California Broadband Investment Model Federal Funding Account Last Mile Funding Analysis

Process Overview and Methods

Developed for:

State of California Public Utilities Commission

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Executive Summary

The California Public Utilities Commission (CPUC) contracted with CostQuest Associates (CostQuest) to estimate the investment required to bring broadband to areas in California lacking service using the Federal Funding Account program eligibility requirements adopted in CPUC Decision 22-04-055.

By analyzing data on service availability, CostQuest determined there are 777,292 unserved locations lacking access to broadband speeds of at least 25 Megabits per second (Mbps) downstream and 3 Mbps upstream through a reliable wireline connection, defined as a fiber to the premises or DOCSIS 3.0 cable connection. See "Served Areas Definition" section below.

Table 1. Unserved Definition

	California Service Definition	Locations
Unserved	**Service < 25x3Mbps.** Lacking access to at least 25Mbps downstream x 3Mbps upstream using FTTP or DOCSIS 3.0.	777,292

CostQuest used a series of forward-looking cost models to estimate the investment to deploy a fiber to the premises network to unserved and underserved[1] locations. Based on the modeling, an estimated $8.5 billion investment will be needed for new fiber and equipment to serve the unserved locations with additional hardening for locations in high fire threat districts. This estimate assumes no re-use of existing infrastructure (e.g., poles, conduit, manholes, etc.) in the total investment.

Table 2. California FTTP Network Investment Summary – Unserved Locations

	Unserved
FTTP Network Investment	$ 6,333,413,778
Additional Fire Hardening	$ 2,170,737,269
Total	**$ 8,504,151,047**
Locations	777,292

Project Scope

The California Public Utilities Commission (CPUC) contracted with CostQuest Associates (CostQuest) to estimate the investment required to build broadband infrastructure in the areas of the state currently lacking service. This estimate is unique, in that it creates a foundation for a broadband provider neutral approach in determining priority areas for last mile funding. This document describes the process for calculating investments.

[1] *For modeling purposes, underserved locations have access to at least 25Mbps downstream x 3 Mbps upstream with FTTP or DOCSIS 3.0 or better, but lacking access to at least 100Mbps upstream x 20Mbps downstream with FTTP or at least DOCSIS 3.0. Served locations have access to at least 100Mbps downstream x 20Mbps upstream using FTTP or at least DOCSIS 3.0.*

CostQuest used a series of models to develop investments. Using CostQuest's BroadbandFabric as the basis of broadband serviceable locations, the models create Service Area Groups and estimate the cost of deploying fiber to the premises (FTTP) service to all serviceable locations.[2] The model also provides for a connection from the Service Area Groups to the nearest statewide middle mile network access point to support FTTP-based service. The California proposed routes for a statewide middle mile network are used in the modeling. Investment to the unserved areas was then identified based on location and proximity to the statewide middle mile network.

The modeling of the last mile and incremental middle mile connections to the statewide middle mile used forward looking, efficient design practices that represent the costs that a potential service provider would incur to deploy a FTTP network. While the logic is identical, the last mile model applies several updates from the California Broadband Cost Model (CBCM) which are described in Appendix B.[3]

The middle mile model is used here to provide sufficient detail to estimate investment of the last mile providers' portion of the middle mile network. Inputs to the models -- the cost of material, labor, and type of labor needed to construct the network -- were adjusted from the CBCM to better represent current cost of materials and prevailing wages for labor costs. Additional adjustments were made to reflect the estimated impact of hardening outside plant in areas prone to fire; estimated hardening costs are reported separately. Given these assumptions, CostQuest estimates that $8.5 billion of total investment from all sources (public and private) is needed if broadband service is provided to all of the Federal Funding Account April 2022 unserved areas.

Processes and Overview

The next sections describe process steps in more detail. The document starts with an overview of broadband network components. It then moves to investment calculation and results for unserved areas.

Broadband Network

A wireline broadband network is a collection of cabling and equipment connecting end users to the internet. The network aggregates broadband traffic from individual end users through various devices and ultimately reaches an internet access point. From a cost modeling and funding allocation perspective, there are two primary components to a broadband network:

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[2] A serviceable location refers to a location that has or can receive broadband service. It may be single family housing unit, a business building, or a commercial structure.

[3] Information around CBCM may be found at https://www.cpuc.ca.gov/industries-and-topics/internet-and-phone/california-broadband-cost-model (last accessed 10/11/2022). The logic of the last mile model used for purposes of funding allocation is also identical to Connect America Cost Model, which determined funding support or auction reserve prices in the Connect America Funding Phase II (CAFII), CAFII auction, and RDOF auction. Inputs have been updated to reflect current material and labor.

the last mile and the middle mile, and the economics of the network vary significantly between the two. The last mile is the connection to the end users while the middle mile aggregates traffic from multiple last mile coverage areas and ultimately connects to the internet. Each of these portions of the network and modeling assumptions are discussed below in more detail. To model the cost of broadband service, CostQuest uses a series of models that calculate the investment for the last mile and the middle mile networks. Last mile networks are designed as fiber routes along roads within a town, subdivision, or other area to reach every passed end user location. As demand in terms of user connections varies across a region, the sizes and quantities of material also varies. The size of the fiber cables may be different along each road, and the equipment used for providing the last mile portion of the fiber-based service is different from the equipment used in the middle mile.

Modeling starts with serving areas and end user locations. Serving areas are geographic areas that define where cables in the last mile network are aggregated to a location that meets the middle mile network. For the purposes of this analysis, CostQuest developed Service Area Groups, which are logical clusters of serving areas.

End user locations[4] define where cables need to be built and determine demand that appropriately sizes equipment in both the last mile and middle mile networks. CostQuest uses a series of procedures and algorithms that cluster demand locations into logical groups to determine equipment placement and sizing. Cables are then efficiently routed along roads to connect end user locations to the equipment. The next few sections describe how the serving areas were created and how the investments were modeled.

Locations

End user locations define basic topology of a broadband network. For this analysis, CQA used Version 3 of its BroadbandFabric as the basis of broadband serviceable locations in California. The BroadbandFabric aggregates hundreds of millions of data points, applies statistical scoring, and managed crowdsourcing to pinpoint the exact rooftop locations of virtually every structure that is a candidate for broadband. The fabric data provides a foundation for precise location and service availability.

Using parcel data, property tax data, building footprints, and addressable points, the fabric is a database of broadband serviceable points. As depicted below, parcel areas (red boundaries) identify general areas where structures may exist. The fabric creation process identifies structures (red hashed areas) and narrows to those that are broadband serviceable (green triangles).

Figure 1 is a sample from the Broadband Mapping Initiative showing the identification of broadband serviceable structures – Source: CQA.

[4] *User locations were determined using the CostQuest BroadbandFabric, version 3.*

Figure 1. Broadband Example Map

Service Area Groups

To provide objectivity across all providers, CostQuest created Service Area Groups that represent the serving areas used in the last mile network. To create the Service Area Groups, CostQuest performed the following steps.

- Determined logical clusters of serviceable locations using broadband unserved areas.
- Deployed iterative clustering to aggregate the logical clusters of unserved with served.
- Produced contiguous serving area boundaries constrained by the total number of served and unserved locations.
- Selected Points of Presence locations by identifying community anchor institutions as the most logical locations within the serving area.

The result of the Service Area Group process created 1,783 groups centered around Community Anchor Institutions[5], among other priority public sites, to represent how a new broadband provider might build a network to serve unserved areas balanced with served areas.

Last Mile Network

The last mile network is the portion of a broadband network that reaches end user locations and is also sometimes called "the access network" or "the loop". Today, FTTP represents the best means of providing wireline broadband services in greenfield[6] networks. FTTP is also the service standard to which other technologies are benchmarked in funding programs.[7] Once FTTP networks are established, bandwidth upgrades can generally be accomplished by updating the fiber optic equipment on the ends of the fiber cables. FTTP networks are also the types of networks many carriers are deploying as they upgrade existing networks and expand into new areas. CostQuest modeled a FTTP network in each Service Area Group as the basis of the last mile resulting in a complete network according to CPUC criteria.

As depicted in the below example, the boundary defines the serving area, and the star defines the "Node 0"[8] location, which is the central point of the network in a serving area that contains the major network operations equipment. Cables emanate from this aggregation point toward end user locations along roads to various devices (described below) deeper in the network. From these devices, additional cables are routed to end users.

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[5] *Community Anchor Institution (CAI) 47 CFR § 54.5*

[6] *Greenfield networks are networks that are built from scratch and do not account for, or use, embedded network structure, cable, or electronics.*

[7] *FTTP is an established and widely deployed means of providing gigabit mass market broadband services. Gigabit services were favored over other technologies in the CAFII and RDOF auctions through the imposition of bid penalties in the auction.*

[8] *In relation to legacy networks, Node 0 is the equivalent of a Central Office (Telco) or Hub (Cable). This document generally refers to this location as the Point of Presence (PoP).*

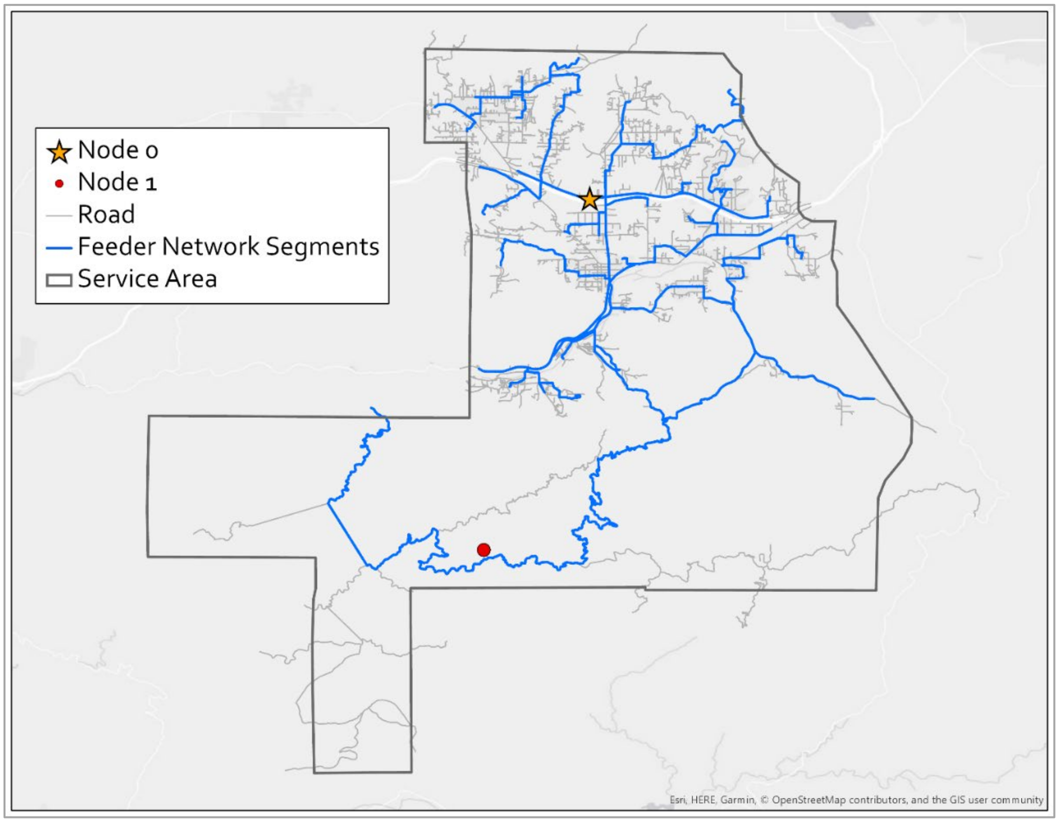

Figure 2. Efficient Road Path (ERP) for Feeder Plant

To help better understand the equipment and connections, a simple diagram of this portion of the network follows:

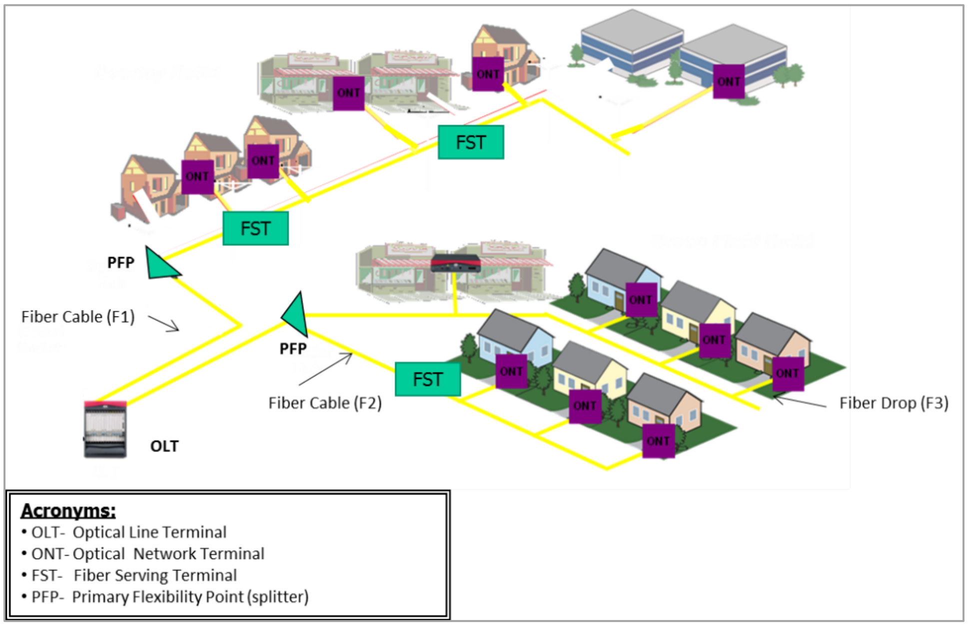

Figure 3. FTTP Loop Architecture

The following is a brief description of the purpose of each device in the FTTP network.

- ***ONT***—An Optical Network Terminal (ONT) is the fiber termination equipment at a customer premises. This is a small device that terminates a fiber strand and makes an optical to electrical conversion. The service provider then provides a gateway to which the end user attaches devices to for broadband service. The cost of material of this device and labor to install are included in the study.
- ***Drop*** —The drop is a fiber cable that terminates at a customer premises. It is either an aerial that extends from a nearby pole or buried in a trench that connects to a Fiber Service Terminal. The cost of the material and the labor to install drop are included in the study.
- ***FST***—Fiber Service Terminal (FST) is a device that serves a few locations and may also be called a Drop Terminal. This device can be placed on a pole in areas served by aerial fiber, in a pedestal at a curb, or along a utility right of way between homes in areas served by buried or underground fiber. This is a point of aggregating end user locations onto fiber cabling that runs back to a fiber splitter. The material for this device and labor to design and install are included in the study.
- ***Fiber cabling***—Fiber cabling is the media that carries the broadband traffic. In a last mile network, it can be separated into two categories: distribution and feeder. The **distribution** is the portion of the loop that connects to the FST and the customer. The **feeder** is the portion that connects the aggregation point to the fiber splitter devices. The fiber may be strung between poles, buried in a trench, or placed into conduit systems.
    - The cost of fiber material, poles, conduit, and manholes along with labor for designing, constructing, and splicing are included in the study.
    - Costs for permitting and rights of way access are also included via loading factors.
    - Poles and manholes are placed at regular intervals based on industry standard practices.
    - The type of plant -- aerial, buried or underground -- is based on a study of the plant mix. Spacing and plant mix inputs vary according to density in terms of locations per square mile. More urban areas generally have a higher percentage underground while more rural areas are either more buried or aerial depending on terrain.
    - Construction inputs – the cost to dig trenches – also vary by density. In rural areas, there are fewer obstacles to deal with compared to urban areas which require accounting for more traffic management, removal/restoration of roads and sidewalks.
    - Terrain also has an impact on the cost of construction where rocky areas are higher cost than compared to areas of mostly dirt. Areas of steeper slopes also

cause a higher cost variation. CostQuest modeling takes into account density and terrain in determining the cost of the network.

- ***Splitter***—A splitter is a passive device (meaning no power used) that "splits" optical signals from one fiber onto multiple cables. In the case of the network designed for this study, feeder fibers were split from one to 64 distribution fibers. The use of splitters allows for smaller cables to be deployed in the feeder plant (reducing the overall cost) and maximizes coverage. Practices for splitter placement vary among providers. Splitters may be centralized (in a serving PoP) or decentralized and placed somewhere closer to the end-user locations. This study uses a decentralized splitter. The material and labor for design and installation are included in the study.
- ***OLT*** —The optical line terminal (OLT) is the optical equipment placed in a serving PoP that aggregates the broadband connections in the service area. From this device, the broadband traffic is carried to the core network and ultimately onto the internet. The material (chassis, cards, patch panels, patch cords) along with labor to design and install are included in the study. This model uses XGS-PON as the optical technology. XGS-PON is currently being deployed by numerous carriers as a means of providing Gigabit or multi-Gigabit services and represents forward looking equipment used for fiber to the premises.
- ***PoP***—A centralized Point of Presence (PoP) that houses carrier equipment within the local serving area or Service Area Group. In relation to legacy networks, this is the equivalent of a Central Office (Telco) or Head End/Hub (Cable).
    - The PoP is the demarcation point between the last mile network and the middle mile network.

By including the above items, the modeled network accounts for all devices, media, material cost, and labor cost to provide a fully operable FTTP last mile network. Values for the above material and labor were derived from the FCC inputs for CAFII[9] and the California Broadband Cost Model, updated to reflect current material prices and California's prevailing wage rates for telecommunications workers.[10]

CostQuest's CostProLoop was used for modeling the investment of the FTTP network, which ingests customer location data, clusters the locations into logical groups, calculates the size of equipment and fiber cables needed, and the distances of cable needed. Based upon unit cost

[9] *While CQA has attempted to model an efficiently designed network for purposes of funding allocation, the design is not an engineering study and should not be interpreted as a construction budget. If multiple different entities are involved in building an actual network, economies of scale will vary around pricing of materials and labor and could differ from those assumed in the modeling. Actual design will determine actual costs incurred. Further, investment does not contemplate ongoing operating expenses or capitalization requirements, which would be in addition to the figures cited in this study.*

[10] *The prevailing wage rates were sourced from https://www.dir.ca.gov/OPRL/2022-1/PWD/Determinations/Statewide/C-422-X-1.pdf., accessed 06/08/2022. While the reference provides the basis for a wage rate, the wage does not include supervision or other loadings normally incurred to calculate a total cost. RSMeans regional adjustment factors were applied to acknowledge the cost of labor variation throughout the state.*

data for material and labor, the model multiplies units required by unit cost inputs to determine investment. The results are produced at a location specific level but were aggregated by census block for purposes of analysis.

Fire Hardening Adjustment

CostQuest made an adjustment to separately estimate the impact of fire hardening by identifying areas prone to wildfires based on data supplied by the State. We used the geographies encompassed by Tier II and Tier III high fire threat areas. In these areas an additional hardening investment is reported as a proxy for the additional cost incurred to harden poles and other devices to minimize damage from fire[11]. The proxy reflects an adjustment to pole investments by a factor of 9 to account for the cost variation between wooden poles and concrete poles. Buried and underground plant was adjusted by the difference between normal construction conditions and hard rock conditions. For buried plant, investments increased 1.47x while investments for underground increased 1.52x. Areas outside fire prone areas were not adjusted. The impact of fire hardening was allocated by service area across all locations falling in fire hardened areas.

Middle Mile Network

The core portion of the network is an interoffice network that connects PoPs to other PoPs and to internet access points. This network aggregates traffic from end users on to high-capacity optical equipment and transports the traffic across regions to the internet. The California Middle Mile Broadband Initiative (MMBI) will deploy a middle mile network to many areas of the state and the cost of this middle mile (the MMBI) is excluded from the study. To account for the aggregation of traffic into the areas to meet the state network, CostQuest modeled extensions from the Service Area Group last mile service territories to the nearest proposed state access point[12].

The steps below outline the process used to develop the Core network topology[13]. The modeled network covers the entire state and reaches every Service Area Group.
The Core model uses a three-layer network,
RingNode1 (RN1), the originating serving PoP.
RN2, a local aggregation point; and
RN3, a regional aggregation point.

The below diagram depicts the rings between the aggregation office locations (green boxes for RN1, RN2, RN3) and to the internet (the globe):

[11] CostQuest has limited market data on the costs of fire hardening. Another way to think about the cost is that some additional cost of replacement due to loss from fire is included in the study.

[12] The California state owned network is based on data as of June 2022.

[13] One spur consists of four submarine segments serving the Channel Islands of California. The cost was based on a per-foot estimate by a submarine cable expert. However, we understand that there may be substantial up-front costs associated with short-distance submarine projects for which we did not have data.

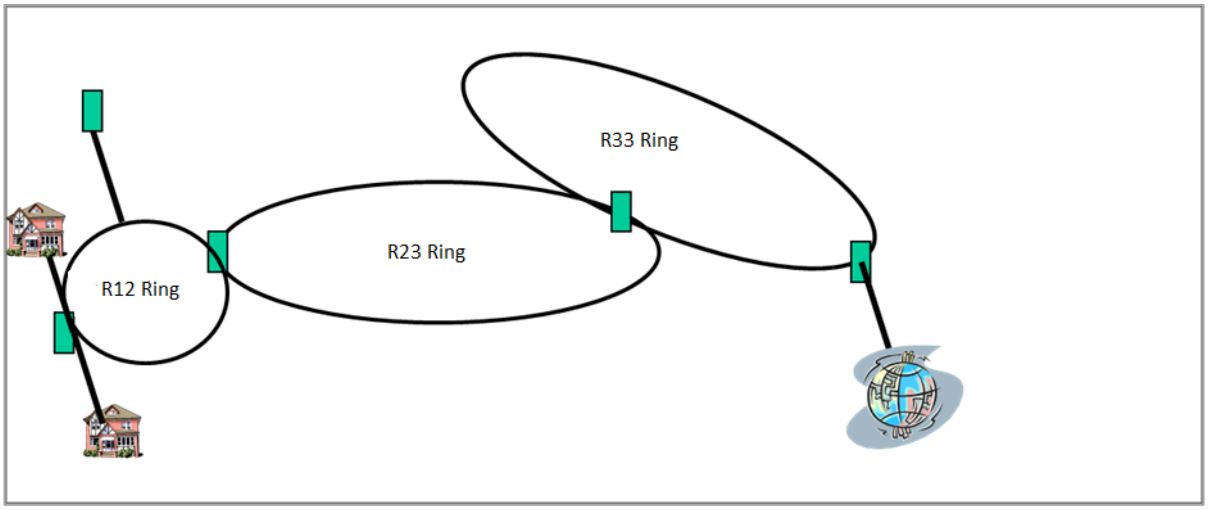

Figure 4. Middle Mile Ring Hierarchies

The routes among them are R12 (from RN1 to RN2), R23 (RN2 to RN3), and R33 (among the RN3s).[14] Each higher-level node includes the functions of the lower levels.

- Each Service Area Group is served by a RN1 (a Node 0 in the loop network). Rings were mechanically generated among Service Area Groups using a minimum-spanning algorithm. Most Service Area Groups will be on rings to enable an alternate route in case of congestion or cable failure. A few Service Area Groups are on "spurs" when an alternate route is not feasible, however, in-and-out cable is modeled for each spur, assuming a local alternate route.
- One Service Area Group was selected as the RN2 on each ring.
- Five Service Area Groups in the state were selected as RN3 based on their proximity to data centers, in a collection of addresses assembled by CostQuest. The locations chosen were in San Jose, Sacramento, Fresno, Bakersfield, and Cerritos. There were no reliable data center locations north of Sacramento. These are not meant to be precise locations. They are used as a surrogate for termination at a commercial data center.
- Broadband demand was created for the study based on the total demand, calculated penetration rate, and an estimate of peak traffic based on average monthly usage published by OpenVault.[15]
- The model determines routes from each RN1 to an RN2 for traffic aggregation and from there to the closest RN3. At that point, the traffic is assumed to terminate. Expense will be added to the business case for connection to the internet.
- Reconfigurable Optical Add Drop Multiplexer (ROADM) equipment is assumed to be used at each node. Direct Ethernet connections between RN1 and RN2 are sometimes feasible but have a limit of approximately 80 km for 10G or less. For longer distances or higher capacities, ROADMs are essential. The current selection of ROADM in the

[14] *R=Ring. RN=Ring Node.*

[15] *OpenVault Broadband Insights Report (OVBI), January 2022. https://openvault.com/resources/ovbi/ retrieved 3/15/22.*

market has “metro” ranges near 1000 km, with 5000 km and longer available at additional cost. One of the advantages of ROADM is that traffic may express through intermediate nodes without optical-to-electrical conversion. This improves latency, a factor in quality of service.

- The model determines the number of wavelengths required to manage traffic from each node and aggregates those wavelengths over all ring segments along the path. Additional fiber pairs will be put into use if the maximum wavelength count is exceeded. From the degree count and the wavelength count by speed, equipment costs are generated for each node.
- The ring structure assumes that each RN1 will have equipment to serve each direction, so that traffic may switch to the alternate in case of failure. The use of redundant aggregation equipment at RN2 and RN3 is based on input redundancy factors.
- The model calculates the cable and structure cost for each cable segment used. Inputs for plant mix are based on the Connect American Cost Model (CACM) and CBCM inputs, adjusted for regional variation – more aerial in the north, buried in the southeast, and underground in the coastal metros.
- The model has been customized for this study by the addition of factors to segregate capital cost for the portion of the ISP’s network that will be owned vs. that purchased from the state network and to increase capital cost for cable segments within the fire zones.
- The network design defines fiber distances and equipment quantities. CostQuest used its CostProCORE model to determine investments for fiber, supporting structures, and optical equipment associated with the extensions from the last mile provider aggregation points to the state network.[16]

Land and Building

Land and building investments account for the structure that houses the last mile provider equipment that terminates FTTP and traffic aggregation structures. Land and building investment vary according to the demand served where urban areas require more equipment and thus larger structures, while rural areas require smaller structures. The FCC’s ACAM inputs for land and building were used in determining the investment to accommodate both the more densely populated areas and the smaller areas that result from the creation of Service Area Groups.

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[16] *Implicit to modeling the network is the assumption that the providers have the capability of monitoring and managing the network. While the loadings used in calculating investment are based on experience of providers and include network management, the creation of new or multiple network operating centers or management teams is not. Likewise, investment in new carrier hotels or collocation facilities to house the equipment of multiple new entrants at points of dedicated internet access is not included. It is assumed that adequate operations support systems are in place.*

Demand was determined by the total number of locations within each Service Area Group. The size of building needed was selected based on demand. Land and building investment were calculated by service area.

Served Areas Definition

A number of data sources were compared and combined to develop the Served Areas used in the study. These data sources include:
CostQuest Associates' BroadbandFabric - A data source that provides the geospatial position of serviceable locations.

CostQuest Associates' Technology Availability Likelihood (TAL) - A data source that estimates the probability of broadband technology in a Census block
FCC's Form 477—June 2020. A data source filed twice yearly by providers. It indicates at a Census block level where a provider does, or can, provide broadband service.

December 31, 2020, CPUC data on service availability—CPUC supplied block level broadband service information. The CPUC also determined the technologies that should be considered when defining served areas.

Table 3. Unserved Locations in California

	California Service Definition	Locations
Unserved	**Service < 25x3Mbps.** Lacking access to at least 25Mbps downstream x 3Mbps upstream using FTTP or DOCSIS 3.0.	777,292

Based on a review of the location specific data, unserved areas may be found across California. Each dot represents an unserved location.

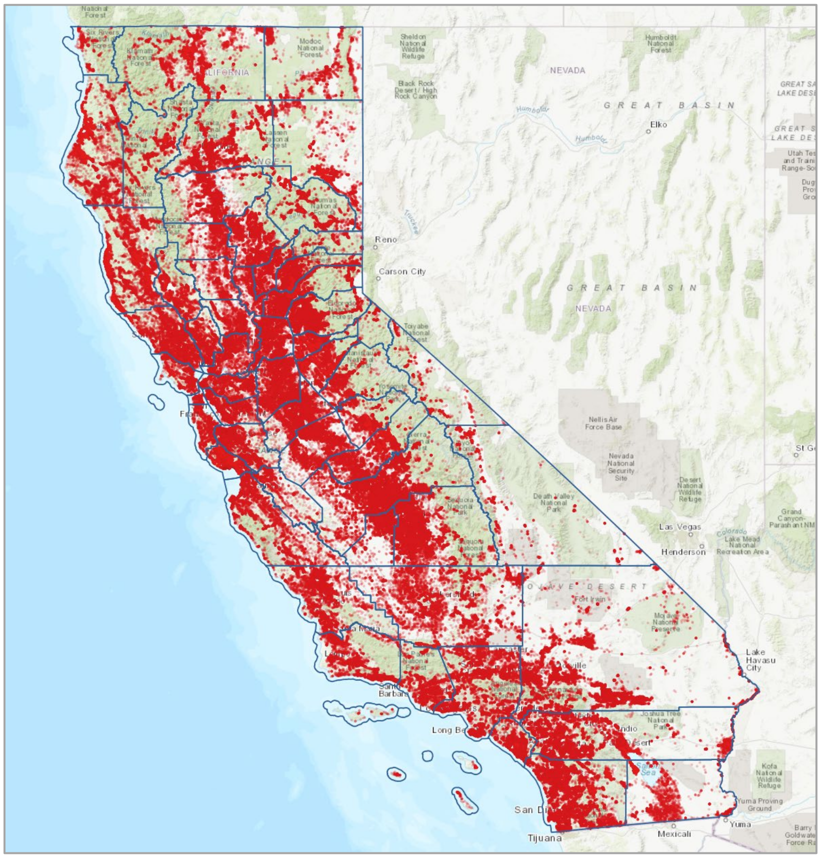

Figure 5. California Defined Unserved Locations

Investment Results

Based on the modeling, CostQuest identified $8.5 billion of investment to be allocated to the to the unserved locations in the state.[17]

Table 4. Investment Results Summary

California FTTP Network Investment Summary - Unserved Locations		
		Unserved
FTTP Network Investment	$	6,333,413,778
Additional Fire Hardening	$	2,170,737,269
Total	**$**	**8,504,151,047**
Locations		777,292

[17] *Areas supported by the California Advanced Services Fund (CASF) and areas presumed as awarded in the Rural Digital Opportunity Fund Auction (RDOF) are not included in either the unserved results.*

By looking at how the costs vary by density of locations per square mile, we can see that there is an inverse relationship between density (locations per square mile) and investment. The figure below is derived from the investment calculations in the unserved areas of California.

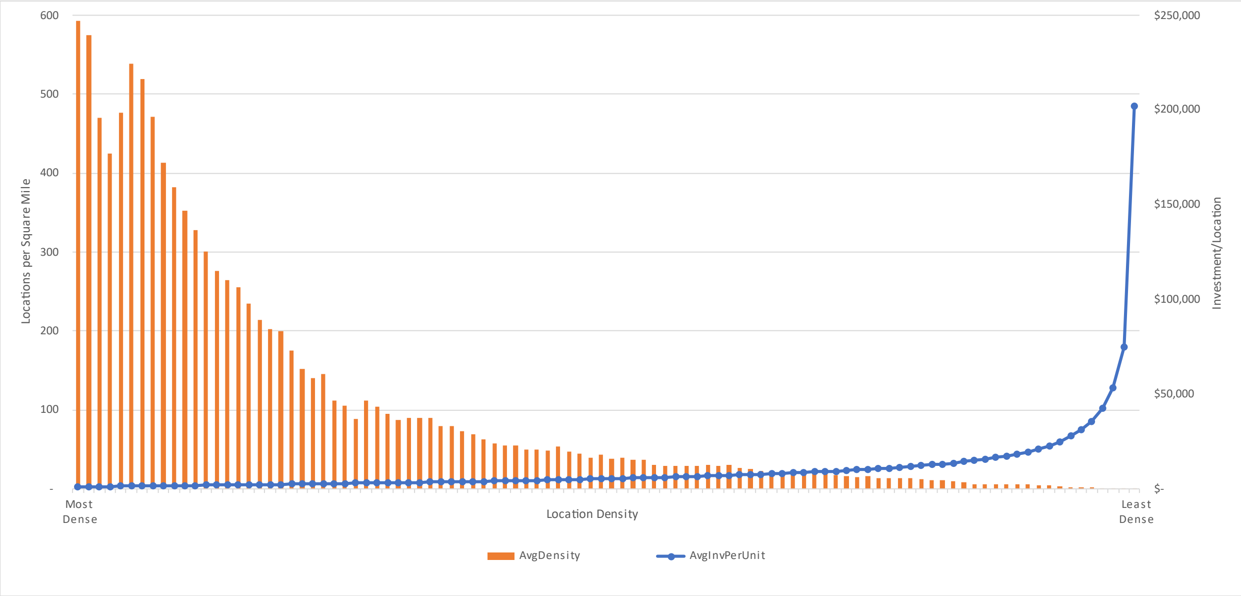

Figure 6. California Investment per Unserved Location

Unit investments by census block were sorted low to high across all unserved areas and locations were accumulated into one percentile groups. Blocks were rank ordered from the lowest investment per unit to highest. Two curves were created from the percentile groups: The density in locations per square mile (orange bars) and the investment to provide broadband per location (blue curve). Each curve represents the trends from the lowest investment per unit to the highest and from most dense to the least.

This illustrates the important properties of network investment. First, as density falls, the number of locations grows at a constant rate. As the cumulative location count flattens, the addition of locations begins to grow very slowly. In other words, most locations are in dense areas. As we move out of dense areas we gain fewer and fewer locations.

Second, the most dense blocks have the lowest investment per location served. Investment rises at a slow but consistent rate as density falls. At some point the orange curves start to flatten. As a result, investment per unit increases signficantly. The flat investment curve shifting to a high growth rate is what gives the blue line, the hockey stick shape.

Different network technologies will demonstrate similar sensitivities. Each technology may reach investment/density thesholds differently, but with communication networks there is always an inverse relationship between location density and investment to serve.

Finally, we can also see how dramatically high costs increase in the least dense areas compared to the rest of the unserved areas. Through expanding on the detail of the percentiles in Table 5, we can see how dramatically costs increase at the right end of the graph. Unserved locations falling in the 88th percentile or higher account for 50% of the investment to unserved locations (blue shading). Said another way, the lower 87% of locations account for the other 50% of investment (yellow shading). The top two most expensive percentiles of unserved locations account for 22% of the investment to unserved locations (blocked area).

Table 5. Unserved Investment Percentile Detail

Summary of FTTP Investment by Percentile of Unserved Locations						
Percentile of Locations	Locations		Investment		Investment Per Location	Percentage of Total Investment
1 to 49	380,883	$	1,046,505,923	$	2,748	17%
50-59	77,718	$	385,393,731	$	4,959	6%
60-69	77,728	$	478,613,747	$	6,158	8%
70-79	77,733	$	616,248,399	$	7,928	10%
80-85	46,633	$	473,517,647	$	10,154	7%
86	7,773	$	89,911,020	$	11,567	1%
87	7,783	$	94,598,986	$	12,155	1%
88	7,767	$	99,370,645	$	12,794	2%
89	7,771	$	105,128,264	$	13,528	2%
90	7,778	$	111,659,240	$	14,356	2%
91	7,778	$	119,414,814	$	15,353	2%
92	7,766	$	127,594,688	$	16,430	2%
93	7,770	$	138,738,250	$	17,856	2%
94	7,773	$	153,736,974	$	19,778	2%
95	7,774	$	173,077,610	$	22,264	3%
96	7,772	$	197,352,910	$	25,393	3%
97	7,773	$	231,400,059	$	29,770	4%
98	7,771	$	290,637,995	$	37,400	5%
99	7,776	$	401,530,784	$	51,637	6%
100	7,772	$	998,982,092	$	128,536	16%
Total	**777,292**	**$**	**6,333,413,778**	**$**	**8,148**	

Appendix A—Model Parameters

Item	Definition
Block Level	Census Block - using Tiger 2010
Delivery type	Fiber to the premises (FTTP)
Network Type	Greenfield networks are networks that are built from scratch and do not account for, or use, embedded network structure, cable, or electronics. The modeling assumes the builder of the broadband network must purchase and install poles, duct, conduit, and manholes.
Costs / Investments	Where possible we are using the modeling approach used for FCC costs with inputs adjusted for current material and labor. California Prevailing Wage used as basis for hourly rate. Structures adjusted for fire hardening where data indicate.
Last Mile Allocations	Last Mile networks allocated to last mile provider.
Middle Mile Allocations	Middle mile networks split between state-owned and last mile provider owned portions.
Location focus	Unserved
Demand Locations	CostQuest estimates. CostQuest Fabric V3.
Network Buildout Types/Geographies	New
	All areas
Poles	Pole space can be purchased/leased. FCC pole investments are used and adjusted for current prices and fire hardening where data indicate.

Appendix B—Differences from Prior Cost Modeling in California

Several factors make this modeling effort significantly different from the December 2020 California Broadband Cost Model analysis. Prior modeling efforts relied on assumptions, inputs, and methods from the FCC Connect America Model. To support development and financial analysis of last mile funding areas, several new modeling approaches were introduced. These changes include:

The new model assumes an entirely new last mile network. We assume the portion of the middle mile built to extend from the Service Area Group's PoP to the county aggregation point shares structure with the last mile plant. The remainder of the middle mile network will not share structure with the last mile network as these networks are built at different times by different providers. The statewide middle mile network is in addition to the provider-built portion of middle mile.

Instead of ILEC wire center boundaries as points of last mile aggregation, the updated model developed theoretical Service Area Groups. Service Area Groups were constrained on total demand size and managed to not cross county boundaries. Compared to the ILEC wire centers, the quantities increased in urban areas as a result of sizing and county constraints. The county boundary constraint tended to subdivide large rural wire centers that could have served multiple smaller towns but now more closely align with locations of community anchor institutions. As a result of using Service Area Groups, the provider-built portion of the middle mile network extends, on average, closer to end user locations than it did in the prior study.

Areas identified as unserved were updated to match State direction and the treatment of legacy technologies.

Instead of using a greenfield, highly shared middle mile, this effort relied on an existing middle mile topology that followed the routes of the currently proposed statewide middle mile network. In cases where the proposed network would not reach the modeled PoPs in a Service Area Group, middle mile extensions were built, and costs attributed to last mile providers.[18]

Instead of using demand and cost inputs developed in FCC modeling, demand behind the cost model was updated to current estimates; cost inputs were updated where there were

[18] *The Prior CA cost model result's last mile was the portion of investment allocated to the un/underserved locations while the middle mile figure is the total for the state. The updated figures for the network represent the investments necessary to serve only the locations eligible for funding. The loop portion of the network is the amount needed to reach the eligible locations. While CA has built a portion of the middle mile network, additional investment is necessary from the last mile aggregation points to the state network. For the funding allocation mechanism, it is assumed the last mile provider builds these extensions as part of its network. These provider-built extensions to the state-owned middle mile are included in the analysis while the state-owned portion of the network is excluded from the above investments. Land & building related investments are included in the last mile provider's portion of the investments.*

significant differences. Labor rate adjustments were made for prevailing wage. Network hardening practices were implemented to mitigate damage from wildfires.

Table 6. Summary of Modeling Differences

	2022 Investment Model ($M)	2020 Cost Model ($M)
Last Mile Investment	$ 5,474	$3,385 - $4,633
Incremental Investment for Links to Statewide Middle Mile	$ 860	
Total Middle Mile Network		$ 2,167
Fire Hardening	$ 2,171	
Total Eligible Area Investment	**$ 8,504**	**$5.552-$6,800**
Serving Areas	1,783	976
Eligible Locations	777,292	513,700 - 779,065

GLOSSARY

Term	Definition
Central Office	A location which houses a switch to serve local telephone subscribers. This may also be known as an aggregation point, hub/head end, Node0 or a PoP (point of presence). It is the building housing telephone switches. It is now also the aggregation point (PoP) for broadband and business data services.
Distribution	Cable from a splitter to a customer premises.
Distribution Terminals	The point where the drop wires from several customers are connected to pairs in a larger cable. Referred to as a "tap" in HFC.
Drop	A wire or cable from a pole or cable terminal to a building/end user location.
Ethernet	A family of wired computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN)
Feeder	Cable from central office to a splitter
Fiber Splitter	A splitter is a passive device (meaning no power used) that "splits" optical signals from one fiber onto multiple fiber cables (or vice versa). Location where wavelengths are split, usually 1:32, to provide optical signal to the distribution network.
Fiber Service Terminal (FST)	Terminal that connects (or aggregates) several customer drops to distribution cabling.
Fiber-to-the-Premises (FTTP)	Last mile network technology contains no copper linkages and brings fiber all the way to the serviceable location.
Headend or Hub	Similar to a central office, a cable operators' location that contains equipment for provisioning of video, voice, and/or data services.
Location	A structure or land record that has or can receive broadband service. For example, a single-family housing unit, a multi-dwelling unit, a business building, or a commercial structure.
Middle Mile	The connection between a service provider and the Internet Backbone. The middle mile consists of one or

	more carrier networks that move traffic from the access service provider to the Internet.
Optical Line Terminal (OLT)	An Access network element providing Passive Optical Network services. Available in varying technologies including BPON, GPON, XGS-PON, and NG-PON2. In conjunction with the ONT, it provides broadband service over fiber cable to a customer. A device which serves as the service provider endpoint of a passive optical network. In an FTTP design, the fiber feeder cable from the FST terminates on an OLT. The OLT aggregates broadband traffic from multiple ONTs and may perform optical-electrical conversion of voice to a circuit switch.
Optical Network Terminal (ONT)	The customer premise interface for FTTP. It performs optical-to-electrical conversion and vice versa, providing the customer with a two-way Ethernet connection. It may also include voice and video connections to the fiber. The ONT technology must match that of the OLT.
Optics or Optical Equipment	When fiber is terminated on a line card, transceivers must be installed to convert between electrical and optical signals. Optics are differentiated by speed, wavelength, and "reach", the output power required to maintain signal strength for a particular distance. Typical reach values are short (under 200 m, for same-building connections), long (10 km), extended (40 km), metro (80 km), and submarine (3500 km).
Passive Optical Network (PON)	A fiber optic network that does not convert optical signals to electrical signals. PON technology allows a fiber optic network to be built without the need for costly connections to the electrical grid.
Statewide Middle Mile Network	The State of California will acquire, build, maintain and operate an essential open-access statewide middle mile network, which will be overseen by the California Department of Technology. See https://middle-mile-broadband-initiative.cdt.ca.gov/.
Reconfigurable Optical Add-Drop Multiplexer (ROADM)	A Transport Network Element which enables many communication signals to be carried over fiber cable using different wavelengths.