Tech Diversity Value in California Digital Divide Projects

Introduction

As the California Public Utilities Commission develops plans for implementation of the Broadband Equity, Access, and Deployment (BEAD) program across the state, it is critically important that they maintain a clear and up-to-date view of broadband network costs as a function of currently-available technology choices, specifically in divide projects. As we noted in our recent study[1] of 132 state-funded fiber-based digital divide projects executed in 2019 through 2022, the prevailing preference toward exclusive use of fiber in the dialogue around BEAD implementation will very likely result in complete exhaustion of the program's $42.45B funding well before reaching the 2021 Bipartisan Infrastructure Law's clearly-stated goal of making fast, affordable broadband available to every family in the United States. California's implementation cost challenge is no exception. For the nearly 1 million locations (primarily families) in California who lack access to fast, affordable broadband, cost-efficient and full-coverage BEAD-funded network deployment to close that gap across the state is essential.

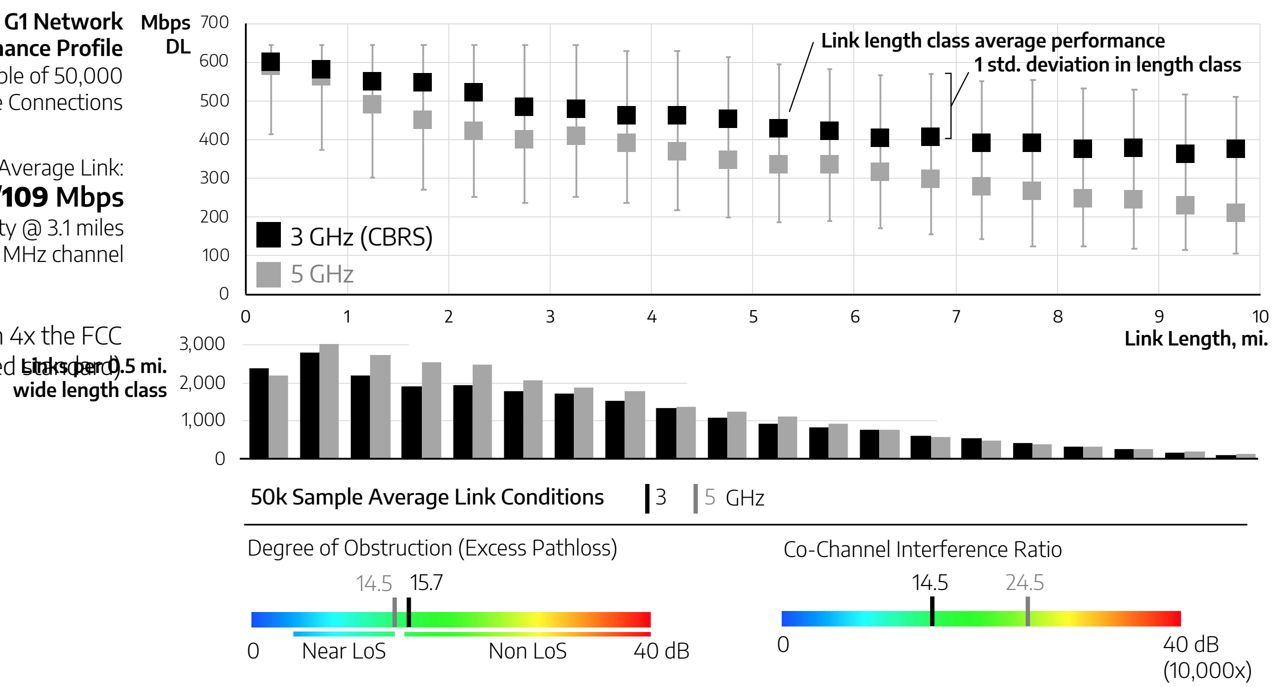
To help address this, we've narrowed our examination here to only the 46 fiber projects funded in California since 2019. The headline problem is that extrapolating from the costs of those past projects — a worthy step, given how informed they were by the harsh realities of California's challenging geography — indicates that a fiber-only approach to closing California's remaining divide will cost as much as 7x more than the funds available.

The good news is we have a solution to that problem. Fortunately, broadband technology, like most categories of tech, does advance over time, given instances of investment in fundamental, step-function innovation. When they offer truly material steps forward, these advances can open up genuinely new possibilities in broadband deployment models. One such recent advance, the development of next-generation fixed wireless access (ngFWA) technology, has been proven over the past two years to do just that — see below a healthy 50k live-link sample of Tarana's leading ISP customers' real-world experiences with our G1 ngFWA platform — and note that we have R&D in full motion to double these speeds and enable even more creative spectrum usage models. Read on to see how we can put ngFWA to productive use in closing California's persistent divide.

G1 Network Performance Profile
Sample of 50,000 Live Connections

Average Link:
414/109 Mbps
DL/UL capacity @ 3.1 miles in 2x40 MHz channel

(More than 4x the FCC speed standard)



Toward Crafting a Solution for California that Works

The scale of California's digital divide is immense. The FCC's broadband mapping initiative has yielded an estimate of 996,302 un- and under-served locations in the state. As shown in the table callout at right, the simple calculation of total broadband-project funds available to the state from all sources divided by the number of un- and underserved locations yields average funding of ~$5k per location. Past fiber projects in the state (in the 2019–2022 time frame) aimed at closing the divide have averaged close to $26k per location served — obviously a significant gap.

California's Digital Divide Challenge at a Glance

Locations to serve:	**996,302**
Total funds available (BEAD + other state and federal sources):	**~$5 billion**
Funds available per location:	**$5k**
Average funds per location spent on digital divide fiber projects in the state, 2019-2022:	**$25.9k**

If that spending pattern is indicative of future projects, then correcting for construction factor inflation since those past projects were priced suggests 2025 implementations will see average costs in excess of **$40k** per location served

We assembled this brief paper to explore further the nature of the challenges California faces on the ground in these projects, through a look in some detail at:

- past California project economics
- a location-density-based model for estimating future fiber project costs, based on those past examples
- implications of recent inflation on factor costs of construction — the most important ingredient in fiber projects
- a profile of California's location density in the context, using relevant examples
- introduction (in brief) of the basic economics of ngFWA deployment, including its quite different cost relationship with location density and, as a result, quite different economics per location, and finally,
- an illustration of how a hybrid fiber+ngFWA network could be designed to solve California's divide problem **within the funds available**, leveraging BEAD's extremely high-cost per location threshold mechanism.

Elements of the Analysis

Past California Divide Projects — 2019–2022

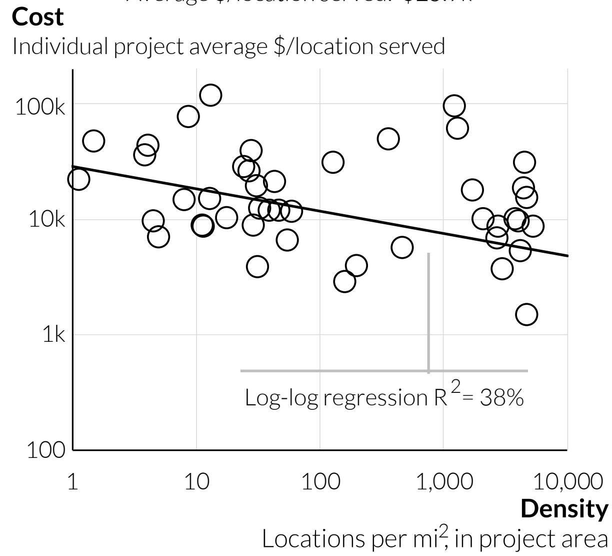
In the latter half of 2022 we were having some challenges getting reliable and comprehensive data on fiber costs in digital divide projects, since interest in comparisons between those costs and the economics of our ngFWA solution was rising in our ISP customer community — many of whom operate both fiber and wireless networks. To get better informed, we tapped project descriptions and costing for 132 divide projects across five states: California, Michigan, Nebraska, Alabama, and Virginia — covering north, south, east, west, and one in the middle of the US, to capture examples across a broad and representative range of conditions. Our study[1] of these projects indicated that — as logic would lead one to expect — there is a reasonably close relationship between the location density (i.e. households per square mile) of a project area and the cost per location served by fiber, since every route-foot of distance between the entry point into an area and each of its destinations needs to be touched by a crew. There are obviously many other influential factors, but particularly for the 46 projects we examined in California, the correlation between cost and density was meaningful.

As shown at right, the relationship between density and cost per location served follows a log-log pattern — i.e. the rise in cost is faster than linear with the drop in density, along both dimensions. The nearly 40% R^2 indicates that this relationship explains a healthy portion, but not the majority of cost variations. In a context such as this paper where an approximate estimate of the relative costs of different network implementation strategies is the goal, we believe this is a useful tool. We reproduce here regression on only the California projects, since that is the scope of the subject at hand.

[See the appendix on page 8 for a listing of these projects and their individual stats.]

Fiber Costs Profile in California Digital-Divide Deployments

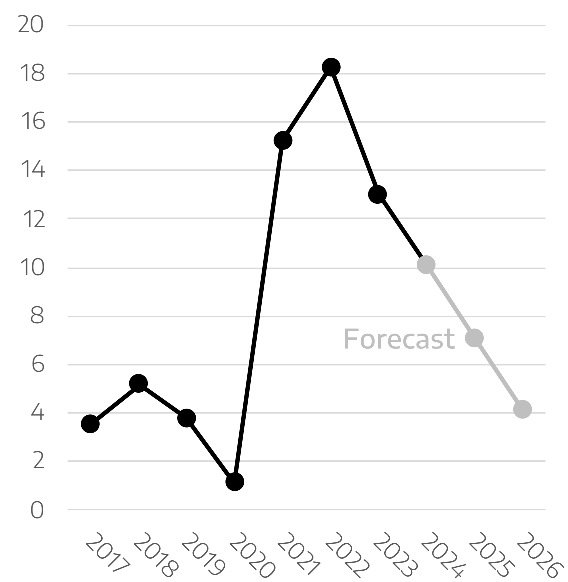
Sources: 46 state-funded fiber broadband projects, 2019-2022
Average $/location served: $25.9k



Construction Factor Cost Inflation

The second important baseline element in a forward-looking all-fiber cost estimation model is accounting for inflation. As indicated by the US Bureau of Labor Statistics data shown at right, the producer price index for non-residential construction (which is the closest index the BLS has to activity that resembles fiber deployment) has gone through a significant spike in inflation since the 132-project sample was priced in their proposals. Note that this is likely underrepresentative, given the specialized-skills nature of fragile fiber deployment and termination. For this analysis we've assumed that the post-peak-COVID downward trend will continue in the coming years (as indicated by the gray Forecast segment). BEAD projects based on mile-by-mile fiber deployment starting in a couple years (once all the proposals are assessed and plans reach the implementation phase) will have cost structures roughly 1.7x higher per household passed or served than was the case in the 132-project sample priced in 2019–2021.

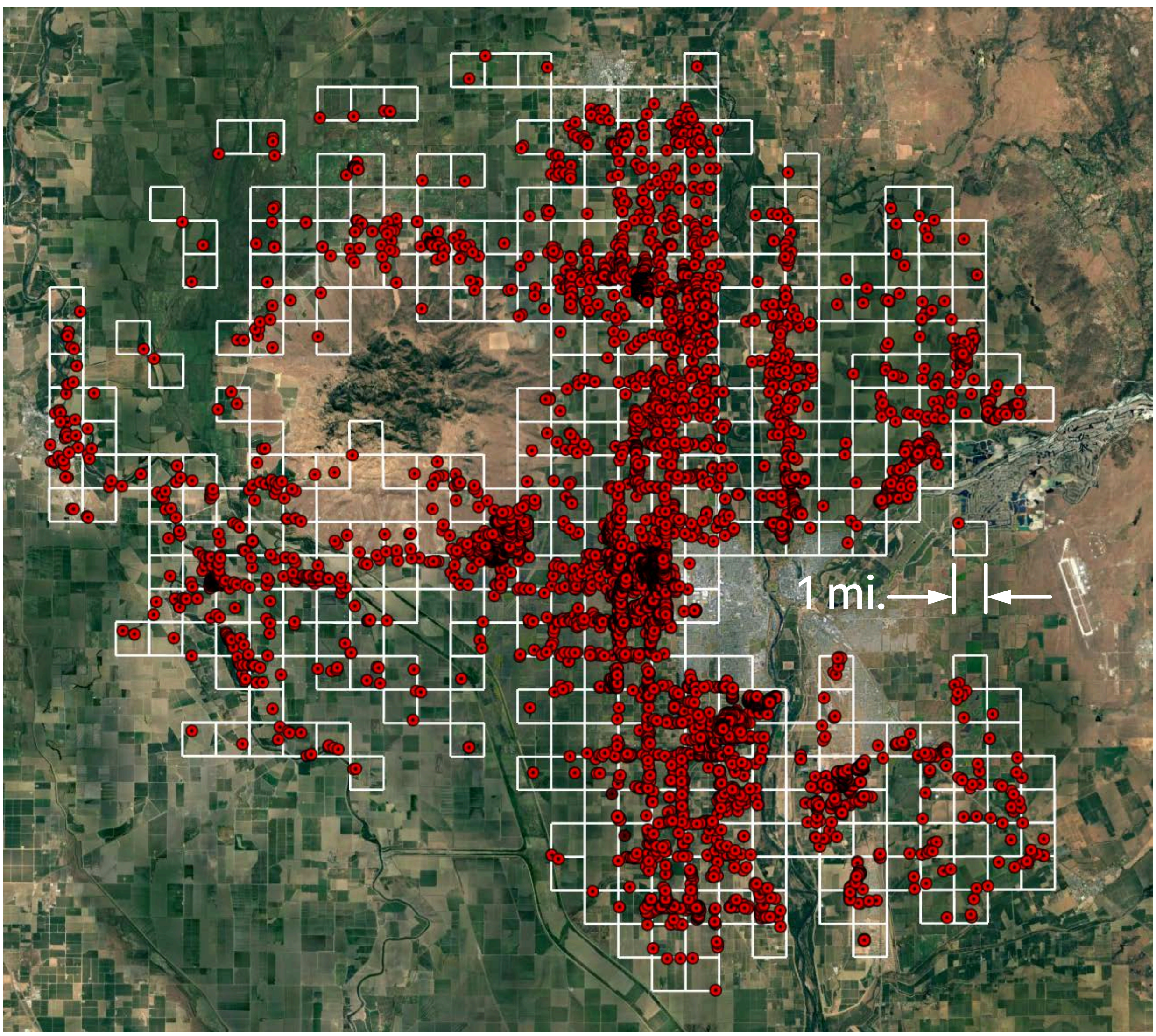
US Producer Price Index for Non-Residential Construction
(Annual Inflation Rate, %)



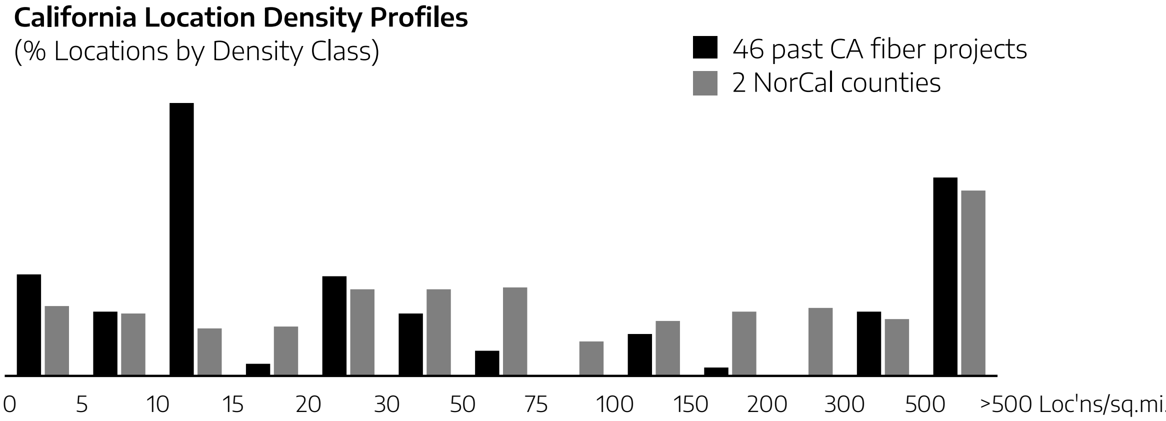
Source: US Bureau of Labor Statistics (note that this index is as close as BLS comes to something relevant to fiber deployment costs)

Estimating Typical Density Distribution of California Divide Projects

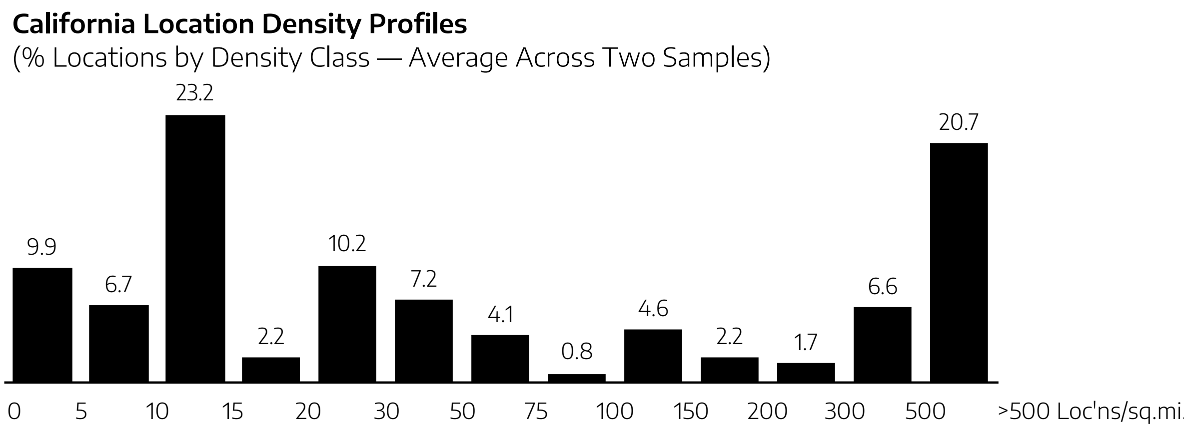
Using the 46 California projects' cost information to model closing the divide for the remaining million locations requires some estimation of their distribution across the geographical density spectrum. Since accessing the detailed broadband map data for the million subject locations in California is not practical for us at this juncture, we've chosen to extrapolate to the general un/underserved location population from two samples: (1) geo distribution in the 46 California projects cohort we introduced above, and (2) data on a not-small sample of individual locations we were offered for a pair of counties (Sutter and Yuba) in northern California where one of our ISP customers has done an ngFWA deployment, funded in large part by the California Advanced Services Fund.[2] The ~7k locations in this data set include a combination of un- and underserved locations in the rural areas of these counties. We used a form of "finite element analysis" where we constructed a grid of 1 mile x 1 mile squares that covered both counties, eliminated any that contained no locations, and arranged the rest into a histogram of density after simply counting locations per occupied square mile and stacking them up (digitally) in density-range buckets.



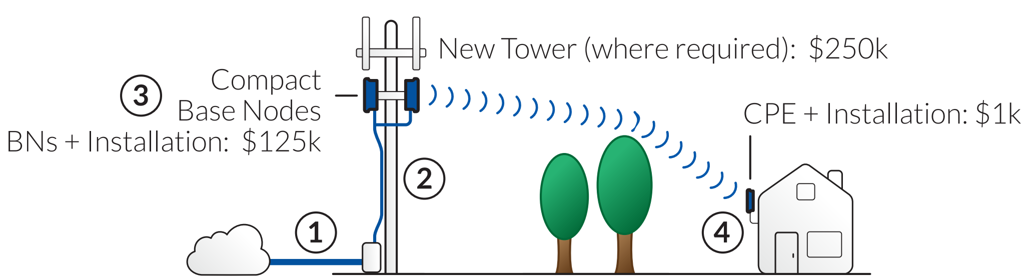
We fold the 46 projects and this example together on the following page.



With the notable exception of the 10–15 bucket, where the fiber projects had a relatively high concentration, and two classes on the right where fiber was not represented at all, most of the density classes were reasonably close to each other across the two samples. To construct something we could use in the final step here, we simply averaged the two data points for each class, as below.



ngFWA Economics As a Function of Density

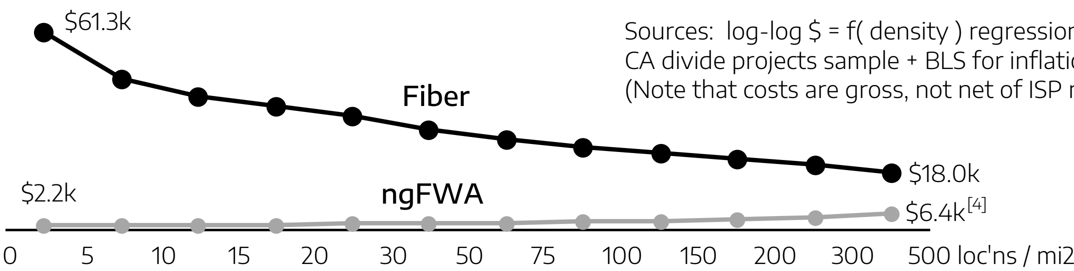


Delivering fiber-class broadband service with ngFWA — as a long-term alternative to fiber, not just as a stop-gap measure — involves four simple elements in the field. From left to right, these are

1. fiber backhaul to . . .
2. an existing “vertical asset” — often a cell tower but in rural environments grain elevators, water towers, et al. are also regularly used — or a new tower where necessary — and on each of these are installed . . .
3. usually four compact base nodes that can communicate with up to 200 locations each, and finally
4. a very smart remote node radio (CPE) installed at each location, sporting the ability to participate with the BN over a symmetric link budget to exchange hundreds of Mbps speeds (heading to Gbps in early 2024) despite obstructions and interference in the path.

Cost per location served with this configuration depends much less on density than with fiber, but instead a combination of that with tower height, spectrum, and a number of other factors. This analysis goes beyond the scope of this piece, so we'll save further details for deeper conversations on ngFWA separately[3]. Combining the 46 fiber projects' cost vs. density profile, plus inflation, with a depiction of the ngFWA per-location cost along the same density classes yields the following:

Cost per Location Served As Function of Density (at Class Averages, Future-Year $)

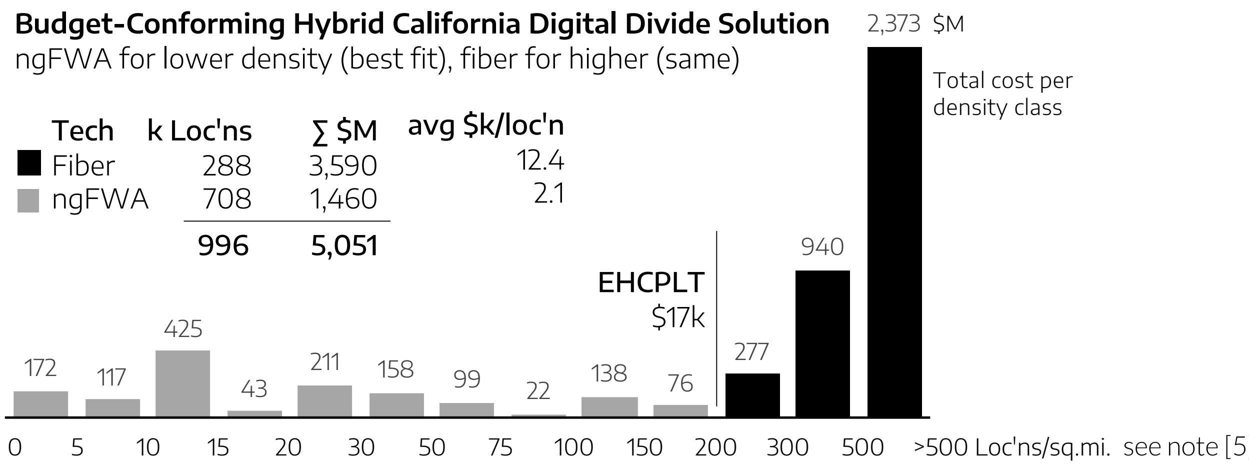


Finally, we applied those per-location costs to the blended density-class location counts from above (both fiber and ngFWA total cost/class, separately), and iterated through varying levels of EHCPLT to find a balance between fiber in the higher-density end of the classes and applying ngFWA everywhere else, so the total expenditure remains within budget.

That iteration ended with the solution portrayed below, achieving fiber service to ~30% of the total locations (on the dense end of the histogram), filling the rest with ngFWA, and coming in essentially on budget. Note that the past California projects often covered a range of density scenarios within each project, so maintaining flexibility for hybrid solutions within individual target areas for single applications will be essential.

Budget-Conforming Hybrid California Digital Divide Solution
ngFWA for lower density (best fit), fiber for higher (same)

Tech	k Loc'ns	∑ $M	avg $k/loc'n
Fiber	288	3,590	12.4
ngFWA	708	1,460	2.1
	996	**5,051**	



In Summary

California's digital divide remains wide. The $5B available from BEAD and other funding sources offer great promise in addressing the issue, but ample evidence indicates that without taking a flexible and equitable approach to technology choices, among those which meet or preferably exceed the reliable, high-speed standard required by the Federal Bipartisan Infrastructure Law and the States' SB156, it will fall well short of BEAD's 100% service requirement. Applying solid fact bases for costs and performance of both fiber and ngFWA network technologies, we have shown that a hybrid approach can help California and its ~million un- and underserved families reach their goals with the resources in hand.

We look forward to the opportunity to engage further on this exciting alternative direction.

Notes

[1] See www.taranawireless.com/fiber-study .

[2] See our brief case study on DigitalPath's NorCal deployment now going strong in Sutter and Yuba counties — supplied as a separate companion document to this work.

[3] With the exception of fiber backhaul to the vertical asset (which is often already in place for existing assets), the cost per individual ngFWA connection does not vary as a function of distance but rather primarily tower utilization — which affects the portion of the fixed tower infrastructure that must be amortized to individual links. This utilization is a function of tower height (which affects range of coverage), overall population density in the cell, and the prevalence of un-/underserved locations in the cell. Tapping a large sample of data collected for other purposes on tower coverage as a function of household density — where it was clear the economics of mobile service tend to yield much taller towers and broader coverage in rural areas than in urban, to keep tower equipment utilization reasonably stable across the network — we built an estimate of typical tower coverage in each of the density classes used here, and therefore potential locations and amortization of tower costs.

[4] The rise from ngFWA costs to serve from $2.2k to $6.4 per location as density increases may seem counterintuitive — but we've assumed higher prevalence (as a % of the population) of un/underserved households in lower density areas, and lower prevalence in higher density areas. The net is less amortization of the fixed tower and BN assets for digital divide customers as density rises. The effects are relatively small, in the scale of the analysis, but worth noting for clarity.

[5] Our approach to determining the optimal EHCPLT to maximize fiber while staying within budget started with calculation of the net-of-match cost per location at each density class midpoint by technology, using the log-log regression model for fiber (col.2 below) and the approach from note [3] for ngFWA (col.4), then multiplied each tech unit cost by the locations in each class (separately) to get total costs per class by technology (cols. 3 and 5). Col.6 shows the tech chosen for the class on the basis of fiber's $k/loc'n in the class relative to the EHCPLT value. If the fiber $k/loc'n exceeded the EHCPLT, the tech choice for the class was ngFWA, otherwise it defaulted to fiber. Finally, tech choice in col. 6 determined which total cost per class (from cols. 3 or 5) to insert into the total product budget tally (col.7). Iteration found the best budget fit at $17k.

EHCPLT math		1	2	3	4	5	6	7
			fiber		ngFWA			
loc'ns / mi2	% of u/u	k loc'ns	$k/loc'n	∑ $M / class	$k/loc'n	∑ $M / class	tech?	∑ $M
5	9.9	99	49.0	4,841	1.7	172.1	ngFWA	172
10	6.7	66	37.6	2,499	1.8	117.2	ngFWA	117
15	23.2	231	33.2	7,669	1.8	424.9	ngFWA	425
20	2.2	22	30.6	666	2.0	42.5	ngFWA	43
30	10.2	101	28.1	2,849	2.1	210.5	ngFWA	211
50	7.2	71	25.1	1,792	2.2	158.1	ngFWA	158
75	4.1	41	22.5	926	2.4	98.9	ngFWA	99
100	0.8	8	20.8	173	2.7	22.3	ngFWA	22
150	4.6	46	19.1	875	3.0	137.9	ngFWA	138
200	2.2	22	17.6	385	3.5	76.2	ngFWA	76
300	1.7	17	16.1	277	4.1	71.1	fiber	277
500	6.6	65	14.4	940	5.1	335.6	fiber	940
>500	20.7	206	11.5	2,373			fiber	2,373
Totals	100	996		26,265		1,867		5,051
		EHCPLT, $k	17.0					

Appendix — The 46-Project Sample of California Projects

Provider	Project Name	Project Total $k	Locations	$/Loc'n	sq.mi.
Charter	Bella Vista	715	60	11,923	1.9
	Brookside	934	243	3,842	0.1
	Country Meadows	2,166	314	6,897	0.1
	Darlene Road	816	7	116,567	0.2
	El Dorado Estates	1,477	276	5,352	0.1
	Foothill Terrace	490	327	1,497	0.1
	Kingswood Estates	1,210	120	10,083	0.8
	Los Alisos	1,300	451	2,881	0.1
	Monterey Manor	796	92	8,654	0.0
	Mountain Shadows	2,007	132	15,203	0.1
	Oxnard Pacific	1,726	171	10,093	0.1
	Plaza Village	658	178	3,699	0.0
	River Oaks	829	45	18,432	9.0
	Riverbank	299	43	6,956	0.2
	Soboba Springs	984	249	3,951	0.1
	Villa Montclair	548	64	8,567	0.0
Cruzio	Equal Access Santa Criz	5,347	940	5,688	0.2
Frontier	Crescent City	1,587	134	11,842	0.1
	Cuyama	12,463	131	95,136	34.0
	Garberville	3,776	106	35,625	4.4
	Herlong	7,669	273	28,091	15.3
	Knights Landing	4,591	148	31,019	0.4
	Lake Isabella	9,595	946	10,143	7.4
	Mad River	8,170	266	30,714	23.0
	Northeast Phase 1	12,323	1,291	9,545	285.3
	Northeast Phase 2	10,359	1207	8,582	44.7
	Piercy	7,797	881	8,850	22.5
	Smith River	1,428	55	25,972	1.0
	Taft Cluster	2,562	265	9,667	65.0
Hunter	Hoopa Valley	8,233	1,254	6,566	143.8
	Mendocino County	290,328	5,894	49,258	520.0
Karuk Tribe	Klamath River	26,045	600	43,408	400.0
Plumas-Sierra Tel	Elysian Valley / Johnstonville	3,972	84	47,282	3.0
	Eureka-Johnsville	1,601	83	19,294	6.0
	Keddie	1,512	39	38,773	3.0
	Lake Davis	2,777	185	15,011	6.0
	Long Valley	4,118	54	76,264	1.3
	Mohawk Valley	2,271	108	21,028	8.2
	Scott Road	4,307	37	116,418	32.8
	Sierra Valley	5,123	235	21,801	29.1
	Southern Lassen	13,631	932	14,625	32.1
Race	Gigafy Arbuckle	4,241	482	8,799	0.3
	Gigafy Backus 2	4,703	266	17,679	8.1
	Gigafy Nevada City	6,155	499	12,334	8.5
	Gigafy Williams	6,759	588	11,495	0.5
WiConduit	West Sonoma County	81,886	1342	61,018	2.9
	California Totals & Average	572,284	22,097	25,899	