ARCADIS | IBI GROUP

COUNTY OF SAN DIEGO
LAND USE AND
ENVIRONMENT GROUP

Tech Memo

Cost and Benefit Analysis of Addressing Broadband Gaps in the County of San Diego

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Prepared for the County of San Diego
By Arcadis IBI Group
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Abstract

Based on data from the Federal Communications Commission (FCC) we have identified 27,000 serviceable locations in unincorporated areas of San Diego County lacking adequate broadband services (i.e. no service on offer providing greater than or equal to 100 Mbps download and 20 Mbps upload in advertised speed). The California Public Utilities Commission (CPUC) is in the process of implementing the Federally funded Broadband Equity, Access, and Deployment (BEAD) program, which will provide capital grants to expand high-quality broadband infrastructure in areas lacking adequate broadband. This report analyzes the costs and benefits of deploying wireline fiber and wireless networks to unincorporated areas of the County potentially eligible for the upcoming BEAD program.

Cost and benefits were estimated for two different combinations of wired and wireless technologies in areas that are expensive to connect. We provide cost/benefit estimates for a full fiber model, as well as a mixed technology model, where fiber access networks could be deployed into areas where it may be financially feasible to do so, and wireless/satellite technologies would be deployed in extremely high-cost areas. Our mid-range estimates indicate that the full fiber model would have capital expenditure requirements of approximately $735 million, while the mixed technology model would cost approximately $300 million. For every dollar invested in broadband infrastructure in San Diego County, the public and private economic benefits are estimated to be between 3.5 and 4.3 times, over a 10-year period.

The subsequent table summarizes the mid-range estimates of cost, required subsidies, and benefits of the two broadband infrastructure development models:

San Diego County
Comprehensive Broadband Plan (CBP) Implementation
Cost/Benefit Summary of Program Design Strategies (mid-range estimates)

	Design 1 (Full Fiber)	**Design 2** (Fiber + Wireless + Satellite)
Locations to be covered with FTTP	27,000	21,000
Locations to be covered with fixed wireless/satellite	-	6,000
Capital costs (millions $)	735	307
Public subsidy required (millions $)	681	253
Economic benefit over 10 years (millions $)	2,415	1,088
Projected benefit/initial subsidy ratio	3.5	4.3

The memo concludes with two key recommendations:

Recommendation 1: The County adopts the primary strategy to encourage and incentivize private sector Internet Service Providers (ISPs) to build infrastructure in underserved areas of the unincorporated regions of the County by applying for BEAD funding; and

Recommendation 2: For low-income residents in extremely high-cost areas that will have to depend on satellite services, the County should consider developing a fund to subsidize the one-time costs for satellite equipment. Covering satellite equipment cost for around 6,000 homes in extremely high-cost areas would cost approximately $5 million.

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Executive Summary

Challenge

The San Diego Comprehensive Economic Development Strategy (CEDS) outlines the key priorities and objectives of the County. CEDS recognizes that Internet access has become "as important to economic well-being as access to water and electricity."[1] Growth in demand for reliable high-speed connectivity since the pandemic has stimulated significant private sector investment in deploying ultra high-speed fiber-optic access networks and upgrading coaxial cable broadband plants in urban centers. In urban centers of the region, residents and businesses typically have a choice between multiple providers offering "Gig level" Internet access services via fiber and cable wireline broadband technologies. However, due to relatively high-cost and low-revenue potential in rural areas, the private sector business case to invest in advanced wireline networks has remained limited (or non-existent).

In rural areas, private investment has focused primarily on deploying relatively low-cost wireless technologies to offer fixed broadband access (i.e. 4G/LTE, 5G). The consequence of these trends has been a widening of the digital divide in broadband infrastructure quality that is available to residents in urban areas (where multiple wireline providers compete and provide service) and rural areas (where people have little option but slower and less reliable copper/DSL, wireless, or satellite broadband technologies). To the extent that access to reliable high-speed Internet has become an essential utility, the resulting divergence in broadband infrastructure quality has adverse implications for the economic well-being and prospects for economic revitalization in rural communities. The 2023 San Diego County Comprehensive Broadband Plan (CBP) studied different elements of the digital divide within the County and identified areas with sub-standard broadband quality of service.[2]

Opportunity

To counteract the digital divide in the private provision of what is now an essential public infrastructure, the Federal government has initiated Broadband Equity, Access, and Deployment (BEAD) Program. BEAD represents the largest single broadband subsidy program in U.S. history. Governed under a set of general Federal program rules, the BEAD program will be administered by the states, which will have some discretion in their application to ensure they meet local needs and conditions. In California, BEAD funding will be allocated by the California Public Utilities Commission (CPUC). CPUC has been holding public consultations on the application of the program rules in the State and published its initial draft rules for allocating approximately $1.9 billion in BEAD at the end of 2023.[3] The BEAD program will provide significant capital cost subsidies (up to 80%) and prioritizes end-to-end fiber-to-the-premises (FTTP) network deployments in underserved areas. BEAD represents a unique opportunity for the County to attract some of the capital expenditures required to further CBP implementation.

[1] https://www.sandiegocounty.gov/content/dam/sdc/cao/osia/docs/SanDiegoCountyCEDSSept2022.pdf

[2] https://www.sandiegocounty.gov/lueg/broadband/

[3] https://www.cpuc.ca.gov/beadprogram

Content

This report evaluates the costs and benefits of alternative model options for addressing connectivity gaps in unincorporated areas. Based on the technical and economic analysis, we outline our recommendations regarding the most cost-effective approach to address identified gaps and attract broadband infrastructure funding into unincorporated areas of the County. We estimate the costs and benefits of two conceptual technical models:

- **Section 1** develops the conceptual design models in light of key considerations and constraints associated with the BEAD funding model as outlined in the draft rules CPUC has recently published.
- **Section 2** summarizes estimates of capital costs of the two models.
- **Section 3** estimates potential economic benefits associated with construction, consumer welfare gains, and property values, and other less tangible impacts of the conceptual infrastructure deployment models.
- **Section 4** summarizes the results of the cost-benefit analysis; and
- **Section 5** discusses options, strategies, and processes the County can utilize to motivate and support private sector providers to develop competitive applications to the BEAD funding allocation processes. Encouragement and support from the County that ensures high-quality private applications to BEAD program will be critical for maximizing public and private capital expenditures required to further CBP implementation.

Methodology and limitations

We use a standards-based methodology to develop two conceptual technical design models that help describe alternative paths for improving connectivity in underserved areas of the County and to estimate the costs and benefits of the two models. The models can be viewed as a framework for the analysis and management of CBP implementation. We use estimates from previous industry and academic research as market benchmarks for estimating the projected capital costs and economic benefits. We conduct sensitivity analysis on the cost and benefit estimates associated with the two technical design models. The estimates constitute "forward-looking" statements which involve known and unknown risks, uncertainties and other factors which may cause the actual results, performance or achievements, to be materially different from the estimates.

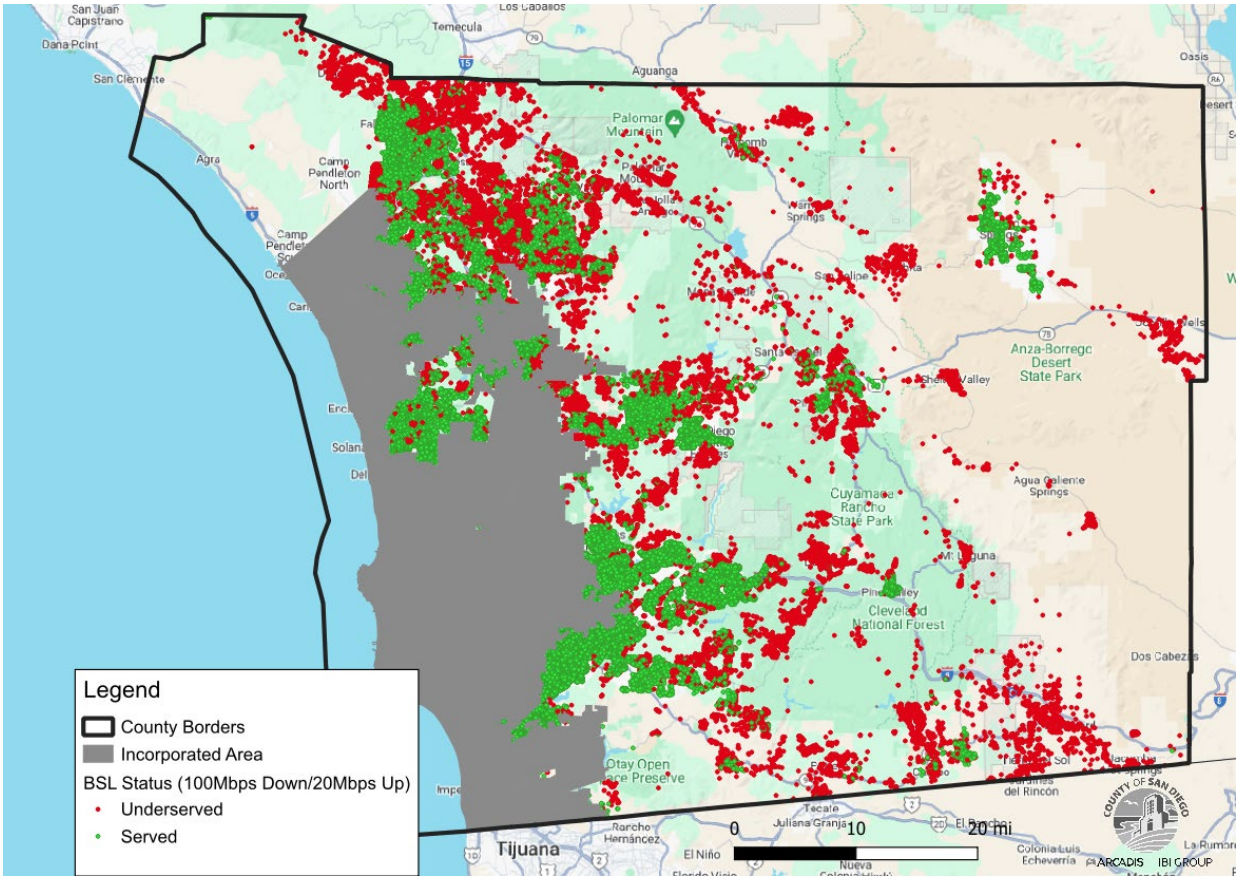
Mapping broadband service gaps

Using granular, location level, data on advertised service speeds from service providers compiled by the Federal Communications Commission (FCC), we estimate there are approximately 27,000 Broadband Serviceable Locations (BSLs) in unincorporated areas of the County that may be considered underserved and eligible for BEAD subsidies (i.e. premises/BSLs where service with speeds equal to or higher than 100 Mbps download and 20 Mbps upload are not available).[4] These BSLs represent approximately 35,000 housing units

[4] A broadband serviceable location (BSL) is "a business or residential location in the United States at which mass-market fixed broadband Internet access service is, or can be, installed." See https://help.bdc.fcc.gov/hc/en-us/articles/16842264428059-About-the-Fabric-What-a-Broadband-Serviceable-Location-BSL-Is-and-Is-Not

(at 1.3 households per BSL), or 100,000 County residents (at 2.8 persons per household).[5] The subsequent map provides an overview of the location of underserved areas that might be eligible for BEAD funding.

Figure 1: Map of served and underserved broadband serviceable locations



Limitations of FCC data

We use the FCC data on service coverage because it is to be utilized as a basis for assessing funding eligibility in the BEAD program. However, it is relevant to note that official FCC data is based on self-reported advertised speeds of Internet service providers (ISPs) in particular areas. Actual speeds and quality of service users experience can vary from those advertised by suppliers. This is particularly the case in markets with relatively limited competition, such as high-cost/low-revenue rural areas where incumbent providers have little incentives to invest in capacity enhancements over time.[6] Consequently, the number of County residents that consider their Internet services inadequate is likely to be far higher than those captured by the official data. Importantly, CPUC's draft rules for BEAD implementation recognize this problem

[5] https://www.census.gov/quickfacts/fact/table/sandiegocountycalifornia/PST045222

[6] See. Rajabiun, R. (2018) Towards a Consumer Centric Perspective on Availability of Access to the Open Internet. Expert report from the National Hispanic Media Coalition (NHMC) to consultations regarding Improving the Quality and Accuracy of Broadband Availability Data to the National Telecommunications and Information Administration. U.S. Department of Commerce (2018). https://www.ntia.doc.gov/files/ntia/publications/nhmc-ntia_broadband_availability_07.16.2018.pdf

with the FCC data and indicate the agency will allow for parties to challenge the classification of an area using standard-based Internet speed measurements.[7]

To mitigate against the bias in FCC data and support potential challenges that expand the range of eligible homes, the County may facilitate community-based speed testing using a broadband speed measurement acceptable to the CPUC (e.g. CalSPEED, M-Lab).[8]

Design model options/strategies

We develop two conceptual technical models as follows:

- **Program Design 1** involves full fiber deployment to all the approximately 27,000 underserved Broadband Serviceable Location (BSLs) eligible for BEAD funding in unincorporated areas of the County (i.e. ~35,000 households, 100,000 residents).
- **Program Design 2** involves a mixed model that includes a combination of wireline FTTP where financially feasible with BEAD subsidies, terrestrial fixed wireless, and satellite-based services for extremely high-cost areas. Assuming 80% capital cost subsidies from BEAD and a $2,000 per premise private sector co-investment, FTTP projects can be financially feasible in areas with average per premise costs in the $10,000 to $13,000 range. Out of the 27,000 underserved BSLs in unincorporated areas, our analysis indicates that the average cost for deploying FTTP to 21,000 BSLs would fall in this range and may make FTTP BEAD applications financially feasible to the private sector. We assume BEAD fiber project applications will likely not be viable in areas with higher costs than this threshold without additional capital cost subsidies. Under Design 2, approximately 6,000 of the 27,000 BSLs will have to rely on terrestrial wireless or satellite based broadband services. The subsequent figures provide visual depictions of the statistical and geospatial distributions of high (where fiber deployments may be feasible with 80% BEAD subsidies) vs. extremely high cost areas (where fiber deployments are not likely to be financial feasible, even with 80% capital cost subsidies) under conceptual program Design 2.

[7] See Volume 1 and Volume 2 of CPUC draft initial rules, published November 2023: Available at: https://www.cpuc.ca.gov/beadprogram

[8] http://calspeed.org/
https://www.measurementlab.net/

Figure 2: Distribution of FTTP deployment costs across census blocks

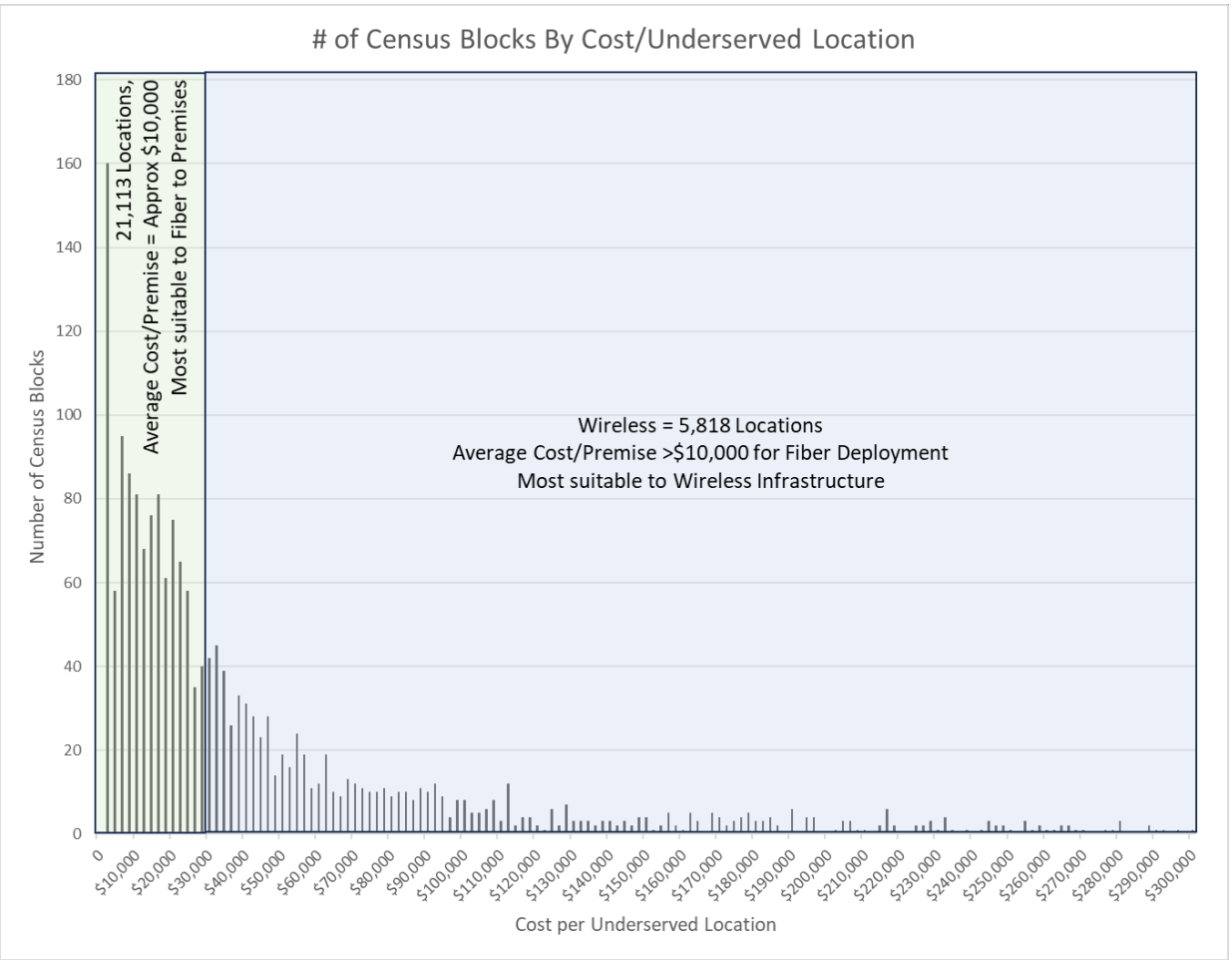
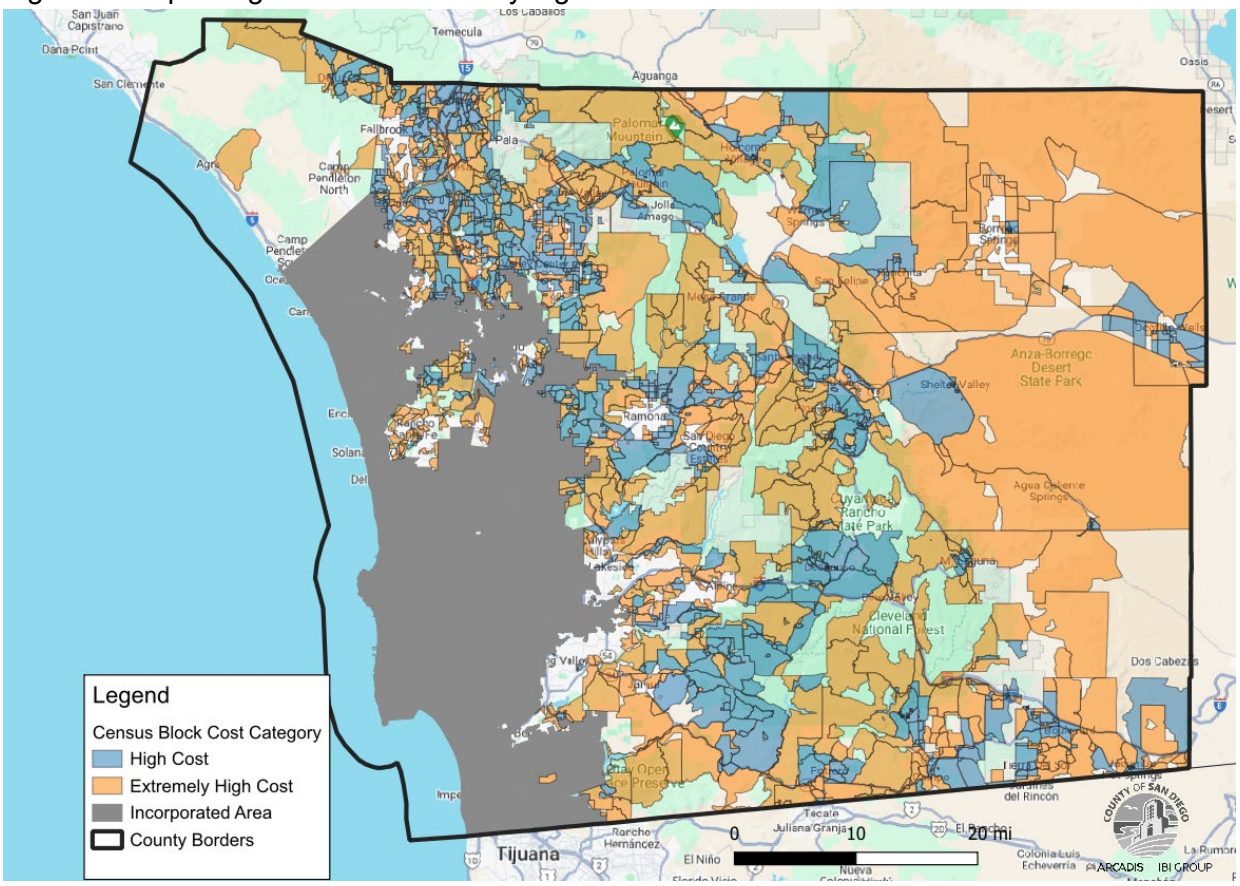


Figure 3: Map of high cost vs. extremely high-cost census blocks



Funding model constraints

The CPUC has not yet specified an Extremely High Cost Per Location Threshold (EHCPLT) for California in BEAD design, but it has indicted a clear preference for funding end-to-end fiber deployments. Given the California BEAD budget constraints, the extent to which the California BEAD program will support wireless deployments in extremely high-cost areas remains unclear. Beyond the $10,000 average per home cost threshold, additional capital cost subsidies on top of BEAD will be required to make FTTP project financially viable to private investors. These could come from the County, or by private sector providers leveraging other Federal and State broadband funding facilities. Since CPUC has indicated a clear preference for FTTP over other technologies, maximizing potential FTTP coverage beyond the EHCPLT threshold will enhance the chances of success in the competitive BEAD application process. In general, we note that Federal and state agencies are reluctant to subsize further wireless deployments or LEO satellite-based services over wireline fiber. As such, County financing may be needed for fixed wireless improvements and satellite fixed cost subsidy components in Program Design 2.

Findings

The subsequent table summarizes the mid-range estimates for the costs and benefits associated with Design 1 (full FTTP) and Design 2 (FTTP plus fixed wireless or satellite) conceptual models. Estimates of the benefits include a range of potential impacts from expanded FTTP networks, but does not include all possible benefits such as environmental

impacts. As expected, the full fiber Design 1 has the highest estimated capital cost of deployment and economic benefits. Designs 2 minimizes deployment costs by limiting FTTP deployments to only where we estimate they are likely to be financially feasible, and upgrades to fixed wireless capacity and LEO satellite access beyond that.

San Diego County
Comprehensive Broadband Plan (CBP) Implementation
Cost/Benefit Summary of Program Design Strategies (mid-range estimates)

	Design 1 (Full Fiber)	**Design 2** (Fiber + Wireless + Satellite)
BSLs to be covered with FTTP	27,000	21,000
Households to be covered with FTTP	35,000	27,000
BSLs to be covered with fixed wireless/satellite	-	6,000
Households with upgraded wireless/satellite	-	7,800
Total FTTP CAPEX estimate (millions)	735	297
Per BSL FTTP CAPEX	27,000	12,500
Total wireless/satellite (millions)	-	10
Per BSL wireless/satellite cost	-	1,700
Total CAPEX (millions)	735	307
Per BSL CAPEX	27,000	11,373
Economic impact estimates		
Transitory impacts from construction		
Full time equivalent job	5,145	2,079
GDP impact (million)	2,132	861
Additional tax revenue to upper-tier governments (millions)	597	241
Private and public impacts		
Increase in property value per home connected with FTTP	20,000	20,000
Additional municipal tax per home connected with FTTP per year	195	195
Additional property tax per year (million)	5	4
Additional property tax over 10 years (million)	53	41
End user/consumer welfare gain from FTTP over older wireline and wireless broadband service, per household per year	960	960
End user/consumer welfare gains from upgraded wireless/satellite, per household, per year		240
Annual end user/consumer welfare gains in target area at 50% take up (million)	17	14
End user welfare gains over 10 years (million)	170	140
Per capita healthcare savings in low diffusion of advanced applications	60	60
Annual public and private healthcare cost savings (million)	6	5
Healthcare cost avoidance over 10 years (million)	60	46
Total benefits over 10 years (million)	283	227
Cost/benefit summary over 10 years (millions $)		
Total benefits (GDP impact + consumer welfare gain + healthcare savings + property tax revenue increase)	2,415	1,088
Difference between total benefits and initial capital costs	**1,680**	**791**
Initial capital costs minus total anticipated tax revenue increase	85	25

Cost/benefit analysis

Excluding extremely high-cost areas from FTTP deployment in Design 2 substantially reduces its costs relatively to Design 1. **In the case of both Program Design models, positive externalities from the program would outweigh initial costs significantly. Anticipated tax revenue growth covers most initial capital expenditures (~90%).**

For every public dollar invested in broadband infrastructure in San Diego County, the public and private economic benefits are estimated to be between 3.5 and 4.3 times, over a 10-year period.

Other relevant considerations

As documented in the summary table above and detailed in this report, there are substantial cost and benefit differences between Design 1 and 2 models for CBP implementation. In addition to the higher benefit and likelihood of success in attracting BEAD subsidies, there are other benefits to FTTP deployments vs. wireless upgrades in the context of other strategic priorities. For example, fiber optic networks tend to use substantially less power than other wireline and wireless broadband technologies.[9] Therefore, their utilization is more aligned with the goals of reducing power consumption and environmental sustainability. However, deploying wireline networks is more construction intensive and therefore has a larger upfront environmental impact on the ground. Buried fiber is more resilient to fire hazards than towers in high-fire hazard areas. Due to higher reliability of FTTP over wireless, maximizing the scope for its deployment is also conducive to promoting more telecommuting and aligning with County policy to reduce Vehicle Miles Travelled (VMT). While they have higher fixed cost of deployment, fiber optic networks tend to have a long lifespan (+30 years), whereas wireless equipment become obsolete and has to be replaced in 5 to 7 years. In rural areas where the business case to upgrade wireless equipment is weak, wireless strategies will require additional public subsidies as demand grows and installed capacity degrades. In the case of LEO satellite-based services that are already available, a key problem is their affordability for low-income residents in high-cost areas who cannot afford the upfront equipment and relatively high monthly subscription prices they involve (e.g. relative to wireline and fixed wireless, where available).

Incentives and strategies

The CPUC has indicated that it will prioritize end-to-end fiber project applications over other technologies in allocating BEAD funding. The CPUC has further estimated that expanding FTTP access networks to the approximately 1 million homes in California lacking access at the 100/20 Mbps level will require ~$10 billion in capital expenditures.[10] Given that total Federal BEAD funding for California is about $1.9 billion, this means the limited funds will primarily be

[9] Controlling for data consumption levels, wireless broadband generally has 10 time the power consumption of wired; fibre has about 1/5 of power consumption of legacy DSL and 1/10 of coaxial cable. See e.g.
Baliga, J., Ayre, R., Hinton, K., & Tucker, R. S. (2011). Energy consumption in wired and wireless access networks. *IEEE Communications Magazine*, *49*(6), 70-77.
https://people.eng.unimelb.edu.au/rtucker/publications/files/energy-wired-wireless.pdf
Aleksic, S., & Lovric, A. (2011). Energy consumption and environmental implications of wired access networks. Am. J. Eng. Applied Sci, 4, 531-539.
https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1001.1481&rep=rep1&type=pdf

[10] CPUC California Broadband Investment Model (2023)
Last Mile Funding Analysis, Process Overview and Methods
https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/communications-division/documents/broadband-implementation-for-california/ffa-webpages/ca-broadband-investment-model_04212023.pdf

allocated to areas where FTTP deployment would become financially viable with anticipated BEAD subsidies, potentially up to 80% of capital costs.[11]

To ensure San Diego County maximizes the share of BEAD subsidies allocated to improving connectivity in unincorporated areas of the County, we recommend starting an open and formal process of engagement (i.e. publishing a positioning paper, advising private sector service providers of the County's preferred criteria for supporting ISP funding applications) with private providers in order to:

- Highlight underserved communities that are eligible for BEAD and other Federal and State public funding sources and encourage providers to take advantage of these opportunities. Offer letters of support for applications as inducements for end-to-end fiber deployment proposal to CPUC under the BEAD application process.
- Understand private providers' plans to apply for upcoming funding opportunities, identify potential gaps in their applications, and encourage them to address potential gaps to maximize infrastructure funding required to further CBP implementation.

[11] The actual level of subsidy will be determined using a competitive process and can vary from this anticipated maximum The Federal BEAD funding rules require the states "to incentivize matches of greater than 25 percent from subgrantees wherever feasible (especially where expected operational costs and revenues are likely to justify greater investment by the subgrantee) to reduce the federal share of projects and extend the reach of BEAD Program funding." Frequently Asked Questions and Answers Draft Version 2.0. Broadband, Equity, Access, and Deployment (BEAD) Program, U.S. Department of Commerce National Telecommunications and Information Administration, Page 42. Available at: https://broadbandusa.ntia.doc.gov/sites/default/files/2022-09/BEAD-Frequently-Asked-Questions-%28FAQs%29_Version-2.0.pdf

While BEAD implementation rules for California are still under development, the interim rules published by the CPUC follow the Federal guidelines by proposing to score applicants "…based on the grant amount requested and amount of matching funding committed by the applicant. Applicants will earn 10 points for meeting the 25 percent match requirement. Applicants will receive 15 points for a 50 percent match amount." Page 32. CPUC BEAD Initial Proposal, Volume II. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M520/K763/520763574.PDF

1. Context and Options

Content

This section provides an overview of the economic and policy context and constraints posed by Federal broadband funding rules to develop a set of alternative technical infrastructure development paths that San Diego County can pursue in order to further CBP implementation.

Universal service policies

In high income countries such as the U.S., access to some form of "high-speed" broadband Internet connectivity is near ubiquitous. The quality and affordability of broadband services can vary significantly across countries and within regional markets.[12] Expanding access to high-quality broadband in rural areas and into remote communities remains a challenge. There is however a growing understanding of the importance of expanding universal access to reliable broadband in rural areas and small population clusters where the private sector business case to increase capacity and deploy next generation technologies is limited (or non-existent). Rural and remote communities typically exhibit a high cost/low return risk profile for new broadband investment and therefore present a weak or non-viable business case for the private sector. This phenomenon bears opportunity costs that impact the quality of life and economic development opportunities for these community residents. This motivates a variety of public sector responses aimed at promoting rural broadband development and universal access to broadband, ranging from direct subsidies to direct investment models where municipalities and regions deploy core network assets and offer wholesale and/or retail services.

Pandemic and the digital divide

Demand for high-speed Internet connectivity has stimulated significant private investment in deploying ultra high-capacity fiber-optic broadband networks in urban centers and larger towns across the U.S. Since the COVID pandemic, rapidly growing residential demand for fast and reliable Internet connectivity has accelerated the pace of fiber access network deployments in urban centers of the country. Despite some improvements in rural connectivity over the past few years, private sector incentives to expand access to relatively high-speed cable and fiber-based broadband access technologies has proven to be limited in rural areas, small towns, villages, and remote communities in all regions. The consequence is a growing rural-urban digital divide in broadband service quality and affordability. All levels of government have been searching for viable solutions to counteract the lack of private sector investment and promote public-private investment incentives in rural broadband, with varying degrees of success. A notable example of these efforts is the Federal Broadband Equity Access and Deployment Program (BEAD), which represents the largest public investment in broadband infrastructure in U.S. history. Approximately $1.9 billion of BEAD's $42 billion national budget has been allocated to California and its distribution will be managed by California Public Utilities Commission (CPUC). Recognizing the higher quality of service and reliability of wireline fiber solutions, the BEAD program prioritizes funding proposals for deploying end-to-end fiber

[12] Rajabiun, R., & Middleton, C. (2018). Strategic choice and broadband divergence in the transition to next generation networks: Evidence from Canada and the US. *Telecommunications Policy*, *42*(1), 37-50. https://ised-isde.canada.ca/site/bureau-concurrence-canada/sites/default/files/attachments/2022/Attachment1JTPO2018.pdf

deployment projects in high-cost areas where private sector business case to deploy new wireline networks is limited (or non-existent).[13]

Funding model constraints

Federal government and CPUC have prioritized funding end-to-end fiber solutions in the design of the BEAD program but achieving 100% wireline fiber coverage is likely to be cost prohibitive. Previous research commissioned by the CPUC estimates that expanding fiber-to-the-premises (FTTP) networks to underserved locations will cost around $10 billion, exceeding California's BEAD allocation by a wide margin.[14] The funding application process is likely to be very competitive, particularly in areas where BEAD capital cost subsidies may be sufficient to incentivize additional private investment in fiber network deployments. In extremely high-cost areas, even with BEAD subsidies of around 80% of capital costs, private sector incentives to develop fiber proposals will be limited. Despite this, CPUC draft BEAD rules state:

> *"As a technical matter, fixed wireless speeds fluctuate heavily given this, speeds that barely qualify as underserved will likely be below 25/3 service during peak usage times.*
>
> *Furthermore, impartial third parties have found that not all cellular fixed wireless subscribers receive speeds above 25/3 and 'thus did not provide a reasonable basis for its 'fast' or 'high-speed' claims. The CPUC has observed that some fixed wireless operators report 25/3 or 100/20 speeds on the National Broadband Map even where their networks frequently reach those speeds only under optimal circumstances and have not been replicated in other testing environments, such as the CPUC's own CalSPEED process." (*Volume 1, page 9)
>
> *"CPUC plans to prioritize end-to-end fiber proposals, consistent with the BEAD NOFO, and to make awards for alternative technologies—such as fixed wireless and coaxial cable—where the costs of fiber exceed the Extremely High Cost Per Location Threshold, per NTIA's requirements, or where no proposals are received for fiber because of geographic or other constraints." (Volume 2, page 20)*
>
> *"Given the unpredictability of fiber construction costs during the BEAD timeline and considering the challenges to reach many extremely remote locations in some parts of California, the costs to deploy fiber to all unserved and underserved locations may exceed available BEAD resources. For that reason, the CPUC anticipates using the Extremely High Cost Per Location Threshold (EHCPLT) mechanism for making awards for alternative technologies, such as fixed wireless and coaxial cable, that may be necessary to address the needs of some locations." (Volume 2, page 22)*

While the CPUC has not yet established a EHCPLT to define the boundary between where it considers fiber to be feasible and where it may fund other technologies, it is clear from the initial rules that end-to-end FTTP projects are more likely to succeed in the competition for limited BEAD funding. CPUC's technical perspective and the initial BEAD rules it has adopted indicate significant aversion to funding wireless projects. Satellite-based services are not eligible for this, as well as various other federal and state broadband funding facilities. Given

[13] See Volume 1 and Volume 2 of CPUC draft initial rules, published November 2023: Available at: https://www.cpuc.ca.gov/beadprogram

[14] CPUC (2023). California Broadband Investment Model. Last Mile Funding Analysis. Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/communications-division/documents/broadband-implementation-for-california/ffa-webpages/ca-broadband-investment-model_04212023.pdf

the improved quality and affordability of satellite-based services, particularly in areas with highly uneven terrain, the County may wish to contemplate how it can assist low-income households in extremely high-cost/remote locations access high-speed connectivity via emerging LEO platforms (e.g. by defraying some of the set-up costs, which can be prohibitive to low-income residents).

Program design strategies

To further the implementation of San Diego County Comprehensive Broadband Plan (CBP), we evaluate the costs and benefits of alternative options for improving connectivity in unincorporated areas. Considering constraints posed by the primary funding model for supporting broadband deployments in underserved areas and industry benchmarks for per household/subscriber private sector investment incentives, we developed two distinct conceptual program design models:[15]

Program Design 1 (Full Fiber)

This model involves end-to-end fiber deployment to all the 27,000 underserved BSLs in unincorporated areas of the County. This design strategy will be the most expensive, but also would have the highest economic benefits and likelihood of success in maximizing BEAD funding and private sector co-investments needed to further CBP implementation. This model represents an ideal long-term state where transition from copper to fiber wireline networks nears completion.

Program Design 2 (Fiber + Wireless + Satellite)

This model allows for a mix of technologies to help minimize deployment cost. In this model fiber connectivity will be extended only to those homes where the average per BSL FTTP deployment cost is sufficiently low to make FTTP deployment projects financially viable with BEAD subsidies. As noted above, the CPUC has not yet specified the Extreme High Cost Per Location Threshold (EHCPLT) it will utilize in the California BEAD plan implementation. We estimate this threshold by assuming maximum BEAD capital cost subsidies of 80% and the mid-range private sector willingness to invest of $2,000 per home, which yields an estimated EHCPLT of $10,000 per home, or $13,000 per BSL. In Design 2 FTTP networks will be expanded to homes in areas with costs below this threshold, which we estimate totals to around 21,000 out of the 27,000 underserved BSLs in unincorporated areas. The remaining 6,000 BSLs are in extremely high-cost areas and will be served with a combination of upgraded fixed wireless and/or subsidized satellite-based services.

Constraints

Design 2 will have substantially lower cost that Design 1, but also lower socioeconomic benefits relative to the full FTTP model because of the substantive gap in reliability and quality

[15] Private sector incentives to invest in FTTP infrastructure in a particular area depend on a variety of factors, including firm level strategies, investors' expected payback and return, and the competitive environment impacting pricing capacity and service take up rates. Large telecommunications carriers are typically reluctant to invest in areas where FTTP deployment costs start to exceed $1500 per home.
See e.g. https://www.fiercetelecom.com/broadband/att-cfo-says-its-fiber-build-pricier-expected
https://www.lightreading.com/fttx/verizon-could-be-a-sleeping-giant-in-us-fiber-expansions

In the context of BEAD program, telecom consulting firm Cartesian estimates that the average provider investment to be around $3,000 per location in California. Available at: https://www.cartesian.com/wp-content/uploads/2023/02/California_BEAD_Funding_Cartesian_ACA_Jan_2024_v4.0.pdf
Although have seen instances where ISPs have co-invested up to $3,000 per home in publicly subsidized rural broadband projects, the average willingness to invest is likely to be lower when consider large carriers' reluctance to go beyond the $1,500 per location cost threshold for FTTP expansion. In this analysis we assume that private sector willingness to invest will range between $1,500 to $2,500 per location.

of service between FTTP and wireless/satellite. To the extent that FTTP project proposals are more likely to succeed in securing Federal and State funding compared to wireless upgrades, maximizing the scope of FTTP projects within this mix will enhance the likelihood of success in the funding process. It is relevant to note that Federal and State agencies typically do not consider satellite-based services eligible for broadband infrastructure subsidy programs. The County may consider funding fixed costs of LEO satellite equipment under the Design 2 model.

Private incentives and public strategies

The feasibility of the models above is contingent on the willingness of private sector providers to take advantage of BEAD funding and co-invest at least $2,000 per household. In reality, some private providers may not be very keen to participate and co-invest in a program targeting very high cost/low revenue areas. For large network providers, this is because going into such areas will have an adverse financial impact on their cost structures with limited upside in terms of revenue/earnings growth. Smaller Internet service providers tend to have limited capacity to raise complementary private investments required for large scale infrastructure improvement programs such as BEAD (i.e. at least 20% of projected capital expenditures (CAPEX)). To ensure there are competitive private applications covering all eligible underserved areas and to maximize infrastructure investment inflows to underserved areas of the County, it is imperative for the County to encourage, support, incentivize, and facilitate private providers to develop high-quality applications to the competitive BEAD funding process.[16]

[16] "High-quality" applications mean those with a relatively higher chance of success under rules CPUC ultimately adopts for assessing BEAD applications. For draft CPUC evaluation criteria see CPUC BEAD Initial Proposal, Volume II. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M520/K763/520763574.PDF

2. Costs of Alternatives

Content

This section summarizes capital cost estimates associated with the two Program Design models outlined in the previous section to characterize basic strategies available to the County to further CBP implementation. The Appendix provides further detail of the costing methodology.

Methodology and assumptions

To develop consistent and realistic estimates of the capital costs associated with the alternative models, we follow these steps:

Step 1: As a first step in the process, we analyzed and mapped fine-grained (i.e. location level) service availability data compiled by the Federal Communications Commission (FCC) to identify locations considered underserved (i.e. lacking access to reliable 100/20 Mbps service) and eligible for BEAD funding. The FCC data indicates there are approximately 27,000 Broadband Serviceable Locations (BSLs). This translates to around 35,000 housing units, or 100,000 County residents.

Step 2: Our costing methodology for deployment builds is guided by the NTIA/CPUC preference for end-to-end fiber in the funding model. We include the local fiber distribution network, fiber drops into homes, and Customer Premises Equipment (CPE) in the calculations. The major cost component is the distribution network, which we estimate by calculating the length of road segments in census blocks with underserved BSLs and multiplying this by the cost of deploying fiber per foot/mile. It is relevant to note that our market research suggests the public sector cost of deploying fiber in southern California tend to be substantially higher than private sector cost we have observed. We use private sector costing here in our low and mid-range estimates; the higher capital cost estimate can be viewed as the case if the County were to buildout the networks vs. letting private providers take the lead. We have not performed significant route optimization on our road segment length estimates. Therefore, our estimates of the length of required fiber builds can be viewed as a conservative upper bound. In reality there could be substantive cost savings with more detailed design optimization or if a provider already has some existing network assets in the area. For the fixed per subscriber component for drops and CPE, we use standard industry benchmarks that we believe are realistic.[17] The subsequent table summarizes our fiber costing assumptions and cost estimate for the end-to-end fiber Program Design 1:

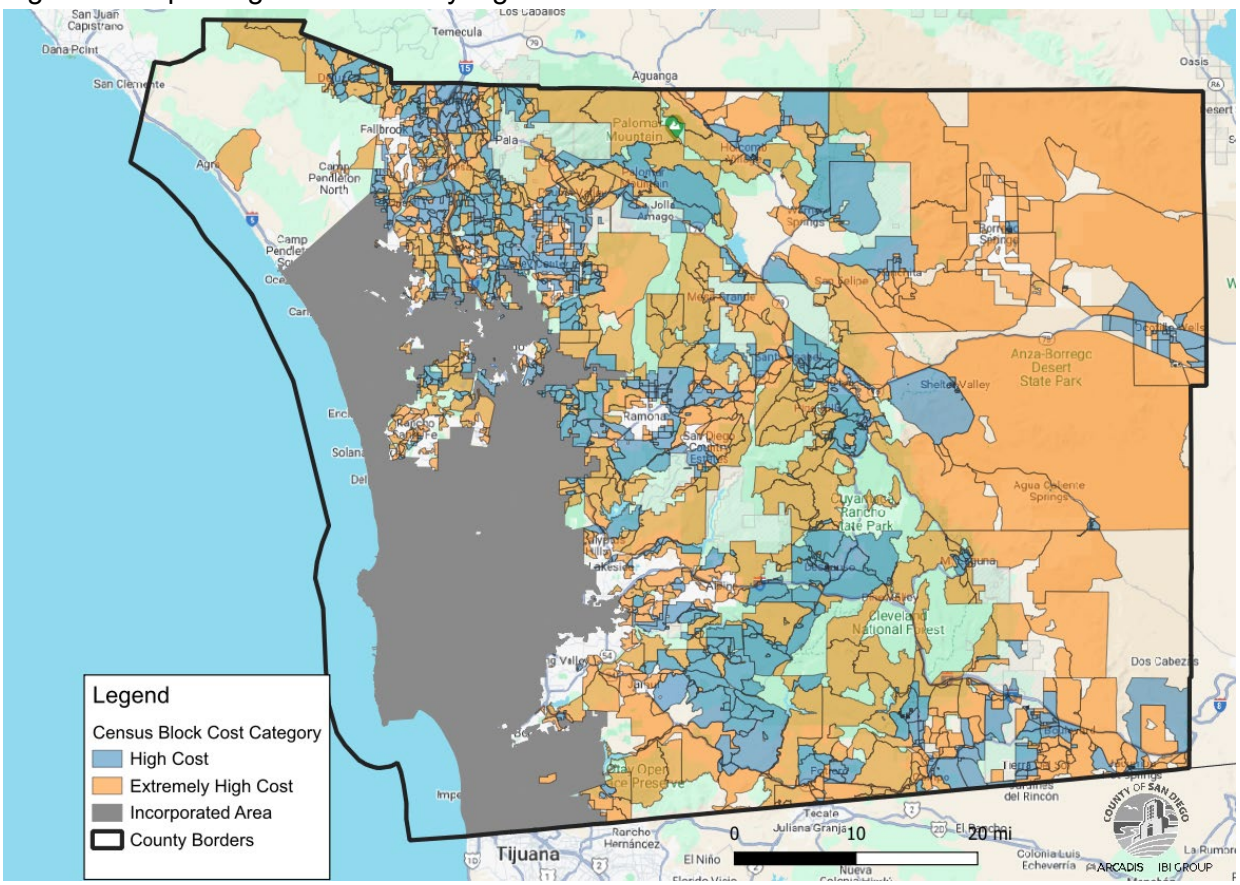
[17] See e.g. https://progoffice.com/fiber-optic-cabling-project-estimator/ ; https://dgtlinfra.com/fiber-optic-cable-installation-process/

Program Design 1 100% FTTP to 27,000 BSLs/35,000 homes			
	Mid-range	Low	High
Assumptions			
Fiber per mile	160,000	105,000	400,000
Per home	875	600	1,000
Estimates			
CAPEX ($ million)	**735**	500	1,800
Cost per BSL ($)	**27000**	18,000	67,000

Step 3: To develop Program Design 2 cost estimates, we segment high-cost from extremely high-cost areas in an iterative that aims to maximize the FTTP coverage while ensuring that the average per BSL cost remains sufficiently low to enable financially viable project proposals to BEAD. As noted earlier, the CPUC has not yet established an Extreme High Cost Per Location Threshold (EHCPLT). We therefore develop our own threshold measure for identifying where fiber builds would be financially feasible with BEAD subsidies within the County, and where even with an 80% capital subsidy private sector business case to propose fiber projects would be limited (or non-existent). In our experience with rural broadband projects, private sector service providers are typically reluctant to invest in wireline networks in areas with higher than $2,000 to $2,500 per home/location deployment costs.[18] Based on this baseline and 80% capital cost subsidy, we estimate the EHCPLT to be around $10,000 per home, or $13,000 per BSL. We estimate that the average per census block cost starts approaching this threshold when we average costs across all blocks with costs less than $30,000 per home. Based on this estimated EHCPLT, we segment very high-cost areas where FTTP may be feasible with BEAD subsidies from extremely high-cost areas where FTTP costs explode, and wireless/satellite will likely remain as the only option.

[18] See e.g. https://www.fiercetelecom.com/broadband/att-cfo-says-its-fiber-build-pricier-expected
https://www.lightreading.com/fttx/verizon-could-be-a-sleeping-giant-in-us-fiber-expansions
In the context of BEAD program, telecom consulting firm Cartesian estimates that the average provider investment to be around $3,000 per location in California. Available at: https://www.cartesian.com/wp-content/uploads/2023/02/California_BEAD_Funding_Cartesian_ACA_Jan_2024_v4.0.pdf
Although have seen instances where ISPs have co-invested up to $3,000 per home in publicly subsidized rural broadband projects, the average willingness to invest is likely to be lower when consider large carriers reluctance to go beyond the $1,500 per location cost threshold for FTTP expansion.

Figure 4: Map of high vs. extremely high-cost census blocks



Step 4: The analysis above indicates that of the 27,000 underserved BSLs in the unincorporated areas, with BEAD subsidies and anticipated levels of private sector co-investments, FTTP deployments to 21,000 BSLs can become financially feasible. For the wireless portion of Design 2, we assume a mid range per subscriber cost of $2,500 per BSL for wireless capacity upgrades in extremely high-cost areas. This is nearly two times higher than average per subscriber deployment costs of wireless over large regions, but we believe it is more realistic given the extremely high-cost and low population density on the edges of the proposed fiber access networks. For the satellite portion of Design 2 we use the current equipment/set up costs from Starlink, the major provider of direct LEO satellite-based broadband services to retail subscribers, which is currently at $600 per subscriber.

The subsequent table summarizes our estimates of capital cost that would be required for the mixed technology Design 2 model.

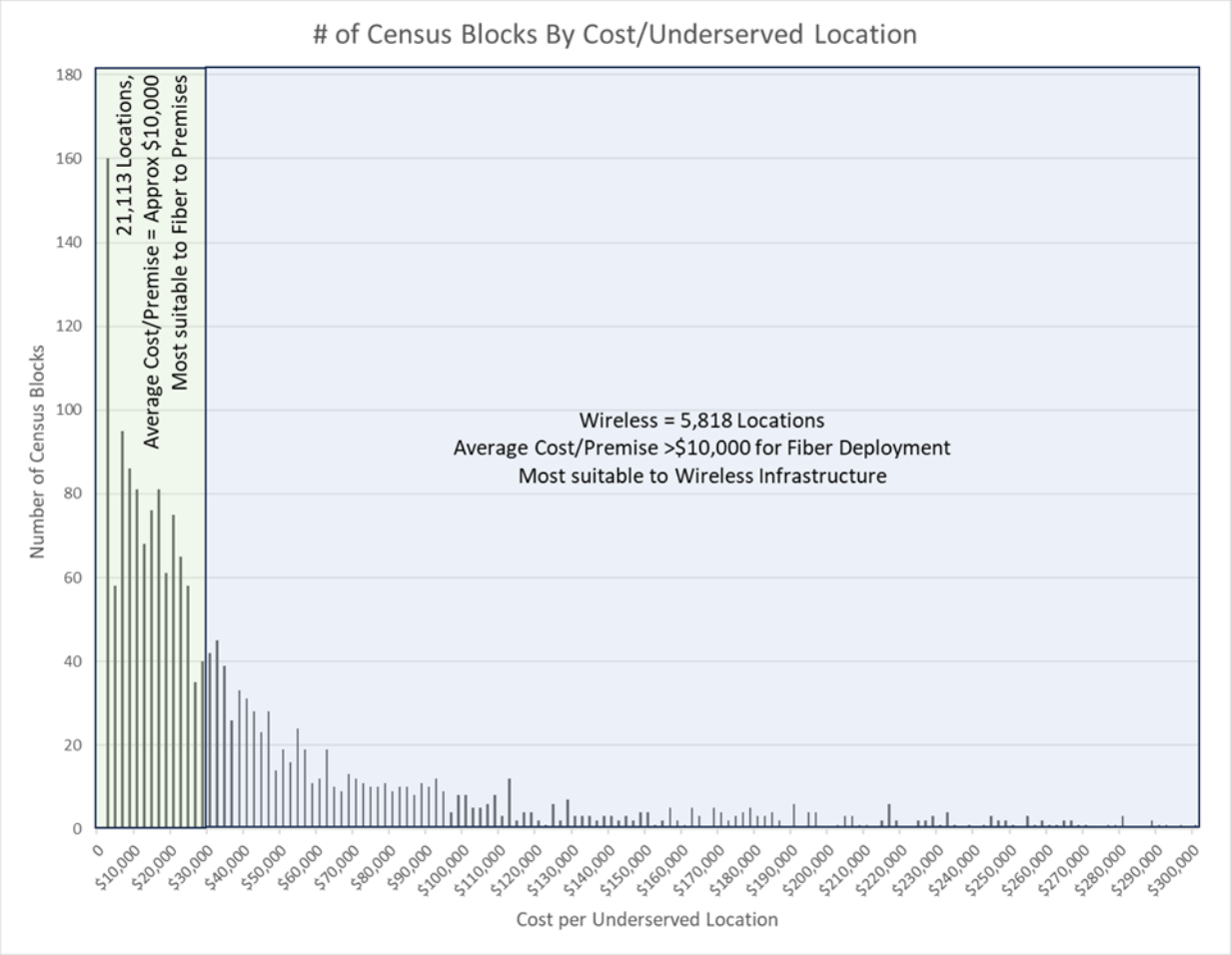
Program Design 2: FTTP to 21,000 BSLs, Wireless/Satellite for 6,000			
$	**Mid-range**	Low	High
FTTP CAPEX (million)	**297**	198	717
FTTP CAPEX per BSL	**12,412**	8,291	29,842
Fixed Wireless CAPEX (million)	8	6	10
Fixed Wireless CAPEX per BSL	2,500	2,000	3,000
Satellite Subsidy (million)	2	2	3
Satellite Subsidy per BSL	800	600	1,000
Total CAPEX (million)	307	206	729
Total Cost per BSL	**11,373**	7,628	27,007

Note: FTTP can provide stable download and upload speeds higher than 1 Gigabit per second (Gbps). Fixed wireless and satellite speeds can reach above 100 Mbps under ideal conditions.

Strategy implications

The exclusion of extremely high-cost areas for wireline FTTP deployment in Design 2 leads to significant cost reduction relative to Design 1. The relatively lower cost of fixed wireless upgrades and subsidizing satellite equipment in extremely high-cost areas reduces the overall per BSL cost from $27,000 to just over $11,000 per BSL. This correlates with our estimates of the level of costs beyond which FTTP deployments would not be feasible even with the substantive capital cost subsidies anticipated with BEAD. Given NTIA/CPUC's apparent preference for maximizing FTTP deployments in BEAD implementation, encouraging service providers to develop applications for FTTP deployment projects in areas where it may be financially feasible will be required to maximize the amount of BEAD that ultimately flow to infrastructure development in unincorporated areas of the County. The County may consider supporting wireless project proposals in extremely high-cost areas where BEAD subsidies will likely remain insufficient to make FTTP deployments financially viable. We have segmented high vs. extremely high-cost census blocks and provide a visual depiction of the distribution of per BSL costs across census blocks with underserved homes in the figure below.

Figure 5: Distribution of per location FTTP deployment costs across census blocks



LEO satellite subsidies

Even with successful BEAD applications to expand fiber and improve wireless services in unincorporated areas, there is likely to be a number of years before the networks are deployed and have an impact on the quality of Internet access residents experience. In extremely high-cost areas with poor wireline and wireless services, improvements in the quality of LEO satellite broadband increasingly make them a viable option. Higher set up costs and monthly subscription price of LEO satellite-based services can however make them unaffordable to low-income residents in extremely high-cost areas. Subsidizing the set-up cost of LEO based services can be a cost-effective approach for the County to expand access to higher quality broadband in extremely high-cost areas where any new fiber and/or terrestrial wireless deployments are not likely to materialize for a long time, if at all. Assuming LEO equipment and set up cost are $800 per user and 6,000 residents in unincorporated areas that take up the subsidy offer, such a program would cost approximately $5 million to initiate.

3. Economic Benefits

Content

In this section we estimate the potential economic benefits of the alternative design strategies and paths to the implementation of the County CBP outlined in previous sections.

Market failures and positive externalities

The 2022-2026 San Diego Comprehensive Economic Development Strategy (CEDS) indicated that due to the pandemic it has become clear that Internet access is as important to economic well-being as access to water and electricity." From a public policy perspective, market prices/revenues generated from user charges to access network infrastructure do not fully capture "positive externalities" associated with essential network infrastructure such as roads, electricity, schools, healthcare, and telecoms. Some of these economic value gains in the transition from basic to Gig level broadband are more tangible (e.g., impact of fiber-based connectivity on home values), while others are harder to quantify (e.g. reliable fiber connectivity enabling educational and employment opportunities, for older people to utilize home healthcare and monitoring services to live longer in their homes). Multifaceted "market failures" in the private provision of social and economic infrastructure drives the role of the public sector in modern economies, largely because "market forces" by themselves cannot capture the value added from deploying essential social and business infrastructure.

Public vs private benefits

Despite the noted costs and risks to public sector entities, the social and economic benefits of improving connectivity may be worthwhile to particular communities and regions. Access to reliable Internet connectivity in underserved areas is critical for achieving most, if not all, social and economic development policy objectives of the County. These include environmental sustainability, quality of life, improving health outcomes of vulnerable populations, building an inclusive, age friendly, safe community, leveraging the County's location to attract new residents, support industry and agriculture, poverty reduction, public service delivery platforms, etc.).

The rest of this section describes some of these channels and provides some quantitative estimates of the public and private economic benefits of expanding ultra-high speed fiber networks as part of the program design strategies outlined above. We also provide some estimates of benefits associated with the wireless service improvements in the Design 2 model.

To assist the County and funding agencies better understand channels through which improving connectivity can generate social and economic benefits that are hard to quantify, below we provide an overview of key economic benefits identified in the research literature on the linkages between diffusion of ultra high-speed broadband (i.e. FTTP, +100 Mbps symmetric). The range and magnitude of the micro/project level economic benefits we estimate reflects impact elasticities observed in FTTP deployments in other jurisdictions. The list is not exhaustive. Further data collection and analysis would be required if the County is interested in exploring particular elements of the list and developing more grounded estimates.

3.1. Employment, GDP, and upper-tier tax revenue

As with other large infrastructure projects, deploying broadband access networks will help create and sustain jobs, increase GDP locally and regionally, and generate tax revenue for the state and Federal governments. All three potential infrastructure investments, the vast majority of which will be from the Federal government, will have a will have a transitory positive impact on employment during the deployment phase by increasing demand for engineering, construction, and related services. Given the higher costs and labor requirements of the end-to-end fiber Program Design 1, it will have the highest employment impact, much which accrue locally if there is sufficient local wireline construction capacity available.

While we use historical job and GDP multipliers to estimate direct impacts of deploying the network, we note that fiscal multipliers tend to be higher in periods of recession/depression when there is slack on the supply side.[19]

The subsequent table provides estimates of the potential impacts of the alternatives in sustaining (and potentially creating) jobs using a variety of different estimated job multipliers for communications network construction, as well as estimated infrastructure investment multipliers developed by researchers specifically in the context of the BEAD investment program.[20]

We note that the infrastructure multipliers we are using here were derived in times of prosperity and local infrastructure spending can have diverse effects that are shaped by local endowments, conditions, capabilities, etc.

Design 1: Our mid-range estimates suggest that construction of Design 1 will help sustain and/or create around **5,000 direct and indirect full-time equivalent jobs** during the deployment stage (divided over however number of years it will take to build). Based on generic and broadband specific infrastructure to GDP multipliers and a baseline tax rate of 28% of GDP, we can further estimate that the project Design 1 can lead to a **GDP increase of approximately $2 billion in the short to medium term, generating around $600 million in tax revenue for the California and Federal governments**.

[19] Owyang, M. T., Ramey, V. A., & Zubairy, S. (2013). Are government spending multipliers greater during periods of slack? Evidence from twentieth-century historical data. *American Economic Review*, *103*(3), 129-34. Available at: https://econweb.ucsd.edu/~vramey/research/ORZ_Published.pdf

[20] Bivens, J. (2019). Updated employment multipliers for the US economy. Economic Policy Institute, 23, 2019. https://www.epi.org/publication/updated-employment-multipliers-for-the-u-s-economy/
The effectiveness of infrastructure investment as a fiscal stimulus: What we've learned (2022). World Bank https://blogs.worldbank.org/ppps/effectiveness-infrastructure-investment-fiscal-stimulus-what-weve-learned
Sprintson, M., & Oughton, E. (2023). The contribution of US broadband infrastructure subsidy and investment programs to GDP using input-output modeling. arXiv preprint arXiv:2311.02431. Available at: https://arxiv.org/ftp/arxiv/papers/2311/2311.02431.pdf

Construction impacts on employment, GDP, and tax revenue			
Design 1			
Assumptions	Mid-range	Low	High
CAPEX ($ million)	735	500	1,800
Direct and indirect job multiplier (full time equivalent jobs per $ million)	7	5	9
GDP multiplier	3	2	4
Tax to GDP ratio	28	28	28
Estimates			
Jobs created/sustained	**5,145**	2,500	16,200
GDP impact	**2,132**	750	5,400
Tax revenue impact	**597**	210	1,512
Design 2			
Assumptions	Mid-range	Low	High
CAPEX ($ million)	297	198	717
Direct and indirect job multiplier (full time equivalent jobs per $ million)	7	5	9
GDP multiplier	3	2	4
Tax to GDP ratio	28	28	28
Estimates			
Jobs created/sustained	**2,079**	990	6,453
GDP impact	**861**	297	2,868
Tax revenue impact	**241**	83	803

Design 2: Exclusion of extremely high-cost areas from Design 2 reduces total capital expenditures, lowering estimated economic impacts using the standard multiplier methodology proportionally. Design 2 will help or sustain around 2,000 direct and indirect full time equivalent jobs, increase GDP by about $850 million, and lead to an increase in tax revenue of about $240 million. Anticipated tax revenue growth would allow the public sector, particularly Federal and State governments, to recuperate a substantial proportion of initial investment over time.

Limitations

It is relevant to further note that we are using only generic and historical public infrastructure spending multipliers to arrive at these estimates and do not consider potential medium to long term impacts that fiber diffusion in the County may have in enabling productivity growth, attracting new residents and businesses, etc. Improvements in wireless and satellite-based services on the edges of the network with extremely high costs can similarly lead to innovation and growth. Those would imply additional benefits to the transitory network infrastructure construction impacts outlined above but estimating them is challenging and error prone.

Although research on GDP and employment effects of transition from 1st generation (i.e. copper/DSL, fiber, fixed wireless) to high-capacity fiber and hybrid fiber/small cell broadband technologies is in its infancy, recent studies suggest that moving from current rural speeds we

observe to fiber-based/100+ Mbps symmetric services can lead to a positive impact of between 0.4% and 1.2% on GDP.[21]

A key insight from previous research for San Diego County is that countries and regions that are already further along in the transition from copper to fiber tend to gain more in terms of GDP (e.g. Northern Europe, East Asian countries leading in FTTP penetration). This increased effect is a function of the nature of networks. In leading communities where more people have access to both high-quality fiber and advanced wireless networks, the positive economic benefits tend to be larger. These "network effects" are considered in the estimates provided above with varying the size of the multipliers used for arriving at estimates of GDP/tax impacts of projects of varying sizes (i.e., more than proportional impact of project size due to positive spillovers).

Medium to long term employment spillovers

There are significant uncertainties about the employment impacts of better broadband beyond the construction stage. On the one hand, better broadband increases both capital and labor productivity, which may lead to demand for less labor by existing businesses as they substitute capital for labor. Better broadband can also allow local businesses to procure some of the labor and services they need from far away places, reducing their need for local labor. On the other hand, better broadband can attract new businesses and enable entrepreneurship in rural areas and isolated communities by collapsing their "distance" to regional and global markets.[22] This would have a positive impact on employment. The answer to the question if better broadband increases or decreases prospects for employment is theoretically ambiguous and needs to be answered empirically.

While some studies have found a strong positive impact from ultra-high capacity FTTP networks on indicators of local employment (and negative impact on unemployment), others have found very small and/or statistically insignificant employment impacts from broadband.[23] In terms of studies finding a positive effect, we note that Singer et al. (2015) used proprietary

[21] Analysis Group (2015) Early Evidence Suggests Gigabit Broadband Drives GDP.
https://www.analysisgroup.com/globalassets/content/insights/publishing/gigabit_broadband_sosa.pdf
Lüdering, J. (2016). Low latency internet and economic growth: A simultaneous approach (No. 34-2016). Joint Discussion Paper Series in Economics.
https://www.uni-marburg.de/fb02/makro/forschung/magkspapers/paper_2016/34-2016_luedering.pdf
Hasbi, M. (2017). Impact of Very High-Speed Broadband on Local Economic Growth: Empirical Evidence. In 14th ITS Asia-Pacific Regional Conference, Kyoto 2017: Mapping ICT into Transformation for the Next Information Society (No. 168484). International Telecommunications Society (ITS).
https://www.econstor.eu/handle/10419/168484
WiK Consult/Ofcom (2018). The Benefits of Ultrafast Broadband Deployment.
https://www.ofcom.org.uk/__data/assets/pdf_file/0016/111481/WIK-Consult-report-The-Benefits-of-Ultrafast-Broadband-Deployment.pdf

[22] Salemink, K., Strijker, D., & Bosworth, G. (2017). Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. *Journal of Rural Studies*, *54*, 360-371. https://www.rug.nl/research/portal/files/35194647/Chapter_2_.pdf

[23] Katz, R. L., Vaterlaus, S., Zenhäusern, P., & Suter, S. (2010). The impact of broadband on jobs and the German economy. Intereconomics, 45(1), 26-34. https://www.intereconomics.eu/contents/year/2010/number/1/article/the-impact-of-broadband-on-jobs-and-the-german-economy.html
Ivus, O., & Boland, M. (2015). The employment and wage impact of broadband deployment in Canada. Canadian Journal of Economics, 48(5), 1803-1830. https://hosted.smith.queensu.ca/faculty/OIvus/docs/articles/Ivus_Boland_CJE_2015.pdf
Singer et al. (2015) The Empirical Link Between Fiber-to-the-Premises Deployment and Employment: A Case Study in Canada. Bell Canada GiC petition.
https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/TRP-CRTC-2015-326-Bell-Canada-Attachment3.pdf/$file/TRP-CRTC-2015-326-Bell-Canada-Attachment3.pdf
Hasbi, M. (2017). Impact of Very High-Speed Broadband on Local Economic Growth: Empirical Evidence. In 14th ITS Asia-Pacific Regional Conference, Kyoto 2017: Mapping ICT into Transformation for the Next Information Society (No. 168484). International Telecommunications Society (ITS). https://www.econstor.eu/handle/10419/168484
Nordin, M., Grenestam, E., & Gullstrand, J. (2019). *Is Super-Fast Broadband Negative? An IV-Estimation of the Broadband Effect on Firms' Sales and Employment Level* (No. 2019: 8) https://project.nek.lu.se/publications/workpap/papers/wp19_8.pdf

data from Bell Aliant FTTP deployments and found that 100% deployment is associated with 3% higher employment rates. Focusing on data from French municipalities, Hasbi (2017) found that the diffusion of ultra high speed/FTTP connections is associated with lower unemployment rate of around 7%. While these estimates are informative, extrapolating from the experience with employment/unemployment impacts of FTTP deployments in San Diego County would not be very informative. This is because communities in these areas are experiencing unique challenges.

3.2 Consumer welfare

Once deployed, from an economic perspective the primary beneficiaries of technological change tend to be consumers that value higher quality connections that reliable fiber access networks enable compared to legacy copper/DSL, cable, and wireless. Current service speeds in underserved areas may be good enough for basic Internet applications such as email and web browsing, but have been considered inadequate for multiple users using multiple devices at the same home for a number of years (i.e. thus the adoption of higher minimum speed standards by the FCC and BEAD program at the 100/20 Mbps threshold). For others, the 25/3 Mbps service capacity might be sufficient. However, a large proportion of consumers consider such service levels are inadequate and tend to subscribe to services between 250 Mbps to 1 Gbps where technologies that can deliver such speeds are available (i.e. where there is fiber and/or upgraded coaxial cable networks).

With COVID telecommuting and school from home, the proportion of households demanding for ultra-high capacity/low latency connectivity has grown rapidly. Current speeds are insufficient to satisfy demand from the substantial proportion of subscribers with demand for “Gig” level services today. While demand for fiber-based Gig services is driving private sector investments in fiber access networks in America’s urban centers and large towns, the business case to do so in high cost/low revenue small towns and rural areas remains limited (to non-existent). The opportunity costs in terms of consumer surplus gains that are forgone from a lack of access to reliable high-quality fiber-based connection is likely to be substantial.

To quantify this consumer welfare loss/potential gain, we rely on estimates from previous research using proprietary data from large North American broadband infrastructure providers, which suggests that potential consumer surplus from FTTP to be somewhere in the range of $200 to $300 per month per subscriber (at zero price).[24] These benefits arise from the time savings and productivity gains that high-availability, high-quality and more symmetric fiber wireline connectivity enables. At market prices of about $80 per month for FTTP services in California (where available), additional per subscriber consumer surplus from FTTP (over legacy cable and DSL) by a subscriber can then be estimated to be between $120 to $220 per month (depending on subjective evaluation of the value of high-quality vs. basic Internet). This range applies to additional gains over cable and DSL-based services, and therefore likely to be even bigger for people that can switch from wireless or satellite to FTTP. Our estimates below are therefore relatively conservative. We have not identified studies that evaluate consumer welfare gains from improved wireless and satellite-based services, but suspect that they are only marginal and estimate them by price difference between legacy wireline and wireless plans of about $20 per month.

[24] See: Nevo, A., Turner, J. L., & Williams, J. W. (2016). Usage-Based Pricing and Demand for Residential Broadband. *Econometrica*, 84(2), 411-443. Available at: https://www.nber.org/papers/w21321.pdf

Using these baselines, we can estimate that at current market prices for Gig service (in urban areas “where available”), deploying fiber access networks where they are not currently available would generate a consumer welfare gain of around **$1,000 annually per subscriber** over existing legacy wireline and wireless-based services. For wireless improvements, we estimate the mid-range consumer welfare gain to be around **$240 per annually per subscriber**. The subsequent table summarizes our estimates of marginal gains in consumer welfare associated with the two program design models.

Consumer Surplus Effects of Technological Change			
Assumptions	**Mid-range**	**Low**	**High**
Marginal consumer welfare gains from FTTP over legacy (per subscriber, per month, $)	80	60	100
Marginal consumer welfare gains from upgraded wireless over legacy (per subscriber, per month, $)	20	15	25
Take up rate	50%	40%	60%
Estimates			
Design 1			
FTTP homes passed	35,000	35,000	35,000
FTTP subscribers in target area	17,500	14,000	21,000
Annualized welfare gains per subscriber	960	720	1200
Annual consumer welfare gains in project area	**16,800,000**	**10,080,000**	**25,200,000**
Total consumer welfare gains over 10 years	**168,000,000**	**100,800,000**	**252,000,000**
Design 2			
FTTP homes passed	27,300	27,300	27,300
FTTP subscribers in target area	13,650	10,920	16,380
Annualized welfare gains per FTTP subscriber	960	720	1200
Total consumer welfare gains from FTTP per year	13,104,000	7,862,400	19,656,000
Wireless/satellite BSLs	6,000	6,000	6,000
Wireless/satellite subscribers	3,000	2,400	3,600
Annual consumer welfare gains per wireless/satellite subscriber	240	180	300
Total consumer welfare gains from wireless/satellite	720,000	432,000	1,080,000
FTTP + wireless + satellite annual consumer welfare gains	**13,824,000**	**8,294,400**	**20,736,000**
Total consumer welfare gains over 10 years	**138,240,000**	**82,944,000**	**207,360,000**

Higher reliability and capabilities enabled by FTTP deployments enable substantive consumer welfare gains over legacy technologies, but market forces cannot always capture these value gains/positive externalities through the price mechanism as in other public infrastructure systems such as roads and education. In Design 1, estimated consumer welfare gains over 10 years would be substantive, but only cover a relatively smaller proportion of required CAPEX compared to Design 2 where extremely high-cost areas have been excluded from the FTTP cost estimates.

Design 1: Mid-range estimate of marginal welfare gains is around $170 million over 10 years. If we add to the projected tax revenue growth from construction of $600 million to this, that would exceed the estimated capital expenditure requirement for this Design of $735 million in the mid-range case.

Design 2: Mid-range estimate of marginal welfare gains is around $140 million over 10 years. If we add to the projected tax revenue growth from construction of $240 million to this, that would exceed the estimated capital expenditure requirement for this Design of $300 million in the mid-range case.

3.3. Property values and municipal taxes

By improving quality of life and the range of opportunities available for social and economic participation, expanding access to ultra-high speed/FTTP networks has the potential to increase property values. Research on the impact of broadband infrastructure quality variation and property values from the U.S. suggests that high-capacity fiber connections have a marginal positive impact of about 3% on median home values, with some variation around this due to regional, competitive, and other sources of variation in home values (ranging from 1% to 7%).[25] Recent research on the impact of connectivity on property values at the regional level in Canada suggests that, controlling for other others, wireless Internet access has a negative impact on the value of rural homes, while wireline connections have a positive impact (+20% additional value from wireline over wireless, or slightly more than addition of a full bathroom).[26] Unfortunately, the literature review for this report was not able to identify previous research analyzing the links between broadband connection availability and property values in California.

The proximity of unincorporated areas of the County to the urban cores of the region with relatively expensive properties represents both a threat and opportunity. Particularly since the COVID pandemic, rural/remote properties that lack access to high-quality broadband are going to be particularly hard to sell or would require a heavy discount. On the other hand, given large gaps between prices in urban areas of the region and underserved communities addressed by the CBP, better rural broadband has the potential to attract people searching for more affordable living, larger spaces, and rural life. The impact of fiber on property values may therefore be on the higher end of the range of estimates from the U.S. market from before COVID.

As documented in the table below, we estimate the potential impact of FTTP deployments on property values based on a range around current average market values of single-family homes in San Diego County and FTTP property value increase elasticities from previous research.[27] We do not anticipate material marginal gains to home values from wireless improvements in relative terms and do not consider them in the analysis that follows.

[25] Molnar, G., Savage, S. J., & Sicker, D. C. (2015). Reevaluating the Broadband Bonus: Evidence from Neighborhood Access to Fiber and United States Housing Prices. FTTH Council Americas. http://scandiainternet.com/documents/FTTH%20Study.pdf https://www.bbcmag.com/pub/doc/BBC_Jul15_GigabitHighway.pdf Molnar, G., Savage, S. J., & Sicker, D. C. (2019). High-speed Internet access and housing values. *Applied Economics*, 51(55), 5923-5936. https://www.tandfonline.com/doi/abs/10.1080/00036846.2019.1631443Deller, S., & Whitacre, B. (2019). Broadband's relationship to rural housing values. *Papers in Regional Science*, 98(5), 2135-2156. https://cced.ces.uwex.edu/files/2019/07/Deller-Whitacre-2019.pdf

[26] David Worden, D., Gillam, W., Razvi, R., and Hambly, H. Making the Connection Between Broadband and Property Values (2021). R2B2 Policy Brief No. 4. https://www.r2b2project.ca/wp-content/uploads/2021/11/Policy-Brief-MPAC-Durham-Nov102021.pdf

[27] We use market data from Rocket Homes San Diego County Market Report (2023) for our baselines.https://www.rockethomes.com/real-estate-trends/ca/san-diego-county
We use the price of single family homes with two bedrooms of $650,000, which is substantially lower than the median price of all homes in the County. This helps correct for the potential of a discount on homes in underserved unincorporated areas.

Estimated impact of FTTP Deployments on Property Values and Municipal Revenue			
	Mid-range	**Low**	**High**
Design 1			
Number of properties to be served with FTTP (count)	27,000	27,000	27,000
Median price (single family, market transaction value)	650,000	600,000	700,000
FTTP premium	3%	1%	7%
Future municipal property tax rate (% of value)	1.0%	1.0%	1.5%
Estimates (using median single home value)			
Median value with FTTP	669,500	606,000	749,000
Added property value per home ($)	**19,500**	**6,000**	**49,000**
Additional municipal revenue per home per year	195	60	735
Annual municipal revenue increase	**5,265,000**	**1,620,000**	**19,845,000**
Additional property taxes over 10 years	**52,650,000**	**16,200,000**	**198,450,000**
Design 2			
Number of properties to be served with FTTP (count)	21,000	21,000	21,000
Median price (single family, market transaction value)	650,000	600,000	700,000
FTTP premium	3%	1%	7%
Future municipal property tax rate (% of value)	1.0%	1.0%	1.5%
Estimates (using median single home value)			
Median value with FTTP	669,500	606,000	749,000
Added property value per home ($)	**19,500**	**6,000**	**49,000**
Additional municipal revenue per home per year	195	60	735
Annual municipal revenue increase	**4,095,000**	**1,260,000**	**15,435,000**
Additional property taxes over 10 years	**40,950,000**	**12,600,000**	**154,350,000**

Using the mid-range FTTP premium of 3% and a median property value of $650,000 for a two-bedroom house in San Diego County would generate an increase in home value of approximately of $20,000 per home. The key insight from this table is that the expected benefit in property value gains from fiber deployments per home in some areas might be higher than the per home cost of fiber deployments. However, coordination failures between property owners and private sector providers make it challenging to capture this potential value, generating market failures in the provision of network infrastructure in relatively high-cost/low-revenue areas.

Even in the very long run and under extremely optimistic assumptions about home value gains and property taxes, the potential tax revenue gains for municipal governments from better broadband tend to fall short of public investments needed to deploy fiber access networks ($200 million the case of Design 1 and $150 with Design 2 in marginal property tax growth over time).

Anticipated property tax revenue growth will cover only a proportion of capital cost required for deploying the network. This observation highlights a generic problem facing municipal governments with limited taxation authority and the need for state and Federal funding to sustain essential infrastructure such as roads and broadband, particularly in rural areas. As

detailed earlier, return to public infrastructure investment in terms of additional labor, business, and value added taxes for state and Federal governments is more substantive (i.e. ~ 28% tax to GDP ratio). Consequently, the Federal and state governments are in a significantly better position to make the initial capital investments in high-quality broadband users in rural areas demand and to recuperate these investments from higher incomes/taxes over time.

The value gains to property values in relatively remote and sparsely populated areas are likely to be relatively lower than in places such as the target area due to limited demand for very remote properties from outsiders/new residents. Property value gains can nevertheless arise as people with better broadband are likely to have stronger incentives to invest more capital in their properties to increase the subjective values of their homes from their own perspective (e.g. potentially with the objective of living independently in them into their old age). Property market prices or tax assessment values do not necessarily capture these sources of positive spillovers on the value of homes in declining areas with low-income populations.

3.4. Home-based healthcare and healthcare costs

Broadband access is increasingly recognized as a social determinant of health.[28] As in the case of telecommuting, COVID has demonstrated that a wider range of healthcare services can be delivered remotely, without significant loss in quality of service. Some healthcare applications do not necessarily require very high-speed/low latency broadband (e.g. ordering medicine, talking to the doctor). The functionality of other advanced applications that enable home monitoring and home-based healthcare delivery depend on reliable connectivity that is hard to deliver on other wired and wireless technologies besides low-latency fiber. Previous research suggests that in addition to the benefits of home healthcare applications for people that tend to require relatively more monitoring and health care services, fiber enabled home-healthcare delivery can have significant cost reduction implications for healthcare delivery in rural areas.[29]

Estimates from rural municipal case studies in Sweden on the economic benefits of FTTP enabled home healthcare applications suggest that a per capita cost reduction in public healthcare deliver of between 1% to 7% (in low and high home healthcare diffusion states). According to data from the California Healthcare Foundation, total public and private per capita healthcare spending in the state stood at about $10,000 in 2023. This would translate to per capita healthcare savings costs of between $60 in the low diffusion state (take up/use of 10%), and $500 per year (diffusion of advanced home healthcare applications to 90%) from access to reliable high-capacity FTTP connections in homes of those with monitoring and healthcare needs that can be managed virtually. In the low-diffusion scenario, potential public and private healthcare savings from the diffusion of advanced telehealth applications and services that require reliable wireline connectivity are estimated to be between **$40 to $60 million over 10 years.** For the mid-range case, potential healthcare cost savings increases to between **$220 and $285 over 10 years.**

[28] Benda, N. C., Veinot, T. C., Sieck, C. J., & Ancker, J. S. (2020). Broadband Internet Access Is a Social Determinant of Health!. *American Journal of Public Health*, *110*(8), 1123-1125. https://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2020.305784

[29] Forzati, M., & Mattsson, C. (2014, July). FTTH-enabled digital home care—A study of economic gains. In 2014 16th International Conference on Transparent Optical Networks (ICTON) (pp. 1-7). IEEE. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1041.9141&rep=rep1&type=pdf

Healthcare Cost Avoidance Enabled by Access to Reliable Low Latency Connectivity and Adoption of Advanced Home Healthcare Applications			
	Mid-range	**Low diffusion/use**	**High diffusion use**
Design 1			
Number of residents connected with FTTP	100,000		
Per capita healthcare expenditures	10000		
Per capita cost reduction	285	60	510
Estimate			
Total healthcare costs in region	1,000,000,000		
Healthcare cost avoidance (annual)	28,500,000	6,000,000	51,000,000
Telehealth induced % reduction	3%	1%	5%
Telehealth induced benefits over 10 years	**285,000,000**	**60,000,000**	510,000,000
Design 2			
Number of residents connected with FTTP	77,000		
Per capita healthcare expenditures	10000		
Per capita cost reduction	285	60	510
Estimate			
Total healthcare costs in region	770,000,000		
Healthcare cost avoidance (annual)	21,945,000	4,620,000	39,270,000
Telehealth induced % reduction	3%	1%	5%
Telehealth induced benefits over 10 years	**219,450,000**	**46,200,000**	392,700,000

It is relevant to note that with COVID, both patients and healthcare service workers have strong incentives to avoid personal contact and intensify their use of Internet-based applications. Consequently, the high-diffusion state outcomes become more likely if healthcare providers and public agencies intensify their efforts to expand access and use of remote healthcare delivery methods, particularly in rural areas where it is hard to find healthcare practitioners and access related resources in person. This is particularly relevant for healthcare delivery to older adults and others with limited mobility and resources. Ensuring high quality monitoring and healthcare delivery by making reliable wireline connections available and affordable can provide a lifeline for enabling this vulnerable group to enjoy independent living as long as possible.

3.5 Agricultural/rural business benefits

More data collection and analysis from target area would be required to assess both the costs and benefits of expanding fiber access to farms that are in the vicinity of the proposed deployment. Nevertheless, it is important to direct the reader to a recent study by the U.S. Department of Agriculture (USDA) which has evaluated the quantum of potential productivity gains from adoption of precision agriculture technologies that require reliable, high capacity, and low latency connections.[30] While legacy technologies may be good enough for certain farming processes and crops, the USDA estimates suggest that high capacity/low latency connectivity is needed to unlock up to 50% of potential value added gains associated with the

[30] USDA (2019) The Case for Rural Broadband. Insights on Rural Broadband Infrastructure and Next Generation Precision Agriculture Technologies https://www.usda.gov/sites/default/files/documents/case-for-rural-broadband.pdf

adoption of precision agricultural technologies (e.g. microclimate modeling technologies, field scouting, remote diagnostics and predictive maintenance, pest prevention and monitoring, robotic harvesting, marketing and sales).

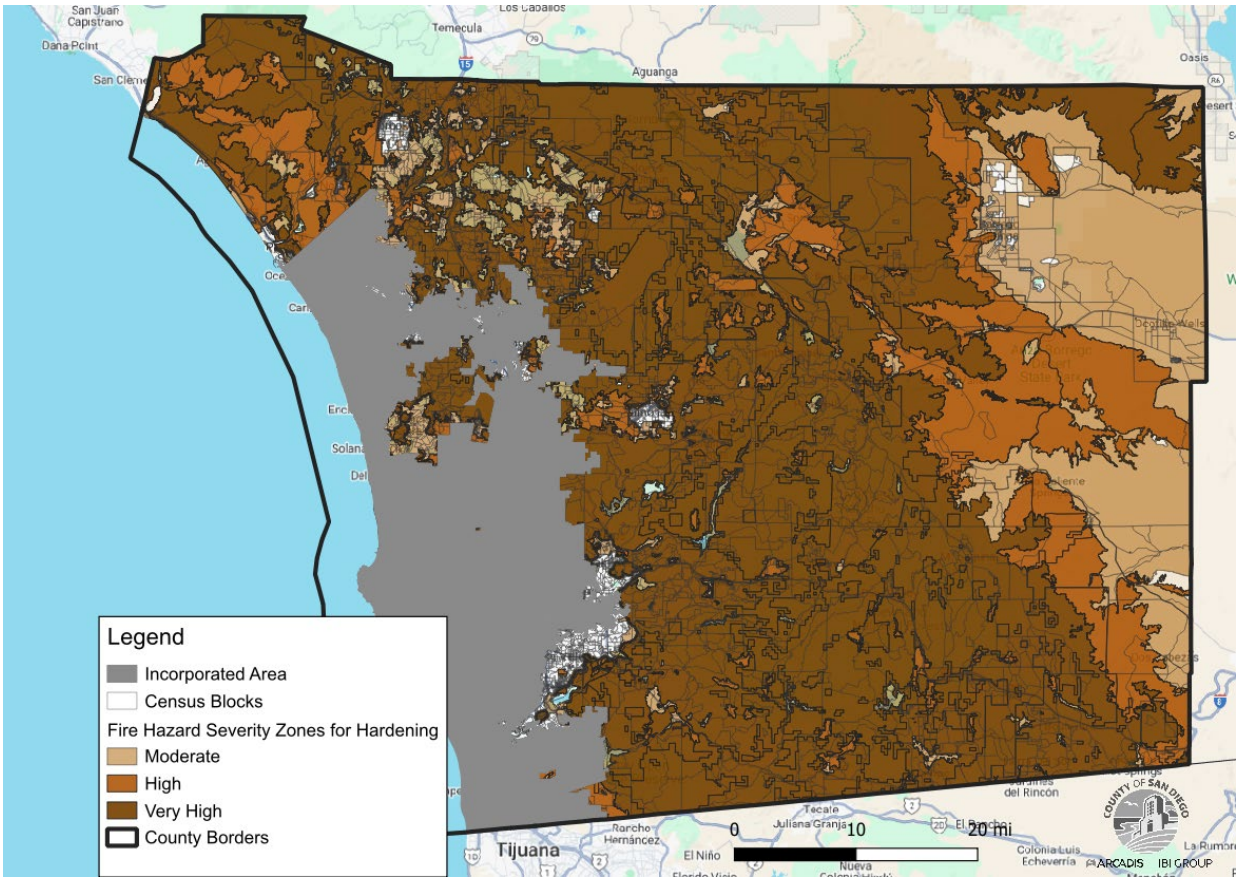
From a broadband network development perspective, it is important to note that connecting farms and other businesses (e.g. hotels and tourist destinations) on the rural edges of networks with fiber might be very expensive (significantly above willingness/ability of farmers to pay for the value it can generate for them). However, there are positive spillovers in targeting high value business consumers such as farms and stores with fiber connections as it can lead to significant reductions in the cost of serving others along rural roads and small population clusters as the fiber passes through to the farm, or other remote but strategic location. The County may wish to contemplate how it can work with the farming community and related businesses that employ and serve people in extremely high-cost areas where expanding fiber deployment may appear cost prohibitive.

3.6. Alignment with other policies/priorities

In addition to quantifying some of the key channels through which the Program Design models can generate private and public benefits, attracting broadband infrastructure funding and expanding reliable connectivity in underserved areas aligns with a number of other strategic priorities of the County.

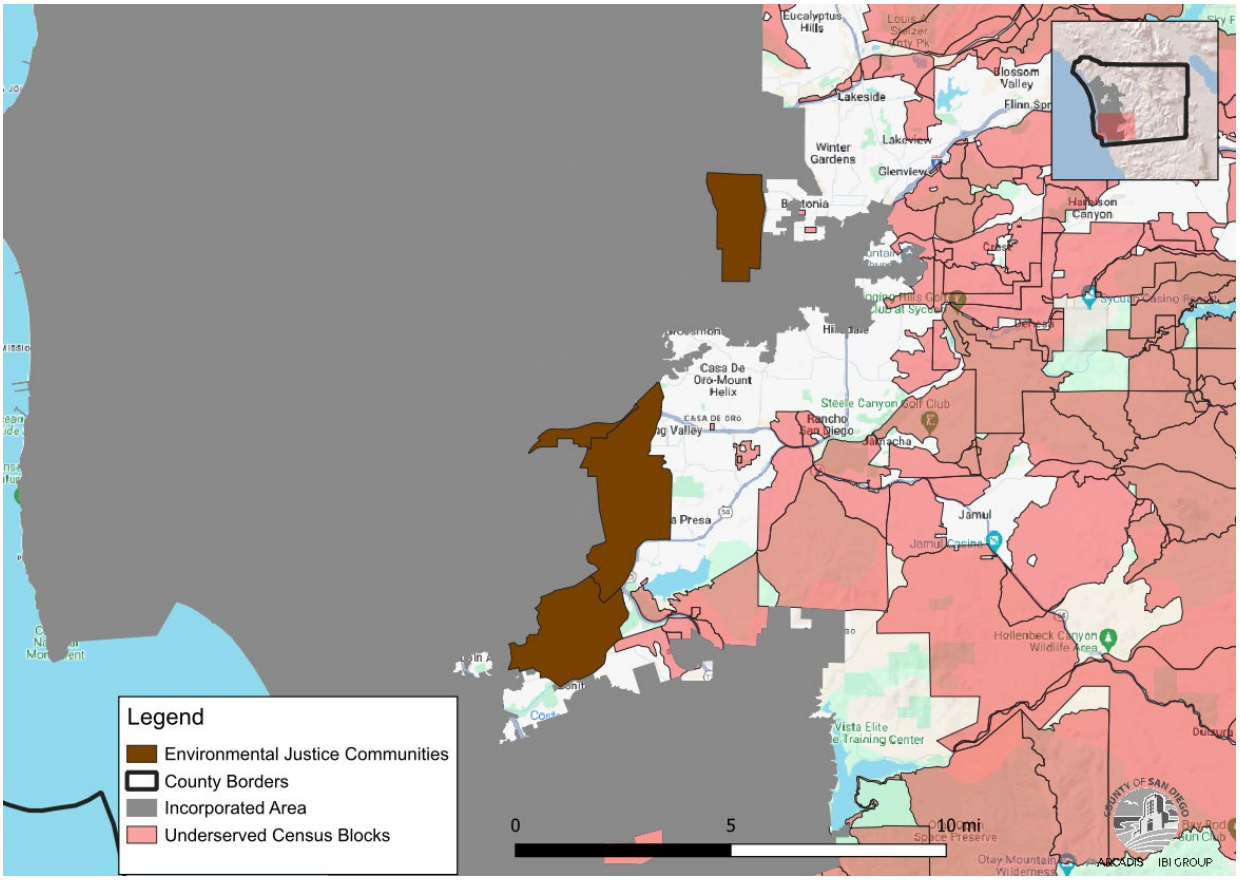
- **Fire hardening/hazard mitigation:** In developing our cost estimates, we have included fire hardening and recommended that the County should encourage buried fiber deployments in areas with moderate to high fiber hazard risk. Benefits of fire hardening of what is now essential service would be hard to quantify but are likely to be material for ensuring network and community resilience in unincorporated areas in case of adverse events. The figure below shows areas recommended for hardening of infrastructure against fire hazards.

Figure 6: Recommended blocks for hardening against fire hazards



- **Environmental Justice Communities (EJC):**[31] FCC data does not identify overlap between EJC communities and underserved census blocks, per the figure below.

Figure 7: Environmental Justice Communities vs. Underserved Census Blocks



- **Reducing Vehicle Miles Travelled (VMT):** Counteracting growth in VMT represents a key policy priority of the State and the County.[32] Reliable wireline connection can make telecommuting more feasible, but recent research suggest that the overall impact of increasing telecommuting and VMT in Southern California is relatively low (~8% reduction for work travel, but only 1.5% reduction in VMT overall).[33] Both Program Design models for CBP implementation will also help further County's VMT reduction strategy, but the direction and magnitude of FTTP deployments on VMT reductions in San Diego County would be challenging to estimate in a reliable manner.[34]

- **Development Feasibility Analysis (DFA) framework:** The County DFA represents two-phased approach was directed to identify policies to reduce vehicle miles traveled (VMT) in the unincorporated county through the implementation of Senate Bill 743. [35]

[31] https://www.sandiegocounty.gov/content/dam/sdc/pds/gpupdate/09-Environmental-Justice-Aug2021.pdf

[32] https://www.sandiegocounty.gov/content/sdc/pds/SB743.html

[33] Evaluating Policies and Incentives to Reduce Vehicle-Miles-Traveled and Air Pollutant Emissions through the Promotion of Telework and Remote Services. METRANS Transportation Center University of Southern California. https://www.metrans.org/assets/research/ma_psr-21-50%20final%20report.pdf

[34] Marz, W., & Şen, S. (2022). Does telecommuting reduce commuting emissions?. Journal of Environmental Economics and Management, 116, 102746. https://www.econstor.eu/bitstream/10419/248902/1/cesifo1_wp9357.pdf

[35] https://engage.sandiegocounty.gov/sustainableframework

Attracting broadband investments and encouraging developers to deploy open access conduits into new development for fiber deployment would be aligned with DFA objectives of reducing VMT. As noted above, the overall impact of better Internet on VMT is theoretically ambiguous and has not been addressed in the empirical literature.

4. Summary of Costs and Benefits

The following tables summarize both the costs and benefits of the conceptual program design models detailed in previous sections. We focus only on capital costs and economic benefits that are more conducive to quantification using traditional telecommunications infrastructure investment multipliers and estimates of FTTP impact elasticities on indicators of public and private value. The summary table provides mid-range benefit over 10 years post deployment. Given the long lifespan of fiber-optic networks (30+ years), the economic benefit estimates outlined here only reflect medium to long term benefits vs. the very long run. In terms of our cost estimates, we have focused on estimating upfront fixed capital cost of the two Program Design models. Wireless equipment tends to degrade relatively rapidly and needs to be refreshed every 5 to 7 years, which tends to generate additional demand for public subsidies in areas where low population density/revenue potential does not support wireless service providers' business case to upgrade equipment over time.

San Diego County Comprehensive Broadband Plan (CBP) Implementation Cost/Benefit Summary of Program Design Strategies (mid-range estimates)		
	Design 1 (Full Fiber)	**Design 2** (Fiber + Wireless + Satellite)
BSLs to be covered with FTTP	27,000	21,000
Households to be covered with FTTP	35,000	27,000
BSLs to be covered with fixed wireless/satellite	-	6,000
Households with upgraded wireless/satellite	-	7,800
Total FTTP CAPEX estimate (millions)	735	297
Per BSL FTTP CAPEX	27,000	12,500
Total wireless/satellite (millions)	-	10
Per BSL wireless/satellite cost	-	1,700
Total CAPEX (millions)	735	307
Per BSL CAPEX	27,000	11,373
Economic impact estimates		
Transitory impacts from construction		
Full time equivalent job	5,145	2,079
GDP impact (million)	2,132	861
Additional tax revenue to upper-tier governments (millions)	597	241
Private and public impacts		
Increase in property value per home connected with FTTP	20,000	20,000
Additional municipal tax per home connected with FTTP per year	195	195
Additional property tax per year (million)	5	4
Additional property tax over 10 years	53	41
Consumer welfare gain from FTTP over legacy, per household per year	960	960
Consumer welfare gains from upgraded wireless/satellite, per household, per year		240
Annual consumer welfare gains in target area at 50% take up (million)	17	14
Consumer welfare gains over 10 years (million)	170	140
Per capita healthcare savings in low diffusion of advanced applications	60	60
Annual public and private healthcare cost savings (million)	6	5
Healthcare cost avoidance over 10 years (million)	60	46
Total benefits over 10 years (million)	283	227
Cost/benefit summary over 10 years (millions $)		
Total benefits (GDP impact + consumer welfare gain + healthcare savings + property tax revenue increase)	2,415	1,088
Difference between total benefits and initial capital costs	**1,680**	**791**
Initial capital costs minus total anticipated tax revenue increase	85	25

5. Incentives and Strategies

Content

This section provides our recommendations regarding next steps that can be taken to encourage private sector service providers to develop competitive applications to BEAD and other funding programs and bring broadband infrastructure investments to underserved areas of the County.

The objectives of the broadband program are to guide and nudge service providers to expand with fiber infrastructure into underserved areas by identifying and publishing areas of underserved premises throughout the County requiring a focus on:

- Broadband deployment to underserved residential and business premises; and
- Addressing public access in underprivileged regions through provision of free Wi-Fi at select anchor institutions (Libraries, Parks, Public Buildings)

To accomplish this, the program will engage Service Providers by publishing a positioning paper, confirming County preferences, and encouraging their participation to secure County support for future applications for state and federal grant applications.

The program will support self-identified eligible service providers in their applications for Federal and/or State funding aligning to the program objectives, by providing official County letters of support to those ISPs to support their applications for competitive federal and/or state grant funds.

5.1 Governance

As the broadband program is to be focused on influencing the implementation of private-sector infrastructure to underserved clusters throughout the County, it is recommended that the program be governed internally. To maintain focus, it should be managed by a single department, and overseen by a steering committee comprised of representatives from key stakeholder departments.

Due to the impact of broadband infrastructure on the wellbeing of County residents and businesses, development, and the economy, typical candidate departments for management or oversight of such a program would include Land Use and Environment, Planning and Development Services, and/or Economic Development and Government Affairs. Other stakeholders might include Purchasing and Contracting, Library, School boards, Parks and Recreation, Technology Office, and Public Works.

5.2 Operating Model

The recommended operating model for broadband infrastructure, closing gaps and addressing infrastructure availability across the County, is one of private sector ownership and operation. The recommendation is for an approach similar to that adopted in Riverside County, whereby San Diego County would identify its preference to address underserved areas and provide support letters for private sector ISPs to enhance their networks accordingly.

This model implies that the participating ISPs will continue to own and operate their own networks. The County should not expect or require ownership of any portion of their networks, as it is not providing any funding directly.

5.3 Eligibility

The program would be open to eligible service providers. Based on eligibility criteria of various State and Federal broadband grant funds, ISPs wishing to participate will be expected to confirm their eligibility for the various funds for which they wish to secure County support.

To provide broadband access to underprivileged residents, a condition of support should be that the ISP establish and provide free Wi-Fi access at and/or around select public infrastructure such as parks and government buildings.

5.4 Incentivizing Private Sector ISPs

County governments play a crucial role in bridging the digital divide and improving Internet access in underserved areas. To incentivize private-sector Internet Service Providers (ISPs) to invest in infrastructure in these identified areas, public sector agencies have a number of potential options.

One strategy is to offer direct subsidies that help reduce the private costs of deploying networks. Another is to offer tax breaks to ISPs willing to expand their services into underserved regions. By creating a more favorable economic environment, governments can attract private-sector investment, encouraging ISPs to build the necessary infrastructure to provide reliable and high-speed Internet access to underserved communities. This approach is more suited to state or federal governments, which have broader taxation authority and financial capacity to fund infrastructure subsidies (or forgo future tax revenue in the case of tax breaks).

Another strategy is to establish public-private partnerships with ISPs to share the costs and risks associated with infrastructure development. Through these partnerships, local and regional governments can collaborate with private-sector entities to jointly plan and implement broadband projects in underserved areas. While this approach leverages the expertise and resources of private ISPs and allows counties to participate in the planning, it does also require that the County share the financial burden by allocating some of its public funds. Due to their design to have control over end-to-end network assets, larger ISPs are typically resistant to entering into such agreements with government entities.

In general, city and county governments may also consider streamlining regulatory processes and permitting requirements for ISPs involved in these projects (something San Diego County has already initiated), reducing hurdles, and expediting the deployment of broadband infrastructure.

Without providing direct funding to ISPs, rural counties can often be more effective by leveraging their influence to assist ISPs in securing additional funding from Federal and state grant programs targeting underserved areas. County governments can provide letters of support for grant applications, emphasizing the importance of expanding broadband access in underserved areas and showcasing the collaborative efforts between the public and private sectors. These letters can strengthen the grant applications and increase the likelihood of the ISP securing funding. In the case of BEAD, community support is required for private sector applicants, providing the County with some capacity to encourage private providers to address

identified connectivity gaps. By actively engaging with the grant application process, the County would demonstrate its commitment to addressing the digital divide and facilitating private-sector investment in critical infrastructure projects.

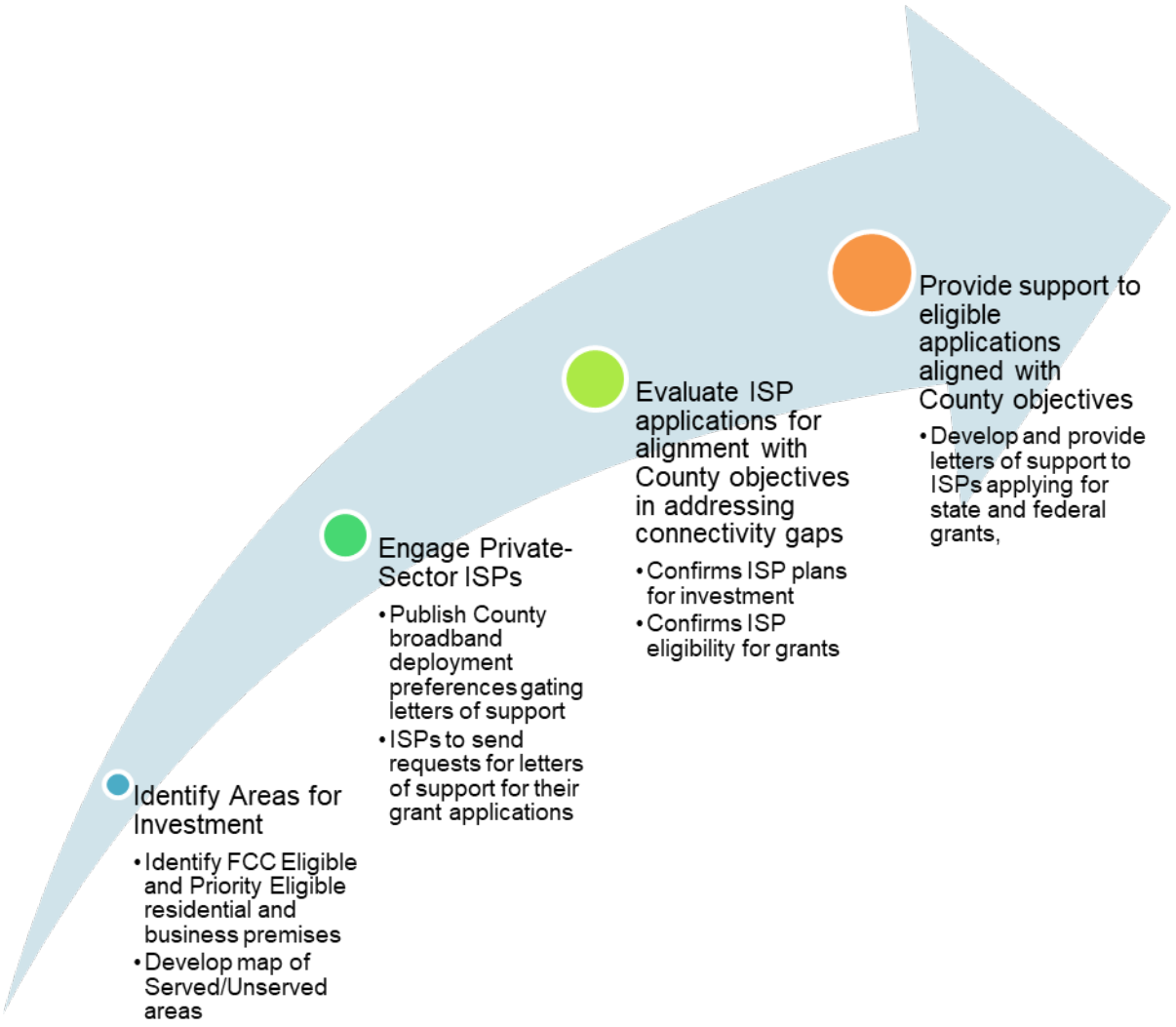
Recommendation 1: It is therefore recommended that the County adopts the primary strategy to encourage and incentivize private sector ISPs to build infrastructure in underserved areas of of the County without providing any direct funding. This would entail providing letters of support to eligible ISPs for state and federal grant applications. Internal communications across the elected officials and staff of the County will be required to ensure that letters of support for broadband infrastructure projects are used as a strategic lever and are therefore to be approved and provided only through the program to an eligible ISP when the proposed project aligns with the program's objectives.

For underserved areas that are not addressed in private sector ISPs plans and do not receive funding, the County may wish to explore alternative options such as providing support for wireless service providers and or subsidizing satellite services for low-income residents. For example, for extremely high-cost areas into which fiber builds are not financially feasible, the County may wish to encourage and provide support for applications to build wireless towers in an open-access model that allows multiple wireless providers to expand their coverage and service quality (and not to disadvantage any one wireless service provider).

Recommendation 2: For low-income residents in extremely high-cost areas that will have to depend on satellite services, the County should consider developing a fund to subsidize the one-time costs for satellite equipment. Assuming that equipment costs are $800 per user and 6,000 residents high-cost areas take up a satellite equipment subsidy offer, the budgetary estimate for this fund would be $5 million.

5.5 Program Process

The following exhibit depicts the proposed program process.



As depicted above, the County's broadband program begins by identifying clusters of underserved premises based on FCC data, aligning it to funding eligibility. These clusters represent residential and business areas eligible for federal and/or state grant support. Utilizing maps showcasing these underserved areas, the program's objective is to strategically address connectivity gaps. Through this process, the County identifies specific regions in need of improved broadband infrastructure.

To facilitate the expansion of broadband services, the County then publishes their preferences for deployment of new broadband infrastructure in unincorporated area of the County, in the form of a positioning paper. This positioning paper serves as a tool, with which to advise service providers of the County's preferred criteria for supporting ISP applications for grant applications.

When ISPs approach the County for letters of support, the County can then evaluate the ISPs' applications based on the previously published preferences and provide letters to those that are in alignment. These letters not only endorse the service providers but also express the County's commitment to supporting private sector investment in underserved areas.

Furthermore, the County can encourage ISPs to extend their commitment by providing free Wi-Fi access to broadband in select public locations, such as parks and government facilities in underprivileged areas. This holistic approach not only focuses on infrastructure development but also aims to enhance digital accessibility for communities in need. Though this engagement process, the County can also encourage ISPs to incorporate factors such as fire hardening in the design of projects they develop for their applications to CPUC for BEAD (and potentially other broadband funding facilities).

5.6 Management Processes

Effectively managing a broadband program requires a comprehensive approach that encompasses various management processes, with a particular focus on project and risk management. The intricate nature of broadband initiatives, characterized by their scope, complexity, and technological dependencies, necessitates a strategic framework to ensure successful implementation.

Project management processes play a pivotal role in defining and organizing the tasks, timelines, and resources required for the program's execution. Concurrently, risk management processes are crucial for identifying, assessing, and mitigating potential challenges that may impede the program's progress. Management process recommendations encompass:

- Project Management: Identify tasks, track milestones, budgets, and outcomes, and regularly update the steering committee on project status; and
- Risk Management: Identify potential risks and develop mitigation strategies, and to regularly assess and adjust the risk management plan as needed.

This dual emphasis on project and risk management not only enhances the likelihood of meeting the program’s objectives within specified timelines but also promotes adaptability in the face of uncertainties, fostering resilience and successful outcomes in the dynamic landscape of broadband program management.

5.7 Tools

Several tools are recommended for the implementation and ongoing management of such a program, including those for communications and collaboration; GIS mapping; and technical consultants operating in the broadband field.

Communications and Collaboration tools would include such items as:

- Website, to serve as a central hub for information dissemination, updates, and interaction with stakeholders; and
- Collaboration tools like TEAMS, to facilitate communications and collaboration among project team members and stakeholders.

GIS mapping tools would be leveraged to visually represent the underserved areas and assist in strategic decision-making; and

Consultants could be engaged to draft technical materials, evaluate responses, and provide expertise, encompassing such items as:

- Drafting responses to questions,

- Drafting reports and presentations to steering committee,
- Comparing responses to underserved areas,
- Identifying remaining gaps likely to exist; and
- Supporting the County to encourage ISPs to expand their networks.

5.8 Outreach

Given the timing of upcoming grant application intake events, it will be critical to engage private sector ISPs, and ensure all County staff and elected officials are informed of the program, its objectives, and approaches.

An outreach to internal staff and elected officials should therefore be initiated to impart the importance of managing the issuance of support letters by the central program team.

At the same time, an outreach to known ISPs should be initiated, to raise awareness of program positioning paper confirming County preferences and encouraging their participation to secure County support for future applications for state and federal grant applications. ISPs should be encouraged to consider and submit applications to the State and Federal grant programs for fiber-based infrastructure projects, in alignment with stated preferences of the funds, thus improving their applications' chances of success.

Appendix – Costing Methodology

Premise Counts and Road Segments

For each census block, FCC data was used to quantify the total number of broadband serviceable locations, as well as the number of those locations that are considered served (having 100/20Mbps service available to them from at least one service provider). Subtracting the served locations from the total locations provides the number of underserved locations.

Roads were then segmented into short lengths. The road segments within each census block were then summed.

Cost Estimates and Sensitivity

The cost to build fiber infrastructure to underserved locations was calculated with two components – connection costs and fiber construction costs. To assess sensitivity of the cost model to component costs, Low, Mid and High-cost assumptions were employed.

- Connection Costs: consist of the cost of a fiber drop from the roadway to the building and the cost of required electronic/optical equipment at the building.
  Based on industry averages, per location connection costs have been estimated as follows:
    - Low: $600
    - Mid: $875
    - High: $1,000
- Fiber Construction Costs: consist of the cost to construct fiber along the road segments, distributing internet connectivity along the road segments to the underserved premises. These costs vary depending on the construction methodology (buried or aerial). Based on recent FFA applications, and CalTrans experience, the cost to construct fiber infrastructure has been estimated as follows:
    - Low (aligning with recent FFA Applications): $20 per foot, or $105,600 per mile,
    - Mid: $30 per foot, or $158,400 per mile; and
    - High (aligning with CalTrans experience): $75 per foot, or $400,000 per mile.

Cost per Underserved Location

For each census block, the total cost of construction was then divided by the number of underserved locations, resulting in a cost per underserved location factor.

To determine the most viable technology for construction of broadband infrastructure, thresholds were developed based on the fiber cost per underserved location factor.

Thresholds of $30,000 and $50,000 were used to determine appropriate areas in which to deploy fiber, fixed wireless, and LEO satellite broadband services. Census blocks with a cost per underserved location factor of less than $30,000 were deemed to be viable for fiber, those with factors between $30,000 and $50,000 fixed wireless, and those over $50,000 were deemed to be best suited for satellite.

Within the unincorporated area of the County, the number of census blocks and underserved premises that could be served by each technology are as follows:

Network Technology	Number of Census Blocks	Number of Underserved Locations	Average Cost per Underserved Location		
			LOW	MID	HIGH
Fiber	1,081	21,133	$8,291	$12,412	$29, 842
Fixed Wireless	286	3,169	$2,000	$2,500	$3,000
LEO Satellite	625	2,649	$600	$800	$1,000

Assessment of Cost of Fiber Construction to Underserved Locations

BEAD grants may fund 80 percent of construction costs, while private sector service providers are typically willing to invest up to $2,000 per potential subscriber/home of their own capital. This enables the expansion of fiber optic broadband networks by the private sector, at an average cost level of $10,000/underserved premise, without any additional funds ($2,000 ISP + $8,000 BEAD). Census blocs with a cost per underserved location factor beyond the $10,000 to $13,000 per home, may be considered extremely high-cost, and may be more feasibly served with fixed wireless technologies, or perhaps even LEO satellite services.

With a cost per underserved location factor developed for each census block within the unincorporated area of the County,

Wireless Connection Costs

We have reviewed a number of sources to collate an acceptable industry benchmark for deploying fixed wireless access (FWA) solutions to deliver a 100/20 Mbps service to each BSL/underserved location.

According to the Wireless Infrastructure Association using information from market research firm iGR typical cost per household for FWA is between $200 to $1,800 depending on a variety of factors.[36] California based Wireless technology solution provider Tarana Wireless has also provided what a FWA cost per household solution would run in rural California as part of simulated total cost of ownership analysis when compared with FTTH.[37] The findings found that the cost per household connected comprised of cost per household passed estimated to be $475, and an additional cost to connect of $600, totaling $1,075 per home connected. The homes passed figure would cover shared infrastructure costs to establish the Tower and antenna, while the additional cost to connect would cover the cost of the receiver and installation/positioning to establish line of sight and connectivity.

[36] Fixed Wireless Home Broadband Service – A Critical Solution for Closing Connectivity Gaps in Rural America. Wireless Infrastructure Association (2023). https://wia.org/fixed-wireless-home-broadband-service-a-critical-solution-for-closing-connectivity-gaps-in-rural-america/

[37] ngFWA vs Fiber: TCO Analysis. Tarana Wireless (2023), https://www.taranawireless.com/ngfwa-vs-fiber-tco-analysis/

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