is likely to be concentrated in wealthy, eco-conscious neighborhoods. Between 2010 to 2015, more than half of U.S. electric vehicle sales took place in California. The City of Berkeley already has one of the highest electric vehicle penetration rates in the nation, at 10% of all vehicles owned.

Distributed generation refers to power generation at the point of consumption. The MIT report notes that at present installed costs, many renewable distributed generation installations remain dependent on subsidies to be economically viable. However, the cost of residential solar has fallen dramatically over the past decade. Bloomberg New Energy Finance projects that solar will become the cheapest source of power by 2040. The rise of distributed generation will challenge the current business model of recovering the fixed costs of the grid through consumption.

Plausible Scenarios

While there have been numerous examples in history of new technologies which have seen exponential growth, it is difficult to project with certainty whether electric vehicles and distributed generation will continue to grow exponentially as they have over the past decade. To help manage this uncertainty, we can make use of scenario planning and consider scenarios based on the interaction of the two technological driving forces as shown in the diagram below.

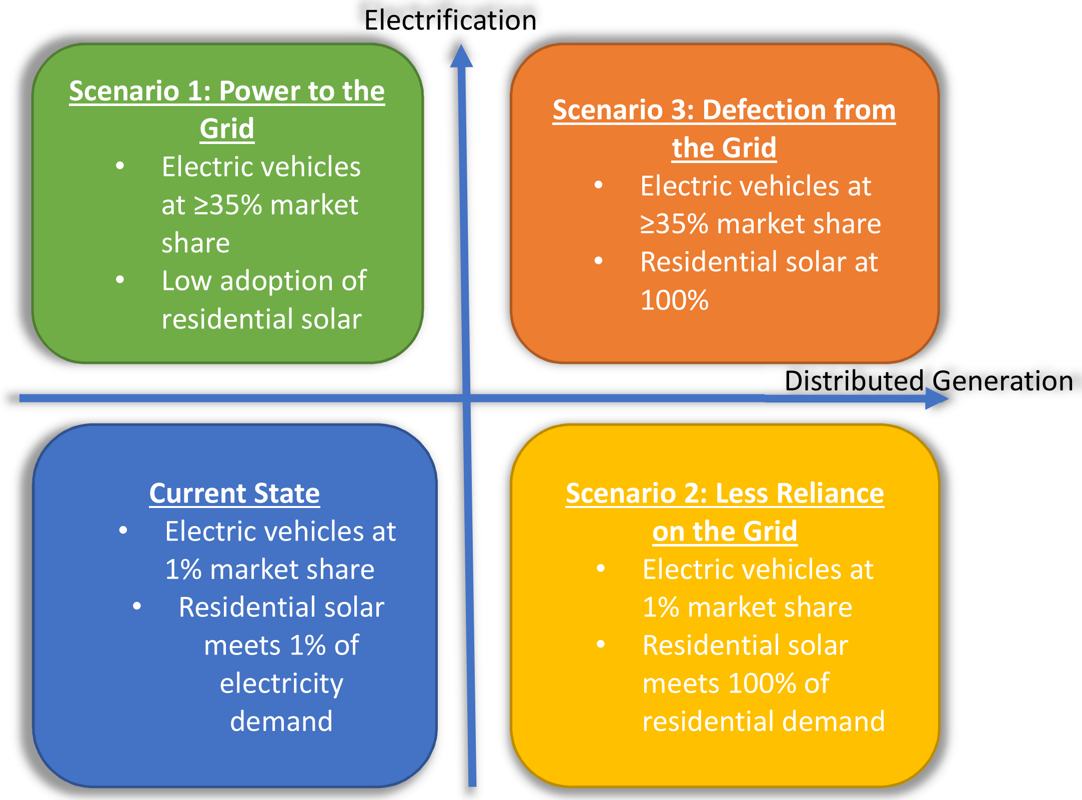

Figure 1: Plausible Scenarios concerning the Electric Grid

The current state is represented by the lower left quadrant in the diagram, where market penetration of both electric vehicles and distributed generation is low. The upper left quadrant represents Scenario 1, where electric vehicle adoption continues to experience exponential growth, while the rate of adoption for residential solar slows. The lower right quadrant represents Scenario 2, where residential solar continues to experience exponential growth, while the adoption rate of electric vehicles slows. The upper right quadrant represents Scenario 3 where both residential solar and electric vehicle adoption continue to grow exponentially.

Scenario 1: Power to the Grid

The proliferation of electric vehicles would increase demand for grid electricity, especially if the grid undergirds the public charging infrastructure for electric vehicles. The MIT report estimates that at 25% penetration, electricity consumption is anticipated to increase by 5.5%. In line with the increase in demand for grid electricity, the benefits of undergrounding will increase under Scenario 1.

Scenario 2: Less Reliance on the Grid

The widespread adoption of distributed generation results in a significant reduction in demand for grid electricity. This would in turn reduce the net benefits of undergrounding. At the same time, this scenario requires the development of a new charging model for fixed distribution costs. The MIT report recommends imposing fixed grid charges, but the Rocky Mountain institute warns that such charges could further dampen electricity demand.

Scenario 3: Defection from the Grid

The rise of both distributed generation and electric vehicles provide consumers with the option of defecting off grid entirely as they are able to generate and store electricity economically within their individual households. Investments in electric vehicles would support the mass production of batteries that enable individual property owners to store their excess energy economically for later use. This scenario is thus the most challenging to the current approach to undergrounding programs and financing grid infrastructure in general. To cope with such a scenario, a paradigm shift in business models might be necessary in order to maintain the grid. A CISCO Blue Paper describes the possibility of expanding the uses of existing utility infrastructure e.g. lamp-posts and utility poles, to providing new public services such as public WiFi, digital media streaming and Closed Circuit Television for traffic and crime monitoring. By providing additional public goods, the justification for a larger degree of public funding for such infrastructure would be strengthened.

Conclusion and Recommendation

It is difficult to project with certainty how technological trends will pan out. It is unlikely that technological changes will enhance the value proposition of converting existing overhead utility lines to undergrounded ones significantly. Under the most optimistic scenario, we see a modest increase in grid electricity demand by 20%. On the flip side, consumers may have the option of defecting from the grid entirely, undermining the feasibility of undergrounding altogether. Should such a scenario pan out, new approaches to enhancing the value proposition of the grid such as the provision of additional services like public WiFi, electric vehicle charging may be necessary.

Technology Trends Affecting Berkeley's Utility Undergrounding Program

Key Objective

This report explores the advantages and disadvantages of undergrounding under current technology, and under various technological scenarios (considering technologies that support and oppose undergrounding). This would give the range of possible net benefits, and support a recommendation on whether to proceed.

1. Introduction

The City of Berkeley wishes to assess the feasibility of undergrounding its overhead utility wires, in the face of changing technology in the energy distribution and internet access domains. Specifically, the City wishes to determine whether technological changes are likely to enhance or diminish the benefits and costs of the undertaking.

2. The Case for Undergrounding Utility Lines

Undergrounded utility lines enhance public safety, and are a public good as they are non-excludable, non-rivalrous and will benefit all current and future residents.

Undergrounded utility wires are more resilient to certain natural disasters such as wild fires and wind storms. During the 1991 Oakland Hills fire, downed power lines ignited spot fires, impeded emergency ingress and egress, as live power lines fell from burning poles, blocking streets and starting new fires. Flames also took out power to pumping stations causing firemen to run out of water for fire-fighting efforts. The U.S. Fire Administration's Technical Report on the fire notes that "the conditions that created the critical fire risk situation… exist in hundreds of other locations and, … there is every reason to expect that another very similar fire will result. In particular, in California, when the Santa Ana (or Diablo) wind is blowing, and a fire occurs in a susceptible area, there is very little that any current fire suppression forces or technologies can do to resist the spread of the fire."[1] About one-seventh of the City of Berkeley is in the Very High Fire Hazard Severity Zone as recommended by CAL Fire (see Figure 1)[2].

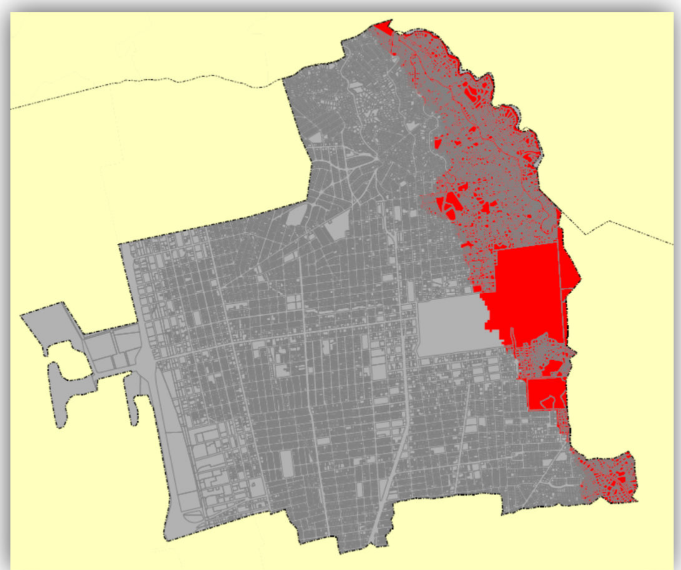

Figure 1: Very High Fire Hazard Severity Zone as recommended by CAL Fire

There are also significant private benefits to undergrounding – better aesthetics will increase property values, which would accrue to individual homeowners when they sell their properties. As such, determining how the undergrounding effort should be funded is also a matter of public concern. The current major source of funds for undergrounding efforts is an electric distribution tariff paid to PG&E by all consumers and governed by the California Public Utilities Commission (CPUC) Rule 20 guideline. It is a common resource safeguarded by the City government, which has the responsibility to ensure that the worthiest projects are prioritized, and also that the distributional outcomes of any investments are equitable. Rule 20 monies can be used to underground arterial and collector streets. The City of Berkeley has accrued $9 million in Rule 20 monies, but the cost of converting remaining arterial (51%) and collector (69%) streets is estimated at $135 million[3]. Under CPUC Rule 20, individual property owners may also organise

[1] J. Gordon Routley, "The East Bay Hills Fire Oakland-Berkeley California", United States Fire Administration, FEMA. https://www.usfa.fema.gov/downloads/pdf/publications/tr-060.pdf
[2] http://www.fire.ca.gov/fire_prevention/fhsz_maps/FHSZ/alameda/Berkeley.pdf
[3] Baseline Study for the Development of a Utility Undergrounding Program, Harris & Associates, 22 Jul 2016

themselves into assessment districts and pay for undergrounding in their district from their own pocket.

3. Why the City of Berkeley should Act

As undergrounding enhances public safety during disasters, it may be considered a public good as it is not possible to deny these public safety benefits to residents even if they did not pay for undergrounding. As such, from the economic standpoint, there may be market failure in the provision of undergrounding due to the free-rider problem. Further, undergrounding can be characterized by a "L-shaped" supply curve (i.e. the cost of providing the first unit of the good is prohibitive owing to high one-time costs, but the marginal cost of providing each additional unit is very low). There are significant one-time installation costs, due to the need to excavate which involves considerable construction costs. Once installed, the operating costs of undergrounded lines are slightly lower as compared to that of overhead lines, as the lines are protected from the elements[4]. A report by the City of Los Angeles[5] found that undergrounded lines cost 12% less to maintain than overhead lines. Left to the market, suppliers would seek to recoup their installation costs by pricing at the average cost level. In this case, this occurs in the secondary electricity market as utility providers charge higher tariffs in order to recover their capital investments in undergrounding. This then results in deadweight loss as the average cost of electricity is higher than the marginal cost. In other words, societal welfare is not maximised as the marginal benefit that a consumer could obtain from consuming additional units of electricity is higher than the marginal cost of providing that unit of electricity, but this consumption does not occur as the price the consumer has to pay for that unit is higher than the marginal cost.

There are also distributional concerns to consider. Public safety can be considered an essential good. A purely market based approach where only those with means enjoy a higher level of safety may be dissonant to shared communal values.

[4] Ibid.

[5] Los Angeles Department of Water and Power. "Utility Undergrounding Program Second Report", March 5 2010

4. Possible Approaches to Undergrounding

There are two main alternatives that the City of Berkeley can consider with regard to its undergrounding plans.

Alternative 1: Underground the whole City. The City could decide to convert all overhead utility wires in the City to undergrounded wires. As the City does not have sufficient capital reserves, the initiative will have to be financed through a new revenue stream. This could include a new bond measure, additional taxes or surcharges on utility bills. Passing a bond measure would require effort in education and outreach, to inform residents on the benefits with proceeding with the measure. Assuming the measure passes, debt service would increase as a proportion of the overall City budget, which would mean a decrease in funding for other City programs unless taxes are concomitantly increased. The main benefits of this alternative would be improvements in public safety during natural hazards like storms and wildfires, as well as increases in property prices.

Alternative 2: Status quo. Under the status quo, the City will continue to convert existing overhead utility lines to undergrounded lines along major roads so as to facilitate emergency ingress and egress using monies set aside under the CPUC Rule 20. As the monies set aside are several orders of magnitude lower than the amount needed to complete the effort, progress will be slow and it will take several decades to complete. A ballpark estimate, based on the figures in the Harris Report, is that it will take at least 250 years to complete this endeavour (i.e. to raise $135 million at a rate of $0.55 million a year). On a smaller scale, a few neighborhoods will self-organise and fund their own conversion projects, for aesthetic and safety reasons. These are likely to be the wealthier neighborhoods in Berkeley, given the large capital investment required and property price premiums to be enjoyed from unblocked views of the Bay. As alluded to in the Harris Report, the City could also explore obtaining CPUC's approval to extend Rule 20 monies to high fire zones, as has been done in San Diego, so as to respond to the specific concern of public safety.

Table 1 presents a Logic Model of the 2 alternatives under consideration.

Table 1: Logic Model			
Alternatives	**Inputs**	**Activities**	**Results**
Underground the whole City	• Money from Berkeley residents • Time by City officials, utility providers	• Education and outreach by Berkeley City officials • Bond measure to raise the requisite monies • Installation by PG&E • Coordination between utility providers on right to access	Outputs • Miles of existing overhead wires converted to underground Outcomes • Higher property values • Improved aesthetics • Improved public safety • Higher utility bills/taxes Impact • Resident wellbeing • Increased desirability of City
Status quo	• Time by City officials (to justify why status quo is superior)	• Education and outreach by Berkeley City officials, albeit to a relatively smaller extent	Outputs • Townhalls / engagement sessions held Outcomes • Better awareness of issue Impact • Avoided increase in cost of living

5. Plausible Evaluation Criteria

The main criteria to evaluate alternatives could be:

Effectiveness. As utility services are essential necessities, any disruption will cause undue hardship to consumers. As such, any disruption to utility services, especially electrical power, should be minimized. As Berkeley is situated within a seismic zone and is on the coast, it would also be useful to consider the ease of restoring supply in case of natural disasters such as earthquakes and storms.

Cost/Impact on City Budget. As it is, the City of Berkeley is in a tight fiscal position with unfunded liabilities in pension payments, past-due infrastructural upgrades and maintenance. The City would have to take on debt in order to fund any new infrastructural developments. The fiscal impact of the alternatives would therefore need to be considered, in terms of the overall lifecycle costs of installation and subsequent maintenance.

Equity. It would also be necessary to study the benefits of the alternatives, and how they are distributed. In particular, whether the benefits would accrue to all Berkeley residents, or disproportionately to particular groups, such as private homeowners residing on the Hills.

6. Advantages and Disadvantages of Undergrounding

This section provides a brief overview of the advantages and disadvantages of undergrounding under current technology, and evaluates the alternatives based on the criteria described in the previous section. Please refer to Daniel Bradway's report for a more detailed benefit-cost analysis of undergrounding in the City of Berkeley.

A 2007 literature review conducted by a private research firm, Infrasource Technology, for the Florida Electric Utilities surveyed over 60 consultant reports, municipal reports, state regulatory reports and international reports, including about 20 benefit-cost analyses, and found that without considering aesthetics, no study on undergrounding could conclude that the benefits outweighed the cost[6]. However, it was very difficult to quantify with accuracy what the impact on aesthetics (and property values) would be, and while there was a general acceptance that property values would appreciate, the degree of appreciation was debatable. For the studies that concluded net positive benefits, high premiums on aesthetics were used. At the same time, the cost of undergrounding far exceeded participants' willingness to pay, as measured through contingent valuation surveys, for the enhancement. This is mainly because undergrounding is very expensive. The Harris Report puts this at $3.6 million per mile, which at meetings with City Officials, representatives from AT&T and Comcast both separately observed seemed to be an underestimate.

The Harris Report further identifies the following advantages of undergrounding: (a) enhanced safety during fires and earthquakes, (b) less frequent outages, (c) improved aesthetics, (d) improved pedestrian access, (e) reduction in car pole accidents and (f) reduced tree trimming costs; and the following disadvantages: (a) construction noise; and (b) traffic impact.

In addition to these disadvantages, a review of recent earthquake impacts on power systems conducted by the Pacific Earthquake Research Center based at the University of California, Berkeley, found that "buried electric transmission and distribution cables may be vulnerable to permanent ground deformation resulting from liquefaction or landslides. In

[6] Richard Brown. Infrasource Technology, "Undergrounding Assessment Phase 1 Final Report: Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion", 28 February 2007, http://grouper.ieee.org/groups/td/dist/sd/doc/2007-02-Undergrounding-Assessment.pdf

contrast, overhead transmission is generally very rugged".[7] In the 2010-2011 Christchurch earthquakes, 50% of the buried 66kV cables failed. New overhead systems had to be installed in order to restore power more quickly to affected consumers. Nevertheless, it took 10 days before power could be restored to 90% of affected consumers.[8] In contrast, damage to overhead lines was generally light. 80 poles shifted, but none broke. The Pacific Earthquake Research Center also found that encasing conduits in reinforced concrete would improve their resilience to seismic damage. Based on an interview with Dr Shakhzod Takirov at the Center, it is estimated that this would increase construction costs by an additional 10%.

Picture: Leaning Poles due to February 2011 Christchurch Earthquake. Source: http://thunderboltnz.blogspot.com

[7] Eric Fujisaki, Shakhzod Takhirov, Qiang Xie, and Khalid M. Mosalam. "Seismic Vulnerability of Power Supply: Lessons Learned from Recent Earthquakes and Future Horizons of Research", Proceedings of the 9th International Conference on Structural Dynamics, EURODYN 2014, 2 Jul 2014

[8] Resilience Lessons: Orion's 2010 and 2011 Earthquake Experience Independent Report, Kestral Group, September 2011, http://www.oriongroup.co.nz/assets/Customers/Kestrel-report-resilience-lessons.pdf

In terms of benefits, property owners and residents in the Hills would gain more from the undergrounding initiative than other residents. This is as they are presently at higher risk of wildland-urban fires and would also likely benefit more from the improved aesthetics arising from unblocked views of the Bay. These property owners should expect an appreciation in real estate value. However, owing to Proposition 13, the City would not benefit from property tax increases until the property is next reassessed e.g. when it is sold or when it is redeveloped.

In terms of the frequency of outages, severe weather is the leading cause of power outages in the United States, and climate change is expected to increase the frequency and intensity of severe weather storms. A report by the President's Council of Economic Advisers and the U.S. Department of Energy recommends strengthening electrical grid infrastructure so as to avert the rising cost of disruptions to electrical power.[9] The report notes that "placing utility lines underground eliminates the distribution system's susceptibility to wind damage, lightning, and vegetation contact. However, underground utility lines present significant challenges, including additional repair time and much higher installation and repair costs… underground wires are (also) more vulnerable to damage from storm surge flooding". The report thus notes that upgrading poles and structures using harder materials constitute the primary hardening measure.

Under the status quo, undergrounding efforts would continue using CPUC Rule 20A monies for the remaining 51% (13.1 miles) of arterial streets and 69% (24.8 miles) of collector streets, albeit at a much slower pace. There would be significant avoided costs from foregoing the capital investment required to underground, and avoided electricity price increases. If fire safety is of utmost concern, the City could explore seeking approval for Rule 20D to extend to Berkeley as well so as to support undergrounding in fire zones. Nevertheless, given the slow rate of accruing Rule 20 monies, the benefits in terms of improved public safety and real estate values would not be realised for a long time (250 years for major roads alone).

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[9] President's Council of Economic Advisers and U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, "Economic Benefits of Increasing Electrical Grid Resilience to Weather Outages", August 2013 https://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf

7. Technological Driving Forces

An interdisciplinary study by MIT on the future of the electric grid identifies two technological changes which may have a disruptive impact on the electric distribution network, namely the increasing penetration of electric vehicles, and distributed generation[10].

Electric Vehicles. Electric vehicles may emerge as a significant distribution load, if market penetration is high. While electric vehicles currently only constitute 1% of total vehicles sold on the market, the number of electric vehicles sold has increased at a 32% compound annual growth rate over 2011-2016[11]. It is unclear whether current growth rates will persist as electric vehicles become more mainstream, and this has given rise to a wide range in the projected market share of electric vehicles by various parties. For instance, ExxonMobil projects that electric vehicles will comprise about 10% of total global sales by 2040, while Bloomberg New Energy Finance projects this at 35%[12].

One of the impediments to wider electric vehicle adoption currently is the high initial cost of purchasing an electric vehicle, even as subsequent costs are cheaper (with refuelling cost being one-third that of conventional vehicles)[13]. A second concern has been about limited battery range. However, companies like Tesla and General Motors have announced plans to sell electric vehicles targeted at the mass market (sub $40,000) with 200-mile ranges by 2018[14]. According to the bullish projection by Bloomberg New Energy Finance, electric vehicles will achieve cost parity with conventional vehicles by 2025, even with low oil prices, paving the way for mass market adoption[15]. Figure 2 shows that if electric vehicle adoption continues to grow on the compound annual growth rate of electric vehicles of 30% projected by Bloomberg New Energy Finance, and

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[10] John G. Kassakian, Richard Schmalensee et al. "The Future of the Electric Grid", Massachusetts Institute of Technology, 2011

[11] Robert Rapier. "US Electric Vehicle Sales Soared in 2016", Forbes, 5 Feb 2017 @ https://www.forbes.com/sites/rrapier/2017/02/05/u-s-electric-vehicle-sales-soared-in-2016/#7c68dc9c217f

[12] Garrett Fitzgerald, Chris Nelder, And James Newcomb. "Electric Vehicles As Distributed Energy Resources", pg 16. Rocky Mountain Institute, 2016. http://www.rmi.org/pdf_evs_as_DERs.

[13] Ibid, pg 15.

[14] Jeff Cobb. "How Many Sub-$40,000 / 200-Mile Range EVs Might We See In 2017?", 28 December 2016. http://www.hybridcars.com/how-many-sub-40000-200-mile-range-evs-might-we-see-in-2017/"

[15] Bloomberg New Energy Finance. "Electric vehicles to be 35% of global new car sales by 2040", 25 February 2016. https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/

costs continue to decrease at a rate of 16% as production scales up[16], electric vehicles will be the cheapest cars in the market by 2030[17].

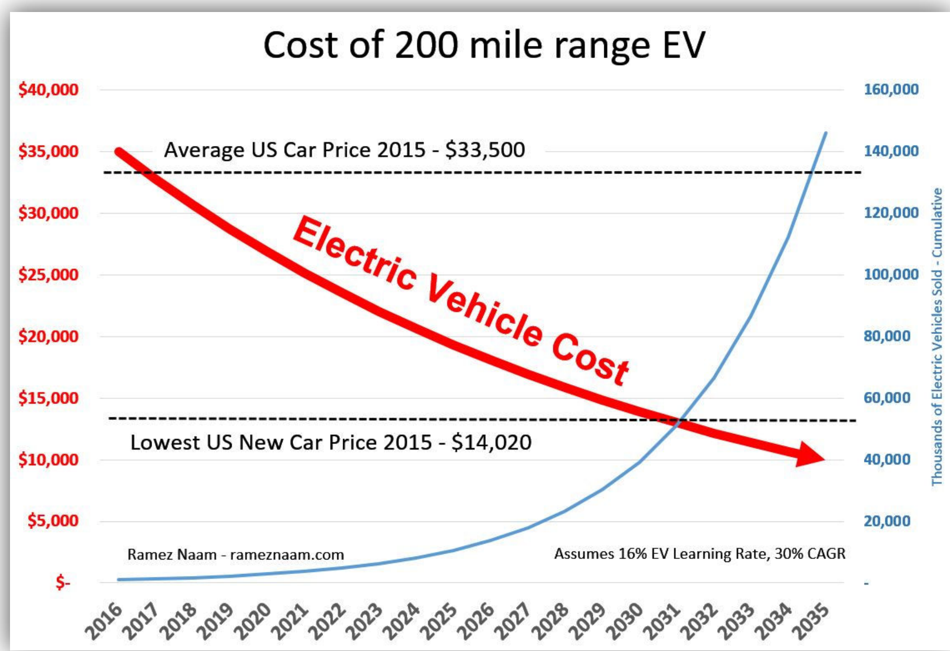

Figure 2: Electric Vehicle Cost Trend

Even if electric vehicle sales do not take off as rapidly as projected, the MIT report notes that the geographical distribution of electric vehicles is likely to be uneven, and concentrated in wealthy, eco-conscious neighborhoods. Between 2010 to 2015, more than half of U.S. electric vehicle sales took place in California (see Figure 3). The state has also set a target for 1.5 million electric vehicles by 2025, with easy access to charging infrastructure. The City of Berkeley already has one of the highest electric vehicle penetration rates in the nation, at 10% of all vehicles owned[18].

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[16] Based on historical cost decreases in the production of the Model T Ford, the world's first mass produced vehicle, while actual empirical data for electric vehicles suggests a learning rate of up to 21%

[17] Ramez Naam. "How Cheap Can Electric Vehicles Get", 12 April 2016. http://rameznaam.com/2016/04/12/how-cheap-can-electric-vehicles-get/

[18] Stephanie Searle, Nikita Pavlenko, and Nic Lutsey. "Leading Edge of Electric Vehicle Market Development In The United States: An Analysis Of California Cities", The International Council on Clean Transportation, September 2016. http://www.theicct.org/sites/default/files/publications/ICCT_EV_Calif_Cities_201609.pdf

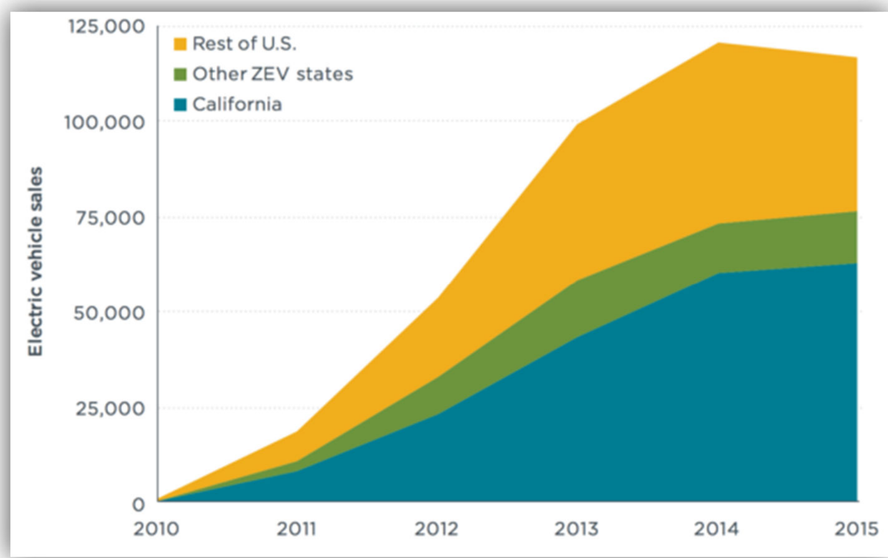

Figure 3: Electric Vehicle Sales in the U.S.[19]

Aside from direct consumer demand, the Rocky Mountain Institute notes that there is the opportunity for tremendous growth in terms of fleet vehicles providing "mobility as a service".[20] Evercar provides electric vehicles and fleet management tools to municipalities. Services like Evercar create the potential for accelerating electric vehicle adoption.

Adding an electric vehicle approximately doubles residential household demand for electricity. It is important that this increased demand be directed to off-peak generation hours, so as to avoid expensive electricity generation options (peaker plants are less efficient but provide rapid response to increases in demand) and overloading local distribution infrastructure[21]. Utilities and regulators have thus created incentives for consumers to charge their electric vehicles during off-peak hours. PG&E for instance, offers electric vehicle rate plans to residential consumers, with lowest prices between 11pm and 7am when demand is the lowest[22]. An experimental rate study in San Diego demonstrated that it is possible to drive such

[19] Ibid.
[20] Garrett Fitzgerald, Chris Nelder, And James Newcomb. "Electric Vehicles As Distributed Energy Resources", pg 18. Rocky Mountain Institute, 2016. http://www.rmi.org/pdf_evs_as_DERs.
[21] John G. Kassakian, Richard Schmalensee et al. "The Future of the Electric Grid", Massachusetts Institute of Technology, 2011
[22] PG&E electric vehicle rate plans. https://www.pge.com/en_US/residential/rate-plans/rate-plan-options/electric-vehicle-base-plan/electric-vehicle-base-plan.page

consumer behaviour through differentiated pricing[23]. Overall then, with the right incentives and programs in place, electric vehicles have created the mechanism for utilities to even out electric loads throughout the day which allow for more efficient electric generation and distribution.

Catering to electric vehicles also offers the opportunity for utility providers to enhance the relevance of the grid by supporting the provision of public charging infrastructure. In December 2016, the CPUC unanimously approved a program initiated by PG&E to deploy 7,500 electric vehicle charging stations in Northern California[24]. By tying up with commercial providers (e.g. shopping malls) and workplaces, utilities could also enhance convenience to their consumers while reaping the increase in revenues from heightened electric demand.

Distributed generation. Distributed generation refers to power generation at the point of consumption. Generating power on-site eliminates the cost of transmission and distribution for the consumer. The MIT Future of the Electric Grid report notes that at present installed costs, many renewable distributed generation installations remain dependent on subsidies to be economically viable. However, it also notes that installed costs for solar photovoltaic systems have fallen from $10.50 per watt in 1998 to $7.60 per watt in 2007, and will ultimately become competitive with grid electricity[25]. A more recent chart (see Figure 4) from the National Renewable Energy Lab shows the cost of residential solar continuing to fall from $7.06 per watt in Q4 2009 to $2.93 a watt in Q1 2016. Bloomberg New Energy Finance projects that solar will become the cheapest source of power by 2040, at $0.04 per kWh.[26] In comparison, the average price of residential electricity is about $0.12 per kWh currently[27].

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[23] Idaho National Laboratory, "Residential Charging Behavior in Response to Utility Experimental Rates in San Diego," April 2015. https://avt.inl.gov/sites/default/files/pdf/EVProj/ResChargingBehaviorInResponseToExperimentalRates.pdf

[24]Press Release by the Sierra Club. "California Public Utilities Commission Unanimously Approves Electric Vehicle Charging Program" http://content.sierraclub.org/press-releases/2016/12/california-public-utilities-commission-unanimously-approves-electric-vehicle

[25] John G. Kassakian, Richard Schmalensee et al. "The Future of the Electric Grid", Massachusetts Institute of Technology, 2011

[26] Katie Fehrenbacher. "Solar Is Going to Get Ridiculously Cheap", Fortune Magazine. 12 June 2016. http://fortune.com/2016/06/13/solar-to-get-crazy-cheap/

[27] Jess Jiang. "The Price of Electricity in Your State", NPR. 28 October 2011. http://www.npr.org/sections/money/2011/10/27/141766341/the-price-of-electricity-in-your-state

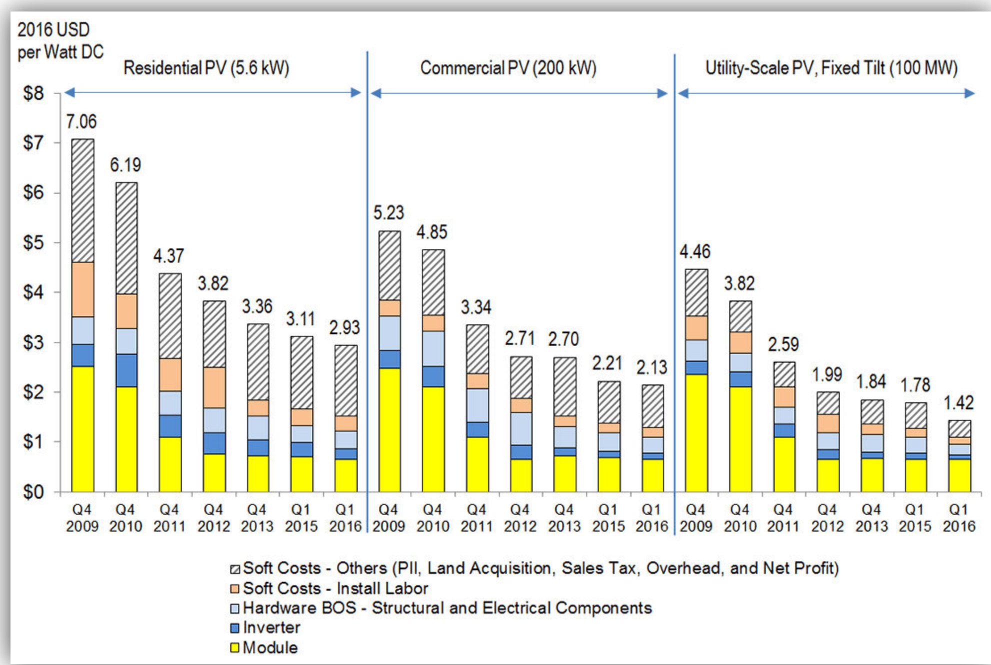

Figure 4: Declining Cost of Solar Power[28]

As shown in Figure 4, the cost of installing solar is driven mainly by solar module costs and soft costs. The cost of solar modules has decreased by 20% with every doubling of global production since 1970s – this is commonly known as "Swanson's Law" after Richard Swanson, the founder of Sunpower Corporation who observed the trend. In terms of soft costs, a Lawrence Berkeley National Lab study suggests potential cost savings as the U.S. market achieves scale. For instance, the soft costs of installing solar in Germany, which has higher solar penetration than the U.S., are approximately half that of the U.S.[29]

A Rocky Mountain Institute report further anticipates solar photovoltaic plus battery systems achieving grid parity within the next 10 to 15 years, based on the averaged forecasts of other reputable sources such as the National Renewable Energy Lab, Bloomberg New Energy Finance and the Boston Consulting Group of solar and battery prices and a 3% per annum

[28] National Renewable Energy Lab. "NREL Report Shows U.S. Solar Photovoltaic Costs Continuing to Fall in 2016", 28 September 2016. http://www.nrel.gov/news/press/2016/37745

[29] Joachim Seel, Galen Barbose, and Ryan Wiser. "Why Are Residential PV Prices in Germany So Much Lower Than in the United States?", Lawrence Berkeley National Laboratory, February 2013. https://emp.lbl.gov/sites/all/files/german-us-pv-price-ppt.pdf

increase in grid electricity prices[30]. The most economical means of generating electricity for residential households with access to solar photovoltaic systems would then evolve from grid electricity to grid plus solar photovoltaic systems to solar photovoltaic plus battery systems over the next 10 to 15 years.

At low penetration rates, solar photovoltaic systems represent a mere reduction in consumer demand for electricity. However, at higher penetrations, system stability becomes an issue based on current infrastructure as it is not designed to support two way flows of electricity. Infrastructural upgrades will be necessary in order to prevent system damage and disruptions such as voltage fluctuations on the grid[31].

New business models would need to be developed as the fixed costs of distribution infrastructure are currently recovered through electricity consumption. However, this would become less feasible and equitable going forward as consumers adopting distributed generation (and who can afford the upfront capital cost of installation) would consume a declining share of grid electricity and thus pay a decreasing share of distribution costs, even while continuing to enjoy access to the grid (and the public good it affords in terms of energy security and resilience). Given this, new financing models for grid infrastructure upgrades like undergrounding would be needed to ensure that consumers who adopt distributed generation technologies pay their fair share of the upgrade. In this regard, the MIT report recommends instituting fixed grid charges although the Rocky Mountain report suggests that such charges could incentivise grid defection should consumers with distributed generation resources decide that the charges exceed the benefits of staying on the grid.

[30] Peter Bronski, Jon Creyts et al. "The Economics of Load Defection", Rocky Mountain Institute, 2015.
[31] John G. Kassakian, Richard Schmalensee et al. "The Future of the Electric Grid", Massachusetts Institute of Technology, 2011

8. Plausible Scenarios

It is difficult to project with certainty whether electric vehicles and distributed generation will continue to grow exponentially as they have over the past decade. There have been numerous examples in history of new technologies which have seen exponential growth (see Figure 5). However, sceptics that electric vehicles and distributed generation will continue their current exponential growth have noted that none of the noted proponents of exponential growth scenarios (e.g. inventor and futurist Ray Kurzweil; engineer, physician, and innovator Peter Diamandis; and entrepreneur, educator, and business consultant Tony Seba) have roots in the traditional electric power industry[32].

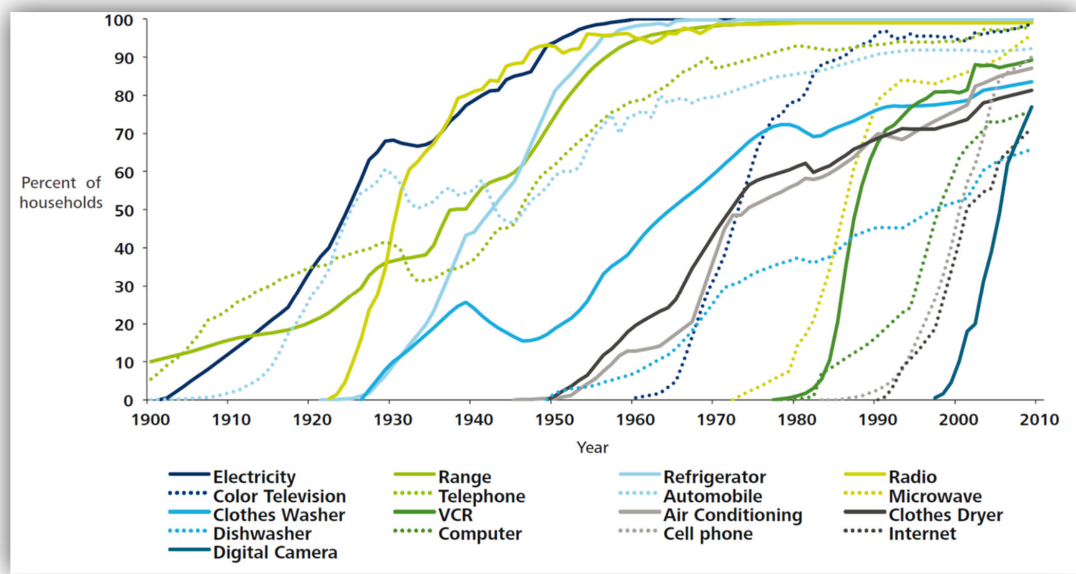

Figure 5: US historical adoption rate for new technologies[33]

To help manage this uncertainty, we can make use of scenario planning and consider scenarios based on the interaction of the two technological driving forces (electric vehicle and distributed generation adoption). We can draw up three plausible scenarios as shown in the following diagram (see Figure 6).

[32] "US Solar Power Growth through 2040 Exponential or inconsequential?" Deloitte Center for Energy Solutions, September 2015. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-solar-innovation-growth.pdf
[33] Ibid.

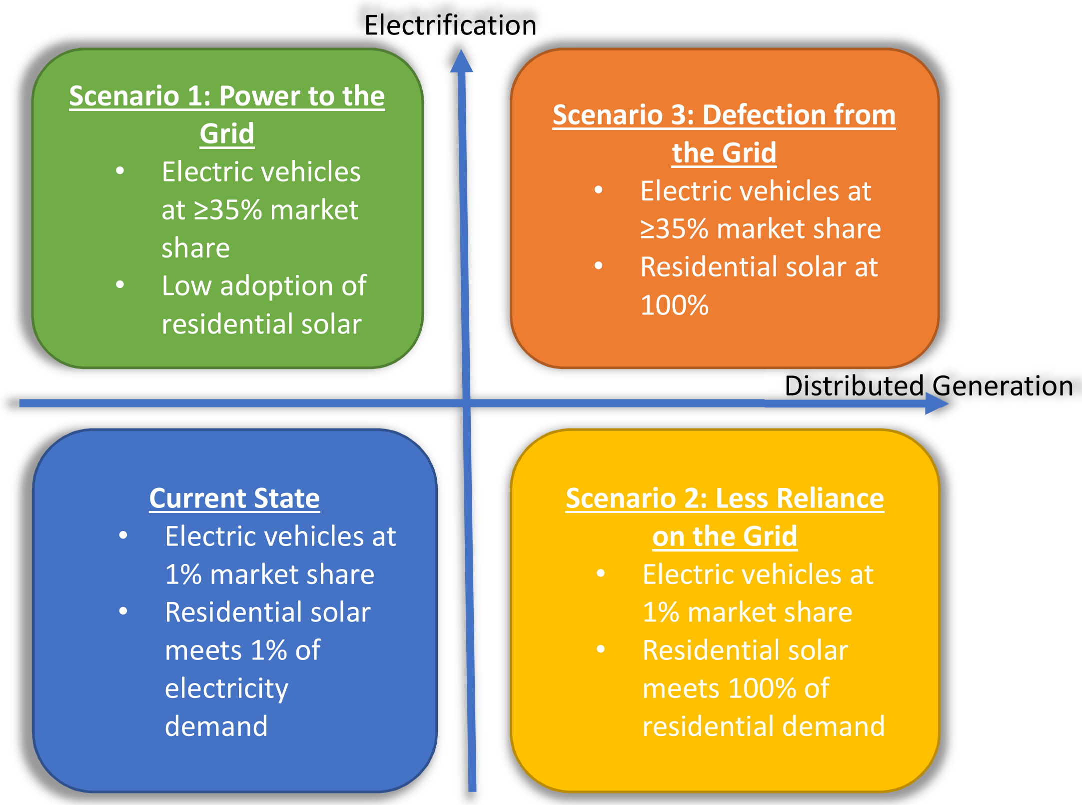

Figure 6: Plausible Scenarios concerning the Electric Grid

The current state is represented by the lower left quadrant in the diagram, where market penetration of both electric vehicles and distributed generation is low. The upper left quadrant represents Scenario 1, where electric vehicle adoption continues to experience exponential growth, while the rate of adoption for residential solar slows. Under Scenario 1, the justification for undergrounding is strengthened as demand for grid electricity increases with the electrification of transport. The lower right quadrant represents Scenario 2, where residential solar continues to experience exponential growth, while the adoption rate of electric vehicles slows. Scenario 2 weakens the justification for undergrounding slightly, as a larger proportion of distributed generation results in lower reliance on the grid and lower consumption of grid electricity. The upper right quadrant represents Scenario 3 where both residential solar and electric vehicle adoption continue to grow exponentially. Under Scenario 3, there is the weakest justification for the undergrounding initiative as the confluence of both technological drivers create conditions that would give consumers the option of defecting from grid electricity and thus avoid grid charges entirely.

9. Scenario Analysis

Analysis under Scenario 1: Power to the Grid

The proliferation of electric vehicles would increase demand for grid electricity, especially if the grid undergirds the public charging infrastructure for electric vehicles. The MIT report estimates that at 25% penetration, electricity consumption is anticipated to increase by 5.5%. An extensive network of public charging infrastructure in turn provides drivers with peace of mind when driving longer distances in their electric vehicles.

Under such a scenario, the current cost recovery approach of funding fixed distribution costs through consumption charges can continue to apply. Grid infrastructure upgrades, like the undergrounding initiative, can continue to be funded through utility rate increases. As utilitization of the grid increases, the benefits of undergrounding, in terms of less frequent outages and lower maintenance costs, increase.

Analysis under Scenario 2: Less Reliance on the Grid

The widespread adoption of distributed generation results in a reduction in demand for grid electricity. Nevertheless, absent the proliferation of electric vehicles, battery costs remain high due to a lack of economies of scale. Consumers therefore remain connected to the grid, to ensure uninterrupted electrical supply during non-generation hours at night and during inclement weather.

The California Independent Systems Operator (CAISO) notes that this scenario creates the risk of a pronounced "duck curve", namely overgeneration during sunlight hours (such that supply exceeds demand) followed by a steep ramp up in electrical demand as the sun sets[34]. CAISO suggests a few approaches of mitigating this, such as selling surplus electricity to neighboring states, and increasing grid storage (to store excess electricity at times of high supply and sell it back to the grid when demand rises).

Under this scenario, a new charging model for fixed distribution costs e.g. fixed grid charges independent of overall usage, would have to be developed, especially as infrastructural upgrades are necessary in order to integrate distributed energy resources into the grid. The

[34] "What the duck curve tells us about managing a green grid", California Independent System Operator, 2016. https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

infrastructural investments required for undergrounding could be recovered in the same fashion, although the benefits of undergrounding would diminish somewhat as utilization of grid electricity decreases overall.

Analysis under Scenario 3: Defection from the Grid

Under this scenario, the rise of distributed generation and electric vehicles provide consumers with the option of defecting off grid entirely as they are able to generate and store electricity economically within their individual households. Investments in electric vehicles would support the mass production of batteries, driving costs down through economies of scale, thus enabling individual property owners to store their excess energy economically for later use.

As electric vehicles are able to store twice as much energy as the average U.S. residence consumes in a day, they become a viable substitute for the grid in terms of providing a safety net for uninterrupted power supply. Although vehicle chargers are currently unidirectional, electric vehicle companies like Tesla are working on vehicle-to-grid technologies to enable vehicles to provide power back to the household[35].

The risk of grid defection is the highest under this scenario should consumers decide that grid charges outweigh the benefits of remaining connected to the grid. A Morgan Stanley blue paper describes this "tipping point" as the confluence of rising utility rates and the increasing operational difficulties faced by utilities in integrating large amounts of distributed energy resources[36]. If consumers defect from the grid, those who remain connected would be left to bear a larger share of fixed costs, which may in turn incentivise more consumers to defect. The Rocky Mountain Institute describes this as a "death spiral" for utilities.

As the utilization of grid electricity is likely to diminish the most considerably under this scenario, the benefits of undergrounding would also be diminished the most. Unfortunately, this scenario might also be more likely for a few factors. First, the two technology trends may be reinforcing. Purchasing an electric vehicle incentivizes owners to install distributed energy resources in order to offset the increased costs of their heightened electricity demand. Energy storage complements distributed generation by making self-generated energy available even

[35] Dom Galeon. "Soon, Tesla Cars Could Power the Grid (and Our Homes)". Futurism.com, 23 September 2016. https://futurism.com/soon-tesla-cars-could-power-the-grid-and-our-homes/

[36] Stephen Byrd, Timothy Radcliff et al. "Solar Power & Energy Storage", Morgan Stanley Blue Paper, 28 July 2014.

during non-generation hours. Second, residents in eco-conscious Berkeley are likely to continue to lead in the adoption of green technologies.

To cope with such a scenario, a paradigm shift in business models might be necessary in order to maintain the grid, which would still be necessary to supply electricity to consumers who lack access to distributed generation, including through public-private partnerships which subsidize grid operations through public funding. A CISCO Blue Paper describes the possibility of expanding the uses of existing utility infrastructure e.g. lamp-posts and utility poles, to providing new public services such as public WiFi, digital media streaming and Closed Circuit Television for traffic and crime monitoring[37]. By providing additional public goods, the justification for higher public funding for such infrastructure would be strengthened.

[37] Rolf Adam. "Utilities in 2050: Hypotheses for the Future of the Industry", CISCO White Paper, 2014.

10. Developments in Infocomms Technology

The aesthetic benefits from undergrounding would not be realised from converting electric wires alone; it would also be necessary to transfer the other utility wires i.e. internet, television and telephone underground as well. It is thus pertinent to consider the technological trends in the ICT domain as well.

The use of and dependence on the Internet will increase into the future. We can expect the other utility services e.g. television and telephony to be increasingly based off the Internet. Within each household, more appliances will be 'smart' and require internet connectivity. As the internet pervades every aspect of daily life, consumers will expect to be always connected. This favors the ongoing shift from wire-bound to wireless last mile connections. A 2015 Pew Research Center study found that the share of Americans with broadband at home has plateaued, and more rely only on their smartphones for online access, especially among youths[38]. While fibre optic cables will serve as the primary means of bringing internet connectivity to a region[39], more internet traffic will be carried wirelessly through 5G cellular data networks as well as fixed wireless antennae. Google recently acquired a fixed wireless provider, Webpass, to complement its fiber operations. Likewise, Facebook is conducting a trial on wireless connectivity in the City of San Jose.[40]

The adoption of wireless last mile connections will reduce the need for utility wires, as well as enhance the value proposition of utility poles as hosts for mounting internet equipment which require line-of-sight to operate. In this regard, the increasing use of wireless last mile connections would diminish the benefits of undergrounding utility wires over time.

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[38] Home broadband 2015, Pew Research Center, 21 Dec 2015

[39] According to a discussion between representatives from AT&T and the Berkeley Undergrounding subcommittee

[40] Michael Reilly. "Google Fiber Stalls as the Industry Gears Up for Ultrafast Wireless", MIT Technology Review, 15 Aug 2016 https://www.technologyreview.com/s/602184/google-fiber-stalls-as-the-industry-gears-up-for-ultrafast-wireless/

11. Conclusion and Recommendation

It is difficult to project with certainty how technological trends will pan out. However, it is unlikely that technological changes will enhance the value proposition of converting existing overhead utility lines to undergrounded ones significantly. Under the most optimistic scenario where only electric vehicles take off, we see a modest increase in grid electricity demand by 20%. While this increases the relevance of the grid, it does not directly influence the major benefit of undergrounding in terms of aesthetics and property prices, and thus would not change the overall benefit-cost ratio significantly. On the flip side, demand for grid electricity is likely to fall if distributed generation proliferates. Such a scenario would complicate financing for undergrounding under the current established approach and thus affect its feasibility.

In summary, technological change increases the complexity of financing the conversion, as certain models e.g. surcharges on consumption or fixed grid charges would be effective and desirable only under certain scenarios, while adversely affecting consumer behaviour and undermining the undergrounding effort in others. Given this complexity, it may be practical to phase out the implementation of the program, say in 5-year blocs, so that the City can respond to technological changes as they develop.

APPENDIX D

NOTES FROM MEETINGS WITH PG&E, AT&T, AND COMCAST

Utility Undergrounding – PG&E meeting notes

Meeting Date/Time: July 10, 2017, 3:00 pm
Meeting Location: Elm conference room
Attending: Public Works Commission: Ray Yep
Disaster and Fire Safety Commission: Paul Degenkolb
Transportation Commission: Tony Bruzzone
PG&E: Treva Reid, East Bay public affairs
John Oldman, Electric operations superintendent
Andrea Miller, Rule20A manager
Vitaly Tyurin, Division leadership team senior manager
Les Putnam, Gas public safety specialist
Rod Bersamina, Public affairs electric support
Councilmember: Susan Wengraf
Public Works Department: Ken Emeziem

Meeting Notes

1. Subcommittee Chair Ray Yep called the meeting to order at 3:00 pm.
2. Introductions and purpose of meeting:
   - All attendees introduced themselves.
   - Paul summarized the purpose of the meeting.
3. Comments by PG&E:
   a. John said that the impacts to overhead (OH) versus undergrounded (UG) utilities depends on the type of disaster. Fires affect OH wires more. UG wires could be more affected by earthquakes, especially in areas susceptible to landslides. He said that UG utilities were more affected in the Napa earthquake than OH.

   b. John said that the long term reliability of UG utilities is better. He said that maintenance on UG utilities could be more than OH. There is a requirement to inspect UG vaults every 3 years. Poles are inspected every 5 years. Poles are now treated to withstand fires. There is also the problem that owners put things on top of vaults. An outage in an UG cable can be 2 – 3 days. Outages in OH wires are typically 6 hours or less.

   c. Les said there are 2 gas lines in Berkeley. They are classified as low pressure.

   d. Andrea said that the CPUC is reviewing the Rule 20 program. It seems that there is interest to focus on arterial streets. It would be appropriate for Berkeley to provide input. A decision is expected by July 2018. Andrea said that UG costs about $3 million per mile for PG&E's cost.

   e. The PG&E attendees did not know of other cities that have a comprehensive undergrounding program. UG is mostly used in new developments.

   f. John said that there are advantages to UG in dense commercial areas. It is not feasible in suburban areas. In Berkeley, there will be concerns on limited right-of-way for UG in the hills.

   g. Regarding technology trends, PG&E has a strategy group. Rod said that Joe Herr would be a good person to talk with. Rod said that with falling solar and battery storage costs, some people may want to disconnect from the grid. He said that PG&E's opinion is that the world is inter-connected and it is better to be connected with the grid.

h. Municipal utilities have less influence with the CPUC than PG&E.

i. Tony suggested that pilot UG projects and not large scale UG will be more feasible. PG&E agrees. Tony asked for PG&E's help setup criteria.

Treva said they appreciated being a part of our study. The meeting was adjourned at 4:15 pm.

Utility Undergrounding – AT&T meeting notes

Meeting Date/Time:	April 6, 2017, 3:00 pm
Meeting Location:	Cypress conference room
Attending:	Public Works Commission: Ray Yep, Larry Henry, Nic Dominguez Disaster and Fire Safety Commission: Victoria Legg, Paul Degenkolb Transportation Commission: Tony Bruzzone AT&T: Daren Chan, Alice Chen, Scott Booth, David Cheney Councilmembers: Susan Wengraf, Kris Worthington Goldman School student: De En Ni, Daniel Bradway

Meeting Notes

1. Subcommittee Chair Ray Yep called the meeting to order at 3:00 pm.
2. Public comments: No members from the public were present.
3. Introductions and purpose of meeting:
   - All attendees introduced themselves.
   - Ray summarized the purpose of the meeting.
4. Comments by AT&T:
   a. AT&T is working on their giga power project throughout the Bay Area but not in Berkeley. They are moving away from copper and their business plan is to bring fiber optic cable to the home. However, they must maintain actual wires for any customer who wants them. They will have wireless to smart devices (such as smart meters). .

   b. To meet 5G demand, will continue to need a wired platform from which wireless picks up (fiber). Looking to least cost most effective structural solutions. Does not favor undergrounding as a delivery system. Does practice utility coordination whenever possible.

   c. AT&T has fiber within city limits. Fiber is often already in existing conduits.

   d. Underground installation includes 12-inch separation above PG&E and four feet from gas.

   e. Alice said that Harris' cost estimates for undergrounding are grossly under estimated. She estimates that the cost is 200 – 300% higher. She mentioned a 3,500 to 4,000 linear foot undergrounding project in Albany that cost $5.9 million (originally estimated to cost $750,000). Project location is Marin Avenue between San Pablo and the BART tracks. The project includes gray water lines and was paid by Rule 20A funds.

   f. Undergrounded wires are typically safer in fire and high wind situations. However, earthquakes, landslides and flooding may damage underground conduits. Tony asked if the conduits can be made stronger. Alice said somewhat. Now using flex materials along fault lines and expect every 20 years or so will need to straighten conduits. Trenches are not built to withstand a 7.0 earthquake.

g. Underground repairs take longer and are easily damaged by digs. Any repair is much more costly than aerial repairs but especially so the bigger the disaster. The rule of thumb is 4 times more expensive after an earthquake and repairs can take many months because repairs cannot start until after municipalities have repaired their streets. In contrast, overhead utility wires can be operational within days or weeks of a disaster.

h. PG&E has a "green book" for construction standards. It states the clearance between conduits. AT&T complies with CPUC GO95 for loading on poles.

i. Alice said that Ken Emeziem is a good resource at the City.

j. For normal maintenance, work on overhead wires will be faster although overhead wires require more overall maintenance from sun and wind damage than wires located underground. Fiber cable is less susceptible to environmental damage than copper. Overhead wires average life is 60-80 years, whereas undergrounded wires could last 100 years. Overall cost between aerial and undergrounded wires is likely a wash.

k. ATT are joint owners with PG&E on 99% of in service poles. Average pole costs $10k. They share maintenance. PG&E dictates the design standards, including pole size which is based on voltage load and pole height, 18 feet for road traffic, 16 feet for sidewalks and 12 feet for houses. Ownership is typically 60% PG&E and 40% AT&T. Sometimes it's a 50-50% ownership split.

l. AT&T does not know of cities that own joint trenches, except in Emeryville around Ikea. The trench was later sold.

m. When asked which cities have undergrounding programs, Alice mentioned the Oakland Hills Piedmont Pines project. It started in 1997 and has just completed Phase One of three phases. Alice also mentioned that Pleasanton did a 1/4 to 1/2 undergrounding project which went well. San Diego is the only known citywide program and which is now rumored to have run out of money to complete the project as originally planned out.

n. Undergrounding utilities can be very complicated. Geological and infrastructure issues can interfere with project completion, property owners can stop the process at any time during the construction phase (Piedmont Pines), plants and trees can be damaged, rocks get moved, streetlights have to be replaced, roads repaved. PG&E, almost always the lead trencher may decide to do one side of the street even when AT&T and Comcast are already on the other side of street

o. AT&T owns and maintains conduit. They do not lease.

p. ATT does not see the need for fiber optic cables changing over the next 20 years because it is easier to work with and the price is expected to drop over time. The connection to the end user may change as the technology changes, 1G to 5G delivery only took 15 years. Business Fiber already available and focus now on residential GigiPower projects. Fiber must reach cell sites and as demand increases, AT&T anticipates small cell GigaPower or microcell overlay sites (line of sight technology) will be added to large cell towers to meet the increased demand. One example - Verizon built out a couple hundred small cells for the SF Superbowl to meet increased demand for wireless reliability.

q. AT&T would like to bring GigiPower to Berkeley but wireless permitting processes have had a material adverse effect on bringing new technology to the city. AT&T encourages the city to partner with them if it desires to pursue GigiPower for its residents.

Daren said they appreciated being a part of our study. The meeting was adjourned at 4:30 pm.

Utility Undergrounding – Comcast meeting notes

Meeting Date/Time: March 30, 2017, 3:00 pm
Meeting Location: Cypress conference room
Attending: Public Works Commission:
Ray Yep, Larry Henry, Nic Dominguez
Disaster and Fire Safety Commission:
Victoria Legg, Paul Degenkolb
Comcast: Ken Maxey, Lee-Ann Peling
Councilmember Susan Wengraf
Goldman School student: De En Ni

Meeting Notes

1. Subcommittee Chair Ray Yep called the meeting to order at 3:00 pm.
2. Public comments: No members from the public were present.
3. Introductions and purpose of meeting:
   - All attendees introduced themselves.
   - Ray summarized the purpose of the meeting.
   - Victoria provided an overview of the Council comments at their March 28th meeting.
4. Comments by Comcast:
   a. Comcast started 52 years ago. The company has merged with NBC Universal.
   b. Comcast is moving to Smart Cities concept e.g. mesh networks where Comcast provides the fiber to wireless providers: wireless water meters, telehealth (KP doing it now), home security partnership with Verison- all possible with adoption of 5G and next gen fiber technology which will permit wireless without necessity to have physical wires attached to homes. This, however, does not remove the necessity for wireless to "attach to something", i.e. buildings or poles as a means to "get back" to fiber wires. The City of Mountain View has an RFP out currently for Smart City project.
   c. Favors micro trenching 12" deep as economical way to install cable underground.
   d. Regarding undergrounding overhead wires, Comcast is rarely involved in the upfront planning. They are generally told after the fact on what to do. Comcast prefers a "one dig" approach to working in streets.
   e. Maintenance with undergrounded utilities is generally not a problem except for cable cuts. Comcast does not share trenches preferring to retain control over own cable. New connections may cost more particularly where there is a moratorium on pavement cuts which makes crossing streets a challenge.
   f. Undergrounding utility challenges in the Berkeley hills and elsewhere in the city include the topography, and narrow streets coupled with few sidewalks creates a problem of where to trench, where to put vaults and getting power to vaults. Vaults under streets is not desirable. Noisy as lids don't fit tightly. Sometimes the only usable space is on private property.

g. In the event of a major emergency, restoring PG&E power must occur before wi-fi services can be made available. Comcast strives to follow right behind PG&E efforts to restore power since power and wi-fi services are needed by emergency services and residents need it to communicate with family and others. Provided wi-fi services within a few hours to emergency shelters after Napa EQ and in areas flooded from this winter's storms.

h. What is put on poles is heavily regulated by the CPCU with inspections every 4-5 years. Requirements are covered under CPUC Rule 95 covering both visual appeal and permissible load bearing.

i. Biggest fiber strand to Berkeley goes to EOC and also considerable fiber around UC. Aware there is a fair amount of fiber installed within the city but cannot provide a map of where fiber is located. Until recently, work has been in residential areas and only newly focused on building out commercial areas of the city.

j. Unlike satellite services, Comcast pays 5% franchise fee for video services, 1% fee goes to school transmissions and the City of Berkeley collects a 7.5% Utility User Tax

k. Competitors to Comcast include AT&T, Webpass, Sonic, etc.

l. Regarding future technology trends, Ken and Lee-Ann did not have specifics to share except fixed wireless which operates on line-of-sight that is especially advantageous in providing consistent services to rural areas. Believe future in urban areas will be antenna installations on building rooftops as only necessary physical hookup to delivery of wireless services. Comcast participates in Innovations Lab located in Denver. Larry asked if we can access them and Lee-Ann said that she would check. Comcast has a fiber backbone and is aware of the trend to 5G wireless.

m. Lee-Ann had the following questions for Berkeley:

  - How was the undergrounding cost estimates developed? Comcast uses $1 million/mile.
  - What is meant by revenue generation from utility corridors?
  - What is horizontal drilling?

n. Lee-Ann is aware of wide scale undergrounding efforts in Tiburon, Santa Rosa, Oakland, San Francisco, and Palo Alto.

We thanked Ken and Lee-Ann for attending. The meeting was adjourned at 4:30 pm.

APPENDIX E

NOTES AND HANDOUTS FROM MEETINGS WITH THE CITY OF PALO ALTO AND CITY OF SAN DIEGO

Palo Alto Meeting Notes on Utility Undergrounding

Meeting Date/Time:	May 4, 2017
Meeting Location:	City of Palo Alto
Attending:	Council Member: Susan Wengraf. Transportation Commission: Tony Bruzzone, Public Works Commission: Larry Henry, Disaster and Fire Safety Commission: Victoria Legg City of Palo Alto: Edward Shikada, Assistant City Manager Palo Alto Dean Batchelor, COO Debbie Lloyd, Acting Assistant Director, Utilities Tom Head Engineer, Electric Utilities

Meeting Notes

Palo Alto has been building up its self-owned utilities (gas, electricity, water, waste) for 100 years. Revenues are enterprise funds, not general funds.

Founding father Stanford wanted Palo Alto to be utility independent. Only known other utilities independent municipalities are Susanville and Long Beach, both natural gas only. Palo Alto has 25,000 utility customers, 21,000 of them are residential customers.

Started undergrounding in 1965, criteria have been aesthetics as well as outage reliability, primarily targeting business districts and major thoroughfares. Once business districts and major thoroughfares are completed (2 UUDs remaining), the city will turn its attention to residential areas.

AT&T shares standard sized pole ownership rights with City of Palo Alto (owns 2 feet of each pole which it can rent out) and has a strong interest in providing dark fiber for commercial enterprises. AT& T has made clear its lack of interest in participating in residential undergrounding projects based on AT&T' s own tariff. Residential alternatives: AT&T/Comcast can cut poles or participate using city's trenches. For cell signal towers, can use streetlight poles (19 already installed),but not traffic signals, and can use rooftops. Globe style lights forbidden as do not hold up well after an EQ.

Undergrounding projects are funded by annually setting aside 1% of utility revenues (approx. annual revenues are $125 MM). Budget roughly $2MM for each street mile. Once $3MM has been set aside, location identified, UUD formed, design completed which includes where all substructures will be located and panel upgrades. All engineering done in-house. Palo Alto chooses the contractor who does all work except connection though contractor provides a quote for each connection and is available for hire to make the connection from street to house. Planning phase factors in 18 months to get approvals from AT&T and Comcast before work can begin.

Has considered leasing as an option but anticipates amount can charge is limited.

Pad mounted transformers are preferred. Although visible to the public, they are safer to work on. Experience shows undergrounded vaults are damaged more easily and more frequently mostly due to water, heat, rodents and other liquid dumping. Underground explosion a risk. Vaults are located under mailboxes in commercial districts where not enough space for aboveground installation. Zero lot lines are a big challenge because neighbor cooperation necessary. Aboveground vaults in residential areas a big challenge-a 6x6 or 4x4 vault sitting in front yard. Vaults must be located where can deliver same voltage as older established neighborhoods.

Directional boring difficult based on number of conduits needed, and what else is undergrounded.

Micro-trenching doesn't work without a concrete cap and12" (Comcast's requirements) is too shallow. Need 30" depth.

About 5-6 years ago, started adding additional conduits for fiber when trenching and when replacing street lights. Fits about 10 conduits in same trench. Palo Alto owns 6 of them. Breakdown of shared cost- 60% Palo Alto, 30% AT&T and 10% Comcast.

Utility customers want all of the city undergrounded. Customers accepted rationale to concentrate first on commercial areas because of AT&T's contribution to cost. Customers also support basing undergrounding priorities on history of outages, by location and by cause.

The future of solar may impact utility revenue stream but not concerned until battery storage improves substantially.

As a utility, emphasis is on energy efficiency and longer term, community solar. An outage a week will trigger a review. Maintenance for undergrounded areas, replace cable on a 30-40-year cycle and transformers on a 30-year replacement cycle. From a public safety perspective, storms are of some concern as outages can occur from falling tree limbs, However, maintenance strong so not a big concern.

Paving plan schedule is 5 years. Easy for city to damage fiber because of 12 inch depth trench.

Palo Alto is a carbon neutral city. Has 900 net metering customers, 19 of them downtown, pay rate same as PG&E -$.13 per 1 kWh but want to reduce to $.08-.09/kWh.

Has not yet implemented any microgrid projects.

Verizon has installed 90 micro antennas.

Palo Alto has rebate incentive for multi-units to install EV chargers.

Palo Alto's critical services are considering battery storage as an alternative option to generators after widespread power loss due to a disaster.

San Diego Meeting Notes on Utility Undergrounding

Meeting Date/Time:	August 21, 2017, 1:30 pm
Meeting Location:	City of San Diego
Attending:	Councilmember: Susan Wengraf Public Works Commission: Ray Yep Disaster and Fire Safety Commission: Victoria Legg Transportation Commission: Tony Bruzzone City of San Diego: Hasan Yousef, Deputy Director Kris McFadden, Director Transportation and Storm Water Vic Bianes, Assistant Director Breanne Busby, Project Manager Bill Harris, Customer Service Program Manager Jim Nabong, Undergrounding manager Alejandra Gavaldon, Mayor's office representative SFG&E Claudia Valenzuela, Public Affairs Manager, External Affairs Kathy Valdivia, Manager, Undergrounding Program

Meeting Notes

The City of San Diego has one of the most aggressive undergrounding (UG) programs in the country, typically completing 15 street miles annually and now gearing up to double the street miles completed each year. The City has a strong working relationship with San Diego Gas and Electric (SDGE) who owns the utility poles within the city. Utilities owned by the city are limited to streetlights, water lines and sewers. The City has 1,400 miles of streets and 400 miles are undergrounded.

San Diego began its UG efforts in the 1970s using 20A funds for aesthetic and power reliability reasons. Funding dollars have been substantially increased by a Franchise Surcharge Tax. The program includes new street lights, repaving streets, improving ADA accessibility, repair of sidewalks, tree and landscape replacement as well as hook-ups from streets to all private property meters. City cost is typically $4 million per mile. Based on experience, the optimal size of an Underground Utility District (UUD) is between 250-300 residential properties and smaller sized commercial UUDs. SDGE has learned from experience that once a UUD exceeds 400 units in size, the project suffers from too many delays. Because San Diego is pushing to substantially increase its annual UG miles, SDGE has been actively contacting contractors and consultants to advise them of SDGE's anticipated needs before the RFIs and RFPs are written.

Their UG Master Plan was originally prepared in 2003 after the creation of the Franchise Surcharge Fund. It was approved by the CPCU and the purpose was to supplement 20A funds. The City established a separate fund just for UG projects. The UG Procedural Ordinance was amended. The plan was updated in 2009 to reflect UUDs established across all council districts, balancing across substations and matching up with other right of way projects. The plan will be updated again when the new census comes out.

The Franchise Surcharge is 3.5% of gross receipts generated within city limits. This generates about $70 million annually which is added to the annual 20A fund allotment of $18 million. The legality of the Franchise surcharge is currently being litigated, however, the City of Santa Barbara, having added a similar tax, recently received a State Supreme Court preliminary ruling in their favor. San Diego is confident they will be beneficiaries of this ruling once it is made final in the fall of 2017. The contested issue is whether the surcharge is in violation of Prop 218.

The City enjoys active mayoral and council members support, which in turn translates into resident support. Residents enjoy a boost in property values and the clean visuals of UG streets. Plans are shared in project areas to gain community cooperation and buy-in. Sometimes, especially in lower income areas, the City will need to cover the cost of hooking up power to meters and/or to replace meters that are no longer serviceable. Most customers, however, pay these costs. On average, 70% of all proposed design are adopted by residents without the need for modifications.

Scheduling involves coordination among other service providers per the city's Street Preservation Ordinance, San Diego's one dig plan. Especially in areas (mostly the hills) where street paving material is concrete, San Diego will actively reach out to other utilities before scheduling an UG project. All departments must post their planned projects into a database which is then checked against planned street repaving. The Street Preservation Ordinance requires no street digs until five years after repaving.

Scheduling can be slowed when a group opts out. Typical problems are people objecting to aboveground vaults, inability to gain permission to go onto a property, meters must be replaced but the owner is unwilling or can't afford the cost, or a group cannot come to agreement on a workable design. SDGE is very supportive of San Diego's goals for UG, although it is expensive to install ($1 million cost per mile), because of power reliability and ease of maintenance. All vaults are aboveground and pad mounted for easy accessibility and wherever possible, placed in city right of way locations. Vaults can be painted or skinned to blend better into the environment they are placed.

Some areas of San Diego, such as canyon lands, hilly, and landslide prone areas, are not eligible for UG. In such areas, SDGE will make other investments to harden the infrastructure such as replacing wood poles with metal/steel poles, or replacing poles with taller ones in areas of high fire risk. Close/Open circuit equipment might be added in areas to withstand high winds and minimize sparking. Liquefaction zones are not an UG concern, partly because vaults are placed aboveground. No transmission lines are UG, only distribution lines.

SDGE uses duct banks, 4 to 5 inches diameter for distribution lines and with space to add additional wires if needed at a later date. Communications conduits are more shallow and are currently being designed to connect directly to nodes and then wi-fi to homes.

The city and SDGE worked together to successfully establish a tariff for the use of 20D public funds in high fire prone areas. SDGE filed an advise letter based on the County of San Diego and CAL Fire maps and input. 20D will cover UD costs but not the cost to remove poles. The CPCU will shortly begin reviewing public funding programs, how dollars are allocated among utilities and how each utility works with municipalities to promote UG. A final report is expected in September, 2019.

San Diego has not experienced big disaster power disruptions except for two significant fires in the county in 2003 and 2007. As a result, there has been substantial post fire planning around alternative redundancies, mutual aid assistance and insurance/CPCU reimbursement for damaged infrastructure.

SDGE is supportive of microgrids and renewable, power stability projects. SDGE funds the cost to UG and the city funds and manages any upgrades. Areas that are under ongoing review and discussion between the City and SDGE include existing power loads, future technologies and expected community growth.

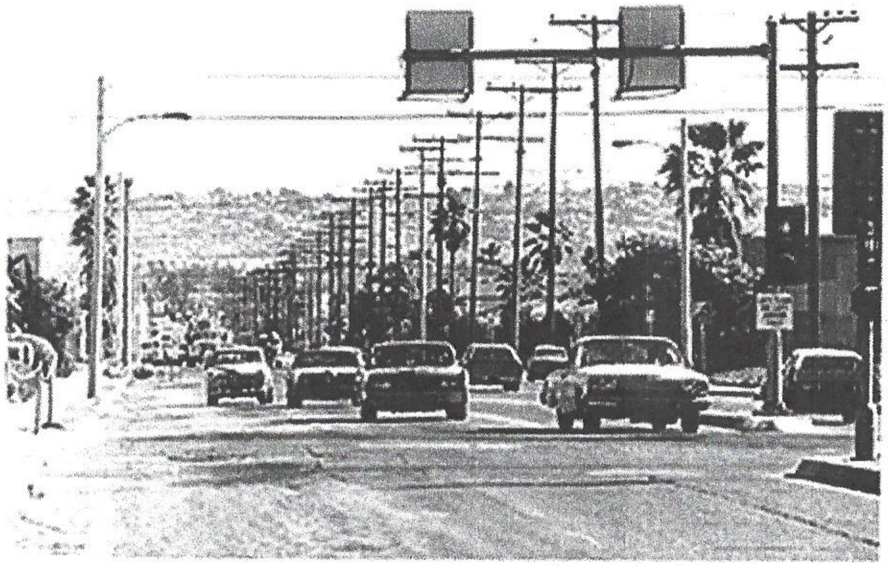
Transportation & Storm Water Department

Utilities Undergrounding Program

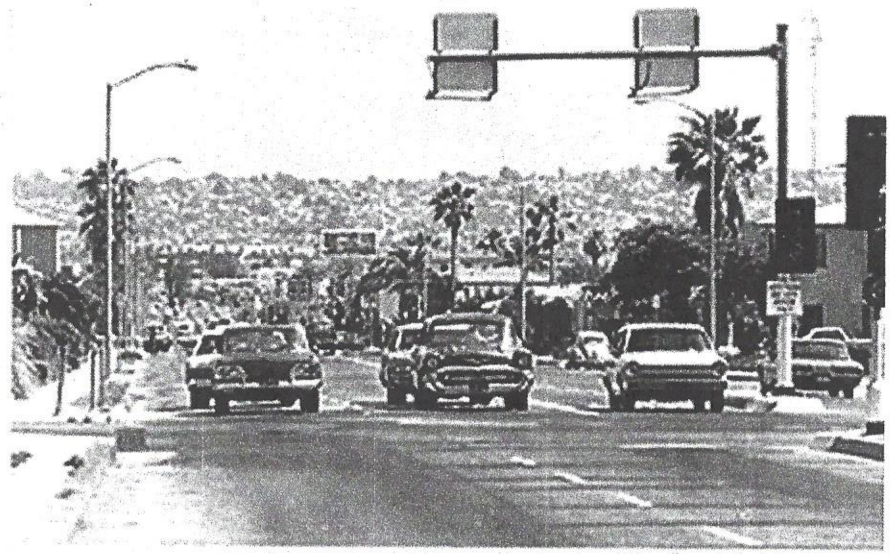
Overview

Presentation to the City of Berkeley, Vice Mayor
August 21, 2017

How it All Began

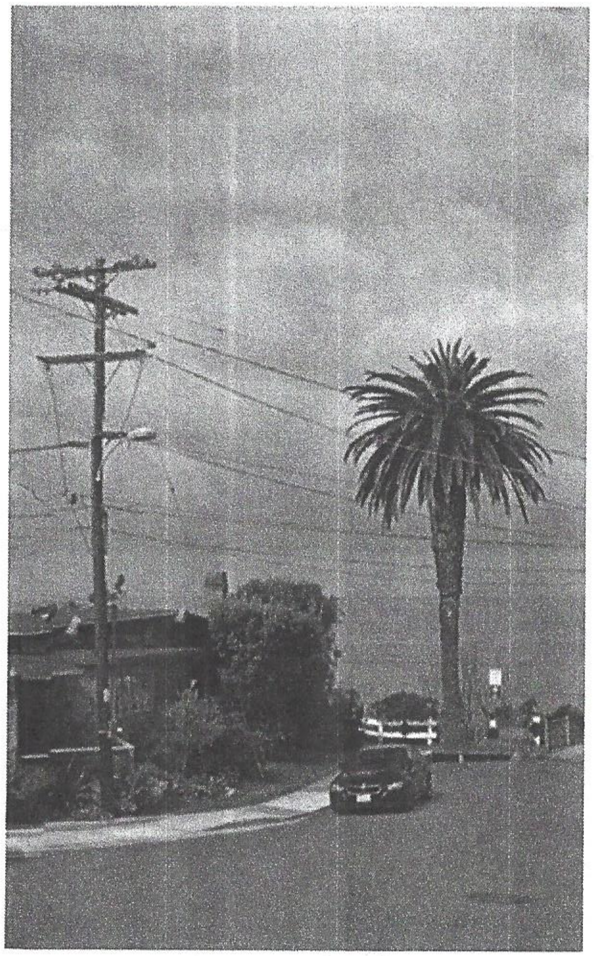


Mission Boulevard, circa 1972 - Before Undergrounding



Mission Boulevard, circa 1972 - After Undergrounding

Shortfalls of Original Program



- Rate of undergrounding too slow
- Hundreds of miles would never be undergrounded
- High public interest in undergrounding
- Special assessment districts introduce too many problems

Transportation & Storm Water

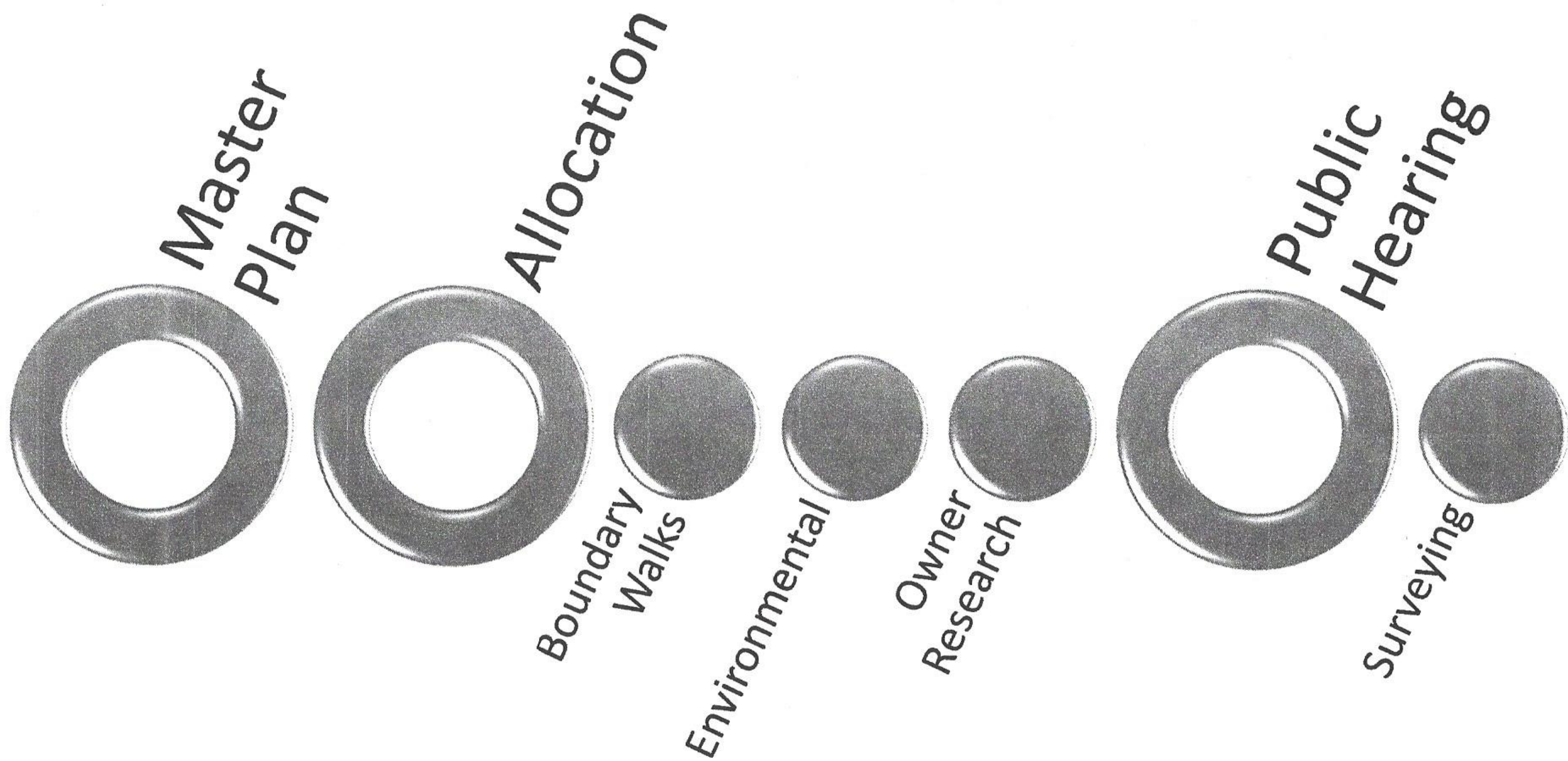
Big Change in 2003...
Creation of the Surcharge Fund

Surcharge Program Components

- Increased franchise fee authorized by the CPUC
- Council Policy established guidance on fund usage
- Underground Utilities Procedural Ordinance was amended

Transportation & Storm Water

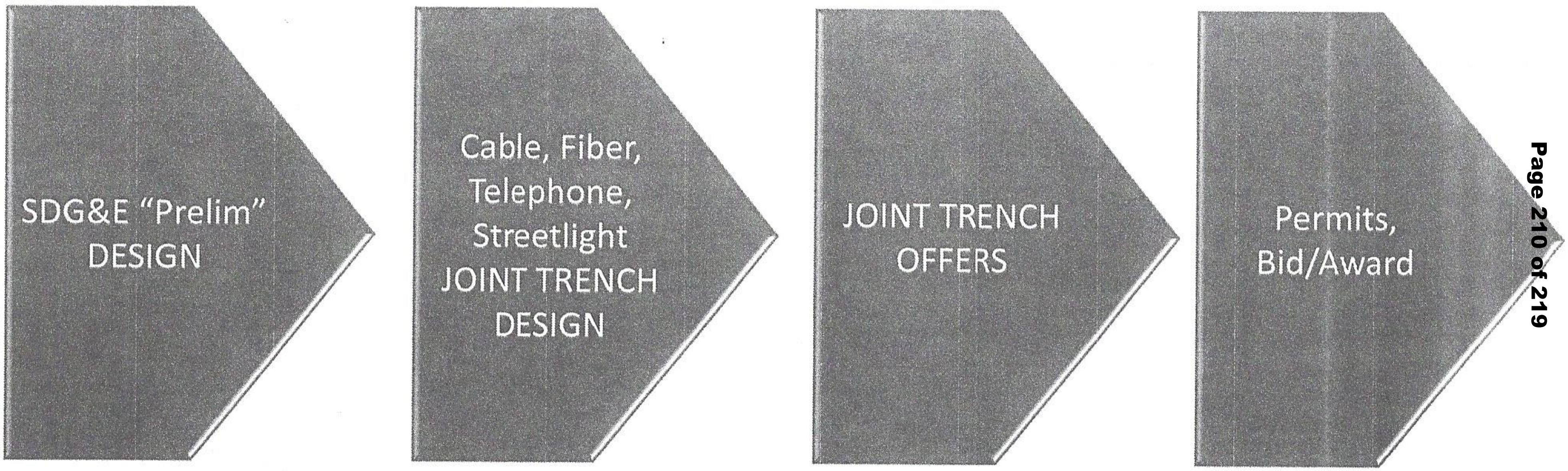
Initiation Process



Rule 20A or Surcharge

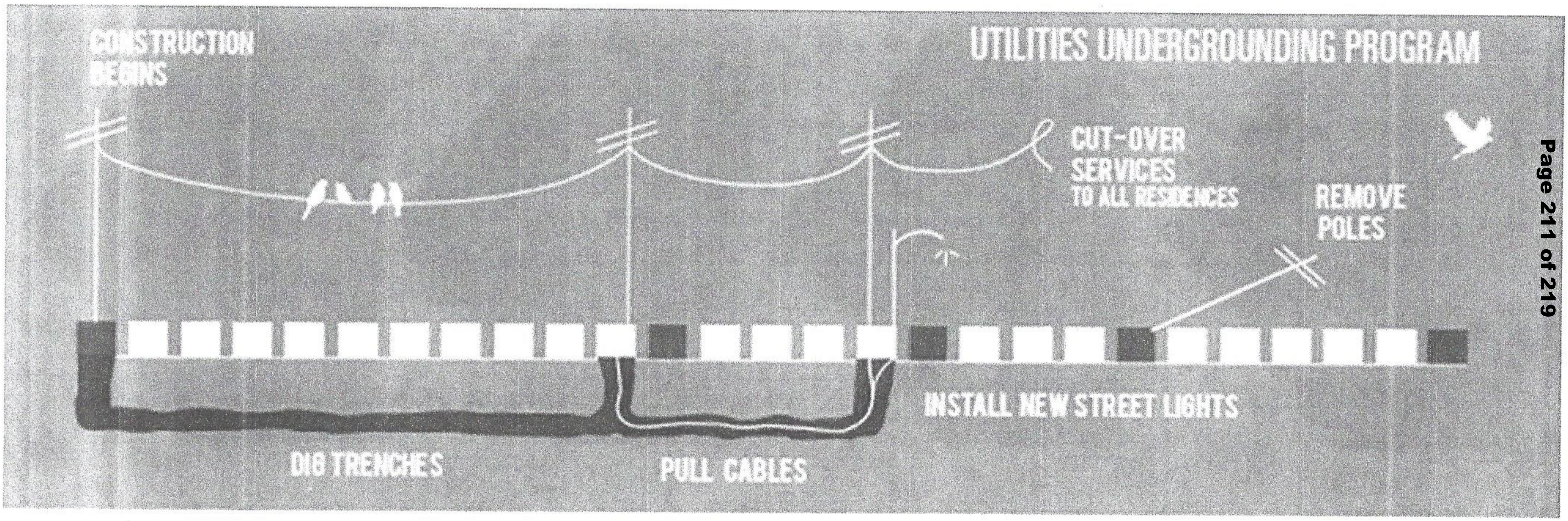
Transportation & Storm Water

Design Process



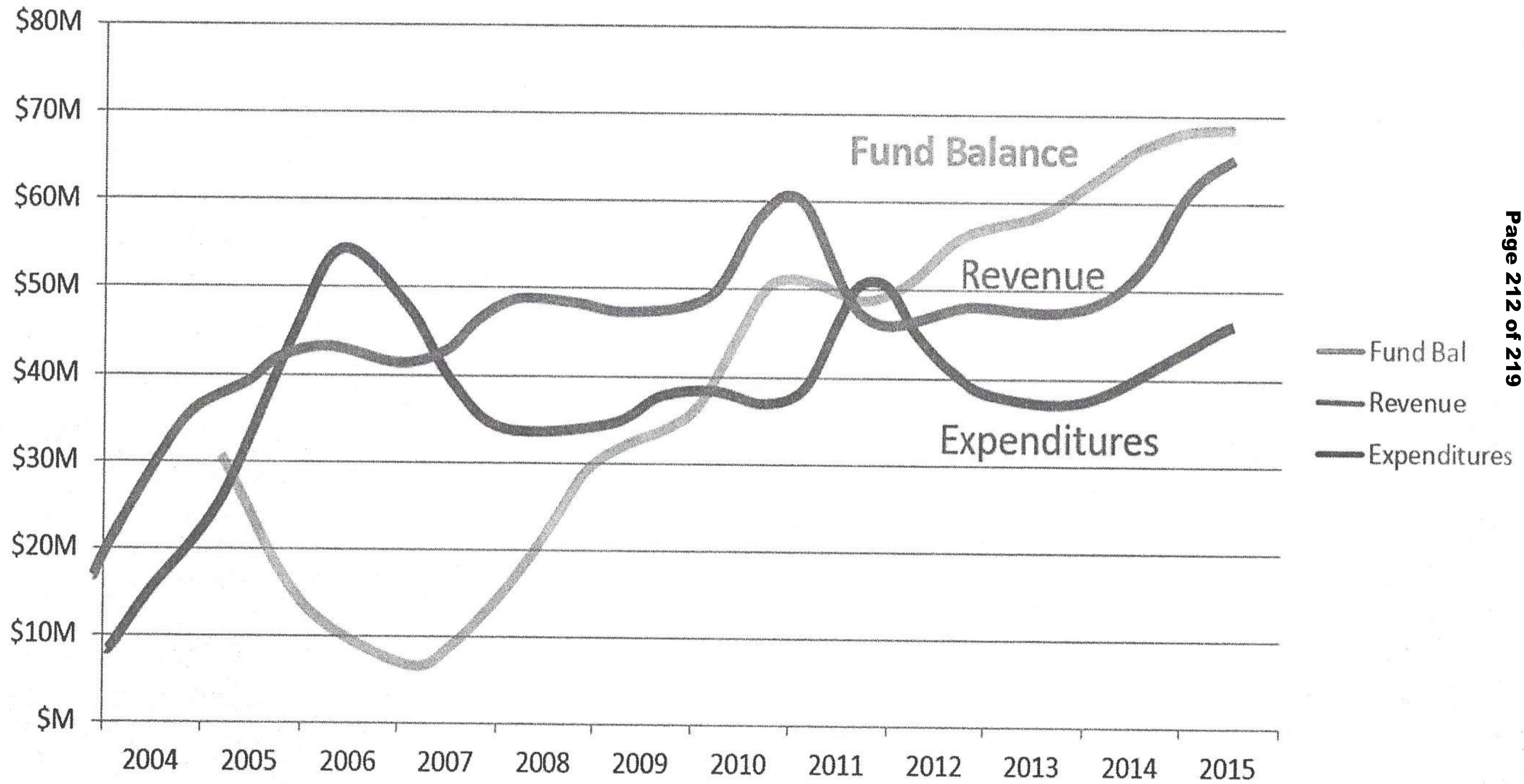
Transportation & Storm Water

Construction Process



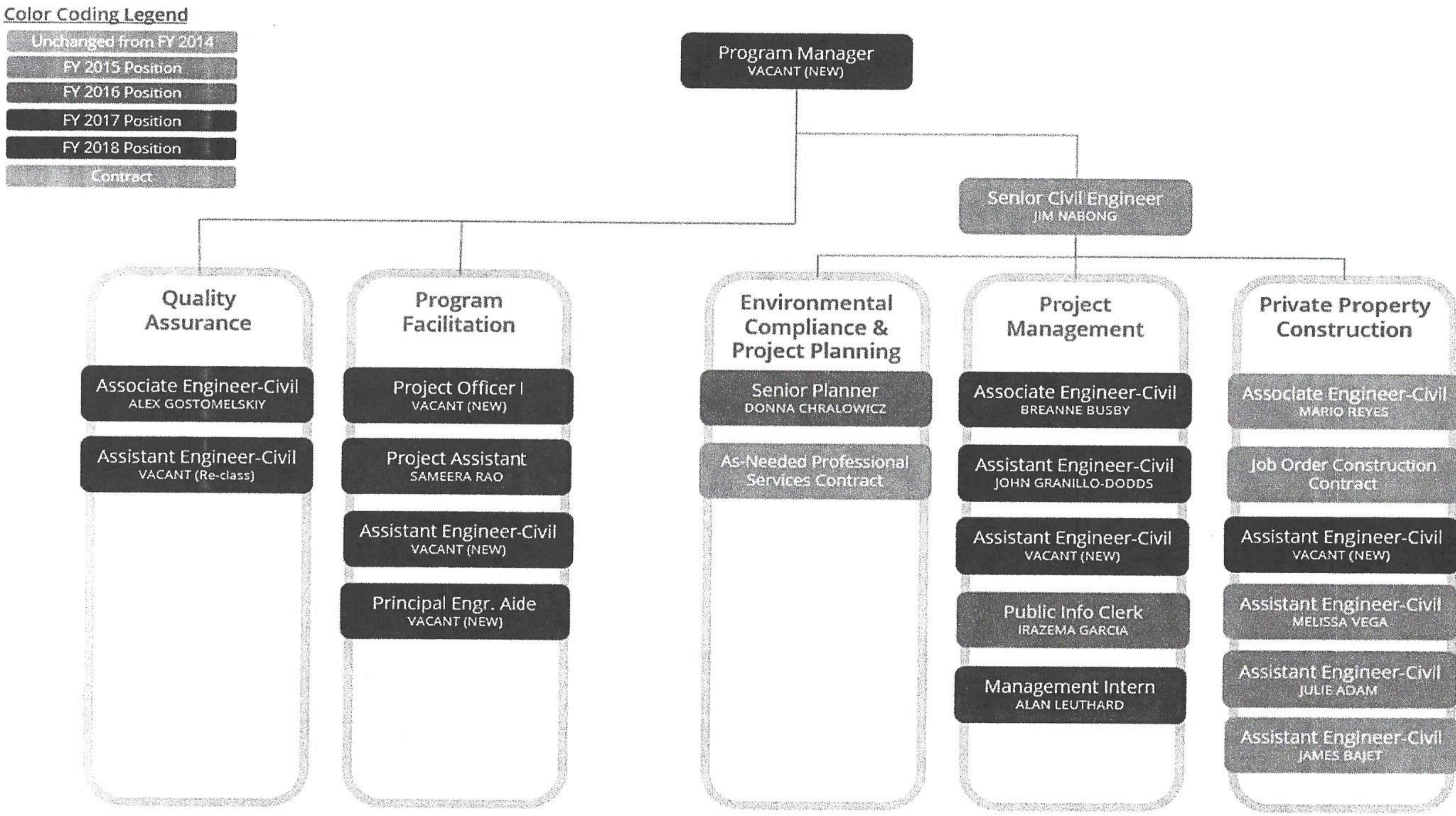
Transportation & Storm Water

Challenges of Managing a Fund



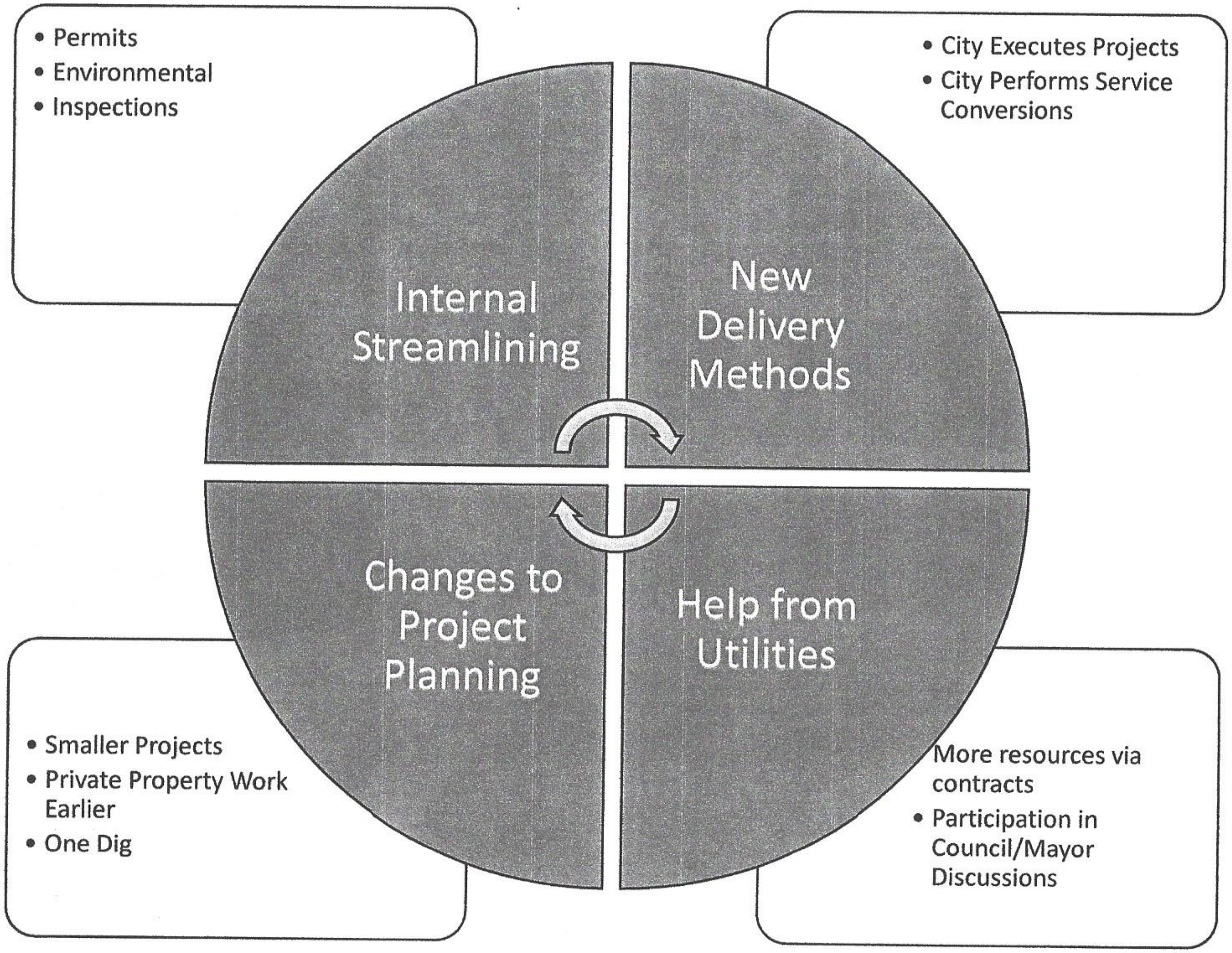
Transportation & Storm Water

Expanding the Team



Transportation & Storm Water

Other Solutions

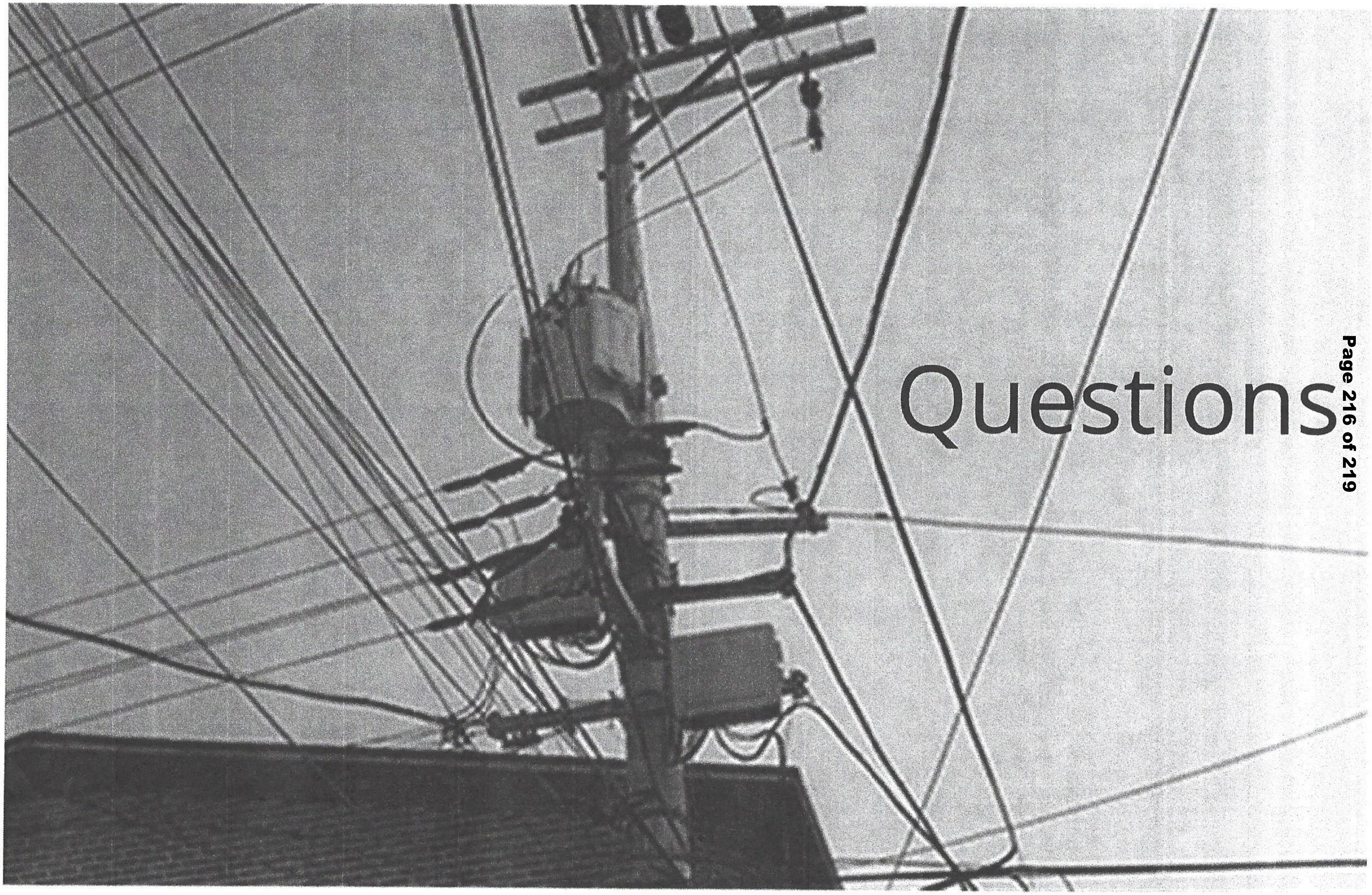


Transportation & Storm Water

Take Away

- Identify a policy champion (Mayor or Councilmember)
- Establish a reliable funding source
- Identify key dedicated staff to manage
- Establish policy and legal structures (local code)
- Work closely with key stakeholders
- Plan for extensive outreach to the public

Transportation & Storm Water



APPENDIX F

CPUC RULE 20

Program Description

Utilities annually allocate funds under Rule 20 to communities, either cities or unincorporated areas of counties, to convert overhead electric and telecommunica facilities to underground electric facilities. The recipient communities may either bank (accumulate) their allotments, or borrow (mortgage) future undergrounding allocations for five years at most.

The Commission instituted the current undergrounding program in 1967. It consists of two parts. The first part, under Tariff Rules 15 and 16, requires new subdiv (and those that were already undergrounded) to provide underground service for all new connections. The second part of the program governs both when and w utility may remove overhead lines and replace them with new underground service, and who shall bear the cost of the conversion.

Instead of specifying a fixed allocation formula, Decision (D) 73078 adopted on September 19, 1967, required each utility to report annually and to propose an a for its Rule 20 allocation. Utilities have submitted their Rule 20 allocation budgets to the CPUC each year by letter and set aside approximately two percent of th electric revenue for overhead conversions. The total allocation then was divided among individual cities or counties based on a 50/50 allocation formula. This fo requires half the allocation to be based on the ratio of the community's overhead meters to total system overhead meters, and half based on the community's to meters to total system meters.

Then D.82-12-069 adopted in December 1982, ordered Pacific Gas and Electric (PG&E) to consult with the League of California Cities to determine PG&E's futur 20A allocation budgets. PG&E and the League agreed to use a "composite inflation and real growth factor" to determine annual Rule 20A allocation budgets. P would adjust annual allocation budgets based on the actual inflation for the period and adjusted growth factors. These escalation factors have been ~5% to 6% 2012, when PG&E began to reduce its annual allocations almost by half based on its 2011 General Rate Case (GRC) settlement.

Tariff Rule 20 is the vehicle for the implementation of the underground conversion programs. Rule 20 provides three levels, A, B, and C, of progressively diminish ratepayer funding for the projects.

Under Rule 20, the Commission requires the utility to allocate a certain amount of money each year for conversion projects. Upon completion of an undergrounc project, the utility records its cost in its electric plant account for inclusion in its rate base. Then the Commission authorizes the utility to recover the cost from ratepayers until the project is fully depreciated.

Rule 20 requires the utility to reallocate to communities having active undergrounding programs amounts initially allocated to others but not spent. Cities also m mortgage 20A funds for five years.

Because ratepayers contribute the bulk of the costs of Rule 20A programs through utility rates, the projects must be in the public interest by meeting one or mor the following criteria:

- Eliminate an unusually heavy concentration of overhead lines;
- Involve a street or road with a high volume of public traffic;
- Benefit a civic or public recreation area or area of unusual scenic interest;
- Be listed as an arterial street or major collector as defined in the Governor's Office of Planning and Research (OPR) Guidelines.

The determination of "general public interest" under these criteria is made by the local government, after holding public hearings, in consultation with the utilities

Contribution Thresholds Per Rule	Ratepayer Contribution Through Utility Rates	Customers Receiving Undergrounding
20A	80%	Max: cost from street to meter Min: zero if use mainline funds
20B	20%	80%
20C	De minimus	100%
20D	~100% *	Max: cost from street to meter Min: zero if use mainline funds

* Note: 20D is a new program approved by the Commission in January 2014 only for San Diego Gas & Electric Company. No completed project data available.

California has approximately 25,526 miles of transmission ... 557 miles of distribution lines, in which approximately 152,000 miles of distrit lines are overhead. Utilities convert less than 100 miles/year to underground. Therefore, if our program remains at the current progress, it will take over a thous years to convert our entire distribution system to underground.

PG&E, SCE, and SDG&E serve approximately 11.4 million electric accounts. Therefore, $126 million dollars' worth of projects completed in 2012 implies each e account would pay ~$11/year or $1/month.

History of Underground Program

- **1967** – Decision 73078 required tariffs for replacement of overhead to underground distribution facilities, annual allocation amounts for overhead conversio and reports of conversion work completed for the preceding years. Tariff Rule 20 was established for electric conversions and Rule 32 for telecommunicatic
- **1968** – Utility allocations (annual cost caps in each community) are set proportional to –
- **1968** – the total number of electric meters;
- **1982** – only the number of overhead meters;
- **1990** – Present – both the total number of meters and the number of overhead meters.
- **2000** – CPUC opened its Rulemaking R.00-01-005 to implement Assembly Bill 1149 regarding undergrounding of electric and telecommunication facilities.
- **2001** – The Commission issued Decision (D.) 01-12-009 in Phase I of the OIR directing expanded use of Rule 20 funds and listing issues for Phase 2
- **2002** – The Commission issued D.02-11-019 to signal consideration of a new rulemaking to address Phase 2 issues.
- **2002** – The Commission in Resolution E-3788 approved franchise fee surcharges within the City of San Diego for electric conversions not eligible for Rules
- **2003** – Commissioner Kennedy assigned at expiration of Commissioner Duque's term.
- **2005** – D.05-04-038 closed OIR 00-01-005. D.01-12-009 remains effective until a new proceeding is opened consistent with the Commission's resources a priorities.
- **2006** – D.06-12-039 authorized AT&T to impose a special surcharge to customers in the City of San Diego for a limited time duration to recover undergroun cost as a result of the City of San Diego Underground Utilities Procedural Ordinance.
- **2014** – D.14-01-002 added Rule 20D to facilitate undergrounding in high fire zone areas of San Diego Gas & Electric Company.

This PowerPoint Presentation on the Overhead to Underground Conversion Program provides more in-depth information on the program.

PG&E, SCE, SDG&E, Liberty Utilities, and PacifiCorp websites have specific information related to the conversion program in their service territory.