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Last-Mile Expansion: Strategic Considerations

Prepared for the Eastern Shore of Virginia Broadband Authority
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1 Introduction

Broadband networks rank among the most important infrastructure assets of our time—for purposes of economic development and competitiveness, innovation, workforce preparedness, healthcare, education, democratic discourse, and environmental sustainability. The Eastern Shore of Virginia Broadband Authority (ESVBA) recognizes the need for affordable high-speed broadband services in Northampton and Accomack counties and is considering how to facilitate development of such essential services.

To that end, ESVBA hired CTC Technology & Energy (CTC), a public sector broadband consultancy,[1] to advise the Authority regarding strategies for expanding the availability of broadband services to residents of the Eastern Shore (the Shore). This report represents the outcome of that engagement and is based on research, fieldwork, and analysis conducted by CTC's analysts and engineers during the latter half of 2017 and the first few months of 2018.

In this report, CTC urges consideration of several factors critical to the deployment and operation of last-mile broadband facilities, discusses eight potential models for expansion, and provides technical and financial analysis to help illuminate both the opportunities and challenges of the eight models.

1.1 Background

In spring 2017, CTC was contracted by ESVBA and charged with undertaking the following scope of work, as defined by a vote of the ESVBA Board of Directors:

> "Identify, evaluate, and recommend business model frameworks that will create viable and sustainable broadband and which best serve the residents of the Eastern Shore.
>
> Identify various potential models, which maintain the ESVBA's 'Open Access' network, encourages commercial investment, and expands and maximizes the impact of public investments to build out the Eastern Shore's local access networks (last mile).

[1] CTC Technology & Energy is a 30-year-old broadband consultancy focused on public sector and non-profit efforts to improve government and utility communications, expand broadband internet service, and develop new strategies for delivery of network capabilities, including broadband public–private partnerships (P3) and innovative collaborations. CTC offers strategic, engineering, business planning, project management, and grant planning services. CTC's clients include the cities of New York, San Francisco, Seattle, Portland (Ore.), Washington, D.C., Boston, Atlanta, San Antonio, Vancouver, B.C., and hundreds of other cities and counties of all sizes. CTC is the leading broadband consultancy working to apply P3 concepts to broadband in such projects as the KentuckyWired network and the city of Westminster, Maryland's fiber P3. CTC also helped define the framework for broadband P3s in the Benton Foundation's paper on "The Emerging World of Broadband Public–Private Partnerships" (https://www.benton.org/sites/default/files/partnerships.pdf).

> Evaluate what models or combination of models would best serve the proliferation of affordable broadband on the Eastern Shore and create threshold metrics to help determine the success of each particular model.
>
> The proposed business models should identify and recommend solutions to economic and network constraints in the current ESVBA and private service provider models, and action plans that will provide a long term sustainable approach to achieve comprehensive high speed broadband access to residential and business on the shore."[2]

ESVBA staff further refined CTC's scope of work, adding the following tasks (in summary form):[3]

1. Develop a strategic plan to help the ESVBA direct its efforts and resources toward a clearly defined vision for its future[4]
2. Suggest customer, stakeholder, and public involvement processes
3. Review potential financing structures and related governance and collateral models available to the ESVBA
4. Provide an analysis of a variety of funding options (including federal subsidy and grant programs, bonding and other loan opportunities, and public-private partnerships) and their potential effects on the business case
5. Provide a 10-year financial pro forma (including analysis of staffing requirements, likely pricing, required revenues, and reserve requirements to support the network)
6. Develop risk analysis for the various models presented
7. Develop considerations and associated benefits and risks with regard to merging with a larger network

1.2 Tasks Undertaken

To identify a sustainable approach to facilitating the ESVBA Board's key policy goal of expanding broadband access, CTC undertook the following tasks:

[2] Signed agreement between CTC and ESVBA, February 5, 2017.
[3] This scope of work was presented to CTC by Mr. Nicholas Pascaretti in spring 2017.
[4] While the scope of work provided to CTC did not include engineering or cost estimation work, we added those tasks in order to fully understand and answer the business and financial questions posed.

1. Met (in person or by teleconference, or both) with a wide range of ESVBA stakeholders on the Shore, including:

    a. ESVBA leadership

    b. All ESVBA Board members

    c. Elected or appointed officials of both Accomack and Northampton counties

    d. Key ESVBA customers, including NASA, NOAA, and the Chesapeake Bay Bridge-Tunnel

    e. The three wireless internet service providers (WISP) currently providing services on the Shore—Chesapeake Communications, Declaration Networks Group (DNG), and Eastern Shore Communications

    f. Internet service providers (ISP), financiers, and other interested parties (such as Microsoft), to determine whether appetite exists for investment in new broadband infrastructure on the Shore and under what circumstances

    g. Residents of the Shore (in a series of Town Hall meetings)

    h. Past ESVBA leadership, including Mr. Nicholas Pascaretti and Mr. Pat Coady

    i. Representatives of some of ESVBA's peer networks, including the Maryland Broadband Cooperative, whose operations and efforts can inform ESVBA's own strategic choices

    j. Selected experts in protecting public broadband networks from legal and legislative challenge by phone and cable incumbents (such as the anti-competitive bill proposed this past session in the Virginia legislature that would have frozen ESVBA's operations)

    k. Federal government officials regarding funding opportunities available for broadband expansion on the Shore

2. Developed an analysis of the potential for federal funding opportunities for broadband expansion on the Shore

3. Developed a market assessment of existing and emerging technologies and how they may impact the ESVBA's current operations and expansion model

4. Considered a range of strategic options by which ESVBA can expand broadband on the Shore
5. Conducted engineering fieldwork and developed a technical design and cost estimate for deployment of a fiber network that would potentially connect every home and business on the Eastern Shore of Virginia, as well as a design and cost estimate for serving the residents located close to ESVBA's existing fiber
6. Developed a technical and cost framework for maintenance and operations of a fiber network so as to fully understand the costs ESVBA is likely to incur if it expands
7. Developed a full financial model and 10-year pro forma for ESVBA's potential expansion, including all relevant financial statements, to fully understand the potential cash flow and related considerations for this effort[5]

1.3 Summary of Options

Given the direction provided by the ESVBA Board and staff, this report offers a range of strategic options for addressing the residential broadband market on the Shore.

We note that none of these options offers a clear-cut, ideal strategy to achieve the Authority's goals. Rather, these options present ESVBA with potential strategies to employ, each with distinct advantages, disadvantages, risks, and opportunities.

Each of these options can be classified into one of three main categories:

- **Retail services**, in which the Authority would deploy, own, operate and maintain fiber-to-the-premises (FTTP) infrastructure and would directly serve business and residential users
- **Dark FTTP lease partnership**, in which the Authority would deploy FTTP outside plant (OSP) infrastructure for lease to a private partner; depending on the chosen variation of this model, the Authority may also deploy the fiber drop cables that connect customers' premises to the ESVBA network
- **Middle-mile wholesale services**, in which the Authority continues offering middle-mile wholesale services to encourage and enable ISPs to offer retail services to customers

The options are identified by category in Table 1, briefly summarized in the sections below, and discussed in detail in Section 5.

[5] CTC's final financial models project outcomes for 20 years, or the lifetime of any new fiber assets; 10-year models are inherently included in these 20-year projections.

Table 1: Summary of Options

Type of Option	Option Number	Option Description
Retail Services	1	Build ubiquitous FTTP
	2	Expand FTTP in population centers
	3	Expand FTTP in proximity to middle-mile fiber
	4a	Incrementally build FTTP to low-cost, high-demand areas
	4b	Incrementally build FTTP to hard-to-reach areas
Dark FTTP Lease (Partnership)	5	Build and lease FTTP OSP infrastructure and fiber drop cables (Westminster Model)
	6	Build and lease FTTP OSP infrastructure (Huntsville Model)
Middle-Mile Wholesale Services	7	Encourage ISPs to leverage middle-mile fiber
	8	Secure build commitments through assistance in obtaining grant funding

A comparative matrix of these models, including important considerations, advantages, and disadvantages, is included in Appendix A.

1.3.1 Retail Service Options

These models represent strategies in which ESVBA would deploy, own, operate and maintain FTTP infrastructure and would directly serve business and residential users. We note that any of the retail models discussed in this section will place the Authority in direct competition with the ISPs its infrastructure currently supports. This competition could spur local ISPs to accelerate their deployments in areas where ESVBA plans to expand. However, it could also reduce ISP interest in these areas, potentially reducing existing revenues for the Authority.

We note that these retail options maintain the Authority's existing pricing and service tier structure. The dependable nature of the Authority's fiber-based product warrants a premium pricing structure, particularly considering available alternatives in the area. However, our models all assume that the Authority discontinues its slowest 10 Megabits per second (Mbps) download / 5 Mbps upload product; leaving this service tier to local ISPs, who are currently offering service at those speeds.

1.3.1.1 Option 1 – Ubiquitous Retail Fiber-to-the-Premises Build-Out

The first option—ubiquitous retail FTTP throughout the Shore—represents the optimal and best outcome from a performance and opportunity standpoint, as it would deliver to each home and business on the Shore the potential for fiber-based service and the flexibility to purchase better and faster products over time as needs grow. This approach is future-focused and would meet the Authority's goal of expanding service to the entire Shore. Further, a ubiquitous network build will probably result in greater competition among local providers.

However, this option comes with considerable cost and risk. With respect to operating the FTTP enterprise itself, ESVBA should understand that entering the retail space, particularly to serve residential customers, is complex and very different from offering commercial service and middle-mile wholesale service. This approach would also create a risk of reduced revenues if ESVBA's current ISP customers are unable or choose not to remain in the residential market because of competition with ESVBA as a retail provider.

CTC's engineers estimate that **FTTP network infrastructure deployment would cost $39.9 million[6] in the first four years of deployment, provided the Authority can obtain and maintain a 36 percent take rate[7] to operate cash positive.** This cost would increase if demand is higher than anticipated in our model, because there are additional costs to connect each new customer.[8]

Our analysis suggests that Shore-wide FTTP will entail annual operations and maintenance expenses of about $5.9 million. This represents the full range of potential operating costs that are a critical component of operating an adequate FTTP network.

Although the Authority has already deployed limited FTTP infrastructure and begun offering retail services to a handful of residential customers as part of the Harborton "pilot project," it is important not to assume that the modest operating costs incurred during the pilot phase, and

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[6] Over the course of this project, CTC staff and ESVBA staff have had an ongoing discussion about FTTP cost estimates, both with respect to capital cost and operations cost. The costs CTC has developed, based on our experience around the country, have been consistently higher than those developed by ESBVA staff in a range of areas, including with respect to utility pole make-ready, customer service support, and other matters. At the direction of ESVBA staff and Ms. Elaine Meil of the ESVBA Board of Directors, CTC has used ESVBA's lower cost assumptions in developing the construction cost estimates and financial analyses herein. However, based on CTC's experience, we believe the actual capital expenses and operating costs will be higher than those included in the financial projections at ESVBA's direction. Higher costs will have a material outcome. CTC therefore notes that this report and supporting documents provide financial projections based upon ESVBA's cost assumptions, not those we have recommended. In our view, the projections herein should therefore be considered an absolute best-case outcome rather than a conservative analysis.

[7] The network "take rate" is the percentage of passings that subscribe to network services.

[8] This financial model is discussed in detail in Section 7 below, and spreadsheets of the financial model and analysis are included in the appendices.

even during expansion of the middle-mile network, mean that additional costs would not present themselves if ESVBA were to operate a larger-scale FTTP network.

Given the potential capital and operating costs, an important consideration for this option is how financing could be secured.[9] The bonding community does not use FTTP revenue projections as security for bonds or loans, which means the Authority would have to rely on general obligation commitments from the counties or other public entities. Considering the magnitude of the required financing, it may be challenging to obtain that kind of financing support.[10]

In our discussions with ESVBA representation, we have noted that maintaining existing service prices would be in the Authority's best interest. In addition to providing enough revenue to support the operation, these prices reflect the quality of the services being delivered—rather than a "bare bones" product, an FTTP connection will offer unmatched reliability. Given this, we suggest the Authority embrace the premium nature of its fiber-based service, and eliminate its lowest-speed product, removing it from competition with WISPs' similar service.

A new federal funding program (Connect America Fund II (CAF-II), which is described in detail below) would reduce the Authority's risk under this model, but only slightly. The dollars available through the federal funding program are based on the Federal Communications Commission's (FCC) cost model for how to make 10/1 Mbps service profitable for an existing communications provider, such as Verizon, that already has infrastructure. That modest increment of funding is nowhere close to enough to enable the deployment of a next-generation network such as FTTP.

1.3.1.2 Option 2 – Limited Retail Fiber-to-the-Premises Build-Out in the Population Centers

The second option assumes that ESVBA builds its fiber network to a considerable portion of the Shore, but not to the most remote and distant locations. **Our high-level calculation is that ESVBA could likely reduce capital costs by up to 50 percent as compared to ubiquitous FTTP build-out while still providing the potential of service to approximately 80 percent of residences.** These projections are based on data and insights from other markets CTC has evaluated. (As with all broadband and other utility projects, the most remote locations represent the highest per-unit construction costs.)

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[9] Discussions with ESVBA representatives have indicated that bond financing may be available through the Virginia Resources Authority (VRA). It is beyond the scope of this report to assess the Authority's bonding capacity, although we encourage the Authority to continue conversations with the VRA to understand its ability to pursue financing.

[10] We note that ESVBA reports that its long-term contracted revenues can be used as security for smaller bond options that would not require any moral obligation from the counties. While the financial implications of a ubiquitous deployment would likely require obligation from the counties, ESVBA may be able to pursue this route for some of the smaller financing options presented in this report.

The benefit of this model would be that ESVBA could greatly reduce its capital cost and risk and still reach a considerable portion of the community. That said, this model does not provide a solution for the remaining 20 percent of the community that ESVBA would not be able to reach. While it may be tempting to assume that the remote areas could then be addressed through private investment in wireless or other approaches, the economics of serving *only* the remote areas are likely not viable. That is, whether the Authority or the private sector elects to serve these areas, they will need to view the service as an investment in the Shore, accepting little to no return on the deployment.

By serving the easier-to-reach, lower-cost, more densely populated areas of the Shore, the Authority would likely reduce the incentive of other service providers to build more extensively, if at all.

The challenge of this approach with regard to the Authority's mission is unfortunately not mitigated by economics.

As a result, we are concerned that this model may reduce the likelihood of private investment in the most challenging last-mile areas, while simultaneously failing to deliver that investment through public means. And, as in the ubiquitous approach, this model would require some sort of financing, which ESVBA may have challenges in securing.

1.3.1.3 Option 3 – Retail Service to Passings Located on Existing ESVBA Fiber Routes

The third model for increasing ESVBA's residential FTTP footprint is more economically viable than the previous two retail service options, but frankly challenging from a mission standpoint. In this model, ESVBA would build fiber to homes and businesses located in relatively close proximity to its existing middle-mile fiber that can be served with only the addition of a fiber drop cable from the backbone into the premises. That is, ESVBA would not need to construct any additional distribution fiber, conduit, or aerial strand. In this scenario, ESVBA could potentially serve approximately 8,000 premises, which is about one-third of the premises in the two counties.

To achieve positive cash flow, the estimated capital cost of network infrastructure to support this model is $1.5 million (assuming a 15 percent take rate, or 1,200 passings) — a mere 4 percent of the capital cost to build the ubiquitous retail model at a 36 percent take rate. The cost would increase if the take rate were higher in order to fund the cost of additional drops and customer premises equipment (CPE). We note that an increased take rate will also generate additional revenue for the Authority, which could be used to fund further deployment.

As discussed in Section 7.2.2, this model assumes the Authority seeks $2.75 million in bonds to cover its capital expenses and initial operational expenses. We note that if the Authority has this level of cash on hand, it could feasibly use this strategy without needing to secure financing.

While economically viable for the customers in proximity to the existing infrastructure, this model reduces the likelihood of a solution for other residents throughout the Shore. As with the partial build-out model, this model (which is essentially an even more partial build) would offer a cost-effective solution for a relatively modest percentage of residents and businesses, but would reduce the economic viability of the remainder of the Shore as a competitive residential market.

In addition, because this approach would exclude a certain portion of the population, ESVBA would likely be subject to public scrutiny regarding the limited network expansion. It would also position ESVBA as a competitor (perceived or real) to the ISPs that ESVBA currently supports with its middle-mile wholesale services. We note that this perceived competition might increase if ESVBA were to serve lower-cost areas in this approach, and it could discourage last-mile build-out by ISPs, further reducing available service options. However, historically, WISP last-mile deployments have only occurred in areas where ESVBA has already deployed. Given this, the Authority may choose to build out to lower cost areas—prioritizing providing service rather than avoiding competition.

Depending upon how aggressive ESVBA is in its buildout, this model may require public financing. It is also important to note that if ESVBA were to accept CAF-II funds, full build-out in eligible census blocks would be required. This would mean that, in eligible census blocks, ESVBA would have to build to all premises—not only those that are 500 feet from existing fiber.

1.3.1.4 Option 4 – Incremental Retail Build-Out

Continuing an incremental build-out approach may prove a prudent strategy that can help ESVBA continue to achieve its goals while minimizing its risks. Two options essentially take opposite approaches to a gradual build-out: one focuses on low-cost, high-demand areas, and the other targets hard-to-reach areas that generally are more expensive to connect, and less likely to see private deployment.

These two options offer distinct opportunities for the Authority. Primarily, an incremental strategy will eliminate ESVBA's need to pursue significant financing or make a risky initial investment. Both strategies "move the needle" (if only slightly) on broadband deployment on the Shore. And taking an increased market presence may spur ISPs to become more aggressive in their own last-mile deployments to secure their respective customer bases. As discussed above, historically, ISPs have only deployed in areas where the Authority has already built out infrastructure. Given this, any presence may increase ISP last-mile deployments. If the ISPs do not respond in this manner, then ESVBA is positioned to accelerate one of the above retail FTTP approaches.

1.3.1.4.1 Option 4a – Incremental Build-Out to Low-Cost, High-Demand Areas

An incremental build-out to low-cost, high-demand areas would **deliver the highest potential return on investment (ROI), and would reach a greater number of residents on the Shore than option 4b.** However, this strategy would also place the Authority in direct competition with the ISPs it supports. Further, the probability of a local ISP eventually offering service in one of these less economically challenging areas is greater than that in the hard-to-reach areas. That is, the Authority may be solving a problem that the market would soon solve on its own.

As discussed above, this strategy may encounter pushback from both residents and local providers. We anticipate a stronger reaction from the providers because the Authority would be competing in areas in which it is also providing wholesale infrastructure for WISPs. Indeed, our discussions with some stakeholders revealed concerns of this exact nature.

1.3.1.4.2 Option 4b – Incremental Build-Out to Hard-to-Reach Areas

In this option, the Authority would focus its efforts on hard-to-reach areas, using its resources to increase broadband availability in regions that prove difficult to serve (and thus will not likely see private investment in the near future).

Like option 4a, this strategy may encounter pushback from both the community and the ISPs. However, this option provides the Authority with a more defensible response to any criticism. **By focusing its efforts on areas that are otherwise unserved (and likely to remain as such), the Authority would be tackling the broadband problem in underserved areas head-on.**

1.3.2 Dark FTTP Lease Partnership Options

In a dark FTTP model, ESVBA would deploy dark FTTP infrastructure (either ubiquitous or limited) that it would lease to a private partner; the private partner(s) would "light" the network and offer retail services to customers.

In this approach, ESVBA would be responsible for the cost to deploy the OSP infrastructure and, depending on the model, potentially the drop cable that connects the customer's home or business to the fiber network. The private partner would be responsible for placing and maintaining all network electronics and customer premises equipment (CPE), as well as network sales, marketing, and operations.

The success of this model would clearly depend on ESVBA's ability to attract a private partner—which is more likely if the network were to reach the entirety of the Shore. In partnerships nationwide, including the two models discussed below, the agreed upon lease fees did not cover the entirety of the cost to deploy OSP infrastructure. Rather, the public entity viewed OSP costs as an investment in the community as a whole, and where possible, recovered the capital expense through other revenue sources. If the Authority were to pursue either of these models, it may need to accept lower partner lease fees, and recover its investment in OSP via other revenues.

Discussions with the Authority have suggested that financing this model will be more expensive, due to the fact that ESVBA would not be the retail service provider. Indeed, pursuing a bond solely for the infrastructure that the Authority will not operate will increase the interest rate on a bond by 1.5 percent. Further, any model that finances against the general obligation of the community (as may be required here) but does not serve the entire community will place the Authority under increased public scrutiny. Given this, our projections for these models are based on a ubiquitous build-out.

There are two primary approaches to a dark FTTP model:

- **A dark FTTP model in which ESVBA would deploy fiber infrastructure—including the fiber drop cables connecting the customer's premises to the distribution network—for lease to a private provider**. The private provider would then add network and consumer electronics to offer retail services. We refer to this model, which is based on the agreement between the city of Westminster, Md., and its partner, Ting Internet, as the **Westminster Model**.

- **A dark FTTP model in which ESVBA would deploy fiber infrastructure for lease to a private partner, but *would not* deploy the fiber drop cable that connects the customer's premises to the FTTP network**. The private partner would be responsible for constructing the fiber drop cables and providing network electronics and CPE to offer retail services. Because this model is based on the agreement between Huntsville (Ala.) Utilities and its private partner, Google Fiber, we refer to it as the **Huntsville Model**.

There are two important metrics to consider in these dark FTTP lease models. The first is the total cost, including necessary financing, for ESVBA to deploy the OSP. The second is the lease fees a private partner would need to pay the Authority in order for ESVBA to recover its initial investment and for the network to cash flow.

1.3.2.1 Option 5 – Build and Lease Fiber-to-the-Premises Outside Plant Infrastructure and Fiber Drop Cables (Westminster Model)

In this model, ESVBA would deploy dark FTTP, including drop cables, that a private partner would lease from the Authority. The partner would add network electronics to "light" the fiber, and offer retail services to customers.

Because ESVBA would be responsible for the cost to deploy a fiber drop to every subscribed passing,[11] the financial success of this model is heavily dependent on the network take rate. Though this model will have higher construction costs than the Huntsville Model, it would give ESVBA "control" over the entirety of fiber assets. And in the event that the private partner exits the partnership, the Authority would maintain ownership of the drop cables.

For comparison, we looked at the implications of this network obtaining and maintaining a take rate of 36 percent—the same take rate necessary for the ubiquitous FTTP retail model to cash flow. **Ubiquitous dark FTTP infrastructure build-out would cost the Authority $37.9 million, necessitating a bond of $46.8 million. In addition, the private partner would need to obtain and maintain a take rate of 36 percent, and ESVBA would need to receive $9.60 per month per passing and $27.20 per month per subscriber from the private partner.**[12] These fees are 1.6 times the fees agreed upon in Westminster.[13]

We discuss this model further in Section 5.2.1 and assess its financial implications in Section 7.3.

1.3.2.2 Option 6 – Build and Lease Fiber-to-the-Premises Outside Plant Infrastructure (Huntsville Utilities Model)

In this model, ESVBA would deploy FTTP OSP passing every home and business on the Shore, but a private partner would be responsible for purchasing network electronics and CPEs, installing fiber drop cables to the premises, and serving end users.

Because the Authority would not be responsible for drop cables, the network take rate would not affect the financial viability of the network for the Authority. Given this, we only project a necessary per-passing fee from the private partner.

A ubiquitous dark FTTP infrastructure build-out would cost the Authority over $29.2 million, necessitating a bond of $39.8 million. To cash flow, ESVBA would need to receive $16.13 per month per passing from the private partner, or 2.15 times the fees obtained agreed upon in Huntsville.[14]

We discuss this model further in Section 5.2.2 and assess its financial implications in Section 7.

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[11] A passing on the network that receives connectivity service from the network operator.

[12] Total deployment costs and the necessary financed amount will increase as take rates increase.

[13] As discussed in Section 7.3, charging the same fees as Westminster will generate a cumulative cash deficit of roughly $27.7 million by the end of year 20.

[14] As discussed in Section 7.4, charging the same fees as those agreed upon in Huntsville will generate a cumulative cash deficit of nearly $37.9 million after 20 years.

1.3.3 Middle-Mile Wholesale Services Options

Middle-mile wholesale services options provide an opportunity for the Authority to continue to leverage its existing assets to assist in broadband services for Shore residents and businesses.

1.3.3.1 Option 7 – Offer Middle-Mile Wholesale Services and Encourage ISPs to Leverage Middle-Mile Fiber

This strategy involves ESVBA continuing to focus on providing wholesale services to local ISPs to meet the needs of the residential market. By reducing those ISPs' expansion costs, the availability of middle-mile fiber to unserved and underserved areas may provide enough incentive for ISPs to deploy last-mile infrastructure.

Notably, this model—which is a type of "status quo" approach that would have the ESVBA continue its current approach—carries the risk that private investors will fail or not follow through. This is a significant concern and, frankly, there is reason for concern given that last-mile residential deployment on the part of the private sector has been slower than many members of the community had hoped.

One potential strategy that aligns with this option to mitigate risk has been set forth by ESVBA Board member Mr. Peter Lalor.[15] In the interest of preventing unfair competition and unkept promises by the ISPs, and promoting timely expansion and efficient use of the existing network, the Lalor model suggests that the Authority would coordinate with the WISPs to determine "domain" over potential passings. After this determination, a "shot clock" would start, requiring passings to be served within a given amount of time.

While we applaud the goals in this strategy, we caution that the Authority will face challenges in obtaining this level of cooperation from the WISPs. We also recommend that the Authority obtain guidance from an experienced telecommunications attorney about the legal framework to enforce such a model.

As discussed above, this model would essentially be an extension of the Authority's current Ethernet Virtual Private Line (EVPL) program. This program enables ISPs to have lower-cost transport to enable them to focus their deployment capital on building towers more efficiently in different towns on the Shore. The Authority has enacted quality control rules including that hub points must be on a proper tower (i.e. no buildings, silos, etc.), at a height of greater than 50 feet, with no wireline extensions from the tower to ensure that hub points can effectively reach

[15] See Appendix B.

the largest potential customer base, a prudent decision to further the Authority's goals of ubiquitous broadband availability.[16]

The current wholesale policy for EVPL deployments that require a network extension—that is, allowing unlimited EVPL connections, but necessitating a build-out plan, budget, and authority for direct residential connections—addresses this risk. We also find the Authority's policy of continuing to charge for services, even if ISPs do not follow through with deployment after an extension is built, to be a prudent effort to mitigate risk to ESVBA.

We note that ESVBA's current incremental residential footprint expansion strategy could be resumed in future years if private investment does not materialize as promised and hoped.

Our analysis does not suggest a need to lower prices for ISPs. Indeed, CTC's 2016 Rate Study suggests that the Authority's rates are directly in line with equitable pricing in surrounding markets. But modest pricing adjustments may be merited as incentives for last-mile investment, based on enforceable, verified build-out targets.

1.3.3.2 Option 8 – Offer Middle-Mile Wholesale Services and Secure Build-Out Commitments Through Assistance in Applying for Grants

As an extension of option 7, the Authority could seek to attract private investment by offering assistance to ISPs in applying for capital grants. ESVBA could offer this support in exchange for middle-mile leases backed by build-out commitments from ISPs. An indirect benefit of this strategy comes from federal enforcement of grant build-out requirements. That is, grant recipients will be required to accomplish their original deployment plans to avoid surrendering funding.

We recommend the following strategies to attract outside capital to the Shore for last-mile residential deployment:

1. **Support grant and loan applications to attract outside capital to the Shore**. By supporting private applications for federal funding, both in loan and grant form, ESVBA may be able to maximize the amount of outside funding coming onto the Shore to invest in broadband infrastructure and services. This represents a critical benefit in that the broadband challenges in the two counties are addressed not only by local dollars but also by outside investments.

2. **Support and encourage bids for CAF-II funding to facilitate construction in the least cost-effective areas.** Support for a CAF-II bid could secure revenues that would *require*

[16] For more information on the Authority's EVPL program, please see https://esvba.com/services/ (accessed March 2018)

deployment in the least financially viable areas of the region. The potential CAF-II funding of just under $1 million per year for a decade could have some impact with respect to the needs of a WISP that is already deploying in the two counties. The federal funds have rigorous conditions, including offering telephone service and being a registered telephone provider, as well as verification and enforcement mechanisms that could serve to ensure that the funds are used to reach the most remote areas on the Shore.

All of these considerations are described in greater detail below, with supporting analysis and spreadsheets in the appendices to this report.

2 Background and Overall Considerations

To develop important data and insights, we held extensive discussions with area stakeholders, including:

- ESVBA leadership
- All ESVBA Board members
- Elected or appointed officials of both Accomack and Northampton counties
- Key ESVBA customers, including NASA, NOAA, and the Chesapeake Bay Bridge-Tunnel
- The three wireless internet service providers (WISP) currently providing services on the Shore: Chesapeake Communications, Declaration Networks Group (DNG), and Eastern Shore Communications
- Internet service providers (ISP), financiers, and other interested parties (such as Microsoft), to determine whether appetite exists for investment in new broadband infrastructure on the Shore and under what circumstances
- Residents of the Shore (in a series of Town Hall meetings)
- Past ESVBA leadership, including Mr. Nicholas Pascaretti and Mr. Pat Coady
- Representatives of some of ESVBA's peer networks, including the Maryland Broadband Cooperative, whose operations and efforts can inform ESVBA's own strategic choices
- Selected experts in protecting public broadband networks from legal and legislative challenge by phone and cable incumbents (such as the anti-competitive bill proposed this past session in the Virginia legislature that would have frozen ESVBA's operations)
- Federal government officials regarding funding opportunities available for broadband expansion on the Shore

The sections below summarize our findings from these discussions, coupled with our analysis of the state of ESVBA.

2.1 ESVBA Has Been Well Managed and Demonstrates Considerable Success

In our view and experience, ESVBA represents one of the best managed and most successful public sector or nonprofit middle-mile networks in the United States.

ESVBA has achieved financial stability and robust positive cash flow, even as many other middle-mile networks established in the same period have struggled or required ongoing subsidy. From its conception through construction and ongoing operations, it has been well regarded by peer networks and public sector broadband professionals and advocates. It has demonstrated considerable technical expertise and execution capability, and has deployed and managed a complex set of network assets—not a small accomplishment in a geographic area where it may be difficult to hire expert network engineers, given the enormous demand for that skill set in metropolitan areas throughout the country.

We note also that the business plan dated May 13, 2009, has been ably executed. The risks identified in the business plan, including construction delays, sales delays, and lack of operating funds, have been ably mitigated.

With respect to the key goals established by the 2009 business plan, only one major area has not materialized—and that shortcoming reflects the challenging economics of broadband deployment everywhere in the country, not just on the Shore. That goal, which was to "provide broadband connectivity to all areas of the Shore by 2012,"[17] is the subject of this report.

2.2 There Exists Tension Between ESVBA's Roles as Wholesaler and Residential Retailer

The primary challenges currently faced by ESVBA, and that have arisen throughout this engagement, are twofold. The first is the question of funding ubiquitous broadband on the Shore, and the second is the tension regarding the role of the Authority with respect to the residential market.

Until recently, the residential market was served only by private sector service providers—small WISPs and Verizon. ESVBA played a clear role with regard to the residential market as a wholesaler of transport and commodity internet bandwidth to the private ISPs.

Because the residential market was inadequately served, however, and a significant percentage of residences on the Shore either had no access or substandard access to broadband services, the Authority began to implement FTTP and residential retail service over the past year. This created an ambiguity and complexity in that the ISPs were now both customers of and competitors to ESVBA.

The tension created by competing with wholesale customers will only increase if ESVBA were to expand its FTTP footprint. This has the potential to cause challenges to the Authority in the medium to long term, not only with respect to political support (or political challenges from

[17] Business Plan, Eastern Shore of Virginia Broadband Authority, May 13, 2009, page 2.

Richmond),[18] but also with respect to wholesale revenues that could diminish if the ISPs seek other providers or if their business viability is reduced.

To fully understand this ambiguity and to gain clarity that would inform our analysis in this project, we looked to ESVBA's founding and corporate documents to find direction regarding the Authority's core mission and role in the residential market. What we found is that neither the articles of incorporation[19] nor the bylaws[20] clarify a mission regarding expansion or types of service. Perhaps the clearest expression is found in the authorizing resolutions of the Boards of Supervisors of the two counties, which clearly contemplate service to the public as well as to companies and institutions.[21] As a result, we conclude that the corporate documents do not preclude any particular form of service or clearly point toward or away from either retail or wholesale service.

That said, we recommend that ESVBA's Board of Directors consider developing and adopting a clear mission statement regarding the role of the Authority in the residential market, based on the strategic direction it chooses to adopt in the wake of this report. Such a mission statement could be revised and changed over time, as circumstances change, but in the meantime, it would potentially provide clarity for ESVBA staff, ESVBA customers, elected officials in the two counties, and the public.

2.3 Some Objectives May Conflict and It Will Be Important for ESVBA to Prioritize Its Goals

Understanding the motivation behind its stated objectives and mapping out potential outcomes are crucial steps for ESVBA as it decides how to move forward in pursuit of its broadband goals. It will be vital for ESVBA's leadership to develop internal consensus about which objectives should take priority and how the Authority might best achieve these goals.

Historically, ESVBA has slowly and incrementally expanded its network, and it is willing to continue with this approach as long as it makes sense. This approach has supported one of

[18] A bill to effectively eliminate the authority of public entities to work in broadband was introduced but did not pass in the Virginia legislature this past session. There is discussion in Richmond that a similar bill may be introduced in the 2018 session. Analysts suggest that the bills are lobbied most strongly by the cable industry, which is not a factor on the Shore.

[19] https://www.esvba.com/wp-content/uploads/2016/01/ESVBA-Articles-of-Incorporation-2.pdf (accessed September 2017).

[20] https://www.esvba.com/wp-content/uploads/2016/01/BL_AsAmended07182013.pdf (accessed September 2017).

[21] Both Board resolutions state that a "wireless broadband authority needs to be created to provide high-speed data service and internet access service to local businesses, local government, and the public." https://www.esvba.com/wp-content/uploads/2016/01/Concurrent-Resolution_Accomack_Northampton002.pdf (accessed September 2017).

ESVBA's fundamental goals: to maintain positive cash flow for the enterprise. Indeed, this goal is inflexible; ESVBA *must* maintain positive cash flow, even as it strategically expands its footprint.

ESVBA leadership has also indicated that its long-term goal is to deploy or facilitate deployment of broadband service to the entire Shore. It is important to understand that this objective could conflict with the Authority's goal of maintaining positive cash flow. While ESVBA likely does not expect to make a significant profit on the network, it is important for the network to be financially sustainable.

A ubiquitous approach would require significant startup capital, most likely at a level only obtainable through financing. This financing would require the Authority to cover principal and debt service payments in addition to operating costs.

To make the enterprise financially sustainable, ESVBA would likely have to price its broadband service too high for some customers to afford, which would in essence *decrease* availability. This is especially likely under a traditional retail model, in which ESVBA owns and operates the network, and acts as the service provider; to recover costs associated with infrastructure deployment, network operations, and maintenance, ESVBA may unintentionally exclude the very customers it is seeking to support.

Conversely, if ESVBA chose to prioritize affordability, broadband service will need to be priced so low that positive cash flow is difficult or impossible to achieve.

Table 2 outlines other potential conflicts between a range of objectives that public entities often prioritize when considering broadband deployment or expansion.

Table 2: Common Goal Alignment

A: Align **C:** Conflict **NI:** No Impact

	Ubiquity	Choice	Competition	Ownership	Performance	Affordability	Risk Aversion	Cash Flow
Ubiquity		A	A	A	NI	C	C	C
Choice	A		A	A	A	A	C	NI
Competition	A	A		A	A	A	C	NI
Ownership	A	A	A		A	A	A	C
Performance	NI	A	A	A		NI	A	A
Affordability	C	A	A	A	NI		C	C
Risk Aversion	C	C	C	A	A	C		A
Cash Flow	C	NI	NI	C	A	C	A	

See Appendix C for a more detailed discussion of common broadband deployment objectives and how they may align and conflict.

2.4 ESVBA Board Members Agree That Action Must Be Taken, But Do Not Agree on a "Best Approach"

Our in-person interviews with Board members, and follow-up calls with many of them, indicate that there is not firm agreement as to the best strategy for the Authority to take. Some members feel comfortable with ESVBA as a retailer, while others were uncomfortable with competing with the ISPs—unless there is no other choice.

There was strong disagreement on the topic of taking on debt, with some members feeling bonding to build the entirety of the Shore is appropriate, so long as current and future cash flows could support debt service. Others feel that the network should grow gradually and sustainably, even if it were to take 50 years.

At least one member felt there was no role for the private sector, and that ESVBA should deliver a public-sector solution over time, without coordination with the private sector; while others felt the private-sector solution should be the first option, and that public option should be the fallback.

2.5 Town Hall Meetings Indicate an Engaged Community That Is Not Satisfied with the Existing Broadband Landscape

The Town Hall meetings held in 2017 showed a community that is not satisfied with the existing landscape on the Shore. Attendees reported that they needed service that WISPs couldn't provide, and demonstrated an impressive sentiment that fiber-based service is both optimal and vital to address the Shore's broadband needs. The overwhelming majority of attendees strongly expressed that they are well aware of the high quality of ESVBA's fiber-based service, and that they want ESVBA as a retailer.

Many attendees took the opportunity to voice their specific concerns about the quality of service they are receiving from local ISPs. The majority of complaints centered around speed and dependability of their service. One attendee discussed their inability to work from home, complaining that the trees on and around their property prevent dependable wireless access, and that their service will drop calls during meetings. A local realtor voiced frustration that they were "stuck with DSL", and have a particularly hard time uploading photos of houses they are trying to sell. They reinforced their complaint with a comment that houses without access to high-speed internet just "aren't selling". Multiple others complained that ESVBA fiber runs directly in front of their house, but they have no way to access it.

One attendee reported that their ISP indicated to them that the line of site issues interfering with service were a result of ESVBA's EVPL policies restricting the ISP's ability to run a wireline connection from a tower into the attendee's house.[22]

Overall, the Town Hall meetings illuminated a demand for fiber-based service, and support from the community for the Authority to make its premium retail services available to more residents and small businesses on the Shore.

2.6 ESVBA's Institutional and Residential Customers Are Satisfied with Its Service

ESVBA customers, ranging from large institutional customers like federal agencies to residential users of internet services, generally give ESVBA strong reviews for reliability, responsiveness, and quality. In the enterprise market, NOAA, NASA, and the Chesapeake Bay Bridge-Tunnel report

[22] Our discussions with ESVBA representatives indicate that such complaints are commonplace, and that some local ISPs have a penchant for blaming the Authority for their inability to provide optimal service to a location. After review of the EVPL program and policies, we feel the Authority's policies both enable ISPs to focus deployment capital on their infrastructure, and protect the quality of the service it provides to EVPL customers. For more discussion on these policies, please see Section 1.3.3.1.

deep satisfaction with the services they receive, particularly as compared with the inadequate services with which they struggled before the ESVBA network was built. One institutional customer described ESVBA service as “critical”, noting the service is always capable of supporting its increasing bandwidth demands.

2.7 ESVBA’s WISP Customers Are Satisfied with Services Received, but Are Also Concerned by the Authority’s Residential Expansion Plans

The WISP customers we engaged suggested they are satisfied with the reliability of the services they are receiving from the Authority, though one noted ESVBA’s response time has recently decreased.

As ESVBA has contemplated expansion in the residential market, it has faced considerable opposition from at least one of the WISPs currently serving some parts of that market. The two other competing ISPs have indicated similar concerns, though to a less vocal degree. At the core of the strategic challenge facing the Authority is the private sector’s concern about ESVBA as a competitor in the residential market. (This concern was also expressed to CTC staff by some members of the ESVBA Board, elected officials, and other stakeholders.)

The core concern of the private sector is that competition for residential customers by ESVBA will reduce the viability of a private enterprise seeking to serve the Shore residential market by siphoning off customers, many of them in the areas where construction costs are lowest and the economics of rural broadband are best.

DNG’s concern with ESVBA’s FTTP strategy has been extensively heard and documented by ESVBA. As we have noted elsewhere, it is a challenging for a provider to both compete with and serve a customer such as a WISP. Inevitably, their interests will not align. DNG suggested that the economic threat that ESVBA’s FTTP expansion presents to DNG is so significant that it may lead DNG to focus its resources (including its recently awarded federal loan) and efforts elsewhere where the business case is stronger.

Representation from the other two local WISPs echoed this concern, suggesting that ESVBA is beginning to compete head-on with WISPs, and that this competition is inefficient. Rather, it was suggested that the Authority should work with local WISPs to provide more tower opportunities for providers to execute wireless deployments. Indeed, one provider suggested that the Authority’s existing policy that only allows EVPL service to 50-foot poles that are exclusively for fixed wireless prevents the provider from negotiating deals with property owners to exchange service for location access. Further, one provider commented that longer network extension payback periods would allow the provider a more economical way to deploy to residences, while the other suggests that shorter contract terms would increase the provider’s ability to deploy efficiently.

3 Industry Overview and Opportunities

The core technology challenge for the residents and businesses of the Shore is that the most widely available technology, digital subscriber line (DSL) over copper, has limited capacity. Further, the DSL service is unlikely to see improvements in coming years because this is not an investment priority for Verizon, which owns and controls the copper plant throughout the Shore.

Other broadband options pose challenges, as well. The optimal, future-proof technology, FTTP, is extremely costly to build. Fixed wireless is far more affordable, but also less capable and requires frequent technology refreshes. The promising (and hyped) new "5G" wireless technologies, which may deliver faster speeds, are still on the drawing board—and are unlikely to be deployed in rural areas.

These technologies are summarized briefly below and described in detail in Appendix D.

3.1 Verizon's DSL Network Does Not Meet the Shore's Broadband Needs

During the past century, phone companies connected virtually every home and business in the United States to a strand of copper wire. Those connections were intended for wireline voice service, but became the primary means of data service for most rural areas of the country in the internet era, through DSL, which enables data service over copper.

Copper has a fraction of the bandwidth capacity of technologies that serve metropolitan areas (such as the cable industry standard, coaxial cable) and suffers from greater signal loss and interference—but because of copper's ubiquity, DSL has been an important way for people to connect to the internet.

While DSL has been an impressive retrofit of existing infrastructure, copper cable is reaching its physical limitations as a broadband medium, and will not be able to meet future bandwidth needs. DSL's technical limitations are further compounded by the relative lack of investment by some phone companies, including Verizon, in rural wireline service. As Verizon's attention has turned to mobile rather than wireline in rural areas, investment and attention to the DSL networks has meant that services have remained static or deteriorated, rather than improving with renewed investment.

3.2 FTTP Is Future-Proof and Ideal for Service, but Costly

There exists little debate that, for purposes of capacity, reliability, and scalability, FTTP is superior to all other fixed broadband technologies. FTTP is superior in capacity to even the best of all theoretical wireless technologies (which also require a large amount of fiber infrastructure for backhaul). Indeed, fiber is one of the few technologies that can legitimately be referred to as future-proof, meaning that it can provide customers better, faster service offerings to accommodate growing demand.

Fiber optic cables are the medium of choice for data transfer. They have enormous bandwidth capacity, which enables operators to offer symmetrical download and upload speeds. Fiber is also not subject to interference, and does not require amplifiers to carry a signal over long distances.[23] This is why the vast majority of the internet backbone comprises bundles of fiber cable strands.

Once a location is connected to fiber, there is no need for significant OSP infrastructure investment for decades. If bandwidth needs exceed the capabilities of the network, the operator only needs to upgrade the network electronics, rather than having to replace the cables. The electronics needed to provide 1 Gigabit per second (Gbps) speed over an FTTP network are already widely available at an affordable price, and the price of the electronics needed to support 10 Gbps connections are declining rapidly.

We note that ESVBA's current services do not use the maximum capacity of its FTTP network, and there is considerable room to increase the speeds offered to customers without upgrading electronics. A DSL or fixed wireless network may need to operate at the maximum capacity currently allowed by the technology to provide a compelling service, with any significant increase in the speeds offered requiring an upgrade to the electronics used to serve customers. ESVBA currently offers speeds that are well below the maximum capabilities of its FTTP network. Given this, ESVBA can increase the speeds offered to customers with only a configuration change, using the current electronics.[24]

3.3 Mobile Broadband Does Not Reach All of the Shore Adequately, But Can Improve With Time

Cellular wireless carriers have been consistently increasing their data speeds with the rollout of faster and higher capacity technologies such as Long-Term Evolution (LTE).[25] In their service areas, carriers provide data plans with speeds comparable and in many cases greater than a typical residential customer's internet service. But mobile signals tend to be weak in rural areas other than the towns and along major roads, and mobile broadband has technological limitations relative to wireline, including lower speeds in general and low upload speeds in particular. Frankly, there are some rural areas where mobile service features speeds comparable to telephone dial-up.

That said, mobile company investment throughout the country is significant and we anticipate that mobile service on the Shore will gradually improve over time. We note, however that there

[23] Maximum distances depend on specific electronics. Six to 25 miles is typical for fiber optic access networks.
[24] This increase is possible up to a certain point. Speeds exceeding multiple Gbps or increasing the overall capacity of the network in response to greatly increased customer demand will require electronics upgrades.
[25] LTE is a 4G cellular wireless technology offering typical data speeds of around 30 Mbps, depending on the signal strength and level of use of the connection.

is no guarantee of this. Historically, rural areas of the nation are the last to see upgrades, which may be the case on the Shore. However, the capabilities of mobile are greatly improved by fiber-based backhaul, and ESVBA's fiber infrastructure is likely to play a part in enabling improved carrier mobile (while also realizing new revenues for ESVBA from mobile company customers).

3.4 Fixed Wireless Technologies Can Address Basic Rural Coverage Needs

Wireless internet service providers (WISP) are potentially able to fill coverage gaps, sending signals from base stations to antennas on or near customer premises. New technologies such as millimeter wave (mmWave) hold the promise that WISPs will be able to deliver far higher speeds. But even with the introduction of mmWave equipment with gigabit speeds, the high cost of electronics and the need for a direct line of sight currently limits the technology to multi-dwelling buildings in urban areas.

WISPs may also use other unlicensed or semi-licensed bands like 3.5 GHz or 900 MHz, but these have low data speed capabilities.

Most wireless networking solutions require the antenna at the customer premises to be in or near the line of sight of the base station antenna. This can be especially challenging in areas with dense vegetation. WISPs often need to lease space on rooftops or at or near the tops of radio towers; even then, some customers may be unreachable without the use of additional repeaters. And because the signal is being sent through the air, climate conditions like rain and fog can impact the quality of service.

Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-multipoint solutions are more affordable to implement and are typically used in a WISP environment. However, they limit the capacity of the network, particularly in the upstream, making the service inadequate for applications that require high-bandwidth connections.

Fixed wireless systems built with off-the-shelf Wi-Fi-band equipment today tend to have an aggregate capacity between 100 and 250 Mbps. With innovations like higher-order multiple input, multiple output (MIMO) antennas, and the use of spatial multiplexing, these capacities will likely increase across vendors to as fast as 750 Mbps. It is important to note, however, that this is the aggregate capacity; in a point-to-multipoint architecture, bandwidth will be shared among all the users connected to a single base station. For this reason, some WISPs are focusing on point-to-point services, where the capacity on each link is fully dedicated to that connection, or a point-to-multipoint architecture deliberately designed with a limited number of customers in the service area.

Wireless equipment generally requires replacement every five to 10 years, both because exposure to the elements causes deterioration, and because the technology continues to advance at a rapid pace, making equipment from a decade ago mostly obsolete. The cost of deploying a wireless network is generally much lower than deploying a wireline network, but the wireless network will require more regular investment.

3.4.1 TV White Spaces

Some wireless providers in rural areas have begun to use vacant television frequencies called TV white spaces (or simply white spaces) to provide service. These TV bands have much better non-line-of-sight transmission qualities than the unlicensed bands; however, because white space technology is still in an early phase of development, compatible equipment is more expensive than other off-the-shelf wireless equipment. Further, these technologies offer speeds well below the FCC's current definition of broadband (at least 25 Mbps down and 3 Mbps up),[26] and should not be considered "broadband technology".

In 2017, Microsoft announced its Rural Airband Initiative, through which it plans to partner with service providers to try to bring connectivity to 2 million people in rural America by 2022 using white spaces equipment.[27]

Microsoft announced 12 initial pilot projects in 12 states; the company will partner with a rural service provider, providing technical support and sharing some of the upfront capital costs in exchange for a share of the revenue.[28]

One of the initial pilot projects to get off the ground is a partnership between Microsoft, the Mid-Atlantic Broadband Communities Corporation (MBC), and the Virginia Tobacco Region Revitalization Commission. The project establishes a "Homework Network" to deliver free access to "filtered educational content" in rural households with school-aged children in Halifax and Charlotte County.[29] Students will be able to use the network to access unlimited educational content at a speed of 3 to 4 Mbps at no cost to the student's family. Connected households will also be able to purchase unfiltered broadband access from the internet provider B2X Online at speeds of 3 to 4 Mbps for $10 per month, or speeds of 8 to 10 Mbps for $40 per month.[30]

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[26] Federal Communications Commission, "2015 Broadband Progress Report", https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2015-broadband-progress-report (accessed March, 2018).

[27] Brad Smith, "A rural broadband strategy: Connecting rural America to new opportunities," *Microsoft Blog,* July 10, 2017, https://blogs.microsoft.com/on-the-issues/2017/07/10/rural-broadband-strategy-connecting-rural-america-new-opportunities/ (accessed October 2017).

[28] Ibid.

[29] Wil McLaughlin, "Closing the gap," *SoVa Now,* May 25, 2017, http://www.sovanow.com/index.php?/news/article/closing_the_gap/ (accessed October 2017).

[30] Jay Greene, "Microsoft's Rural Broadband Solution: TV 'White Space,'" *Fox Business*, July 11, 2017, http://www.foxbusiness.com/features/2017/07/11/microsofts-rural-broadband-solution-tv-white-space.html (accessed October 2017).

Based on successful completion of the pilot project, the Tobacco Commission committed an additional $10 million to help MBC scale the project to deliver service to students from 183 schools in Southside Virginia.[31] At the end of August 2017, MBC president and CEO Tad Deriso reported that the company was on track to connect 1,000 households in the next five months.[32]

It is not clear how Microsoft intends to support subsequent deployments. However, even those communities that do not receive direct investment or technical support from Microsoft could still benefit from the economies of scale that the initiative enable. Microsoft representatives say they hope to see the cost of white space receivers drop from their current price of almost $1,000 to $200 by the end of 2018.[33]

We note that although ESVBA may choose to employ this solution, pursuing this technological approach would place ESVBA directly in competition with area WISPs with similar technology, service pricing, and coverage issues. Offering a wireless product would also require ESVBA to invest in a new area of technical expertise, including wireless engineering and installation, antenna sighting, and a new type of distribution electronics with a separate product lifecycle. Given this, this strategy would be in contrast to continuing a fiber expansion which would leverage ESVBA's existing knowledge and resources to a fuller extent while also providing a higher-end, higher-speed product.

3.4.2 Fixed "5G" Wireless

Like faster mobile service, fixed wireless 5G will require deployment of fiber to provide backhaul to dense deployments of relatively short-range but high-capacity transmitters.[34] Indeed, current deployment strategies for 5G would require a wireless access point with a fiber connection every 300 to 600 feet (every two to four utility poles or streetlights) to deliver speeds of up to 1 Gbps to the home or business. This would represent an enormous investment in wireless and fiber infrastructure to ESVBA.

It is important to note that prototype 5G technologies are seeing preliminary deployment in urban areas only. For example, the companies Monkeybrains and Webpass provide services in

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[31] Wil McLaughlin, "Closing the gap," *SoVa Now,* May 25, 2017, http://www.sovanow.com/index.php?/news/article/closing_the_gap/ (accessed October 2017).

[32] "Rural broadband initiatives, economic development collaboration highlight caucus meeting," *Work It, SoVa,"* August 23, 2017, http://www.godanriver.com/work_it_sova/news/rural-broadband-initiatives-economic-development-collaboration-highlight-caucus-meeting/article_75d9908a-8851-11e7-8e2c-db74c3aa36c1.html (accessed October 2017)

[33] Jane Wakefield, "Microsoft to plug rural broadband gap with TV white space," *BBC News,* July 12, 2017, http://www.bbc.com/news/technology-40580888 (accessed October 2017).

[34] "5G" is currently more of a marketing term than a defined set of technologies. At the moment, 5G is a catchphrase encompassing efforts by research and development community, hardware and software manufacturers, wireless service providers, and standards committees.

San Francisco, Boston, and Denver using proprietary equipment that might be considered an early version of 5G technology. These providers interconnect their fiber networks with high-speed wireless networks. In these examples, very high-frequency (microwave and mmWave, respectively) equipment links rooftops of tall buildings, and serve apartments and businesses in the buildings over the internal wiring of the buildings.[35] Also in urban areas, another version of newly commercialized mmWave technology for high-speed residential broadband service avoids any need for building wires, instead connecting wirelessly with window-mounted devices in customers' apartments.[36]

In addition to providing an alternative approach to gigabit broadband to large buildings, the industry foresees 5G as accommodating growing broadband needs and connecting both fixed and mobile users. It is also envisioned as connecting new generations of devices and machines, with a strong focus on automation—adding intelligence to vehicles and machines and creating new ways to collect and analyze data.

That said, 5G is a long way from widescale deployment in the metropolitan areas of the U.S. and even further from deployment in rural areas where the required density of 5G infrastructure may be more difficult and costly to achieve. Initial Verizon 5G trial cities provide "a variety of terrain, neighborhood layouts, and population density,"[37] but still generally focus on major metropolitan areas.

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[35] Boris Maysel, "When and How to Use Multi-Gig mmWave," Presentation, Siklu, p.8, https://www.siklu.com/wp-content/uploads/2016/09/mmWave-for-Consultants-webinar.pdf (accessed June 2017).
[36] David Talbot, "Wireless, Super-Fast Internet Access is Coming to Your Home," *MIT Technology Review*, May 16, 2016, https://www.technologyreview.com/s/601442/wireless-super-fast-internet-access-is-coming-to-your-home/ (accessed April 2017).
[37] Diana Goovarts, "Verizon Announces 5G Customer Trials in 11 Cities with 5G Forum Partners," *Wireless Week*, https://www.wirelessweek.com/news/2017/02/verizon-announces-5g-customer-trials-11-cities-5g-forum-partners (accessed April 2017).

4 Overview of Potential Federal Funding Sources

This section of the report provides a brief summary and analysis of three potential federal broadband funding programs that are of interest to the Authority.

The first is the U.S. Department of Agriculture's broadband loan program, which is famously bureaucratic and cumbersome—and, for ESVBA, may be a less efficient option than other forms of loans or bonds. During our stakeholder meetings for this engagement, we were told by Mr. Robert Nichols that Declaration Networks Group (DNG) has applied for and received a loan under this program that it potentially plans to utilize to expand its network on the Shore.

The second is a small but outstanding rural broadband grant program administered by the U.S. Department of Agriculture called Community Connect. This program makes modest-sized grants of approximately $500,000 to $1.5 million for deployment of new broadband capabilities in very low income, unserved areas. The grant opportunity tends to open in spring; and the application window for the 2018 grant cycle has not opened yet.

The third and perhaps most significant opportunity—the Connect America Fund Phase II (CAF-II)—comes through a likely reverse auction for an ongoing operating subsidy that will be administered by the FCC this year. In brief summary, the FCC will award to the lowest qualified bidder an ongoing operating subsidy that could be as high as $1 million per year for the Shore region. The subsidy would last for 10 years, and the winning applicant would be required to register as a regulated phone company and to provide services of 10/1 Mbps to some of the most remote areas on the Shore.

While the subsidy is modest relative to the enormity of the cost of constructing new broadband infrastructure in these most remote areas, it does potentially somewhat improve the economics of a rural strategy. Most importantly, federal requirements and enforcement mechanisms would ensure that the 10/1 Mbps service is in fact deployed and maintained.

These programs are described briefly below and in greater detail in Appendix E.

4.1 USDA Broadband Loan Program

The Rural Broadband Access Loan and Loan Guarantee Program has historically been the federal loan program with the greatest promise for rural broadband. In fact, 100 loans in 43 states (representing a total value of $2 billion) were made through the program from 2003 through 2013. Awards range from $100,000 (minimum) to $100 million (maximum), with an average award of $640,000. The program is administered through the Rural Utilities Service (RUS) under the authority of the U.S. Department of Agriculture (USDA).

The program is intended to ensure that rural consumers enjoy the same quality and range of broadband services that are available in urban and suburban communities. (A parallel Electric Loan Program provides capital and leadership to maintain, expand, upgrade and modernize rural electric infrastructure.)

The Broadband Loan Program provides financing to support the construction, improvement, and acquisition of facilities required to provide broadband services. Applications are prioritized based on the percentage of unserved households in the proposed service area. Broadband projects must be completed within three years from the date that loan funds become available.

Loans are limited to eligible rural communities (i.e., an area with less than 20,000 inhabitants and not adjacent to an urbanized area with more than 50,000 inhabitants). All facilities receiving federal financing must be used for a public purpose. And to be eligible for the Broadband Loan Program, at least 15 percent of the households must be unserved and no part of the proposed funded service area may have three or more incumbent service providers (unless the borrower is applying to upgrade existing facilities in its existing service area). Broadband loan borrowers must also have equity of at least 10 percent of the amount of the loan.

4.2 USDA Community Connect Program

Community Connect is a modest-sized but significant grant program for local and tribal governments that targets deployment to completely unserved, very low-income rural communities. The program is administered by RUS.

The grants target communities where low population densities and poverty make deployment costs high, and build-out of infrastructure unlikely. Funding is limited to contiguous areas with a population less than 20,000 that do not currently have broadband and where such service would not otherwise be provided. Service areas need not be in the same community—or even the same state—so long as the areas are contiguous.

Community Connect grantees must offer broadband service to *all* businesses, residents, and community facilities in the service area, with free service provided for at least two years to all critical facilities and at least one community center that offers weekend hours and public computers. Grants can be used to offset the cost of providing such service and to lease spectrum, towers, and buildings that are part of the project design. A portion of the grant (the lesser of 10 percent or $150,000) can be used to construct, acquire or expand an existing community center.

The Community Connect application process is rigorous and competitive (with awards given to approximately 10 percent of applicants) and once awarded, program requirements are demanding (e.g., requiring last-mile service be available for all households in the service area).

The program has been funded consistently since it was introduced in 2002 and represents an important opportunity.

4.3 Connect America Fund Phase II (CAF-II) Auction Funding Opportunity

Over the course of the next year, new funding to support broadband operations on the Shore will be made available by the FCC. The funding will be awarded based on a reverse auction whose date has not yet been announced.[38]

The funding is available because Verizon declined the FCC's offer of support for Virginia broadband under the Connect America Fund Phase II (CAF-II), part of the FCC's reform and modernization of its universal service support programs. Phase II of the Connect America Fund offered annual monetary support (effectively, an ongoing operating subsidy) for the large phone companies to provide wireline broadband and voice services to areas that not already served.

4.3.1 Background

The FCC made an offer of support to Verizon for an amount determined by the Connect America Cost Model (CAM), an FCC tool that estimates the cost to provide voice and broadband-capable network connections to all locations in the country. Funding based on the CAM was offered to incumbent "price cap" carriers based on their existing service areas. Carriers could accept or reject offers by state, but otherwise could not "cherry pick" census blocks within the state. Verizon declined the funding offer for statewide support in Virginia.

The model calculates the cost by census block areas, considering geographical and regional factors that would affect construction in each region. The model determines census bocks that are eligible for funding based on the estimated cost to build and then excludes census blocks where costs are too low (indicating the area should not require a subsidy to incentivize a build-out) or too high[39] (indicating the area might be better served by another technology) or where other qualifying services already exist. Census blocks were marked ineligible for funding if 1) a subsidized carrier is offering services of at least 3 Mbps down and 678 Kbps up, or 2) a carrier, subsidized or unsubsidized, is offering services of at least 10 Mbps down and 1 Mbps up.

The locations on the Shore that are eligible for funding are included in the maps below. Accomack County has 2,033 supported locations, and an annual price cap support of $604,582. Northampton County has 1,272 supported locations and an annual price cap support of

[38] When available, the auction timeline will be announced on the FCC's "Connect America Fund Phase II Auction (Auction 903)" page, available: https://www.fcc.gov/auction/903, accessed February 2018.
[39] These areas may be eligible for funds through the Remote Area Fund, which will award support subsequent to the completion of the CAF Phase II competitive bidding process.

$362,713. Taken together, the Shore has 3,305 locations eligible for support, and an annual price cap for support of $967,295.

Figure 1: CAF-II Eligible Locations in Accomack County

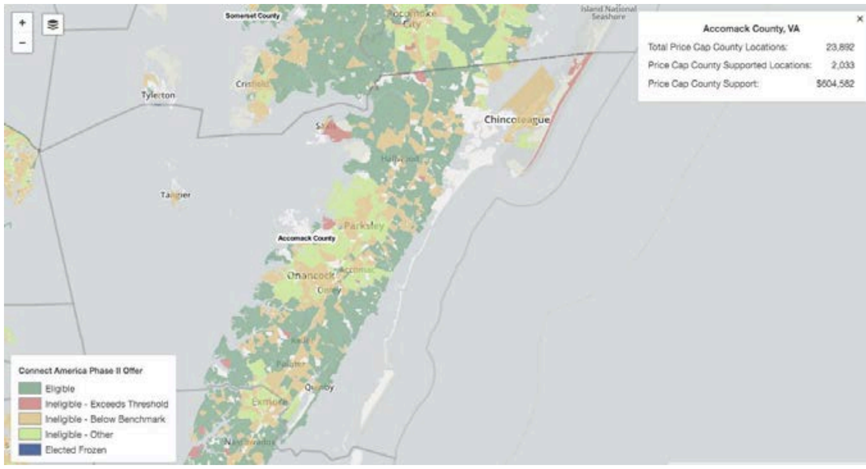


Figure 2: CAF-II Eligible Locations in Northampton County

4.3.2 The Opportunity Presented

To address the initial census block offers that were declined by price cap carriers (including Verizon), the FCC will in 2018 hold a reverse auction that will allow bids for subsidy funding for the remaining areas, and that will be awarded to the lowest-cost qualified proposal. The areas of the Shore that the FCC has preliminarily determined to be eligible for the Phase II auction are marked in orange below.

Figure 3: Northern Shore Areas Eligible for Funding Through CAF-II Auction

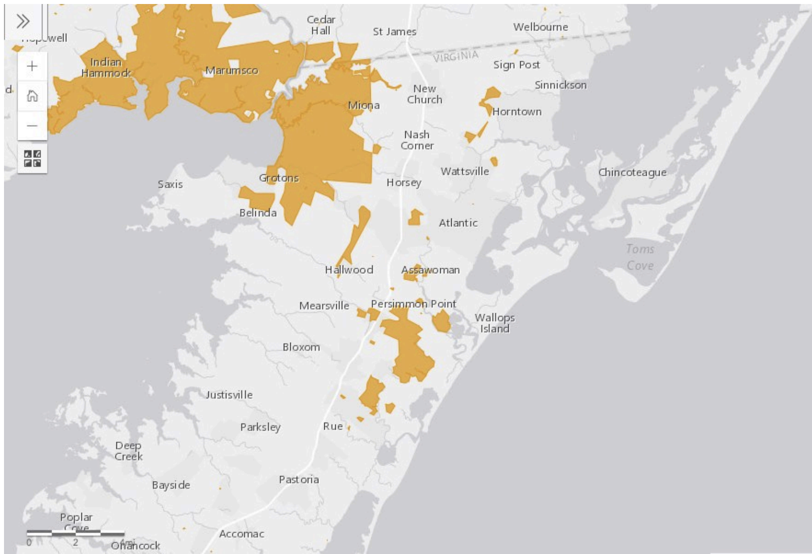
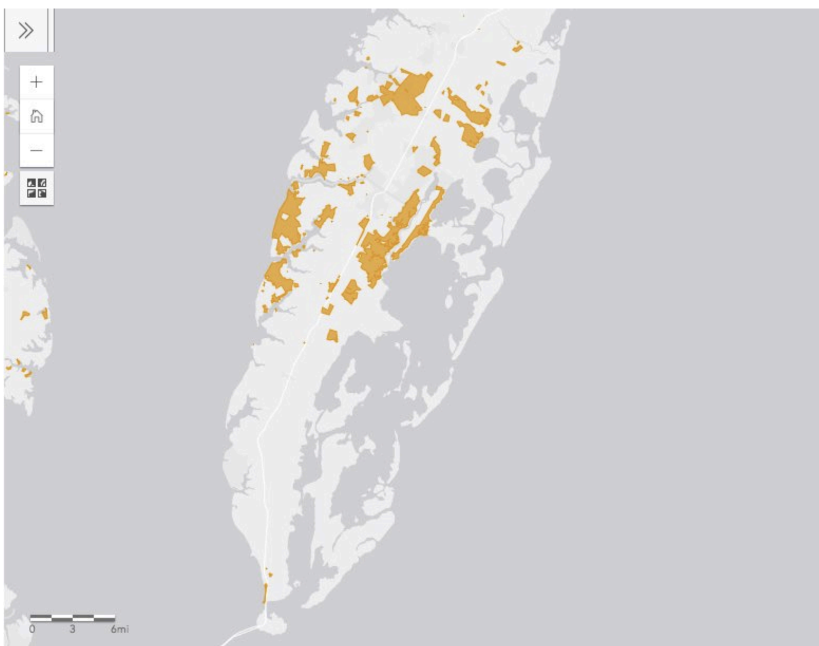


Figure 4: Southern Shore Areas Eligible for Funding Through CAF-II Auction



The Commission has determined that census block groups or tracts will be the minimum geographic unit for bidding. Thus, parties will be required to bid on all of the locations within the eligible census blocks of each census block group or census tract (depending on which is ultimately adopted as the minimum geographic unit). As previously mentioned, there are 3,305 supported locations on the Shore, and as much as $967,295 will be made available annually through the auction to incentivize carrier build-outs to these locations. The annual funding is set to last for 10 years.

4.3.3 Eligibility and Requirements

To participate in the CAF-II auction, a bidder must establish baseline financial and technical capabilities. There are two pathways for establishing eligibility:

- Demonstrate two years of experience providing a voice, broadband, and/or electric distribution or transmission service and submit one-year of audited financials
- Submit three years' audited financials with the short-form application and a letter of interest from an eligible bank willing to issue a letter of credit for a specified amount

Winning bidders must:

- Provide in their long-form applications additional information about qualifications, funding, and the network that they intend to use to meet their obligations
- Within a specified number of days, submit a letter from an eligible bank committing to issue a letter of credit; upon notification that the entity is ready to be authorized, it must obtain a letter of credit from an eligible bank that remains open and covers disbursements until build-out is complete and verified
- Within 180 days of being announced as winning bidders, certify they are eligible telecommunications carriers in any areas for which they seek support and submit relevant documentation

The program requires annual progress reports from winning bidders. Each must offer service to 40 percent of supported locations in their accepted areas by the third year of support and must add an additional 20 percent each year, serving 100 percent of the supported locations in their accepted area by the end of year six.

5 Strategic Options

Given the considerations above, this section of the report offers a range of strategic options for addressing the residential broadband market on the Shore. This section also offers analysis of how each of these strategic options would serve ESVBA's goals for maximizing broadband availability throughout the Shore.

5.1 Retail Services Options

These models represent strategies in which ESVBA would deploy, own, operate and maintain FTTP infrastructure and would directly serve business and residential users.

Given the potential capital and operating costs of a deployment that can support retail service, an important consideration for these options is how financing could be secured. The bonding community does not use FTTP revenue projections as security for bonds or loans, which means the Authority would have to rely on general obligation commitments from the counties or other public entities. Considering the magnitude of the required financing, it may be challenging to obtain that level of support.

5.1.1 Option 1: Ubiquitous Retail Fiber-to-the-Premises Throughout the Shore

This option represents the optimal and best outcome from a performance and opportunity standpoint, as it would deliver to each home and business on the Shore the potential for fiber-based service and the flexibility to purchase better and faster products over time as needs grow.

This option satisfies the policy goals and vision of the Authority to maximize the reach of broadband on the Shore. Further, a ubiquitous network build will probably result in greater competition among local providers. That said, it comes with considerable cost and risk, both with respect to operations of the FTTP enterprise itself, and with respect to the risk of reduced revenues if current ISP customers are unable or choose not to remain in the residential market because of competition with ESVBA.

5.1.1.1 Ubiquitous FTTP Construction Entails Capital Costs of $39.9 million

CTC's engineers prepared a high-level network design and cost estimate for expanding ESVBA's current network into a gigabit-capable FTTP network to all businesses and residences in Accomack and Northampton counties. The design and cost estimate are underpinned by data and insight gathered by CTC engineers through discussions with ESVBA stakeholders; we developed the overall design and cost estimate based on extrapolation from detailed sample designs.

The network design and cost estimate are discussed in detail in Section 6 below.

In summary, assuming a combination of aerial and underground construction and based on the existing utilities in each area, the full FTTP network deployment will cost $39.9 million, inclusive of OSP construction labor, materials, engineering, permitting, network electronics, drop installation, customer premises equipment (CPE), and testing (see Section 6). The cost per passing is $1,660 on average.

5.1.1.2 The Retail FTTP Approach Carries a Range of New and Increased Operating Costs

We urge that the Authority consider the full range of potential operating costs that are required to operate an adequate FTTP network. These costs are discussed in general below and spelled out in some detail (with underlying assumptions) in the financial model and in the spreadsheets in the appendices to this report.

Critically, it is important not to assume that the modest operating costs incurred during the Harborton pilot phase and even during expansion of the middle-mile network mean that additional costs will not present themselves during operations of a larger-scale FTTP network.

For example, customer service costs may be very limited for an FTTP network with only a few customers, but those early customers are most likely technology-savvy early adopters who do not have significant needs for day-to-day customer service support. In contrast, a customer base of hundreds or thousands of less technology-savvy consumers will present significant customer service costs associated with day-to-day operations and minor technology problems, many of which may not even be attributable to the network.

By way of illustration, consider the likelihood of receiving calls and complaints about poor-quality service that is actually attributable to the end-user's device or in-home Wi-Fi network and that has no relationship to the operations of the fiber network itself. To maintain customer loyalty and protect revenues, a provider must still take these calls and help customers resolve such issues.

Along the same lines, the Authority will face new costs for sales, marketing, billing, and collections that are not evident with the small customer base in the pilot area. These functions will require effort and funds in a way they do not for an enterprise network serving relatively few large institutional and ISP customers, as the Authority currently does.

Our analysis suggests that Shore-wide FTTP at a 36 percent take rate will entail annual operations and maintenance expenses of about $5.8 million.[40] This number is based on our experience with other public FTTP networks and our observations of the field since its infancy, but we caution

[40] For more detailed discussion of these expenses, please see Section 7.1.4.

that ESVBA's expenses could be higher than estimated—which would have a major impact on the sustainability of the network. By the same token, ESVBA could also realize some efficiencies that would enable it to reduce operating costs (the financial analysis below considers scenarios that entail both higher and lower operating expenses).

The operating costs included in our base case analysis represent the full range of expenses that comparable FTTP networks incur—from insurance and utilities to pole attachment fees. Some of these expenses will remain constant, while others will increase as the network expands and the customer base increases.

Among the more significant operating costs that ESVBA will incur are the following:

Staffing: Even leveraging existing staff to the greatest extent feasible, deploying and operating an FTTP network will require the addition of new staff—an estimated 8.5 full-time equivalent (FTE) new staff members in year one, rising to 18.5 FTE staff members across all disciplines by year four. ESVBA's labor expenses will total over $1.8 million by year four.

These numbers assume one shift of customer service representative support and one and a half shifts of customer technicians. If ESVBA were to implement full 24x7 staffing, the number of new employees and the network's labor expenses would rise.

It is important to note, too, that many of the new staff will be in roles that are new to ESVBA—so training for new and existing staff will be essential. Recruiting may present an additional challenge, as skilled personnel, particularly in network engineering and operations, are in great demand throughout the country.

Vendor maintenance contracts: We estimate this annual expense at $59,600 (10 percent of the accrued investment).

Locates and ticket processing: This essential task will account for about $52,100 in annual expenses.

Maintenance: Fiber and network maintenance costs are calculated at 0.25 percent of the total construction cost, per year. This is estimated based on a typical rate of occurrence in ESVBA's environment, and the cost of individual repairs. These costs will total roughly $94,300 once the network is built out—in addition to staffing costs for the personnel who maintain the fiber.

Pole attachment expenses: As ESVBA builds out the network, pole attachment fees will reach about $28,600 per year. We understand from ESVBA leadership that pole attachment fees have been minimal to date, but we caution against assuming that this situation would continue in the event of a larger build-out.

5.1.1.3 The Ubiquitous Retail FTTP Approach Requires a 36 Percent Take Rate at ESVBA's Current Pricing

CTC's financial analysts developed a financial analysis that examines the feasibility of ESVBA building and operating an FTTP network under a municipal retail model over a span of 20 years. The financial analysis—which is built on a range of cost and revenue assumptions—reflects a scenario in which ESVBA owns, operates, and provides retail voice, video, and data services to residents and businesses.

In brief summary, the financial model demonstrates that the cost of building and maintaining fiber requires that a 36 percent market share (or nearly 8,640 new subscribers) is required in order to maintain positive cash flow.[41]

The financial model is designed to be cash flow positive in year one, which is accomplished through startup funding and bond financing. Over time, given the cost to construct, maintain, and operate the FTTP network, the model indicates that a 36 percent take rate[42] of households and businesses passed will be required to maintain positive cash flow.[43]

In the base case analysis, we assume ESVBA offers three data services:

- A 25 Mbps download/12 Mbps upload service at $60 per month
- A 50 Mbps download/25 Mbps upload service at $86 per month
- A 100 Mbps download/50 Mbps upload service at $150 per month

This model assumes the Authority no longer offers its 10 Mbps download/5 Mbps upload service, and assumes local WISPs will embrace the market looking for such speeds.

The financial model is described in detail in Section 7.1 below.

5.1.1.4 CAF-II Funding Would Only Slightly Reduce Take Rate

Although this funding represents the most significant federal funding opportunity for the region since the Recovery Act broadband programs of eight years ago, the impact is still modest with respect to the potential for improving the economics of ubiquitous FTTP throughout the community. The challenge is that the additional revenue has relatively modest impact relative to the required revenue for the model to achieve positive cash flow.

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[41] This financial model is discussed in detail in Section 7 below, and spreadsheets of the financial model and analysis are included in the appendices.

[42] Indicates take rate in year 4.

[43] Based on the cost estimate in the engineering section below. Please note that these are solely financial calculations rather than market projections; we have not analyzed whether this required take rate is realistic.

The reason for this modest impact is that the dollars available through the federal funding program are based on the FCC's cost model for how to make profitable service of 10/1 Mbps on the part of an existing communications provider such as Verizon that already has infrastructure. That modest increment of funding, designed to move Verizon from a position of loss to one of profitability, is nowhere close to enough to enable the deployment of a next-generation network such as FTTP.

5.1.2 Option 2: Limited Retail Fiber-to-the-Premises in the Population Centers

This option represents a considerably reduced fiber footprint relative to the one presented above, in which 100 percent of residences and businesses on the Shore would have the potential to purchase fiber-based services.

In contrast, this option assumes that ESVBA builds its fiber network to a considerable portion of the Shore, but not to the most remote and distant locations. Our high-level calculation is that ESVBA could likely reduce capital costs by 50 percent while still providing the potential of service to approximately 80 percent of residences. (As with all broadband and other utility projects, the most remote locations represent the highest per-unit construction costs.)

This model would enable ESVBA to greatly reduce its capital cost and risk and still reach a considerable percentage of the community. That said, this model does not provide a solution for the remaining 10 to 20 percent of the community that ESVBA would not be able to reach. Indeed, the bulk of the spending would be in and around the towns but not in the remote areas.

While it may be tempting to assume that the remote areas could then be addressed through private investment in wireless or otherwise, we note that the economics of serving the remote areas only are not viable. Any provider that seeks to serve the entire Shore will need the more favorable economics of serving the populations centers to develop a viable model. By serving the easier-to-reach, lower-cost, more densely populated areas of the Shore, ESVBA would likely reduce the incentive of wireless service providers to build more extensively, if at all. Put otherwise, these areas are the most economically viable, for the private ISPs as well as for ESVBA. Whether public or private, a plan that addresses only these more viable areas effectively fails to address the needs of the rest of the Shore.

The challenge of this approach with regard to ESVBA's mission is unfortunately not mitigated by economics. There is still considerable risk to ESVBA in this reduced approach. As a result, we are concerned that this model reduces the likelihood of private investment in the most challenging last-mile areas, while simultaneously failing to deliver that investment through public means. And, as in the ubiquitous approach, this model would require some sort of financing, which ESVBA may have challenges in securing.

5.1.3 Option 3: Retail Service to Passings Located on Existing ESVBA Fiber Routes

This model for increasing ESVBA's residential FTTP footprint is the most economically viable, but challenging from a mission standpoint.

In this model, ESVBA would build fiber to homes and businesses located in relatively close proximity to its existing middle-mile fiber backbone that can be served with only the addition of a fiber drop cable from the backbone into the premises. That is, ESVBA would not need to construct any additional distribution fiber, conduit, or aerial strand. The cost of construction would be greatly reduced from the ubiquitous buildout on a per-home basis because of the proximity to the existing infrastructure, but we note that the cost is still not insignificant.

In this scenario, ESVBA could serve a maximum of 8,000 premises, which is about one-third of the premises in the two counties.

To achieve positive cash flow, the estimated capital cost of the network infrastructure in this model is $1.5 million (assuming a 15 percent take rate, or 1,200 passings)— 4 percent of the capital cost to build the ubiquitous retail model at a 36 percent take rate. The cost would increase if take rate were higher in order to fund the cost of additional drops and customer premises equipment (CPE).

We note that the Authority's current incremental buildout model recovers the Authority's investment in each passing in two years. Our model forecasts a longer recovery time as part of a comprehensive 20-year strategy.

As discussed in Section 7.2.2, this model assumes the Authority seeks $2.75 million in bonds to cover its capital expenses and initial operational expenses. We note that if the Authority has this level of cash on hand, it could feasibly use this strategy without needing to secure financing.

As with the partial build model, this effort would offer a cost-effective solution for connecting a relatively modest percentage of residences and businesses, but would reduce the likelihood of a solution for the remaining premises. In other words, the attractiveness of the residential market for private investment would be reduced by the fact that the more cost-effective locations have been served over ESVBA fiber.

Depending upon how aggressive ESVBA is in its buildout strategy, this model may require public financing. It is also important to note that if ESVBA were to accept CAF-II funds, full build-out in eligible census blocks would be required. This would mean that, in eligible census blocks, ESVBA would have to build to all premises—not only those that are close to and easily accessible from existing fiber.

In addition, because this approach would exclude a certain portion of the population, ESVBA would likely be subject to public scrutiny regarding the limited network expansion. It would also position ESVBA as a competitor (perceived or real) to the ISPs that ESVBA currently supports with its middle-mile wholesale services; especially if ESVBA were to serve lower-cost areas in this approach, it could discourage last-mile build-out by ISPs, and further reduce available service options.

We understand the frustration of the residents of the Shore who note that they can see ESVBA's fiber from their homes but cannot access services. The challenge, unfortunately, is that providing fiber-based services to that minority of premises would reduce the likelihood of viable and sustainable private investment to reach a higher percentage of the community.

5.1.4 Option 4: Incremental Retail Build-Out

Continuing an incremental build-out approach may prove a prudent strategy that can help achieve ESVBA's goals while minimizing its risks. There are two options for an incremental build-out that essentially take opposite approaches to a gradual build-out: one focuses on low-cost, high-demand areas, and the other targets hard-to-reach (generally more expensive, and less likely to see private deployment) areas.

The two offer distinct opportunities and risks for the Authority. Primarily, an incremental strategy will avoid ESVBA pursuing any significant financing, and does not necessitate a risky initial investment. Both strategies "move the needle," if only slightly, on broadband deployment on the Shore. Further, increased market presence may spur ISPs to become more aggressive in their own last-mile deployments to secure their respective customer bases. If the ISPs do not respond to the Authority's satisfaction, then ESVBA is positioned to accelerate one of the above retail FTTP approaches.

Building to low-cost, high-demand areas capitalizes on areas that can generate a return on ESVBA's investment, and will likely impact the greatest number of users on the Shore. However, deploying in these areas—potential markets for local ISPs—places the Authority in direct competition with providers that see high-return, high-demand areas as preferred territory. On the other hand, targeting hard-to-reach areas addresses that may not be served by private providers in the near to distant future may offer ESVBA little to no immediate return on investment, and may only impact a small number of users.

Both strategies may encounter opposition from residents and ISPs on the Shore. To residents, any targeted deployment may seem unfair if they are unable to benefit from the Authority's efforts. As indicated by our discussions with ISPs, any further retail market entry by the entity that sells wholesale access to support their last-mile deployments will be unpalatable.

The financial feasibility of these strategies is straightforward. In short, the Authority must obtain and maintain residential retail subscribership to recover its initial investment in each incremental build. The Authority may choose to deploy in an area that will not recover its initial investment, but must make up for that shortfall in other revenues from other Authority operations.

That said, the economics of each incremental build (i.e., the necessary deployment capital, subscriber take rate, and data product prices) must be considered on a case-by-case basis. We anticipate that the necessary take rates and subscriber fees would be quite high in both option 4a and 4b.

5.1.4.1 Option 4a – Incremental Retail Build-Out, Focused on Low-Cost, High-Demand Areas

If the Authority chooses to focus its incremental build-out efforts on low-cost, high-demand areas, it would offer a strategy that will offer the highest ROI, and impact a greater number of residents on the Shore than option 4b. However, this strategy will also place the Authority in direct competition with the ISPs it supports. Further, the probability of a local ISP eventually offering service in one of these less economically challenging areas is greater than in other areas. That is, the Authority may solve a problem that was soon to be solved.

As discussed above, this strategy may encounter pushback from both residents and local providers. We anticipate a stronger reaction from the providers because the Authority is competing in areas in which it is also providing the infrastructure for WISPs' transport needs. Indeed, our discussions with stakeholders revealed concerns of this nature.

5.1.4.2 Option 4b – Incremental Retail Build-Out, Focused on Hard-to-Reach Areas

In this option, the Authority would focus its efforts on hard-to-reach areas, using its resources to increase broadband availability in regions that prove difficult to deployment. The primary benefit of this approach is that it addresses the problem for communities that likely will not see private investment in the near future, due to the challenging economics of deployment in the area.

Like option 4a, this strategy may encounter pushback from both the community and the ISPs for similar reasons to that option. However, this option provides the Authority with a more defendable response to any criticism. By focusing its efforts on areas that are otherwise unserved (and likely to remain as such), the Authority is tackling the problem in underserved areas head-on.

5.2 Dark Fiber-to-the-Premises Options

In a dark FTTP model, ESVBA would construct dark FTTP infrastructure that it would lease to a private partner for service delivery to customers; the private partner(s) would "light" the network and offer retail services.

In this approach, ESVBA would be responsible for the cost to deploy the OSP infrastructure and, depending on the model, potentially the drop cable that connects the customer's home or business to the fiber network. In this model, the private partner would be responsible for placing and maintaining all network electronics and CPE, as well as network sales, marketing, and operations.

We note that these models will introduce a more aggressive competitor into the market, which may elicit strong reactions from existing ISPs. Although some may respond by competing more aggressively, likely the new entrant will force some out of the market. The Authority must carefully consider this reality before electing to pursue this approach.

There are two primary approaches to a dark FTTP model:

- A dark FTTP model in which ESVBA would deploy fiber infrastructure—including the fiber drop cables connecting the customer's premises to the distribution network—for lease to a private provider. The private provider would then add network and consumer electronics to offer retail services. Because this model is based on the agreement between the city of Westminster, Md., and its partner, Ting Internet, we refer to it as the Westminster Model.

- A dark FTTP model in which ESVBA would deploy fiber infrastructure for lease to a private partner, but *would not* deploy the fiber drop cable that connects the customer's premises to the FTTP network. The private partner would be responsible for constructing the fiber drop cables and providing network electronics and CPE to offer retail services. Because this model is based on the agreement between Huntsville (Ala.) Utilities and its private partner, Google Fiber, we refer to it as the Huntsville Model.

We note that each of these approaches carries potential advantages and disadvantages. While this "partnership" approach balances the skill sets of the public and private sectors, the Authority would have to seek financing via general obligation commitments from the counties or other public entities. Such financing carries considerable risk, and the cost of financing these models would require a higher take rate and subscriber fees to maintain positive cash flow.

The success of this model would clearly depend on ESVBA's ability to attract a private partner—which is more likely if the network were to reach the entirety of the Shore. In partnerships nationwide, including the two models discussed below, the agreed upon lease fees did not cover the entirety of the cost to deploy OSP infrastructure. Rather, the public entity viewed OSP costs as an investment in the community as a whole, and where possible, recovered the capital expense through other revenue sources. If the Authority were to pursue either of these models, it may need to accept lower partner lease fees, and recover its investment in OSP via other revenues.

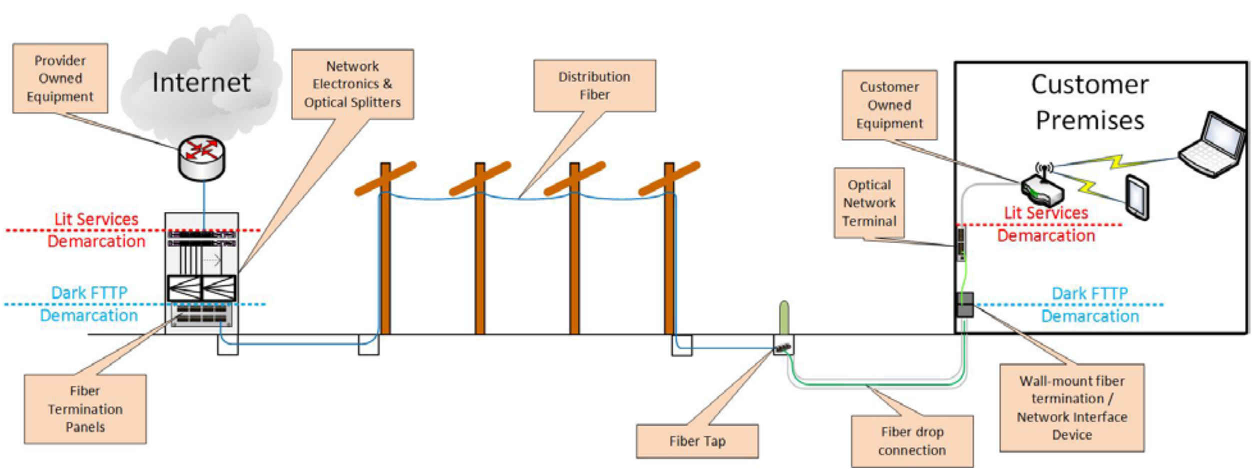
Further, any model that finances against the general obligation of the community (as may be required here) but does not serve the entire community will place the Authority under increased public scrutiny. Given this, our projections for these models are based on a ubiquitous build-out.

(We note that a build-out that focuses on population centers or targets those locations within close proximity to the existing fiber would be less financially risky than a fully ubiquitous deployment, but it would still require financing. And such targeted approaches could set ESVBA up for public scrutiny by excluding areas that are likely already excluded by the private sector because of an inability to achieve a reasonable ROI there.)

5.2.1 Option 5: Build and Lease Fiber-to-the-Premises Outside Plant Infrastructure and Fiber Drop Cables (Westminster Model)

In each of the dark FTTP models, ESVBA would be responsible for the FTTP infrastructure up to a demarcation point. In the Westminster Model, the Authority would be responsible for constructing and maintaining all the fiber infrastructure, including the drop cable that runs from the curb into a customer premises (Figure 5).

Figure 5: Demarcation Point Between ESVBA and Partner Networks in Westminster Model



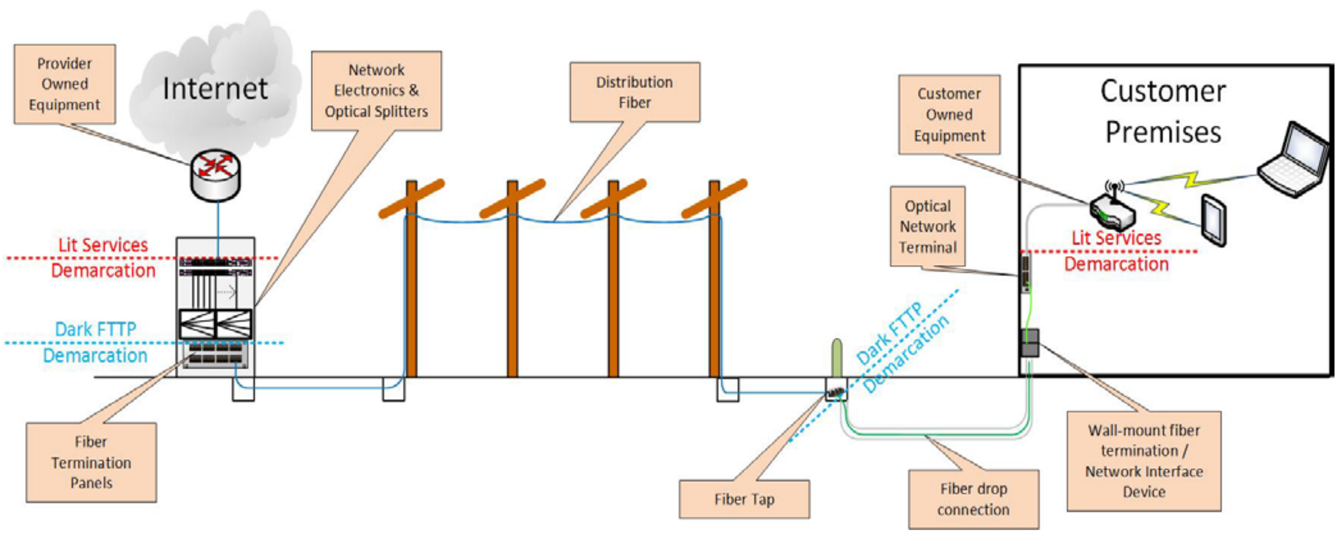
For comparison, we looked at the implications of this network obtaining and maintaining a take rate of 36 percent—the same take rate necessary for the ubiquitous FTTP retail model to cash flow. Ubiquitous dark FTTP infrastructure build-out would cost the Authority $37.9 million, necessitating a bond of $46.8 million. In addition, the private partner would need to obtain and maintain a take rate of 36 percent, and ESVBA would need to receive $9.60 per month per passing and $27.20 per month per subscriber from the private partner.[44] These fees are 1.6 times the fees agreed upon in Westminster.[45]

We assess the financial implications of this model in Section 7.3.

5.2.2 Option 6: Build and Lease Fiber-to-the-Premises Outside Plant Infrastructure (Huntsville Model)

In the Huntsville Model, the Authority would construct and own the network infrastructure throughout the community up to a demarcation point in the public right-of-way (PROW), and the private partner is responsible for connecting drop cables from the PROW into the customer's premises. See Figure 6, below.

Figure 6: Demarcation Point Between ESVBA and Partner Networks in Huntsville Model



Because the Authority would not be responsible for drop cables, the network take rate would not affect the financial viability of the network for the Authority. Given this, we only project a necessary per-passing fee from the private partner.

A ubiquitous dark FTTP infrastructure build-out would cost the Authority over $29.2 million, necessitating a bond of $39.8 million. To cash flow, ESVBA would need to receive $16.13 per

[44] Total deployment costs and the necessary financed amount will increase as take rates increase.
[45] As discussed in Section 7.3, charging the same fees as Westminster will generate a cumulative cash deficit of roughly $25.9 million by the end of year 20.

month per passing from the private partner, or 2.15 times the fees obtained agreed upon in Huntsville.[46]

The assess the financial implications of this model in Section 7.4.

5.3 Middle-Mile Wholesale Services Options

ESVBA may elect to continue to pursue a middle-mile wholesale services option, in which it provides middle-mile connectivity to local ISPs, leveraging the providers' strengths to facilitate last-mile deployment. Although these options will not immediately achieve the Authority's goals, they do offer a lower-risk strategy than the above six options.

Depending on the available infrastructure, this strategy may require deploying additional network extensions. For these extensions to be feasible, any Authority capital spent on network extensions must be recovered either by EVPL lease fees (i.e., wholesale contracts with ISPs), or by revenues from other sources within the Authority. That is, the feasibility of each extension would be on a case-by-case basis, and as such, we cannot accurately project the financial implications of these strategies in the scope of this analysis.

Further, we note that these strategies do not address ESVBA's goal of ubiquity. Indeed, they are similar to ESVBA's current operating model, which has not resulted in ubiquitous service to the entirety of the Shore. That said, we feel these strategies may continue to gradually move the Authority toward its goals without the need for significant capital investment.

5.3.1 Option 7: Offer Middle-Mile Wholesale Services and Encourage ISPs to Leverage Middle-Mile Fiber

This model focuses on ESVBA continuing to provide wholesale services to local ISPs to meet the needs of the residential market. Notably, this model would not require changing anything about ESVBA's commercial and institutional customer practices. Rather, it represents a less costly approach, certainly in the short term, for addressing last-mile expansion to residential customers.

5.3.1.1 Pricing Strategy Might Encourage New Investment Through Cautious Case-by-Case Incentive-Based Pricing for WISPs

As the pricing study we completed in 2016 demonstrated, ESVBA is neither the lowest- nor the highest-cost provider when compared to providers serving similar territories. Our analysis does not suggest requirement need to lower prices for ISPs. ESVBA has lowered prices multiple times in recent years and ESVBA pricing aligns with peer providers in the region and nationally. Further,

[46] As discussed in Section 7.4, charging the same fees as those agreed upon in Huntsville will generate a cumulative cash deficit of nearly $36.1 million after 20 years.

regardless of the expansion strategy adopted, it is critical that ESVBA maintains a solid financial position to support expansion and equipment replenishments.

That said, ESVBA could consider strategic pricing mechanisms in light of its mission to enable increased last-mile deployment. Modest pricing adjustments may be merited as incentives for last-mile investment, based on enforceable, verified build-out targets.

One way to accomplish might be to offer credits on fees paid *after* verification of deployment. To be clear, we are not suggesting retroactive credits based on past deployments; rather, so long as the arrangement is agreed to in advance, the strategy would create incentives for the ISP to deploy in the last mile. In this way, ESVBA could prudently use its pricing as a means of spurring deployment and increase its own middle-mile business in the process—but do so in a way that does not substantially risk ESVBA's current financial stability or run the risk of reducing pricing without seeing the benefits of expanded last-mile deployment.

We note that enacting a credits program, even for 100 percent of the cost of services, will not effectively move the needle for ISPs, in terms of total deployment costs. Additionally, there would be increased operational costs to the Authority to verify, track, and deliver credits to ISPs. However, this extension of goodwill might have a slight positive impact on last-mile deployments.

On the other side of the equation, we note that ISPs will always ask for lower prices, and that our study referenced above indicates that ESVBA's prices are in line with the regional market. Before adopting this strategy, we encourage the Authority to consider the impact its current approach is making on its goals of last-mile deployment. Although adjusting pricing may help in specific areas, unless the new price can significantly change the economics of deployment, this strategy may continue to elicit the same results.

5.3.1.2 This Option Carries the Risk that Private Investors Will Fail or Not Follow Through

Like the other options that the Authority has before it, this one is neither cost-free nor risk-free.

If ESVBA itself does not build in the last mile, the community runs the risk that the private sector will fail to do so. This is a significant concern, and frankly, there is reason for concern given that last-mile residential deployment on the part of the private sector has been slower than many members of the community had hoped.

One potential strategy that aligns with this option to mitigate risk would be similar to that set forth in Mr. Peter Lalor's suggested model.[47] In the interest of preventing unfair competition and unkept promises by the ISPs, and promoting timely expansion and efficient use of the existing

[47] See Appendix B.

network, the Authority would coordinate with the WISPs to determine "domain" over potential passings. After this determination, a "shot clock" would start, requiring passings to be served within a given amount of time. While we applaud the goals in this strategy, we caution that the Authority will face challenges obtaining this level of cooperation from the WISPs, and further, we cannot comment on the Authority's regulatory power to enforce such a model. Rather, this opinion must come from an experienced telecommunications attorney.

The Authority's current wholesale policy for deployments that require a network extension—that is, allowing unlimited Ethernet Virtual Private Line (EVPL) connections, but necessitating a build-out plan, budget, and authority for direct residential connections—addresses this risk. We also find the Authority's policy of continuing to charge for services, even if ISPs do not follow through with deployment after an extension is built, to be a prudent effort to mitigate risk to ESVBA.

We note that ESVBA's current incremental residential footprint expansion strategy could be resumed in future years if private investment does not materialize as promised and hoped.

We do not suggest minimizing this risk or concern. Rather, we recommend strategies that might improve the likelihood of private investment, even if only slightly. We note also that ESVBA's own residential footprint expansion plans could be resumed in future years if private investment does not materialize as promised and hoped.

5.3.2 Option 8: Offer Middle-Mile Wholesale Services and Obtain Build-Out Commitments through Assistance in Obtaining Grant Funding

As an extension of option 7, ESVBA could leverage its experience as an infrastructure operator to assist local ISPs in applying for grant funding in exchange for middle-mile services backed by build-out commitments. This strategy could either focus on supporting grant and loan applications to attract outside capital to the Shore as a whole, or focus on supporting and encouraging bids for CAF-II funding to facilitate construction in the least cost-effective areas, or both. Each of these strategies is discussed below.

5.3.2.1 The Model Allows for Creative Partnering on Federal Funding Opportunities

The potential CAF-II funding of just under $1 million per year for a decade could have some impact with respect to the needs of a wireless internet service provider that is already deploying in the two counties. (The potential for an additional $1 million in revenues would have more impact on a WISP strategy than on an ESVBA strategy because the capital cost of deployment is considerably lower than that of FTTP.) At the same time, and in a very positive vein, the federal funds are likely to have rigorous conditions attached to them, as well as verification and enforcement mechanisms that could serve to ensure that the funds are used to reach the Shore's most remote areas. Coordination among ISP and ESVBA, as well as support for a bid, could thus secure revenues that would *require* deployment in the least-financially viable areas of the region.

5.3.2.2 This Model Maximizes Capital Inflows from Outside the Shore

By creating optimal conditions for federal funding, both in loan and grant form, this strategy maximizes the amount of outside funding coming onto the Shore to invest in broadband infrastructure and services. This represents a critical benefit in that the broadband challenges in the two counties is addressed this way not only by local dollars but also by federal and private investments.

5.3.2.3 This Model Rewards Cooperation and Collaboration Between Public and Private Sectors

Both in recent months and in the past, ESVBA has made considerable efforts to coordinate with and cooperate with private ISPs, and to solicit input regarding optimal middle-mile expansion strategies. This approach is well conceived and absolutely necessary.

This model facilitates coordination—and rewards it—in part because it reduces the risk of tension between ESVBA and its ISP customers. Ongoing communications serve not only to facilitate mutually beneficial investments and processes, but also to avoid potential hazards.

Our concern is that absent communication between ESVBA staff and WISPs, there is a risk that either entity could take steps that are mutually problematic. Furthermore, and most importantly, the two counties would suffer as a result of the reduced investment and as a result of losing outside investment.

6 Engineering Analysis and Cost Estimation

Over the course of this project, CTC staff and ESVBA staff have had an ongoing discussion about FTTP cost estimates, both with respect to capital cost and operations cost. The costs CTC has developed, based on our experience around the country, have been consistently higher than those developed by ESBVA staff in a range of areas, including with respect to utility pole make-ready, customer service support, and other matters.

At the direction of ESVBA staff and Ms. Elaine Meil of the ESVBA Board of Directors, CTC has used ESVBA's lower cost assumptions in developing the financial analysis herein. However, based on CTC's experience, we believe the actual capital expenses and operating costs will be higher than those included in the financial projections at ESVBA's direction. Higher costs will have a material outcome. CTC therefore notes that this report and supporting documents provide financial projections based upon ESVBA's cost assumptions, not those we have recommended. In our view, the projections herein should therefore be considered an absolute best-case outcome rather than a conservative analysis.

6.1 Fiber-to-the-Premises Design and Cost Estimate

CTC prepared two high-level network design and cost estimates for expanding ESVBA's current network to provide FTTP service in Accomack and Northampton Counties. The cost estimates provide data relevant to assessing the financial viability of the network deployment and to developing a business model for a potential construction effort. These estimates also enable financial modeling to determine the approximate revenue levels necessary for the Authority to service any debt incurred in building the network.

The design and cost estimates are underpinned by data and insight gathered by CTC engineers through detailed discussions with ESVBA staff regarding the design principles ESVBA has used to expand the FTTP network thus far, as well as costs ESVBA has experienced in bringing FTTP service to customers. The estimates assume that design, engineering, and construction efforts will continue to be performed in-house by new or existing ESVBA staff using existing methodologies.

The first cost estimate is for a full FTTP network where ESVBA expands the network to pass all businesses and residences in the Counties. The second estimate is for expanding service to businesses and residences that are already passed by existing ESVBA fiber. This second scenario assumes that customers will only be connected if the premises can be reached using only a service drop, without constructing any additional aerial strand or conduit.

6.2 Cost Estimate for a Ubiquitous Fiber-to-the-Premises Build

Using cost assumptions provided by ESVBA, the full FTTP network deployment may cost approximately $39.9 million,[48] inclusive of OSP construction labor, materials, engineering, network electronics, drop installation, CPE, and testing (see Section 6.2.4). The cost per passing would be $1,660 on average.

Table 3: Estimated Full Area FTTP Cost (36 Percent Take Rate)

Cost Component	Total Estimated Cost
OSP	$29.1 million
Central Network Electronics	$470,000
FTTP Service Drop and Lateral Installations	$8.6 million
CPE	$1.7 million
Total Estimated Cost:	$39.9 million

The estimated total cost breakdown assumes a percentage of residents and businesses that subscribe to the service, otherwise known as the penetration rate or the "take rate," of 36 percent, which is within the range of penetration rates that may exist in a market where both the telephone companies and fixed wireless providers also provide broadband service. This take rate of 36 percent is necessary for the network to achieve positive cash flow over the course of 20 years. We note if this take rate were to change, total costs would change as well.

6.2.1 Network Design and Cost Assumptions

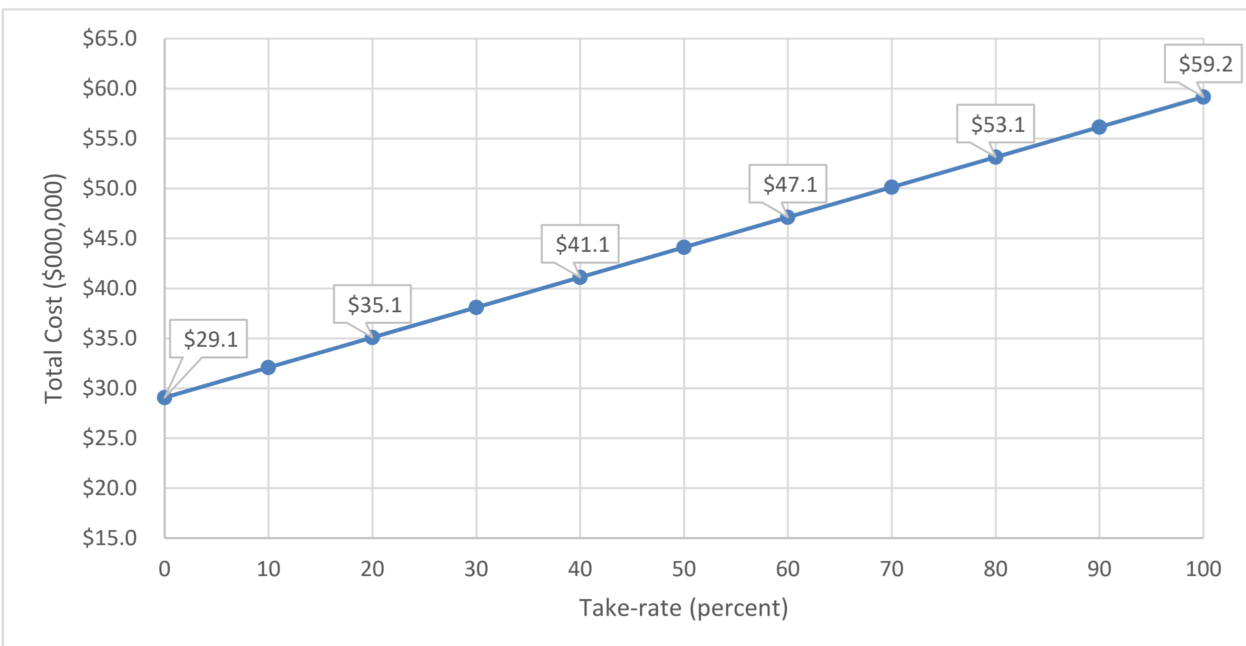
At ESVBA's request, CTC included the following assumptions into this cost estimate:

- ESVBA will use the four existing ESVBA hub facilities to house network electronics and provide backhaul to the internet
- The network will pass all homes and businesses in Accomack and Northampton Counties
- Network electronics will be housed only at hub locations, using passive optical splitters in the field
- Subscribers will be served from 1x32 GPON splitters
- Aerial fiber will be installed in the communications space

[48] The cost estimate developed by CTC for constructing a ubiquitous FTTP network totals roughly $65.7 million. Compared to the estimate presented in this report, CTC's estimate includes increased OSP engineering costs of roughly $15.3 million, increased QA/QC costs of roughly $8 million, and increased make ready costs, bringing the general OSP construction costs to roughly $27.2 million. CTC believes these estimates more closely reflect our experience with similar projects around the country.

- Underground fiber will rely primarily on plowing or trenching, using directional boring only when necessary
- There will be little or no cost for make ready and permitting as allowed by ESVBA's agreement with pole owners in the area
- Access points on the backbone for service drops are up to 1,000 feet apart
- The shared, per-subscriber cost of the OLT optic is approximately $50
- Typical service installation cost is approximately $1,200, inclusive of drop materials, installation and splicing labor, and CPE
- The customer will reimburse ESVBA for service drop installation including a ring cut and splicing if necessary
- OSP engineering costs will total approximately $1 million for ESVBA staffing during the project
- Quality control and quality assurance costs will total approximately $2 million for ESVBA staffing during the project

Figure 7: Total Estimated Cost Versus Take Rate



The cost is roughly linear by take rate as the cost of adding additional subscribers is a fixed cost.

Actual costs may vary due to factors that cannot be precisely known until the detailed design is completed, or until construction commences. These factors include: 1) costs of private easements, 2) utility pole replacement and make-ready costs, 3) variations in labor and material costs, 4) subsurface hard rock, and 5) the ESVBA's operational and business model. We have incorporated suitable assumptions to address these items based on our experiences in similar markets.

The total cost of operations will also vary with the business model chosen and the level of existing resources that can be leveraged by ESVBA.

6.2.2 Network Sample Designs

Our model develops the total design and cost estimate based on extrapolation from detailed sample designs. Figure 8 provides the sample design areas used. Figure 9 provides a close-up view of a sample design area.

Figure 8: Sample Design Areas Used in Model

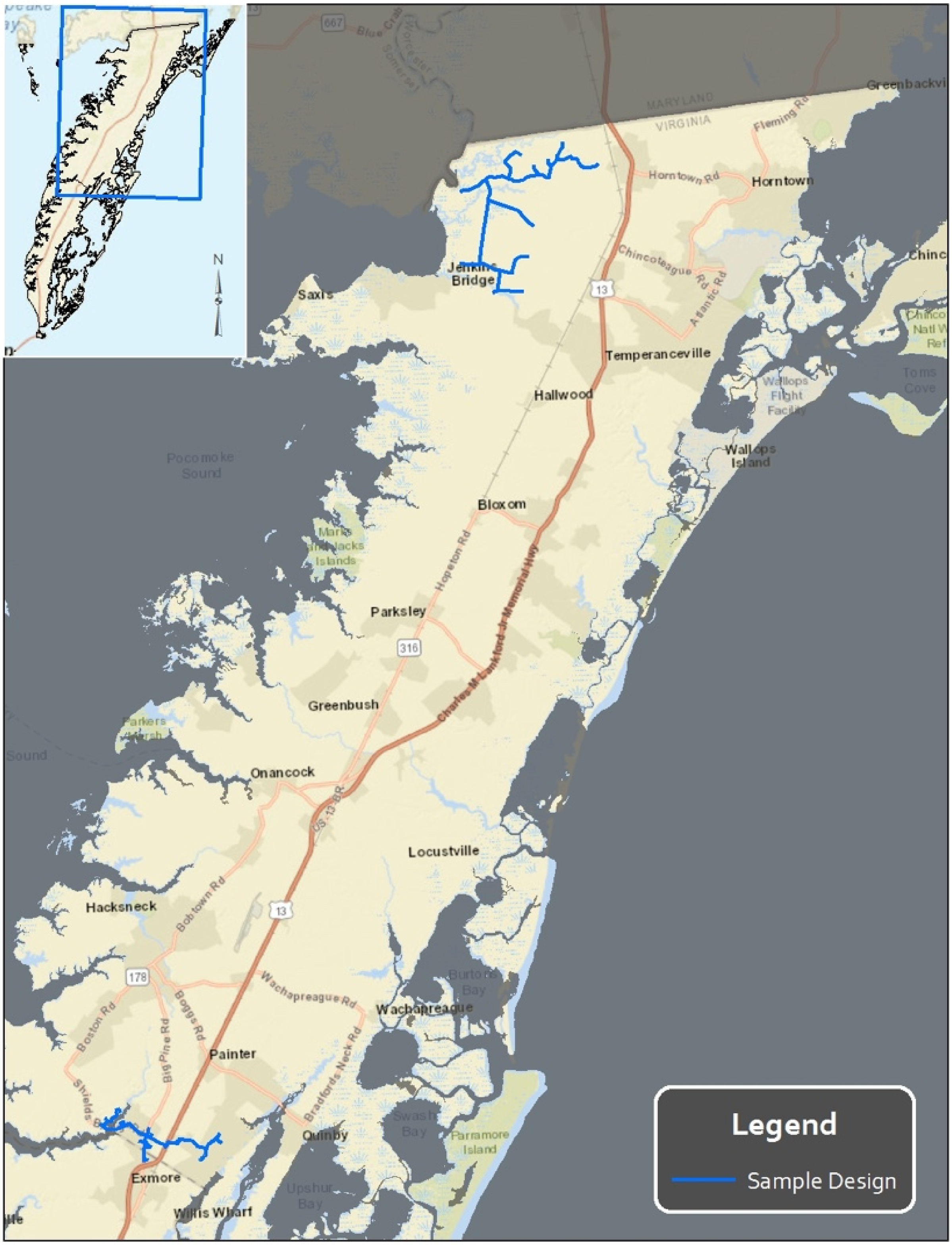


Figure 9: Sample Design Area Close-up

6.2.3 OSP Cost Estimation Methodology

As with any utility, the design and associated costs for construction vary with the unique physical layout of the service area—no two streets are likely to have the exact same configuration of fiber optic cables, communications conduit, underground vaults, and utility pole attachments. Costs vary further due to soil conditions, such as the prevalence of subsurface hard rock; the condition of utility poles and feasibility of “aerial” construction involving the attachment of fiber infrastructure to utility poles; and crossings of bridges, railways, and highways.

To estimate costs, we extrapolated the costs for strategically selected sample designs on the basis of street mileage and passings. Specifically, we developed sample FTTP designs to generate costs per passing for an area that represents approximately the population density of the service area as a whole. Densities were calculated using miles of road in Accomack and Northampton Counties and the number of occupied residential and commercial buildings in the area based on GIS and census data.

We incorporated construction design drawings and unit costs from previous ESVBA projects to inform our assumptions about typical costs for this estimate. Based on our discussions with ESVBA, we assumed that approximately 80 percent of new fiber would be located aerially on utility poles with the rest being underground.

The assumptions, sample designs, and cost estimates were used to extrapolate a cost per passing for the OSP. This number was then multiplied by the number of passings in the service area based on each County's address, parcel, or building data. The actual cost to construct FTTP to every premises in the area could differ from the estimate due to changes in the assumptions underlying the model. For example, if make ready and pole replacement costs are too high, the network would have to be constructed underground—which could significantly increase the cost of construction. Further and more extensive analysis would be required to develop a more accurate cost estimate across the entire service area.

6.2.4 Cost Estimate Breakdown

The cost components for OSP construction include the following tasks:

- ***Engineering*** – assumes engineering will be performed by ESVBA staff using similar methodologies as have been employed thus far. This includes system-level architecture planning, preliminary designs, and field walk-outs where necessary to determine candidate fiber routing. ESVBA notes that they have had very low engineering costs as their agreement with area pole owners requires only that they report which poles are used and the height of attachments. They are not required to produced detailed drawings or apply for permits for aerial construction. ESVBA estimates OSP engineering at approximately $1 million for internal staffing costs for the ubiquitous build. No engineering costs are included in the backbone area estimate.

- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance. The quality control/quality assurance is estimated at approximately $2 million for the ubiquitous build. No QA/QC costs are included in the backbone area estimate.

- ***General OSP Construction*** – consists of all labor and materials related to "typical" underground or aerial OSP construction, including conduit placement, utility pole make-ready construction, aerial strand installation, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities. General OSP construction is estimated at roughly $21.7 million for the ubiquitous build. No general OSP construction costs are included in the backbone area estimate.

- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables. Backbone and distribution plant splicing is estimated at roughly $2.2 million. No backbone or distribution splicing costs are included in the backbone area estimate.

- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures which interconnect the fiber distribution plant with the backbone, terminating backbone fiber cables within the hubs, and testing backbone cables. The backbone hub, termination, and testing cost is estimated at roughly $2.2 million. No backbone hub, termination, and testing costs are included in the backbone area estimate.

- ***Backbone Network Electronics*** – includes material and labor costs of installing routers, switches, OLTs, and optics as well as licensing and maintenance fees. ESVBA currently has a backbone network capable of significant additional capacity without a significant investment in additional electronics. The ubiquitous build estimate includes additional distribution switches and OLTs while the backbone area build estimate includes only additional OLT optics to support new subscribers. The backbone network electronics cost is estimated at approximately $470,000 for the ubiquitous build and approximately $61,000 for the backbone area build.

- ***Subscriber Activation*** – consists of all costs related to fiber service drop and CPE installation, including OSP construction on private property, building penetration, inside plant construction to a typical backbone network service "demarcation" point, and all materials and labor related to the termination of fiber cables at the demarcation point. Based on experience, ESVBA estimated and average cost of $1,200 per subscriber, including $1000 for the service drop, $100 for installation labor, and $100 for CPE. Assuming a take rate of 36 percent, the subscriber activation costs are estimated at roughly $10.4 million for the ubiquitous build and roughly $1.5 million for the backbone area build at a 15 percent take rate.

6.2.4.1 OSP Costs

In terms of OSP, the estimated cost to construct the proposed FTTP network is roughly $29.1 million, or about $1,200 per passing.[49] As discussed above, the model assumes a mixture of aerial and underground fiber construction based on estimates provided by ESVBA. Table 4 provides an

[49] The passing count includes individual single-unit buildings and units in small (less than 20) multi-dwelling and multi-business buildings as single passings. The passings count does not include multi-dwelling and multi-business buildings over 20 units. Larger MDUs often have restrictions on which providers can offer services.

overview of the OSP construction costs per passing and per mile. Table 4 provides a breakdown of the estimated OSP costs for the ESVBA. (Note that the costs have been rounded.)

Table 4: Estimated OSP Costs Per Passing and Per Mile

Cost Estimate	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost Per Plant Mile
High End	1158.3	$29,100,000	24,000	$1,200	$25,000

Table 5: Estimated Backbone OSP Construction Costs

Cost Component	Total Estimated Cost
OSP Engineering	$1 million
Quality Control/Quality Assurance	$2 million
General OSP Construction	$21.7 million
Backbone and Distribution Plant Splicing	$2.2 million
Backbone Hub, Termination, and Testing	$2.2 million
Total Estimated Cost:	$29.1 million

Costs for aerial and underground placement were estimated using available unit cost data provided by ESVBA for materials and labor for placing, pulling, and plowing fiber. The material costs were generally known with the exception of unknown economies of scale and inflation rates, and barring any sort of phenomenon restricting material availability and costs. Where unit costs were not available, labor and material cost estimates for construction in comparable markets were used.

Aerial construction entails the attachment of fiber infrastructure to existing utility poles, which could offer significant savings compared to all-underground construction, but increases uncertainty around cost and timeline. Costs related to pole remediation and "make ready" construction can make aerial construction cost-prohibitive in comparison to underground construction. At ESVBA's request, this estimate assumes no make ready costs as the Authority's agreement with area pole owners has allowed them to place fiber thus far with little or no make ready.[50]

[50] CTC notes that make ready typically represents a significant portion of the total aerial build cost of a fiber network and that the increased scale of a ubiquitous build may result in increased make ready costs for ESVBA.

While anomalies and unique challenges will arise regardless of the design or construction methodology, the relatively large scale of this project is likely to provide ample opportunity for variations in construction difficulty to yield relatively predictable results on average.

We assume underground construction will consist of a mix of plowing, trenching, and, when necessary, directional drilling. The design model assumes a single 1.25-inch, flexible, High-Density Polyethylene (HDPE) conduit over underground distribution paths.

6.2.4.2 Central Network Electronics Costs

Upgrades to the central network electronics will cost roughly $460,000, or about $20 per passing, based on an assumed take rate of 36 percent.[51] (These costs may increase or decrease depending on take rate and the costs may be phased in as subscribers are added to the network.) Central network electronics consist of the electronics to connect subscribers to the FTTP network at the core and hubs. Table 6 lists the estimated costs for each segment.

Table 6: Estimated Central Network Electronics Costs

Network Segment	Subtotal	Passings	Cost per Passing
Distribution Electronics	$46,000	24,000	$2
Access Electronics (OLT)	$413,000	24,000	$17
Central Network Electronics Total	$460,000	24,000	$20

The distribution electronics connect the access electronics to ESVBA's transport network. This means adding additional 10 gigabit switching capacity to connect new OLTs. The cost of distribution electronics for the network is roughly $46,000.

The access network electronics at the hubs are optical line terminals (OLTs) which connect the subscribers' CPE to the FTTP network. The cost of the access network electronics for the network is roughly $424,000 or about $50 per subscriber. These costs are based on a take rate of 36 percent and include optical splitters for that take rate.

6.2.4.3 Customer Premises Equipment and Service Drop Installation Costs

CPE are the subscriber's interface to the FTTP network. For this cost estimate, we assumed a CPE price of $99 per customer based on the equipment commonly installed by ESVBA.

[51] The take rate affects the electronics and drop costs, but also may affect other parts of the network, as ESVBA may make different design choices based on the expected take rate.

Each activated subscriber would also require installation of a fiber drop cable and related electronics, which would cost about $1,200 per subscriber, or roughly $10.4 million total (assuming a 36 percent take rate).

The drop installation cost is the biggest variable in the total cost of adding a subscriber. A short aerial drop can cost as little as $250 to install, whereas a long underground drop installation can cost upward of $3,000. (We estimate an average of $1000 per drop installation from an average drop length of approximately 500 feet based on our model, which derives the average length from the average property frontage.)

The other per-subscriber expenses include the cost of the optical network terminal (ONT) at the premises, a portion of the optical line termination (OLT) costs at the hub (as discussed in the previous section), the labor to install and configure the electronics, and the incidental materials needed to perform the installation. The numbers provided in the table below are averages based on ESVBA's experience to date, and will vary depending on the type of premises and the internal wiring available at each premises.

Table 7: Per-Subscriber Cost Estimates

Construction and Electronics Required to Activate a Subscriber	Estimated Average Cost
Drop Installation and Materials	$1000
Subscriber Electronics (ONT and OLT)	$100
Total	**$1,200**

6.3 Cost Estimate for Customers Located on Existing ESVBA Fiber Routes

Using cost assumptions provided by ESVBA, deploying FTTP service to premises passed by existing ESVBA fiber may cost approximately $1.5 million, inclusive of OLT network electronics, service drop materials and installation, CPE, and testing (see Table 8). In this scenario, the estimated total cost breakdown assumes a take rate, of 15 percent, which is the take rate necessary for the network to achieve positive cash flow in this model. As with the ubiquitous model, any change in the network take rate will affect total construction costs.

Table 8: Estimated Backbone Area FTTP Cost (15 Percent Take Rate)

Cost Component	Total Estimated Cost
Central Network Electronics	$61,000
FTTP Service Drop and Lateral Installations	$1.2million
CPE	$240,000
Total Estimated Cost:	$1.5 million

This scenario includes only customers that can be served by building a service drop directly from the existing fiber backbone. In CTC's estimation, this would include customers within roughly 500 feet of backbone fiber, totaling about 8,000 passings, but availability would be determined by the ability to reach each customer with only a service drop, not by distance from the fiber.

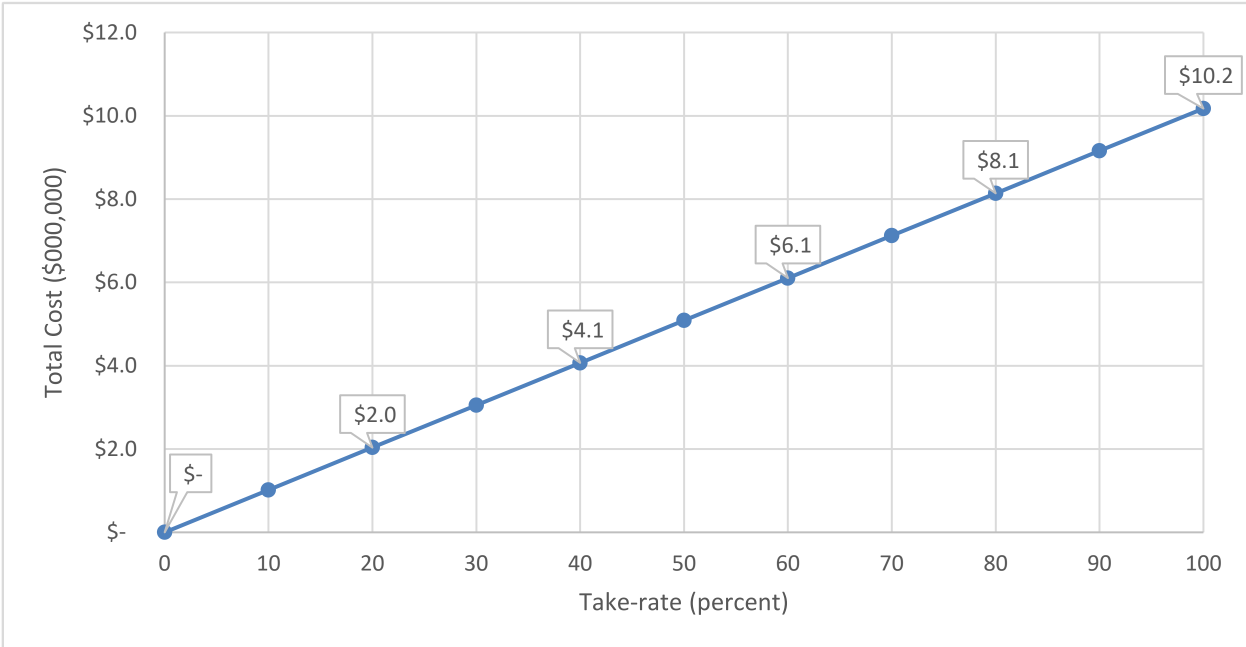
The estimate does not include costs for additional engineering, quality assurance, quality control, conduit, aerial strand, make ready, backbone fiber, or feeder fiber. ESVBA estimates that it is capable of supporting up to 100 percent of the passings in this model without investing in network electronics beyond optics for the OLTs.

6.3.1 Network Design and Cost Assumptions

At ESVBA's request, CTC included the following assumptions into this cost estimate:

- Include only customers that can be reached by a service drop without constructing additional aerial strand, conduit, or fiber, totaling roughly 8,000 passings
- ESVBA will use the four existing ESVBA hub facilities to house network electronics and provide backhaul to the internet
- Aerial fiber will be installed in the communications space
- Underground fiber will rely primarily on plowing or trenching, using directional boring only when necessary
- Network electronics will be housed only at hub locations, using passive optical splitters in the field
- Subscribers will be served from 1x32 GPON splitters connected at the existing backbone
- Access points on the backbone for service drops are up to 1,000 feet apart
- The shared, per-subscriber cost of the OLT optic is approximately $50
- There will be no additional central electronics costs required beyond the OLT optic
- There will be no costs for engineering, quality assurance, or quality control
- Typical service installation cost is approximately $1,200, inclusive of drop materials, installation and splicing labor, and CPE
- The customer will reimburse ESVBA for service drop installation including a ring cut and splicing if necessary

Figure 10: Total Estimated Cost Versus Take Rate



The cost is roughly linear by take rate as the cost of adding additional subscribers is a fixed cost. In our estimates, CTC used an average subscriber activation cost of $1,200 provided by ESVBA, inclusive of service drop installation and CPE and a shared cost of the OLT at roughly $50 per customer.

Actual costs may vary due to factors that cannot be precisely known until the detailed design is completed, or until construction commences. These factors include: 1) costs of private easements, 2) utility pole replacement and make-ready costs, 3) variations in labor and material costs, and 4) the ESVBA's operational and business model. We have incorporated suitable assumptions to address these items based on our experiences in similar markets.

The total cost of operations will also vary with the business model chosen and the level of existing resources that can be leveraged by ESVBA.

7 Financial Models and Analysis

This section examines the feasibility of the Authority using four of the above options to bring last-mile connectivity to the Shore, including:

- Option 1: Ubiquitous retail FTTP throughout the Shore
- Option 3: Retail service to passings located on existing ESVBA routes
- Option 5: Build and lease FTTP OSP infrastructure and fiber drop cables (Westminster Model)
- Option 6: Build and lease FTTP OSP infrastructure (Huntsville Model)

This analysis uses the cost estimates presented in Section 6 to illuminate necessary metrics, including: take rates, financing, and pricing—both from customers and potential network operating partners—for the Authority to operate cash-positive annually.[52]

7.1 Ubiquitous Retail Model

The financial analysis in this section assumes the Authority expands its current fiber assets, and owns, operates, and provides retail data services to residential and business customers via a fully FTTP network Shore-wide. This financial analysis is based on several assumptions (outlined below and further detailed in the spreadsheet in Appendix F).

One goal of this analysis is to illuminate the financial implications of the expansion as a discreet effort, independent of the Authority's current operations. It is important for the Authority to understand the specific factors necessary for this model to operate cash positive. The addition of existing or projected revenue from the Authority's current operations will obscure the financial implications of this model. Given this, we limit our discussion of cash flows in this model to only those generated by the new expansion.

Please note that we used a "flat" model in the analysis (i.e., we did not include inflation and salary cost increases because we assume that these operating cost increases will be offset and passed on to subscribers in the form of increased prices). Models that add an inflation factor to both

[52] Over the course of this project, CTC staff and ESVBA staff have had an ongoing discussion about FTTP cost estimates, both with respect to capital cost and operations cost. The costs CTC has developed, based on our experience around the country, have been consistently higher than those developed by ESBVA staff in a range of areas, including with respect to utility pole make-ready, customer service support, and other matters. At the direction of ESVBA staff and Ms. Elaine Meil of the ESVBA Board of Directors, CTC has used ESVBA's lower cost assumptions in developing the financial analysis herein. However, based on CTC's experience, we believe the actual capital expenses and operating costs will be higher than those included in the financial projections at ESVBA's direction. Higher costs will have a material outcome. CTC therefore notes that this report and supporting documents provide financial projections based upon ESVBA's cost assumptions, not those we have recommended. In our view, the projections herein should therefore be considered an absolute best-case outcome rather than a conservative analysis.

revenues and expenses typically greatly overstate future cash flow because net revenues are unlikely to increase as quickly as inflation. At best, the provider will be able to match expenses increases with a dollar-for-dollar rate increase, which is what the flat model represents.

The model assumes that subscribership for data services will ramp up over years one through four, and then remain steady.

7.1.1 Ubiquitous Retail Model Overview

The financial model is designed to be cash flow positive in year one; which is accomplished through bond financing. **Over time, given the cost to construct, maintain, and operate the FTTP network, the model indicates that a 36 percent take rate[53] of households and businesses passed will be required to maintain positive cash flow.[54]** That is, a 36 percent take rate, this model would provide service to nearly 8,640 passings.

In this model, we assume the Authority offers three data services at its current pricing and speeds:

- A 25 Mbps download/12 Mbps upload service at $60 per month
- A 50 Mbps download/25 Mbps upload service at $86 per month
- A 100 Mbps download/50 Mbps upload service at $150 per month

As noted above, this model assumes the Authority no longer offers its 10 Mbps download/5 Mbps upload service, and assumes local WISPs will embrace the market looking for such speeds.

We assume that 80 percent of subscribers will subscribe to the 25/12 Mbps service, 18 percent of subscribers will purchase 50/25 Mbps service, and 2 percent of subscribers will purchase 100/50 Mbps service.

We assume that all new subscribers will be charged a one-time $250 connection fee prior to receiving services.

We have included a financial summary for this model in Table 9.

[53] Indicates take rate by the end of year four.
[54] Based on the cost estimate in Section 6.

Table 9: Ubiquitous Retail Model Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$453,036	$6,892,080	$6,892,080	$6,892,080	$6,892,080
Total Cash Expenses	(923,350)	(2,197,590)	(2,197,590)	(2,197,590)	(2,197,590)
Depreciation	(574,220)	(2,361,320)	(2,280,130)	(2,266,130)	(2,266,130)
Interest Expense	(597,500)	(2,058,990)	(1,613,740)	(1,044,630)	(318,120)
Taxes	-	-	-	-	-
Net Income	$(1,642,034)	$274,180	$800,620	$1,383,730	$2,110,240

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$50,886	$579,080	$1,708,110	$2,941,300	$4,203,150
Depreciation Reserve	-	2,406,140	4,730,050	6,564,150	8,970,780
Debt Service Reserve	597,500	2,147,500	2,147,500	2,147,500	2,147,500
Total Cash Balance	$648,386	$5,132,720	$8,585,660	$11,652,950	$15,321,430

Although this model will not generate a positive net income in year one, we assume the financed amount will cover the shortfall, and the Authority will finish year one with a surplus of almost $50,900. This surplus will continue to grow as net income becomes positive in year five and later years, generating a cumulative unrestricted cash balance of just over $1.7 million by the end of year 10, and over $4.2 million by the end of year 20.

7.1.2 Ubiquitous Retail Model Financing

The initial years of network deployment and operations will be capital-intensive, well beyond what initial subscriber revenues can support. This analysis projects the Authority covering these expenses by pursuing a series of 20-year bonds, totaling $42.95 million.

We assumed that the Authority's interest rate would be 5 percent, and that bond issuance costs will be equal to 1 percent of the principal borrowed. We assumed that a debt service reserve at 5 percent is necessary for the lifetime of the bond. Principal repayment on will start in the third year after issuance.[55]

The model assumes a straight-line depreciation of assets, and that the OSP will have a 20-year life span while the network equipment will need to be replaced after 10 years. CPE as well as other miscellaneous implementation costs will need to be replaced every five years. Network equipment, including last mile and CPE will be replaced or upgraded at 80 percent of original cost, miscellaneous implementation costs (test equipment, vehicles, computers) will also be at 80 percent. The model plans for a depreciation reserve account, starting in year three at 35 percent, to fund future electronics replacements and upgrades.

[55] The scope of work for this report does not include a review of the Authority's financing capability or review of local or Commonwealth finance restrictions. A more detailed review and opinion from the Authority's accountants of financing capability and restrictions is recommended if bonds are pursued.

Table 10 shows the income statement for years one, five, 10, 15, and 20. The Authority's net income remains negative in years one through three, totaling roughly negative $1.6 million in year one, growing to positive $274,200 in year five. By year 10, net income will equal just over $800,600, growing to nearly $1.4 million in year 15 and over $2.1 million in year 20.

Table 10: Ubiquitous Retail Model Income Statement

Income Statement		Year 1	Year 5	Year 10	Year 15	Year 20
Revenues						
Internet - Residential		$327,648	$6,546,264	$6,546,264	$6,546,264	$6,546,264
Internet - Business		17,088	345,816	345,816	345,816	345,816
Connection Fee (net)		108,300	-	-	-	-
	Total	$453,036	$6,892,080	$6,892,080	$6,892,080	$6,892,080
Operating Costs						
Operation Costs		$79,850	$377,590	$377,590	$377,590	$377,590
Labor Costs		843,500	1,820,000	1,820,000	1,820,000	1,820,000
	Total	$923,350	$2,197,590	$2,197,590	$2,197,590	$2,197,590
EBITDA		$(470,314)	$4,694,490	$4,694,490	$4,694,490	$4,694,490
Depreciation		574,220	2,361,320	2,280,130	2,266,130	2,266,130
Operating Income (EBITDA less Depreciation)		$(1,044,534)	$2,333,170	$2,414,360	$2,428,360	$2,428,360
Non-Operating Income						
Interest Income		$-	$11,380	$17,190	$21,780	$27,800
Interest Expense (20-Year Bond)		(597,500)	(2,070,370)	(1,630,930)	(1,066,410)	(345,920)
	Total	$(597,500)	$(2,058,990)	$(1,613,740)	$(1,044,630)	$(318,120)
Net Income (before taxes)		$(1,642,034)	$274,180	$800,620	$1,383,730	$2,110,240
Facility Taxes		$ -	$ -	$ -	$ -	$ -
Net Income		$(1,642,034)	$274,180	$800,620	$1,383,730	$2,110,240

Table 11 shows the cash flow statement for years one, five, 10, 15, and 20. The cumulative unrestricted cash balance is almost $50,900 at the end of year one and just over $1.7 million by the end of year 10. By the end of year 15, the unrestricted cash balance is over $2.9 million; it is roughly $4.2 million by the end of year 20.

Table 11: Ubiquitous Retail Model Cash Flow Statement

Cash Flow Statement		Year 1	Year 5	Year 10	Year 15	Year 20
Net Income		$(1,642,034)	$274,180	$800,620	$1,383,730	$2,110,240
Cash Outflows						
Debt Service Reserve		$(597,500)	$-	$-	$-	$-
Depreciation Reserve		-	(826,460)	(798,050)	(793,150)	(793,150)
Financing		(119,500)	-	-	-	-
Capital Expenditures		(10,114,300)	(35,000)	(64,000)	(221,600)	-
	Total	$(10,831,300)	$(861,460)	$(862,050)	$(1,014,750)	$(793,150)
Cash Inflows						
Depreciation Reserve		$-	$-	64,000	221,600	$-
20-Year Bond Proceeds		11,950,000	-	-	-	-
	Total	$11,950,000	$-	$64,000	$221,600	$-
Total Cash Outflows and Inflows		$1,118,700	$(861,460)	$(798,050)	$(793,150)	$(793,150)
Non-Cash Expenses - Depreciation		$574,220	$2,361,320	$2,280,130	$2,266,130	$2,266,130
Adjustments						
Proceeds from Additional Cash Flows (20-Year Bond)		$(11,950,000)	$ -	$ -	$ -	$ -
Adjusted Available Net Revenue		$(11,899,114)	$1,774,040	$2,282,700	$2,856,710	$3,583,220
Principal Payments on Debt						
20 Year Bond Principal		$-	$1,543,410	$2,043,280	$2,607,800	$3,328,290
	Total	$-	$1,543,410	$2,043,280	$2,607,800	$3,328,290
Net Cash		$50,886	$230,630	$239,420	$248,910	$254,930
Cash Balance						
Unrestricted Cash Balance		$50,886	$579,080	$1,708,110	$2,941,300	$4,203,150
Depreciation Reserve		-	2,406,140	4,730,050	6,564,150	8,970,780
Debt Service Reserve		597,500	2,147,500	2,147,500	2,147,500	2,147,500
Total Cash Balance		$648,386	$5,132,720	$8,585,660	$11,652,950	$15,321,430

7.1.3 Ubiquitous Retail Model Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment, material and construction labor associated with building, implementing, and lighting a fiber network. Table 12 shows the capital additions costs in years one through four, assuming a 36 percent take rate, or just over 8,200 subscribers.

This analysis projects that capital additions in year one will total roughly $10.1 million. These costs will total just over $17.2 million in year two, nearly $10.6 million in year three, and just over $2.6 million in year four, for a total of roughly $40.5 million in the first four years.

Table 12: Ubiquitous Retail Model Capital Additions

Capital Additions	Year 1	Year 2	Year 3	Year 4
Network Equipment				
Core & GPON Equipment	$597,100	$-	$-	$-
Additional Annual Capital	-	-	-	-
Total	$597,100	$-	$-	$-
Outside Plant and Facilities				
Total Backbone and FTTP	$8,721,000	$14,535,000	$5,814,000	$-
Additional Annual Capital	-	-	-	-
Total	$8,721,000	$14,535,000	$5,814,000	$-
Last Mile and CPE				
CPE (residential and small commercial)	$86,200	$429,600	$773,300	$429,800
Average Drop Cost	433,000	2,159,000	3,886,000	2,160,000
Additional Annual Replacement Capital	-	-	-	-
Total	$519,200	$2,588,600	$4,659,300	$2,589,800
Miscellaneous Implementation Costs				
OSS & Portal	$75,000	$-	$-	$-
Vehicles	35,000	70,000	70,000	35,000
Service Equipment	50,000	-	-	-
Work Station, Computers, and Software	17,000	8,000	10,000	2,000
Fiber OTDR and Other Tools	50,000	-	-	-
Fiber Management Software	50,000	-	-	-
Additional Annual Capital	-	-	-	-
Total	$277,000	$78,000	$80,000	$37,000
Total Capital Additions	$10,114,300	$17,201,600	$10,553,300	$2,626,800

Please see Appendix F for a complete income statement, cash flow statement, and capital addition statement.

7.1.4 Ubiquitous Retail Model Operating and Maintenance Expenses

The cost to deploy an FTTP network goes far beyond fiber implementation. Network deployment on a ubiquitous scale will require additional staffing for sales and marketing, as well as network operations.

Training new and existing staff is important to fully realize the economies of efficiently operating the ubiquitous FTTP network. The training will be particularly important in the short-term as the new enterprise establishes itself as a unique entity providing services on a larger scale than what the Authority provides today. We estimate education and training at 0.5 percent of direct payroll expenses.

Marketing and sales are critical. It is important to be proactive in setting member expectations, addressing security concerns, and educating members on how to initiate services.

Staffing with skills in the following disciplines will be required:

- Sales/Promotion
- Internet and related technologies
- Staff Management
- Strategic Planning
- Finance
- Vendor Negotiations
- Networking (addressing, segmentation)
- Marketing

The expanded business and increased responsibilities will require the addition of new staff. The initial additional positions, staffing levels, and base salaries are shown in Table 13.

These numbers assume one shift of both customer service representative support and one and a half shifts for subscriber technicians, and we assume one customer service representative and service technician per 3,000 customers. Changing to full 24x7 staffing will increase costs. Similarly, reducing the support hours will decrease the required staffing. In the model, we added 40 percent overhead to the base (year one) salaries.

Table 13: Ubiquitous Retail Model Labor Expenses

New Employees	Year 1	Year 2	Year 3	Year 4+	Year 1 Salary
Contract & Marketing Manager	0.50	1.00	1.00	1.00	$100,000
GIS & Recordkeeping	0.50	1.00	1.00	1.00	$85,000
Network Engineer	0.50	0.50	0.50	0.50	$110,000
Sales & Marketing Representatives	2.00	3.00	3.00	3.00	$60,000
Customer Service Representatives	1.00	1.00	3.00	3.00	$55,000
Service Technicians/Installers & IT Support	1.00	2.00	4.00	5.00	$75,000
HR, Administration & Support	1.00	1.00	1.00	1.00	$70,000
Call Center Support	1.00	1.00	2.00	2.00	$55,000
Fiber Plant O&M Technicians	1.00	2.00	2.00	2.00	$80,000
Total New Staff	8.5	12.5	17.5	18.5	

The Authority's total labor expenses will total roughly $843,500 in year one, nearly $1.3 million in year two, just over $1.7 million in year three, and roughly $1.8 million in year four on.

Additional key operating and maintenance assumptions include:

- Insurance is estimated to be $5,000 in year one and $15,000 from year two on
- Utilities are estimated to be $1,200 in year one and $2,400 from year two on
- Office expenses are estimated to be $3,000 in year one and $6,000 from year two on

- Locates and ticket processing are estimated to be $5,200 in year one, $26,100 in year two, and $52,100 from year three on
- Contingency is estimated to be $5,000 in year one and $15,000 from year two on
- Legal fees are estimated to be $5,000 annually
- Consulting fees are estimated to be $5,000 annually
- Marketing expenses are estimated at $15,000 in year one, $20,000 in year two, and $5,000 in year three on
- Pole attachment expenses are estimated at roughly $4,300 in year one, $15,700 in year two, $25,700 in year three, and $28,600 in year four on

Vendor maintenance contract fees are expected to start at $59,600 in year two and remain steady from year two on (based upon 10 percent of accrued investment). Annual variable operating expenses not including direct internet access include:

- Education and training are calculated as 0.5 percent of direct payroll expense (roughly $4,200 in year one, $6,400 in year two, $8,600 in year three and $9,100 in year four on)
- Customer billing is estimated at $0.25 per bill, assuming the Authority's existing billing software will be used
- Allowance for bad debts is computed as 0.25 percent of revenues
- Churn is anticipated to be 1.5 percent annually, which initiates a $250 per-subscriber acquisition cost.

Fiber and network maintenance costs are calculated at 0.25 percent of the total construction cost per year. This is estimated based on a typical rate of occurrence in the Authority's environment, and the cost of individual repairs. These costs will total almost $22,900 in year one, just over $64,600 in year two, roughly $88,900 in year three, and nearly $94,300 in year four on. This is in addition to staffing costs to maintain the fiber.

Table 14 shows the Authority's projected operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network expands and the subscriber base increases.

Table 14: Ubiquitous Retail Model Operating Expenses and P&I Payments

Operating Expenses	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$5,000	$15,000	$15,000	$15,000	$15,000
Utilities	1,200	2,400	2,400	2,400	2,400
Office Expenses	3,000	6,000	6,000	6,000	6,000
Locates & Ticket Processing	5,200	52,100	52,100	52,100	52,100
Contingency	5,000	15,000	15,000	15,000	15,000
Fiber & Network Maintenance	22,890	94,270	94,270	94,270	94,270
Vendor Maintenance Contracts	-	59,600	59,600	59,600	59,600
Legal	5,000	5,000	5,000	5,000	5,000
Consulting	5,000	5,000	5,000	5,000	5,000
Marketing	15,000	10,000	10,000	10,000	10,000
Education and Training	4,220	9,100	9,100	9,100	9,100
Customer Billing (Unit)	1,300	25,910	25,910	25,910	25,910
Allowance for Bad Debts	1,130	17,230	17,230	17,230	17,230
Churn (acquisition costs)	1,620	32,390	32,390	32,390	32,390
Pole Attachment Expense	4,290	28,590	28,590	28,590	28,590
Sub-Total	$79,850	$377,590	$377,590	$377,590	$377,590
Labor Expenses	$843,500	$1,820,000	$1,820,000	$1,820,000	$1,820,000
Sub-Total	$843,500	$1,820,000	$1,820,000	$1,820,000	$1,820,000
Total Expenses	$923,350	$2,197,590	$2,197,590	$2,197,590	$2,197,590
Principal and Interest	$597,500	$3,602,400	$3,657,020	$3,652,430	$3,646,410
Facility Taxes	-	-	-	-	-
Sub-Total	$597,500	$3,602,400	$3,657,020	$3,652,430	$3,646,410
Total Expenses, P&I, and Taxes	$1,520,850	$5,799,990	$5,854,610	$5,850,020	$5,844,000

The Authority's total operation and maintenance expenses, including principal and interest payments will equal just over $1.5 million in year one, and roughly $5.8 million in years five through 20.

7.2 Existing Fiber Routes Retail Model

The financial analysis in this section assumes the Authority deploys to homes and businesses on the Shore that are already along existing fiber routes, and only need fiber drop cables and CPE to receive data service. This financial analysis is based on several assumptions (outlined below and further detailed in the spreadsheet in Appendix G).

One goal of this analysis is to illuminate the financial implications of the expansion as a discreet effort, independent of the Authority's current operations. It is important for the Authority to understand the specific factors necessary for this model to operate cash positive. The addition of existing or projected revenue from the Authority's current operations will obscure the financial implications of this model. Given this, we limit our discussion of cash flows in this model to only those generated by the new expansion.

As discussed below, this model assumes the Authority seeks $2.75 million in bonds to cover its capital expenses and initial operational expenses. We note that if the Authority has this level of cash on hand, it could feasibly use this strategy without needing to secure financing.

Please note that we used a “flat” model in the analysis (i.e., we did not include inflation and salary cost increases because we assume that these operating cost increases will be offset and passed on to subscribers in the form of increased prices). Models that add an inflation factor to both revenues and expenses typically greatly overstate future cash flow because net revenues are unlikely to increase as quickly as inflation. At best, the provider will be able to match expenses increases with a dollar-for-dollar rate increase, which is what the flat model represents.

The model assumes that subscribership for data services will ramp up over years one through three, and then remain steady.

7.2.1 Existing Fiber Routes Retail Model Overview

The financial model is designed to be cash flow positive in year one; which is accomplished through bond financing. **There are roughly 8,000 passings that would qualify for this model, though for the Authority’s effort to cash flow, it would only need to obtain and maintain a 15 percent take rate, or roughly 1,200 passings.**[56]

In this model, we assume the Authority offers three data services at its current pricing and speeds:

- A 25 Mbps download/12 Mbps upload service at $60 per month
- A 50 Mbps download/25 Mbps upload service at $86 per month
- A 100 Mbps download/50 Mbps upload service at $150 per month

As noted above, this model assumes the Authority no longer offers its 10 Mbps download/5 Mbps upload service, and assumes local WISPs will embrace that market looking for such speeds.

We assume that 80 percent of subscribers will subscribe to the 25/12 Mbps service, 18 percent of subscribers will purchase 50/25 Mbps service, and 2 percent of subscribers will purchase 100/50 Mbps service.

[56] Based on the cost estimate in Section 6.

We assume that all new subscribers will be charged a one-time $250 connection fee prior to receiving services.

We have included a financial summary for this model in Table 15.

Table 15: Existing Fiber Routes Retail Model Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$65,984	$975,120	$975,120	$975,120	$975,120
Total Cash Expenses	(569,270)	(684,300)	(684,300)	(684,300)	(684,300)
Depreciation	(38,090)	(142,550)	(127,880)	(126,270)	(126,270)
Interest Expense	(47,500)	(132,040)	(104,730)	(69,150)	(23,180)
Taxes	-	-	-	-	-
Net Income	$(588,876)	$16,230	$58,210	$95,400	$141,370

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$15,614	$113,656	$114,426	$129,626	$144,316
Depreciation Reserve	-	168,070	115,450	(15,000)	53,830
Debt Service Reserve	47,500	137,500	137,500	137,500	137,500
Total Cash Balance	$63,114	$419,226	$367,376	$252,126	$335,646

Although this model will not generate a positive net income in year one, we assume the financed amount or startup capital will cover the shortfall, and the Authority will finish year one with a surplus of over $15,600. This surplus will continue to grow as net income becomes positive in year five and later years, generating a cumulative unrestricted cash balance of just over $114,400 by the end of year 10, and over $144,300 by the end of year 20.

7.2.2 Existing Fiber Routes Retail Model Financing

The initial years of network deployment and operations will be capital-intensive, though significantly less so than the ubiquitous retail model. In the initial years, subscriber revenues will not be sufficient enough to support operations. This analysis projects the Authority covering these relatively modest expenses by pursuing a series of 20-year bonds, totaling $2.75 million.

We assumed that the Authority's interest rate would be 5 percent, and that bond issuance costs will be equal to 1 percent of the principal borrowed. We assume a debt service reserve of 5 percent is necessary for the lifetime of the bond. Principal repayment on the bond will start in the third year after issuance.[57]

[57] The scope of work for this report does not include a review of the Authority's financing capability or review of local or Commonwealth finance restrictions. A more detailed review and opinion from the Authority's accountants of financing capability and restrictions is recommended if bonds are pursued.

We note that if the Authority has $2.75 million in cash on hand, it would be able to pursue this model without obtaining financing, provided it obtains and maintains a take rate of 15 percent.

The model assumes a straight-line depreciation of assets, and that the OSP will have a 20-year life span while the network equipment will need to be replaced after 10 years. CPE as well as other miscellaneous implementation costs will need to be replaced every five years. Network equipment, including last mile and CPE will be replaced or upgraded at 80 percent of original cost, miscellaneous implementation costs (test equipment, vehicles, computers) will also be at 80 percent. The model plans for a depreciation reserve account, starting in year three at 42 percent, to fund future electronics replacements and upgrades.

Table 16 shows the income statement for years one, five, 10, 15, and 20. The Authority's net income remains negative in years one through three, totaling roughly negative $589,000 in year one, growing to positive $16,200 in year five. By year 10, net income will equal nearly $58,200, growing to $95,400 in year 15 and over $141,400 in year 20.

Table 16: Existing Fiber Routes Retail Model Income Statement

Income Statement		Year 1	Year 5	Year 10	Year 15	Year 20
Revenues						
Internet - Residential		$46,992	$925,968	$925,968	$925,968	$925,968
Internet - Business		3,192	49,152	49,152	49,152	49,152
Connection Fee (net)		15,800	-	-	-	-
	Total	$65,984	$975,120	$975,120	$975,120	$975,120
Operating Costs						
Operation Costs		$35,520	$66,550	$66,550	$66,550	$66,550
Labor Costs		533,750	617,750	617,750	617,750	617,750
	Total	$569,270	$684,300	$684,300	$684,300	$684,300
EBITDA		$(503,286)	$290,820	$290,820	$290,820	$290,820
Depreciation		38,090	142,550	127,880	126,270	126,270
Operating Income (EBITDA less Depreciation)		$(541,376)	$148,270	$162,940	$164,550	$164,550
Non-Operating Income						
Interest Income		$-	$760	$630	$310	$480
Interest Expense (20-Year Bond)		(47,500)	(132,800)	(105,360)	(69,460)	(23,660)
	Total	$(47,500)	$(132,040)	$(104,730)	$(69,150)	$(23,180)
Net Income (before taxes)		$(588,876)	$16,230	$58,210	$95,400	$141,370
Facility Taxes		$ -	$ -	$ -	$ -	$ -
Net Income		$(588,876)	$16,230	$58,210	$95,400	$141,370

Table 17 shows the cash flow statement for years one, five, 10, 15, and 20. The cumulative unrestricted cash balance is just over $15,600 at the end of year one and over $114,400 by the end of year 10. By the end of year 15, the unrestricted cash balance is just over $129,600; it is roughly $144,300 by the end of year 20.

Table 17: Existing Fiber Routes Retail Model Cash Flow Statement

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$(588,876)	$16,230	$58,210	$95,400	$141,370
Cash Outflows					
Debt Service Reserve	$(47,500)	$-	$-	$-	$-
Depreciation Reserve	-	(59,870)	(53,710)	(53,030)	(53,030)
Financing	(9,500)	-	-	-	-
Capital Expenditures	(326,600)	-	(1,600)	(136,800)	-
Total	$(383,600)	$(59,870)	$(55,310)	$(189,830)	$(53,030)
Cash Inflows					
Depreciation Reserve	$-	$-	1,600	136,800	$-
20-Year Bond Proceeds	950,000	-	-	-	-
Total	$950,000	$-	$1,600	$136,800	$-
Total Cash Outflows and Inflows	$566,400	$(49,890)	$(44,760)	$(44,190)	$(44,190)
Non-Cash Expenses - Depreciation	$38,090	$142,550	$127,880	$126,270	$126,270
Adjustments					
Proceeds from Additional Cash Flows (20-Year Bond)	$(950,000)	$-	$-	$-	$-
Adjusted Available Net Revenue	$(934,386)	$98,910	$132,380	$168,640	$214,610
Principal Payments on Debt					
20 Year Bond Principal	$-	$88,230	$129,890	$165,790	$211,590
Total	$-	$88,230	$129,890	$165,790	$211,590
Net Cash	$15,614	$10,680	$2,490	$2,850	$3,020
Cash Balance					
Unrestricted Cash Balance	$15,614	$113,656	$114,426	$129,626	$144,316
Depreciation Reserve	-	168,070	115,450	(15,000)	53,830
Debt Service Reserve	47,500	137,500	137,500	137,500	137,500
Total Cash Balance	$63,114	$419,226	$367,376	$252,126	$335,646

7.2.3 Existing Fiber Routes Model Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment, material and construction labor associated with building, implementing, and lighting a fiber network. Table 18 shows the capital additions costs in years one through four, assuming a 15 percent take rate, or just about 1,200 subscribers.

This analysis projects that capital additions in year one will total roughly $326,600. These costs will total almost $365,700 in year two, roughly $660,300 in year three, and roughly $366,900 in year four, for a total of just over $1.7 million in the first four years.

Table 18: Existing Fiber Routes Retail Model Capital Additions

Capital Additions	Year 1	Year 2	Year 3	Year 4
Network Equipment				
Core & GPON Equipment	$80,100	$-	$-	$-
Additional Annual Capital	-	-	-	-
Total	$80,100	$-	$-	$-
Last Mile and CPE				
CPE (residential and small commercial)	$12,500	$60,700	$109,300	$60,900
Average Drop Cost	63,000	305,000	549,000	306,000
Additional Annual Replacement Capital	-	-	-	-
Total	$75,500	$365,700	$658,300	$366,900
Miscellaneous Implementation Costs				
Vehicles	35,000	-	-	-
Service Equipment	25,000	-	-	-
Work Station, Computers, and Software	11,000	-	2,000	-
Fiber OTDR and Other Tools	50,000	-	-	-
Fiber Management Software	50,000	-	-	-
Additional Annual Capital	-	-	-	-
Total	$171,000	$-	$2,000	$-
Total Capital Additions	$326,600	$365,700	$660,300	$366,900

Please see Appendix G for a complete income statement, cash flow statement, and capital addition statement.

7.2.4 Existing Fiber Routes Retail Model Operating and Maintenance Expenses

The cost to deploy an FTTP network goes far beyond fiber implementation. Network deployment on to passings already on existing fiber routes will require modest additional staffing for sales and marketing, as well as network operations.

Training new and existing staff is important to fully realize the economies of efficiently operating the ubiquitous FTTP network. The training will be particularly important in the short-term as the new enterprise establishes itself as a unique entity providing services on a larger scale than what the Authority provides today. We estimate education and training at 0.5 percent of direct payroll expenses.

Marketing and sales are critical. It is important to be proactive in setting member expectations, addressing security concerns, and educating members on how to initiate services.

Staffing with skills in the following disciplines will be required:

- Sales/Promotion
- Internet and related technologies
- Staff Management
- Strategic Planning
- Finance
- Vendor Negotiations
- Networking (addressing, segmentation)
- Marketing

The expanded business and increased responsibilities will require the addition of new staff. The initial additional positions, staffing levels, and base salaries are shown in Table 13.

These numbers assume one shift of both customer service representative support and one and a half shifts for subscriber technicians, and we assume one customer service representative and service technician per 3,000 customers. Changing to full 24x7 staffing will increase costs. Similarly, reducing the support hours will decrease the required staffing. In the model, we added 40 percent overhead to the base (year one) salaries.

Table 19: Existing Fiber Routes Retail Model Labor Expenses

New Employees	Year 1	Year 2	Year 3+	Year 1 Salary
Contract & Marketing Manager	0.25	0.25	0.25	$100,000
GIS & Recordkeeping	0.25	0.25	0.25	$85,000
Network Engineer	0.50	0.50	0.50	$110,000
Sales & Marketing Representatives	1.00	1.00	2.00	$60,000
Customer Service Representatives	1.00	1.00	1.00	$55,000
Service Technicians/Installers & IT Support	1.00	1.00	1.00	$75,000
HR, Administration & Support	0.50	0.50	0.50	$70,000
Call Center Support	1.00	1.00	1.00	$55,000
Total New Staff	5.5	5.5	6.5	

The Authority's total labor expenses will total roughly $533,800 in years one and two, and nearly $617,800 in year three on.

Additional key operating and maintenance assumptions include:

- Insurance is estimated to be $5,000 in year one and $10,000 from year two on
- Utilities are estimated to be $600 in year one and $1,200 from year two on
- Office expenses are estimated to be $1,500 in year one and $3,000 from year two on
- Contingency is estimated to be $5,000 in year one and $10,000 from year two on

- Legal fees are estimated to be $5,000 annually
- Consulting fees are estimated to be $5,000 annually
- Marketing expenses are estimated at $10,000 in year one, $15,000 in year two, and $7,500 in year three on

Vendor maintenance contract fees are expected to start at $8,000 in year two and remain steady from year two on (based upon 10 percent of accrued investment). Annual variable operating expenses not including direct internet access include:

- Education and training are calculated as 0.5 percent of direct payroll expense (roughly $2,700 in year one and $3,100 in year four on)
- Customer billing is estimated at $0.25 per bill, assuming the Authority's existing billing software will be used
- Allowance for bad debts is computed as 0.25 percent of revenues
- Churn is anticipated to be 1.5 percent annually, which initiates a $250 per-subscriber acquisition cost.

Fiber and network maintenance costs are calculated at 0.25 percent of the total construction cost per year. This is estimated based on a typical rate of occurrence in the Authority's environment, and the cost of individual repairs. These costs will total roughly $200 in year one, just over $900 in year two, roughly $2,300 in year three, and nearly $3,100 in year four on. This is in addition to staffing costs to maintain the fiber.

Table 20 shows the Authority's projected operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network expands and the subscriber base increases.

Table 20: Existing Fiber Routes Retail Model Operating Expenses and P&I Payments

Operating Expenses	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$5,000	$15,000	$15,000	$15,000	$15,000
Utilities	600	1,200	1,200	1,200	1,200
Office Expenses	1,500	3,000	3,000	3,000	3,000
Contingency	5,000	10,000	10,000	10,000	10,000
Fiber & Network Maintenance	160	3,060	3,060	3,060	3,060
Vendor Maintenance Contracts	-	8,000	8,000	8,000	8,000
Legal	5,000	5,000	5,000	5,000	5,000
Consulting	5,000	5,000	5,000	5,000	5,000
Marketing	10,000	7,500	7,500	7,500	7,500
Education and Training	2,670	3,090	3,090	3,090	3,090
Customer Billing (Unit)	190	3,670	3,670	3,670	3,670
Allowance for Bad Debts	160	2,440	2,440	2,440	2,440
Churn (acquisition costs)	240	4,590	4,590	4,590	4,590
Sub-Total	$35,520	$66,550	$66,550	$66,550	$66,550
Labor Expenses	$533,750	$617,750	$617,750	$617,750	$617,750
Sub-Total	$533,750	$617,750	$617,750	$617,750	$617,750
Total Expenses	$569,270	$684,300	$684,300	$684,300	$684,300
Principal and Interest	$47,500	$220,270	$234,620	$234,940	$234,770
Facility Taxes	-	-	-	-	-
Sub-Total	$47,500	$220,270	$234,620	$234,940	$234,770
Total Expenses, P&I, and Taxes	$616,770	$904,570	$918,920	$919,240	$919,070

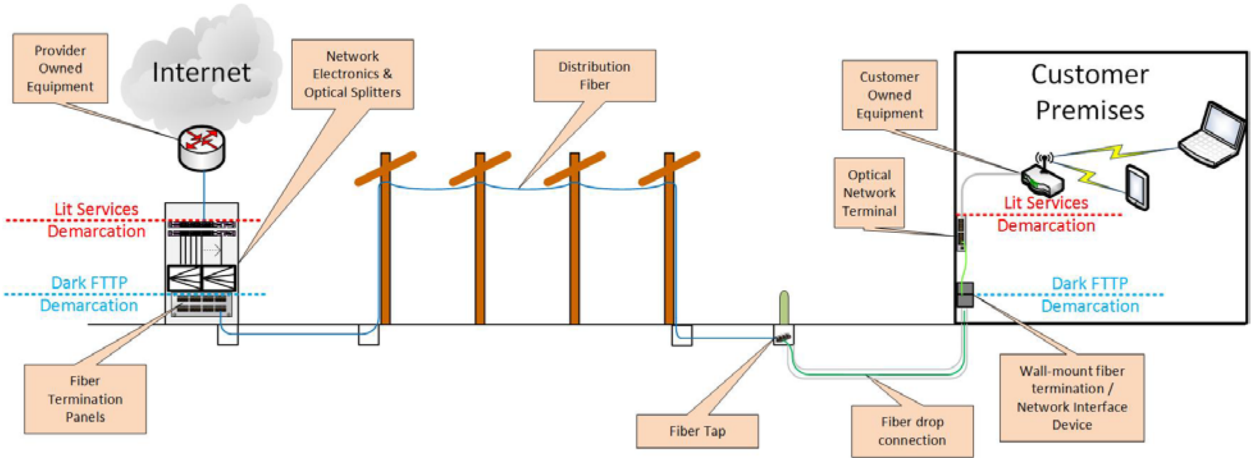
The Authority's total operation and maintenance expenses, including principal and interest payments will total nearly $616,800 million in year one, roughly $904,600 in year five, $918,900 in year 10, $919,200 in year fifteen and just over $919,000 in year 20.

7.3 Westminster Model

Our first dark FTTP lease model assumes that the Authority expands and owns network infrastructure throughout the entirety of the Shore up to a demarcation point in the network subscriber's home or business, and leases the dark fiber backbone, distribution fiber, and fiber drops to a private partner. The private partner would be responsible for all network electronics and CPE, as well as network sales, marketing, and operations.

This demarcation is illustrated in Figure 11.

Figure 11: Demarcation Between Authority and Partner Network Elements (Westminster Model)



Network electronics and CPE are significant additional expenses for the private partner to consider, and as such, the Authority should bear them in mind when negotiating pricing with potential partners.

The financial analysis presented here represents a minimum requirement for the Authority to cash flow each year, excluding any potential revenue from other dark fiber lease opportunities that may be available to it. We have provided a complete financial model in Excel format that can be leveraged to show the impact of changing assumptions. The spreadsheet can be an important tool for the Authority to use if it negotiates with a private partner.

Please note that we used a "flat model" in the analysis, which means that inflation and operating cost increases (including salaries) are not used because it is assumed that operating cost increases will be offset by increases in operator lease payments over time (and likely passed on to subscribers in the form of increased prices). We anticipate that the Authority will apply an inflation factor, typically based on a Consumer Price Index (CPI), to the portion of the per-subscriber fee that covers projected operating expenses during negotiations with a private partner.

These financial projections do not include any economic development or other indirect benefits, which are often not easily quantifiable.

In our modeling, we compared a similar dark FTTP deployment in the city of Westminster, Maryland. In their contract with Ting Internet, the city negotiated a per-passing fee ($6) plus per-subscriber fee ($17) per month for dark FTTP usage. That is, Ting pays the city for every premises the network passes, plus an additional fee for every subscriber receiving service over the network, totaling $6 per non-subscribed passing and $23 per subscribed passing. As such, the take rate is vitally important to the feasibility of the project.

To facilitate comparison, our base case assumes the network obtains and maintains a 36 percent take rate, the same take rate assumed in our ubiquitous FTTP model. At this take rate, if ESVBA charges the same lease fees paid by Ting in Westminster, Maryland will result in a cumulative cash deficit of nearly $25.9 million after 20 years. To operate cash positive at this take rate, the Authority would need to charge the private partner $9.60 per passing and $27.20 per subscriber, or 1.6 times the fees agreed upon in Westminster.

We include these references to demonstrate what pricing is attractive enough to incent partnership, the financial implications of that pricing, as well as what Westminster pricing would look like in relation to network deployment costs for the Authority.

7.3.1 Westminster Model Overview

In this model, we present what would be necessary to maintain positive cash flow given the estimated OSP construction and operating costs. In this model, we assume the private partner can obtain and maintain a 36 percent take rate.

Using our construction cost estimate from Section 6, we estimate each drop to cost an average of $1,000. If 36 percent of the 23,992 passings on the Shore were to subscribe (roughly 8,640 subscribers), drop cost construction would total over $8.6 million.

Though the Authority will be responsible for funding and constructing the drops, these costs are offset by the per-subscriber lease fees that are the responsibility of the private partner.

To maintain positive cash flow with this model, assuming the private partner can obtain and maintain a 36 percent take rate, the Authority would need to charge the partner $9.60 per passing and an additional $27.20 per subscriber. These are 1.6 times the fees the city of Westminster could obtain in its agreement with Ting Internet.

We have included a financial summary for this model in Table 21. As shown, the Authority's net income would be negative in the initial years, growing to $62,200 in year five. By year 20, net income will total nearly $2.5 million. The model will operate cash positive, finishing year one with a cumulative surplus of nearly $135,900. This surplus will grow to just over $6.7 million by the end of year 10, and nearly $11.3 million by the end of year 20.

Table 21: Westminster Model Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$196,600	$5,555,680	$5,583,320	$5,583,320	$5,583,320
Total Cash Expenses	(304,220)	(631,260)	(631,260)	(631,260)	(631,260)
Depreciation	(477,700)	(1,910,830)	(1,905,740)	(1,905,740)	(1,905,740)
Interest Expense	(708,500)	(2,951,360)	(2,395,820)	(1,624,480)	(567,460)
Taxes	-	-	-	-	-
Net Income	$(1,293,820)	$62,230	$650,500	$1,421,840	$2,478,860
Cash Flow Statement	**Year 1**	**Year 5**	**Year 10**	**Year 15**	**Year 20**
Unrestricted Cash Balance	$135,880	$4,468,300	$6,732,870	$8,997,670	$11,262,160
Depreciation Reserve	-	56,250	9,260	(7,440)	57,460
Debt Service Reserve	545,000	2,340,000	2,340,000	2,340,000	2,340,000
Total Cash Balance	$680,880	$6,864,550	$9,082,130	$11,330,230	$13,659,620

7.3.2 Westminster Model Financing

This financial analysis assumes that the Authority will cover its OSP construction costs and additional capital requirements through taking a series of 20-year bonds, totaling $46.8 million. We assumed that the Authority's interest rate would be 6.5 percent, and that bond issuance costs will be equal to 1 percent of the principal borrowed.[58] We assume a debt service reserve of 5 percent is necessary for the life of the bond. Principal repayment on the bond will start in the third year after issuance.

The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment. The resulting principal and interest (P&I) payments will be the major factor in determining the Authority's long-term financial requirements; P&I accounts for roughly 85 percent of the annual costs in this model after the construction period.

7.3.3 Westminster Model Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network.

This analysis projects that the capital additions (including vehicles and test equipment) in year one will total approximately $9.3 million. These costs will total approximately $16.7 million in year two, $9.7 million in year three, and roughly $2.2 million in year four. This totals just under $37.9 million in capital additions for years one through four.

[58] We note that interest rates will be higher on this bond

These costs are illustrated in Table 22.

Table 22: Westminster Model Capital Additions

Capital Additions		Year 1	Year 2	Year 3	Year 4
Outside Plant and Facilities					
Total Backbone and FTTP		$8,721,000	$14,535,000	$5,814,000	$-
	Total	$8,721,000	$14,535,000	$5,814,000	$-
Last Mile and CPE					
Average Drop Cost		$433,000	$2,159,000	$3,886,000	$2,160,000
	Total	$433,000	$2,159,000	$3,886,000	$2,160,000
Miscellaneous Implementation Costs					
Vehicles		$35,000	$35,000	$ -	$ -
Work Station, Computers, and Software		5,000	3,000	-	-
Fiber OTDR and Other Tools		50,000	-	-	-
Fiber Management Software		50,000			
Additional Annual Capital		-	-	-	-
	Total	$140,000	$38,000	$-	$-
Total Annual Capital Additions		$9,294,000	$16,732,000	$9,700,000	$2,160,000

Please see Appendix H for a complete income statement, cash flow statement, and capital addition statement.

7.3.4 Westminster Model Operating and Maintenance Expenses

The cost to deploy a dark FTTP network goes far beyond fiber implementation. Network deployment requires sales and marketing, network maintenance and technical operations, and other functions. In this model, we assume that the Authority's partner will be responsible for lighting the fiber and selling service. As such, ESVBA's financial requirements are limited to expenses related to OSP infrastructure (including drops) and network administration.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

These expanded responsibilities will require a modest addition of new staff. We assume the Authority will add a total of 4 FTE positions within the first two years, and will then maintain that level of staffing. Our assumptions include:

- 1 FTE GIS & record keeping position
- 1 FTE customer service representative position
- 2 FTE fiber plant operating & maintenance technicians

Salaries and benefits are based on estimated market wages, and benefits are estimated at 40 percent of base salary. Salaries (including benefits) are summarized in Table 23.

Table 23: Westminster Model Labor Expenses

New Employees	Year 1	Year 2	Year 3+	Labor Cost
GIS & Record Keeping	0.50	1.00	1.00	85,000
Customer Service Representative	1.00	1.00	1.00	55,000
Fiber Plant O&M Technicians	1.00	2.00	2.00	80,000
Total New Staff	2.50	4	4	

Additional key operating and maintenance assumptions include the following:

- Insurance is estimated to be $5,000 in year one and $15,000 from year two on
- Utilities are estimated to be $600 in year one and $1,200 from year two on
- Office expenses are estimated to be $1,500 in year one and $3,000 from year two on
- Locates and ticket processing are estimated to be $5,200 in year one, $26,100 in year two, and $52,100 from year three on
- Contingency is estimated to be $5,000 annually
- Legal fees are estimated to be $5,000 annually
- Consulting fees are estimated to be $5,000 annually
- Pole attachment expenses are estimated at roughly $4,300 in year one, $15,700 in year two, $25,700 in year three, and $28,600 in year four on

Annual variable operating expenses not including direct internet access include:

- Education and training are calculated as 0.5 percent of direct payroll expense (roughly $1,200 in year one, and $2,100 in year two on)

Fiber and network maintenance costs are calculated at 0.25 percent of the total construction cost per year. This is estimated based on a typical rate of occurrence in the Authority's environment, and the cost of individual repairs. These costs will total almost $22,900 in year one, just over

$64,600 in year two, roughly $88,900 in year three, and nearly $94,300 in year four on. This is in addition to staffing costs to maintain the fiber.

Table 24 shows the Authority's projected operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network expands and the subscriber base increases.

Table 24: Westminster Model Operating and Maintenance Expenses

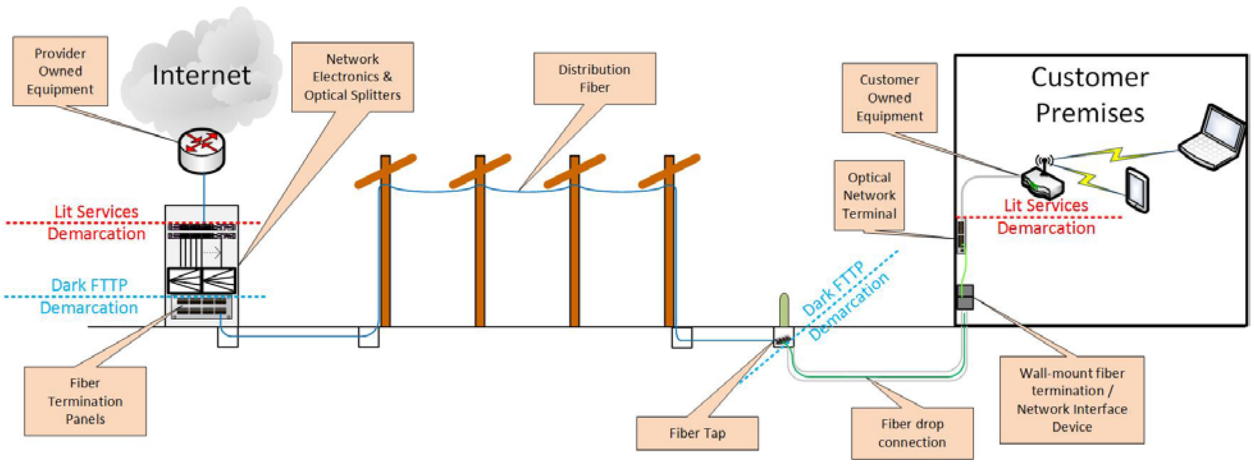
Operating Expenses	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$5,000	$15,000	$15,000	$15,000	$15,000
Utilities	600	1,200	1,200	1,200	1,200
Office Expenses	1,500	3,000	3,000	3,000	3,000
Locates & Ticket Processing	5,200	52,100	52,100	52,100	52,100
Contingency	5,000	5,000	5,000	5,000	5,000
Fiber & Network Maintenance	22,890	94,270	94,270	94,270	94,270
Legal	5,000	5,000	5,000	5,000	5,000
Consulting	5,000	5,000	5,000	5,000	5,000
Marketing	15,000	10,000	10,000	10,000	10,000
Education and Training	1,240	2,100	2,100	2,100	2,100
Pole Attachment Expense	4,290	28,590	28,590	28,590	28,590
Sub-Total	$55,720	$211,260	$211,260	$211,260	$211,260
Labor Expenses	$248,500	$420,000	$420,000	$420,000	$420,000
Sub-Total	$248,500	$420,000	$420,000	$420,000	$420,000
Total Expenses	$304,220	$631,260	$631,260	$631,260	$631,260
Principal and Interest	$708,500	$4,359,680	$4,480,130	$4,480,170	$4,480,010
Facility Taxes	-	-	-	-	-
Sub-Total	$708,500	$4,359,680	$4,480,130	$4,480,170	$4,480,010
Total Expenses, P&I, and Taxes	$1,012,720	$4,990,940	$5,111,390	$5,111,430	$5,111,270

The Authority's total operating expenses, including principal and interest payments, will equal just over $1 million in year one, nearly $5 million in year five, and roughly $5.1 million in years 10 through 20.

7.4 Huntsville Model

Our second dark FTTP lease model assumes that the Authority constructs and owns network infrastructure throughout the Shore up to a demarcation point in the PROW, and leases the dark fiber backbone and distribution fiber to a private partner. This demarcation is illustrated in Figure 12.

Figure 12: Demarcation Between Authority and Partner Network Elements (Huntsville Model)



In this model, the private partner would be responsible for constructing drop cables into each subscriber's home or business; network electronics and CPE; and network sales, marketing, and operations. It should be noted that network electronics and CPE are significant additional expenses for the private partner to consider, and as such, the Authority should bear them in mind when negotiating pricing with potential partners.

The financial analysis presented here represents a minimum requirement for the Authority to obtain a break-even cash flow each year. We have provided a complete financial model in Excel format (Appendix I) that can be leveraged to show the impact of changing assumptions. The spreadsheet can be an important tool for the Authority to use if it negotiates with a private partner.

Please note that we used a "flat model" in the analysis, which means that inflation and operating cost increases (including salaries) are not used because it is assumed that operating cost increases will be offset by increases in operator lease payments over time (and likely passed on to subscribers in the form of increased prices). We anticipate that the Authority will apply an inflation factor, typically based on a Consumer Price Index (CPI), to the portion of the per-subscriber fee that covers projected operating expenses during negotiations with a private partner.

These financial projections do not include any economic development or other indirect benefits, which are often not easily quantifiable.

In our modeling, we compared a similar FTTP deployment in the city of Huntsville, Ala. In its contract with Google Fiber, Huntsville Utilities negotiated a monthly per-passing fee of $7.50.

We include this reference to demonstrate what pricing is attractive enough to incent partnership, the financial implications of that pricing, as well as what Huntsville pricing would look like in relation to network deployment costs for the Authority. If ESVBA were to charge similar lease fees as those paid by Google in Huntsville, it will result in cumulative cash deficits of nearly $36.1 million after 20 years.

7.4.1 Huntsville Model Overview

In this section, we present what would be necessary to maintain positive cash flow given the estimated OSP construction and operating costs. The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

To cover network deployment, operating expenses, and maintain a positive cash flow, the Authority would need to charge a private partner $16.13 per month per passing, for a total of 23,992 small business and residential passings. This lease fee is 2.15 times the fee to which Huntsville Utilities and Google Fiber agreed.

As Table 25 shows, though this model will not generate a positive net income in the initial years, it will operate cash-positive, finishing year one with a cumulative surplus of roughly $116,200, year 10 with roughly $5.1 million, and nearly $7.1 million by the end of year 20.

Table 25: Huntsville Model Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$92,840	$4,596,030	$4,642,450	$4,642,450	$4,642,450
Total Cash Expenses	(303,130)	(609,670)	(609,670)	(609,670)	(609,670)
Depreciation	(456,050)	(1,478,930)	(1,473,840)	(1,473,840)	(1,473,840)
Interest Expense	(682,500)	(2,502,690)	(2,025,720)	(1,365,420)	(460,540)
Taxes	-	-	-	-	-
Net Income	$(1,348,840)	$4,740	$533,220	$1,193,520	$2,098,400

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$116,210	$4,036,020	$5,050,590	$6,065,510	$7,080,160
Depreciation Reserve	-	59,910	17,160	4,660	73,760
Debt Service Reserve	525,000	1,990,000	1,990,000	1,990,000	1,990,000
Total Cash Balance	$641,210	$6,085,930	$7,057,750	$8,060,170	$9,143,920

7.4.2 Huntsville Model Financing

This financial analysis assumes that the Authority will cover its OSP construction costs and additional capital requirements through taking a series of 20-year bonds, totaling $39.8 million. We assumed that the Authority's interest rate would be 6.5 percent, and that bond issuance costs will be equal to 1 percent of the principal borrowed. We assume a debt service reserve of 5 percent is necessary for the life of the bond. Principal repayment on the bond will start in the third year after issuance.

The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment. The resulting principal and interest (P&I) payments will be the major factor in determining the Authority's long-term financial requirements; P&I accounts for roughly 84 percent of the Authority's annual costs in our base case model after the construction period.

7.4.3 Huntsville Model Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network. Again, because the Authority's responsibility will be limited to OSP, we have not included any costs for fiber drops, or core network equipment.

This analysis projects that the capital additions (including vehicles and test equipment) in year one will total approximately $8.9 million. These costs will total approximately $14.6 million in year two, and roughly $5.8 million in year three. This totals over $29.2 million in capital additions for years one through three.

These costs are illustrated in Table 26.

Table 26: Huntsville Model Capital Additions

Capital Additions	Year 1	Year 2	Year 3
Outside Plant and Facilities			
Total Backbone and FTTP	$8,721,000	$14,535,000	$5,814,000
Additional Annual Capital	-	-	-
Total	$8,721,000	$14,535,000	$5,814,000
Miscellaneous Implementation Costs			
Vehicles	$35,000	$35,000	$ -
Work Station, Computers, and Software	5,000	3,000	-
Fiber OTDR and Other Tools	50,000	-	-
Fiber Management Software	50,000	-	-
Additional Annual Capital	-	-	-
Total	$140,000	$38,000	$ -
Total Annual Capital Additions	$8,861,000	$14,573,000	$5,814,000

Please see Appendix I for a complete income statement, cash flow statement, and capital addition statement.

7.4.4 Huntsville Model Operating and Maintenance Expenses

The cost to deploy a dark FTTP network goes far beyond fiber implementation. Network deployment requires sales and marketing, network maintenance and technical operations, and other functions. In this model, we assume that the Authority's partner will be responsible for lighting the fiber and selling service. As such, ESVBA's financial requirements are limited to expenses related to OSP infrastructure and network administration.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

These expanded responsibilities will require a modest addition of new staff. We assume the Authority will add a total of 4 FTE positions within the first two years, and will then maintain that level of staffing. Our assumptions include:

- 1 FTE GIS & record keeping position
- 1 FTE customer service representative position
- 2 FTE fiber plant operating & maintenance technicians

Salaries and benefits are based on estimated market wages, and benefits are estimated at 40 percent of base salary. Salaries (including benefits) are summarized in Table 27.

Table 27: Huntsville Model Labor Expenses

New Employees	Year 1	Year 2	Year 3+	Labor Cost
GIS & Record Keeping	0.50	1.00	1.00	85,000
Customer Service Representative	1.00	1.00	1.00	55,000
Fiber Plant O&M Technicians	1.00	2.00	2.00	80,000
Total New Staff	2.50	4	4	

Additional key operating and maintenance assumptions include the following:

- Insurance is estimated to be $5,000 in year one and $15,000 from year two on
- Utilities are estimated to be $600 in year one and $1,200 from year two on
- Office expenses are estimated to be $1,500 in year one and $3,000 from year two on
- Locates and ticket processing are estimated to be $5,200 in year one, $26,100 in year two, and $52,100 from year three on
- Contingency is estimated to be $5,000 annually
- Legal fees are estimated to be $5,000 annually
- Consulting fees are estimated to be $5,000 annually

- Pole attachment expenses are estimated at roughly $4,300 in year one, $15,700 in year two, $25,700 in year three, and $28,600 in year four on

Annual variable operating expenses not including direct internet access include:

- Education and training are calculated as 0.5 percent of direct payroll expense (roughly $1,200 in year one, and $2,100 in year two on)

Fiber and network maintenance costs are calculated at 0.25 percent of the total construction cost per year. This is estimated based on a typical rate of occurrence in the Authority's environment, and the cost of individual repairs. These costs will total almost $21,800 in year one, just over $58,100 in year two, and roughly $72,700 in year three on. This is in addition to staffing costs to maintain the fiber.

Table 28 shows the Authority's projected operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network expands.

Table 28: Huntsville Model Operating and Maintenance Expenses

Operating Expenses	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$5,000	$15,000	$15,000	$15,000	$15,000
Utilities	600	1,200	1,200	1,200	1,200
Office Expenses	1,500	3,000	3,000	3,000	3,000
Locates & Ticket Processing	5,200	52,100	52,100	52,100	52,100
Contingency	5,000	5,000	5,000	5,000	5,000
Fiber & Network Maintenance	21,800	72,680	72,680	72,680	72,680
Legal	5,000	5,000	5,000	5,000	5,000
Consulting	5,000	5,000	5,000	5,000	5,000
Marketing	15,000	10,000	10,000	10,000	10,000
Education and Training	1,240	2,100	2,100	2,100	2,100
Pole Attachment Expense	4,290	28,590	28,590	28,590	28,590
Sub-Total	$54,630	$189,670	$189,670	$189,670	$189,670
Labor Expenses	$248,500	$420,000	$420,000	$420,000	$420,000
Sub-Total	$248,500	$420,000	$420,000	$420,000	$420,000
Total Expenses	$303,130	$609,670	$609,670	$609,670	$609,670
Principal and Interest	$682,500	$3,729,670	$3,809,990	$3,810,020	$3,809,850
Facility Taxes	-	-	-	-	-
Sub-Total	$682,500	$3,729,670	$3,809,990	$3,810,020	$3,809,850
Total Expenses, P&I, and Taxes	$985,630	$4,339,340	$4,419,660	$4,419,690	$4,419,520

The Authority's total operating expenses, including principal and interest payments, will equal just over $985,600 in year one, roughly $4.3 million in year five, and nearly $4.2 million in years 10 through 20.

Appendix A: Summary Comparison of Options

This Appendix is attached as a separate Microsoft Excel spreadsheet.

Appendix B: The Lalor Model

This model was proposed by Mr. Peter Lalor in July 2017 as a strategic option for the Authority to address last-mile deployment on the Shore.

GOALS

CREATE STRUCTURE THAT:

(A) PROTECTS ISPs FROM UNFAIR COMPETITION

(B) PROTECTS CUSTOMERS FROM UNKEPT PROMISES BY ISPs

(C) ENCOURAGES RAPID EXPANSION OF SERVICE

(D) ENCOURAGES COST-EFFECTIVE USE OF EXISTING FIBER ASSET

MECHANISMS

1) Identify all addresses as WISPable or Non-WISPable, and PON-able or non-PON-able, from perspective of private sector ISPs.

2) All non-exempt (see point 3) WISP-able or PON-able addresses claimed by any ISP will be protected for a specified period of time (see point T-1 below), provided, however, that one or more ISPs makes a binding commitment to ESVBA to offer service to that address, at or below a schedule of price caps set by ESVBA, within the period of time; the mechanics of the process must discourage unrealistic claiming of addresses.

3) Any addresses that adjoin RoW where there is currently existing ESVBA fiber are automatically exempted and reserved for ESVBA PONs.

4) Addresses that are both Non-WISPable and non-PON-able will be available for ESVBA fiber extension.

5) ESVBA PONs will offer equipment through customer premises router/AP, no value added services.

6) ESVBA PONs will support ISP provision of specified value-added services such as telephony, IP-based video content, etc. to individual addresses.

TIMING

T-1. ESVBA establishes deal structure and schedule of price caps by __________________.

T-2. Each ISP identifies WISP-able and PON-able addresses by _________________; ISPs will be protected from ESVBA competition for any addresses they list for a period of one year, provided that service is available at that address within one year—and, if it is continuously available going forward, for five years.

T-3. Six months after the date of T-2, the claiming ISP will show to ESVBA either an executed contract for the address, or evidence of physical improvements/investments in close proximity to the address, or will post a bond of $___ that will be forfeit if service is not available on the one-year anniversary of T-2.

T-4. This procedure will be repeated annually at ESVBA's discretion.

Appendix C: Potential Conflicts Between Goals and Objectives

No matter how demographically and geographically different they are, most public entities that seek to deploy FTTP networks share certain objectives. Sometimes the primary objectives align, but they also may directly conflict with one another. It is important for the Authority to consider its primary, nonnegotiable goals—and to expand to other objectives from that starting point. CTC's understanding based on the ESVBA business plan developed in 2011 is that its overarching goal is to increase broadband availability throughout the Shore.

This analysis seeks to help the Authority understand the interplay between common objectives so that it can make decisions about which of its goals are most important, and how to achieve access to broadband in a way that makes sense for residents and businesses on the Shore.

The Relationship Between Common Broadband Objectives

Many public entities share common objectives when considering an investment in deploying or expanding a broadband network. In our experience, most public entities aim to prioritize some or all of the following goals:

- Ubiquity
- Affordability
- Consumer choice
- Competition in the market
- Ownership and control of assets
- Performance
- Risk aversion
- Positive cash flow

Choosing which goals to prioritize can be challenging, and a public entity may determine that its goals necessarily shift as it evaluates the financial and political feasibility of pursuing broadband deployment. We sought to provide the Authority with information to empower decisions about its connectivity needs that will have ongoing positive outcomes. We used as the basis for our analysis the assumption that the Authority wants to ultimately pursue a universal, or ubiquitous, solution—regardless of the technology chosen (FTTP or wireless). Although the public entity may ultimately decide that a ubiquitous build out that connects every home and business in its service area is not feasible, this analysis is based on that assumption.

It is important for the public entity to understand how these objectives interact with each other, how pursuing one objective may mean foregoing another, and how prioritizing objectives can impact ESVBA leadership's decision-making process as it moves forward. Each public entity must balance its needs so that it can achieve its goals without sacrificing objectives it deems essential.

It is important to understand what is behind each of these objectives, and why the Authority may be compelled to pursue one over another.

As an example, risk aversion is top priority for some public entities; it may be politically challenging to build a network, and the only way to complete it is to assure key stakeholders and the public that there is minimal risk involved. As we explain below, however, risk aversion directly conflicts with the goal of deploying broadband throughout an entire community.

We illustrate in Table 29 below the intersection of common objectives. As the key at the top of the table shows, one objective may have no impact on another (NI), objectives may align (A), or they may conflict (C).

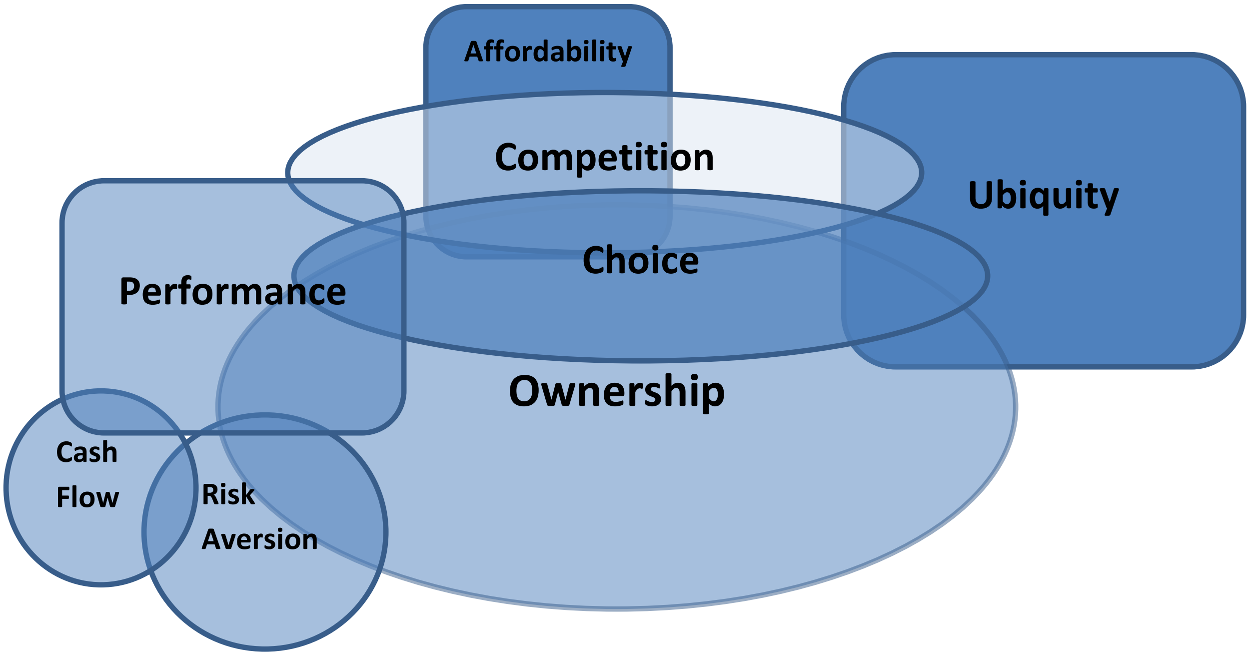
Table 29: Common Goal Alignment

A: Align | C: Conflict | NI: No Impact

	Ubiquity	Choice	Competition	Ownership	Performance	Affordability	Risk Aversion	Cash Flow
Ubiquity		A	A	A	NI	C	C	C
Choice	A		A	A	A	A	C	NI
Competition	A	A		A	A	A	C	NI
Ownership	A	A	A		A	A	A	C
Performance	NI	A	A	A		NI	A	A
Affordability	C	A	A	A	NI		C	C
Risk Aversion	C	C	C	A	A	C		A
Cash Flow	C	NI	NI	C	A	C	A	

In the sections below, we further define these objectives, explain this table, and outline how the objectives listed here interact and overlap with one another. We also describe how prioritizing one objective may impact the Authority's ability to focus on another. Figure 13, below, shows illustrates the relationship between common objectives.

Figure 13: Interplay Between Objectives



There are numerous possible outcomes associated with different objectives, and the Authority must determine what it believes will best serve its unique needs, and have the greatest impact on the community. This analysis does not seek to urge the Authority in any particular direction, but takes into consideration its potential goals, and attempts to clarify and flesh out what may drive a desire to achieve certain objectives.

As we noted, some objectives may interact favorably with others, overlap, or have no impact. For example, performance either interacts favorably or not at all with other objectives, and prioritizing performance can have a significant positive impact on the network's viability by setting it apart from incumbent providers. There are no real disadvantages to making performance a top priority for the network because doing so does not require the exclusion of any other objectives.

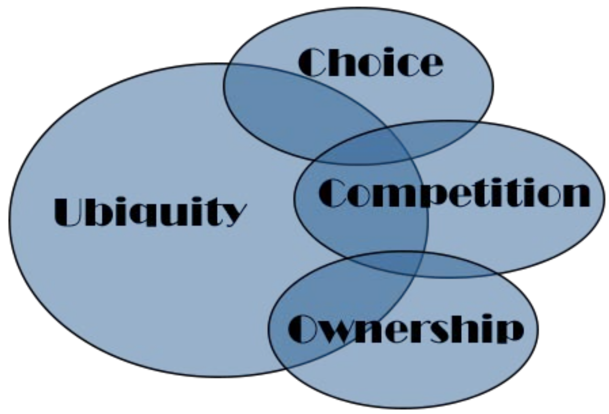
Detailed Descriptions of Common Objectives

Here we outline an in-depth explanation of what each objective typically means to a public entity in its pursuit of broadband deployment. We also describe how these objectives interact with each other, and the potential implications for the Authority.

Ubiquity – Service Is Brought to All Areas of a Community

For most communities that opt to build and operate a network, ubiquity—which refers to designing and building the network so that it connects every residence, business, and institution in the community—is a key objective. Incumbent providers have traditionally often built only to the most affluent areas of a community where they are sure to see a significant ROI, a practice known as "cherry picking." Many public entities are compelled to build a ubiquitous network to safeguard against leaving behind those parts of a community that may not be desirable to private providers. Public entities throughout the nation have prioritized ubiquity as a primary goal in their broadband pursuits,[59] and our analysis assumes this as a baseline objective for the Authority. As illustrated in Figure 14, ubiquity aligns with choice, competition, and ownership.

Figure 14: Ubiquity Aligns with Choice, Competition, and Ownership



This is a reasonable objective for any public entity; it makes sense that leaders want to bring service to the entire community, and we recognize that the Authority may aim to deploy a ubiquitous network. However, it is important to note that communitywide build-out often entails significant risk and cost. The financial risk alone is considerable, and in order to make the model sustainable, the service may have to be priced out of some consumers' reach.[60] If the Authority opts to pursue an FTTP build-out where it retains ownership of the fiber optic network, it may have to seek large bonds to cover the capital costs of building the network, which it cannot directly procure. The Authority would have to rely on the counties or other public entities, and either ESVBA or the public entities or a combination would then be responsible for making principal and interest (P&I) payments, or debt service.

If the Authority seeks to use revenues from the FTTP network and any retail service offered over it to cover its debt service payments, service fees will have to be calculated with the total cost of P&I in mind. Unless the Authority can implement a sliding scale fee structure for its most vulnerable populations, those prices may not be affordable to all customers; thus, service prices

[59] See, for example: http://www.cnet.com/news/connecticut-communities-join-together-for-gigabit-broadband/, http://broadband.blandinfoundation.org/_uls/resources/Vision_Statement_FINAL_0228.pdf, and https://www.portlandoregon.gov/revenue/article/394185.

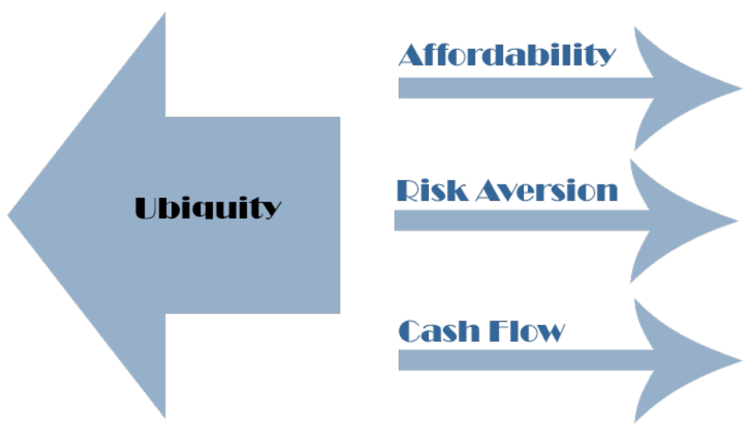
[60] This is not to say that pricing cannot be adjusted through various means to absorb additional costs to consumers, but this will likely come with a higher price tag for the ESVBA.

based on the Authority's need to pay for a ubiquitous build-out will likely conflict with the goal of ensuring that service is truly *accessible* to all potential customers on the Shore.

A full-scale build-out is typically not compatible with avoiding risk, as localities that seek ubiquity are likely to face stringent deadlines and much higher capital costs than a phased build-out. The Authority has indicated that it likely aims to develop network infrastructure in a phased approach; we note that even a phased build-out can be expensive.

Maintaining positive cash flow is another objective that conflicts with ubiquity. While the Authority likely does not expect to make a profit on the FTTP network, it is important for the network to be financially sustainable, covering at least any debt service payments and operating costs. This is often referred to as "positive cash flow" or "breakeven." Assuming the Authority is responsible for the cost of deploying the network, the higher cost to build to every structure in the Shore means that the point at which the network can establish positive cash flow will come much later than if the Authority slowly built out and began generating subscriber revenue earlier in the build-out process. Ubiquity generally conflicts with positive cash flow. Figure 15 illustrates the conflict between ubiquity and affordability, cash flow, and risk aversion.

Figure 15: Ubiquity Conflicts with Affordability, Cash Flow, and Risk Aversion



The Authority may determine that the advantages of pursuing a ubiquitous network build-out will outweigh any of the potential conflicts with other common objectives. Further, as we noted, ESVBA can take steps to manage some of the potential challenges associated with conflicting objectives (e.g., developing programs to help cover subscriber fees to ensure the service is not priced out of some consumers' reach).

Affordability – Service Can Be Purchased by Citizens at All Income Levels

Affordability is important even in communities that may have few low-income areas. While this objective is certainly more important for vulnerable portions of the community, affordability is often a necessary objective for public entities. For example, the Authority may prioritize affordability in an effort to ensure that entrepreneurs and tech startups in its service area can afford the robust connectivity necessary to support their business endeavors.

There are areas in the Shore where demand is likely low enough that private providers are unlikely to build there. Private providers typically cherry pick based on where they determine they are most likely to recover their cost to build. While the Authority may not be faced with the choice to potentially offset service costs for a large number of low-income residents, still it may benefit from choosing to invest in infrastructure throughout the community.

Providing affordable service to the entire community would likely create benefits for the Authority in terms of enhanced quality of life and economic benefits. Further, the Authority could work with local government and nonprofit agencies to fully leverage benefits that are not monetarily quantifiable. These “benefits beyond the balance sheet” cannot be measured on a financial statement, but their impact communitywide is often profound.

The Authority may be able to balance ubiquity and affordability by negotiating an agreement with one or more private partners that includes sensitivity to the need for affordable, accessible services in all parts of the Shore. Similarly, the Authority may decide to subsidize services for certain portions of the Shore.

Choice, competition, and ownership all interact favorably with affordability. If the Authority can reduce pricing to a level that is attainable to all potential subscribers in the Shore, the expansion of choice and the likelihood of increased competition will be notable. And if the Authority retains ownership of its assets, it can make choices about affordability similar to the control it can exert over performance.

If the Authority attempts to find ways to subsidize services directly, it may find that prioritizing risk aversion and attaining positive cash flow become more difficult. The more debt and responsibility the Authority takes on,[61] the higher its risk and the longer it will take for the FTTP network to achieve positive cash flow. Similarly, even if the Authority does not directly subsidize services, prioritizing affordability may mean pricing the product low enough that it is challenging to also prioritize risk aversion and cash flow. It will be important for the Authority to determine its priorities, and to strike a balance so that one objective is not achieved at the exclusion of another.

[61] Discussions with ESVBA representatives have indicated that bond financing may be available through the Virginia Resources Authority (VRA). It is beyond the scope of this report to assess the Authority’s bonding capacity, although we encourage the Authority to continue conversations with the VRA to understand its ability to pursue financing.

Consumer Choice – Citizens Can Purchase Service from Various Providers

Public entities often pursue open access as a means to increase consumer choice; this is an important consideration and a high priority for many communities. Incumbent cable and internet providers may have little economic incentive to expand to areas of the community where they believe they will not recover significant portions of their cost.

A ubiquitous network that fosters open access, boosts competition, and reaches all parts of the Shore can enhance consumer choice on a number of levels. In addition to gaining access to residential services that may previously have been unavailable, consumers may end up with greater flexibility to access services at various community locations. Ubiquity and competition enable enhanced services at community centers, religious institutions, educational facilities, and other locations that benefit residents.

Affordability of services ties directly with competition and consumer choice—being able to pay for services is often a major barrier for consumers. Having affordable access to services with competitive speeds can significantly improve quality of life, make residential areas more desirable, and spur business growth. Access to premium residential services at affordable prices can also incite home-based businesses, support continued education, and enable access to basic human services like healthcare and education.

Risk aversion could negatively impact consumer choice. If the Authority decides that it will slowly and organically build out its network and does not take steps to prioritize particularly vulnerable areas, it is possible that only the consumers who have traditionally enjoyed provider choice will be positively affected. The Authority may find that it can balance risk mitigation with community benefit by deliberately funding service to portions of the community that may be undesirable for a private entity.

Competition in the Market – Enabling Multiple Providers to Compete

Fostering competition in the market is generally the second component of an open access pursuit. That is, public entities often seek to develop an open access infrastructure to enable multiple providers to offer service over the network and enhance competition. Like consumer choice, this is generally a key reason public entities attempt to pursue a traditional open access infrastructure. Similar to consumer choice, competition in the market can be achieved through open access in the traditional sense as well as through other means.

What is important for most objectives is to determine whether they are primary, how they may conflict with others, and how best to pursue whatever the public entity deems is its most important goal(s). We believe that competition both upholds and is upheld by other potential primary objectives—it aligns with, does not impact, or is not impacted by other common objectives. The only potential exception to this is risk aversion, which we explain below.

Choice and competition go hand in hand, and seeking ways to encourage competition will likely only result in greater consumer choice in communities. Similarly, a ubiquitous network build will probably result in greater competition among local providers. This is not only through providers potentially offering services over the Authority's network, but also in the form of incumbent providers lowering prices and enhancing services in response to improved services by other providers.[62] This also speaks to competition vis-à-vis affordability and network performance: the greater the market competition, the greater the likelihood that other providers will seek to improve their services and lower their prices.

Competition in the market and consumer choice can be prioritized simultaneously with other objectives without negative consequences, and localities often find that focusing on the overall well-being of their communities and citizens has numerous advantages.

It is important to note, however, that there may be some risk involved with creating competition in the market. The service provider industry can be inhospitable, particularly when the perception is that a public entity is attempting to compete with private industry. A major challenge faced by networks built and operated by public institutions is opposition from existing, private-sector providers. There are a number of reasons for this, some of which are related to perception while others relate to the market itself. Criticisms could range from unauthorized use of general or other funds for debt service coverage, to questioning the need or demand for public-based connectivity services.

An important risk that the Authority should keep in mind is the potential for litigation from objectors ranging from incumbent providers to watchdog groups. Lafayette Utilities System (LUS) was sued by incumbent providers the same year it proposed creation of a separate utility for FTTP,[63] and the Tennessee Cable Telecommunications Association filed a lawsuit against Chattanooga's Electric Power Board (EPB).[64] These are only two examples of the litigation that public sector entrants to the market have faced from incumbent providers and others.

Ownership and Control of Assets

Retaining ownership of OSP assets is important to mitigate risk; owning assets is an important way for localities to retain some control of their networks. This includes a scenario in which a public entity pursues partnership with a private provider; a good way to balance risk and reward

[62] Marguerite Reardon, "Google's fiber effect: Fuel for a broadband explosion," *CNET*, April 30, 2014, http://www.cnet.com/news/googles-fiber-effect-fuel-for-a-broadband-explosion/, accessed December 2017.
[63] "About LUS Fiber: Timeline," LUS Fiber, *LUS Fiber,* http://lusfiber.com/index.php/about-lus-fiber/historical-timeline, accessed December 2017.
[64] "Cable Group Files Suit To Try To Block EPB Fiber Optic Plan," *The Chattanoogan*, Sept. 21, 2007, http://www.chattanoogan.com/2007/9/21/113785/Cable-Group-Files-Suit-To-Try-To-Block.aspx, accessed December 2017.

is for the Authority to maintain ownership and control of the fiber assets while it assigns operational responsibilities to a private partner. This enables both parties to perform functions that highlight their strengths while not having to expend resources and energy attempting to carry out tasks for which they are ill-equipped.

Cash flow could potentially conflict with ownership and control of assets, depending on the degree to which the Authority chooses to exert control. Maintaining a fiber optic network can be costly, particularly if the Authority opts to be the retail provider for the service. Operational expenses are a sizable and often unpredictable portion of overall network cost, and it can be difficult to get the take rate necessary to reach positive cash flow.

The Authority may choose to oversee and maintain the network—a function with which it is already well accustomed and for which it is already staffed to some degree—and rely on a private partner to deliver retail services. The Authority may also be able to govern price points to support consumer affordability and service speeds to enhance performance. And because the Authority would own the network, it would be in control of performance.

Performance – Standing Out with a Superior Network

Many communities are already served to some degree by incumbent providers—whether by large national cable or telephone companies, or small local ISPs. Network performance can thus be a powerful differentiator for a community broadband endeavor.

Prioritizing performance in a retail offering is not only advantageous, we believe it is necessary to make a public entity's offering stand out among existing broadband providers. Market entry is generally a major challenge for public sector retail providers, and even a public–private partnership will likely benefit from focusing on one or two highly specialized offerings to allow it to thrive among incumbents.

The Authority may find that it struggles and is more prone to failure if it attempts to compete with incumbent providers by offering services similar to existing packages. Instead, it is prudent to recognize gaps in the existing broadband market and seek to fill those with a unique service offering that incumbents are not currently able to provide. A high-speed, high-quality service may enable the Authority and/or a private partner to enter the market and avoid competing with "me too" services.

A high-quality scalable service may be the differentiator the Authority needs to stand out. By focusing on an extremely powerful data-only offering and communicating with potential subscribers about the advantages of a high-performance, unfettered data product, the Authority may spark the shift in the market it needs to be successful. The goal is to focus on *unbundling* from the traditional triple-play (i.e., focusing on data, not on cable and phone service), and effectively encouraging consumers to leverage the data service to its fullest capacity.[65]

Performance interacts favorably or not at all with other objectives. There are no disadvantages to prioritizing performance as a key objective in a community build, and we believe that this should be a main focus of any fiber enterprise.

If the Authority retains ownership of its assets, it also has better control over performance. By owning the network over which services are provided and overseeing a private entity that is serving end users, the Authority can require the level of performance that it deems appropriate to best serve the community's needs.

Risk aversion and cash flow both interact well with performance. We believe that the Authority minimizes its risk by entering the market with a high-performance network. The Authority can set itself apart from other providers by offering a high-speed data product that incumbents cannot.[66] Further, it can differentiate itself by having an always-on, extremely reliable service that customers can use in new and beneficial ways—like to operate a home-based business, telecommute to their job, or pursue an advanced degree.

Risk Aversion – Minimizing the Authority's Exposure and Liability

There are numerous potential risks the Authority may face as it considers FTTP deployment—financial, legal, and political, for example. While it is necessary to avoid risk to some degree, it is equally important to balance risk and reward. It may take considerably longer to design, build, and deploy a network if risk aversion is the Authority's top objective. The "slow and steady" approach is not without merits, but it is also unlikely to give a community a competitive edge. Decreased speed to market—or building out slowly—gives competitors more time to respond to the Authority's approach.

Figure 16 shows a risk and reward matrix that highlights the Authority's most likely low-risk-low-reward, low-risk-high-reward, high-risk-high-reward, and high-risk-low-reward outcomes. The lowest risk with the highest potential reward lies in building the network in a phased approach, specifically based on the Google Fiber build-to-demand model.[67] In this approach, the company signs up subscribers by neighborhood (known as "fiberhoods" in the Google Fiber model); once

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[65] It may be challenging to attract users who are accustomed to triple play services, but it will be a far greater challenge to compete with incumbent providers by offering the same packages.

[66] It is important to note that products like AT&T Fiber and Comcast Gigabit Pro do not set their advertised 1 Gbps and 2 Gbps service as a baseline. Rather, these products offer a 10 Mbps to 100 Mbps baseline with the potential to deliver 1 Gbps to 2 Gbps service as occasional exceptions. The ESVBA, on the other hand, may be able to provide service up to 10 Gbps and beyond, with 1 Gbps as its baseline.

[67] Alistair Barr, "Google Fiber Is Fast, but Is It Fair?", *The Wall Street Journal*, August 22, 2014, http://www.wsj.com/articles/google-fuels-internet-access-plus-debate-1408731700, accessed December 2017.

a neighborhood has reached a certain threshold level of committed subscribers, fiber will be built there.

Figure 16: Risk and Reward Matrix

		Risk	
		High	**Low**
Reward	**High**	o Deploy a ubiquitous communitywide FTTP build, partner with a private provider to operate the retail component, ESVBA maintains ownership and control of assets	o Prioritize risk aversion to avoid bonding, slowly expand network in a phased approach and engage a private partner for operation and retail services
	Low	o Compete with tiered services similar to incumbents – a "me-too" offering.	o Maintain current network and do not pursue expansion of services

If the Authority chooses this approach, it must recognize that it necessarily sacrifices certain other objectives like affordability and consumer choice. Risk aversion will generally come at the expense of objectives like these, and is especially in conflict with a ubiquitous build-out.

These objectives do not have to be mutually exclusive; instead, the Authority must decide to what degree it wants to prioritize which objective, and be prepared for possible conflicts and how to mitigate those. For example, if the Authority chooses a phased approach, it may opt to first expand service to a location that can demonstrate the power of the network. This will support marketing, and can potentially help convince consumers to sign up for service, thereby achieving ubiquity in a lower risk fashion.

Risk aversion conflicts with ubiquity, choice, competition, and affordability. As we previously noted, it will be challenging to obtain a ubiquitous build-out at all, and especially not within a few years, if the Authority prioritizes risk aversion as its key objective. Because the network is unlikely to be built out quickly in this case, it also reduces the likelihood of increased competition and choice.

If the Authority chooses to prioritize risk aversion, it will align with ownership, cash flow, and performance. Ownership of the assets usually means lower risk for the Authority because it has greater control and flexibility.

Positive Cash Flow – Becoming Financially Sustainable

Becoming cash flow positive is an important goal for any business or entity, and it is also a bit complex to define. Net income is often referred to as "cash flow," though this is technically incorrect because depreciation is a non-cash expense.

Earnings before interest, taxes, depreciation, and amortization (EBITDA) is the difference between operating revenues and operating expenses; it is a key metric in designing a viable financial model, along with net income. In a capital-intensive business such as an FTTP enterprise, EBIDTA must quickly become positive to keep the enterprise afloat. When EBITDA becomes positive, the business can be said to be cash flow positive. Net income then deducts interest, taxes, and depreciation. Revenues are tied to an enterprise's ability to be sustainable or cash flow positive. Collecting revenues to pay off debt and support business operations bolsters the net income and increases the likelihood that it will become positive.

Several objectives may conflict with cash flow, like affordability, ownership, and ubiquity. As we noted, revenue collection directly impacts cash flow so higher revenues mean a greater likelihood of being cash flow positive. If the service is priced affordably, this may mean lower monthly service fees and a longer path to the enterprise becoming cash flow positive, or self-sustaining.

Ownership may also impact cash flow, especially if the Authority elects to retain ownership of all network electronics, including CPE. Depreciation costs are significant, and it is important to reserve funds for equipment and infrastructure replacement. Typically, last-mile fiber and CPE are replaced after approximately five years, core network equipment is replaced after seven years, and outside fiber and facilities are replaced after 20 to 30 years. Because the useful life of fiber is generally assumed to be 20 years or more, our financial analyses do not account for its replacement. If the Authority opts to build and own only the dark fiber portion of the network, its risk will be much lower than if it is responsible for core network equipment and CPE replenishments.

Another element of ownership in the context of cash flow is the need for network maintenance and locating costs. Even if a public entity has experience with maintaining a fiber optic network, increased costs associated with serving an increased volume of end users may be significant in terms of both locating and replacing equipment at customer homes and businesses.

Appendix D: Technology Overview

The following is a summary of the types of technology either currently deployed on the Shore or likely to be deployed in coming years.

In summary, there is little debate that, for purposes of capacity, reliability, and scalability, FTTP is superior to all other fixed broadband technologies. FTTP is superior in capacity to even the best of all theoretical wireless technologies (which, we note, would require a large amount of fiber infrastructure for backhaul). Indeed, fiber is one of the few technologies that can legitimately be referred to as "future-proof," meaning that it will provide customers better, faster service offerings to accommodate growing demand.

Quite frankly, wireless technologies available today cannot approach fiber's capabilities. We note wireless deployments can be a truly effective solution for short distances in targeted areas with optimal topographical conditions. Millimeter-wave wireless networking can provide gigabit speeds, but is limited to direct line of sight, and, for the foreseeable future, its high cost limits it to multi-dwelling buildings in urban areas. Given this, for reliable, dependable, high-speed, low-latency, future-proof technology, fiber is the best approach.

Indeed, the biggest advantage that fiber offers is bandwidth. A strand of standard single-mode fiber optic cable has a theoretical physical capacity in excess of 10,000 GHz,[68] far in excess of the entire usable wireless spectrum combined, and thousands of times the capacity of any other type of wired medium. Furthermore, the capacity can be symmetrically allocated between upstream and downstream data flows using off-the-shelf technology.

Fiber-to-the-Premises

Fiber optic cables are the medium of choice for data transfer. They have enormous bandwidth capacity, which enables operators to offer symmetrical download and upload speeds. Fiber is also not subject to interference, and does not require amplifiers to carry a signal over long distances.[69] This is why the vast majority of the internet backbone comprises bundles of fiber cable strands.

Once a location is connected to fiber, there is no need for significant OSP infrastructure investment for decades. If more bandwidth is needed, the operator need only upgrade the network electronics, rather than having to replace the cables.

[68] Conservative estimate derived from the channel widths of the 1285 to 1330 nm and 1525 to 1575 nm bands in G.652 industry-standard single-mode fiber optics.
[69] Maximum distances depend on specific electronics. Six to 25 miles is typical for fiber optic access networks.

The electronics needed to provide 1 Gbps speed over an FTTP network are already widely available at an affordable price, and the price of the electronics needed to support 10 Gbps connections are declining rapidly.

Fiber overview

Fiber is the newest and most advanced form of wireline communications infrastructure. Fiber cables contain thin strands of glass (or in some cases plastic). Most commercial broadband providers already use fiber in portions of their network architecture, but then connect the user over wireless, coaxial, or copper lines. Since the 1980s, fiber has been incorporated into middle-mile and backhaul connections—the lines that are used to aggregate data traffic and provide high-capacity transport between cities and across continents. Fiber optic cables have a range of fiber strand counts depending on the specific application; a backbone fiber cable could have hundreds of strands, while a fiber cable serving a neighborhood or a few buildings would have a few dozen strands and a cable to an individual house might have one or two strands.

Fiber carries data as a series of pulses of light, traveling from one end of the fiber to the other. This is a major change from the electrical signals of metal conductor-based networks of telephones and cable television. Fiber cables and their optical light signals do not experience most of the physical limitations of metal-based networks. Optical light signals can travel great distances with minimal signal deterioration. Typical fiber networks can carry broadband data signals up to 50 miles between electronics. The superior range eliminates the need for electrical power and equipment in the middle of most networks. Fiber networks also have lower operating costs relative to cable networks because they require less staffing and maintenance.

Fiber networks have better reliability than cable networks. With less equipment needed to operate the network, there are fewer points of failure that could disrupt communications. Optical fibers do not conduct electricity and are immune to electromagnetic interference. These properties allow fiber to be deployed where conductive materials would be dangerous, such as near power lines. Lastly, fiber optics do not corrode due to weather and environmental conditions in the same way that metallic components can deteriorate over time.

Figure 17 illustrates a sample FTTP network, demonstrating how high levels of capacity and reliability are brought directly to the premises. Figure 18 (below) illustrates in more detail how an FTTP network provides connectivity without a technical bottleneck to the internet or other service providers, and can also provide a flexible, high-speed backbone for wireless services.

Figure 17: Sample FTTP Network

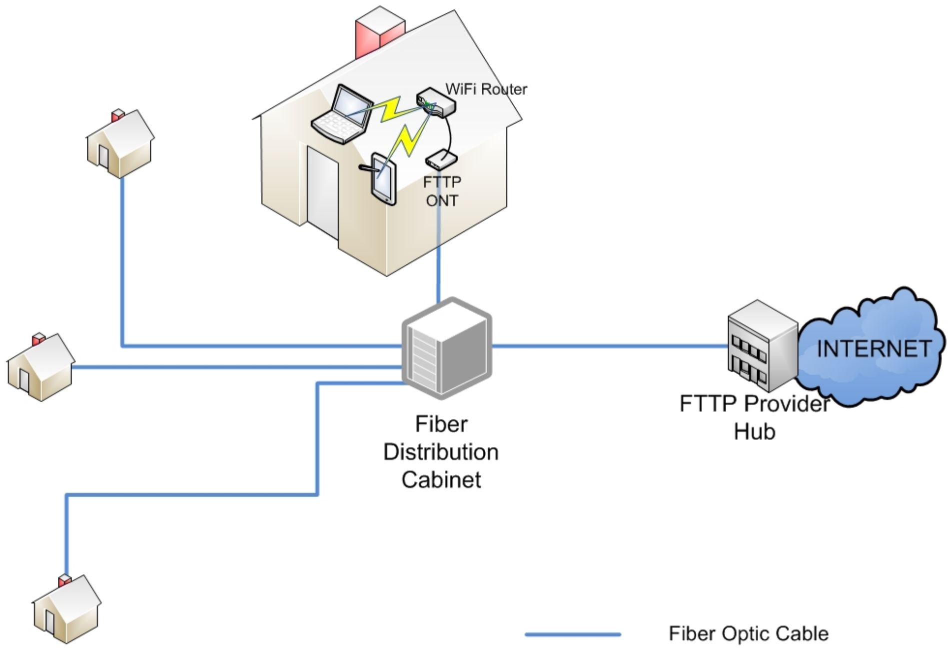
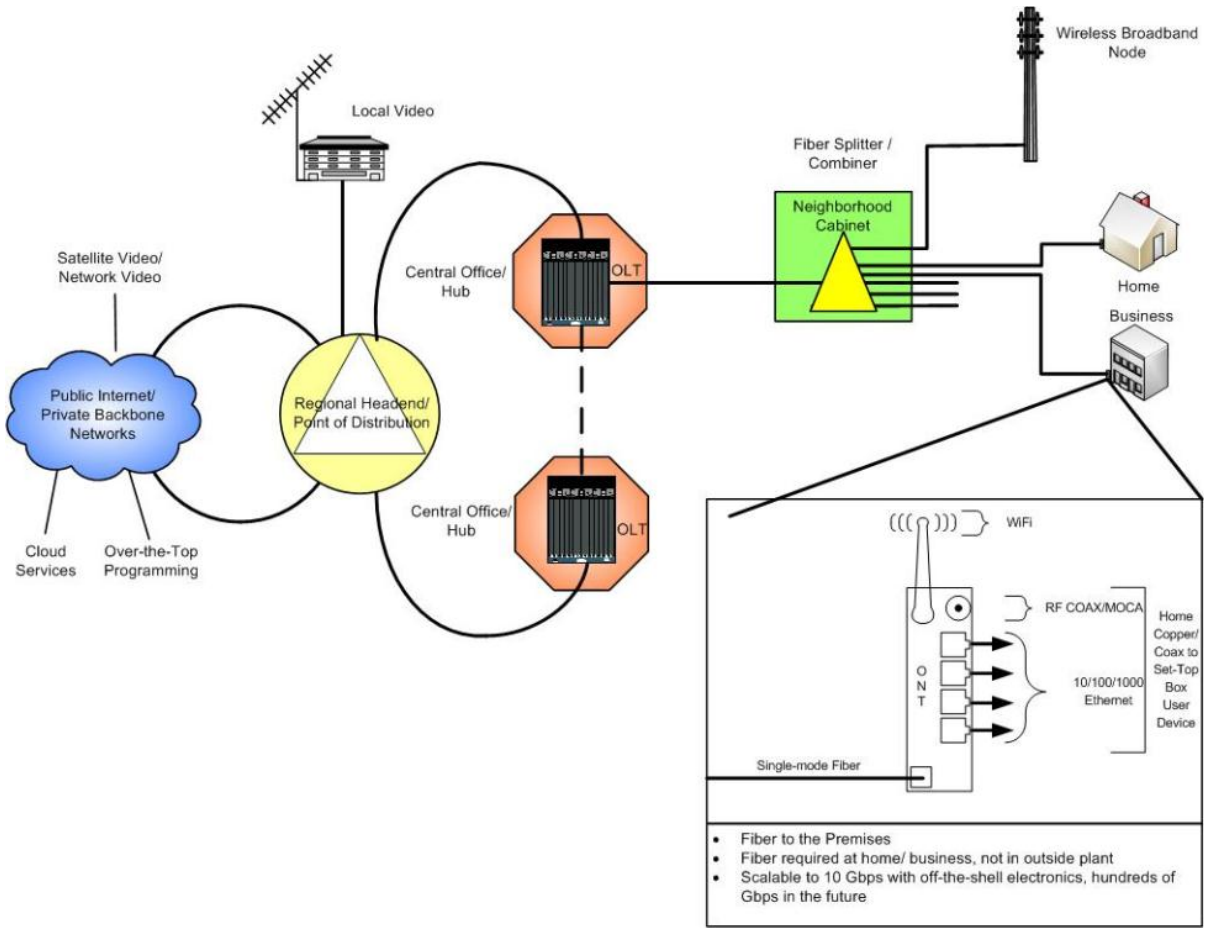


Figure 18: Sample FTTP Network (Detailed)



Fiber has a much greater physical capacity than coaxial cable, and FTTP networks therefore eliminate one of the most significant bottlenecks in a cable system. Off-the-shelf FTTP equipment (as deployed in Verizon's FiOS networks, Google Fiber networks, Sonic Internet's network in San Francisco, AT&T Fiber networks, and Chattanooga EPB's network) are capable of delivering 1 Gbps services to each customer over a single fiber. The technology is also well-suited to open access, with the ability to assign individual fibers to individual service providers, or provision separate electronic capacity.

The main limitation on the speeds fiber networks can achieve is not based on the properties of the fiber optic cables themselves, but instead on the processing power of the networking equipment connected to the fibers.

Some FTTP operators, such as Verizon FiOS, use passive optical network (PON) technology, typically splitting the fiber capacity in a neighborhood cabinet to connect 16 to 32 customers. These provide less capacity than the direct fiber networks (also known as active Ethernet or point-to-point), but are still generally able to sustain a constant 100 Mbps to all users in the downstream direction. Recognizing that most customers' consumption today is highly variable and that some degree of oversubscription is likely in any network, it is reasonable to expect that symmetrical connections of 1 Gbps capacity can be supported over most PON networks. In fact, most of the "Gig" services advertised recently, operate over PON networks.

Currently deployed PON networks have capacity of 2.5 Gbps/622 Mbps (GPON) or 10 Gbps/2.5 Gbps (10GPON), or between about 75 Mbps and 300 Mbps of "dedicated" capacity per customer even with a splitter ratio of 1:32.

The following table summarizes the pros and cons of fiber technology.

Table 30: Pros and Cons of Fiber Technology

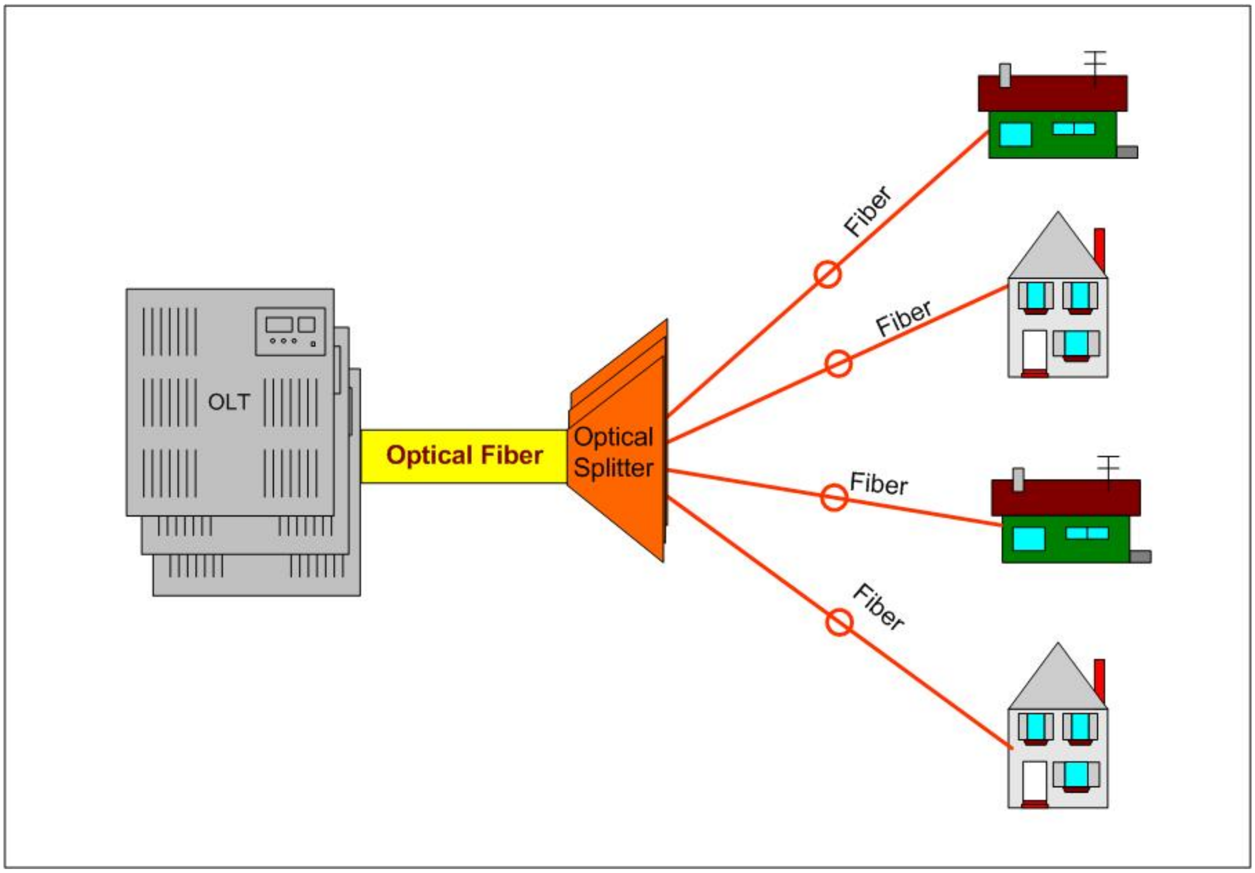
Pros	Cons
• Higher capacity and more reliability than cable systems • Optical light signals can travel great distances (up to 50 miles between electronics) with minimal signal deterioration • Optical fibers do not conduct electricity and are immune to electromagnetic interference • Fiber networks are more reliable and require less maintenance than cable networks • Fiber can be deployed where conductive materials would be dangerous, such as near power lines • Fiber can provide a flexible, high-speed backbone for wireless services	• Capacity limited by the processing power of the networking equipment connected to the fibers • Highest-capacity connections require direct fiber connections to customer premises

Factors impacting quality and speed of service

The following factors will determine an FTTP customer's service speed and quality:

- **Network electronics:** Core equipment in an FTTP network is housed at a central office (CO) or video headend office (VHO). As network electronics continue to improve, FTTP providers will be able to add higher tiers of service.
- **Network architecture:** Some FTTP operators use passive optical network (PON) technology, splitting the fiber capacity in a neighborhood cabinet to connect up to 64 users (Figure 19).

Figure 19: FTTP-PON Network Architecture



Digital Subscriber Line

During the last century, phone companies connected virtually every home and business in the U.S. to a strand of copper wire. Those connections were intended for wireline voice service, but became the primary means of data service for most rural areas of the country in the internet era, through a technology known as digital subscriber line (DSL), which enables data service over copper. Copper has a fraction of the bandwidth capacity of technologies that serve metropolitan areas (such as the cable industry standard, coaxial cable), and suffers from greater signal loss and interference—but because of copper's ubiquity, DSL has been an important way for people to connect to the internet. While DSL has been an impressive retrofit of existing infrastructure, copper cable is reaching its physical limitations as a broadband medium, and will not be able to meet future bandwidth needs. DSL's technical limitations are further compounded by the relative lack of investment by some phone companies, including Verizon, in rural wireline service. As Verizon's attention has turned to mobile over wireline in rural areas, investment and attention to the DSL networks has meant that services have remained static or deteriorated, rather than improving with renewed investment.

Technical capacity and limitations

Bandwidth limits on copper cables are directly related to the underlying physical properties of the medium. Higher data rates require a broader frequency range of operation. Twisted-pair copper wire is limited to a few tens of megahertz in usable bandwidth, at most, with dramatic signal loss increasing with distance at higher frequencies.

The main determinant of DSL speed is the length of the copper line from the telephone company central office. In systems operated by large telecommunications companies, the average length is 10,000 feet, corresponding to available DSL speeds between 1.5 Mbps and 6 Mbps. In systems operated by small companies in rural areas, the average length is 20,000 feet, corresponding to maximum speeds below 1.5 Mbps.

The fastest copper telephone line technologies widely deployed in outside cable plant in the U.S. are VDSL and VDSL-2, the technologies underlying AT&T's U-verse and other services. Because these technologies use high frequencies, they are limited to 3,000 feet over typical copper lines and require fiber to the node (FTTN)—much closer than in most HFC systems. Therefore, in order to operate VDSL and VDSL-2, telecommunications companies must invest in large-scale fiber optic construction and install remote cabinets in each neighborhood.

In practice, telephone companies using VDSL-2 over highly upgraded copper lines have been able to provide 25 Mbps over a single copper pair and 45 Mbps over two pairs to the home or business—but it took a significant investment to make it possible for a small percentage of the copper phone lines to temporarily keep pace with cable. Providing even greater speeds will require some combination of even deeper fiber construction, a breakthrough in transmission technology over copper lines, and conditioning and upgrading of the existing copper lines.

The Alcatel-Lucent G.Fast DSL product in development has reached speeds of 500 to 800 Mbps in various environments—but it is limited to 330 feet, requiring the construction of fiber to the curb in front of each home or business—an investment that would be comparable to building a FTTP network.[70] As a result, G.Fast has so far mostly been focused on deployments using telephone wires inside buildings.

Factors impacting quality and speed of service

The following factors will determine a DSL customer's service speed and quality:

- **Length of copper line/proximity to fiber:** The longer a signal has to travel over copper cable, the slower the possible connection speed.
- **Condition of copper cable:** Copper cable corrodes over time. As it deteriorates, interference increases and the available bandwidth shrinks, limiting the possible connection speed.
- **Number of copper pairs available:** To overcome the inherent limits of copper cable, some operators bundle multiple copper pairs. Some technologies, such as G.Fast, are highly susceptible to cross-talk interference between different pairs of copper, limiting how many customers can receive the service in a given cable.

Future capacity and lifespan of investment

The growing demand for bandwidth has collided with the physical limitations of copper as a medium for transporting data. Even if an operator can satisfy present demand using existing copper assets, it is a significant challenge to upgrade a DSL network in a way that the majority of a large scale network can continue to serve future demand. As a result, most telecommunications companies are minimizing their investment in copper lines, and some are abandoning copper lines for wireless services or migrating to FTTP. New investment in DSL will likely become obsolete within a decade.

Fixed Wireless

The high cost of building wired networks slows or forestalls build-outs of new wired broadband networks. Wireless internet service providers (WISPs) are potentially able to fill these coverage gaps, sending signals from base stations to antennas on or near customer premises. Until

[70] Mikael Ricknas, "Alcatel-Lucent gives DSL networks a gigabit boost," *PC World*, July 2, 2013, http://www.pcworld.com/article/2043483/alcatellucent-gives-dsl-networks-a-gigabit-boost.html (accessed June 2017).

recently, as millimeter wave technology has become available, WISPs were not able to offer connection speeds on a market-wide basis comparable to cable or FTTP built to each premises, and often needed to impose data caps on customers to manage limitations on capacity. Even with the introduction of millimeter-wave equipment with gigabit speeds, the high cost of electronics and the need for a direct line of sight limits the technology to multi-dwelling buildings that can justify the investment.

Technical capacity and limitations

WISPs like San Francisco's Webpass and Monkeybrains use a combination of millimeter wave technologies, which require direct line of sight, and the same unlicensed spectrum bands as Wi-Fi, which does not have strong long-distance transmission qualities.[71] (This is in contrast to the large mobile carriers like AT&T, Sprint, T-Mobile, and Verizon Wireless, which offer 4G service using licensed spectrum.) WISPs may also use other unlicensed or semi-licensed bands like 3.5 GHz or 900 MHz, but these also have low data speed capabilities.

Most wireless networking solutions require the antenna at the customer premises to be in or near the line of sight of the base station antenna. This can be especially challenging in areas with dense vegetation or multiple tall buildings. WISPs often need to lease space on rooftops or at or near the tops of radio towers; even then, some customers may be unreachable without the use of additional repeaters. And because the signal is being sent through the air, climate conditions like rain and fog can impact the quality of service.

Some wireless providers in rural areas have begun to use vacant television frequencies called TV white space (or simply white space) to provide service. These TV bands have much better non-line-of-sight transmission qualities than the unlicensed bands; however, because white space technology is still in an early phase of development, compatible equipment is more expensive than other off-the-shelf wireless equipment.

Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-multipoint solutions are more affordable to implement and are typically used in a WISP environment. However, they limit the capacity of the network, particularly in the upstream, making the service inadequate for applications that require high-bandwidth connections.

Fixed wireless systems built with off-the-shelf Wi-Fi-band equipment today tend to have an aggregate capacity between 100 and 250 Mbps. With innovations like higher-order multiple input, multiple output (MIMO) antennas, and the use of spatial multiplexing, these capacities will likely increase across vendors to as fast as 750 Mbps. It is important to note, however, that this

[71] Webpass and Monkeybrains are also using higher-speed millimeter-wave proto-5G equipment, discussed in more detail in Section 1.1.2.

is the aggregate capacity; in a point-to-multipoint architecture, bandwidth will be shared among all the users connected to a single base station. For this reason, some WISPs are focusing on point-to-point services, where the capacity on each link is fully dedicated to that connection, or a point-to-multipoint architecture deliberately designed with a limited number of customers in the service area. Millimeter-wave technologies, described in more detail below, provide the potential for significantly higher bandwidth, yet these technologies are mostly used today in point-to-point architectures, or in very short-range point-to-multipoint deployments.

Factors impacting quality and speed of service

The following factors will determine a fixed wireless customer's service speed and quality:

- **Wireless equipment used:** Different wireless equipment has different aggregate bandwidth capacity and uses a range of different spectrum bands, each with its own unique transmission capabilities.

- **Backhaul connection**: Although the bottleneck tends to be in the last-mile connection, if a WISP cannot get an adequate connection back to the internet from the tower, equipment upgrades will not be able to increase available speeds beyond a certain point.

- **Unobstructed line of sight:** Most wireless networking equipment require a clear, or nearly clear, line of sight between antennas for optimum performance. WISPs often lease space on rooftops or near the tops of radio towers, in order to cover the maximum number of premises with each base station. In mountainous regions, many premises may not have a clear line of sight to a radio tower.

- **Weather conditions and foliage:** Depending on the spectrum used, weather conditions like rain or fog may cause interference. Also, line-of-sight paths that are clear during the winter may be obstructed by foliage during the warmer months.

Future capacity and lifespan of investment

Wireless equipment generally requires replacement every five to 10 years, both because exposure to the elements causes deterioration, and because the technology continues to advance at a rapid pace, making equipment from a decade ago mostly obsolete. The cost of deploying a wireless network is generally much lower than deploying a wireline network, but the wireless network will require more regular investment.

Mobile Broadband

Cellular wireless carriers have been consistently increasing their data speeds with the rollout of faster and higher capacity technologies, such as Long-Term Evolution (LTE)[72]. Over the past few years, they have provided data plans with speeds comparable and in many cases greater than a typical residential customer's internet service.

Technical capacity

Wireless providers operate a mixture of third-generation (3G) and fourth-generation (4G) technologies. The service providers typically provide devices (smartphones, air cards, tablet computers) bundled with 3G or 4G services. Typically devices are not portable from carrier to carrier, because they are "locked" into the carrier by software and/or because differences in the frequency bands used by the carriers limits compatibility of the devices (discussed below). Therefore, the purchase of a device is a de facto commitment to a particular service provider, as long as the user uses the device.

The strict definition of 4G from the International Telecommunications Union (ITU) was originally limited to networks capable of peak speeds of 100 Mbps to 1+ Gbps depending on the user environment;[73] according to that definition, 4G technologies[74] are not yet deployed.

In practice, a number of existing technologies (e.g., LTE) are called 4G and represent a speed increase over 3G technologies as well as a difference of architecture—more like a data cloud than a cellular telephone network overlaid with data services. The ITU and other expert groups have more or less accepted this.[75]

[72] LTE is a 4G cellular wireless technology offering data speeds of typically around 30 Mbps, depending on the signal strength and level of use of the connection.
[73] Stephen M. Blust, "Development of IMT-Advanced: The SMaRT approach," International Telecommunication Union, http://www.itu.int/itunews/manager/display.asp?lang=en&year=2008&issue=10&ipage=39&ext=html (access June 2017).
[74] Such as LTE Advanced under development.
[75] Stephen Lawson, "ITU softens on the definition of 4G mobile," *NetworkWorld*, December 17, 2010, http://www.networkworld.com/article/2197135/wireless/itu-softens-on-the-definition-of-4g-mobile.html (accessed June 2017).

Table 31: Typical Performance for Advertised 2G/3G/4G Services

Applications	Technology (Download/Upload Service Speeds)[76]	
	3G–EVDO Rev A, HSPA+ (600 Kbps–1.5 Mbps/500 Kbps–1.2 Mbps)	4G –LTE (1.5 Mbps–30 Mbps/500 Kbps–5 Mbps)
Simple text e-mails without attachments (50 KB)	Good (1 second)	Good (1 second)
Web browsing	Good	Good
E-mail with large attachments or graphics (500 KB)	Good (3 seconds)	Good (1 second)
Play MP3 music files (5 MB)	Fair (27 seconds)	Good (7 seconds)
Play video files (100 MB for a typical 10-minute YouTube video)	Fair (9 minutes)	Good (3 minutes)
Maps and GPS for smartphones	Fair	Good
Internet for home	Fair	Good

Limitations

Most businesses and residents will find that wireless broadband has technological limitations relative to wireline. These include:

1) *Lower speeds.* At its peak, LTE provides only about one-tenth the speed available from FTTP and cable modems. In coming years LTE Advanced may be capable of offering Gbps speeds with optimum spectrum and a dense build-out of antennas—but even this will be shared with the users in a particular geographic area and can be surpassed by more advanced versions of wireline technologies.

[76] This table assumes a single user. For downloading small files up to 50 KB, it assumes that less than 5 seconds is good, 5–10 seconds is OK, and more than 10 seconds is bad. For downloading large files up to 500 KB, it assumes that less than 5 seconds is good, 5–15 seconds is OK, and more than 25 seconds is bad. For playing music, it assumes that less than 30 seconds is good, 30–60 seconds is OK, and more than 100 seconds is bad. For playing videos, it assumes that less than 5 minutes is good, 5–15 minutes is OK, and more than 15 minutes is bad.

2) *More asymmetrical capacity, with uploads limited in speed.* As a result it is more difficult to share large files (e.g., video, data backup) over a wireless service, because these will take too long to transfer; it is also less feasible to use video conferencing or any other two-way real-time application that requires high bandwidth.

3) *Stricter bandwidth caps or speed throttling.* Most service providers limit usage more strictly than wireline services. Though wireless service providers offer unlimited data plans, those plans may not be affordable or throttle speeds after a certain amount of use per month.

From a residential customer's perspective, a mobile wireless data cap may still be sufficient for a light user of the internet (especially customers who do not realize that the data cap is limiting their use). And higher connection speed may be considered a more desirable feature than unlimited, unfettered data.

Mobile broadband is only available where cell service exists. Furthermore, there are some areas, particularly indoors or in basements, where the cell service is relatively weak, and the broadband service is limited to slower service with speeds comparable to telephone dial-up.

"5G" Wireless Is Promising but Does Not Represent an Immediate Opportunity

Though no formal standard yet exists, next-generation wireless technologies are often referred to as "5G" in marketing and other contexts. At the moment, 5G is currently a catchphrase encompassing efforts by research and development community, hardware and software manufacturers, wireless service providers, and standards committees.[77] It is not a single standard, but elements of it are being developed in the ITU, and by 3GPP (who developed GSM and LTE).[78]

Fixed wireless 5G will still require further deployment of fiber optic cable to provide backhaul to dense deployments of relatively short-range but high-capacity transmitters. In addition, advanced wireless technologies may also require enhancement of the speeds and capabilities of existing technologies that govern data transmission over fiber. In addition, 5G will probably complement and replace many existing wireless carrier technologies. As conceived, it may also link to the development path of unlicensed Wi-Fi and WiGig technologies, so that in some ways there may be more synergies and connections between the wireless networks built by service providers and the unlicensed networks deployed by individuals, institutions, and wireless service

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[77] For example, ITU WP 5D is responsible for the overall radio system aspects of International Mobile Telecommunications (IMT) systems, comprising the IMT-2000, IMT-Advanced and IMT for 2020 and beyond. *See:* "Working Party 5D (WP 5D) - IMT Systems," ITU, http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/default.aspx (accessed June 2017).

[78] Andreas Maeder et. al, "A Scalable and Flexible Radio Access Network Architecture for Fifth Generation Mobile Networks," *IEEE Communications Magazine*, Volume 54, Issue 11, November 15, 2016, p. 16, http://ieeexplore.ieee.org/document/7744804/?reload=true (accessed April 2017).

providers who do not use wireless spectrum. It may also provide an alternative broadband medium for homes and businesses, though it is important to note that a wired service will always be able to provide a higher speed and more reliable service than will a wireless connection.

It is important to note that prototype-5G technologies are seeing preliminary deployment in urban areas only. For example, the companies Monkeybrains and Webpass (the latter was acquired by Google last year) are providing services in San Francisco, Boston, and Denver using proprietary equipment that might be considered an early version of 5G technology. These providers interconnect their fiber networks with high-speed wireless networks. In these examples, very high-frequency (microwave and millimeter wave, respectively) link rooftops of tall buildings, and serve apartments and businesses in the buildings over the internal wiring of the buildings.[79] Also in urban areas, another version of newly-commercialized millimeter wave technology for high-speed residential broadband service avoids any need for building wires, instead connecting wirelessly with window-mounted devices in customers' apartments.[80]

In addition to providing an alternative approach to gigabit broadband to large buildings, the industry foresees 5G as accommodating current growing broadband needs and connecting new types of technologies. Indeed, 5G is envisioned as a technology that will connect both fixed and mobile users. It is envisioned as connecting the types of devices used now, such as fixed access points and smart phones, but also connecting new generations of devices and machines, with a strong focus on automation—adding intelligence to vehicles and machines; making it possible to radically change how things are controlled and managed; and creating new ways to collect and analyze data.

That said, 5G is a long way from widescale deployment in the metropolitan areas of the U.S. and even further from deployment in rural areas. Initial Verizon 5G trial cities include Ann Arbor; Atlanta; Bernardsville, NJ; Brockton, MA; Dallas; Houston; Denver; Miami; Seattle; and Washington, D.C.—with the idea that these provide "a variety of terrain, neighborhood layouts, and population density," [81] but still generally focus on major metropolitan areas.

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[79] Boris Maysel, "When and How to Use Multi-Gig mmWave," Presentation, Siklu, p.8, https://www.siklu.com/wp-content/uploads/2016/09/mmWave-for-Consultants-webinar.pdf (accessed June 2017).
[80] David Talbot, "Wireless, Super-Fast Internet Access is Coming to Your Home," *MIT Technology Review*, May 16, 2016, https://www.technologyreview.com/s/601442/wireless-super-fast-internet-access-is-coming-to-your-home/ (accessed April 2017).
[81] Diana Goovarts, "Verizon Announces 5G Customer Trials in 11 Cities with 5G Forum Partners," *Wireless Week*, https://www.wirelessweek.com/news/2017/02/verizon-announces-5g-customer-trials-11-cities-5g-forum-partners (accessed April 2017).

Required Functionality of 5G and Driving Forces

The 5G community sees 5G bringing six major improvements relative to existing wireless technologies:[82]

1) Higher capacity
2) Higher data rate
3) Lower latency
4) Massive device connectivity
5) Reduced cost
6) Consistent quality of experience

Higher capacity is the ability to simultaneously connect many more users and devices than the current network. As currently envisioned, a 5G served area needs to be able to serve 20 Gbps of aggregate capacity, which is the amount expected in some environments in the early 2020s.[83] Therefore, the access device—whether a macro cell, small cell, or indoor device—needs to be able to have sufficient spectrum, and, using a variety of advanced technologies, potentially needs to serve 100 times more devices than do current cell sites.

Higher data rate is the ability of an individual user or device to send and receive high speed transmissions. The 5G standard is being developed with data rate potentially in the 1 Gbps or more range per user/device[84]—with "power users" being able to access even higher speed in some situations. This compares to 30 Mbps in current 4G wireless networks. Since the wireless environment is expected to support more interactive applications, the data rate also needs to be much more symmetrical than the current environment, which typically has ten to a hundred more times as much capacity in the network-to-user direction as in the user-to-network direction.

Lower latency is a reduction in the time it takes for a signal or message to go from one end to another end of the network. The objective is less than 10 milliseconds (ms) and potentially less than 5 ms[85] to support critical machine to machine communications—notably including cars and other vehicles, for which low latency is critical for collision avoidance and other safety-related applications. This compares to latency up to about 50 ms in current 4G wireless networks. The reduction is to be accomplished by reducing the number of intermediate components and the delay from each network "hop." It will also be accomplished by providing the ability to directly connect devices to each other independent of base station in a relay mesh mode.

[82] Akhil Gupta, R.K. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies," *IEEE Access*, Volume 3, p. 1208, http://ieeexplore.ieee.org/document/7169508/ (accessed April 2017).
[83] Maeder, p. 17.
[84] Maeder, p. 17.
[85] Gupta, p. 1209.

Massive device connectivity is the ability to seamlessly connect large numbers of critical devices in a dense configuration. As it is being developed, 5G needs to be able to simultaneously connect more than 100 mission critical devices per square kilometer (in addition to a complement of standard devices and users).

5G needs to optimize and **reduce costs** in all network components. Unlike in previous deployments, where the service providers built to connect more people and businesses to wireless networks and thus increase the total size of the revenue "pie," the industry now understands that almost all people and businesses are already connected. If the many new components and systems of 5G are to be deployed and operated using a similar level of revenue as the industry receives today, the network build-out needs to be cost-effective. Because of the large number of components, the components must each be lower cost, lower complexity devices. They need to be small, minimizing the "real estate" they occupy and be highly energy-efficient and low maintenance. And 5G networks must have ability to operate even if individual devices fail, and not require each site being costly and resilient, with full backup power. Service providers may consider business models in which one or more infrastructure companies provide access to shared radios and fiber backhaul to multiple providers at once.

Finally, there needs to be **consistent quality of experience provisioning**. 5G will support an extremely diverse set of users, devices and applications. The network needs to provide a quality of service or quality of experience that suits each one.[86] Current 4G networks can prioritize applications and users, and provide packet delivery and service guarantees. 5G will need to do all of that but also support user groups that currently are served by wireline services, and user groups and devices that do not yet exist. This calls for a wider range of customized services, including high-criticality, low bandwidth uses (such as electric utility control components); moderate-bandwidth, high-criticality uses (automated vehicles); moderate-bandwidth, moderate-criticality uses (email, texting); and high bandwidth; and moderate criticality (video, CCTV, gaming). The network must be able to tune to the appropriate use and work with a business model that efficiently accommodates all the uses.

Proposed Architecture

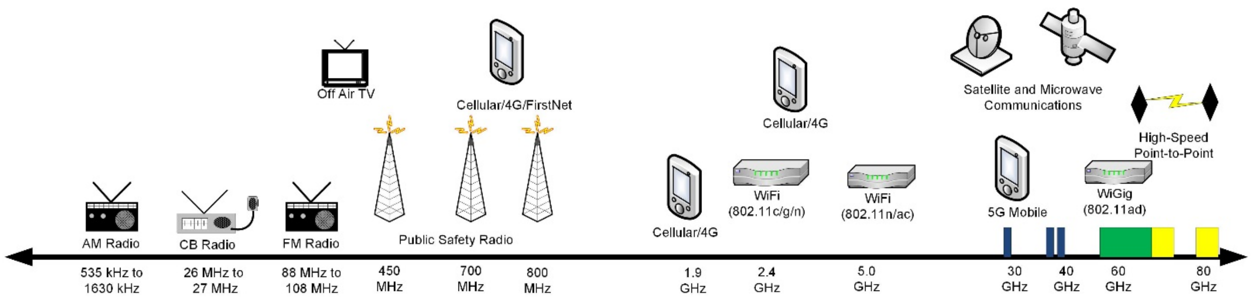
5G is planned to use a range of network layouts, including some that resemble current point-to-multipoint cellular deployments, and some that add multitiered service delivery, mesh, and separate indoor and outdoor networks. 5G is expected to use spectrum currently assigned for licensed wireless use, along with new higher-frequency bands and unlicensed bands.[87] Emerging

[86] Maeder, p. 21.
[87] Maeder, p. 17.

and future generations of Wi-Fi may also be included under 5G, potentially leading to greater integration between private unlicensed networks and commercial carrier networks.[88]

5G can be expected to use any of the existing commercial bands—including the 700 and 800 MHz cellular, and the higher-frequency 1.9, 2.1 and 2.5 GHz bands (Figure 20). In addition, high-frequency spectrum bands at 28 GHz and 39 GHz (blue bands) are becoming available for mobile use, as well as an unlicensed band at 60 GHz (green bands).

Figure 20: New Spectrum Is Likely to Be Central to 5G Deployment



The high-frequency bands have several advantages, including wide channels, and small wave forms that enable the use of smaller antenna elements on microchips. However, high frequencies have the disadvantage that they are more susceptible to being blocked or scattered by obstructions including buildings, walls, foliage, and even raindrops. As a result, high frequency signals need a direct line of sight or near light of sight. Long distance links are not advisable.

Near 60 GHz there is high absorption from oxygen, further limiting the range. Still, the bands near 60 GHz are envisioned for unlicensed use—potentially for connectivity indoors, or short range connections from utility poles to houses.

At frequencies above 70 GHz (yellow bands), spectrum is set up in a lightly-licensed arrangement, for point-to-point communications. In the future, technological innovations may also make mobile communications feasible in these bands.[89]

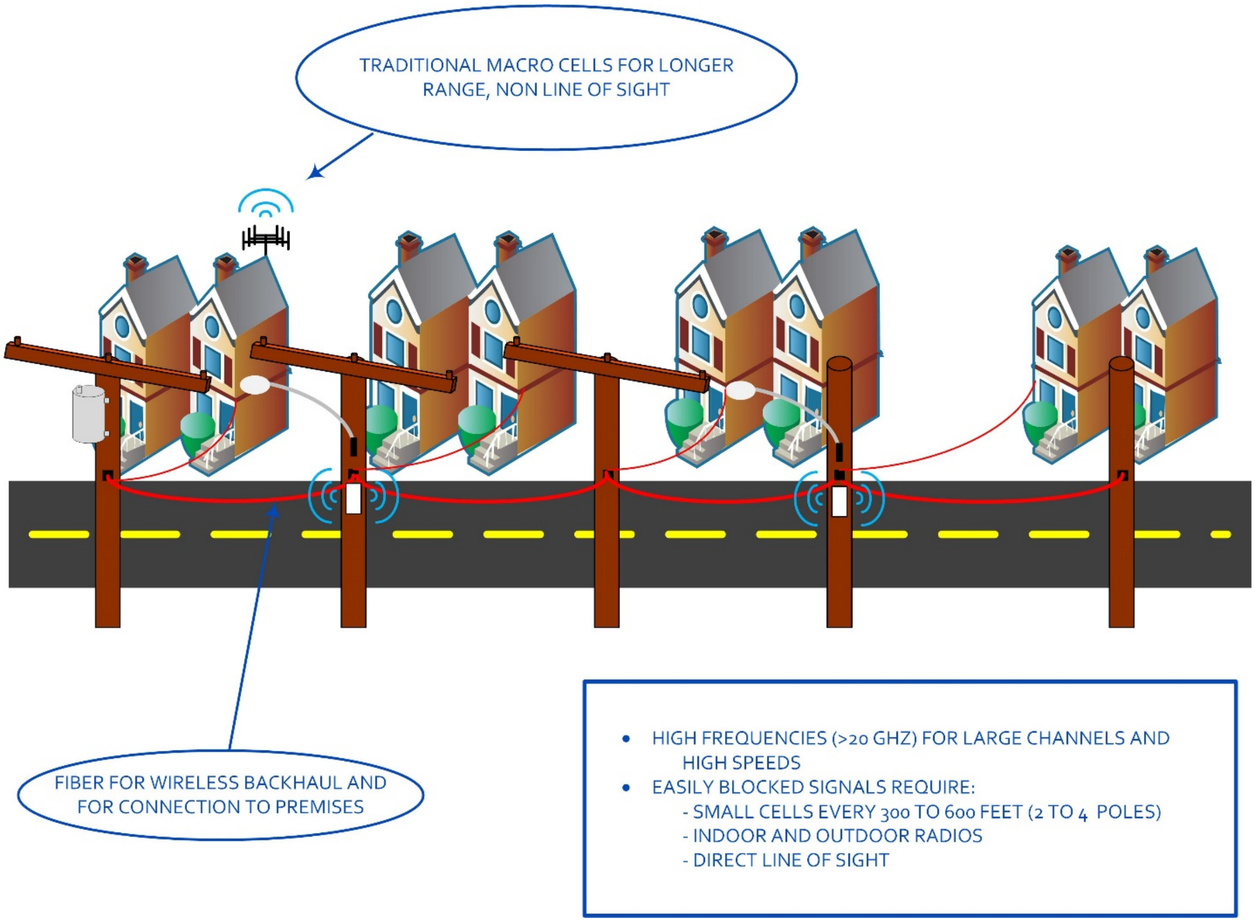
Deployment Path

It is envisioned that 5G deployment will begin as an enhancement of existing 4G networks, filling especially high demand areas.[90] For example, in a busy city street or in a transit center, 5G access points connected to fiber can provide boosted data capacity to 5G-ready phones and devices

[88] Maeder, p. 16.
[89] Notice of Proposed Rulemaking, Federal Communications Commission, p. 145 to 154, adopted October 22, 2015, https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-138A1.pdf (accessed June 2017).
[90] Maeder, p. 22.

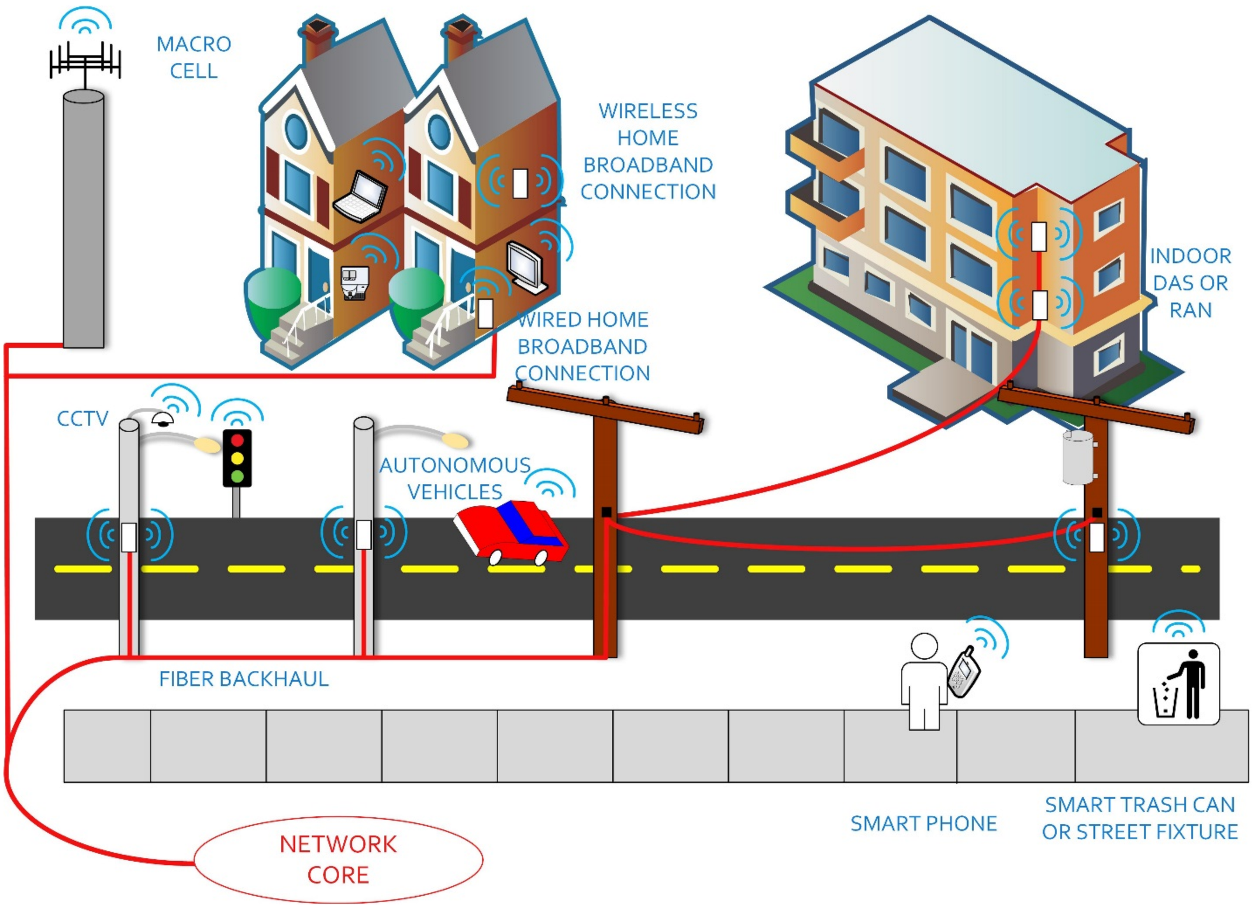
within a few hundred feet, offloading capacity from the 4G network while those devices and users are in proximity to the 5G access points (Figure 21).

Figure 21: 5G Devices Installed on Poles Augment Capacity Nearby



As demands of automated vehicles grow, corridors can be activated with 5G access points on light poles or utility poles or building facades. As access points become widespread, they can provide alternative broadband service to residences and businesses near the devices. Since the high frequency signals have difficulty passing through walls and windows, service to buildings with 5G networking may require outdoor antennas to pick up the signals (Figure 22).

Figure 22: 5G Ecosystem Includes Extensive Fiber, Indoor and Outdoor Networks, and Service to Machines



It is estimated that 80 percent of 5G use will be indoors,[91] so in-building service cannot be a mere afterthought. Again, because of the attenuation from the walls, 5G networking indoors will require both outdoor and indoor antennas. These can be provided through different approaches.

In a single-family residence, one approach would be to set up an indoor customer-owned IEEE 801.11ac/ad WiGig/Wi-Fi hotspot, that connected through the home broadband connection to the public network. A variation of that approach would be to use a service-provider supplied indoor hotspot that also used licensed 5G spectrum, essentially a 5G version of the 3G/4G nanocell and picocell equipment that wireless carriers provide customers to improve their service. The home broadband connection itself could be a wired connection or a wireless connection through an outdoor-mounted 5G antenna.

In multi-dwelling units or large office or industrial buildings, service providers could provide 5G service through 5G versions of distributed antenna systems (DAS) or indoor small cells.

[91] Gupta, p. 1208.

The future environment will likely be a continuation of 4G and 5G communications over currently used wireless bands complemented by the 5G high frequency antennas located indoors and outdoors. The lower-frequency spectrum bands and macro cells will be needed to fill in the gaps with non-line of sight coverage where 5G antennas are not built, or coverage gaps in between, or for service to areas where it is not cost effective to place antennas or backhaul links to the antennas.

Flexible Approach to Radio Access Network (RAN) Infrastructure

4G and 5G networks are evolving to enable service providers to flexibly apportion "slices" of network connectivity on demand in the network core and wireless infrastructure. This evolution results from developments in processing speed, aggregation of spectrum bands, and software designed radios.[92] Slicing would enable new ways of doing business, including 1) enabling a wireless user to connect through a wider pool of spectrum and capacity, 2) facilitating a smoother handoff of services between carrier networks and home/business/institutional wireless networks, and 3) potentially facilitating the separation of the wireless service provider and the operation of the RAN infrastructure—enabling service providers to connect their core network to one or more RAN providers and enabling the RAN providers to manage the RAN for any number of providers.

This trend is already visible with the increasing role of infrastructure companies in building towers, DAS systems, small cells and backhaul. The technology potentially enables the infrastructure companies to increase their role to managing the spectrum and the RAN, if they can obtain the rights to the spectrum. The technology also potentially reduces overall deployment costs, if a smaller pool of RAN providers can serve multiple service providers over a consolidated RAN or RANs.

The ability to have a more fluid network that can operate over a range of separate physical networks also creates a greater role for providers without their own licensed spectrum (cities, institutions, cable operators) who can potentially provide strong 5G service through unlicensed spectrum, particularly on campuses and indoors, or obtain use of licensed spectrum through an infrastructure company that operates antennas and spectrum and makes it available on a wholesale basis.

Status of Development and Deployment

Cities are experiencing a substantial increase in applications for placing wireless infrastructure in the right-of-way and on public and private property. At this point, the focus is on deployment of 4G small cell technologies that provide "densification" in busy areas. This equipment may also become a placeholder for higher-frequency 5G equipment, which will need to be more closely

[92] Maeder, p. 21.

spaced. In addition, the policies and practices that are adopted in the 4G densification will set the stage for practices in the 5G build-out in the coming years.

The current research includes development of Massive MIMO—essentially placement of multiple antennas within access points and devices. MIMO is already in use in 4G and Wi-Fi using dual or four antennas, but Massive MIMO may use dozens or hundreds of antennas, and increase capacity by enabling devices to connect simultaneously through many separate physical paths.[93] Because of the small waveform, high frequency bands are well suited to the development of devices with multiple miniaturized antennas.

Wireless service providers are in the process of beginning trials and acquiring spectrum for 5G. Several companies hold 28 GHz and 39 GHz spectrum but little deployment has taken place. Verizon and AT&T are acquiring spectrum in those bands, in part by seeking to acquire firms that hold the spectrum.[94]

Need for Fiber to Enable and Complement 5G

The increasing call for broadband capacity, especially mobile and in support of new applications, is driving the deployment of a new generation of wireless infrastructure, which in turn is driving the deployment of fiber and other infrastructure to connect it.

Fiber is unique in its ability to flexibly deliver hundreds of Gbps in single strand. Once constructed, fiber is low-impact, and does not require large-footprint cabinets or intermediate power. Powered components are only required in the central office hub facilities or at the endpoint—and the endpoint equipment can be very compact.

Considering that 5G infrastructure requires access points every 300 to 600 feet (every two to four utility poles or streetlights),[95] and that each of the access points requires upwards of 20 Gbps, then one mile of street needs hundreds of Gbps of capacity, and an entire community needs hundreds of Tbps (or hundreds of thousands of Gbps). The architecture in Figure 21 will require a hybrid of widely-deployed fiber and a combination of point-to-point and point-to-multipoint wireless components.

[93] Gupta, p. 1213.

[94] Thomas Gryta and Ryan Knutson, "Verizon, AT&T in Billion-Dollar Bidding War for 5G Spectrum," *Wall Street Journal*, April 25, 2015, https://www.wsj.com/articles/verizon-at-t-in-billion-dollar-bidding-war-for-5g-spectrum-1493146927?mg=id-wsj (accessed April 2017).

[95] Tianyang Bai, Ahmad Alkhateeb, and Robert W. Heath, "Coverage and capacity of millimeter-wave cellular networks," *IEEE Communications Magazine*, September 2014, Volume 52, Issue 9, p. 76, http://ieeexplore.ieee.org/document/6894455/ (accessed June 2017).

Appendix E: Background Regarding Relevant Federal Funding Programs

FCC: Connect America Fund Phase II Auction

The Connect America Fund Phase II (CAF-II) is part of the Federal Communications Commission's reform and modernization of its universal service support programs. Phase II of the Connect America Fund offers annual monetary support for service providers to deploy wireline broadband and voice services to areas that are not already being served by competitive service providers offering a minimum level of service. The program makes use of three funding models: 1) the Connect America Cost Model, [96] 2) the Alternative Connect America Cost Model, [97] and 3) the Connect America Phase II Auction.[98]

The Connect America Cost Model (CAM) is a tool developed to estimate the cost to provide voice and broadband-capable network connections to all locations in the country. The model calculates the cost by census block areas, considering geographical and regional factors that would affect construction in each region. The model determines census bocks that are eligible for funding based on the estimated cost to build and then excludes census blocks where costs are too low (indicating the area should not require a subsidy to incentivize a build-out) or too high[99] (indicating the area might be better served by another technology) or where other qualifying services already exist. Census blocks were marked ineligible for funding if 1) a subsidized carrier is offering services of at least 3 Mbps down and 678 Kbps up; 2) a carrier, subsidized or unsubsidized, is offering services of at least 10 Mbps down and 1 Mbps up. The locations on the Shore that are eligible for funding are included in the maps below. Accomack County has 2,033 supported locations, and an annual price cap support of $604,582 and Northampton County has 1,272 supported locations an annual price cap support of $362,713. Taken together, the Shore has 3,305 locations eligible for support, and an annual price cap for support of $967,295.

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[96] Price Cap Resources; https://www.fcc.gov/general/price-cap-resources

[97] The Alternative Connect America Cost Model (A-CAM) is a tool developed to provide "rate-of-return" carriers an opportunity to transition from legacy support offerings to model-based support for expanding their service areas. The process was similar to the CAM-based funding offers, but applied to the rate-of-return carrier service areas. Since the Shore is served by a price cap carrier, rather than a rate of return carrier, A-CAM does not apply to the region; https://www.fcc.gov/general/rate-return-resources#model

[98] Connect America Phase II Auction; https://www.fcc.gov/connect-america-fund-phase-ii-auction

[99] These areas may be eligible for funds through the Remote Area Fund, which will award support subsequent to the completion of the CAF Phase II competitive bidding process.

Figure 23: CAF-II Eligible Locations in Accomack County

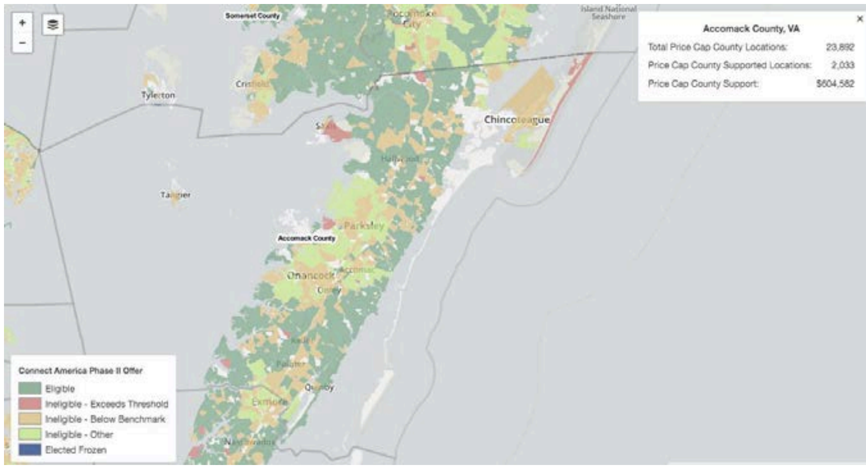
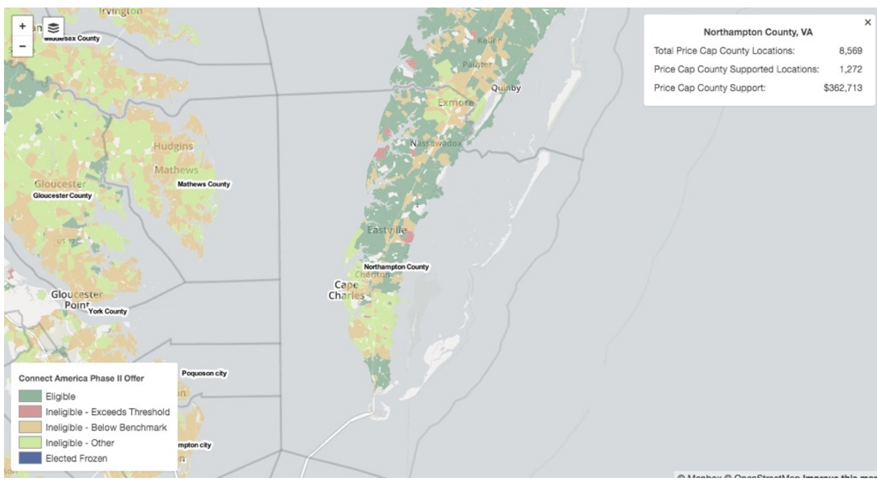


Figure 24: CAF-II Eligible Locations in Northampton County



Funding based on the CAM was offered to incumbent "price cap" carriers based on their existing service areas. Carriers could accept or reject offers by state, but otherwise could not "cherry pick" census blocks within the state. Verizon declined the funding offer for statewide support in Virginia.

To address the initial census block offers that were declined by price cap and rate-of-return carrier offers, the FCC will hold a reverse auction that will allow carriers to bid on support for the remaining areas by submitting the lowest-cost proposal. The areas of the Shore that the FCC has preliminarily determined to be eligible for the Phase II auction are marked in orange below.

Figure 25: Eligible Northern Shore Areas for Funding through CAF-II Auction

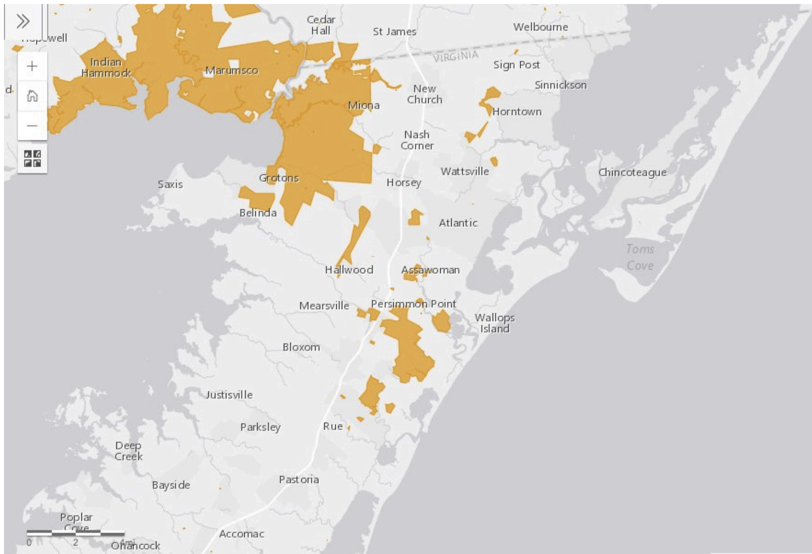
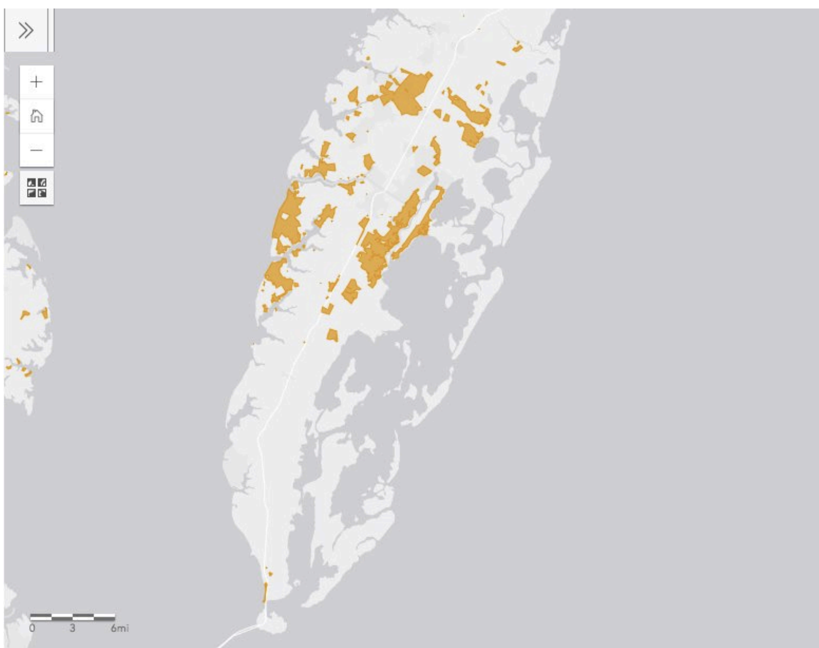


Figure 26: Eligible Southern Shore Areas for Funding through CAF-II Auction



The Commission has determined that census block groups or tracts will be the minimum geographic unit for bidding. Thus, parties will be required to bid on all of the locations within the eligible census blocks of each census block group or census tract (depending on which is ultimately adopted as the minimum geographic unit). As previously mentioned, there are 3,305 supported locations on the Shore, and as much as $967,295 will be made available annually through the auction to incentivize carrier build-outs to these locations. The annual funding is set to last for ten years.

In order to participate in the CAF-II auction, a carrier must establish baseline financial and technical capabilities in order to be found eligible to bid. There are two pathways for establishing eligibility:

- Demonstrate two years of experience providing a voice, broadband, and/or electric distribution or transmission service and submit one-year of audited financials, or
- Submit three years of audited financials with the short-form application and a letter of interest from an eligible bank willing to issue a letter of credit for a specified amount

Winning bidders must:

- Provide in their long-form applications additional information about qualifications, funding, and the network that they intend to use to meet their obligations
- Within a specified number of days, submit a letter from an eligible bank committing to issue a letter of credit; upon notification that the entity is ready to be authorized, must obtain a letter of credit from an eligible bank that remains open and covers disbursements until build-out is complete and verified
- Within 180 days of being announced as winning bidders, certify they are eligible telecommunications carriers in any areas for which they seek support and submit relevant documentation

The program requires annual progress reports from carriers. Each carrier must offer service to 40 percent of supported locations in their accepted areas by the third year of support and must add an additional 20 percent each year, serving 100 percent of the supported locations in their accepted area by the end of year six.

More information about the auction, including evaluation criteria for bids, accountability requirements and important dates and deadlines (not yet announced) can be found on the FCC's Connect America Fund Phase II Auction site.

USDA: Community Connect Grants

Community Connect, which is administered through the Rural Utilities Service (RUS) under the authority of the United States Department of Agriculture (USDA), is a modest-sized, but significant grant program for local and tribal government that targets deployment to completely unserved, very low-income rural communities (with fewer than 20,000 residents). Grantees must offer service at the broadband grant speed (defined as 5 Mbps download plus upload) to *all* households and community institutions in the Proposed Funded Service Area (PFSA), with free service for at least two years to a community center. The application process is rigorous and competitive (with awards given to approximately 10 percent of applicants) and once awarded, program requirements are demanding (e.g., requiring last-mile service be available for all households in the service area). The program has been funded consistently since it was introduced in 2002 and thus represents an important opportunity for qualifying communities.

The Community Connect process generally opens in the spring. The following are key dates that should be built into a prospective service provider's annual planning. However, recognizing that the funding calendar may fluctuate, we advise applicants to stay apprised of opportunities through Grants.gov (http://www.grants.gov):

- **Winter:** Prior to the opening of the application window, or as soon as possible thereafter, Applicants should secure a DUNS number. This process is free and takes only one to two business days to complete. DUNS numbers can be secured through the web form (http://fedgov.dnb.com/webform) or by calling Dun & Bradstreet (800-526-9018).

- **Winter/early spring:** Prior to the opening of the application window, or as soon as possible thereafter, Applicants should complete System of Award Management (SAM) registration or update their existing registration. To remain active, registrants must update their information annually. SAM registration is a prerequisite to the grant program and applications can take three to 12 days to process. The application is available online (https://www.sam.gov) and detailed instructions are provided below. A DUNS number is required for the SAM registration process and should be obtained first.

- **Spring to summer:** The window during which rural communities ("Applicants") can apply to RUS for funding is typically announced in spring, with a 45 to 60-day application window. [100] The exact dates differ from year-to-year and are announced on the Community Connect Grants website (http://www.rd.usda.gov/programs-services/community-connect-grants) and through Grants.Gov. The FY 2016 grant process is not yet open.

  The Notice Of Solicitation of Applications (NOSA) is issued *before* appropriations are assured and costs associated with the application process are incurred at the applicant's risk. This gives RUS time to process applications within the current fiscal year, even though funding is not guaranteed absent a continuing resolution or final appropriations act. Despite this apparent uncertainty, Community Connect has been consistently funded (at roughly $15 million annually) since the program was first announced in 2002.

- **Before Beginning the Application Process:** USDA recommends contacting the USDA Broadband Division, Telecommunications Program via email

[100] Note that this schedule may vary. In fact, for 2015, the Notice of Service Availability (NOSA) was published December 17, 2014 with applications due February 17, 2015.

(community.connect@wdc.usda.gov) or by phone (202-720-0800), or by contacting the General Field Representative that serves your area before attempting to fill out any forms or applications.[101] Field representatives are eager to provide assistance.

- **<u>During the Application Window</u>:** USDA will hold a series of webinars before and during the application window, which will provide detailed information about the application process and an opportunity to ask questions of agency staff.[102] Registration is available on the Community Connect homepage (http://www.rd.usda.gov/programs-services/community-connect-grants). An archived presentation explaining the latest changes to the grant program process is available online.[103]

  Applicants are provided 45 to 60 days to complete the application process. All applicants are rank-ordered and awards are given in rank order until funds are expended. If there are similarly ranked proposals, additional consideration will be given to those that provide faster speeds of service, that are located in a tribal or trust area, fund areas of persistent poverty, or that benefit persons with disabilities. Thus, there is no reason to complete the application before the close of the application window and we advise taking time to review the application guide and consult with agency staff.

- **<u>Fall</u>:** The time at which awards are typically announced.

- **<u>180 Days after Issuance of the Award</u>:** Construction must begin 180 days following issuance of the award.

- **<u>Annually Thereafter</u>:** If awarded, reports must be submitted annually. Such submissions must include an annual performance activity report and audit, beginning with the first year a portion of the funds were expended. With limited exception, First Tier Sub-Awards of $25,000 or more must be reported by the Recipient to http://www.fsrs.gov no later than the end of the month following the month the obligation was made. Awards are typically for a multiyear period and are not renewable.

- **<u>Annually Thereafter</u>:** Grant recipients must maintain an active SAM registration. Accounts may be updated online and data must be reviewed in one sitting. [104]

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[101] A list of representatives to notify is available here: http://www.rd.usda.gov/files/UTP_TelecomGFRs.pdf.
[102] Information is available at: http://www.rd.usda.gov/files/UTP_RDApplyStakeholderWebinars.pdf.
[103] USDA, Scott Steiner, "Community-Oriented Connectivity Broadband Grant Program Fiscal Year 2015," (http://www.rd.usda.gov/files/UTP_CC2015CombinedPresentation.pdf).
[104] SAM registration updates can be completed online at: https://www.sam.gov/sam/helpPage/SAM_Reg_Status_Help_Page.html#step5content. SAM registration will expire and become "inactive" if you do not log in and update the entity registration record at least once annually.

- **At the Close of the Award Period:** Applicants must submit a final performance report, which may serve as the last annual report and must include an evaluation of the success of the project.

The application process is discussed in more detail below.

Projects and Entities Likely to Be Funded

Community Connect is an extremely competitive grant program, with approximately 10 percent of the anticipated 150 applicants receiving funding.

Entities Awarded:

Awards can be given to both public and private entities. Eligible applicants include incorporated organizations, Indian tribes or tribal organizations, state or local units of government, or cooperatives, private corporations, and limited-liability companies organized on a for-profit or not-for-profit basis. Individuals or partnerships are not eligible. An applicant must have the legal capacity and authority to own and operate the proposed broadband facilities, to enter into contracts, and to otherwise comply with applicable federal statutes and regulations. Thus, awards cannot be granted to a local government entity that does not want to own or operate the broadband service.

Eligible Projects:

Community Connect is intended to target communities where broadband service is not available and where low population densities and poverty make deployment costs high, and build-out of infrastructure unlikely. Funding is limited to contiguous areas with a population less than 20,000 that does not currently have Broadband Transmission Service (as determined by the FCC National Broadband Map, and defined as 3Mbps download plus upload), and where such service would not otherwise be provided.[105] Service areas need not be in the same community—or even the same state—so long as the areas are contiguous.

Once awarded, projects must offer last-mile service at the broadband grant speed (5 Mbps download plus upload) to *all* businesses, residents, and community facilities in the PFSA, with free service provided to all critical facilities,[106] and at least one community center with weekend hours and two to 10 public computer access points for at least two years from the grant award.[107]

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[105] Existing broadband availability can be determined using the National Broadband Map (http://www.broadbandmap.gov/). Existing satellite services are not considered broadband and will not invalidate an application. Applicants must configure the PFSA to exclude areas where DSL services exist.

[106] Critical community facilities include public schools, public libraries, public medical clinics, public hospitals, community colleges, public universities, law enforcement, and fire and ambulance stations.

[107] Though grantees cannot charge for such services, the award can be used to cover these costs for the recipient.

Grants can be used to offset the cost of providing such service and to lease spectrum, towers, and buildings that are part of the project design.[108] A portion of the grant (the lesser of 10 percent or $150,000) can be used to construct, acquire or expand an existing community center.[109] Note that Community Connect historically required provision of at least 10 computer access points in a public community center; however, now requires only two such access points—with a *maximum* of 10.

In sum, Community Connect awards must:

- Provide broadband infrastructure in an area where service does not currently exist;
- Offer last-mile service (at least 5 Mbps download plus upload) to all premises in the PFSA;
- Benefit rural areas (defined as communities with fewer than 20,000 residents *and* not adjacent to cities with more than 50,000 residents); and
- Provide complementary service for at least two years to all critical facilities and a community center that meets the grant requirements.

Eligible areas must not:

- Already have broadband service
- Receive federal funding to make such service available.[110]

To prepare the most competitive Community Connect grant application possible, we would recommend that an applicant acquire or create a utility chart of an area within its unserved footprint, then target the lowest-income portions of that area.

Successful Applications*:*
USDA maintains a comprehensive database of all successful Community Grant awards since the program's inception.[111] These awards are sorted by state and chronologically.

Evaluation Criteria

Applications are scored on a 100-point scale on three basic criteria (as detailed in 7 CFR §1739.17): PFSA challenges (50 points), local participation (40 points), and management experience (10 points). Additional "bonus" points (15) are available for projects located in trust

[108] Leasing costs can only be covered for three years.
[109] Note that additional funds can be used to provide the computer access points and their connection to the network. Applicants may use their own resources to cover costs exceeding this limit.
[110] Applicants should check all available sources to confirm that service is not available, including service provider websites, the NTIA and FCC National Broadband Map (http://broadbandmap.gov/), and a listing of communities served by existing RUS borrowers and grantees (http://broadbandsearch.sc.egov.usda.gov/SearchTabs.aspx).
[111] The grant database is available online at: http://www.rd.usda.gov/programs-services/community-connect-grants

or tribal areas and priority is given to areas with pervasive poverty (i.e., where more than 20 percent of the PFSA is living in poverty).

PFSA challenges (50 points) are assessed based on the following five factors:

1. Economic Characteristics (15 points) (median income, unemployment);
2. Educational Challenges (15 points) (e.g., consequences of inadequate access for educational institutions and lack of distance learning);
3. Health Care Needs (10 points) (based on a list of medical facilities and letters from health care professionals documenting anticipated use of the proposed network);
4. Public Safety Issues (10 points) (Include a listing of police, fire and rescue services who service the PFSA); and
5. Small Area Income and Poverty Estimates (applications with at least 20 percent of the population living in poverty will receive the maximum – 50 points – for this category).[112]

Applicants should emphasize factors that demonstrate the unique need of the PFSA for the project, such as persistent poverty, out-migration, rurality, speed of existing broadband offerings, and presence of community members with disabilities.

Local participation is determined based on the evidence of support for the project by local residents, institutions, and critical community facilities, as well as historic community engagement in civic issues.

Management experience is based on the management team's level of experience and its past success operating broadband systems.

USDA: Rural Utilities Service Broadband Loans

The USDA Rural Utilities Service (RUS) provides loans for telecommunications infrastructure, which may support broadband deployment. The Rural Broadband Access Loan and Loan Guarantee Program (Broadband Loan Program) has historically been the RUS program with the greatest promise for broadband. The Broadband Loan Program is intended to ensure that rural consumers enjoy the same quality and range of broadband services that are available in urban and suburban communities. Although these programs offer loans at competitive rates, they are notoriously paperwork and labor intensive. As such, it may be preferable to rely on public bonds or private loans.

[112] Poverty determination is based on U.S. Census data, available at: http://www.census.gov/did/www/saipe/data/statecounty/data/2010.html

In fact, 100 loans in 43 states (representing a total value of $2-billion) were provided through the program from 2003 through 2013. Awards range from $100,000 (minimum) to $100 million (maximum), with an average award of $640,000.[113] The application process is not onerous and there is some flexibility in what loans can cover. The program recently completed a federal rulemaking following the enactment of the Agricultural Act of 2014 (Farm Bill).[114] While loans were historically accepted on a rolling basis, the rulemaking now establishes two distinct application periods each year. Applications will be prioritized based on the percent of unserved households in the proposed service area.

RUS broadband loans are available for both nonprofits and for-profit organizations, including corporations, limited-liability corporations, cooperatives, Indian tribes, and state or local governments. Individuals and partnerships are not eligible for broadband loans. While loans are available to corporations, an entity that provides telecommunications or broadband service to at least 20 percent of the households in the United States is limited to a loan amount that is no more than 15 percent of the available funds for the given fiscal year.

The program provides direct cost-of-money loans, direct four percent loans, and private loan guarantees. Loan guarantees may cover up to 100 percent of construction costs to qualified borrowers in rural areas.

The Broadband Loan Program provides financing to support the construction, improvement, and acquisition of facilities required to provide broadband services, defined as service with at least a downstream transmission capacity of 4 Mbps and an upstream transmission capacity of 1 Mbps. Broadband projects must be completed within three years from the date that loan funds become available. The loans and loan guarantees finance maintenance, upgrades, expansion, or replacement of electric distribution, transmission (bulk and sub-transmission), generation, and headquarters (office, service and warehouse) facilities in rural areas.

There are a number of restrictions for the RUS Broadband Loan program. In particular:

- Loans are limited to eligible rural communities (i.e., an area with less than 20,000 inhabitants and not adjacent to an urbanized area with more than 50,000 inhabitants);
- Borrowers must have the legal authority to provide, construct, operate and maintain the proposed facilities or services;
- All facilities receiving federal financing must be used for a public purpose;

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[113] S*ee* 76 Fed. Reg. 13771 for details on previous awards.

[114] For additional information, visit USDA, Rural Development, "Farm Bill Broadband Loans and Loan Guarantees," http://www.rd.usda.gov/programs-services/farm-bill-broadband-loans-loan-guarantees

- To be eligible for the Broadband Loan Program, at least 15 percent of the households must be unserved and no part of the proposed funded service area may have three of more incumbent service providers (unless the borrower is applying to upgrade existing facilities in their existing service area);
- No part of the proposed funded service area may overlap with the service area of current RUS borrowers;
- Broadband loan borrowers must have equity of at least 10 percent of the amount of the loan; and
- Broadband loans cannot be used to fund the purchase or lease of any vehicles not used primarily in construction or system improvements.

Appendix F: Ubiquitous Retail Model Financial Statements

This financial model is attached as a Microsoft Excel spreadsheet.

Appendix G: Existing Fiber Routes Retail Model Financial Statements

This financial model is attached as a Microsoft Excel spreadsheet.

Appendix H: Ubiquitous Westminster Model Financial Statements

This financial model is attached as a Microsoft Excel spreadsheet.

Appendix I: Ubiquitous Huntsville Model Financial Statements

This financial model is attached as a Microsoft Excel spreadsheet.